Effects of varieties and fertilizer application on soil properties and yield of sesame (*Sesamum indicum* L.) in Makurdi, Benue State, Nigeria

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Abstract

Field experiments were carried out in 2018 and 2019 cropping seasons to determine the effects of varieties and fertilizer application rates on soil properties and yield of sesame at the Teaching and Research Farm, Federal University of Agriculture, Makurdi, Nigeria. Treatments consisted of three sesame varieties (Jigida, NCRIBEN-01M and NCRIBEN-032) and four rates of NPK 20:10:10 fertilizer (0, 50,100 and 150 kg ha^{-1}). The experiments were laid out in a Randomized Complete Block Design (RCBD) and replicated thrice. Composite surface (0-30 cm) soil samples were collected prior to planting and after harvest. Data collected include number of capsules per plant, seeds per capsule, length of capsule (cm), 1000 seeds capsule weight (g), 1000 seeds weight (g) and seed yield (t ha^{-1}). Data were subjected to analysis and significant means were separated using Least Significant Difference (LSD) at 5% level of probability. Results indicated that improved varieties (NCRIBEN-01M and NCRIBEN-032) performed better than local variety in terms of yield in both cropping seasons. Sesame yield increased with increase in fertilizer rates up to 150 kg ha^{-1}. The highest yield obtained in 2018 and 2019 cropping seasons was 0.54 and 0.44 t ha^{-1} respectively. The effects of varieties on soil properties did not differ significantly however, the improved varieties left lower essential nutrients in soil when compared with the local variety. Fertilizer application at 150 kg ha^{-1} gave a slight increase in soil nutrient and is hereby recommended for sustainable sesame production in the study area.

Keywords: Sesame varieties, Fertilizer, Yield, Makurdi, Southern Guinea Savanna, Nigeria

Introduction

Sesame (*Sesamum indicum* L.) is one of the most ancient oilseed crops known to mankind (Langham *et al.,* 2008). Since its introduction to Nigeria after the Second World War, it has been regarded as a crop of insignificant importance compared to groundnut and other cash crops. Sesame is cultivated in almost all tropical and subtropical Asian and African countries for its highly nutritious and edible seeds (Iwo *et al.*, 2002). The oil is used for cooking, baking, candy making, soaps, lubricant, body massage, hair treatment, food manufacture, industrial uses and alternative medicine for blood pressure, aging, stress and tension (Ahmed *et al.*, 2009). The sesame seeds serve as ingredients in soup and a source of oil (Biswas *et al.*, 2001). It is widely cultivated in the northern and central part of Nigeria (USAID, 2002; Iorlamen *et al.*, 2014). The demand for sesame and its products is growing both at the national and international levels. Thus huge market potential exists for sesame. However, owing to its previous status as a minor crop, there have been little research efforts towards improved production of the crop (NCRI, 2002).

Soil fertilization is one of the main factors increasing the yield of plants (Ojeniyi *et al.*, 2016). It affects the accumulation, mineralization and humification of organic matter added to the soil and determines plant production potentials (Ali *et al.*, 2015). The amount of mineral fertilizer introduced into the soil affects the amount of mineral nitrogen available to the plants and the organic carbon content of the soil (Ojeniyi *et al.*, 2016). Fertilizer effects on plant growth and yield depends on the crop grown and the environmental conditions that crop encounters. Responses of various crops, including sesame, soybeans, maize, groundnut, wheat and rice to fertilizer application have been studied in Nigeria (Eifediyi *et al.*, 2016; Ojeniyi *et al.*, 2016) and found to improve crop productivity.

Survey reports by various researchers in the savanna areas revealed that the yield of the sesame crop is low, probably due to lack of improved varieties and poor cultural practices carried out by farmers. According to Eifediyi *et al.* (2018), cultivating the crop early in the season predisposes it to vegetative growth and pest invasion. In addition, traditional sesame growers in the study area rarely use fertilizers to increase the yield. Studies have shown that the crop performs well with the application of inorganic fertilizers (Ojeniyi *et al.*, 2016; Eifediyi *et al.*, 2018) and the use of improved varieties.

