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Full Length Research Paper

Mulching effects on soil microbial, physicochemical properties and performance of cowpea on coastal plain sand

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The presence of residue mulches in farm has been known to effectively save the soil surface, prevent soil erosion on slopes, helps reduce soil moisture loss through evaporation, and insulates soil, protect roots from extreme temperatures, improve soil biology, aeration, aggregation of soil particles and reduce drainage over time, improve soil fertility as certain mulch types decompose, inhibits certain plant diseases, reduces the likelihood of tree damage from "weed whackers" or the dreaded "lawn mower blight", give planting beds a uniform and provide favorable preservation of ecological stability. This experiment was conducted in the Teaching and Research Farm of Akwa Ibom State University, Obio Akpa Campus to assess the effect of sawdust, pulverized palm bunch and *Calopogonium mucunoides* leaves mulches effects on soil microbial, physicochemical properties and performance of white dwarf cowpea (*Vigna unguiculata*) on coastal plain sand of Southern Nigeria. Results showed that soil mulched with *Calopogonium mucunoides* leaves recorded the highest in the following parameters measured: pH of 6.45, organic carbon (5.16%), nitrogen (2.26%), ECEC of 11.35 cmol, available phosphorus of 323 mg kg^{-1}, base saturation (91.11%), 100% seed emergence and leaf area. The highest moisture content of 35% was obtained in the sawdust mulched soil. The highest peas moisture content (5.63%), crude fiber (3.91), lipid (4.71), total ash (4.82) and carbohydrates (61.88%) were obtained in the soil mulched with *Calopogonium mucunoides* while highest bacterial counts of 37×10^5 cfu g^{-1} soil and the fungi counts (51×10^3 cfu g^{-1} soil). The studied soil contained more than 70% sand. The soil is described as sandy loam which gives rise to Typic Paludult, characteristics of soil derived from Coastal Plain Sand.

Keywords: Bean, Calopogonium mucunoides, and Paludult

INTRODUCTION

Mulching is defined as the process of covering the soil with mulch in order to prevent evaporation of moisture from the soil, improve the fertility of the soil and also to reduce the growth of weeds in the garden or farm. Mulch is organic matter made up of dead plant material such as leaves, straws, semi-rotten vegetables, dry grass, hay, etc. (Baumhardt and Jones, 2002).The use of mulches and good agricultural practices can mitigate the effect of climate and provide nutrients, plant protection, shelter and adequate microclimate needed by soil organisms in order to sustain soil productivity. Other effects of mulches on soil are to keep the superficial soil layers at more even temperature, damper and more permeable to water than the unmulched soil both seasonal and diurnal fluctuation in soil temperature, slow down the rate of evaporation and erosion from a bare, wet soil considerably. More so, there is a shift on the part of farmers to establish organically certified goods and to tap into lucrative organic export market. Mulch is usually, but not exclusively, organic in nature. It may be permanent (e.g., plastic sheeting) or temporary (e.g. bark chips). It may be applied to bare soil or around existing plants. Mulches of manure or compost will be incorporated naturally into the soil by the activity of worms and other organisms and when applied correctly, can dramatically improve soil productivity.

Cowpea (*Vigna unguiculata*) is used in many parts of the world for its high-protein seeds, but also for its nutrient-rich edible leaves, forage, and soil enrichment. Cowpea is generally more heat-tolerant than common bean. Cowpeas are one of the most important food legume crops in the semi-arid tropics that cover Africa and South America. A drought-tolerant and warm-weather crop, cowpeas are well-adapted to the drier regions of the tropics, where other food legumes do not perform as well. It also has the useful ability to fix atmospheric nitrogen through its root nodules, and it grows well in poor soils. Cowpea is often called “black-eyed pea” due to its black or brown-ringed hylum. Cowpea is called the “hungry-season crop” because it is the first crop to be harvested before the cereal crops. Its fresh or dried seeds, pods and leaves are commonly used as human food. Since they are highly valuable as food, cowpeas are only occasionally used to feed livestock but the hay and silage can be an important fodder. Water demands of urban populations are essentially growing, so water availability for agricultural producers is constantly reduced, and the associated costs rise. To address both of these issues, producers are searching for new ways to reduce their demands. Mulching is one cultural practice which can be used to addresses this problem.

