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Residual Effect of Mulching on Soil Properties in Makurdi, Southern Guinea Savanna Agroecology of Nigeria

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ABSTRACT

The objective of this experiment is to examine the residual effect of mulching on soil properties in Makurdi, Southern Guinea Savanna Agroecology of Nigeria. This study is carried out in the 2016 cropping season as a follow-up research from the 2015 trials at the Teaching and Research Farm of the University of Agriculture, Makurdi. It involves the re-cultivation of an experimental set-up, which has five treatments, 2 and 4t/ha of both dead grasses and sawdust as well as a control which has been replicated three times in a Randomized Complete Block Design (RCBD). Soil samples from each treatment are analysed before and after the experiment and percentage changes in the parameters calculated. Results reveal that in addition to soil surface protection, the decomposition of the mulch applied from 4t/ha improved soil physical properties like bulk density and porosity. It also increases chemical properties such as pH, organic matter, nitrogen, phosphorus, cations and base saturation which could significantly improve crop performance. It has demonstrated that the effect of mulching at 4t/ha goes beyond the first season after it is applied on the farm. That when mulches decompose, they release their constituent nutrients into the soil and these can be made available in the succeeding season(s) for crop use.

Keywords: Soil, mulching, organic matter, residual effect and soil properties.

INTRODUCTION

Continuous cropping without addition of nutrients and organic matter is a major threat to sustainable crop production in sub-Saharan Africa (Anikwe, 1994). Mbah and Onweremadu (2009) state that about 70% of Nigeria's soils are derived from granite and have limited inherent agricultural potentials, with these soils being light textured, most often infertile and deficient in nitrogen, phosphorus and sulphur. Water holding capacity and organic matter status of these granite-derived

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soils are poor (Anikwe and Nwobodo, 2002). These low fertility soils are susceptible to degradation upon cultivation especially where management is not appropriate (Burt and Akamigbo, 1990). Infiltration and soil evaporation are among the key processes that determine soil water availability to crops in semi-arid agriculture (Lal, 1975). He states further that the presence of crop residue mulch at the soil-atmosphere interface has a direct influence on infiltration of rainwater into the soil and evaporation from the soil. Mulch cover reduces surface runoff and holds rainwater at the soil surface thereby giving it more time to infiltrate into the soil. Trials conducted in certain parts of Nigeria between 1988 and 1995 indicated that mulching significantly reduced surface runoff and hence soil loss (Biswas and Khosla, 1971). Mulch cover shields the soil. Soil biota increases under mulched soil environment thereby improving nutrient cycling and organic matter build-up upon its decomposition in succeeding seasons (Chaudhry, Malik and Sidhu, 2004). Mulching with a biodegradable material improves soil physical properties and enhances soil microbial activities which result in release of nutrients and changes in other chemical properties of soil (Glab and Kulig, 2008).

There is therefore dire need for a critical assessment of the residual impact of mulching on soil properties in order to bring to the fore the after-effect usefulness of mulching with a view to maximize the full benefits of this important agronomic practice. This will further add to the efforts at enhancing food security in Nigeria at reduced inputs. The objective of the study was to assess the residual effect of mulching on soil properties in the study area.

MATERIALS AND METHOD

Experiment was carried out at the Teaching and Research Farm of University of Agriculture Makurdi, Southern Guinea Savanna Agro ecological zone of Nigeria. It is located between latitude 7^0 41^I N to 7^0 42^I N and longitude $8^0$37 E to 8^0 38 E at the average elevation of 97m above mean sea level with slope ranging from 1 – 5%, with annual rainfall of about 1,250mm and a mean temperature of 25-30^0C (Agber, Wuese and Ali, 2017). The soil is classified as Typic ustropepts based on the United States Department of Agriculture (USDA) soil taxonomy (Fagbami and Akamigbo, 1986).

The experiment consisted of 5 treatments replicated 3 times in a Randomized Complete Block Design (RCBD). Sawdust and dead grasses previously used as mulching material the preceding cropping season (2015) was incorporated the proceeding season (2016) to serve as manure. The vegetative cover was manually cleared. Ridges were prepared 0.5m high and 0.75m wide on previously mulched plots. Soil samples were taken with auger and core samplers for soil physical and chemical analyses. Soil samples were collected before and after the experiment, one bulk samples was collected representing the initial state of the soil, but at the end of the experiment two (2) bulk samples were taken from each treatment and separately analyzed to cross check with that at the beginning of the experiment.

