Assessment of integrated soil nutrient sources on growth and yield parameters on sorghum in the soil of Makurdi, Nigeria

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Abstract

Research was carried out at University Commercial Crop Farm, Federal University of Agriculture Makurdi, to evaluate the effects of different soil nutrient sources on the growth and yield of sorghum in the 2016 and 2017 cropping season under rain-fed condition. The experiment consisted of fourteen treatments; (I) Control, (II) Soybean intercrop, (III) 2.0 t/ha^{-1} of PM, (IV) 2.0 t/ha^{-1} of PM + Soybean, (V) 3.5 t/ha^{-1} of PM, (VI) 3.5 t/ha^{-1} of PM + Soybean, (VII) 0.2 t/ha^{-1} of CP, (VIII) 0.2 t/ha^{-1} of CP + Soybean, (IX) 0.4 t/ha^{-1} of CP, (X) 0.4 t/ha^{-1} of CP + Soybean, (XI) 30 kg N/ha^{-1}, (XII) 30 kg N/ha^{-1} + Soybean, (XIII) 60 kg N/ha^{-1}, and (XIV) 60 kg N/ha^{-1} + Soybean. The experiment was laid in Randomised Complete Block Design in three (3) replications. Sole applications of compost manure at 0.4 t/ha^{-1} had significant difference on leaf area. Soybean as nutrient source did not have significant difference on crop parameters. Poultry manure, NPK fertilizer and compost manure significantly affected growth and yield parameters in the two cropping seasons. The highest yield were obtained from application of NPK fertilizer at 60 kg N/ha^{-1} in plots where sorghum was intercropped with soybeans, this was not however significant when compared with plots where NPK fertilizer was applied without soybean mixture.

Keywords: nutrients, compost, yield, Nigeria, agricultural culture.

Avaliação de fontes integradas de nutrientes no solo dos parâmetros de crescimento e produção de sorgo no solo de Makurdi, Nigéria

Resumo

A pesquisa foi realizada na *University Commercial Crop Farm*, Universidade Federal de Agricultura Makurdi, para avaliar os efeitos de diferentes fontes de nutrientes do solo no crescimento e rendimento do sorgo na safra de 2016 e 2017 sob condições de sequeiro. O experimento constou de quatorze tratamentos; (I) Controle, (II) Consórcio de soja, (III) 2,0 t/ha^{-1} de PM, (IV) 2,0 t/ha^{-1} de PM + Soja, (V) 3,5 t/ha^{-1} de PM, (VI) 3,5 t/ha^{-1} de PM + Soja, (VII) 0,2 t/ha^{-1} de PB, (VIII) 0,2 t/ha^{-1} de PB + Soja, (IX) 0,4 t/ha^{-1} de PB, (X) 0,4 t/ha^{-1} de PB + Soja, (XI) 30 kg N/ha^{-1}, (XII) 30 kg N/ha^{-1} + Soja, (XIII) 60 kg N/ha^{-1}, e (XIV) 60 kg N/ha^{-1} + Soja. O experimento foi colocado em Design de Bloco Completo Randomizado em três (3) repetições. Aplicações isoladas de esterco de compostagem na dose de 0,4 t/ha^{-1} tiveram diferença significativa na área foliar. A soja como fonte de nutriente não apresentou diferença significativa nos parâmetros da cultura. O esterco de frango, o fertilizante NPK e o esterco composto afetaram significativamente os parâmetros de crescimento e rendimento nas duas safras. As maiores produtividades foram obtidas com a aplicação do fertilizante NPK na dose de 60 kg N/ha^{-1} nas parcelas onde o sorgo foi consorciado com a soja, porém não foi significativo quando comparado com as parcelas onde foi aplicado o fertilizante NPK sem mistura de soja.

Palavras-chave: nutrientes, composto, rendimento, Nigéria, cultura agrícola.

1. Introduction

The decline in food security is becoming a recurrent challenge affecting family living in most parts of Nigeria. The underlining factor responsible for the food insecurity is land degradation accompanied with increasing climate changes. According to Gruhn et al. (2000) and Sanchez (2002) land degradation and associated soil fertility declines are considered the major bio-physical root causes for the decline in per capital food production in Sub-Saharan African in general.

