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Integrating Nitrogen Fertilizer and Green Manure for Sorghum Production (*Sorghum bicolor* L. Moench) on Striga (*Striga hermonthica* Del. Benth) Infested Field at Katsina in the Sudan Savanna of Nigeria

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Abstract: *A field experiment was conducted during the wet seasons of 2013 and 2014 at the College experimental Farm of Hassan Usman Katsina Polytechnic, Katsina (12 56 "N, 7 36" E; 465m above sea level) in the Sudan savanna of Nigeria, to evaluate the effects of integrating nitrogen fertilizer and organic manures on sorghum grown on Striga- infested field. The treatments consisted of four levels of organic manure Cassia obtusifolia green manure at 0, 7.5 and 15t ha^{-1} and cow dung 10 t ha^{-1} and three levels of nitrogen (0, 40 and 80 kg N ha^{-1}) and The experiment was laid in a split-plot design and replicated three times; with nitrogen assigned to the main plot, and organic manure were assigned to the sub-plots. The experimental sites were inoculated to boost Striga level. Application of green manure at 15 t ha^{-1} gave statistically comparable plant height, leaf area index and shoot dry weight to 10 t ha^{-1} cow dung. Significantly larger LAI was obtained by the use of cow dung at 10 and 15t ha^{-1} green manure when compared to the untreated control. Striga infestation to sorghum crop was slightly higher in untreated plots than the treated. Shoot dwt increased with green manure rate from 0-15 t ha^{-1}. Sorghum grain yield increased with increase in manure rates from 0-15 t ha^{-1}. The grain yield obtained in 2014, by green manure at 15 t ha^{-1} significantly outweighed that of cow dung. Nitrogen application at 80 kg N ha^{-1} reduced number of infested sorghum plants with Striga compared to the untreated control. Plant height, number of leaves, LAI, shoot dry weight and grain yield were significantly recorded by 80 kg N ha^{-1} compared to zero and 40 kg N ha^{-1}. In conclusion, application of 10 t ha^{-1} cow dung and 15t ha^{-1}green manure resulted statistically in corroborate plant height, LAI and shoot dry weight. The highest values of grain yield of sorghum was recorded by 15t ha^{-1} green manure under Striga pressure and infestations. The use of 80 kg N ha^{-1} gave the highest values of plant height, number of leaves plant^{-1}, shoot dry weight and sorghum yield with reduced Striga infestation to sorghum compared to all other treatments.*

Key words: *Integration, Green manure, Nitrogen, Sorghum, Striga, field*

INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench) is the fifth most important cereal crop in the world being surpassed only by rice (*Oryza sativa* L.), wheat (*Triticum aestivum* L.), barley (*Hordeum vulgare* L.) and maize (*Zea mays* L.) (Abunyewa, 2008). The world Sorghum grain production is between 55 and 70 million tones per annum on 40 and 45 million hectares of land (Samuel *et al.,* 2013). The world average yield was put at 1.4t (Samuel *et al.,* 2013). In 2010, the USA was the world largest annual producer of sorghum with 8.8t, followed by India with 7.0t, Mexico with 6.9t, Nigeria with 4.8t and Argentina with 3.6t (CGIAR, 2013). Its unique adaptation to environmental extremes occasioned by abiotic and biotic stresses and significance of diets in the poor people in the semi-arid tropics, where drought is responsible for the frequent failure of other crops (Godharle *et al*., 2010). Nigeria is the fourth largest producer of sorghum in the world, with an annual production in excess of 4 million metric tones. In the semi-arid tropics sorghum is used in various ways. It is a principal source of nutrition for millions of people and provides a major source of energy to human diets in Africa and much of Asia. Sorghum grain is primarily used for human consumption and as a staple food in the diet of many people in countries of the world in these regions (Anon., 2015). The vegetative parts of the crops are used as animal feed. Sorghum serves as a major raw material in the brewing industry. Some varieties of sorghum can be malted to produce nutritious food stuff for infants, as well as in bakery products.