Soil analysis was carried out at the Advanced Analytical Soil Testing Laboratory of the Department of the Soil Science, University of Agriculture, Makurdi, Benue State in Nigeria. The soil samples were air dried, gently crushed using mortar and pestle and passed through a 2mm sieve. The sieved samples were collected and packed for laboratory analysis. The parameters were analysed using standard procedures as follows: Particle size distribution **(**Bouyoucos, 1951), bulk density (Core method), soil total porosity (% F) was calculated from the relation % Ft= (1-Bd/pd) x 100 where Bd is the bulk density and pd particle density, soil pH in water (1:1) was determined using the pH meter, organic matter from organic carbon **(**wet oxidation method of Walkley and Black, 1934): % organic matter in soil = organic carbon x 1.724, total nitrogen was determined by the Macro-kjeldahl digestion method (Jackson, 1965), Cation exchange capacity was determined by neutral ammonium acetate method, Available Phosphorus was determined by Bray -1 method (Bray and Kurtz, 1945), Exchangeable cations were determined by atomic absorption spectrophotometer (Mehlich, 1984), Base saturation was determined by dividing the sample of exchangeable bases by the cation exchange capacity and multiplying by 100.

RESULTS AND DISCUSSION

The results of the soil physical and chemical properties in 2015 and 2016 are presented on Tables 1 and 3, Tables 2 and 4 are the statuses of soil properties, while Table 5 presents the percentage changes in the soil properties between the 2015 and 2016 season after application of mulching. The result of the soil physical properties as presented on Table 1 shows that soil bulk density at 0-15cm depth ranged from 1.39-1.41g cm^{-3} at T_2 and T_4 to T_1 respectively. At 15-30cm, it was from 1.41gcm^{-3} at T_3 and T_4 to 1.48gcm^{-3} at T_1 and at T_5. The result of porosity shows that at 0-15cm, the lowest porosity is obtained from T_3 with 46.54% while the highest was at T_1 with 51.64%. The result of soil chemical properties is presented on Table 1. It shows that the pH at 0-15 ranged from 6.69 at T_3 to 6.72 at $T_{1.}$ At 15-30cm, it ranged from 6.73 at T_1 and T_4 to 6.77 at T_5. Organic matter at 0-15cm ranged from 1.34 at T_1 to 1.38 at T_2. At 15-30cm, it ranged from 1.19 at T_1 to 1.47 at T_5. Nitrogen at 0-15cm ranged from 0.033% at T_1 to 0.055% at T_5. While at 15-30cm, it ranged from 0.024% at T_1 to 0.039% at T_5. Phosphorus at 0-15cm ranged from 3.00mgkg^{-1} at T_1 to 4.80mgkg^{-1} at T_5. While at 15-30cm, it ranged from 2.00mgkg^{-1} at T_1 to 4.2mgkg^{-1} at T_5. The result of cations, including potassium at 0-15cm ranged from 0.20Cmol/kg^{-1} at T_1 to 0.39Cmol/kg^{-1} at T_2 and T_3. While at 15-30cm, it ranged from 0.15Cmol/kg^{-1} at T_1 to 0.33Cmol/kg^{-1} at T_4. Sodium at 0-15cm ranged from 0.23Cmol kg^{-1} at T_1 to 0.37Cmol kg^{-1} at T_2. While at 15-30cm, it ranged from 0.22Cmol kg^{-1} at T_1 to 0.34Cmol kg^{-1} at T_3. Magnesium at 0-15cm as ranged from 2.09Cmol kg^{-1}at T_1 to 2.42Cmol kg^{-1} at T_3. At 15-30cm, it ranged from 2.03Cmol kg^{-1}at T_2 to 2.16Cmol kg^{-1} at T_5. Calcium at 0-15cm ranged from 2.29Cmol kg^{-1} at T_1 to 2.61Cmol kg^{-1} at T_3, however at 15-30cm, it ranged from 2.19Cmol kg^{-1} at T_1 to 2.34Cmol kg^{-1} at T_3.

