



EVALUATION OF BIOLOGICAL NITROGEN FIXATION (BNF) AND GREEN MANURE POTENTIAL OF SOME FORAGE LEGUMES

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ABSTRACT

A pot experiment was conducted in 2013 rainy season at the Screen house, Faculty of Agriculture, University of Maiduguri to evaluate biological nitrogen fixation (BNF) and green manure potentials of some forage legumes. The experiment consisted of 8 forage legumes – *Mucuna pruriens white*(T2), *Stylosanthesis guianensis*(T3), *Cajanus cajan brown*(T5), *Cajanus cajan white*(T7), *Centrosema pubescens*(T9), *Lablab purpureus white*(T11), *Lablab purpureus black* (12) and *sesbania rostrata*(15). The plants were grown for six weeks, then roots and above ground fresh biomass weighed. Percent N, P, and K content were determined in the laboratory. The result showed *Mucuna*, *Sesbania*, *Cajanus cajan*, *Stylosanthesis* and *Lablab* were the top N₂-fixers with 23.88, 14.27, 13.78, 13.58 and 9.18 kg/ha respectively. Therefore, above top N-fixers were recommended for use as green manure in the cropping systems of the region.

Keyword: Biomass, BNF, Forage, Legumes

INTRODUCTION

According to plant physiologists, there are sixteen chemical elements that were proven to be necessary for the growth and reproduction of crop plants. Of these, nitrogen (N) is the single most important soil-based element for plant growth. Except for water availability, it is nitrogen that limits crop growth most frequently (Forage Information Systems-FIS, 2023; SFC- Saskatchewan Forage Council, 2008). An important effect of N on crops is increase in yield (Bashir, 2024). One kilogram (kg) of nitrogen supplied as fertilizer adds between 80 and 100 kg of dry matter to a cereal crop (Russel, 2006). N is the most expensive of the fertilizer elements and agriculture spend more money on it than on any of the known inputs. Paradoxically, N is the most abundant element in the atmosphere - natural atmospheric air being 78 % di-nitrogen (N₂) inert gas (FIS-Forage Information Systems, 2023). In the natural form, N₂ is bonded strongly and is unavailable to higher plants (Ting, 1982; Caddel *et al.*, 2017). Before N₂ is used by crop plants, it must be reduced to ammonia (NH₃), the most important compound in the ecosystem (FIS, 2023). The agricultural requirements for nitrogen need to be fulfilled by the two major sources in the world (Ladha *et al.*, 2022) :-

- Industrial N₂ fixation into fertilizers in the Haber-Bosch process, or
- Biological nitrogen fixation (BNF) in legumes.

Of the reported estimated 175 million metric tonnes of available or fixed nitrogen formed on earth each year, about 90 million tonnes (52%) are produced commercially as fertilizers by the Haber process (Ting, 1982; Kebede, 2021). In the Haber industrial process, N₂ is reacted with molecular hydrogen where the element is reduced directly to ammonia (NH₃) (Ting, 1982; FIS, 2023) as follows: $N_2 + 3H_2 = 2NH_3$. The Haber process made it possible to mass produce synthetic N fertilizers, the worldwide use of which has been responsible for the dramatic increase in crop yields (Blanco, 2011). However, commercially manufactured N fertilizers meet only half of the world requirements for the element (Blanco, 2011). Also, most of the industrially produced fertilizers are consumed by agriculture in the industrialized countries. Sub-Saharan Africa soils display a combination of poor fertility and the lowest fertilizer application rate; about 7 kg/ha, compared to 150 kg/ha in India and a world average of 140 kg/ha (IFPRI-International Food Police Research Institute, 2010).

