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USING SOYBEANS, MANURE, ORGANIC NPK® (COMPOST) AND NPK FERTILIZER TO ENHANCE SOIL NUTRIENTS, ORGANIC MATTER AND GRAIN YIELD OF SORGHUM IN MAKURDI, NIGERIA

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ABSTRACT

A field trial was conducted in 2016 and 2017 at Commercial Crop Farms of the University of Agriculture, Makurdi to evaluate the effect of manure, compost and NPK fertilizer under soybeans-sorghum mixed cropping. The experiment consisted of three (3) levels of poultry manure (0, 2.0 and 3.5 t/ha), three (3) levels of compost manure (0, 0.2 and 0.4 t/ha) and three (3) levels of NPK (0, 30 and 60 KgN/ha). Soybean was intercropped with sorghum as a nitrogen fixer in selected plots. The experiment was laid out in a Randomised Complete Block Design and replicated three (3) times. Soybean as nutrient source marginally enhanced organic matter and nutrients content in the soil. Poultry manure retains the highest concentration of OM and nutrients in the soil compared to compost and NPK fertilizer. Also, grain yield of sorghum was significant at ($P<0.05$) with manure and fertilizer application; NPK fertilizer at 60 kg N/ha in sorghum-legume mixture gave the highest yield (1035.0 kg/ha and 1138.4 kg/ha in 2016 and 2017 respectively). The lowest yield was obtained from non fertilizer treatments. The concentration of organic matter and plant nutrients elements in the soil and grain yield of sorghum were enhanced by addition of manure and fertilizer. Therefore, sustainable cultivation of sorghum is possible via the use of fertilizer, manure and a nitrogen fixer are used as soil amendments.

KEYWORD: NPK, Organic manures soil nutrients, soil pH, organic matter

INTRODUCTION

There is urgent need to improve productivity of cultivable soil to curb the threat to food security imposed on the African continent as a result of land degradation and climatic variability. Hitherto, inorganic fertilizers provided reliable option for increasing nutrients supplying power of the soil and ultimately crop yield in sub Saharan countries (Makinde et al., 2001; Narwal and Antil, 2005; Brady and Weil,2007; Havlin et al., 2014; Reddy, 2016). Although, the practice of using inorganic fertilizer as nutrients booster has gained global acceptance, over the years, research has shown that synthetic chemical inputs in the soil have negative consequence on the soil environment and human life and plant life as a whole. Doan et al., (2015) reported that chemical fertilizer as farm input has deleterious effects on soil physical properties; depletes soil organic matter, leached soil nutrients and consequently, soil erosion. Continuous use of mineral fertilizers results in increasing soil acidity, nutrient imbalance and crop yield (Ojeniyi, 2000).

Besides environmental consequences, there exist economic considerations that have placed limitations on the continuous use of chemical fertilizers as external nutrient source; the scarcity of the commodity, high cost limits the use of the commodity by most smallholders' farmers in sub Saharan Countries resulting to low crop yield per unit land area. To arrest the decline in food security and yet ensure protection of the soil environment, integrated approach that incorporates crop nutrients from available sources should be continuously practiced. Such a system will combine not only inorganic and organic fertilizers but also, nutrients from components elements in the farm system. This will ultimately compensate for nutrient loss in the short term and increase soil organic matter concentration and other soil properties. Ayoola and Adeniyan (2006) advocated for the combination of old and new methods of nutrient management into ecologically sound and economically viable farming systems that utilize available organic and inorganic sources of nutrients in a judicious and efficient way. In most sub Saharan countries, integrated nutrient management

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system has proven to be economically viable and sustainable for soil productivity and high crop yield (FAO, 2000). With the negative impact of global warming, it is expedient to cultivate crop that can adapt to prevailing environment and demands low nutrients inputs without negative consequence on food security and soil environment. Sorghum is a major staple food crop that strives in poor soils amongst other environmental constraints. It is the second most important cereals after maize with 22% of total cereal area in sub-Sahara Africa (FAO STAT, 2004). Nonetheless, the yield per unit area of land is on the decrease and thus, there is need to improve agronomic practice so as to increase the yield per unit area of the crop. It has been demonstrated that legumes generally add nitrogen in the soil via biological nitrogen fixation (Chalk, 1998). The objective of this work is to demonstrate the potential of soybeans and the efficacy of compost (Organic NPK®) and poultry manure to improve soil nutrients and soil organic matter content for sustainable grain yield of sorghum.

