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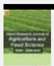

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Effect of Incorporating Zamarke (*Sesbania rostrata*) as a Green Manure on some Soil Physicochemical Properties in Sudan Savannah Zone, Aliero, Kebbi State Nigeria

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ABSTRACT

A Field experiment was conducted at the University Botanical Garden, in Kebbi State University of Science and Technology, Aliero, Aliero local Government area, to evaluate the effect of incorporating Sesbania rostrata as a green manure on the early growth of maize (Zea Mays L.). The experiment consists of four treatments; Control, Green manure (Sesbania rostrata), NPK Fertilizer (20:10:10) and intercropped Sesbania plant (as T1, T2, T3 and T4 respectively) that were fitted into Randomized Complete Block Design (RCBD) and replicated three times. Results from the experiment indicated that the most effective practice on germination count (%), plant height and leaf area of the Maize plants, in most cases at latter stage of the growth was found with T2 (Green manure) with 90.27% at 15 DAP, 22.88cm, and 11.60cm2 respectively, and T3 ranked the second with 82.34%at 15 DAP, 18.70cm and 18.80cm^2 respectively. However, in most cases, T3 (NPK Fertilizer) gave a similar effect as that of T4 (intercropped Sesbania plant). Germination count (%), Plants height and leaf area were highest with green manure treatment (T2), while the rest, in most cases, were statistically similar. Green manure treatments gave highly significant effect on the growth parameters, of 90.27% at 15 DAP, 22.88 cm, 11.60 cm^2 for germination count (%), Plants height and leaf area respectively over the control treatment with 81.94% at 15DAP, 8.87cm and 4.77cm^2 at the latter stage of growth, while they were unaffected by green manure treatments at early stage that is at 1WAP. Green manure of Sesbania rostrata was found to be the best management practice to be used in improving soil fertility and growth of Maize particularly for the study area. To achieve an increased and sustainable maize production in the study area, with less use of inorganic fertilizers, there is need to adopt a green manure cropping system that is environmentally friendly and can improved nutrient availability to crops.

Keywords: *legumes, Sesbania rostrata, green manure, nitrogen fixation, soil chemical properties, nutrient cycle*

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INTRODUCTION

Soil fertility is one of the major threats to crop production in the Sudano-Sahelian zone (Chude, 1998). FPDD (2011) showed that majority of soils in Sudano-Sahelian region are inherently low in fertility and marginal in their productivity. This might be attributed to the dominant sand fraction of soils, and low turnover of plant residues which is due mainly to low rainfall coupled with wide spread of wind and water erosions. Another cause of low fertility is nutrient mining and poor agronomic management practices by resource poor farmers. Nutrient balances are negative for many cropping systems indicating that farmers are mining their soils. Consequently, a sustainable crop production could be achieved by application of chemical fertilizers and animal manure to replenish the depleted soil nutrients and increase the organic matter content of the soils as reported by Kwari and Bibinu (2002).

The use of inorganic fertilizers to overcome declining soil fertility in the sub-Saharan Africa is however limited by the economics conditions of resource-poor farmers who are the majority in the region (Drechesel and Gyiele, 1999) and untimely availability (Adedoyin, 1995). Under intensive agriculture, the use of inorganic fertilizer has not been helpful because it is associated with soil acidity, nutrient imbalance and reduction in crop yield (Kang *and* Juo, 1980).

The use of organic manure to meet the nutrient requirement of crop would be an inevitable practice since organic manures generally improve the soil physical, chemical and biological properties along with conserving capacity of the moisture holding capacity of soil and this, resulting in enhanced crop productivity along with maintaining the quality of crop produce (Malieswarappa *et al*., 1999). Improvement in the public health and environmental condition are also the strong reason for advocating the use of organic material (AbouelMadg *et al.,* 2006). In the present chemical input farming system, natural (use of organic amendment viz. green mature, poultry manure, farmyard manure etc) can be considered to be a solution to many problems for different cropping system in different agro-ecological zones (Sharma & Behera 2009).

Green manuring (GM) crops generally have a considerable amount of biomass which comprises of aboveground and belowground biomass. They also have the ability to increase solar energy harvest and C flux into the soil and provide food for soil macro- and micro-organisms. Green manuring with nitrogen fixing legume crop can provide a substantial portion of N requirement for crops and also add organic matter (OM) to maintain soil fertility (FAO, 2009) which is essential for sustainable agriculture. Many authors have demonstrated the paramount importance of green manuring in improving soil physical properties (bulk density, porosity), soil structure and water holding capacity, soil organic carbon (SOC) and nutrient availability (FAO, 2015) as well as the reduction of N losses through runoff, leaching and soil erosion.