Climate variability occasioned by prolong period of rainfall and long spell of drought period occurring within the same region, rising average temperatures are capable of decreasing crop and livestock productivity. With poor soils, extreme climatic conditions, among other socio-economic constraints, it is expedient to adopt a farming system that encompasses a set of soil fertility and crop management practice that combined both organic and inorganic inputs to curb rising food insecurity. Such a system must guarantee sustainable supply of nutrients to crops at low cost and addresses challenges of climate variability. Solving the problem of declining soil fertility combined with extreme climate conditions will largely enhance sustainable food security. Although, there is wide recognition that soil nutrients loss can be ameliorated via inorganic fertilizer application, studies have revealed that continuous use of this input has consequences on soil health (Kamara et al., 2000; Brady; Weil, 2007; Adepetu et al., 2014).

Over the years organic amendments such as animal waste and plant residues have provided reliable alternative to inorganic fertilizers; soil quality, improve nutrient supply, favourable roots environment, soil water retention and ultimately increased crop yield are some of the positive attributes of organic amendments (Adeniyan; Ojeniyi, 2005; Zavalloni et al., 2011; Adekiya et al., 2012). However, with high yielding and early maturing crop varieties, organic amendments alone cannot meet crop nutrients demand. Since sole application of inorganic or organic fertilizer inputs cannot meet farmer expectations, integrated nutrient management systems which has proven to be viable option for improving land productivity and high crop yield (Fao, 2000) has been advocated.

The use of integrated nutrient management system as a farm practice for sorghum production has not received much attention amongst farmers in the southern guinea savannah. Whereas the negative impact of global warming has amplified the need to cultivate drought tolerant crops to ameliorate declining food security. Sorghum is a major staple food crops 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, 2010). There has been a rising demand for sorghum in Benue State over the years; nonetheless, the yield per unit area of land is on the decrease. Therefore, there is need to improve agronomic practice so as to increase the yield per unit area of the crop particularly in Makurdi where sorghum is produced by most farmers.

The objective of this study was to evaluate the efficacy of integrated nutrient management system of the growth and yield of sorghum in Makurdi, Nigeria.

2. Materials and Methods

2.1 Experimental site

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 70°41’1’’ N and longitude 80°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 °C.

2.2 Experimental treatments and design

The treatments were; (I) Control, (II) Soybean intercrop,(III) 2.0 t/ha^{-1} of PM, (IV) 2.0 t/ha^{-1} of PM + Soybean, (V) 3.5 t/ha^{-1} of PM, (VI) 3.5 t/ha^{-1} of PM + Soybean, (VII) 0.2 t/ha^{-1} of CP, (VIII) 0.2 t/ha^{-1} of CP + Soybean, (IX) 0.4 t/ha^{-1} of CP, (X) 0.4 t/ha^{-1} of CP + Soybean, (XI) 30 kg N/ha^{-1}, (XII) 30 kg N/ha^{-1} + Soybean, (XIII) 60 kg N/ha^{-1}, (XIV) 60 kg N/ha^{-1} + 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 before sorghum (local variety) was planted. 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.

2.3 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 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 & 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.Na and K in the extracts were determined by the flame photometer while Ca and Mg were determined usingAtomic Absorption Spectrophotometer (AAS), exchange acidity by the 1 M KC1 extraction and0.01 M NaOH titration.

2.4 Crop data collection and statistical analysis

The following crop data were collected; Leaf area, plant height, panicle length and grain yield. Leaf area (cm^2) and plant height (cm) were collected at 3 weeks intervals. The panicle length (cm) and grain yield (kg/ha^{-1}) were determined at harvest. Crop data collected were subjected to analysis of variance (ANOVA) and the means that were statistically different were separated using *Fisher's* least significant difference (F-LSD) at 5% level of probability (Obi, 2001).

3. Results and Discussion

3.1 Soil properties of the experimental site

The results of selected soil properties of the experimental site before application of fertilizer are presented in (Table 1). The particle size distribution analysis of soils of the experimental site indicates that the percentage sand was 76.64% in 2016. 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. The organic matter in 2016 cropping season was 1.18%. Total Nitrogen (N) was 0.21%. Phosphorus (P) was 1.20 mg/kg^{-1}. 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, in Makurdi, Nigeria.

Soil parameters 0-15 cm	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})	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

Source: Authors, 2023.