MATERIALS AND METHODS

Experimental Site

The field trials were conducted at Commercial Crop Farms of the University of Agriculture, Makurdi, in 2016 and 2017 under rain-fed conditions. The area falls within latitude 7^0 41^1 N and longitude 8^0 37^1 E, at an elevation of about 97 meters above sea level in the Southern Guinea Savanna Agro- Ecological Zone of Nigeria. The area has two distinct seasons; wet and dry; the wet season starts from April and ends in October with mean annual rainfall of 1250 mm and mean temperature of 32^0C.

Experimental Treatments and Design

The treatments were; Control, Soybean intercrop, 2.0 t/ha of PM, 2.0 t/ha of PM+ Soybean, 3.5 t/ha of PM, 3.5 t/ha of PM+ Soybean, 0.2 t/ha of compost (CP), 0.2 t/ha of compost (CP) + Soybean, 0.4 t/ha of compost (CP), 0.4 t/ha of compost (CP) + Soybean, 30 Kg N/ha, 30 Kg N/ha + Soybean, 60 Kg N/ha, 60 Kg N/ha + Soybean. These treatments were laid in Randomized Complete Block Design (RCBD) and replicated three (3) times. The manure was ploughed into the soil at land preparation one week before sorghum (local variety) was planted. This was followed by fertilizer application at two weeks after planting. Four seeds per hole were planted at 0.75 m x 0.5m spacing and were later thinned to two stands per hole two weeks after planting

Soil sampling and analysis

Before commencement of the experiments in 2016 and 2017 cropping seasons, surface (0-15 cm) soil samples were collected at eight different points with the aid of a soil auger using random sampling method. The samples were bulked for analysis. The soil samples were air dried, ground and pass through 2 mm sieve and taken for routine soil analysis in the laboratory as follows; Soil pH was determined in a 1:1 soil-water suspension by the glass electrode method, particle size analysis by the hydrometer method of Bouyoucos (1951) in which sodium hexametaphosphate (calgon solution) was used as dispersing agent. Total organic carbon was by chromic acid oxidation procedure of Walkley and Black (1934), total nitrogen was determined using the procedure described by Anderson and Ingram (1996), the Molybdenum-blue method as described by IITA (1979) was used to determine available phosphorus.

Exchangeable bases were determined by the neutral ammonium acetate saturation. Sodium (Na) and K in the extracts were determined by the flame photometer while Ca and Mg were determined using Atomic Absorption Spectrophotometer (AAS), exchange acidity by the 1 M KC1 extraction and 0.01M NaOH titration. The cation exchange capacity was determined by summation of exchangeable bases.

Crop data collection and statistical analysis

The panicle length (cm) and grain yield (kg/ha) were determined at harvest. Crop data collected were subjected to analysis of variance (ANOVA) and the means that were statistically different were compared using Fisher's least significant difference (F-LSD) at 5% level of probability (Obi, 2001).

RESULTS

Soil properties of the Experimental Site

The result of selected soil properties of the experimental site before application of fertilizer is presented in Table 1. The particle size distribution analysis of soils of the experimental site indicates that the percentage sand was 76.64 % and 78.36 in 2016 and 2017 respectively. The silt content was 14.36%. Clay content was 9.0% and the textural class was determined as sandy loam. The soil pH (H_2O) was 6.64 and 6.66 in 2016 and 2017 respectively. The organic matter in 2016 cropping season was 1.18 % total nitrogen (N) was 0.21 % while phosphorus (P) was 1.20 mg/kg. The exchangeable cations; K, Ca, Mg, and Na were 0.20 cmolkg^{-1}, 3.40 cmolkg^{-1}, 2.18 cmolkg^{-1} and 0.15 cmolkg^{-1} respectively. The CEC of soil was 5.83 cmolkg^{-1}.

