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RESEARCH ARTICLE

EFFECT OF MUNICIPAL SOLID WASTE TREATMENT METHODS ON THE GROWTH AND PERFORMANCE OF AMARANTHS (*Amaranthus hybridus*) IN SUDAN SAVANNAH OF NIGERIA

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ABSTRACT

A study was conducted to assess the effect municipal solid waste (MSW) treatment methods on the growth and performance of amaranths (*Amaranthus hybridus*) in the Sudan Savannah of Nigeria. MSW were collected from different locations in Kano metropolis, mixed together and then subjected to different treatment methods (pyrolysis, composting and untreated). Products of this treatment methods were applied to soil at different rate of 0, 5, 10 and 15ton ha^{-1}. Effect of MSW treatment methods on the performance of amaranths was assessed by sowing amaranths seed in the amended soil in field and pot trial phases using RCBD and CRD respectively. Result from plant trials shows significant differences ($p \leq 0.05$) on plant height and number of leaves with highly significant difference ($p \leq 0.01$) on leaf area of amaranths in the pot trial. Significant differences ($P \leq 0.05$) were observed on the number of leaves as well as fresh and dry weight of amaranths in the field trial. From the study, it was concluded that municipal solid waste treatment methods affect the growth and performance of amaranths. There was an observed significant increase in the performance of amaranths following biochar application. Untreated (raw) wastes are relatively easier and less expensive to be used but has less pronounced effect on plant growth when compared with the control treatment. The recommended treatment method for municipal solid wastes depends on the overall purpose of application. It is therefore recommended that stakeholders be involved in the recycling of municipal solid wastes through composting as that may reduce expenses for procurement of inorganic fertilizer and provide waste management solution as well as increased crop yield for small holder farmers.

KEYWORDS

Municipal Solid Wastes (MSW), Pyrolysis, Composting

1. Introduction

Declining land productivity and reduced crop yields are among the major constraint facing small holder farmers in Sudan savannah. Application of fertilizer, from both organic and inorganic sources offers a solution to farmers under these conditions. In economically developing countries, waste management is becoming difficult due to the large amount of wastes generated. Municipal Solid Wastes (MSW) are generally generated from three main sources which include domestic solid waste (from households and public areas), commercial solid waste (from shops, restaurants, hotels, offices, and markets) and industrial solid waste (waste from industries, but not including construction and demolition waste, chemical waste, or other special types of waste) (Chandler et al., 1997; SUTD, 2012).

The use of organic portion of MSW has been recognized generally as an effective means for improving soil physical and chemical properties and subsequently increasing crop yields (Zink and Allen, 1998). However, constraints related to economics, technology, and qualified personnel have narrowed the choice of acceptable solid waste management and treatment option for use in soil. Amaranths is one of the most important annual vegetables in the tropics which has a growing period of 5-6 weeks. It thrives well on soil with high organic matter and respond well organic fertilizer application. Although the crop responds to organic fertilizer, studies on effect of organic wastes the growth and performance of amaranths are scarce. A study of the effect of MSW treatment methods on soil chemical properties and performance of amaranths (*Amaranthus hybridus*) would help find solutions to the use of the wastes in soil and also determine which treatment method offers the best solution for soil improvement. The aim of this study therefore was to assess the effect of the municipal solid waste treatment methods on the growth and performance of amaranths (*Amaranthus hybridus*) in the study area.

2. Material and Methods

2.1 The Study Area

This study was carried out at Faculty of Agriculture, Bayero University Kano, located along Gwarzo Road, Ungogo Local Government Area of Kano State (11.9742°N; 8.4684°E, 460 m above sea level) in the Savannah zone of Northern Nigeria. The climate of the area is characterized by a rainy season during the month of May to September and a cool dry season between the months of October to February. Rainfalls normally begin in late April to early May and reach its peak in August (Buba, 2009; Adamu et al., 2014). The mean annual temperature is averagely warm to hot throughout the year at about 25°C ± 7°C (Adamu et al., 2014). The rate of evaporation in the study area has been estimated to be very high with a potential evapotranspiration rate of 1772 mm (Olofin and Tanko, 2002).

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2.2 Municipal Solid Waste Sources and Treatment

Materials used for this study are biodegradable wastes (fruits and vegetable wastes) sourced from landfill sites of Yankaba and Yanlemo markets in Kano metropolis and plant residues collected within the University campus. Wastes collected from different sources were mixed together and divided into three parts which were then subjected to different treatments that include pyrolysis, composting and non-treated one. Individual treatment methods and their respective products are given as seen in Table 1.