3.2 Chemical composition of poultry manure and organic NPK® (compost)

The result 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^{-1}), Ca (10.81 cmol/kg^{-1}), Mg (0.53 cmol/kg^{-1}), Na (1.78 cmol/kg^{-1}) and CEC (14.27 cmol/kg^{-1}). Similarly, the nutrient composition of compost was; organic matter (48.65%), Nitrogen (8.20%), Phosphorus (6.12 mg/kg^{-1}), Potassium (3.80 cmol/kg^{-1}), Calcium (13.28 cmol/kg^{-1}), Magnesium (8.13 cmol/kg^{-1}), and Sodium (0.62 cmol/kg^{-1}). 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 and organic NPK® (compost).

Parameters	Poultry manure	Compost
pH	7.4	7.0
Organic matter (%)	26.41	48.65
Total nitrogen (%)	2.25	8.20
Phosphorus (mg/kg^{-1})	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

Source: Authors, 2023.

3.3 Crop data

Leaf area of sorghum as affected by application of varying nutrient sources are presented in (Table 3). The results indicated that leaf area was significantly affected by integrated soil nutrients application. There was significant difference between control and soybean component as sole nutrient source at 6 and 12 WAP in 2016 season. However, there was no significant difference between sole application poultry manure at 2.0 t/ha^{-1} and soybean plus 2.0 t/ha^{-1} of poultry manure at all intervals. Similarly, there was no significant difference between sole application poultry manure at 3.5 t/ha and soybean plus 3.5 t/ha of poultry manure at all intervals. Compost manure at 0.2 t/ha^{-1} did not have significant difference with soybean plus compost at 0.2 t/ha^{-1} at all intervals.

Also, compost manure at 0.4 t/ha^{-1} did not have significant difference on leaf area with soybean plus compost at 0.4 t/ha^{-1} at all intervals in 2014 season (Table 3). Application of 30 kg N/ha^{-1} of mineral fertilizer did not have significant difference on leaf area of sorghum with soybean plus 30 kg N/ha^{-1} of mineral fertilizer. Similarly, sole application of 60 kg N/ha^{-1} of mineral fertilizer did not have significant difference on leaf area with soybean plus 60 kg N/ha^{-1} of mineral fertilizer. In 2017 season, there was no significant difference between control and soybean component as sole nutrient source at 9 and 12 WAP. Sole application poultry manure at 2.0 t/ha^{-1} and soybean plus 2.0 t/ha^{-1} of poultry manure did not have significant difference on leaf area of sorghum at all intervals.

Poultry manure at 3.5 t/ha^{-1} and soybean plus 3.5 t/ha^{-1} of poultry manure did not have significant difference on leaf area at 9 and 12 WAP. Similarly, sole application of compost at 0.2 or 0.4 t/ha^{-1} did not have significant difference on leaf area with soybean plus compost at 0.2 or 0.4 t/ha^{-1}. There was significant difference on leaf area of sorghum between.

As seen in table 3 above, leaf area was not significantly affected by soybean mixture in the two cropping seasons. However, there was marginal improvement in leaf area with soybean mixture over the control, sole fertilizer and compost or manure treatments. This revealed the potential benefits of soybean in a cropping system. This result agreed with Ofori & Stern (1987) who reported that leaf area of sorghum was significantly increased in soybean/sorghum mixture. Also, Fuyita et al. (1990) reported that leaf area was significantly improved in a cowpea/maize mixed cropping system. Similarly, Bavec et al. (2005) reported an increase in leaf area of maize due to inter cropping with climbing beans. In contrast, Mouneke & Okpara (2001) did not find any significant effect on growth parameters due to cereal/legume intercrop. The difference in the observed trends may be due to variations in the growth conditions which might have affected the growth pattern of the crops in the study.

Table 3. Effect of nutrient sources on leaf area (cm^2) of sorghum.

