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GROWTH PERFORMANCE OF SORGHUM (*SORGHUM BICOLOR* L.) AS INFLUENCED BY LEGUMES INCORPORATION AND NITROGEN APPLICATION IN SUDAN SAVANNA OF NIGERIA

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ABSTRACT

Soil fertility improvement creates the environment for plant to optimally express itself in growth and development, and subsequently higher yield. The study was set up to determine the influence of incorporated legumes and nitrogen on growth and development of sorghum (*Sorghum bicolor* L.). Field experiments were carried out in the wet seasons of 2015 and 2016 at the Research Farm of Federal University Dutsin-Ma, Nigeria, The treatments consisted of four levels of N (0, 30, 60 and 90kg N ha $^{-1}$), and four legumes (Lablab (*Lablab purpureus*), Mucuna (*Mucuna pruriens*), Soybean (*Glycine max* L. Merrill), and Cowpea (*Vigna unguiculata* L.)) and no legume. SAMSORG 40 variety was used in this experiment. The experiment was laid out in a randomized complete block design and replicated three times. Nitrogen application significantly (P<0.05) increased plant height, number of leaves, total dry weight, leaf-area index and crop growth rate. Fertilization of sorghum with 60kg N ha^{-1} showed marked increases in growth parameters measured. Application of 60kg N ha^{-1} was found to be sufficient for remarkable growth and development of sorghum in study area. Incorporation of lablab, mucuna, soybean and cowpea significantly (P<0.05) influenced sorghum growth and development. However, there was no significant difference among plots that received no legume and legume incorporated plots on number of leaves, leaf area index and crop growth rate with exception of plots with incorporated mucuna that gave lowest values for these parameters. Incorporated lablab and cowpea produced better performance on sorghum plant height and total dry matter.

***Keywords*:** Incorporation, Legume, Nitrogen, Sorghum. Growth

INTRODUCTION

Sorghum (*Sorghum bicolor* L.) is one of the major cereals grown in Sudan and Guinea Savanna zones of Nigeria. The estimated annual world total output of sorghum in 2016 was 63.9 million metric tonnes (FAO, 2018). World cereal production in 2016 showed that sorghum is second most important cereal in Nigeria after maize. Importantly, Nigeria had the highest production in Africa and accounted for 6.94 million metric tonnes, which is barely 10.9% of the world production figure (FAO, 2018). Andrew (1972) reported that sorghum serves as regular food for most of Nigerians living in the Sudan and Guinea savanna zones. It is used in farming communities in making beer and malt and its stem is used for fencing and making of temporary buildings (Miko and Menga, 2008). The sorghum straws can be used as fodder, bedding, building materials and fuel. The young stems and leaves are useful as forage for ruminants and the grains can be used to produce livestock feed. Sorghum is produced for grain, forage, syrup, and sugar (Musa *et al*., 2012). Despite the glowing potential of Nigerian savanna zone for sorghum production, average yield per hectare is still very low. According to FAO (2018), the estimated sorghum yield per hectare in 2016 is 11931 hectograms per hectare (1193.1kg ha^{-1}).

Nigerian savanna soils hardly sustain worthwhile crop production without adopting a strategy of improving their fertility status through either organic or inorganic fertilizer addition. Sustainable crop production is best achieved through organic matter input which is easily achieved through legume incorporation to maintain or build up soil fertility. Therefore, appropriate technology must put in place to ameliorate poor soil fertility challenges facing savanna soils through legume-cereal cropping system. Green manure utilizes legumes which fix nitrogen from the atmosphere and when such legumes are ploughed in, they add both organic matter and N to the soil and fertilize it (Tothill, 1986). The succulent stage of the legumes enhances easy decomposition and mineralization. Organic matter is the major factor in soil fertility and productivity. Soil organic matter is an important regulator of numerous environmental constraints to crop productivity (Woomer *et al*., 1994). Incorporated legumes have ability to improve physical, biological and chemical properties of soil. Thus, this study aimed at improving these properties for increased sorghum production. Incorporation of crop residues was useful to the soil in terms of increased soil organic concentration (SOC) that is not only beneficial to soil but also helps in a sequestration of carbon from atmospheric carbon dioxide (Ogunwole *et al*., 2010).