Table 1: Treatment Methods and their Respective Products

S/N	Treatment Method	Product
1	Untreated	Raw
2	Pyrolysis	Biochar
3	Composting	Compost

In the untreated, waste materials were air-dried, ground and used as raw for field trials, while in pyrolysis method collected waste materials were placed inside a pyrolysis chamber at the Department of Soil Science and subjected to heating (300-400^{o}C temperature) in the absence of oxygen as recommended (Lehman, 2007). This treatment resulted in the production of a charred product (biochar) which was ground for field trial. In the composting method, the collected wastes were subjected to biological decomposition using composting bin at the Department of Soil Science for period of 8 weeks as recommended by (USDA, 2010). During the composting period, materials in the bin were turned on a weekly basis for good aeration, moisture management and uniform decomposition. At the end, compost was produced which was air-dried and ground for field trial.

2.3 Treatment Combinations

Prior to the commencement of the trial, soil samples were collected in a W-shape framework across the plot at about 0-20 cm depth. The samples were mixed together and came up with a composite soil sample of the study site in order to assess the physicochemical properties of the soil of the study area. MSW amendments were applied at graded rate forming total of 10 treatment combinations as seen in Table 2.

Table 2: Municipal Solid Waste Treatment Combinations Used in the Soil

Application Rate	Description
Raw_5 t ha^{-1}	Untreated MSW applied to the soil at the rate of 5 t ha^{-1}
Raw_10 t ha^{-1}	Untreated MSW applied to the soil at the rate of 10 t ha^{-1}
Raw_15 t ha^{-1}	Untreated MSW applied to the soil at the rate of 15 t ha^{-1}
Biochar_5 t ha^{-1}	Product of pyrolysis applied to the soil at the rate of 5 t ha^{-1}
Biochar_10 t ha^{-1}	Product of pyrolysis applied to the soil at the rate of 10 t ha^{-1}
Biochar_15 t ha^{-1}	Product of pyrolysis applied to the soil at the rate of 15 t ha^{-1}
Compost_5 t ha^{-1}	Product of composting applied to the soil at the rate of 5 t ha^{-1}
Compost_10 t ha^{-1}	Product of composting applied to the soil at the rate of 10 t ha^{-1}
Compost_15 t ha^{-1}	Product of composting applied to the soil at the rate of 15 t ha^{-1}
Control	Non-amended soil, receiving no any form of MSW products

2.4 Agronomic Practices

Vegetable amaranths (*Amaranthus hybridus*) - a local variety (Farin Iri) was used to determine the effect of the different MSW treatment products on the performance of amaranths in the field and pot trials. The land clearing for field trial was manually done using hand-hoe as well as harrowing in the field before the layout. Beds of 1.5 m by 1.5 m were made with discard of 0.5 m and 1 m between plots and replications respectively. Randomized Complete Block Design (RCBD) was used for field trial consisting of 10 treatments (Table 2) that were replicated three times thus forming 30 plots. For the pot trial, Completely Randomized Design (CRD) was adopted where total of 30 pots were randomly arranged inside the screen house containing soil with different treatments.

Two weeks after applying different soil amendments as obtained after MSW treatments, amaranths seeds were sown by broadcasting method at the rate of 1.5 Kg ha^{-1}. After the germination, the plants were thinned to 15 cm apart in each of plots. Weeding between plots and replications was carried out manually using hand hoe while handpicking was used to remove weeds within the plot. For the pot trial same sowing method was also adopted which were later thinned to 3 plants per pot. Handpicking was also used to removed weeds from the pots. Regular irrigation was carried out in the pot trial to maintain the soil moisture status at field capacity.

Number of leaves, plant height, leaf area and chlorophyll content were assessed at 4, 6 and 8 weeks after sowing (WAS) while fresh and dry weights were assessed at harvest. Plant height was assessed by using measuring tape and number of leaves was assessed by counting from plants that were randomly marked from each plots and pots. Leaf area and chlorophyll content were assessed using leaf area meter (YMJ-A) and chlorophyll content meter (CCM-200P) respectively. For assessment of the fresh and dry weight, plants from each treatment were harvested and tagged accordingly. Fresh weight was assessed by weighing the plant immediately after harvesting while dry weight was obtained by weighing after oven-drying the sampled plant at 65^{o}C for 24 hours.