Treatment	3WAP		6WAP		9WAP		12WAP	
	2016	2017	2016	2017	2016	2017	2016	2017
Control	55.2	66.1	111.1	112.4	219.7	221.1	298.8	302.2
Sorghum/soybean	68.1	66.1	117.5	116.1	221.0	222.7	302.2	302.9
2.0 t/ha^{-1} PM	64.7	60.0	118.0	116.0	236.6	244.0	313.5	308.5
2.0 t/ha^{-1} PM + soybean	61.2	65.4	119.7	116.5	236.7	244.5	313.8	309.0
3.5 t/ha^{-1} PM	60.1	66.0	120.0	121.0	228.9	256.1	317.7	323.1
3.5 t/ha^{-1} PM + soybean	69.0	63.5	120.1	124.0	228.9	257.8	319.0	323.4
0.2 t/ha^{-1} CP	63.0	58.1	123.0	146.0	234.8	241.0	318.7	324.0
0.2 t/ha^{-1} CP + soybean	73.5	61.5	123.8	148.6	236.5	241.0	318.7	324.8
0.4 t/ha^{-1} CP	65.0	63.3	126.0	243.9	243.0	245.0	325.1	330.0
0.4 t/ha^{-1} CP + soybean	64.7	60.1	127.1	124.5	243.9	245.5	325.2	330.6
30 Kg N/ha^{-1}	62.0	60.7	128.0	135.0	361.0	356.0	414.0	416.1
30 KgN/ha^{-1} + soybean	67.0	57.8	128.1	117.6	361.3	359.8	418.8	420.7
60 Kg N/ha^{-1}	64.4	59.1	132.4	144.5	422.0	388.1	425.0	427.9
60 KgN/ha^{-1} + soybean	68.3	60.3	133.2	144.8	423.4	389.8	425.6	428.0
LSD (0.05)	NS	NS	2.91	2.04	2.88	2.03	2.25	1.56

Note: WAP = Weeks after planting; PM = Poultry manure; NS = No significant difference. Source: Author, 2023.

Table 4 presents plant height as affected by application of nutrient from varying sources in 2016 and 2017 cropping seasons. The tallest plants were obtained from plots treated with application of 60 kg N/ha^{-1} of mineral fertilizer as sole nutrient source or plus soybean (359.7) at 12 WAP in 2016 season. The smallest plant heights were obtained from the control at intervals of 6, 9 and 12 WAP. Plant height was significantly affected by application of varying nutrient sourcesat6, 9 and 12 WAP in 2014. In 2017 cropping season, application of 60 kg N/ha^{-1} of mineral fertilizer produced the tallest plant (364.3) at 12 WAP. The control gave the shortest plants height at 6, 9 and 12 WAP. The introduction of soybean did not have significant effect on plant height in both seasons.

Plant height followed a similar plant as leaf area of sorghum. Plant height of sorghum was not significantly affected by soybean intercrop in the two cropping seasons as seen in (Table 4) above. However, there was marginal improvement in plant height with soybean intercrop. This finding agrees with findings by Bavec et al. (2005) who reported that plant height of maize was significantly improved when maize was inter cropped with climbing beans.

Table 4. Effect of nutrient sources on plant height (cm^2) of sorghum.

Treatment	3WAP		6WAP		9WAP		12WAP	
	2016	2017	2016	2017	2016	2017	2016	2017
Control	17.3	15.1	78.6	76.4	177.0	187.4	230.2	234.4
Sorghum/ soybean	15.1	15.7	78.7	77.2	178.0	189.6	230.8	235.0
2.0 t/ha^{-1} PM	20.5	20.1	113.0	120.0	308.0	320.0	344.0	350.2
2.0 t/ha^{-1} PM + soybean	17.0	16.0	116.3	120.3	311.2	323.7	345.6	351.6
3.5 t/ha^{-1} PM	19.0	21.6	116.5	122.9	312.0	324.3	348.0	360.1
3.5 t/ha^{-1} PM + soybean	17.8	15.0	118.9	123.2	318.4	327.0	348.5	360.4
0.2 t/ha^{-1} CP	21.0	22.0	106.0	123.6	308.0	316.0	349.0	360.0
0.2 t/ha^{-1} CP+ soybean	16.6	18.0	109.4	123.7	308.2	316.2	349.9	363.1
0.4 t/ha^{-1} CP	20.1	19.8	126.0	124.0	318.5	326.0	350.0	362.3
0.4 t/ha^{-1} CP + soybean	18.5	14.0	126.7	124.2	318.7	326.4	351.4	362.7
30 Kg N/ha^{-1}	20.0	21.3	112.0	114.0	309.0	311.0	354.1	361.2
30 Kg N/ha^{-1} + soybean	16.5	16.3	119.4	114.1	310.1	311.5	355.8	361.7
60 Kg N/ha^{-1}	19.8	21.6	130.0	138.0	333.0	340.0	359.7	364.0
60 Kg N/ha^{-1} + soybean	16.8	15.3	130.2	138.0	336.7	340.6	359.7	364.3
LSD (0.05)	NS	NS	8.51	3.62	3.97	1.16	3.41	5.75

Note: WAP = Weeks after planting; PM = Poultry manure; NS = No significant difference. Source: Authors, 2023.