The reasons for applying mulch include conservation of soil moisture, improving fertility and health of the soil, reducing weed growth and enhancing the visual appeal of the area. The process is used both in commercial crop production and in gardening and when applied correctly, can dramatically improve soil productivity. It may not always be possible to procure more water, so farmers must adopt management practices which maximize water use efficiently. Applying organic mulches is one cultural practice which can help this goal. Information on good mulching materials is scanty; therefore research on mulching materials become inevitable as one cultural practice which can be used to addresses this problem. The aim of this research is to evaluate selected mulching materials effects on coastal plain sand. The objectives of this study are to determine:

(1) Physicochemical properties of mulched and unmulched soil.
(2) Seed emergence under difference soil mulching material.
(3) Proximate analysis of cowpea peas planted in mulched and soil.
(4) Microbial (fungi and bacteria) properties of the soil of difference mulching materials.

Hypotheses

Ho: T1= 0: Treatment effect is zero
Ho: H1 + 0: Treatment effect is not zero.

MATERIALS AND METHODS

The study area

The Teaching and Research Farm of Akwa Ibom State University, Obio Akpa Campus is situated between latitudes 4°30'N and 5°30'N and longitudes 7°30'E and 8°00'E of the Greenwich Meridian (SLUS-AK, 1989). The area is in the humid tropical region, characterized by two seasons; rainy season with heavy amount of rainfall accompanied by high velocity of wind, and dry season with severe intensity of sunlight experience in the early hours of the day and usually set in the evening (Enwezor *et al.,* 1990).

Land preparation and field layout

A portion of uncultivated portion of land measuring 17 m x 15 m was manually slashed and clears using cutlasses and shovels during 2018 planting season. The area was demarcated into 4 x 3 m plot and space of 1 m between each plot and replicated three times. Plots were mulched with 10 t ha^{-1} sawdust obtained from the local timber market, mulched with *Calopogonium mucunoides* leaves and with palm pulverized bunch, respectively. Unmulched plot was included to serve as control and left for 14 days for soil to equilibrate, then five seeds of cowpea (*Vigna unguiculata* - akoti – Efik/Ibibio) white variety was obtained from popular Abak local market were planted directly into field plots. The treatments were completely randomized. No form of agrochemical was applied during the study period.

Soil sampling

Soil was sampled before planting and 80 days after planting for the determination of the soil reaction (pH), organic carbon, phosphorus, calcium, magnesium, sodium, total nitrogen, moisture content, particle size analysis and for microbial counts. Composite soil samples were taken and placed into well labeled polythene bags and taken to the Soil Science Laboratory of University of Uyo for analysis. At University of Uyo laboratory, soil samples were air-dried at room temperature, crushed and passed through 2 mm sieve and stored in labeled polythene bags for various analyses. All analytical determinations were carried out in duplicates. Blank determinations were also done *inter alia* to eliminate any sources of impurities in the reagents used. The following were done:

Soil reaction (pH)

Soil reaction was determined in water with glass electrodes in the 1:2.5 soil water ratios (Udo and Ogunwale, 1978).

Moisture content in the soil

The oven soil sample were air-dried and put in the oven at 105°C to a constant weight for the determination of percent moisture content. The percent moisture was determined thus:

% moisture content = A-B x 100/B
Where; A = air dried soil + moisture can, B = Oven dried

Organic carbon

Organic carbon was determined by the dichromate wet oxidation method of Walkly and Black (1934) as described by Nelson and Sommers, (1982). Percent organic matter contents were calculated from organic carbon value using the Van Bremmien multiplication factor of 1.724 on the assumption that organic matter contains 58 percent carbon.

Total nitrogen

Total nitrogen in the soil was determined by macrokjeldahl digestion and distillation method of Jackson, (1970).