Nitrogen is known to be the major constraint to increased sorghum production in Nigerian savanna especially Sudan savanna which is characterized by low soil total nitrogen and soil organic matter. Nitrogen is the most limiting nutrient under continued cropping and the major constraint to increased sorghum production in the Savanna zone of Nigeria (Bagayoko *et al*., 2000). Application of inorganic fertilizers as nitrogen source is well appreciated by farmers but their usage is constrained by fertilizer high cost, poor distribution, adulteration, low subsidy, scarce financial resources and inadequate credit facilities (Adesoji *et al*. 2013). As such, these factors have often limited its actual use of inorganic fertilizers by farmers in Nigeria. It should be noted that efficient use of mineral fertilizers ensures high crop yields but their long time use causes ill-effects like multi-nutrient deficiency, environmental pollution, decline in soil organic matter and inhibition of soil natural biological activity that facilitates the storing of carbon (Adesoji, 2015). In view of the foregoing, it is therefore necessary to adopt a legume based cropping system that is capable of maintaining or building up soil fertility for increased sorghum production. Therefore, the objective of this study is to evaluate the influence of incorporated legumes and nitrogen on growth performance of sorghum.

MATERIALS AND METHODS

Experimental Site and Soil Characteristics

The research was conducted in the wet seasons of 2015 and 2016 at the Research Farm of Federal University Dutsin-Ma, at Badole (Longitude 07^{0}29'29" E and Latitude 12^{0}27'18" N) with altitude of 605 m in the Sudan savanna ecological zone of Nigeria. The annual rainfall for the duration of the study was 582 and 684.9mmfor 2015 and 2016, respectively. The physico-chemical parameters of the top soil (0-30cm depth) of the experiment site was collected before planting in 2015 as determined by standard procedures is presented in Table 1

Treatments and Experimental Design

The treatments consisted of four levels of N (0, 30, 60 and 90kg N ha $^{-1}$), and four legumes (Lablab (*Lablab purpureus*), Mucuna (*Mucuna pruriens*), Soybean (*Glycine max* L. Merrill), and Cowpea (*Vigna unguiculata* L.)) and no legume. SAMSORG 40 variety was used in this experiment. The experiment was laid out in a randomized complete block design with factorial combinations of nitrogen levels and various legumes (Treatments consisted of a 5x4 factorial arrangement in a randomized complete block design). The experiment was replicated three times. The gross plot size was 5m x 3 m (15 m^{2}) and the net plot was 5m x 1.5m (7.5m^{2}).

Table 1: Physico-chemical characteristics of soil experimental site during rainy season of 2015

Soil Characteristics	Value
Particle size (g/kg)	
Clay	62
Silt	74
Sand	864
Textural class	Loamy Sand
Chemical property	
pH (0.01MCacl$_2$; 1:2.5w/v)	4.65
pH in H_2O	4.76
Organic carbon (g kg^{-1})	2.7
Total nitrogen (g kg^{-1})	0.4
Available phosphorus(mg kg^{-1})	6.14
Exchangeable base (cmol kg^{-1})	
Ca	4.84
Mg	1.17
K	0.26
Na	0.62
CEC	7.54

Crop Management Practices

Sorghum seeds, 5-7 seeds per hole were sowed at a spacing of 50 cm on the ridges of 75 cm spacing. After two weeks of sowing, the sorghum seedlings were thinned to two seedlings per stand. The legumes were planted sorghum seedlings was thinned to two seedlings per stand at two weeks after sowing. The legumes were planted simultaneously with sorghum at a space of 16.7cm from the sorghum stands for lablab, mucuna and cowpea while soybean was panted drilled in between the sorghum stands. The legumes were incorporated at seven weeks after sowing during earthen-up cultural practice. The experimental plot consisted of four (4) ridges of 3 m apart.

Application of nitrogen fertilizer as urea (46%N) to the sorghum plants was done at 2 and 6 weeks after sowing (WAS) according to the treatment. Basal applications of 30 kg of P_2O_5, and 30 kg of K_2O were done at sowing. Weeding was done at 3, 6 and 9WAS using hoe.

