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# MULCHING AN ARENIC HAPLUDULT IN SOUTHEASTERN NIGERIA: EFFECTS ON SELECTED SOIL PROPERTIES AND RHIZOME YIELD OF TURMERIC.

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## ABSTRACT
***A study was carried out over two cropping seasons at Umudike, southeastern Nigeria, to determine the type and quantity of mulch that would improve some selected physical properties of an Arenic Hapludult and optimize the rhizome yield of turmeric. Effects of mulch rate on bulk density (BD), total porosity (TP), macro-porosity (Ma. P), water stable aggregates (WSA > 0.5 mm) and mean-weight diameter (MWD) significantly depended on the type of mulch material used. Straw mulch reduced BD and increased other parameters more than wood shavings. Optimum values of WSA > 0.5 mm (23.2) and MWD (0.535) occurred at the 4 t/ha mulch rate, whereas, maximum values of TP (54.08%), Ma. P (26.55%) and minimum value of BD (1.51 g/cm$^3$), were achieved at mulching beyond 4 t/ha. Apart from total porosity, which was found to be optimum, BD, organic carbon (OC), Ma. P and MWD explained individually between 80 and 99% of the variability in yield. Results also showed that all mulched plots out-yielded the bare plots. Rhizome yield varied with the rate of mulch application with yield increases declining in the order 8, 4 and 0 t/ha mulch rate. Increase in the rhizome yield of turmeric was dependent on the type of mulch used, with straw mulch out-yielding wood shavings by 38.4 and 76.6% in 2004 and 2005, respectively.***

**Keywords:** Turmeric rhizomes, soil physical properties, mulching, arenic hapludult

## INTRODUCTION
Turmeric is a shallow-rooted crop and an herbaceous plant with thick and fleshy rhizomes. It belongs to the genus Curcuma and to the family, *Zingiberaceae,* and consists of many species. *Curcuma longa* Linn is the highest yielding turmeric of commercial value. Its origin has been traced to South and Southeast Asia. India is reputed to be the largest producer of turmeric. Turmeric is used as a spice and is the main constituent of curry powder. Besides its use as a spice, turmeric finds a place in the cosmetics industry for its brilliant yellow colour and characteristic perfume. It is also being used as a dye for colouring fabrics among other uses.

A crop's genetic potential and environmental setting usually control its yield. However, soil conditions at the rooting depth of a crop influence the full exploitation of its genetic potentials. Any sound soil management programme must provide three conditions: a satisfactory state of soil tilth for the development of the root; an adequate amount of the right kind of plant nutrients for good crop production; and protection against excessive soil loss and run off. Mulch practices have been shown to satisfy these conditions through their effects on soil and water conservation (Fournier 1967; Lal *et al*., 1980; Adeoye, 1982).

Crop residues have numerous competing uses such as fodder, fuel, construction and mulch materials. Similarly, costs are incurred in its application and these costs increase with mulch rate. Therefore, it is necessary to establish optimum mulch application rates. Mulumba and Lal (2008) studied the long term (11 years) effects of mulching (0, 2, 4, 8, 16 t/ha/year without crop cultivation) on soil physical properties of a silt loam Arenic Ochraqualf in central Ohio. Results demonstrated that mulch rates significantly increased available water capacity by 18 - 35%, total porosity by 35 - 46% and soil moisture retention at low suctions from 29 - 70%. At high suctions, no differences in soil moisture content were observed between mulch levels. Soil bulk density was not affected by mulch rate. High correlations were obtained between mulch rate and soil mean weight diameter ($R^2$ = 0.87) and percent water-stable aggregates ($R^2$ = 0.84). The study was able to determine optimum rate of 4 t/ha for increased porosity and 8 t/ha for enhanced available water capacity, moisture retention and aggregate stability.