Despite the importance of sorghum as a food crop and industrial material the yields of the crop on farmers level remains low, 1.5 t ha^{-1} compared to yields of up to 4.6 t ha^{-1} from research fields. Soil degradation, which is brought about by loss of organic matter accompanying continuous cropping became aggravated when inorganic fertilizer was applied repeatedly (Howard, *et al.*,2001). This is because crop responses to applied fertilizer depend on soil organic matter content which also contains trace elements which are absent in organic fertilizers. Parasitic weeds such as *Striga* establish preferentially on poor soils and fields which have been exhausted by continuous cropping (Vogt *et al.*,1991). Most *Striga* infested areas are characterized by agricultural production systems that witness low crop productivity. The use of inorganic nitrogen (Mumera and Bello,1993; Pieterse,1996) and organic fertilizer (Ogborn, 1984; Bello,1987) has been reported to reduce *Striga* infestation. Depending on level of infestation, *Striga hermonthica* causes 20-100 % yield reduction in Sorghum. Smaling *et al.*(1992) demonstrated the need for integrated nutrient management, especially in areas of low soil fertility where farmers cannot afford to rely on mineral fertilizer alone. Integrated soil fertility management systems can reduce the inorganic fertilizer requirement, and at the same time increase the efficiency of the added input (Lee, 2007). Some weed plants have the potential to provide the nutrients. When we compare the available nutrients with the synthetic fertilizers and their market values, the use of weeds to improve soil fertility will reduce the input cost of crop production. Exploiting available natural resources is a better way of utilizing poor and marginal soils to get better yield.

Some members of leguminoseae commonly are most common used for green manuring. Where green manure was properly managed and incorporated into the soil, substantial amounts of nitrogen and other nutrients as well as organic matter were added to the soil and this improved soil physical, chemical and biological properties in favour of crop plants (Francis *et al.,* 1986; Hullungale, 1988 and Tejeda *et al.*, 2004). Suryawanshi *et al.*(2011) reported that green manure with *Cassia obtusifolia* produced higher total dry matter (1154kg ha^{-1}) in maize than *Parthenium hytrophorus.* The phosphorus and potassium content were also higher in *Cassia obtusifolia*. *Cassia obtusifolia* contains more nitrogen, phosphorus and potassium than most other weeds. However, its assimilation rate was less compared to the other weeds. Although much work has been conducted on sorghum, there is little work in the area of green manuring especially with cassia obtusifolia under high striga infestation.

Objectives of the study

In view of the importance of Sorghum and the deleterious effect of striga infestation in Northern Nigeria as well as benefit of green manuring with legumes, this investigation was conducted with the following objectives:

a. To investigate the influence of *Cassia obtusifolia* green manure on *Striga and* growth and yield of two sorghum varieties grown on a *Striga*- infested field and compare with cow dung at Katsina
b. To investigate the influence of nitrogen on *Striga* and growth and yield of two sorghum varieties grown on a *Striga*- infested field at Katsina.

MATERIAL AND METHODS

3.1 Experimental Sites

Two field trials were conducted during the wet seasons of 2013 and 2014 to investigate the effects of nitrogen and green manuring with *Cassia obtusifolia* L. on two varieties of sorghum grown on a *Striga*- infested field at the Experimental farm of Hassan Usman Katsina Polytechnic, Katsina (Lat. 12 56 "N, 7 36" E; 465m above sea level) in the Sudan Savanna zone of Nigeria. Details of meteorological data in the two seasons were recorded and are presented in Appendices 1-2. Prior to land preparation in each season, soil samples were collected randomly from the experimental site at 0-30cm depth using a soil auger. The soil samples were bulked, air dried, ground and sieved using a 2mm wire mesh before being subjected to laboratory analysis for physical and chemical properties using standard procedures as described by Black (1965). The results of analysis are presented in Table 1. The chemical properties of *Cassia obtusifolia* green manure and cow dung used were determined by the standard procedure above and are presented in Tables 1&2.

The Experiment consisted of two sorghum varieties (SAMSORG-40 and SAMSORG-41) (Anon,2015). Four levels of organic manure (*Cassia* green manure at 0, 7.5 and 15t ha^{-1} and cow dung at 10t ha^{-1}) and three nitrogen levels (0, 40 and 80kgNha^{-1}). The experiment was laid out in a split plot design, with nitrogen levels assigned to main plots and factorial combinations of organic manure levels and variety assigned to the sub-plots. The treatments were replicated thrice. The gross plot size consisted of six ridges,75cm apart, each 3m long giving an area of 13.5 m^2, while the net plot consisted of the two inner ridges, giving an area of 4.5 m^2.