The other half or 85 million tons of fixed N are the direct result of BNF (Kebede, 2021). "Biological nitrogen fixation" refers to the bacteria mediated reduction of N₂ atmospheric gas by



legumes to NH_3 (ammonia), the most important biological process for life on earth after photosynthesis (Ting, 1982, FIS, 2023). Tropical forage legumes consist of a variety of herbaceous plants selected from undomesticated and cultivated forage species (CIAT-International Centre for Agriculture in the Tropics, 2019). These species had multiple uses in the low-input farming systems of the tropics, including N-fixation, restoration of soil fertility of degraded agricultural land and high potential for carbon sequestration – second only to forests (CIAT, 2019). Carbon sequestration is the process of capture and storage of carbon dioxide (CO_2) to mitigate dangerous climate change (Agroforestry, 2015). N_2 fixation values in forage legumes under condition in Nigeria were in the order of 13 to 24 kg N/ha (Yakubu *et al.*, 2007) and 70 to 90 kg N/ha in *Sesbania rostrata* and 37 to 160 kg N/ha in pigeon pea (IITA, 1983; Egbe *et al.*, 2006). These species if introduced into a farming system will fix sufficient N for increased crop yields in view of the scarce and expensive chemical fertilizers. The study was therefore carried out to evaluate N_2 -fixing capacity in the forage plants and to recommend the best 5 N-fixers for use as green manure.

MATERIALS AND METHODS

Seeds of the Forage Legume Species

Seeds of best-bet manure species were collected from the National Animal Production Research Institute- NAPRT shika, Zaria. These were *Mucuna pruriens* (T₂), *stylosanthesis guianensis* (T₃), *Cajanus cajan* brown (T₅), *Centrosema pubescens* (T₉), *Lablab purpureus* white (T₁₁) and *Lablab purpureus* black (T₁₂). *Cajanus cajan* white (T₇) was obtained from the Federal University of Agriculture Makurdi, Benue State. The undomesticated species of *Sesbania rostrata* (T₁₅) was collected from fields around Maiduguri, Borno State. Seeds of Pearl Millet variety 9702 were obtained from Lake Chad Research Institute, Maiduguri, as the test crop.

Experiment:

A pot experiment was conducted at the screen house faculty of Agriculture, University of Maiduguri. Treatments consisted of 8 forage plants. The plants were grown for six weeks, after harvest, their biomass yield was measured. The N, P and K contents in the forage plants were determined in the laboratory according to Bashir (2019).

RESULTS AND DISCUSSION

Biomass Yields and Nutrient Composition of Forage Legumes

The biomass yields and nutrient composition of the legume species were presented in table 1. The result showed that the plants highest in biomass production in the experiment were *Mucuna pruriens*, *Cajanus cajan* brown, *Sesbania rostrata*, *Lablab purpureus* and *Cajanus cajan* white with 820, 440, 375, 368 and 364 kg/ha respectively. Similar result trend were reported by FAO (2011) where such forage species produced variable biomass in field planting. Kusvuran *et al.* (2015) defined biomass in green manuring as the sum total weight of plant components above and below the soil line, and is an important concept, which directly affects soil productivity. The finding of this experiment was in agreement with FAO (2011) that *Mucuna* and pigeon pea are great producers of biomass even on extremely low fertility soils. Biomass produced by forage legumes is the precursor of biological nitrogen fixation, an important concept in tropical cropping systems. The nutrient composition of the legume species was also presented in table 1. The result showed that the species highest in combined NPK analysis are *Sesbania rostrata*, *Cajanus cajan* white, *Lablab purpureus* black, *Centrosema pubescens* and *Cajanus cajan* brown with 8.55, 8.33, 7.17, 6.97 and 6.87 % respectively. Adesoji *et al.* (2014) reported lower result of NPK composition in green manure legumes in Samaru Zaria than the result of the present study, with *Mucuna* containing the lowest % NPK (4.39) in Zaria. Nalivata *et al.* (2017) classified organic materials for use in agriculture as follows: NPK content greater than 2.5 % high quality, NPK content less than 2.5 % low quality. Clearly, legumes species were shown to be of the highest quality organic resources for sustainable crop production in Nigeria where intensive livestock production is absent. As shown in figure 1, the average NPK content in legumes in the experiment was very high 7.0%, comparative total NPK analysis of Farmyard manure according to Kuepper (2003) is a meagre 1.79 %. It might be deduced from Fig.1 that the average NPK content in