The recent increase in awareness, production and cultivation of sesame across the savanna zones has necessitated the need to determine its response to various fertilizer levels. Therefore, the objective of the study was to assess the yield of sesame varieties as affected by fertilizer application with the aim to identifying appropriate fertilizer rate that will give optimal yield of sesame in Makurdi, Benue State, Nigeria.

Materials and Methods

Experimental site description

This study was conducted in 2018 and 2019 cropping seasons at the Teaching and Research Farm, Federal University of Agriculture, Makurdi-Nigeria. The study location falls within the Southern Guinea Savanna Zone of Nigeria with mean annual rainfall of about 1, 250 mm and mean daily temperature of 25-30 ^{0}C. It is located between latitudes 7^{0}41' N and 7^{0}42' N and longitudes 8^{0}37' E and 8^{0}38' E.

Land preparation, experimental design and treatment

The experimental site was cleared and demarcated into experimental units. The treatments consisted of three sesame varieties (Jigida, NCRIBEN-01M and NCRIBEN-032) and four rates of NPK 20:10:10 fertilizer (0, 50,100 and 150 kg ha^{-1}). The improved varieties (NCRIBEN-01M and NCRIBEN-032) of sesame were sourced from the National Cereals Research Institute, Badeggi, Niger State, and Jigida (local variety) was sourced from the local farmers. The treatments were laid out in a Randomized Complete Block Design (RCBD) with sesame varieties occupying the main plots and fertilizer application at sub plots and were replicated thrice.

Seeds were sown at an inter and intra row spacing of 75 cm x 5 cm. Sesame seeds were drilled along the ridges and latter thinned to have two plants per stand two weeks after planting (WAP) to give a plant population of 133,333 plants ha^{-1}. Weeding operations at 3 and 9 weeks after planting (WAP) were done during the period of the experiments. The fertilizer application was done at 2 WAP by band placement in alternate rows.

Sesame crop was harvested when about 50 % of the capsules turned yellow in colour from green. Harvesting was not delayed in order to prevent seed loss through shattering. Harvesting was done by cutting the stems with sickles, pulling the plants from the root was avoided in order to prevent contamination of seeds with sand. After harvesting, the plants were tied with a rope into bundles and positioned erect on a tarpaulin for the capsules to be fully dried.

Soil sampling and analysis

Surface depth of (0-30 cm) soil samples were collected from eight points and bulked, composite soil samples were air dried, crushed and sieved using a 2 mm-mesh sieve and analyzed using standard soil analytical procedures at the Advanced Soil Science Laboratory of the Federal University of Agriculture, Makurdi. Particle size distribution was determined by the hydrometer method (Bouyoucos, 1951). Soil pH was measured with the glass electrode pH meter. Soil organic carbon (OC) was determined by the Walkley and Black method and total N by the macro-Kjeldahl digestion method (Bremner and Mulraney, 1982), Available P was determined by the Bray and Kurtz (1945) extraction method. Exchangeable cations were extracted using 1 NH_4OAc solution, K and Na were read using flame photometer, while Ca and Mg were determined using the Atomic Absorption Spectrophotometer (AAS). Effective cation exchange capacity (ECEC) was established as the summation of the exchangeable cations (K, Na, Ca, Mg) and exchange acidity (LaBarge and Lindsey, 2012).

Crop data collection and statistical analysis

Data were collected for the yield parameters of sesame for both cropping seasons as follows: The lengths of ten capsules from each net plot were measured from bottom of a sesame capsule to the capsule apex using a meter rule and the average value recorded. Five plants in a net plot were sampled, the number of capsules on each plant counted and the average value determined and recorded. One thousand capsules were taken from ten sampled plants per plot and weighed also on a sensitive Mettler top-loading electronic balance (Model P. 1200) and the mean weights were then recorded. Ten dry capsules were sampled randomly from each net plot. They were split open and the number of seeds in each capsule counted and the average values were recorded. A total of 1000 sesame seeds from each plot were counted and weighed on an electronic top-loading Mettler balance to obtain the weight of 1000 seeds. From the seed yield per plot, seed yield per hectare for each plot was computed by converting it into kilogram per hectare by extrapolation. Data collected for the yield parameters of sesame for both cropping seasons were subjected to the Analysis of Variance (ANOVA) using Genstat Release 10.3 DE after which significant means were separated using Least Significant Difference (LSD) at 5 % level of probability.