Mbagwu (2006) determined the minimum rate of straw mulch for optimising the physical conditions of the top soil (0 - 20 cm depth) of a fragile ultisol and maize (*Zea mays*) and cowpea (*Vigna unguiculata* L.Walp) yields. Results obtained showed that water retention and percent water- stable aggregates > 0.5 mm were maximal, whereas soil compaction (measured by dry bulk density) was minimal at the 2.0 t/ha mulch rate. Maize and cowpea yields were optimal at the 4.0 t/ha rate with respective increases over the bare plots of 80 and 67% at that rate. However, according to Lentz and Bjorneberg (2003), residue mulching may not always improve soil physical properties because positive effects depend on the quality and quantity of residue applied, management duration, tillage system, site-specific soil properties, and climate. Lal (1995) had reported that the magnitude of mulch effects on nutrient supply and improvement on soil physical properties depended on the quantity and quality of mulch, soil properties and prevailing climatic conditions. The objectives of the research were to: (1) determine the type and quantity of mulch material that would optimize the physical properties of an Arenic Hapludult; and (2) evaluate their effects on the rhizome yield of turmeric.

## MATERIALS AND METHOD

This study was carried out for two consecutive cropping seasons (2004 / 05 and 2005/06) in the National Root Crops Research Institute (NRCRI) Umudike Research Farm (latitude $05^{o}\ 29^{/}$ N; longitude $07^{o}\ 33^{/}$ E) in southeastern Nigeria on a loamy sand soil (Arenic Hapludult). The site was disc-ploughed and disc-harrowed to a depth of about 20 cm. Beds, each measuring, 3 m x 2 m, were made with a one metre distance separating adjacent beds. The experimental design used was split plot in randomized complete block design (RCBD) with three replications. The main plot treatments were two mulch types, straw (*Pennisentum purpureum*) and wood shavings. The sub- plot treatments comprised three mulch rates (0, 4, and 8 t/ha). Planting was done in June each year. The mulch treatments (dry weights) were applied immediately after planting. Fertilizer (N. P. K, 15:15:15) was applied 8 weeks after planting (WAP) at the rate of 400 kg/ha. Pri-mextra and gramazone herbicides were applied, as pre-emergence, at the rates of 1.5 and 0.53 kg/ha active ingredients, respectively. Supportive rouging was done at regular intervals to keep the plots weed free. The crop was harvested in January (28 WAP) and the rhizome yield (t/ha) measured. Yield from the mulched plots were compared with the yield from unmulched (control) plots by computing a mulch factor thus:

$$M = ((Ym/Yc)\ \ 1) \times 100 \ldots\ldots\ldots\ldots\ldots (1)$$

where M = mulch factor (i.e. the percentage increase in yield over the control due to mulching); Ym = yield on the mulched plot and Yc = yield on the control plot.

Bulk density was calculated by the method of Blake and Hartge (1986a). Total porosity (TP), was determined using the relationship between soil bulk density (BD) and particle density (PD) (Blake and Hartge, 1986b). Macro-porosity (Ma. P) and micro-porosity (Mi. P) were calculated from bulk density values, with assumed particle density of 2.65 Mg $m^{-3}$, as follows:

$TP = 100\ (1 - BD / PD)$;

$Ma.\ P = TP - \theta$ (60 cm tension); and $Mi.\ P = TP - Ma.\ P$; where θ is the volumetric water content.

Water stable aggregate (WSA > 0.5 mm) was determined following the methods of Kemper and Rosenau (1986). Mean-weight diameter (MWD) was calculated from water stable aggregates using the formular:

$$MWD = \sum_{i=1}^{n} Xi\ Wi$$

where Xi is the diameter of the ith sieve size and Wi is the proportion of the total aggregates in the ith fraction, and n = total number of size fractions (Kemper and Rosenau, 1986). Particle size distribution was measured by the hydrometer method as described by Gee and Bauder (1986). Percent organic carbon (%O.C.) was determined by the dichromate oxidation method of Walkley and Black method (Nelson and Sommers, 1982). Total nitrogen was determined by micro-Kjeldahl method (Bremner and Mulvaney, 1982). Soil pH ($H_2O$) was measured (soil / water ratio of 1:2.5) with a digital pH meter (McLean, 1982). Exchangeable bases were extracted with 1N $NH_4OAc$ (Jackson, 1958). Exchangeable acidity was determined by the titrimetric method after extraction with 1.0 M KCl (McLean, 1982). Effective cation exchange capacity (ECEC) was determined from the sum of the exchangeable bases and the exchangeable acidity. Statistical method of analysis of variance for a split plot design as outlined by Steel and Torrie (1980) was used for the analysis. Mean separation for significant ($P < 0.05$) effects was carried out using F-LSD, as described by Obi (1986). Correlation coefficients, coefficients of determination and regression equations, were used to explain relationships between yield and soil properties.

## RESULTS AND DISCUSSION

## EXPERIMENTAL SITE

The selected soil physical properties of the study site before treatment application are as shown in Table 1. The soil was loamy sand, with acidic soil reaction. Total N, exchangeable K, ECEC, and OC, were very low. The low nutrient status of the soil is desirable, for easy detection of treatment responses. The rainfall distribution as recorded at Umudike, followed the bi-modal pattern, typical of the tropical rainforest. The first and second peaks were in July and September respectively in both years (Table 2). Total annual rainfall amount, within the period of study ranged from 1911.4 to 2054.8 mm. Turmeric is known for its wide range of ecological adaptation with regard to poor soil and harsh climatic conditions.

**Chemical characteristics of the mulch materials used.**

Chemical characteristics of the mulch materials used are shown in Table 3. The organic matter content was high (5.10 %) in straw, but low (1.31%) in wood shavings. Total N was low (0.126%), in straw, but high (0.378%), in wood shavings. Available K was high in both straw (0.50 mg/kg), and wood shavings (0.640 mg/kg). Straw had wider C/N ratio (23.5:1), than wood shavings (2:1). Mulch material with wide C/N ratio would serve as better mulch, as decomposition will take a longer time to be achieved.

**Table 1. Physico-chemical properties of soil of the study site at the start of the experiment**

| Property | Values |
|---|---|
| Sand (%) | 81.8 |
| Silt (%) | 7.4 |
| Clay (%) | 10.8 |
| Texture [a] | LS |
| Organic Carbon (%) | 0.75 |
| pH($H_2O$) | 5.42 |
| ECEC cmolkg$^{-1}$ [b] | 3.98 |
| Total Nitrogen (%) | 0.084 |
| Available K (ppm) | 0.102 |
| Carbon/Nitrogen (C/N) | 8.9:1 |

**a.** LS = loamy sand; b. ECEC = effective cation exchange capacity

**Table 2. Rainfall data of the experimental site for 2004 and 2005**

| | Year | | | |
|---|---|---|---|---|
| | 2004 | | 2005 | |
| **Month** | **Rainfall amount (mm)** | **Number of rainy days** | **Rainfall amount (mm)** | **Number of rainy days** |
| January | 0.2 | 0 | 17.3 | 2 |
| February | 11.9 | 2 | 126.7 | 5 |
| March | 22.4 | 4 | 64.0 | 6 |
| April | 134.5 | 9 | 141.3 | 11 |
| May | 217.6 | 11 | 222.4 | 17 |
| June | 279.4 | 18 | 264.4 | 18 |
| July | 309.5 | 18 | 277.0 | 24 |
| August | 304.3 | 21 | 225.0 | 21 |
| September | 324.9 | 19 | 339.7 | 17 |
| October | 249.1 | 16 | 323.0 | 18 |
| November | 5.5 | 4 | 45.4 | 6 |
| December | 5.1 | 1 | 8.6 | 2 |
| **Total** | **1911.4** | **123** | **2054.8** | **147** |

Source: National Root Crops Research Institute Meteorology Station, Umudike

**Table 3.Chemical characteristics of the mulch materials used**

| | Mulch Type | |
|---|---|---|
| **Property** | Straw | Wood shavings |
| Organic carbon (%) | 2.96 | 0.76 |
| Total nitrogen (%) | 0.126 | 0.378 |
| Available Potassium (mg/kg) | 0.50 | 0.640 |
| C/N ratio | 23.5 : 1 | 2 : 1 |