Sesbania rostrata is well known for its capability of nodule formation and nitrogen fixation and produce relatively higher organic matter (Bhuma, 2001). Well nodulated Sesbania plants can derive up to 90% N from fixation (Sharma & Behera, 2009) and consequently contribute N in crop cultivation. Therefore, this investigation focused on the use of Sesbania (*Sesbania rostrata*) as green manure added to the soil. This work aims to describe the effects due to green manure of *Sesbania rostrata* on the soil physicochemical properties. The obtained data may be useful to the farmers in the study area.

MATERIALS AND METHODS

Experimental site

Field experiments will be conducted in rainy seasons at the University botanical garden in Kebbi State University of Science and Technology, Aliero. is located between latitude of 12°16'42' N, and longitude of 4°27'6'S (Kowal and Knabe, 1972), in the Sudan savanna of Nigeria. The rainfall distribution is unimodal, starting on average of mid-April and lasting until the end of October.

Treatments and experimental design

Treatments comprising green manure, inter cropped *Sesbania rostrata*, NPK at recommended rates and control. The experiment consists of four treatments as follows:
T1. = Green manure, T2. =Inter cropped, T3. = Inorganic fertilizer (NPK 15:15:15) and
T4. = Control. The treatments were laid out in a Randomized Complete Block Design (RCBD)and were replicated three times in the experimental site.

Soil sampling and preparation

Prior to the commencement, after incorporation and at the end of the experiment, top Soil Samples of 0cm-30cm deep was collected randomly using soil auger from the experimental plot and mixed together to form a composite sample. The samples were air dried, sieved with a 2mm mesh-size sieve and took to laboratory to determine the soil's physicochemical properties such as; Particle size analysis (Sand, Silt and Clay determination), Organic Carbon, pH, Total Nitrogen Available Phosphorus, Cation Exchange Capacity (CEC), Electrical Conductivity (EC) and Exchangeable Cation using standard laboratory procedures

Analytical procedures

Particle size

Particle size would be determined by Bouyoucos hydrometer method as described by Udo *et al.,* (2009). Forty grams of soil will be weighed into a glass cylinder and 200 ml of distilled water and 50 ml of Calgon (Sodium hexametaphosphate) will be added. The content will be allowed to stand overnight, after which it will be stirred for 10 minutes. The suspension will then be transferred to a 1 litre cylinder and filled to the lower mark with distilled water. The suspension will be allowed to equilibrate with room temperature and the temperature will be recorded. The suspension will be thoroughly stirred and time noted. At 20 seconds the hydrometer will be inserted and reading will be taken at 40 seconds for silt + clay. Temperature will also be noted. The suspension will be re-shaken and reading taken at the end of 2 hours for clay.

Soil reaction (pH)

The soil pH was measured in 1:2.5 soil/water ratio (Udo et al., 2009). Twenty grams of air-dry soil was weighed in a 50 mls beaker and 20 mls distilled water added to it. The mixture will be stirred with glass rod and allowed to stand for 30 minutes. The pH would be measured with glass electrode.

Organic carbon (OC)

The OC was determined by Walkey and Black-wet oxidation method (Udo *et al.,* 2009). Two grams of soil sample will be weighed and transferred to 250 ml flask. Ten millilitre of 1N $K_2Cr_2O_7$ solution will be added to it and swirled gently to disperse the soil. Using an automatic pipette, 20 ml concentrated H_2SO_4 will be added to the suspension and allowed to stand for 30 minutes. After cooling, 100 ml of distilled water will be added and then allowed to stand for 30 minutes. Few (3-4) drops of diphenylamine indicator will be added and then titrated with 0.5 N FeSO4 to dark green end point. Blank titration will be made in the same manner, but without soil.

Total nitrogen

Total nitrogen was determined by macro-kjeldahl digestion method described by Bremner and Mulvaney, (1987). One gram of soil will be weighed into 500 ml macro-Kjeldahl flask and 1 tablet of Hg catalyst will be added, followed by 10 ml of concentrated H2SO4. The content will be heated for 3-5 hours until it becomes clear white solution. After cooling, one hundred millimetre of distilled water will be added and transferred into another clear macro-Kjeldahl flask. Fifty millilitre of H3 BO3 indicator solution will be put into 250 ml conical flask, which will be placed under condenser of the distillation apparatus. The macro-Kjeldahl flask containing the digest will then be attached to the distillation apparatus and 100 ml of 10 M NaOH solution will be poured into the macro-kjeldahl flask. The distillation apparatus will be switched-on, until about 150 ml of the distillate is collected. The distillate will be titrated with 0.1 N HCL to pink end-point.