Results and discussion

Soil properties of the experimental site prior to planting

Selected soil properties of the experimental site before planting are shown on Table 1. The results indicated that soils for both cropping seasons were sandy loam in texture. This texture is ideal for sesame production as it required a well drained soil for optimum growth and yield. The high sand content of the soil (71.8 % for 2018 and 75.50 % for 2019) was indicative of the low clay content which could be attributed to the soil separates sorting activities by organisms, clay eluviation, and surface soil erosion, parent material or a combination of these factors (Odunze *et al.*, 2006; Malgwi *et al.*, 2008; Adamu *et al.*, 2010).

The slightly acidic pH of the soils (6.08 – 6.05) indicates that the soils are suitable for sesame production. Bennet (2011) reported that sesame is intolerant of very acidic or saline soils hence the pH obtained from this soil is ideal for optimum sesame production. Very low pH values have a drastic effect on growth, through some varieties can tolerate a pH range of 8 (Naturland, 2002; Akinoso *et al.*, 2010).

The soils were low in essential plant nutrients and organic carbon when compared with soil fertility ratings by Esu (1991). The low nutrient status of this soil is a characteristic of tropical soils where the slash and burn practice coupled with high insolation and rainfall prevents the build-up of organic matter which is the store house of most nutrients (Anjembe, 2004). This is in line with the observations made by Aduayi *et al.* (2002) and Senjobi *et al.* (2013) who reported that Nigerian soils are deficient in most nutrients.

Effect of varieties and fertilizer application rates on soil properties

The effect of varieties and fertilizer application rates on soil properties in 2018 and 2019 are presented on Table 2a-c. Fertilizer application significantly affected most of the soil properties studied irrespective of the varieties. The effects of fertilizer applications on soil physical and chemical properties are importance to agricultural sustainability and to increased crop yield (Ayoola, 2006; Oloworeke, 2014). The physical and chemical properties of a soil are one of the fundamental factors affecting crop growth, development and yield. This is because these properties have very high degree of correlation with crop production and high influence on soil fertility and crop performance (Adeniyan, 2008 and Onwudiwe *et al.,* 2014). For the study under consideration more focus was on the chemical properties and results revealed that the soil properties were improved with increasing rates of fertilizer application though no significant difference was observed in the interaction effects of most of the soil parameters in both seasons.

Many African soils show nutrient deficiency problems after only a short period of cultivation because of their nature as well as prevailing environmental conditions. Farmers have sought to furnish additional nutrients through the application of chemical fertilizer so that the yields of crops will no longer be limited by the amounts of plant nutrients that the natural system can supply (Agber *et al.*, 2012; Agbede *et al.,* 2013). Fertilizers are usually applied to soil for increasing or maintaining crop yields to meet the increasing demand of food (Olatunji and Ibrahim, 2014; Babbu *et al.,* 2015). The application of inorganic fertilizers results in higher soil organic matter accumulation and biological activity due to increased plant biomass production and organic matter returns to soil in the form of decaying roots, litter and crop residues (Adekiya *et al.*, 2009; Babbu *et al.,* 2015). Addition of soil organic matter enhances soil organic carbon content, which is an important indicator of soil quality and crop productivity (Babbu *et al.,* 2015). Fertilizer additions also affect the chemical composition of soil solution which can be responsible for dispersion/flocculation of clay particles and thus, affects the soil aggregation stability (Haynes and Naidu, 1998).

Effect of varieties and fertilizer application rates on yield of sesame

The effects of varieties and fertilizer application rates on the yield of sesame are presented on Table 4. Results indicated that the varieties and fertilizer application had significant difference on all the parameters measured with the exception of capsule length and number of seeds per capsule and weight of 1000 seeds. There were significant differences among the varieties with respect to some of the yield attributes such as number of capsules per plant, weight of 1000 capsules and 1000 seeds as well as grain yield as a result of the physiological differences among the varieties and apart from the local variety (Jigida), the other varieties have been bred for higher yield and other desirable qualities. The number of capsules and yield of the improved varieties (NCRIBEN-01M and NCRIBEN-032) were higher than those of the local variety. NCRIBEN-032 gave significantly higher yield than the other varieties in 2018 and 2019 cropping seasons.