legumes (7.0%) was 291 % higher than the NPK analysis of barnyard manure (1.79%). These forage species might probably enrich the soil for higher crop yield when used as green manure. Sullivan (2003) concurred with the finding of the present study that N, P, K, Ca, Mg, S and other plant essential micronutrients are contained in the tissue of manuring forage legumes.

Table 1: Biomass Yield and Nutrient Composition of some Forage Legumes.

Forage Legumes	Biomass yield (kg/ha)	Nutrient Composition (%)		
		N	P	K
<i>MucunaPruriens</i> White Zaria (T ₂)	820.0	3.06	0.12	2.46
<i>StylosanthesisGuinensis</i> Zaria (T ₃)	242.5	4.30	0.07	2.18
<i>CajanusCajan</i> Brown Zaria (T ₅)	440.0	3.36	0.08	3.43
<i>CajanusCajanIgbonbu</i> White (T ₇)	364.0	4.13	0.09	4.11
<i>CentrosemaPubescens</i> (T ₉)	310.0	2.85	0.09	4.03
<i>Lablab Purpureus</i> White (T ₁₁)	368.5	2.64	0.09	3.80
<i>Lablab Purpureus</i> Black (T ₁₂)	145.2	4.03	0.09	3.05
<i>SesbaniaRostrataLimanti</i> (T ₁₅)	375.0	4.13	0.09	4.33
Millet Var. LCI (T ₁₉)	115.5	1.06		

Nutrient Uptake by Forage Legumes

Results for nutrient uptake (kg/ha) by the forage species are shown in table 2. *Mucuna* had the highest N uptake of 25.1 as well as uptake of total NPK of 46.2 kg/ha. The result is followed by an equal N uptake of about 15 kg/ha in *Sesbania* and pigeon pea. The result also showed total NPK uptake in *Sesbania* followed *Mucuna* with 32.1 and an equal amount of 30.33 kg/ha in pigeon peas. *Lablab* white, *Centrosoma* and *Stylosanthesis* had lower but substantial NPK uptake of 24.1, 21.6 and 15.9 kg/ha respectively. Bashir (2009) obtained lower N uptake result (5.46 kg/ha) but similar total NPK (29.38) in 8 weeks old *Sesbania* compared to result of the present study. These results were confirmed by FAO (2011) that pigeon pea and *Mucuna* are great producers of biomass weight even on low fertility soils.

Preston (2023) defined nutrient uptake as the amount of each nutrient element required for the crop to complete its life cycle. NPK uptake was highest in legumes, *Mucuna* with 46 kg/ha in the present study. These plant species have shown high potential to improve soil properties for crop production if applied as green manure.

Table 2: Nutrient Uptake in some Forage Legumes.

Forage Legumes	Nutrient Uptake (kg/ha)			
	N	P	K	NPK
<i>MucunaPruriens</i> White Zaria (T ₂)	25.1	1.0	20.2	46.2
<i>StylosanthesisGuinensis</i> Zaria (T ₃)	10.4	0.20	5.30	15.9
<i>CajanusCajan</i> Brown Zaria (T ₅)	14.8	0.35	15.1	30.3
<i>CajanusCajanIgbonbu</i> White (T ₇)	15.0	0.33	15.0	30.3
<i>CentrosemaPubescens</i> (T ₉)	8.84	0.28	12.50	21.6
<i>Lablab Purpureus</i> White (T ₁₁)	9.73	0.33	14.0	24.1
<i>Lablab Purpureus</i> Black (T ₁₂)	5.85	0.13	4.43	10.4
<i>SesbaniaRostrataLimanti</i> (T ₁₅)	15.49	0.34	16.24	32.1
Millet Var. LCI (T ₁₉)	1.22			