Table 5. Effect of nutrient sources on panicle length and yield of sorghum.

Treatment	Yield (kg/ha)		Panicle length (cm)	
	2016	2017	2016	2017
Control	372.7	367.0	27.0	26.1
Sorghum/soybean	373.0	367.7	27.0	26.4
2.0 t/ha PM	387.1	430.0	26.2	27.0
2.0 t/ha PM + soybean	386.3	438.3	27.2	27.6
3.5 t/ha PM	410.7	501.1	27.0	28.8
3.5 t/ha PM + soybean	415.6	508.9	27.9	28.8
0.2 t/ha CP	387.0	483.7	28.0	30.0
0.2 t/ha CP + soybean	481.3	490.6	30.1	30.2
0.4 t/ha CP	633.0	693.0	30.0	33.0
0.4 t/ha CP + soybean	634.3	694.7	30.4	33.0
30 Kg N/ha	1016.1	1112.0	30.4	33.1
30 Kg N/ha+ soybean	1016.5	1116.6	30.4	33.3
60 Kg N/ha	1035.0	1134.8	30.6	30.7
60 Kg N/ha+ soybean	1035.7	1138.4	30.6	30.7
LSD (0.05)	13.11	8.58	NS	NS

Source: Authors, 2023.

The panicle length of sorghum was not significantly affected by application fertilizer from varying sources even though there were marginal differences in panicle length with respect to the levels fertilizer and/or manure treatments (Table 5). Sole application of NPK fertilizer at 60 kg N/ha^{-1} or in soybean mixture gave the longest panicle length (30.6 cm) in 2016 season. The shortest panicle length was (26.2) obtained from the application of poultry manure at 2.0 t/ha. Similarly, there was no significant difference in panicle length with respect to manure or fertilizer treatments. Unlike in 2016 season, panicle length was marginally increased with increasing levels of fertilizer or manure application. The shortest (26.1cm) was obtained from the control in the 2017 season. The application of NPK at 30 kg N/ha^{-1} in soybean mixture gave the longest panicle length (33.3 cm).

Grain yield of sorghum was significantly affected by application of fertilizer or manure in both seasons (Table 5). The highest grain yield was obtained from application of NPK fertilizer at 60 kg N/ha in soybean mixture (1035.7 kg/ha^{-1}). The lowest grain yield was obtained from control (372.7 kg/ha^{-1}). There was no significant difference in panicle length with soybean mixture and varying levels of fertilizer or manure. Similar trend was observed in the 2017 season even though the highest grain yield was obtained from sole application of NPK at 60 kg N/ha^{-1}. Soybean in the sorghum mixture might have enhanced efficient utilization of soil nutrients and consequently higher yield. This finding has been reported by Olufajo (1992); Agbeje et al. (2002) and Mbah et al. (2007). This trend did not agree with the findings of Mouneke & Okpara (2007) who reported a reduction in grain yield under inter crop over sole cropping. This might have been due competition over available nutrients (especially phosphorus and potassium) and soil possible moisture.

4. Conclusions

Organic and inorganic amendments in combination with legume component improve growth and yield parameters of sorghum. Also, sorghum planted in mixture with soybeans and treated with organic and inorganic soil amendments, marginally increased, leaf area, plant height and grain yield.

The higher values of growth and yield parameters where various soil nutrients sources were applied, shows that integrated nutrient management is effective in enhancing the growth and yield of sorghum. Thus the use of inorganic fertilizers can actually be minimized by incorporating soybean and compost manure for sustainable crop production.

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6. Auhors' Contributions

T. S. Ter: conceptualized the trial, source for all farm inputs and wrote the article. *J. T. Maga*: was responsible for crop data collection and performed crop data analysis. *B.C. Anjembe*: carried out laboratory soil analysis and proofread the article Describe each author's contributions to the study.

7. Conflicts of Interest

All the authors have read and approved that the article be forwarded to Brazilian Journal of Science for publication.

8. Ethics Approval

Not applicable.

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