Determination of Exchangeable Bases

Calcium (Ca) and magnesium (Mg) were determined by titration method (ETDA) of Jackson (1970) as modified by Nelson and Sommers, (1982). The concentration of exchangeable Ca and Mg were determined using EDTA titration method where by calcium and magnesium indicator (EBT) complex was associated by titrating with standard 0.005M EDTA solution. In the EDTA titration method, the metallic cations (Ca^+ and Mg^+) were titrated with EDTA and end point was detected using metal sensitive indicators. For the determination of sodium (Na) and potassium (K), the soil sample were leached with ammonium acetate, then exchangeable Na and K in the leachates determined by flame photometer (Corning ELL model) as described by Thomas, (1982). Effective cation exchange capacity (ECEC) was calculated by adding all the exchangeable cations (Ca Mg, K and Na) and exchange acidity (Kamprath, 1984).

Exchangeable acidity

Exchangeable acidity (AL plus H) was extracted with molar KCL solution and acidity determined by titration method of McCean, (1965).

Phosphorus

Available phosphorous was determined by Bray and Kutz No. 1 (1945) methods as adopted by Page *et al.* (1982) and Sparks, (1996).

Particle size analysis

Mechanical analysis of the soil was done by hydrometer method of Boyouscous, (1962) as modified by Klute, (ed) (1986).

Cultivation and enumeration of soil bacteria

For the purpose of cultivation and enumeration of soil bacteria, 1.0 g of each previously sieved soil sample was thoroughly shaken in 9 ml of sterile distilled water to give 10^{-1} dilution. One milliliter (1ml) of the 10^{-1} dilution was transferred into the next test tube containing 9.0 ml normal saline (diluents) and diluted serially in one-tenth step wise up to 10^{-5} dilution (Harrigan and McCane, 1990).

Cultivation and enumeration of fungi in soils

Cultivation and enumeration of soil fungi, 1.0 g of each previously sieved fine soil sample was shaken thoroughly in 10 ml of sterile distilled water to give 10^{-1} dilution. From the 10^{-1} dilution, 1ml was transferred into the next test tube containing 9.0 ml sterile distilled water and diluted serially in one-tenth stepwise up to 10^{-2} dilution. Aliquot (1 ml) of 10^{-2} dilutions was transferred aseptically on to freshly prepared Sabouraud's dextrose agar plate's to which 0.2 ml of 0.5% Ampicillin was added to suppress bacterial growth and allow the growth of fungi (Harrigan and McCane, 1990).

Sampling of test plant

At 75 days after plant emergence, plant leaf areas of cowpea plants were measured using a meter tape. Fresh peas at eighty days after planting were harvested and oven-dried at 80°C to constant weight to determine moisture and dry matter content and proximate composition of peas.

Proximate analysis

The foreign particles present in the grains were carefully removed by method of hand picking. The various pea samples were ground using agate mortar. The mortar was decontaminated by washing with distilled water and soap after each sample was ground. The proximate and mineral analysis was done according to Standard procedure of AOAC (2000). All the chemicals used in this study were of analytical grade. The proximate compositions were determined using atomic absorption spectrometer and flame emission spectrometer.

Determination of moisture content

The moisture dish was accurately weighed. Approximately 1.0 g of the sample was added and then reweighed. It was then kept in vacuum oven for five hours. The dish was then removed from the oven, cooled and reweighed. This was repeated until a constant weight was obtained.

Determination of ash content

5 g of the sample was accurately weighed in a crucible which had been dried. The crucible was then dried in oven at 100°C. It was then transferred to muffle furnace and temperature increased to 550±5°C. This was maintained for 8 hours until a white ash was obtained. The crucible was removed from desiccators and weighed soon after cooling.

Determination of Crude Protein Procedure:

The crude protein was determined using micro Kjeldahl method as described by AOAC, (2000)

% N (wet) = (A-B) x 1.4007 x 100
Weigh (g) of sample A= volume (ml) std HCl
B = volume (ml) std NaOH x normality of std NaOH

Determination of crude lipid

This was done gravimetrically. Five gram of the sample was weighed into thimble. Extract ant was carried out using petroleum ether (40-60°C) for three hours. The Extract ant was distilled off and the flask reweighed.
Percent (%) lipid = weight of lipid × 100 Weight of sample.