The significant response of yield to fertilizer application is an indication of the role of fertilizers in plant nutrition. Nitrogen, phosphorus and potassium are the three most limiting of the essential plant nutrient elements and are required in large quantities by crops especially in Nigerian soils with low inherent fertility (Ibrahim *et al.*, 2017). The yield increased with increasing rates of fertilizer application in both cropping seasons irrespective of the sesame varieties. The findings are in conformity with the results obtained by Babeji *et al*. (2006) who reported significant increase in the yield attributes of sesame with increase in nitrogen fertilizer.

The statuses of nutrients in soils of Nigeria especially those with history of intensive cultivation are generally low, hence the significant response of sesame yield and its other attributes to fertilizer application. In recent times, many farmers and researchers in Nigeria have used many fertilizer types to improve the yield of sesame, but the yield still remains very low, about 450 kg ha^{-1} (Eifediyi *et al.*, 2016), compared to the much higher yield in Egypt (1,323 kg ha^{-1}) and Ethiopia (825 kg ha^{-1}) (FAO, 2009). When soils are continually cultivated, it results in low yields due to the mining of the soil nutrients. This calls for the use of external inputs in order to reverse the loss of nutrients and maintain productivity (Agbede, 2009). The replenishment of nutrient and enhanced quality of tropical soils could be achieved through the addition of fertilizers (Shangakkara *et al.*, 2004). Fertilizer is a component of sustainable crop production systems and sesame requires adequate supply of nutrients particularly nitrogen, phosphorus and potassium (NPK) for good growth and high yield hence the response of the sesame varieties to fertilizer application in the current study.

Fertilizer application is one major farming operation needed to correct deficiencies in the soil in order to ensure proper growth and functioning of crops with the aim of increasing yield (Srivastava *et al*., 2006; Brady and Weil, 2014). Adekayode and Ogunkoya (2010) observed improved maize growth parameters with corresponding higher yield in plots treated with fertilizers at 300 and 250 kg per hectare in Nigeria. The report by Eifediyi *et al.* (2016) that an increase in the level of fertilizer application resulted in an increase in the growth and yield parameters of sesame confirms the current result. Similarly El-Nakhlawy and Shaheen (2009) stated that vegetative production in plants increases with increased level of fertilizer and this is also in conformity with the results of the current study. Eifediyi *et al.* (2016) also observed an increase in number of leaves of sesame when inorganic fertilizer was used in southern Guinea savanna zone in Nigeria**.**

Crops require nutrients to perform optimally both in the vegetative and reproductive stages of their life cycle however; most Nigerian soils have been reported to be deficient in these essential nutrients (Ibrahim *et al.*, 2017). Hence the need for application of external source for these plant nutrients. For the study under consideration, increase in yield and yield attributes with increasing levels of fertilizer application from the control plots where fertilizer was not applied to plots that received 150 kg ha^{-1} of the NPK 20:10:10 was observed. Responses of various crops, including sesame, soybeans, maize, ground nut, wheat and rice to fertilizer application have been studied in Nigeria (Eifediyi *et al.*, 2016; Ojeniyi *et al.*, 2016). Eifediyi *et al.* (2016) reported that NPK fertilizer significantly ($p<0.05$) influenced the yield of sesame. The results of their study also revealed that NPK fertilizer at the rate of 400 kg ha^{-1} and 300kg ha^{-1} produced the highest grain yield of sesame for 2013 and 2014 respectively; these dosage of fertilizer used in obtaining optimum yield were higher than the 150 kg ha^{-1} in the present study. Jakusko and Usman (2013) obtained maximum yield of sesame with NPK fertilizer at the rate of 300 kg ha^{-1} and 200 kg ha^{-1} in 2009 and 2010, respectively.