Table 1: Soil Properties of the Experimental Site

Soil parameters	2016	2017
Sand (%)	76.64	78.36
Silt (%)	14.36	10.04
Clay (%)	9.0	11.60
Textural class	Sandy loam	Sandy loam
$pH_{(H2O)}$	6.64	6.66
pH(KCl)	5.88	5.67
Organic matter (%)	1.18	1.80
Total nitrogen (%)	0.21	0.23
Phosphorus (mg/kg)	1.20	1.64
K (cmol kg^{-1})	0.20	0.23
Ca (cmol/kg^{-1})	3.40	4.76
Mg (cmol kg^{-1})	2.18	2.51
Na (cmol kg^{-1})	0.15	0.18
CEC (cmol kg^{-1})	5.83	7.68

Chemical Composition of Poultry Manure and Organic NPK® (compost)

The results of chemical analysis of poultry manure and organic NPK® (compost) are presented in Table 2. The soil pH of poultry manure was 7.4, organic matter content was 26.41% , nitrogen, 2.25%, phosphorus was 12.10 % and exchangeable cations composition of poultry manure were; K (1.15 cmol/kg), Ca (10.81 cmol/kg), Mg (0.53 cmol/kg), Na (1.78 cmol/kg) and CEC (14.27 cmol/kg). Similarly, the nutrient composition of compost was; organic matter (48.65%), nitrogen (8.20%), phosphorus (6.12 mg/kg), potassium (3.80 cmol/kg), calcium (13.28 cmol/kg), magnesium (8.13 cmol/kg), and sodium (0.62 cmol/kg). This indicates the relative potentials of poultry manure and organic NPK® (compost) to improve soil fertility status and consequently boost crop production when in cooperated in the soil

Table 2: Chemical Properties of Poultry manure and Organic NPK® (compost)

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Parameters	Poultry manure	Compost
pH	7.4	7.0
Organic matter (%)	26.41	48.65
Total nitrogen (%)	2.25	8.20
Phosphorus (mg/kg)	12.10	6.12
K (cmol kg^{-1})	1.15	3.80
Ca (cmol kg^{-1})	10.81	13.28
Mg (cmol/kg^{-1})	0.53	8.13
Na (cmol kg^{-1})	1.78	0.62

Table 3: Effect of integrated nutrient sources on selected soil properties in Makurdi, 2016

Treatment	pH	OM (%)	N (%)	P (mg/Kg)	K cmol/kg	Ca cmol/kg	Mg cmol/kg	Na cmol/g	CEC cmol/kg
Control	6.60	1.06	0.14	0.78	0.20	2.15	2.40	0.15	4.90
Legume	6.58	2.01	0.23	1.83	0.20	2.69	2.40	0.14	5.43
2.0 t/ha PM	6.64	3.03	0.23	2.66	0.44	2.60	3.10	0.21	6.35
2.0 t/ha P M+ Legume	6.58	3.05	0.24	3.03	0.23	2.50	2.41	0.19	5.33
3.5 t/ha PM	6.65	3.30	0.36	3.15	0.33	2.63	3.01	0.30	6.27
3.5 t/ha PM + Legume	6.58	3.32	0.38	3.05	0.23	2.71	2.98	0.21	6.13
0.2 t/ha CP	6.64	3.01	0.24	2.64	0.44	2.59	3.03	0.23	6.29
0.2 t/ha CP + Legume	6.56	3.17	0.24	2.60	0.23	2.20	3.00	0.19	5.62
0.4 t/ha CP	6.65	3.80	0.32	3.01	0.60	2.66	3.03	0.26	6.55
0.4 t/ha CP + Legume	6.56	3.83	0.36	2.93	0.28	2.29	3.30	0.20	6.07
30 Kg N/ha of NPK	6.50	1.16	0.15	1.14	0.22	2.48	2.23	0.24	5.17
30 Kg N/ha + Legume	6.49	1.16	0.26	1.04	0.19	2.50	2.42	0.20	5.31
60 Kg N/ha of NPK	6.52	1.15	0.21	1.44	0.24	2.45	2.40	0.10	5.19
60 Kg N/ha + Legume	6.50	1.18	0.23	1.42	0.21	2.50	2.45	0.22	5.38