The experimental site which was already striga infested was further inoculated with *Striga* seeds, a day to sowing. This was done by using 25g of *Striga* seeds per 1kg of fine sand to inoculate each field. The inoculants was uniformly applied by broadcasting on ridges prior to manure application. This was done to boost the *Striga* level of the infested field

Dressed seed of Sorghum was sown on June 20th and 15th in 2013 and 2014, respectively, at 4 - 5 seeds per hill at intrar row spacing of 30cm and seedlings were thinned to two plants per stand at 3 weeks after sowing (WAS).

Nitrogen in the form of Urea (46%N) was applied in two doses according to treatment at 3 and 6 W A S by side dressing. Pre- plant (Paraquat) and hoe weeding at 3&6 WAS were adopted to control weeds.

The crop was harvested when the panicles had attained physiological maturity (Eastin *et al.,* 1973).

Data collected included Plant height, number of leaves, leaf area index, shoot dry weight, *Striga* infestation, 100 seed- weight and grain yield, Striga shoot count and number of sorghum plants infested with Striga stands per $18m^2$.

The data collected were subjected to analysis of variance to test the significance of differences between treatment means using the F-test as described by Snedecor and Cochran (1967). The treatment means were compared using the Duncan Multiple Range Test (Duncan, 1955).

RESULTS AND DISCUSSION

Table 1. The physical and chemical properties of soil of the experimental site in both seasons show that the soil was sandy loam and carbon and total nitrogen contents were generally low (Table 1). Available P was low in 2013 and moderate in 2014.The exchangeable bases such as , K, Mg and Ca were relatively higher in 2014 than 2013 while the reverse was the true with CEC. Cow dung analysis revealed that N and K were slightly higher in 2014 than in 2013, while the reverse was true for P (Table 2).

Analysis for the chemical composition of *Cassia obtusifolia* green manure revealed that the N, P and K contents were slightly higher in 2014 than in 2013 (Table 3).

Post harvest analysis of bulked soil samples from the 3 replicates against each treatment are presented in Table 4. In both years residual N and P levels increased from 0.26-0.5% and 14.98- 15.77 mg/kg P in 2013 and 0.32- 0.66 % N and 13.29- 20.33mg/kg P as green manure rate was raised from 0-10 t ha^{-1}, while exchangeable K was very low and inconsistent with increasing green manure rate in both years. However, green manure at 15 t ha^{-1} maintained a lead above 10 t ha^{-1} of manure with respect to the three major nutrients in both years, except with K in 2013. Similarly, the three residual nutrients in the soil tended to increase with N application rate, except total N and available P in 2013 and exchangeable K in 2014.

Table 5 and 6 show the effects of nitrogen and organic manure on the growth, yield and yield components of sorghum at Katsina in 2013 and 2014 respectively. In both years, Green manure produced the tallest plants, heavier shoot dry weight and yield except with the highest yield recorded by cow dung in 2014. Taller plants were as a result of increased green manure from 0- 15 t ha^{-1} and cow dung at 10 t ha^{-1}in both sites indicating that increasing green manure and cow dung at the given rates had pronounced effect on vegetative growth of sorghum plants. This was obviously as a result of improvement of soil structures, textures and nutrients content following the application. This observation is in agreement with a report by Benefeldt (2002), who pointed to the potential uses of poultry manure as fertilizer and for soil amendments. Similarly, Mahadi (2011) reported that application of 8 and 12 t ha^{-1} of cow dung promoted plant height of maize. The lower yield of sorghum was obtained from the untreated control. On the other hand, no significant effect was recorded by organic manure treatments on the number of leaves of sorghum and *striga* infestation. With nitrogen treatments, the highest values of number of leaves, shoot dry weight and yield was obtained by the application of 80 kg N ha^{-1} in 2013 and with plant height in 2014 this was statistically similar with the number of leaves and *striga* infestation recorded by the use of 40 kg N ha^{-1}. The *striga* infestation was significantly recorded from the untreated control, while application of 80 kg N ha^{-1} reduced *striga* infestation significantly across the year under study. The highest sorghum grain yield was recorded by the use of *Cassia obtusifolia* green manure at 15 t ha^{-1} across all the treatments and periods under study. Sorghum grain yield increased with green manure rates and by the cow dung treatment. This was because nutrients in the manure were possibly released toward pre and post-anthesis stages. Nutrients such as N and P are important for grain formation and yield development. The application of manure provides other essential nutrients that are limiting in mineral fertilizers, and this could increase grain yield of sorghum even under *Striga* pressure as observed by Parker and Riches (1993). The finding showed that *Cassia* green manure significantly increased growth and yield of sorghum, probably due to improved soil physical and chemical properties. In both years residual N and P levels increased from 0.26-0.5% and 14.98-15.77 mg/kg P in 2013 and 0.32- 0.66 % N and 13.29- 20.33mg/kg P as green manure rate was raised from 0-10 t ha^{-1}, while exchangeable K was very low and inconsistent with increasing green manure rate in both years (Table 4). Organic matter is known to improve moisture holding capacity, enhance root growth, water and nutrient uptake capability of plant. The importance of N in organic matter in improving sorghum performance has been highlighted by Arunah *et al*. (2006), who found that poultry manure was superior to the applied N in promoting yield of sorghum. *Striga* shoots were rarely recorded when higher doses of organic manures were used. The high manure level enhanced vigorous crop growth and leaf spread (LAI) (Table 10), which smothered emerged *Striga* shoots, leading to dieback. The non significant effect of the varying rates of organic manure on *Striga* shoot count in Katsina in 2014 this could lead to the insufficient amount of nitrogen to suppress the parasitic weed.