Conclusions

Results indicated that improved varieties performed better than local varieties in terms of yield in both cropping seasons. Sesame yield increased with increase in fertilizer rates up to 150 kg ha^{-1}. The highest yield obtained in 2018 and 2019 cropping seasons was 0.54 and 0.44 t ha^{-1} respectively. The effects of varieties on soil properties did not differ significantly however, the improved varieties left lower essential nutrients in soil when compared with the local variety.

Recommendation

Fertilizer application at 150 kg ha^{-1} of NPK 20:10:10 gave a slight increase in soil nutrient and is hereby recommended for sustainable sesame production in the study area.

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Table 1: Selected soil properties of the experimental site prior to planting

Soil properties	2018	2019
Chemical Properties		
pH	6.08	6.50
Organic Carbon (%)	0.52	0.53
Organic Matter (%)	0.90	0.91
Total Nitrogen (%)	0.11	0.12
Available P ($mgkg^{-1}$)	3.90	4.35
Exchangeable Cation ($Cmol\ kg^{-1}$)		
Ca	3.00	2.30
Mg	2.80	2.10
K	0.27	0.31
Na	0.24	0.20
EB	6.31	4.91
EA	1.10	0.90
CEC	7.41	5.81
Base Saturation (%)	85.20	84.51
Physical properties		
Particle size distribution		
Sand (%)	71.8	75.50
Silt (%)	10.00	9.50
Clay (%)	18.20	15.00
Textural Class	Sandy loam	Sandy loam

Table 2a: Effect of varieties and fertilizer rates on selected soil properties

Varieties	pH		Sand (%)		Clay (%)		Silt (%)	
	2018	2019	2018	2019	2018	2019	2018	2019
V1	6.13	6.32	69.16	69.48	19.08	18.99	11.76	11.81
V2	6.15	6.30	68.47	69.30	19.41	18.56	12.12	12.14
V3	6.14	6.32	68.68	69.23	18.70	18.69	12.51	12.08
LSD(P≤0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Fertilizer rates								
F1	6.07	6.57	68.46	69.18	19.28	19.82	12.11	11.00
F2	6.18	6.18	69.46	69.56	17.61	17.96	12.92	12.48
F3	6.10	6.29	67.59	70.49	20.89	16.98	11.52	12.90
F4	6.21	6.23	69.56	68.13	18.48	20.22	11.96	11.65
LSD (P≤0.05)	NS	0.18	NS	NS	0.14	0.77	0.76	NS

NS= Not significant, F1 = 0 kg ha^{-1}, F2 = 50 kg ha^{-1}, F3 = 100 kg ha^{-1}, F4 = 150 kg ha^{-1}, V1 = jigida, V2 = NCRIBEN-01M, V3 = NCRIBEN-032

Table 2b: Effect of varieties and fertilizer rates on selected soil properties

Varieties	Mg ($cmol\ kg^{-1}$)		N (%)		Na ($cmol\ kg^{-1}$)		OC (%)		OM (%)		P ($mg\ kg^{-1}$)	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
V1	2.99	2.87	0.077	0.077	0.33	0.24	0.75	0.62	1.29	1.07	3.25	3.64
V2	3.03	2.83	0.082	0.073	0.48	0.24	0.76	0.57	1.31	0.98	3.34	3.55
V3	3.02	2.87	0.080	0.077	0.39	0.24	0.69	0.62	1.18	1.06	3.19	3.69
LSD(P≤0.05)	NS	NS	0.02	NS	NS	NS	0.06	NS	NS	NS	0.12	NS
Fertilizer rates												
F1	2.90	2.77	0.073	0.053	0.24	0.21	0.61	0.66	1.05	1.14	3.44	2.50
F2	2.89	2.84	0.074	0.063	0.34	0.23	0.69	0.43	1.18	0.75	3.19	3.45
F3	3.16	2.84	0.083	0.087	0.56	0.24	0.80	0.55	1.38	0.95	3.68	3.85
F4	3.09	2.97	0.085	0.099	0.46	0.27	0.83	0.76	1.43	1.32	2.74	4.72
LSD(P≤0.05)	NS	NS	0.008	0.005	0.12	0.03	0.11	0.06	0.14	0.13	0.25	0.41