## Effects of mulch application on BD, MWD, TP, WSA > 0.5 mm and Ma. P.

Mulch rate significantly affected BD, Pt, Pe and MWD. However, mulch type significantly influenced only Pe and MWD (Table 4). Increase in mulch rate increased MWD, WSA > 0.5 mm, Ma. P and TP, but reduced BD. Maximum values for Ma. P (26.55%) and TP (54.08%) were obtained at 8 t/ha rate, whereas for macro aggregate stability indices (WSA > 0.5 mm and MWD), optimum values were obtained at the 4 t/ha mulch rate. Lower BD and higher TP, Ma. P and WSA > 0.5 mm was observed in mulched plots and as mulch rate increased. This may have resulted from the beneficial effects of a mulch cover to breakdown the kinetic energy of the rain drops, thereby reducing their impact on the soil, resulting in reduced soil compaction and aggregate disintegration. It would appear that the decomposition of the mulch materials provided soil organic matter (SOM) which helped to stabilize the aggregate, explaining the lower values of BD and higher values of WSA > 0.5 mm, TP and Ma. P obtained on mulched plots.

## Effect of treatments on rhizome yield of turmeric.

The effects of mulch type and rate on rhizome yield of turmeric in 2004 and 2005 are presented in Table 5. Mulch type and rate showed highly significant effects (P = 0.001) on yield. Mulching with straw compared to wood shavings resulted in much higher rhizome yield. Total rhizome yield per hectare increased by 38.62% in 2004 and by 76.64% in 2005. Straw contains higher percent OM, conserves soil moisture better, and improves soil structure better than wood shavings (Nwokocha et al., 2006).

**Table 5. Rhizome yield of turmeric as influenced by mulch application at Umudike.**

| | Rhizome yield (t/ha) | | |
|---|---|---|---|
| **Treatments** | **2004** | **2005** | **Means** |
| **Mulch type** | | | |
| Straw | 10.23 | 10.51 | 10.37 |
| Wood shavings | 7.38 | 5.95 | 6.67 |
| LSD (0.05) | 0.75** | 0.25** | |
| **Mulch rate (t/ha)** | | | |
| 0 | 4.06 | 3.52 | 3.79 |
| 4 | 10.60 | 8.66 | 9.63 |
| 8 | 11.76 | 12.51 | 12.14 |
| LSD (0.05) | 1.05** | 0.48** | |

*,** = Significant at 5% and 1% alpha levels; NS = Not significant at 5% alpha level

These attributes of straw over wood shavings might have been responsible for the higher rhizome yield observed in straw-mulched plots. Mulch rate significantly influenced (P = 0.01) rhizome yield in both years (Table 5). The increase in yield due to mulch rate followed the trend; 8 > 4 > 0 t/ha in both cropping seasons. This confirms the observation of Lal (1975), that the ability of mulch to enhance soil quality and improve yield, depends on the quantity and quality of mulch applied.

The computed mulch factor value was higher in 2005 (255%) than in 2004 (189%), at the 8 t/ha mulch rate (Fig. 1). In 2004 (first year of study), a mulch factor improvement of 29% was achieved whereas, in 2005 (second year of study), a higher mulch factor improvement of 109% was recorded.

## Yield of Turmeric and Soil Physical Properties

Apart from total porosity, other soil properties explained individually between 80 and 99% variability in yield (Table 6). Non significant relationship between turmeric yield and total porosity implied that total porosity was optimal for turmeric performance. Negative correlation between bulk density and turmeric yield, like in other root crops, was expected. By reducing bulk density, mulching helped to improve root penetration.