2.5 Statistical Analysis

Analysis of Variance (ANOVA) technique was used to determine the level of significance between treatment means using the GenStat Software (17th Edition). Means with significant differences were separated using Students-Newman-Keuls (SNK) at 5% level of probability.

3. Results

3.1 Physicochemical Properties of the Soil of the Study Area

As presented in Table 3, the soil of the study area is a loamy sand in texture with sand, silt and clay fractions of 87%, 7% and 6% respectively. The soil was observed to be slightly acidic with pH value of 6.47 and low EC value of 0.22 dSm^{-1}. The Total N of the soil was observed to be moderate (1.1 gkg^{-1}), going by rating scale (Esu, 1991; Landon, 1991). Soil of the area is generally low in fertility as expressed by the low values of the soil quality parameters assessed.

3.2 Effect of Municipal Solid Waste Treatment Methods on the Performance of Amaranths

As presented in Table 4, significant difference ($p \leq 0.05$) was observed on plant height at 4 weeks after planting in the pot trial where Compost_15 t ha^{-1}, Compost_10 t ha^{-1} and Biochar_5 t ha^{-1} amended soils produced the highest mean of 13.0 cm, 12.8 cm and 13.2 cm respectively. For the field trial however, no significant difference was observed across all the treatment plots.

Table 5 shows the effect of MSW treatments on the number of leaves as obtained after the statistical analysis. Pot trial recorded significant difference ($p \leq 0.05$) at 8 weeks after sowing with highest mean recorded in Raw_5 t ha^{-1} (16.3) and Raw_10 t ha^{-1} (16) amended soils while Control recorded the least mean (13.7). For the field trial however, significant difference ($p \leq 0.05$) was observed at 6 weeks after sowing with Raw_10 t ha^{-1} amended plot observed to have highest mean (18.0) while least mean was obtained in the Control plot (13.7).

As shown in Table 6, highly significant differences ($p \leq 0.01$) were recorded on the leaf area of amaranths at 8 weeks after sowing in the pot experiment with highest mean recorded in Compost_15 t ha^{-1} (233.5 mm^2), Biochar_15 t ha^{-1} (209.4 mm^2), Biochar_10 t ha^{-1} (207.4 mm^2) and Biochar_5 t ha^{-1} (208.2 mm^2) treated soils. However, no significant differences were observed across the treatments in the field trial.

No significant differences were however observed on the chlorophyll content at 4, 6 and 8 weeks after sowing in the two trials as shown in Table 7. As presented in Table 8, fresh and dry weights of amaranths in the pot trial recorded no significant differences across the treatments. In the field trial however, significant differences ($p \leq 0.05$) were recorded on dry weight of amaranths where Biochar_15 t ha^{-1} plot was observed to have highest mean (8.8 g) with Control having the least mean (4.9 g) with no significant differences recorded on the amaranths fresh weight (Table 12).

Table 3: Pre-planting Physicochemical Properties of the Soil of the Study Area

Variable	Value
Particle size distribution	
Sand (%)	87
Clay (%)	7
Silt (%)	6
Texture	Loamy sand
Soil pH.	6.47
Electrical Conductivity (dSm^{-1})	0.22
ECEC (cmol(+)kg^{-1})	3.68
Organic Carbon (gkg^{-1})	5.6
Total Nitrogen (gkg^{-1})	1.1
Available Phosphorus ($mgkg^{-1}$)	2.17
Exchangeable Acidity (cmol(+)kg^{-1})	0.83
Calcium (cmol(+)kg^{-1})	3.26
Magnesium (cmol(+)kg^{-1})	0.19
Potassium (cmol(+)kg^{-1})	0.13
Sodium (cmol(+)kg^{-1})	0.10