Available phosphorus (Bray - 1P)

Available phosphorus was determined by Bray and Kurtz (Bray – 1) method as described by Olsen and Sommers, (1982). Two grams of soil will be weighed into 250 ml plastic bottle and 14 ml of Ammonium fluoride (0.03N NH4F) in 0.025 N HCL (extracting solution) will be added and shaken on a mechanical shaker for an hour. The content will be filtered through a No.1 white paper, and 20 ml of the extract will be mixed with 5 ml of Ammonium molybdate in a test tube. Finally, 1 ml of stannous chloride (SnCl2) will be added. After 5 minutes, colour will develop, and the percentage transmittance will be measured on the spectrophotometer at wavelength of 660 nm. A standard curve will be prepared and the P concentration in the soil sample will be extrapolated from the standard curve.

Exchangeable bases

Ten grams of the soil will be weighed into a 500 ml conical flask and 30 ml of 1N NH4OAC will be added. The content will be shaken and then filtered into 100 ml conical flask using No.1 filter paper. The volume will be made up to 100 ml mark with 1N NH4OAC. The content will be analysed as follows: for Ca and Mg; 20 ml of the extract will be pipetted into a 250 ml conical flask and 100 ml of distilled water will be added, fifteen millilitre of NH4 buffer, 10 drops each of KCN, TEA, NH_2O4HCl and EBT indicator will be added and titrated with 0.02 N Na2 EDTA to bluish end point. For Ca alone, the above procedure will be followed except that EBT will be replaced by Mureoxide indicator and NH4 buffer will be replaced with 20% NaOH. The content was titrated with 0.02 N Na 2 EDTA a reddish end point; Potassium and Sodium will be determined by flame photometer (Rhoades, 1982).

Exchangeable acidity

Exchangeable H+ and Al3+ was extracted with 1 N KCL and the extract was titrated with 0.05 N NaOH. The total acidity was obtained by summing up the amounts of H+ and Al3+ obtained, (Grant, 1982). Effective cation exchange capacity (ECEC) The ECEC of the soil sample was computed by summation of exchangeable bases and exchangeable acidity (Ca^{2+} + Mg^{2+} + K^+ + Na^+ + H^+ + Al^{3+}).

RESULTS

The soil was found to be sandy clay on textural triangle and strongly acidic (pH 5.0) (Table 1). Total N value of 0.03 g/kg-1, was less than the critical level of 1.5 g/kg-1 (Esu, 1991) and the phosphorus level was found to be lower than 10 mg kg-1 critical level reported by Esu, (1991). The 0.02 cmol kg-1 obtained in this study for potassium was less than the critical level of 0.15 cmol kg-1 (Esu, 1991). This shows that the soil used for the study was very low in major nutrient elements, which justifies

Table1: Showing soil physicochemical properties before the experiment

	Parameters									
Treatments	pH(H_2O)	OC	TN	AV	K^+	Ca^{2+}	Mg^{2+}	EC	CEC	Na^{+1}
	7.4	1.02	0.03	0.16	0.02	0.22	0.11	39.40	25.0	0.03

Means followed by different letters are statistically different following least significant differences (LSD) at *p = 0.05, NS = Not Significant
Textural classe=Sandy Clay
Sand=56.80%
Silt=2.16%
Clay=41.52%

Table 2: Showing soil physicochemical properties after Sesbania incorporation.

	Parameters									
Treatments	pH(H_2O)	OC	TN	AV	K^+	Ca^{2+}	Mg^{2+}	EC	CEC	Na^{+1}
Before incorporation	7.4a	1.02b	0.03b	0.16b	0.02b	0.26	0.18	39.33b	25.30	0.04
Green manure	5.7b	1.23a	0.04a	0.26a	0.03a	0.23	0.11	40.20a	25.16	0.03
F-test	**	*	**	**	*	Ns	Ns	**	Ns	Ns
LSD	0.03	0.11	0.001	0.01	0.01	0.04	0.08	0.13	0.25	0.01

Means followed by different letters are statistically different following least significant differences (LSD) at *p = 0.05, NS = Not Significant
Textural classes=Sandy Clay
Sand=55.36%
Silt=1.44%
Clay=43.20%

the application of fertilizers to the field.