**Table 4. Effects of mulch type and rate on some selected physical properties of an Ultisol at Umudike.**

| **Treatments** | **TP** (%) | **Ma. P** (%) | **BD** ($g/cm^3$) | **MWD** (%) | **WSA** (%) |
|---|---|---|---|---|---|
| **Mulch type** | | | | | |
| Straw | 50.13 | 21.33 | 1.56 | 0.528 | 21.52 |
| Wood shavings | 51.91 | 18.92 | 1.55 | 0.508 | 18.79 |
| LSD (0.05) | NS | 0.21** | NS | 0.015* | NS |
| **Mulch rate (t/ha)** | | | | | |
| 0 | 49.71 | 11.55 | 1.57 | 0.466 | 13.71 |
| 4 | 49.29 | 22.26 | 1.58 | 0.535 | 23.15 |
| 8 | 54.08 | 26.55 | 1.51 | 0.555 | 23.60 |
| LSD (0.05) | 2.08** | 0.64** | 0.03* | 0.040* | 3.11** |

*, ** = Significant at 5 and 1% alpha levels respectively; NS = Not significant at 5% probability level.

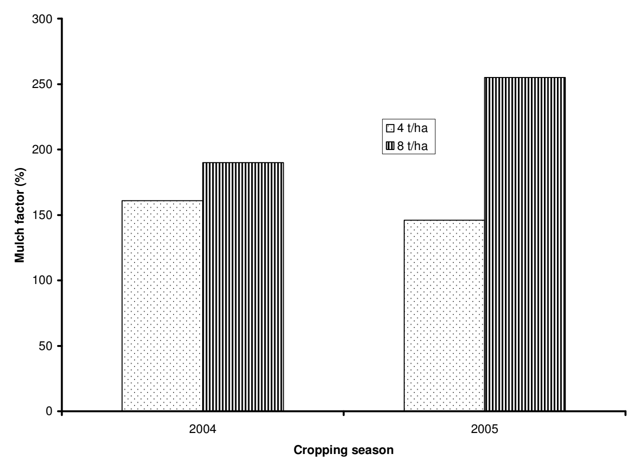


**Fig. 1. Influence of mulch rate on rhizome yield of turmeric in an Ultisol**

**Table 6. Relationships between turmeric rhizomes yield and some physical properties of an Ultisol (Y in t/ha)**

| Dependent variables (N = 18) | Regression models | $R^2$ |
|---|---|---|
| Water stable aggregates (WSA > 0.5 mm) | Y = 0.61 + 0.41(WSA > 0.5 mm) | 0.90** |
| Bulk density (BD) | Y = 55.3  30.71(BD) | 0.99* |
| Organic matter (OM) | Y = 2.19 + 8.80(OM) | 0.80** |
| Total porosity ($P_t$) | Y = 3.06 + 0.11($P_t$) | NS |
| Macro-porosity ($P_e$) | Y = -2.60 + 0.53($P_e$) | 0.89** |
| Mean weight diameter (MWD) | Y = -7.77 + 31.97(MWD) | 0.98** |

*, ** = Significant at 5 and 1% alpha levels respectively; NS = Not significant at 5% alpha level.

## CONCLUSIONS

The results of this study showed that all mulched plots out-yielded the bare plots. Yields varied with the rate of mulch application, with yield increases declining in the order 8, 4 and 0 t/ha mulch rate. Increase in the rhizome yield of turmeric was dependent on the mulch type used with straw mulch out-yielding wood shavings. Effects of mulch rate on BD, TP , Ma. P , WSA > 0.5 mm and MWD were dependent on the type of mulch material used. Straw mulch reduced BD and increased TP , Ma. P , WSA > 0.5 mm and MWD more than wood shavings. Optimum values of MWD and WSA > 0.5 mm for soil improvement occurred at the 4 t/ha mulch rate, whereas, for TP , Ma. P and BD, optimum rate was achieved at mulching beyond 4 t/ha. Decreases in WSA > 0.5 mm, Ma. P , and MWD on the bare plots were detrimental to the rhizome development of turmeric. Apart from total porosity, which was found to be optimum, BD, OC, Ma. P and MWD explained individually between 80 and 99% variability in yield. Negative correlation observed between BD and rhizome yield of turmeric, was as expected in all root crops.

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