Biological Nitrogen Fixation (BNF) in Forage Legumes

The result for N-fixed was shown in table 3. *Mucuna* fixed the highest N (23.88 kg/ha), followed by that fixed in *sesbania* (14.27 kg/ha), *cajanus cajan* white (13.78 kg/ha) and *stylosanthesis guianensis* (9.18 kg/ha). That fixed in *lablab purperens* white was 8.51 kg/ha. The result for N₂-fixation in the present study were higher than those of Yakubu *et al.* (2007) in five forage legumes ranging from 13 to 24 kg N/tonne of dry matter. Result of N₂-fixation by forage legumes under condition in Nigeria reported by IITA (1983) and Egbe *et al.* (2006) include *sesbania rostrata* with 70 to 90 and pigeon pea



37 to 160 kg N/ha. This result was in agreement with FAO (2011) that pigeon pea is a great producer of biomass even on degraded soils. The legume species in the experiment can be ranked based on level of BNF (kg/ha) as *Mucuna pruriens* (23.88), >*Sesbania rostrata* (14.27) >*Cajanus cajan* white (13.78) >*Cajanus cajan* brown (13.58) >*Stylosanthesis guianensis* (9.18) >*Lablab purpureus* white (8.51) >*Centrosema pubescens* (7.62) >*Lablab purpureus* black (5.85). The ability of forage legumes to fix N from the atmosphere or BNF is invaluable in soil fertility and significant in increasing crop yields. Of the sixteen chemical elements proved to be necessary for growth and reproduction of crop plants, nitrogen is the single most important soil-based nutrient. Except for water availability, it is N that limits crop growth most frequently (Ting, 1982). The two most striking effects of nitrogenous fertilizers on crops are the imparting of deep green colour of the leaves and an increased rate of growth (Russel, 2006). Wakili *et al.* (2023) report the photosynthetic efficiency of leaves depends on nitrogen concentration in leaves. One kilogramme (kg) of nitrogen supplied as fertilizer adds between 80 and 100 kg of dry matter to a growing cereal crop (Russel, 2006). According to Wakili *et al.* (2023) N-fertilization provides sufficient nutritional requirements and hence promotes grain yield. In a study in the semi-arid environment, Bashir (2019) report *Sesbania rostrata* green manure increased the yield of Sorghum grain from 970 kg/ha (control) to 1,630 kg/ha, which was statistically at par with yield (1,700 kg/ha) in plots of NPK fertilizer. Dubeux *et al.* (2022) reported forage legumes in cropping systems are an alternative to replace N chemical fertilizers. Research has shown universal effects of legume green manuring on cereal yields and BNF N can substitute for 60 to 100 kg fertilizer N/ha (Iancheva and Naydenova, 2021). Bashir (2019); Debeux *et al.* (2022) reported the use of these species as green manure can substitute for 85 to 100 % of fertilizer N application. These forage legume species if introduced into the regional farming system will fix sufficient BNF-N for increased crop yields in view of scarce/expensive chemical fertilizers.

Table 3: Biological Nitrogen Fixation in some Forage Legumes.

Forage Legumes	N-Uptake (kg/ha)	N-Fixed (kg/ha)	Ndfa (%)
<i>MucunaPruriens</i> White Zaria (T ₂)	25.1	23.88	95
<i>StylosanthesisGuinensis</i> Zaria (T ₃)	10.4	9.18	88
<i>CajanusCajan</i> Brown Zaria (T ₅)	14.8	13.58	92
<i>CajanusCajan</i> Igbonbu White (T ₇)	15.0	13.78	92
<i>CentrosemaPubescens</i> (T ₉)	8.84	7.62	86
<i>Lablab Purpureus</i> White (T ₁₁)	9.73	8.51	87
<i>Lablab Purpureus</i> Black (T ₁₂)	5.85	4.63	79
<i>SesbaniaRostrata</i> Limanti (T ₁₅)	15.49	14.27	92
Millet Var. LCI (T ₁₉)	1.22		