Table 4: Effect of MSW Treatments on Plant Height of Amaranths

Soil treatments	Pot trial Plant height (cm)			Field trial Plant height (cm)		
	4	6	8	4	6	8
Control	7.7b	13.3	15.6	14.2	26.3	58.1
Raw_5 t ha^{-1}	11.7ab	21.4	22.8	14.5	27.5	64.7
Raw _10 t ha^{-1}	10.8ab	18.6	20.6	19.3	38.7	72.4
Raw _15 t ha^{-1}	11.9ab	19.4	21.2	16.4	41.9	75.6
Biochar_5 t ha^{-1}	13.2a	21.0	22.8	18.5	33.6	68.0
Biochar_10 t ha^{-1}	10.7ab	16.9	18.4	19.7	37.5	68.6
Biochar_15 t ha^{-1}	11.2ab	19.8	21.7	15.5	39.5	72.5
Compost_5 t ha^{-1}	12.0ab	18.6	19.7	17.3	30.2	62.6
Compost_10 t ha^{-1}	12.8a	21.4	22.7	11.8	26.2	61.9
Compost_15 t ha^{-1}	13.0a	19.5	20.7	13.3	31.9	64.9
P-Value	0.05*	0.2	0.3	0.18	0.07	0.77
SED±	1.476	2.693	2.722	2.084	3.83	7.00

4 = 4 weeks after sowing (WAS), 6 = 6 WAS, 8 = 8 WAS. *=significant difference, means followed by the same letter(s) in a columns are not significantly different at 5% probability level using Students-Newman-Keuls test

Table 5: Effect of MSW Treatments Products on Number of Leaves of Amaranths

Soil treatments	Pot trial Number of leaves			Field trial Number of leaves		
	4	6	8	4	6	8
Control	6.3	11.0	13.7b	8.33	13.7b	19.33
Raw_5 t ha^{-1}	8.3	13.0	16.3a	9.00	15.0ab	21.67
Raw _10 t ha^{-1}	7.7	12.3	16.0a	11.33	18.0a	23.33
Raw _15 t ha^{-1}	8.3	12.3	14.3ab	9.33	17.3ab	22.33
Biochar_5 t ha^{-1}	8.0	11.7	15.7ab	11.33	16.7ab	20.33
Biochar_10 t ha^{-1}	7.7	11.7	14.7ab	10.00	16.7ab	20.33
Biochar_15 t ha^{-1}	8.3	12.0	14.3ab	9.67	17.7ab	20.33
Compost_5 t ha^{-1}	7.7	11.7	15.3ab	9.33	14.3ab	21.33
Compost_10 t ha^{-1}	8.0	12.7	15.7ab	8.67	14.3ab	20.00
Compost_15 t ha^{-1}	9.0	12.7	15.7ab	9.00	15.0ab	20.00
P-Value	0.64	0.65	0.04*	0.13	0.01**	0.30
SED±	0.951	0.990	0.763	0.756	0.83	1.083

** = highly significant difference, means followed by the same letter(s) in a columns are not significantly different at 5% probability level using Students-Newman-Keuls test.

Table 6: Effect of MSW Treatments on Leaf Area of Amaranths						
Soil treatments	Pot trial Leaf area (mm^2)			Field trial Leaf area (mm^2)		
	4	6	8	4	6	8
Control	136.1	170.9	199.1ab	127.8	197.3	234.0
Raw_5 t ha^{-1}	138.8	177.6	199.0ab	135.3	240.2	250.1
Raw _10 t ha^{-1}	127.7	179.7	197.0ab	124..4	236.4	266.8
Raw _15 t ha^{-1}	126.5	172.2	194.8abc	126.5	212.5	265.7
Biochar_5 t ha^{-1}	152.9	183.1	208.2a	119.7	222.7	258.7
Biochar_10 t ha^{-1}	154.1	196.6	207.4a	107.4	244.3	288.0
Biochar_15 t ha^{-1}	146.6	186.0	209.4a	129.5	235.4	252.0
Compost_5 t ha^{-1}	145.3	186.6	198.8ab	108.1	207.7	260.8
Compost_10 t ha^{-1}	135.0	151.1	165.8b	108.6	203.7	303.7
Compost_15 t ha^{-1}	134.0	195.7	233.5a	114.9	235.7	270.6
P-Value	0.87	0.16	0.009**	0.91	0.23	0.27
SED±	18.32	14.36	12.33	14.34	14.01	16.72

** = highly significant difference, means followed by the same letter(s) in a columns are not significantly different at 5% probability level using Students-Newman-Keuls test.