The Exchangeable Acidity at 0-15cm ranged from 0.97Cmol kg^{-1} at T_5 to 0.99Cmol kg^{-1} at T_2 and T_3.While at 15-30cm, it ranged from 0.96Cmolkg^{-1} at T_1, T_2, T_4 and T_5 to 0.97Cmol kg^{-1} at T_3. Total Exchangeable bases at 0-15cm ranged from 5.04Cmol kg^{-1} at T_1 to 5.79Cmol kg^{-1} at T_3. At 15-30cm, it ranged from 4.63Cmol kg^{-1} at T_1 to 5.53Cmol kg^{-1} at T_4. The Cation Exchange Capacity at 0-15cm ranged from 5.79Cmol kg^{-1} at T_5 to 6.79Cmol kg^{-1} at T_3. At 15-30cm, it ranged from 5.59Cmol kg^{-1} at T_1 to 6.48Cmol kg^{-1} at T_4. The Base saturation at 0-15cm as ranged from 84.06% at T_1 to 85.35% at T_4, while at 15-30cm, it ranged from 83.57% at T_3 to 85.07% at T_4.

The result of soil analysis at the end of the 2016 season reveals that there was improvement in soil physical properties. There was decreased bulk density and increased porosity under the mulched plots opposed to the control. Improved porosity means increased infiltration and aeration. This will have effect on decomposition of soil organic matter, leading to higher availability of plant food (Nutrient elements) and increased crop performance. This is in agreement with the works of Lal (1975), who posits that application of surface crop residue at the rate of 4-6 t/ha increased infiltration, an indication of predominance of macropores in the profile. Tian, Kang and Brossard (1994) confirm that when organic mulches decompose, they increase soil organic matter content, CEC, enhance biological activity, improve soil structure and increase plant nutrients. Wuese (2018) obtains higher soil nutrients when much sawdust was applied at the rate of 4-8 t/ha in Makurdi under open and tied ridges as well as flat cultivation. There was decreased soil pH (tending towards neutrality), increased organic matter, Nitrogen, Phosphorus and cations as well as base saturation in the succeeding season. This means increased soil fertility which will eventually lead to higher crop yield when compared to unmatched plots. Lal (1975) observes higher soil fertility status and cation exchange capacity in mulched plots. He concludes that mulched plots usually have higher concentration of divalent cations on the exchange complex, more total nitrogen and available phosphorus than unmulched plots. The decomposition of applied much materials such as chipped wood has been observed to increase soil fertility and maintain soil organic matter (Chiroma, Folorunsho and Alhassan, 2006; Hendrickson, 1987), and improve soil physical properties (Lalande, Furlan, Angers and Lemieux, 1998). Tiarks, Mazurak and Chesnin (1974) confirm that when mulches decompose, they release their inherent nutrient elements as seen in increased residual phosphorus in the succeeding season. They further state that mulch form *Gliricidia sepium* at 5t/ha., significantly increased crude protein, carbohydrates, nitrogen, phosphorus and ash content of maize grain in both years of cropping season, thereby improving nutritional content of maize grain. The results of the data from this work suggest that in addition to soil surface to protection, when mulches decompose in the soil, they improve soil physical properties like bulk density, and porosity and increase chemical properties such as pH, organic matter, N, P, cation and base saturation. This leads to higher crop performance in the following seasons.

CONCLUSION

Residual Effect of Mulching on Soil Properties in Makurdi, Southern Guinea Savanna Agroecology of Nigeria was examined. It was conducted in the 2016 cropping season as a follow-up study from the 2015 trials at the Teaching and Research Farm of the University of Agriculture, Makurdi. The re-cultivation of an experimental set-up, which had five treatments, including control was replicated three times in a Randomized Complete Block Design (RCBD). The result of soil analysis at the end of the 2016 season revealed that there was improvement in soil physical properties. There was decreased bulk density and increased porosity under the mulched plots opposed to the control. Improved porosity means increased infiltration and aeration. This will have effect on decomposition of soil organic matter, leading to higher availability of plant food (Nutrient elements) and increased crop performance. This study revealed that the effect of mulching at 4t/ha went beyond the first season after it is applied on the farm. That when mulches decompose, they released their constituent nutrients into the soil and these can be made available in the succeeding season(s) for crop use.

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Table1: Physical and Chemical properties of the Experimental Site before the Experiment in 2015.