Effect of incorporating green manure on soil physicochemical properties

Incorporation of green manure crop (*Sesbania rostrata*) significantly influenced some of the soil physicochemical properties after incorporation (Table 2). Incorporation of green manure crop (*Sesbania rostrata*) significantly resulted in lower soil pH (5.7) after incorporation when compare with weedy fallow. Incorporation of green manure crop (*Sesbania rostrata*) significantly resulted in increase of the amount of the major nutrient elements of N, P and K to 0.039g/kg^{-1}, 0.19 mg/kg-1and 0.03cmol/kg-1 respectively. Green manuring of Sesbania *rostrata* also results to significant increase of the amount of the Organic carbon content of the soil (1.23g/kg^{-1}). It also resulted to significant increase of Ec content of the soil of (40.2). Incorporation of green manure crop (*Sesbania rostrata*) on the other hand shows no significant difference of Ca+, Mg and CEC of the soil. Incorporation of green manure crop (*Sesbania rostrata*) resulted in significant decrease of the Na+ content of the soil when compared with weedy fallow.

Effect of treatments on soil physicochemical properties after harvest

Incorporation of green manure crop (*Sesbania rostrata*) significantly influenced soil pH after Maize harvest(Table 3). Incorporation of green manure crop (*Sesbania rostrata*) significantly resulted in lower soil pH(5.7) after Maize harvest when compare with weedy fallow. Application of NPK and intercropping of Sesbania plant also resulted to significantly lower pH of 5.9 and 5.7 respectively. Incorporation of green manure crop show significant different on soil organic carbon at harvest (Table 3). Incorporation of (*Sesbania rostrata)* results to statistically highest soil organic carbon content which was higher than NPK, intercropping Sesbania plant and control. Incorporation of *Sesbania rostrata* significantly increased organic carbon while application of NPK (20:10:10) and intercropping Sesbania plant results to the decrease in soil organic carbon (Table 3).

Incorporation of green manure crop (*Sesbania rostrata*) significantly increased soil total N in the study which was statistically higher than that of NPK application and the lowest value of N was realized with intercropping of Sesbania plant in comparison with control (Table 3). The result obtained shows that green manuring of *Sesbania rostrata* show no significant influence on soil available Phosphorus at harvest (Table 3). Application of NPK significantly influenced soil available P. (Table 3). The lowest value of available P was found with intercropping of Sesbania plant (Table 3). The highest values of exchangeable bases were found with incorporation of green manure crop (*Sesbania rostrata)* in comparison with control (Table 3) except in the case of Pottasium (K) and Sodium (Na). Incorporation of green manure crop (*Sesbania rostrata*) significantly increased soil the Electrical Conductivity (EC) and no significant increase of Cation Exchange Capacity (CEC) compared with Control.

Table 3: Showing physicochemical properties of soil after harvest.

Parameters	pH	OC	TN	AV	K^+	Ca^{2+}	Mg^{2+}	EC	CEC	Na^{+1}
Green manure.	5.7c	1.23a	0.04a	0.26ab	0.03b	0.26a	0.18	40.20a	25.30	0.03a
NPK	5.5d	0.13b	0.04a	0.27a	0.05a	0.16cd	0.22	40.13a	25.20	0.02a
Intercropped Sesbania	5.8b	0.13b	0.03b	0.23b	0.03b	0.18bc	0.17	40.16a	25.30	0.03a
Control	6.07a	1.20a	0.04a	0.26ab	0.05a	0.22ab	0.16	39.30	25.16	0.02b
F-test.	*	*	*	*	*	*	Ns	*	Ns	*
LSD	0.03	0.11	0.001	0.01	0.01	0.04	0.08	0.13	0.25	0.01

*Means followed by different letters are statistically different following least significant differences (LSD) at *p = 0.05, NS = Not Significant*
Textural classes=Sandy Clay
Sand =56.80%
Silt =2.16%
Clay = 41.52%

DISCUSSION

The low levels of nutrients obtained in the experimental soils indicate low fertility status and may be attributed to the effects of intensive and continuous cultivation that may aggravate OM oxidation and their consequent leaching/erosion (Ayito *et al.,* 2018 and Habtamu, 2015). Similar low values of organic C, total nitrogen and available phosphorus were reported by Ibrahim, (2007) for soils in the Sudan savannah zones of Nigeria.

Effect of treatments on soil chemical properties

Soil pH

Incorporation of green manure crop in this study resulted in the reduction of soil pH. Ogunwole *et al.*, (2010) attributed the reduction in soil pH after green manure incorporation due to the decomposition of biomass of crop residues which released organic acids which might cause the pH depression in the soils. A decrease in pH in this study accords with the findings of Adesoji *et al.*, (2013), and Kalhapure *et al.* (2013) who reported a general reduction in pH after application of fertilizer and legume biomass.