NS= Not significant, F1 = 0 kg ha^{-1}, F2 = 50 kg ha^{-1}, F3 = 100 kg ha^{-1}, F4 = 150 kg ha^{-1}, V1 = jigida, V2 = NCRIBEN-01M, V3 = NCRIBEN-032

Table 2c: Effect of varieties and fertilizer rates on selected soil properties

Varieties	BS (%)		CEC(cmol kg^{-1})		Ca (cmol kg^{-1})		EA (cmol kg^{-1})		EB(cmol kg^{-})		K (cmol kg^{-1})	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
V1	85.26	84.26	7.81	7.74	3.14	3.13	1.15	1.22	6.63	6.52	0.28	0.28
V2	85.38	84.28	7.86	7.61	3.14	3.07	1.15	1.19	6.71	6.41	0.30	0.28
V3	85.33	84.20	7.73	7.74	3.07	3.14	1.13	1.22	6.60	6.52	0.27	0.29
LSD ($P \leq 0.05$)	0.73	NS	0.49	NS	0.30	NS	NS	NS	NS	NS	NS	NS
Fertilizer rates												
F1	84.77	83.79	7.55	7.26	3.00	2.88	1.15	1.18	6.40	6.08	0.26	0.22
F2	85.05	83.98	7.51	7.77	2.99	3.21	1.12	1.24	6.35	6.52	0.26	0.25
F3	85.90	84.28	8.02	7.66	3.19	3.05	1.13	1.20	6.89	6.46	0.29	0.32
F4	85.57	84.95	8.12	8.09	3.27	3.28	1.17	1.22	6.95	6.87	0.33	0.34
LSD ($P \leq 0.05$)	0.84	NS	0.57	0.49	0.35	0.30	NS	NS	0.34	0.51	0.034	0.02

NS= Not significant, F1 = 0 kg ha^{-1}, F2 = 50 kg ha^{-1}, F3 = 100 kg ha^{-1}, F4 = 150 kg ha^{-1}, V1 = jigida, V2 = NCRIBEN-01M, V3 = NCRIBEN-032

Table 3: Effect of varieties and fertilizer rates on the yield of sesame

Varieties	**Capsule Length (cm)**		**No. of capsules per plant**		**No. of seeds per capsule**		**Weight of 1000 capsules (g)**		**Weight of 1000 seeds (g)**		**Seed yield (t ha^{-1})**	
	2018	**2019**	**2018**	**2019**	**2018**	**2019**	**2018**	**2019**	**2018**	**2019**	**2018**	**2019**
V1	3.01	2.99	13.92	14.47	48.42	68	337.4	370.1	137.19	135.42	0.34	0.43
V2	3.03	3.01	17.89	14.67	59.58	67	379.9	372.0	136.94	138.81	0.54	0.44
V3	3.03	3.02	24.11	14.92	54.94	228	382.5	375.0	139.69	140.67	0.48	0.44
LSD ($P \leq 0.05$)	NS	0.034	3.20	0.93	NS	NS	17.19	6.32	NS	5.023	0.10	NS
Fertilizer rates												
F1	2.90	2.88	12.41	12.48	50.37	62	348.3	344.4	122.96	121.81	0.38	0.38
F2	3.06	2.99	13.11	13.59	54.48	66	361.8	361.3	133.93	133.67	0.43	0.43
F3	2.99	3.02	14.04	15.11	57.11	69	389.1	377.8	143.81	142.37	0.44	0.45
F4	3.16	3.15	16.33	17.56	60.63	288	420.5	405.9	151.07	155.33	0.49	0.49
LSD ($P \leq 0.05$)	0.0345	NS	0.84	NS	1.47	NS	8.63	NS	4.62	NS	0.0162	0.10

NS = Not significant, F1 = 0 kg ha^{-1}, F2 = 50 kg ha^{-1}, F3 = 100 kg ha^{-1}, F4 = 150 kg ha^{-1}, V1 = Jigida, V2 = NCRIBEN-01M, V3 = NCRIBEN-032