Application of nitrogen at 0-80 kg N ha^{-1} showed no significant effect on plant height and LAI in 2013. In 2014, 80 kg N ha^{-1} resulted in taller plants, more number of leaves, shoot dry weight, grain yield and with reduction *Striga* infestation to sorghum than 0-40 kg N ha^{-1}. This revealed corroborates the finding that nitrogen at 40-80 kg N ha^{-1} influences *striga* infestation as reported earlier by Lagoke *et al*. (1994) and that application of nitrogenous fertilizer reduced the severity of *striga* attack and increased yield of mentioned crop. Indeed there was a general decline in infestation with increasing N rates. These results are in agreement with the reports by Mumera and Bello (1993), who found that *Striga* infestation declined with increasing N availability. Generally, high *Striga* infestation was recorded on the untreated control compared to plots that were treated with N at the rates of 40-80 kg N ha^{-1}. An indication that nitrogen at this rate of 40-80 kg N ha^{-1} is capable of reducing *Striga* infestation. Similar report was made by Lagoke *et al*. (1994), who reported that application of certain levels of nitrogenous fertilizer reduced the severity of *Striga* and increased yield of the affected sorghum crop. They opined that increasing nitrogen rate from 0-80 kg N ha^{-1} had positive effect on vegetative growth of sorghum plants vice visa: plant height, number of leaves and shoot dwt. Non- leguminous such as sorghum, requires N application for good vegetative growth. A report indicated that maximum sorghum plant height was obtained with 100 kg N ha^{-1} (Soleimani, 2008). Furthermore, the taller plants obtained in the present investigation may be due to the adequate rainfall in the season of study as shown in Table 1. Ample moisture in the soil could have promoted the released the nutrients for crop uptake, and consequently improved the yield and yield attributes of sorghum. The low shoot dry weight of plants in the untreated control might be due to the absence or rather insufficient amount of nitrogen for crop development. This result, is in agreement with the findings by Ali (2000), who reported significant positive effect of nitrogen on fodder yield of sorghum. The least grain yield was also obtained from the untreated plots.

Table 1 : Physical and chemical characteristic of soil (0-30cm) taken from the experimental site during 2013 and 2014 wet seasons at Katsina

Soil properties	2013	2014
Physical properties		
Sand (%)	80.0	76.0
Silt (%)	6.00	8.5
Clay (%)	14.0	16.4
Textural class	Sandy loam	Sandy loam
Chemical properties		
pH in water (1:2.5).	6.35	6.45
pH in 0.01m $CaCl_2$ (1:2.5.).	5.82	5.08
Organic carbon (g/kg).	0.70	0.41
Total Nitrogen (g/kg).	0.24	0.50
Available P mg/kg	3.08	4.30
Exchangeable cation (Cmol/kg)		
K	0.12	1.23
Mg	0.91	1.52
Ca	2.00	4.03
Na	0.41	0.21
CEC (meq/100g)	6.40	5.27

Table 2 : N, P and K contents of cow dung manure used in the experiments at Katsina in 2013 and 2014 wet seasons.

Nutrients (%)	Katsina	
	2013	2014
Total N	1.70	1.85
Available P	1.56	1.43
Available K	0.65	0.70

Table 3 : N, P and K contents of *Cassia* green manure used in the experiments at Katsina in 2013 and 2014 wet seasons.