Soil organic carbon

The soil organic carbon content increased significantly due to green manure incorporation compared to weedy fallow. This might be due to decomposition and mineralization of the incorporated green manure residues. This finding is in line with the reports of (Preston S, 2003 and Sharma *et al.*, 2009).
Application of NPK gave significant increases in soil organic carbon. The increase in soil organic carbon could be probably due to the fact that mineral N enhances microbial decomposition of plant residues which will definitely increase soil organic carbon (Pikul *et al.*, 2008; Poirier *et al.*, 2009). However, significant interaction recorded in this study might be probably due to high N concentration of green manure which is greater than 1.7%N considered threshold for transition from net immobilization to net mineralization (Wong *et al.*, 1995).

Soil total nitrogen

Ogunwole *et al.* (2010) and Adesoji *et al.* (2014) attributed the increase in soil total nitrogen probably due to the quality (i.e. nutrient composition) and small C: N ratio of incorporated legume, which is one indication of the rate of decomposition in the soil. Soil nutrients are better released in soil with low C: N ratio than soil with higher C: N ratio (Adesoji A G *et al.*, 2014). Similar findings have been reported by Egbe, (2010), who reported an increase in soil N when incorporated with food legumes in moist savannah of Nigeria. These increases in soil total N observed might be due synergy between OM amendments and N fertilizers that was attributed to improvements in soil properties and N availability from such fertilizers which stimulate crop growth such as maize (Andrien, and Tran, 2001). This significant interaction observed could be attributed to the highest quality and quantity of green manure biomass incorporated.

Soil available phosphorus

This increase could be attributed to decomposition of organic materials releases organic acids which could dissolve inorganic P compounds (Musandu, 1995). Another reason it might be due to high microbial activity induced by the added organic residues which speed up P cycling (Melero *et al.*, 2007). These results are also in parity to that of (Habtamu, 2015) who found that application of compost can enhance the availability of P and even fixed P can be made available to plants after solubilization by soil microorganisms, rise in soil pH and complexation of soluble Al and Fe by organic molecules. Significant increases observed in soil available P after N application could be attributed to the role of N in mediating the utilization of phosphorous, potassium and other elements in plant (Brady, 1984).

Soil exchangeable bases

The increase in soil exchangeable Ca^{2+}, K^{+} and Mg^{2+} after incorporation of *Sesbania rostrata* compared to control, might be attributed to the addition of organic matter into soils which in most cases increases CEC due to its humic acids which increase the negative charge (Lifeng *et al*., 2006). The higher the organic matter content in a soil the higher the CEC that soil has and hence the higher its exchangeable bases (Ca^{2+}, K^{+}, Mg^{2+} and Na^{+}). This explains the significant differences observed in exchangeable bases compared to control. These concur with the findings of (Kaiser *et al*., 2008 and Brix, 2008) who report increase in CEC and exchangeable bases in treatments where both mineral and organic fertilizers were incorporated. Similarly, World Bank, (1995) elucidated that a significant improvements were observed in soil total N, OC, available P and CEC by using organic amendments. The results presented herein show that the application of organic and mineral N sources improved the general soil fertility parameters with Ca^{2+}, Mg^{2+} and K^{+} increasing in all treatments.

Significant reduction, observed in soil exchangeable Ca^{2+} and Mg^{2+} after N fertilization could probably be that it had been accumulated in the maize plant which could reduce the amount of soil exchangeable calcium and magnesium. Egbe *et al.,* (2012) attributed the reduction of exchangeable calcium and magnesium to uptake in grain filling. However, increase in cations such as K+ and Na+ might be due to the effects of organic matter. These results are in agreement with that of (Sarwar G et al., 2010) who found that cations such as Ca^{2+}, Mg^{2+} and K^{+} were produced during compost decomposition. However, interaction of green manure and NPK fertilizer on soil exchangeable calcium and magnesium were not consistent and did not fallow any pattern.

Conclusion

This research was conducted in the university's Botanical Garden to assess the impact of incorporating Zamarke (Sesbania rostrata) as green manure on various soil physical and chemical properties. The analyzed parameters included particle size distribution (percentages of sand, silt, and clay), pH, total nitrogen, available phosphorus, exchangeable bases, cation exchange capacity (CEC), and electrical conductivity (EC). The findings of the study demonstrated that the use of Sesbania rostrata as green manure significantly enhances soil fertility. Furthermore, the study revealed that the application of nitrogen fertilizers in crop production could be reduced by 60 kg ha–1 N when preceded by the incorporation of legumes, thereby highlighting its potential for sustainable agricultural practices.

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