Determination of total carbohydrate

This was done conveniently by method of difference.
Total carbohydrate = 100- (% lipid + % ash +% moist + % protein)

Statistical analysis

Descriptive statistics were used to interpret the results while analysis of variance (ANOVA) was used to test the level of variability amongst treatments.

RESULTS

Physicochemical properties of the soil used for the study are presented in (Table 1). After treatment application, the soil pH decreased from 5.12, increased to 6.10 and 6.45 in the soil mulched with sawdust, soil mulched with pulverized palm bunch and in the soil mulch with *Calopogonium mucunoides* leaves, respectively. While a decrease was noted in the soil mulch with sawdust (5.09).Thus, the Soil was acidic in nature with pH values of 5.12, 5.09, 6.10, 6.45 in the unmulched, soil mulched with sawdust, pulverized palm bunch and soil mulched with *Calopogonium mucunoides*, respectively. The highest organic carbon (5.16%) was obtained in the soil mulched with *Calopogonium mucunoides* leaves. This was followed by the soil mulched with pulverized palm bunch (4.11%) while the least was obtained in the soil mulched with sawdust which had 2.82%. Percent total nitrogen increase in palm bunch soil and *Calopogonium mucunoides* leaves mulched soil treatments options compared to unmulched soil option and not in the soil mulched with sawdust. The highest nitrogen (2.26%) was recorded in soil mulched with *Calopogonium mucunoides* leaves.

The highest moisture content of 35% was recorded in the sawdust mulched soil at day 80. This was followed by soil mulched with *Calopogonium mucunoides* leaves which had 33%. Highest ECEC of 10.35 cmol kg^{-1} was recorded in the soil mulch with *Calopogonium mucunoides* leaves which had 10.26 cmol kg^{-1}. This was followed by the soil mulched by pulverized palm bunch. In the control soil available phosphorus (Av. P) had 267 mg kg^{-1} recorded, in the soil mulched with sawdust Av.P had 199 mg kg^{-1}, in the soil mulched with pulverized palm bunch Av.P had 318 mg kg^{-1} and in the soil mulched with *Calopogonium mucunoides* had 323 mg kg^{-1} soil. Highest percent base saturation 91.11 was recorded in the soil mulched with *Calopogonium mucunoides* leaves followed by 89.77 in the soil mulched with pulverized palm bunch and the least (73.21) was obtained in the sawdust soil. The studied soil contained more than 70% sand. It is described as sandy loam (Esu, 1999) which gives rise to Typic Paludult, characteristics of soil derived from

Coastal Plain Sand.

Percent seed emergence are presented in (Table 2). Percent seed emergence increased with time with the maximum percent emergence recorded on the 8^{th} day after planting for each treatments option. The lowest seed emergence (70%) was recorded in the sawdust mulched soil while the highest (100% each) were recorded in the unmulched (control) soil and the soil mulched with *Calopogonium mucunoides* leaves. Cowpea plants were more blooming in the palm bunch mulching soil as compared to other experimental plot. The result of pea proximate analysis showed that the cowpea seeds from the *Calopogonium mucunoides* leave mulched soil had the highest moisture content (5.63%) while those from unmulched soil had the least (5.11%). The highest value for carbohydrates (61.88%) was obtained in the soil mulched with *Calopogonium mucunoides* leave while the least 59.19% was recorded in the soil mulched with *Calopogonium mucunoides* leave mulched soil. Peas from the soil mulched with *Calopogonium leaves* had the highest amount of crude fiber (3.91%) (Tables 3 and 4). Soil bacteria counts are shown in (Tables 5 and 6) at day 75, the highest bacteria ($40x10^5$ cfu g^{-1} soil) was recorded in the soil mulched with *Calopogonium mucunoides* leaves followed by that of pulverized palm bunch mulched soil which had $37x\ 10^5$ cfu g^{-1} soil. In treatments options, expect in the control (Z), there were sharp increase in bacterial counts with the highest counts recorded in the *Calopogonium mucunoiudes* leaves mulched soil at day 75 of the study period. Since Fcal > flab: null hypothesis is rejected and conclude that there is significant difference between bacterial counts under difference mulching materials at day 75 after treatment (ANOVA Table 7).

