

Effect of sources and rates of mulch application on soil physical properties and yield of fluted pumpkin (*Telfairia occidentalis*) on an ultisol in Southern Nigeria

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ABSTRACT

The use of mulching and other soil amendments have become regular as a means of improving agricultural production of the Ultisols in the farming systems of southern Nigeria area. A field investigation of the effect of different sources and rates of mulch application on some soil physical properties and performance of fluted pumpkin (*Telfairia occidentalis*) was conducted in 2014 cropping season at the Abia State University Teaching and Research Farm, Umudike in southeastern Nigeria. Rice mill waste (RMW) and Sawdust (SD) were applied as mulch materials at 5t/ha, 10t/ha and 15t/ha. and 0 t ha⁻¹ (the control). The experiment was laid out in randomized Complete Block Design (RCBD) with seven treatments, (RMW5, RMW10, RMW15, SD5, SD10, SD15 and C (control), in three (3) replications. The result showed that mulching did not significantly alter the soil texture, while bulk density decreased with increasing rates of mulching. Total porosity, hydraulic conductivity and volumetric moisture content were significantly ($P > 0.05$) higher for mulched plots than the control. There was no significant difference between 0 t ha⁻¹ (control) and 5 t ha⁻¹ of RMW and SD. However, at 10 – 15 t ha⁻¹ both RMW and SD produced significantly higher yield of fluted pumpkin and vine length in 6 – 12 WAP. Application of 15 t ha⁻¹ RMW increased the yield of vine length of fluted pumpkin from 93.2cm for 0 t ha⁻¹ (control) to as high as 246.3cm for 15 t ha⁻¹. Total porosity, volumetric moisture content and all yield parameters were higher for rice mill waste than sawdust.

Keywords: Rice mill waste, Sawdust, Fluted pumpkin, Ultisol, Total porosity, Hydraulic conductivity

INTRODUCTION

The role of soil physical conditions in providing good crop production environment has long been recognized (Mbagwu, 2002). A good soil structure Improves soil aeration, moisture content and soil temperature for optimum crop performance. One of the cultural practices

that has been useful for the development and maintenance of good soil environment is mulching. Anikwe (2000) defined mulch as a layer of dissimilar material usually applied to the soil surface, while Mahesh *et al.* (2007) defined it as any material, organic or inorganic, natural or synthetic which is placed on the soil surface to prevent soil

degradation and improve soil environment for continuous and sustained crop production. The use of mulch has been found to influence soil aggregation, water holding capacity (Rose, 2000), hydraulic conductivity (Franzluebbe, 2002) and bulk density (Celick and Kilic, 2004). Mulch application has been found to increase total porosity, available moisture content, soil aggregation and moisture content at field moisture capacity (Lukman and Lal, 2008). Studies involving the use of both rice mill waste and sawdust as soil amendment have become necessary given the potential of these materials and their availability in the area. This work will provide additional information on the effect of these materials on the physical and hydrological properties of the soils and yield of fluted pumpkin, when used as surface mulch in rainfall ecological zone of southeastern Nigeria.

MATERIALS AND METHODS

Location

This study was carried out at the Teaching and Research Farm of the Abia State University, Umuahia located 5° 25' N and 7° 35' E in the rainforest ecological zone of southeastern Nigeria. The area lies about 122 m above sea level and characterized by two distinct seasons, the wet season, which lasts from April to October and dry season which lasts from November to March. The mean annual rainfall ranges between 1800 and 2000 mm with a bimodal pattern, while the mean daily temperature which ranges between 28 and 32°C is highest in the months of February through April.

Land preparation, treatments and experimental design

The site was mechanically cleared, ploughed, harrowed and planting beds made in 2014. Each bed measured 3.0 x 3.0 m and each plot was separated by a 1 m boarder, while each bed was separated by a

0.5 m boarder. The treatments comprised rice mill waste (RMW), and sawdust (SD) applied at four rates (0t/ha, 5t/ha, 10t/ha and 15t/ha). These materials were allowed for seven days to cure before being applied as surface mulch. The treatments were RMW_{5t/ha} (T₁), RMW_{10t/ha} (T₂), RMW_{15t/ha} (T₃), SD_{5t/ha} (T₄), SD_{10t/ha} (T₅), SD_{15t/ha} (T₆) and 0_{t/ha} (T₇) (control). The experiment was laid out in Randomized Complete Block Design (RCBD) with seven treatments and three replicates, giving a total of 21 sub-plots occupying a total area of 294m² (approx. 0.03ha)

Planting

Mature fluted pumpkin seeds were obtained from the National Root Crops Research Institute, Umudike. The seeds were air-dried for twenty-four (24) hours before sowing. Two seeds were sown per stand at 1 m x 1 m, giving plant population of 20,000 plants ha⁻¹.