Data Collection

Data on growth parameters were taken on number of leaves, plant height, leaf-area index (LAI), total dry matter per plant and crop growth rate (CGR). Samplings were done at 9 and 12 weeks after sowing (WAS) from five randomly selected plants in each net plot. Plant height of each of the randomly tagged plants of sorghum was measured using a meter rule from the ground level to the tip of the topmost leaf but during reproductive stage, the height was measured from the ground level to the tip of the panicle. Number of leaves per plant was obtained by counting the number of leaves from randomly tagged plants from net plot and average number was recorded per plant. Data on total dry matter per plant were collected from three randomly selected plants from each plot (border rows). The sample were oven dried at a temperature of 70ºC to a constant weight and weighed using a top loading Meltler-P 1210 weighing balance and the mean weight was recorded as total dry matter (g) per plant. The mean dry weight was used to calculate crop growth rate (CGR) using formula described by Watson (1952) and Radford (1967) as follows:

$$\text{Mean CGR} = \frac{W_2 - W_1}{T_2 - T_1} \cdot \frac{1}{GA}$$

Where, W_2 and W_1 are dry weight in grammes (g) per plant at times T_2 and T_1 in weeks, respectively. GA is the ground area. The unit of measurement is g m^{-2} wk^{-1}. Leaf area was calculated by multiplying the length of the leaf by its width and a factor of 0.75 as described by Lazarov (1965). Leaf area index was calculated as the ratio of leaf area to the area of ground cover at 9 and 12WAS as described by Watson (1947 and 1952) using the following formula,

$$\text{LAI} = \frac{\text{Total leaf area per plant x 0.75 (cm}^2)}{\text{Area of ground covered per plant (cm}^2)}$$

Statistical Analysis

Data obtained were subjected to statistical analysis of variance (ANOVA) to test for significance of difference among means as described by Gomez and Gomez (1984) using SAS package version 9.0 of statistical analysis (SAS, 2002) and the differences among treatment means were separated using Duncan's Multiple Range Test (DMRT) (Duncan, 1955) at 5% level of probability.

RESULTS

Incorporation of lablab, mucuna, soybean and cowpea into soil after seven weeks of growth with sorghum significantly ($P<0.05$) influenced sorghum number of leaves per plant at 9 and 12WAS of the two years of study and combined (Table 2) but this was not significantly different from the plots that received no legume incorporation, and incorporation of mucuna gave significantly lowest number of leaves per plant.

Nitrogen fertilization significantly ($P<0.05$) increased number of leaves per plant at both 9 and 12WAS in 2015 and 2016 and combined (Table 2) where there was no significant difference among nitrogen rates but no nitrogen addition plots produced the significantly lowest number of leaves. Application of 30kg N ha^{-1} at 9WAS and 60kg N ha^{-1} at 12WAS in both years and combined produced the significantly highest number of leaves. In combined means, application of 30kg N ha^{-1}at 9 WAS significantly ($P<0.05$) produced higher number of leaves per plant (10.2 leaves per plant) than the control (8.9 leaves per plant) and 60kg N ha^{-1} at 12WAS significantly produced higher number of leaves per plant (10.6 leaves per plant) than the control (9.6 leaves per plant).

Table 2: Influence of incorporated legumes and nitrogen on number of leaves $plant^{-1}$ of sorghum in 2015, 2016 and combined.

	Number of leaves $plant^{-1}$					
	9WAS			12WAS		
Treatment	2015	2016	Combined	2015	2016	Combined
Incorporated Legume (L)						
No Legume	9.1a	10.3bc	9.7a	10.8a	10.7a	10.7a
Lablab	9.3a	10.9ab	10.1a	10.1a	10.7a	10.4ab
Mucuna	7.7b	10.0c	8.9b	9.3b	9.4b	9.5c
Soybean	8.7a	11.2a	9.9a	10.3a	10.3a	10.4ab
Cowpea	9.2a	10.6abc	10.0a	10.2a	9.7b	10.0b
SE±	0.33	0.24	0.25	0.24	0.20	0.17
Nitrogen(N) Kg ha^{-1}						
0	7.2b	10.6b	8.9b	9.1b	10.2ab	9.6c
30	8.9a	11.4a	10.2a	10.3a	10.0b	10.1b
60	9.5a	10.1b	10.0a	10.8a	10.3ab	10.6a
90	9.5a	10.5b	10.0a	10.4a	10.6a	10.5ab
SE±	0.29	0.19	0.22	0.22	0.16	0.15

WAS: Weeks after sowing. Means followed by the same letter(s) within the same column and treatment are not significantly different at 5% level of probability using DMRT.