Sample	Depth	Sand	Silt	Clay	BD	TP	pH	OM	N	P	K	Na	Mg	Ca	EA	EB	CEC	BS
	(cm)	(%)	(%)	(%)	(gcm^{-2})	(%)	(water)	(%)	(%)	($mgkg^{-1}$)	Cmolkg^{-1}							(%)
T_1	0-15	79.28	13.07	7.64	1.43	51.64	6.72	1.34	0.033	0.30	0.20	0.23	2.09	2.29	0.98	5.04	5.79	84.06
	15-30	79.75	13.10	7.13	1.48	44.02	6.73	1.19	0.024	0.20	0.15	0.22	2.07	2.19	0.96	4.63	5.79	83.83
T_2	0-15	79.24	13.09	7.67	1.39	46.66	6.71	1.38	0.040	0.38	0.39	0.36	2.34	2.58	0.99	5.68	6.67	85.11
	15-30	76.61	13.15	7.23	1.42	46.10	6.74	1.23	0.031	0.30	0.24	0.32	2.03	2.32	0.96	4.91	5.87	83.65
T_3	0-15	79.27	13.06	7.54	1.41	46.54	6.69	1.45	0.048	0.42	0.39	0.37	2.42	2.61	0.99	5.79	6.79	85.31
	15-30	76.60	13.11	7.28	1.41	46.54	6.75	1.22	0.035	0.37	0.21	0.34	2.04	2.34	0.97	4.93	5.90	83.57
T_4	0-15	79.68	13.06	7.24	1.39	47.44	6.70	1.50	0.045	0.43	0.37	0.32	2.32	2.57	0.98	5.58	6.56	85.35
	15-30	79.89	13.14	6.96	1.41	46.54	6.73	1.20	0.039	0.39	0.33	0.30	2.10	2.28	0.96	5.53	6.48	85.07
T_5	0-15	79.50	13.07	7.42	1.40	46.92	6.70	1.67	0.055	0.48	0.36	0.30	2.37	2.56	0.97	5.64	6.61	85.27
	15-30	79.87	13.08	7.04	1.48	44.02	6.72	1.47	0.039	0.42	0.29	0.31	2.16	2.23	0.96	4.96	5.92	84.50

BD = Bulk density, TP = Total porosity, OM = organic matter, EA = Exchangeable acidity, EB = exchangeable Bases, CEC = Cation exchangeable capacity and BS = Base saturation, T_1 = control, T_2 = 2t/ha dry grass, T_3 = 4t/ha dry grass, T_4 = 2t/ha saw dust, T_5 = 4t/ha saw dust.

Source: Field survey, 2015 - 2016

Table 2: Status of Soil Chemical Properties before the Experiment in 2015.

Sample	Depth (cm)	pH	OM (%)	N (%)	P (mg/kg)	K (Cmol/kg)	Na (Cmol/kg)	Mg (Cmol/kg)	Ca (Cmol/kg)	CEC (Cmol/kg)	BS (%)
T_1	0-15	N	Very low	Very low	Low	Low	Low	Moderate	Low	Very low	Very high
	15-30	N	Very low	Very low	Low	Very low	Low	Moderate	Low	Very	Very high
T_2	0-15	N	Very low	Very low	Low	Moderate	Moderate	Moderate	Low	Low	Very high
	15-30	N	Very low	Very low	Low	Low	Moderate	Moderate	Low	Very low	Very high
T_3	0-15	N	Very low	Very low	Low	Moderate	Moderate	Moderate	Low	Low	Very high
	15-30	N	Very low	Very low	Low	Low	Moderate	Moderate	Low	Very low	Very high
T_4	0-15	N	Very low	Very low	Low	Moderate	Moderate	Moderate	Low	Low	Very high
	15-30	N	Very low	Very low	Low	moderate	Moderate	Moderate	Low	Low	Very high
T_5	0-15	N	Very low	Very low	Low	Moderate	Moderate	Moderate	Low	Low	Very high
	15-30	N	Very low	Very low	Low	low	Moderate	Moderate	Low	Very low	Very high

N = Neutral, OM = Organic matter, CEC = Cation exchange capacity and BS = Base saturation.
T_1 = control, T_2 = 2t/ha dry grass, T_3 = 4t/ha dry grass, T_4 = 2t/ha saw dust, T_5 = 4t/ha saw dust.
Source: Field survey, 2015

Table 3: Physical and Chemical properties of the Experimental Site after the Experiment at 0-15 cm Soil Depth in 2016