Nutrients (%)	Katsina	
	2013	2014
Total N	1.57	1.78
Available P	1.45	1.50
Available K	0.52	0.61

Table 4 Physical and chemical analysis of soil sample from the experimental location based on treatments at post harvest in Katsina 2013 and 2014.

Treatments	2013			2014		
	Nitrogen (%)	Available Phosporus. (mg/kg)	Exchangeable Potassium (meq/100g)	Nitrogen (%)	Available Phosporus. (mg/kg)	Exchangeable Potassium (meq/100g)
M_0	0.26	14.98	0.04	0.32	13.29	0.04

M_1	0.39	19.10	0.08	0.44	13.81	0.04
M_2	0.52	15.61	0.07	0.66	16.29	0.05
M_3	0.59	15.77	0.07	0.75	20.33	0.06
N_0	0.33	14.86	0.05	0.45	14.56	0.05
N_1	0.44	13.26	0.05	0.48	15.11	0.04
N_2	0.43	20.96	0.05	0.57	18.10	0.06

Table: 5 Effects of nitrogen and organic manure on the growth, yield and yield components of sorghum grain yield in 2013, wet season at Katsina.

Treatments	Plant height (cm)	Number of leaves @ 12WAS	L A I @ 12WAS	Striga infestation	Shoot dry weight (g)	Grain yield (kg ha^{-1})
0 t ha^{-1}	86.4c	11.2	2.10b	0.83	33.3b	1280d
Cow dung at 10 t ha^{-1}	136.2ab	11.5	2.38a	0.28	38.2ab	1940a
***Cassia* at 15 t ha^{-1}**	141.3a	11.7	2.25a	0.39	42.8a	1888b
SE±	4.25	0.18	0.04	0.22	2.14	17.2
Nitrogen (N).						
0 kg ha^{-1}	115.2	11.0b	2.22	0.88a	30.7c	1554c
40 kg ha^{-1}	124.7	11.6ab	2.24	0.42ab	39.7b	1644b
80 kg ha^{-1}	126.5	12.8a	2.25	0.21b	43.5a	1785a
SE±	3.90	0.20	0.02	0.42	0.61	5.59
Interactions.						
MxN	NS	NS	NS	NS	NS	*

Means followed by the same letter (s) within a column of each treatment group are not significantly different at 5% level of probability using DMRT.
1.*Cassia* = Green manure.
2.NS Not significant at 5% level of probability.
* = significant at 5% level of probability.

Table: 6 Effects of nitrogen and organic manure on the growth, yield and yield components of sorghum grain yield in 2014, wet season at Katsina.

Treatments	Plant height (cm)	Number of leaves @ 12WAS	L A I @ 12WAS	Striga infestation	Shoot dry weight (g)	Grain yield (kg ha^{-1})
0 t ha^{-1}	84.5b	11.5	2.10b	0.94	40.8b	1429d
Cow dung at 10 t ha^{-1}	118a	11.5	3.72a	0.85	50.4a	1839b
***Cassia* at 15 t ha^{-1}**	123a	11.7	3.36a	0.67	51.5a	2056a
SE±	3.26	0.18	0.16	0.16	1.98	3.45
Nitrogen (N).						
0 kg ha^{-1}	101.9b	11.0b	2.31	1.89a	38.9b	1650c
40 kg ha^{-1}	112.3ab	12.8ab	2.29	0.33b	50.8a	1745b
80 kg ha^{-1}	117.2a	13.8a	2.28	0.17b	52.5a	1861a
SE±	2.67	0.17	0.05	0.191	0.81	5.94
Interactions.						
MxN	NS	NS	NS	NS	NS	*

Means followed by the same letter (s) within a column of each treatment group are not significantly different at 5% level of probability using DMRT.
1.*Cassia* = Green manure.

2.NS Not significant at 5% level of probability.
* = significant at 5% level of probability.

CONCLUSION

Application of 15 t ha^{-1} *Cassia* green manure or 10 t ha^{-1} of cow dung ameliorated the negative impact *Striga* infestation and improved the growth and yield of sorghum under high *Striga* pressure. In the same vein, the use of 80 kg N ha^{-1} consistently suppressed *Striga* infestation and improved sorghum crop growth and yield under high *Striga* pressure.

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