Soil Sample Collection and Analysis

Composite soil samples were collected at sixteen (16) weeks after planting (WAP) from 0 – 20 cm depth from each plot for some physical and hydrological properties. Undisturbed core samples were also taken from the same depth with core cylinder measuring 5 cm long and 5 cm internal diameter for the determination of bulk density, moisture content and hydraulic conductivity. Particle size analysis was determined by hydrometer method revised by Gee and Bauder (1996). Bulk density determination was by the core method described by Blake and Hartge (1986) while total porosity was calculated from the bulk density using the method of Flint and Flint (2002) and an assumed average particle density of 2.65 Mgm⁻³ using the equation below:

$$P = (1 - B_d/B_p) \times 100\%$$

Where: P = total porosity (%) ($\text{m}^3 \text{m}^{-3}$)

B_d = bulk density (Mg m^{-3})

B_p = Particle density (2.65 Mg m^{-3}).

Hydraulic conductivity was done by the constant head permeameter method of Stoite (1997). Some growth and yield parameters of the fluted pumpkin were also measured at three weeks interval. Number of leaves and vine length were taken at 3, 6, 9 and 12 Weeks After Planting (WAP), while harvestable leaves yield was taken at 6, 9 and 12 WAP.

RESULTS

Characteristics of the experimental site

Some pertinent physical properties of the 0 – 20 cm depth of the experimental site are shown in Table 1. The soil texture was sandy loam with sand, silt and clay contents of 77.6, 10.2 and 12.2% respectively. Other physical properties of the site were bulk density (1.73 Mg m^{-3}); total porosity (39.20%); volumetric moisture content ($12.05 \text{ m}^3 \text{m}^{-3}$) and hydraulic conductivity (28.20 cm hr^{-1}).

Characterization of mulch materials used in the experiment

Some chemical properties of the mulch materials (sawdust and rice mill waste) are as shown in Table 2. The data showed that rice mill waste was higher in total nitrogen and available phosphorus than sawdust, while the later was marginally higher than the former in calcium, magnesium, potassium and sodium. The low nutrient content of these materials can be attributed to their age.

Mulch effect on some physical properties of the soil

The effect of mulch material on soil texture, bulk density, total porosity, volumetric moisture content and hydraulic conductivity are presented in Table 3. Results showed that treatments did not have significant ($p < 0.05$) effect on soil texture. Essentially, soil texture as an inherent soil property is most times not affected by treatment.

Total porosity values ranged from 34.10 % in the control to 57.00 % in the RMW_{15/ha} treatment (T₃). All mulched plots showed significantly ($P < 0.05$) higher total porosity than the control. Similarly, T₃ recorded significantly higher total porosity than the other treatments.

Table 1: Some physical properties of the 0 – 20 cm depth of the experimental site

Parameters	
Sand	77.60
Silt } %	10.20
Clay } %	12.20
Textural class	loamy sand
Bulk density (Mg m^{-3})	1.73
Total porosity (%)	39.20
Volumetric moisture content ($\text{m}^3 \text{m}^{-3}$)	12.05
Hydraulic conductivity (cm hr^{-1})	28.20

Table 2: Soil chemical properties of the mulch materials used in the experiment

Properties	Rice mill waste	Sawdust
Total nitrogen (%)	0.93	0.28
Avail. Phosphorus (Mg kg ⁻¹)	0.83	0.15
Calcium	0.60	0.70
Magnesium	0.12	0.18
Potassium	0.18	0.28
Sodium	0.06	0.08

Mulch effect on number of leaves and vine length of fluted pumpkin

Effect of different sources and rates of mulch on number of leaves and vine length of fluted pumpkin are shown in Table 4. Application of mulch significantly ($P < 0.05$) affected both number of leaves and vine length of fluted pumpkin. Across all sampling dates, number of leaves of fluted pumpkin increased with increasing mulch application rate. Again, at all sampling periods, number of leaves was higher for mulched plots than the control (unmulched plots) with the difference being significant for T_2 and T_3 . Also, at 12 WAP, T_6 was significantly higher when compared against the control.