Since f calculated is greater than F tabulated, null hypothesis at 5% probability level is rejected and conclude that mulching materials differ in their ability to sustain fungi in the soil (ANOVA Table 8).

Soil fungi counts are shown in Fig. 8. After treatments to day 75, the highest fungi counts ($51x10^3$ cfu g^{-1} soil) was recorded in the soil mulched with *Calopogonium mucunoides* leaves followed by that of pulverized palm bunch mulched soil which had $47x10^3$ cfu g^{-1} soil.

DISCUSSION

Sharp increase in the soil pH in the soil mulched with *Calopogonium mucunoides* leaves on day 75 of the study period as compared to other treatments option may have been due to improved soil aeration leading to increase in microbial population and activities as earlier reported by Isirimah *et al.* (2003). Etukudoh, (2011) also observed increase in soil pH in the crude oil contaminated soil amended with poultry manure which in addition to providing food for the soil microbes may have improved aeration of the soil.

Increased in soil pH in the soil mulched with pulverized palm bunch and in the soil mulched with *Calopogonium mucunoides* leaves indicate the richness of those mulching materials with N while decreasing in sawdust indicate N deficiency. More organic matter percent in the *Calopogonium mucunoides* mulched soil indicated that more plant residues are returns to the soil and these will go through the decomposition and mineralization processes to provide nutrients and habitat to organisms living in the soil. Organic matter will also bind soil particles into aggregates and improves the water holding capacity of soil. Percent organic carbon decreased in the sawdust treatment option may have resulted from the immobilization resulting from the use of available carbon material as energy source by the soil microbes as a result of spontaneous increase in microbial population due to the shortage of nitrogen in the mulching material, hence the decrease in nitrogen as earlier reported by Cary and Sauvage, (1995).

The greater seed emergence in the soil mulched with *Calopogonium mucunoides* leaves confirm the finding of Louise and Bush – Brown, (1996) that good mulching material regulates the temperature of the soil, aided seed emergence and encourages faster growth. Soil mulched with *Calopogonium mucunoides* leaves mulch also has the largest leaf areas.

This also resulted in high microbial population hence more biochemical activities and mineralization. Thus, *Calopogonium mucunoides* leaves and pulverized palm are due fact that they are better mulching materials which aided microbial multiplication and activities due to aeration condition of the soil as earlier reported by Amakiri, (2000). Soil microorganisms may not have put greater demands on the soil limited nitrogen because nutrients in the better mulching materials mineralized nutrients and are made available microbes as compared to sawdust. The highest moisture content of 35% was recorded in the soil mulched with sawdust in day 75. This therefore means that sawdust mulches can retain soil moisture, regulate soil temperature, suppress weed growth, and for aesthetics as earlier reported by Alfred *et al.* (2009).

Soil mulched with *Calopogonium mucunoides* leaves has the highest ECEC 10.35 cmol kg^{-1} followed by the soil mulched by pulverized palm bunch (10.26 cmol kg^{-1}). The studied soil contained more than 70% sand. It is described as sandy loam (Esu. 1999) which gives rise to Typic Paludult, characteristics of Soil derived from coastal plain sand. The pea samples from *Calopogonium mucunoides* leaves mulched soil had the highest percent seed emergence increased with time with the maximum percent emergence recorded on the 8 days after planting from each treatment option. The lowest percent seed emergence (60%) was recorded in the sawdust mulched soil while the highest (100% each) was recorded in the *Calopogonium mucunoides* leaves mulched soil treatment option. Higher percent seed emergence observed