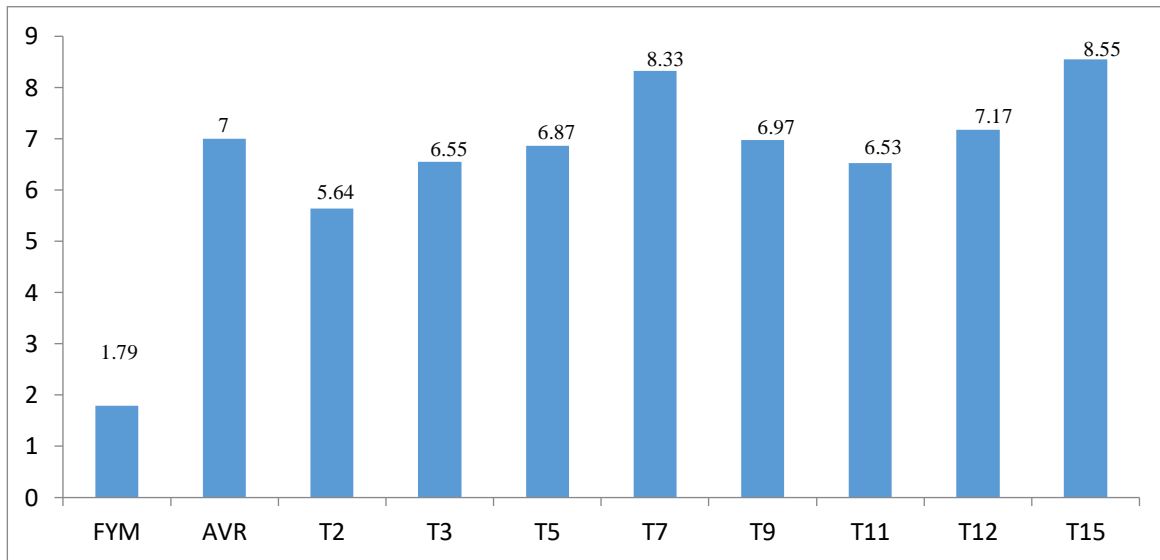


Figure 1: Comparison of Species % NPK with FYM (Key to T₁ to T₁₇ see Table 1)

CONCLUSION AND RECOMMENDATION

In the experiment the forage species richest in % NPK composition were *Sesbania rostrata* > *Cajanus cajan* white > *Lablab purpureus* black > *Centrosema pubescens* > *Cajanus cajan* brown. The average NPK composition (7.0%) of forages was found to be 291% higher than that of Farmyard manure (1.79%). While the best 5 fixers of BNF – N (kg/ha), the most important criterion in green manure selection, were *Mucuna pruriens* (23.88) > *Sesbania rostrata* (14.27) > *Cajanus cajan* (13.78) > *Stylosanthesis guianensis* (9.18) > *Lablab purpureus* white (8.51). These high N fixing species if used in a farming system as green manure can increase crops yield in place of chemical fertilizer as well as replace farmyard manure.

The top 5 N-fixers in the experiment i.e. *Mucuna pruriens*, *Sesbania rostrata*, *Cajanus cajan*, *Stylosanthesis guianensis* and *Lablab purpureus* white are recommended for use as green manure in the farming systems of the savanna of northern Nigeria. With the rich nutrient content in their tissue, these species can enrich the soil for increased crop yields. They can substitute the expensive chemical fertilizers.

Future research be carried out on the effects of these species as green manure on soil and crop growth.

Institutional Farms should pioneer the needed research because academics possess the personnel capacity, especially polytechnics and colleges of agriculture.

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