Table 7: Effect of MSW Treatments on Chlorophyll Content of Amaranths						
Soil treatments	Pot trial Chlorophyll content (μmolcm^{-2})			Field trial Chlorophyll content (μmolcm^{-2})		
	4	6	8	4	6	8
Control	12.2	16.8	25.4	10.2	17.0	20.0
Raw_5 t ha^{-1}	12.6	14.3	22.5	10.5	20.3	26.1
Raw _10 t ha^{-1}	13.8	17.2	25.6	11.8	20.5	24.6
Raw _15 t ha^{-1}	13.2	18.9	26.2	12.2	19.5	23.3
Biochar_5 t ha^{-1}	13.0	16.2	27.8	11.3	17.7	20.7
Biochar_10 t ha^{-1}	13.2	16.4	30.2	14.3	18.6	24.4
Biochar_15 t ha^{-1}	14.3	17.9	24.0	10.6	19.5	23.8
Compost_5 t ha^{-1}	11.6	15.9	23.5	10.9	17.6	23.3
Compost_10 t ha^{-1}	12.8	13.9	26.1	10.6	21.1	25.0
Compost_15 t ha^{-1}	13.2	14.6	27.1	11.5	20.2	22.8
P-Value	0.99	0.51	0.56	0.08	0.34	0.46
SED±	2.600	2.275	3.396	0.868	1.260	1.861

Table 8: Effect of MSW Treatments on the Fresh and Dry Weight of Amaranths				
Soil treatments	Pot trial Fresh weight (g)	Dry weight (g)	Field trial Fresh weight (g)	Dry weight (g)
Control	14.5	1.9	38.7b	4.9b
Raw_5 t ha^{-1}	39.0	4.3	56.6ab	7.1ab
Raw _10 t ha^{-1}	36.4	4.5	58.2ab	8.2ab
Raw _15 t ha^{-1}	33.3	6.7	69.3a	8.2ab
Biochar_5 t ha^{-1}	44.7	6.7	53.2ab	6.8ab
Biochar_10 t ha^{-1}	29.8	3.8	56.6ab	6.9ab
Biochar_15 t ha^{-1}	37.7	7.3	62.1ab	8.8a
Compost_5 t ha^{-1}	34.5	4.3	56.5ab	7.6ab
Compost_10 t ha^{-1}	36.4	6.7	46.4ab	4.9b
Compost_15 t ha^{-1}	38.6	7.8	51.1ab	7.3ab
P-Value	0.40	0.28	0.080	0.012*
SED±	10.77	2.303	5.720	0.713

* = significant difference, means followed by the same letter(s) in a columns are not significant at 5% probability level using Students-Newman-Keuls test.

4. Discussion

Increase in the performance of amaranths (*Amaranthus hybridus*) observed is generally attributed to nutrients contents of the amendments, nutrient release pattern in the soil as well as the level of control during the trial. Organic amendments have been reported to have significant influence on growth and yield of *Amaranthus hybridus* (Walters et al., 1993; Webber et al., 1993). Increase in the plant height and number of leaves of amaranths (*Amaranthus hybridus*) in the pot trial is connectible to the type amendments used, their effect on soil and the level of control. A group researcher observed increase in the plant height of *Amaranthus cruentus,* with application of composted organic fertilizer (Makinde et al., 2010). Increase in yields of amaranths with biochar applications on highly weathered soils in the humid tropics is also reported (Lehmann et al., 2006).

Results on the number of leaves may be attributed to the nutrient release pattern as raw amendment have slow and gradual nutrients release pattern. Finding from show that application of untreated organic amendments has significance effect on number of leaves of amaranths (Adeyemi et al., 1999). Results of the of the dry weight may be attributed to higher nutrient absorption, less competition for growth resources in the field trial. Similar result was reported by (Rondon et al., 2004).

Long-term field trials proved that composted wastes have an equalizing effect of annual/seasonal fluctuations regarding water, air and heat balance of soils, the availability of plant nutrients and thus the final crop yields (Amlinger, 2007). In his study, he reported that crop yields after pure compost application were mostly lower when compared to mineral fertilization at least during the first years. This can be explained by the slow release of nutrients (especially N) during mineralization of compost.

5. Conclusion

From the study, it was concluded that municipal solid waste treatment methods affect the growth and performance of amaranths. There was also an observed significant increase in the performance of amaranths following biochar application. Untreated (raw) wastes are relatively easier and less expensive to be used but has less pronounced effect on plant growth when compared with the control treatment. The recommended treatment method for municipal solid wastes depends on the overall purpose of application. It is therefore recommended that stakeholders be involved in the recycling of municipal solid wastes through composting as that may reduce expenses for procurement of inorganic fertilizer and provide waste management solution as well as increased crop yield for small holder farmers. Awareness through extension agents and media on the use of these available resources in farming activities is also recommended as that can reduce production cost.

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