Effect of different sources and rates of mulch application on vine length of fluted pumpkin was significant. Data on Table 4 showed that RMW applied at the rates of 10t/ha and 15t/ha (T_2 and T_3) significantly

($P < 0.05$) increased vine length of fluted pumpkin over the control. Similarly, T_1 at 3 and 6 WAP, and T_6 at 9 WAP were significantly higher than the control. Amongst the mulched plots, at 3 WAP, T_2 and T_3 were significantly higher than the others. Also, T_1 and T_6 were higher than T_4 . At 6 WAP, all mulched plots were statistically higher than T_4 , while T_1 , T_4 and T_5 were similar. At 9 WAP, vine length ranged between 76.40 and 273 cm recorded in T_4 and T_3 respectively.

Mulch effect on yield of fluted pumpkin

The effect of treatments on yield of fluted pumpkin, (*Telfairia occidentalis*) is presented in Table 5. Yield of fluted pumpkin was significantly ($P < 0.05$) affected by treatment at all times of harvest. Yield consistently increased with increasing rates of application.

Table 3: Effect of different sources and rates of mulch on some soil physical properties

Treatment	Sand (%)	Silt (%)	Clay (%)	Textural class	Bulk density (Mg cm ⁻³)	Total porosity (%)	SMC (m ³ m ⁻³)	Ksat (cm/hr)
T ₁	81.40	9.10	9.50	LS	1.49	44.00	12.82	30.31
T ₂	82.30	7.87	9.83	LS	1.46	45.00	13.11	31.60
T ₃	81.60	8.10	10.30	LS	1.28	57.00	14.32	38.20
T ₄	82.90	8.10	9.00	LS	1.52	42.64	12.68	30.32
T ₅	82.70	7.10	10.20	LS	1.50	43.40	13.00	32.06
T ₆	82.30	7.89	9.83	LS	1.47	44.52	13.13	39.23
T ₇	80.80	9.00	10.20	LS	1.75	34.10	12.17	30.42
LSD (0.05)	14.54	7.80	6.23		0.19	5.63	0.16	1.25

T₁ (RMW_{5t/ha}), T₂ (RMW_{10t/ha}), T₃ (RMW_{15t/ha}), T₄ (SD_{5t/ha}), T₅ (SD_{10t/ha})

T₆ (SD_{15t/ha}), T₇ (0t/ha). SMC = Volumetric soil moisture content, Ksat = Saturated hydraulic conductivity

Table 4: Effect of different sources and rates of mulch on number of leaves and vine length of fluted pumpkin

Treatment	Number of leaves				Length of vine (cm)			
	3	6	9	12	3	6	9	12
	WAP				WAP			
T ₁	56.30	73.40	75.20	103.20	62.40	68.20	181.30	186.70
T ₂	75.00	92.30	110.30	170.00	83.30	86.40	212.00	212.70
T ₃	85.00	96.00	168.30	190.00	92.80	94.30	273.00	246.30
T ₄	48.20	61.20	60.80	86.40	34.60	52.40	76.40	152.60
T ₅	51.70	76.30	76.00	100.00	45.30	67.80	99.00	195.00
T ₆	70.00	83.70	83.30	151.70	59.90	73.30	203.00	203.30
T ₇	45.00	76.00	72.00	69.30	47.00	63.30	112.00	93.20
LSD (p<0.05)	12.51	13.10	42.49	64.29	20.23	15.40	32.40	28.32

T₁= RMW_{5t/ha}; T₂= RMW_{10t/ha}; T₃= RMW_{15t/ha}; T₄= SD_{5t/ha}; T₅= SD_{10t/ha}; T₆= SD_{15t/ha} T₇ = 0t/ha (control) ; WAP = Weeks after planting

Table 5: Effect of different sources and rates of mulch application on yield of fluted Pumpkin

Treatment	Yield of fluted pumpkin (kg/ha)		
	6	9	12
	WAP		
T ₁ (RMW _{5t/ha})	589	648	756
T ₂ (RMW _{10t/ha})	640	706	883
T ₃ (RMW _{15t/ha})	650	737	966
T ₄ (SD _{5t/ha})	386	472	672
T ₅ (SD _{10t/ha})	467	550	777
T ₆ (SD _{15t/ha})	525	640	790
T ₇ (0t/ha)	395	347	659
LSD (0.05)	76.7	91.7	143.6

WAP = Weeks after planting

DISCUSSION

Both source and rate of mulch affected soil bulk density significantly. In comparison with the control, mulching reduced soil bulk density as all the mulched plots recorded reduced bulk density values. The application of RMW at the rate of 15 t/ha gave significant ($p < 0.05$) lowest bulk density of 1.28 Mg m^{-3} . Generally, the application of RMW was more effective in reducing soil bulk density when compared with SD. This observation was in line with the reports of Anikwe and Nwobodo (2002), Ojeniyi *et al.* (2006) and Eze *et al.* (2015). The relative ease of decomposition of RMW over SD may have increased the soil organic matter and total porosity in plots that received the former thereby reducing the bulk density.