PM = poultry manure, CP = compost

Table 4: Effect of integrated nutrient sources on selected soil properties in Makurdi, 2017

Treatment	pH	OM (%)	N (%)	P (mg/kg)	K cmol/kg	Ca cmol/kg	Mg cmol/kg	Na (cmol/kg)	CEC cmol/kg
Control	6.42	1.41	0.20	2.00	0.20	2.48	2.40	0.19	5.27
Legume	6.60	1.82	0.29	2.00	0.21	2.65	2.48	0.20	5.54
2.0 t/ha PM	6.66	2.04	0.25	2.97	0.25	2.67	2.46	0.20	5.58
2.0 t/ha PM + Legume	6.63	2.88	0.31	2.62	0.22	2.70	2.50	0.21	5.63
3.5 t/ha PM	6.69	3.06	0.25	2.99	0.30	2.65	3.01	0.32	6.28
3.5 t/ha PM + Legume	6.64	3.53	0.34	3.10	0.23	2.98	2.54	0.22	5.97
0.2 t/ha CP	6.66	3.05	0.23	3.08	0.61	2.66	3.29	0.30	6.86
0.2 t/ha CP + Legume	6.65	3.38	0.30	3.01	0.24	2.90	2.70	0.21	6.05
0.4 t/ha CP	6.66	3.72	0.23	2.66	0.45	2.59	3.10	0.22	6.36
0.4 t/ha CP + Legume	6.65	4.01	0.34	2.34	0.25	3.04	2.74	0.24	6.27
30 Kg N/ha of NPK	6.64	1.65	0.22	0.86	0.22	2.53	2.51	0.14	5.40
30 Kg N/ha + Legume	6.59	1.70	0.31	2.32	0.20	2.50	2.50	0.11	5.31
60 Kg N/ha of NPK	6.60	1.66	0.23	1.56	0.22	2.55	2.59	0.16	5.52
60 Kg N/ha + Legume	6.60	1.72	0.32	1.34	0.20	2.53	2.56	0.21	5.50

CP=compost, PM= poultry manure

Soil pH

Soil pH was marginally reduced in plots where soybean was adopted as sole nutrient source in the two cropping seasons (Tables 3 and 4). Similarly soybeans plus varying levels of manure or compost lowered soil pH in 2016 cropping season. The lowest pH in 2016 cropping season was obtained from application of NPK at 30 kg N/ha plus soybeans. The highest pH (6.65%) in 2016 cropping season was obtained from application of compost at 0.4 t/ha. In 2017 cropping season the pH remain unchanged with sole application of varying levels of compost and poultry manure at 2.0 tonnes per hectare. The highest pH (6.69) was obtained from application of poultry manure at 3.50 tonnes per hectare. The control gave the lowest pH (6.42).

Soil organic matter

The soil organic matter (SOM) was marginally increased with inclusion of soybeans in the mixture either as sole nutrient source or with application of compost® or poultry manure. The highest SOM (3.83 %) in 2016 was obtained from application of compost® at 0.40 tonnes per hectare plus soybeans mixture. The lowest SOM (1.06 %) was obtained from the control treatment. The highest SOM (4.01 %) in 2017 was obtained from application of compost® at 0.4 tonnes per hectare plus soybeans mixture. The lowest SOM (1.41 %) was obtained from the control.

Total Nitrogen (N)

Inclusion of soybean in the mixture either as sole or with compost® or poultry manure increased the concentration of total nitrogen in the soil in 2016 cropping season (Table 3). The concentration of N in the soil was highest (0.38 %) with application of poultry manure at 3.5 t/ha plus soybean as nutrient source. This was followed by sole application of poultry manure at 3.50 tonnes per hectare and compost® at 0.4 t/ha plus soybean. Similar trend was observed in 2017 cropping seasons.