Legumes incorporation significantly ($P<0.05$) influenced sorghum plant height at 9 and 12WAS of the two years of study and combined (Table 3). At 9WAS, there was not significantly different between legume incorporation and plots that received no legume incorporation on plant height and incorporation of mucuna gave significantly lowest number of leaves per plant. However at 12WAS, no legume plots produced significantly shortest plant height which was at par with mucuna incorporation.

Nitrogen fertilization significantly ($P<0.05$) increased sorghum plant height at both 9 and 12WAS in 2015 and 2016 and combined except at 12WAS combined (Table 3). There was no significant difference among nitrogen rates on plant height at 9WAS in 2015 while application of 60 and 90kg N ha^{-1} at 9WAS of 2016 significantly reduced plant height. Application of 60kg N ha^{-1} produced significantly tallest plants. In combined means, there was no significant difference among the N levels at 9WAS and application of 60kg N ha^{-1} at 12 WAS produced significantly taller plants (168.1cm) than plants (152.9cm) in no nitrogen addition plots.

Table 3: Influence of incorporated legumes and nitrogen on plant height plant^{-1}(cm) of sorghum in 2015, 2016 and combined.

	Plant height plant^{-1}(cm)					
	9WAS			12WAS		
Treatment	2015	2016	Combined	2015	2016	Combined
Incorporated Legume (L)						
No Legume	155.2ab	135.7ab	146.6a	154.8c	150.9	153.5c
Lablab	153.4ab	140.1a	151.5a	170.2ab	156.4	165.0a
Mucuna	134.2c	124.6b	131.5b	159.0bc	147.1	155.2bc
Soybean	147.0b	143.1a	147.8a	165.8abc	156.6	162.3ab
Cowpea	156.8a	124.6b	148.1a	176.0a	156.6	166.3a
SE±	3.10	4.56	3.15	4.12	3.16	2.59
Nitrogen(N) Kg ha^{-1}						
0	133.4b	149.1a	141.3	149.6c	156.2ab	152.9b
30	151.2a	146.2a	148.7	162.2b	150.9b	156.5b
60	156.5a	132.9b	144.7	180.0a	156.1ab	168.1a
90	156.1a	135.2b	145.7	168.8b	159.8a	164.3a
SE±	2.77	2.61	2.81	3.69	2.16	2.31

WAS: Weeks after sowing. Means followed by the same letter(s) within the same column and treatment are not significantly different at 5% level of probability using DMRT.

Incorporation of legumes significantly ($P<0.05$) influenced leaf area index (LAI) of sorghum at 9 and 12WAS of the two years of study and combined (Table 4) but this was not significantly different from the plots that received no legume incorporation.

Application of nitrogen significantly ($P<0.05$) increased leaf area index at both 9 and 12WAS in 2015 and (Table 4) where there was no significant difference among nitrogen rates but no nitrogen addition plots produced the significantly smallest sorghum leaf area index. Nitrogen addition at both 9 and 12WAS in 2016 was not significant on leaf area index. The largest leaf area index was produced with application of 30kg N ha^{-1} in both years and combined. In combined means at 9WAS and 12WAS, application of 30kg N ha^{-1} produced significantly ($P<0.05$) larger leaf area index (2.3 and 2.6, respectively) than the control (1.96 and 2.55, respectively).

Table 4: Influence of incorporated legumes and nitrogen on leaf area index (LAI) of sorghum in 2015, 2016 and combined.