This higher total porosity of the mulched plots over the control can be attributed to the presence and activities of both macro and micro fauna which may have invaded the mulch materials to bring about breakdown and subsequent decomposition. Nnaji (2009) had reported significantly higher total porosity for plots mulched with RMW over un-amended plots. Eze *et al.* (2015) had reported a lower bulk density with a higher

total porosity at a mulching rate of 15t/ha in comparison with 0 and 10 t/ha of rice bran.

Volumetric moisture content was significantly affected by both the type of mulch material and rate of application. Volumetric moisture content for all mulched plots was significantly higher when compared with the control. Among the mulched plots, T₃ had significantly highest volumetric moisture content. For RMW, each incremental rate of application significantly increased volumetric moisture content, while T₅ and T₆ were non-significant. RMW was superior to SD in conserving soil water. Volumetric moisture content followed the same trend with total porosity which increased the water storage capacity of the soil (Omenihu, 2010). Furthermore, the protective effect of the mulch may have aided water conservation by reducing evaporation.

The effect of mulching on soil hydraulic conductivity was significant. Relative to the control, the effect of T₁, T₂ and T₄ on hydraulic conductivity was not significant. However, T₃ and T₆ had significantly higher hydraulic conductivity compared to the

other treatments. SD recorded higher values of hydraulic conductivity than RMW probably on account of the higher ability of the RMW to promote soil aggregation than the SD. The sandy nature of the soils further facilitated the rapid hydraulic conductivity in the various plots.

Mulching with RMW at all rates and SD_{15t/ha} were significantly higher than the control, while the control was higher than T₄. For the 12 WAP, the highest vine length of 246.3 cm was associated with T₃, while the lowest length of 93.2 cm occurred in the control. At equal rates of application, RMW was superior to SD, out-yielding it in both number of leaves and vine length. The increased number of leaves and vine length of fluted pumpkin recorded with increasing rate of mulch application can be attributed to improved soil moisture content due to reduced evaporation, moderation of soil temperature and build up in organic matter content (Wicks *et al*, 1994; Ogban *et al*, 2006; Eze *et al*, 2015). The difference in vine length for T₄ (SD_{5t/ha}) was 75.20 cm at 9 and 12 WAP and the difference for T₁ (RMW_{5t/ha}) for same period was 5.4 cm. Possible implication of the above result is that SD takes longer to mineralize than RMW.

Mulch effect on harvestable yield of fluted pumpkin is in agreement with the findings of Ashworth and Harrison (2003) who attributed this increase to reduced nutrient losses due to weed control and improved hydrothermal regimes of the soil. Lal (2000) reported that yields were doubled due to reduced competition resulting from mulching. At 6 and 9 WAP, all mulch-amended plots, except T₄ at 6 WAP, significantly out-yielded the control, while T₄ was lower than T₆ at 9 WAP. At 12 WAP, all amended plots but T₄ recorded higher yield in comparison with the control,

the difference being significant for T₂ and T₃. Application rate of SD at this did not have any effect on harvestable yield of *Telferia*, while for RMW, T₃ was higher than T₁. Between RMW and SD, at equal rates of application, RMW was superior to SD. The lower yields obtained from plots amended with SD when compared with RMW may be explained by its low nitrogen content and high C:N ratio. Allison and Anderson (2011) observed that sawdust is extremely low in nitrogen and ash constituents that are of primary importance in crop production, especially vegetables.

CONCLUSION

This study showed that mulching of an ultisol in south eastern Nigeria with 10t/ha and 15t/ha of rice mill waste and saw dust respectively increased performance and yield of fluted pumpkin (*Telfairia occidentalis*). , at equal rates of application, RMW was superior to SD. The mulch materials also enhanced the soil physical properties by improving soil moisture content due to reduced evaporation, moderation of soil temperature and increases in organic matter content.

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