Available Phosphorus (P)

Phosphorus (P) in the soil was depleted by soybean as sole nutrient source (Tables 3 and 4). Available P increased with increasing levels of compost or poultry manure plus soybean. Available P concentration in the soil was highest (3.15 mg/kg) with application of poultry manure at 3.50 tonnes per hectare in 2016 cropping season. This was followed by application of poultry manure at 3.50 t/ha plus soybean as nutrient source. The lowest available P (0.78 mg/kg) was obtained from the control. Application of compost and poultry manure retained higher available P in the soil compared to either application of compost or poultry manure plus soybean. This trend was also observed in 2017 cropping season (Table 4).

Exchangeable Cations (K, Ca, Mg and Na)

Exchangeable cations (K, Ca, Mg and Na) and CEC increased with increasing levels of compost and poultry manure application (Tables 3 and 4). Soybeans when treated as sole nutrient source lowered exchangeable cations and consequently lowered the ECEC of the soil in the study area in both cropping seasons. Potassium (K) increased with increasing levels of compost and poultry manure. The highest K (0.60 cmol/kg) was obtained from application of compost at 0.4 t/ha in 2016. The lowest quantity of K (0.20 cmol/kg) was obtained from the control and sole soybean treatments. A similar sequence was observed in 2017 cropping season (Table 4). The highest amount of calcium concentration in soil (2.71 cmol/kg) in 2016 was obtained from application of poultry manure at 3.50 t/ha. The lowest calcium (2.15 cmol/kg) was obtained from the control plots. Magnesium (Mg), sodium (Na) and ECEC followed a similar trend as K and Ca. This trend was obtained in 2017 cropping season (Table 4).

Effect of integrated soil fertility management on panicle length and grain yield of sorghum

The effects of integrated soil fertility on panicle length of sorghum are presented in Table 5. Integrated soil fertility management did not have significant ($p > 0.05$) effect on panicle length of sorghum as can be seen in Table 5. Although panicle length was marginally increased with increasing levels of fertilizer, and manure application during the two cropping seasons, it was statistically the same across the treatments. Grain yield of sorghum was significantly ($p < 0.05$) affected by integrated soil fertility management during the two cropping seasons. However, soybean component in the mixture did not have significant effect on grain yield of sorghum.

Table 5: Effect of treatment on panicle length and yield of sorghum in 2016 and 2017

Treatment	Panicle length		Yield	
	2016	2017	2016	2017
Control	27.0	26.1	372.7	367.0
Legume	27.0	26.4	373.0	367.7
2.0 t/ha PM	26.2	27.0	387.1	430.0
2.0 t/ha PM + Legume	27.2	27.6	386.3	438.3
3.5 t/ha PM	27.0	28.8	410.7	501.1
3.5 t/ha PM + Legume	27.9	28.8	415.6	508.9
0.2 t/ha CP	28.0	30.0	387.0	483.7
0.2 t/ha CP + Legume	30.1	30.2	481.3	490.6
0.4 t/ha CP	33.0	30.2	633.0	693.0
0.4 t/ha CP + Legume	30.4	33.0	634.3	694.7
30 Kg N/ha of NPK	30.4	33.1	1016.1	1112.0
30 Kg N/ha+ Legume	30.4	33.3	1016.5	1116.6
60 Kg N/ha of NPK	30.7	30.7	1035.0	1134.8
60 Kg N/ha+ Legume	30.7	30.7	1035.7	1138.4
LSD (0.05)	NS	NS	13.11	8.58