Sample	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	BD (gcm^{-3})	TP (%)	pH (water)	OM (%)	N (%)	P ($mgkg^{-1}$)	K	Na	Ca	Mg	EA	EB	CEC	BS (%)
											← Cmolkg^{-1} →							
T_1	0-15	78.88	13.01	8.11	1.48	46.15	6.70	1.29	0.027	0.27	0.22	0.21	2.16	2.34	0.99	4.93	5.92	83.28
T_2	0-15	79.16	13.14	7.70	1.44	45.66	6.74	1.38	0.035	0.37	0.39	0.39	2.37	2.74	0.98	5.89	6.87	85.74
T_3	0-15	78.89	13.13	7.98	1.47	44.53	6.70	1.43	0.038	0.39	0.41	0.36	2.42	2.65	0.99	5.84	6.83	85.51
T_4	0-15	79.44	13.11	7.45	1.43	42.26	6.71	1.46	0.047	0.45	0.43	0.36	2.33	2.62	0.98	5.74	6.72	85.42
T_5	0-15	78.94	13.00	8.06	1.42	46.42	6.69	1.63	0.051	0.37	0.37	0.36	2.35	2.63	0.99	5.71	6.70	85.22

BD =Bulk density, TP = Total porosity, OM = Organic matter, EA = Exchangeable acidity, EB = Exchangeable bases, CEC = Cation exchangeable capacity and BS =Base saturation,
T_1 = control, T_2 = 2 t/ha dry grass, T_3 = 4 t/ha dry grass, T_4 = 2 t/ha saw dust, T_5 = 4 t/ha saw dust.
Source: Field survey, 2016

Table 4: Status of the Soil Chemical Properties after the Experiment in 2016

Sample	Depth (cm)	pH	OM (%)	N (%)	P (mgkg-1)	K	Na	Mg	Ca	CEC	BS (%)
						Cmolkg-1					
T_1	0-15	Neutral	Very low	Very low	Low	Low	Low	Moderate	Low	Very low	Very high
T_2	0-15	Neutral	Very low	Very low	Low	Moderate	Moderate	Moderate	Low	Moderate	Very high
T_3	0-15	Neutral	Very low	Very low	Low	Moderate	Moderate	Moderate	Low	Moderate	Very high
T_4	0-15	Neutral	Very low	Very low	Low	Moderate	Moderate	Moderate	Low	Moderate	Very high
T_5	0-15	Neutral	Very low	Very low	Low	Moderate	Moderate	Moderate	Low	Moderate	Very high

OM = Organic matter, EA = Exchangeable acidity, EB = exchangeable Bases, CEC = Cation exchangeable capacity and BS =Base saturation, T_1 = Control, T_2 = 2 t/ha dry grass, T_3 = 4 t/ha dry grass, T_4 = 2 t/ha saw dust, T_5 = 4 t/ha saw dust.
Source: Field survey, 2016

Table 5: Percentage Change in Soil Properties after the Experiment 2016 at 0-15 cm Depth

Sample	Sand (%)	Silt (%)	Clay (%)	BD (g/kg)	TP (%)	pH	OM (%)	N (%)	P (mg/kg)	K	Na	Ca	Mg	EA	EB	CEC	BS (%)
										Cmolkg-1							
T_1	0.50	0.46	-6.15	-3.49	10.63	0.29	3.70	18.18	91.00	-10.00	8.70	5.68	-11.96	-91.02	2.18	-2.25	0.93
T_2	0.10	-0.38	-0.60	-3.60	2.14	-0.45	0.00	12.50	2.63	0.00	-8.33	8.14	-17.06	1.01	3.70	-2.99	-0.74
T_3	0.48	-0.54	-5.84	-4.26	4.28	-0.15	1.38	20.83	7.14	-5.13	2.70	7.28	-9.50	0.00	-0.86	-0.59	-0.23
T_4	0.30	-0.38	-2.90	-2.88	10.92	-0.15	2.67	-4.44	-4.65	-16.22	-12.50	9.34	-12.93	0.00	-2.44	-2.44	-0.082
T_5	0.70	0.54	-8.63	-1.43	1.07	-0.15	2.40	7.27	22.92	-2.78	-2.86	8.20	-10.97	-2.06	-1.36	-1.36	0.059

BD =Bulk density, TP = Total porosity, OM = Organic matter, EA = Exchangeable acidity, EB = Exchangeable bases, CEC = Cation exchangeable capacity and BS =Base saturation, T_1 = Control, T_2 = 2t/ha dry grass, T_3 = 4t/ha dry grass, T_4 = 2t/ha saw dust, T_5 = 4t/ha saw dust. Source: Field survey (2016)