	Leaf area index (LAI)					
	9WAS			12WAS		
Treatment	2015	2016	Combined	2015	2016	Combined
Incorporated Legume (L)						
No Legume	2.5a	2.3a	2.4a	2.3a	3.1a	2.8a
Lablab	2.4ab	2.4ab	2.4a	2.3a	3.2a	2.7a
Mucuna	1.7d	2.0b	1.9b	2.1b	2.6b	2.3b
Soybean	2.1c	2.5a	2.3a	2.1b	3.2a	2.6a
Cowpea	2.2bc	2.2ab	2.2a	2.3a	3.2a	2.8a
SE±	0.09	0.12	0.08	0.06	0.09	0.07
Nitrogen(N) Kg ha^{-1}						
0	1.76c	2.2	1.96b	1.94c	3.2	2.55b
30	2.21b	2.4	2.30a	2.17b	3.0	2.60ab
60	2.38ab	2.2	2.30a	2.27b	3.1	2.69ab
90	2.46a	2.4	2.44a	2.45a	3.1	2.76a
SE±	0.078	0.11	0.725	0.051	0.07	0.058

WAS: Weeks after sowing. Means followed by the same letter(s) within the same column and treatment are not significantly different at 5% level of probability using DMRT.

Incorporation of legumes into soil after seven weeks of growth significantly (P<0.05) influenced sorghum total dry matter per plant at both 9 and 12WAS in 2015 and 2016 and combined except at 9WAS in 2016 (Table5). Incorporation of lablab and cowpea produced significantly highest total dry matter per plant.

Nitrogen application significantly (P<0.05) increased total dry matter per plant of sorghum at 9 and 12WAS of the two years of study and combined (Table 5). Application of 60kg N ha^{-1} significantly increased total dry matter per plant but at par with application of 90kg N ha^{-1}. In combined means at 9WAS and 12WAS, application of 60kg N ha^{-1} significantly produced higher total dry matter (90.9g and 155.7g, respectively) than the total dry matter (49.7g and 106.2g, respectively) of the control.

Legumes incorporation significantly (P<0.05) influenced crop growth rate of sorghum at 2016 only (Table 6). Incorporation of mucuna significantly reduced crop growth of sorghum while there was no significant difference among remaining incorporated legumes and no legume plots on crop growth rate.

Nitrogen application significantly (P<0.05) increased crop growth rate at 2015 and combined (Table 6). Application of 90kg N ha^{-1} significantly increased crop growth rate of sorghum while the remaining rates of nitrogen were statistically similar. In combined means, application of 30kg N ha^{-1} significantly (P<0.05) produced higher crop growth rate (21.8 g m^{-2} wk^{-1}) than the control (18.8 g m^{-2} wk^{-1}).

Table 5: Influence of incorporated legumes and nitrogen on total dry matter $plant^{-1}$ of sorghum in 2015, 2016 and combined.

	Total dry matter $plant^{-1}$					
	9WAS			12WAS		
Treatment	2015	2016	Combined	2015	2016	Combined
Incorporated Legume (L)						
No Legume	111.5b	19.9	65.7bc	211.7b	54.2a	133.7ab
Lablab	146.3a	26.6	86.5a	261.2a	52.6a	159.3a
Mucuna	86.7b	20.4	53.1c	197.4b	31.6b	118.1b
Soybean	104.9b	24.4	64.7bc	199.5b	50.1a	128.5ab
Cowpea	138.2a	25.6	81.9ab	230.9ab	55.3a	146.6ab
SE±	8.58	2.67	6.6	13.45	3.97	10.3
Nitrogen(N) Kg ha^{-1}						
0	71.9d	27.5a	49.7c	150.9c	61.6a	106.2b
30	107.7c	20.5b	64.1bc	212.7b	46.5c	129.6b
60	159.7a	22.0ab	90.9a	254.5a	56.8ab	155.7a
90	130.8b	22.8ab	76.8ab	262.4a	52.3bc	157.4a
SE±	7.67	2.0	5.90	12.03	2.54	9.18

WAS: Weeks after sowing. Means followed by the same letter(s) within the same column and treatment are not significantly different at 5% level of probability using DMRT

Table 6: Influence of incorporated legumes and nitrogen on crop growth rate (CGR) of sorghum in 2015, 2016 and combined.

	Crop growth rate (CGR) 9-12WAS		
Treatment	2015	2016	Combined
Incorporated Legume (L)			
No Legume	33.4	11.4a	22.7
Lablab	38.3	8.7a	24.3
Mucuna	36.9	3.7b	21.7
Soybean	31.5	8.5a	21.3
Cowpea	30.9	9.9a	21.6
SE±	4.92	1.27	2.91
Nitrogen(N) Kg ha^{-1}			
0	26.3b	11.3	18.8b
30	35.0ab	8.7	21.8ab
60	31.6ab	11.6	21.6ab
90	43.9a	9.8	26.9a
SE±	4.4	0.97	2.6

WAS: Weeks after sowing. Means followed by the same letter(s) within the same column and treatment are not significantly different at 5% level of probability using DMRT.