DISCUSSION

The pH of the soil was affected by treatments at the end of the two cropping seasons The pH was improved with manure treatments and organic NPK® (compost) treatment as against the control. Soybean also lowered the pH. The increase in pH could be attributed to organic matter contents in compost and poultry manure which could have mineralized to release base forming cations (Ca, Mg, K and Na). The presence of these exchangeable cations often raises the soil pH and consequently reduces soil acidity. Babalola (2006) and Agbede (2009) have reported positive effect of organic manure on soil pH. Application of NPK and control lowered soil pH. This may be attributed to leaching loses associated with tropical soils and removal of exchangeable cations following organic matter depletion of top soil as a result of tillage operation (Dorna et al 1996). This finding agreed with that of Adepetu *et al.* (2014) who stated that continuous use of mineral fertilizer to supply plant nutrients could lead to increase in soil acidity. The decrease in pH associated with soybean could be attributed to oxidation of the diatomic nitrogen (N_2) fixed in the soil by legumes into nitrate (NO_3) thus freeing hydrogen (H^+) ions in the soil solution, thereby lowering soil pH. According to Dorna *et al* (1996) N-fixing plants take up more cations than anions, thus net efflux of H^+ into the rhizosphere occurs resulting in decreases in rhizosphere pH and eventually in the bulk soil.

There was an increase in the levels of SOM and other nutrients with respect to compost and poultry manure application for the two cropping seasons. This demonstrates the relative ability of compost and poultry manure to enhance the fertility status of soils. According to Ter *et al*. (2014) application of varying rates of organic amendments improves soil properties in Makurdi, sub-humid guinea savanna zone of Nigeria. This trend has been demonstrated in a number of other studies as reported by Haynes (1986), Agboola and Unamma (1991) and Babalola (2006).

Soil nitrogen was improved with soybean component in the mixture over non fertilizer treatments. This attest to the fact that leguminous crop plays a major role in nitrogen availability as reported by Brady and Weil (2007), Agbede (2009) and Adepetu *et al*. (2014).The phosphorus level in the soil was largely decreased in non fertilizer treatments and plots with sorghum-soybeans mixture This may be adduced to removal of the element largely by soybean in the mixture and then sorghum. Phosphorus is essential for physiological processes of ripening and protein synthesis. Therefore, depletion of phosphorus in the soil where a protein-rich crop as soybeans is grown would be expected (Adepetu *et al*., 2014). On the other hand, Al and Fe ions are present freely in soil solution at low soil pH (Brady and Weil, 2007; Agbede, 2009; Havlin *et al.,*2014). These ions (Al and Fe) fix phosphorus in form of phosphates which lowered P in the soil and make it temporarily unavailable (Adepetu *et al*., 2014). Manure plots increased the phosphorus concentration in the soil. It is apparent that crop management practices that would facilitate addition of plant mineral nutrient elements in the soil from traditional sources is essential for sustainable crop production.

The concentration of exchangeable cations in the soil during the two cropping seasons was marginally decreased by Soybean/sorghum mixture. This may be attributed to the effect of soybean on soil pH as can be observed. Soil pH has an inverse relationship with soil CEC and by extension the concentration of exchangeable cations (Ca, Mg, K and Na^+) in soil. This finding is in line with the finding of Anikwe and

Okonkwo (2003) who reported that legume crops contributed to the lowering of exchangeable bases.

Grain yield followed a similar trend as observed with growth parameters during 2016 and 2017 cropping season. Legume in the sorghum mixture might have enhanced efficient utilization of soil nutrients and consequently higher yield. Similar observation was made by Vanlauwe et al (2006) who reported an average threshold increase in the yield of maize – legume based mixture with fertilizer application. This observation did not agree with findings by Mbah *et al* (2007) who reported a reduction in grain yield under inter crop over sole cropping. This might have been due to competition over available nutrients (especially phosphorus and potassium) and soil moisture.

CONCLUSION

The study revealed that application of organic NPK® (compost) and poultry manure increased soil pH and improved the concentration of organic matter, total nitrogen, available phosphorus and exchangeable cations in the soil. Sole application of NPK fertilizer depleted soil organic matter and lowered soil pH. The concentration of total nitrogen and organic matter in the soil was improved in soybean and sorghum mixture. This is adduced to nitrogen fixation associated with leguminous plant. However, the sorghum-soybeans mixture did not have statistical difference ($P>0.005$) on grain yield in the two cropping seasons

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