Table 1. Physico-chemical properties of the soil used for the study

Parameter Measured	Values			
	Z	A1	A2	A3
pH (H_2O) 1:2.5	5.12	5.09	6.10	6.45
Organic Carbon (%)	3.91	2.82	4.11	5.16
Total N (%)	1.60	1.12	1.96	2.26
Available phosphorus (mg kg^{-1})	267	199	323	318
Exchangeable bases				
Ca (cmol kg^{-1})	3.07	2.22	4.65	3.58
Mg (cmol kg^{-1})	1.30	1.09	3.56	1.95
Na (cmol kg^{-1})	0.73	0.68	1.00	0.83
K (cmol kg^{-1})	0.16	0.11	0.73	1.00
Exchangeable acidity- Al^{3+} and H^+ (cmol kg^{-1})				
ECEC (cmol kg^{-1})	6.55	5.60	10.26	10.35
BS (%)	80.31	73.21	89.77	91.11
Moisture content (%)	28	35	32	33
Sand (%)	73.8	74.0	73.8	73.8
Silt (%)	21.0	20.6	21.2	21.2
Clay (%)	5.2	5.4	5.0	5.0
Textural class	Sandy Loam	Sandy loam	Sandy loam	Sandy loam

Symbol: pH = Soil reaction, Ca = Calcium, Mg = Magnesium, Na = Sodium, K = Potassium, ECEC = Effective cation exchange capacity, BS = base saturation. Z = Control (unmulched soil), A1 = Soil mulched with sawdust, A2 = Soil mulched with pulverized palm bunch, A3 = Soil mulch with Calopogonium mucunoides leaves.

Table 2. White dwarf cowpea variety plant percent germination and leaf area

Parameter	Sawdust Mulch	Calapogonium leaves mulch	Palm mulch	Bunch Control (unmulched soil)
% germination (EDP)	80	100	90	70
Leaf area (SFD) (cm)	3.60	7.77	6.27	4.50

Key: EDP = eight days after planting, SFD = Seventy five days after planting.
Source: Field work, 2018

Table 3. ANOVA of pea Carbohydrate (eighty days after planting)

Sources of variation	D.F	SS	MSS	Fcal	Ftab
Total	11	19.9068			
Treatment	**3**	13.67	4.56	5.85	4.07
Error	**8**	6.24	0.78		

Table 4. ANOVA of pea crude protein (eight days after planting)

Sources of variation	D.F	SS	MSS	Fcal	Ftab
Total	11	26.28			
Treatment	3	25.89	8.63	0.42	4.07
Error	8	0.39	20.51		

Table 5. Bacterial counts (x 10^5 cfu g^{-1} soil) at 75 day after mulching application.

	Z	A1	A2	A3	Total
R_1	18	28	30	36	112
R_2	11	27	35	35	108
R_3	20	26	37	40	116
Total	49	81	102	111	336
Means	14	27	34	37	

Key: Z = Unmulched soil, A1 = Soil mulched with sawdust, A2 = soil mulched with pulverized palm bunch, A3 = Soil mulched with *Calopogonium mucunoides* leaves.

in this soil indicated that *Calopogonium mucunoides* leaves provided a more ambient or favorable microclimate conditions that enhanced seed germination and emergence.

Conclusion and Recommendations

Mulch serves the soil surface, prevents soil erosion on slopes, and helps reduce soil moisture loss through evaporation, helps control weed germination and growth, insulates soil, protect roots from extreme temperatures, and improve soil biology, aeration, structure (aggregation of soil particles), and drainage over time, improve soil fertility as certain mulch types decompose, inhibits certain plant diseases, reduces the likelihood of tree damage from "weed whackers" or the dreaded "lawn mower blight" gives planting beds a uniform. On the other hand some mulching has the capability of introducing new weed species into farm. Mulching can be pretty expensive to apply. This is very true if the garden or farm is very large one. Not only is mulching expensive when applying on large filed, but it can also be a very tedious task which will require a lot of labor and material. Mulching is capable of harboring certain harmful diseases and pests because of the fact that it can provide a very conducive breeding environment for harmful pests and disease causing organisms to live and multiply and can end up invading the whole farm. There are certain instances where applying mulching can end up releasing toxic chemicals to the soil after the mulch decomposes. In view of afore going, it is therefore recommended that mulching must be done with extreme care.

Authors' declaration

We declared that this study is an original research by our research team and we agree to publish it in the journal.

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