DISCUSSION

The overall performance of sorghum plants was far better in 2015 than in 2016 because of even distribution of rainfall in 2015. In 2016, the rainfall in September was poor (15mm) and its distribution was unevenly. This period was a period of flowering and grain filling of the crop; hence, the crop growth performance was affected adversely which made them lower in values than that of 2015.

Increase observed in plant height and total dry weight of sorghum as a result of incorporation of lablab and cowpea could be attributed to the amount of N fixed by both legumes into the soil and amount of embedded nutrients released into soil after incorporation and subsequent decomposition and mineralization. These responses confirmed the fact that the application of green manure adds N, adds (or recycles) other nutrients, increases the organic matter content of the soil, and affects the soil physical and biological properties (Venturaand Watanabe, 1993). It should be noted that addition of organic fertilizers is more advantageous than just the release of plant nutrients to the soil but they also have positive effects like improvements in water retention, soil aeration, soil structure, cation exchange capacity (CEC) and microbial activity (Adesoji, 2015).

The similarities observed on plots that received no legume incorporation and legume incorporated plots on most of the parameters could be attributed to inability of the legumes to accumulate enough dry matter because of shading and competition from the main crop, sorghum, which was planted simultaneously with the legumes. Effectiveness of green manure depends on amount of biomass generate by the legume before incorporation. The lower the biomass, lower is the green manure that will be generated. Talgre *et al*. (2012) reported that soil fertility is especially affected by soil organic matter, which depends on biomass input to compensate mineralization and further reported that higher biomass return to the soil can increase soil organic carbon and soil total N. The reduction in sorghum growth obtained in plots that received mucuna incorporation could be attributed to unfavourable environment created by the decomposition of buried mucuna even when the main crop, sorghum was still on in the field.

Nitrogen application enhanced growth performance of sorghum as exemplified by the marked increases observed in the number of leaves, plant height, leaf area index, total dry matter and crop growth rate. These increases in growth attributes of sorghum demonstrated the key role nitrogen plays as a component of protein and nucleic acids and when it is sub-optimal, growth is reduced (Haque *et al*., 2001). The enhanced growth performance of sorghum could be attributed to importance of nitrogen as a constituent of protein and also integral component of many other compounds essential for plant growth processes including chlorophyll and many enzymes (Onasanya *et al*., 2009). The application of nitrogen fertilizer was reported to enhance the growth of sweet sorghum as observed in the plant height, LAI, CGR, and other growth indices (Olugbemi and Abayomi, 2016). Almodares *et al*. (2006) reported that the effect of nitrogen fertilizer on leaf area, leaf dry weight, stem dry weight and total dry weight at different growth stages was significant at 1% level and the highest measurements were obtained with application of 180kg urea ha^{-1} and the lowest at control (0kg urea ha^{-1}). It has been reported that plant height increased progressively up to harvest over with the application of nitrogen fertilizers (Bilal *et al*., 2000). Singh *et al*. (2014) reported that leaf area index of sweet sorghum increased with increase in N fertilizer application. The plots that received nitrogen application produced bigger and more robust sorghum plants than plots without nitrogen addition. The plots without nitrogen application produced short and stunted sorghum plants with light yellowish green leaves and were slow in growth.

CONCLUSION

Improving soil fertility through the addition of plant nutrient is a crucial factor for enhanced crop growth and better biomass production necessary for increased food crop production. Based on the results obtained from this study, it can be concluded that application of nitrogen significantly increased number of leaves, plant height, leaf area index, total dry matter and crop growth rate of sorghum. Application of 60kg N ha^{-1} seems to be the best rate for maximum sorghum growth and development in the study area. Incorporation of lablab, mucuna, soybean and cowpea significantly influenced growth parameters studied. However, there was no significant difference between no legume and legume incorporation on number of leaves, leaf area index and crop growth rate of sorghum with exception of incorporated mucuna that gave lowest values for these parameters. Lablab and cowpea incorporation significantly increased plant height and total dry matter.

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