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Response to fertilizer of native grasses (*Pennisetum polystachion* and *Setaria sphacelata*) and legume (*Tephrosia pedicellata*) of savannah in Sudanian Benin

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Abstract: Response to nitrogen fertilizer of 2 grass species, *Pennisetum polystachion* and *Setaria sphacelata*, and one legume *Tephrosia pedicellata* was studied in northern Benin. The 3 species are native in Sudanian grasslands and occur on tropical ferruginous soils. The experimental plots were fertilized with a basal dressing of potassium chloride and triple superphosphate before testing nitrogen fertilizer at rates of 0, 60 and 120 kg/ha N, respectively. The highest biomass was produced with 120 kg/ha (4.98, 2.13 and 1.1 t/ha DM for *Pennisetum*, *Setaria* and *Tephrosia*, respectively). The highest number of pods per plant with *Tephrosia* was produced with the control plot (35.75 pods per plant) and the lowest with an N rate of 60 kg/ha (23.75 pods per plant). The highest tussock diameters for *Setaria* and *Pennisetum* were 76.4 and 71.9 cm, respectively, at an N rate of 120 kg/ha. These 3 native forage species showed good performance under cultivation.

Keywords: Grass, Legume, Nitrogen Fertilizer, Savanna, Benin

1. Introduction

Sub-Saharan livestock production is increasingly constrained by feed shortage, both quantitatively and qualitatively. Natural forage is not sufficient to satisfy animal requirement in the dry season when the peak biomass decreases by 25-50% and N contents falls well below 1% [1-4]. Animal production can be improved through good management of natural grasslands, introduction of improved fodder species or by creating artificial grasslands with the supply of fertilizer and water to maintain high productivity [5-6]. An improvement in soil fertility and management techniques can lead to optimum production from the fodder species.

The study of Benin Sudanian grassland floristic composition [7] showed that many native fodder species are highly palatable to cattle. Most are not well known, so the pasture improvement program is still based on exotic species. Some native grass species became scarce and may disappear due to the extension of agricultural activities. A program of domestication of some fodder species had been undertaken to make more species available for the pasture management program and to improve animal feeding. In Benin, the most limiting factor in animal production is feed availability [8]; as a consequence, an improvement of fodder balance with an introduction of improved species with high nutritional value can significantly increase animal productivity.

Numerous studies [5, 9-13] have documented that nitrogen fertilizer increases yield significantly, but for all plant species, the quantity of N needed to give maximum yield of forage in the presence of P and K is neither known. There have been divergent views on legume response to N fertilizer application. References [14-15] observed no significant increase in yield of soybean due to N fertilization, but [16] observed that N fertilizer is beneficial only if applied when soybean N requirement is no longer being met by N reserves and biological symbiosis with nodule bacteria. References [17, 18]reported that side dressing of soybean plants with N fertilizer at the bloom stage increased yield over a 5-year period and could enhance soybean performance and increase farmer profit. The aim of the present study was to quantify the response of *Pennisetum polystachion* (Fallow grass), S*etaria sphacelata* (savanna grass) and *Tephrosia sphacelata* (fallow leguminous) to nitrogen fertilizer after applying a basal dressing of potassium and phosphorus on ferruginous soil.

2. Materials and Methods

2.1. Site Description

The study was conducted in the northern Sudanian zone of Benin at INA agricultural research station (9°58'N, 2°44'E; altitude 358 m above sea level). It experiences a moist Sudanian climate with a rainy season of about 6-7 months starting in April-May and a pronounced dry season from November-March. The average annual rainfall is about 1,200 mm and the potential evapo-transpiration is about 1,535 mm/year with an annual mean temperature of about 27°C.

The soil is classified as a tropical ferruginous soil [19] formed on granite. The texture of the surface layer is sandy with good microbial activity [20]. According to [21], the ferruginous soil of Benin consists mainly of lixisols, which are highly weathered soils with low levels of available nutrients particularly N and P in the surface layer (Table 1). The natural vegetation is dominated by some old fallows and tree savannas.

Table 1. *Soil characteristics at 0-15-50 and 50-80 cm depths.*

Parameters	0-15 cm	15-50 cm	50-80 cm
Texture	Sandy loam	Sandy loam	Clay sandy
C (%)	0.89	0.33	-[1]
N (%)	0.067	0.032	-
O.M. (%)	1.53	0.57	-
pH water (1/2.5)	5.9	6.1	6.5
Exch. K^+ (meq/100g)	0.24	0.11	0.19
CEC(meq/100g)	3.70	2.25	5.10
P Bray 1 (ppm)	7	-	1

Source: [20]. 1 Very low concentration; O.M: Organic Matter; CEC: Cationic Exchange Capacity

2.2. Experimental Design and Measured Parameters

The experimental design was a randomized complete block design with 3 pasture species (*Pennisetum polystachion* – fallow grass; *Setaria sphacelata* – savanna grass; *Tephrosia pedicellata* – a legume) x 3 rates of nitrogen fertilizer (0, 60 and 120 kg/ha, applied as urea) with 4 replicates. The domestication program started in 1993 and continued in 2003 with tests of adaptability of native grass species [6, 22]. This study was carried out in the 2003 wet season (June-October). Pasture species were planted at the beginning of July in rows 0.5 m apart with 0.3 m between plants within rows. This gave a plant density of9 plants/m^2. The main plots were pasture species with fertilizer treatments as sub-plots. Individual sub-plots were 2 m x 1 m. Nitrogen was applied in the form of urea as a split dressing one week (one-third) and 4 weeks (two-thirds) after sowing. A basal fertilizer dressing of 75 kg/ha triple superphosphate, 35.25 kg/ha P_2O_5 and 75 kg/ha potassium chloride (45 kg/ha K_2O) was applied to all plots at sowing.

The measured parameters were total biomass, tussock diameters (for the 2 grasses), number of pods and root nodules per plant (for the legume). Standing biomass on a single quadrant (1 m x 1 m) per sub-plot was cut at 15 cm above the ground level, and samples were dried in an electric oven at 65^{o}C for 24 h. Plant recovery in the plot was expressed as tussock diameter at the top with 3 tussocks per treatment being measured. Measurements were made with a long ruler on the top of each tussock following 2 perpendicular directions. The numbers of pods and root nodules per legume plant were counted on 3 plants per sub-plot selected at random. Soil surrounding the plant was previously wet and the legume was carefully removed from the soil, the roots were washed with water and all visible root nodules were directly counted. On the legume aerial parts, all pods were directly counted.

Data were subjected to statistical analyses using SAS (SAS, Institute Inc., Cary, NC, 27513-2414 USA). The effect of species and the N-rates fertilizer on the total aerial biomass, tussock diameters, pods production and root nodules were compared in a 2-way analysis of variance (ANOVA) using the General Linear Models Procedure (Proc GLM). Factors were the type of species, N rate fertilizer and interaction. Differences between treatments were subjected to the Students-Newman-Keuls test for significance at $P<0.05$.

3. Results

3.1. Total Biomass

Both grasses responded positively to nitrogen application. The biomass production of *Setaria sphacelata* increased significantly at both rates of N ($P<0.05$). On the other hand, *Pennisetum polystachion* biomass responded ($P<0.05$) only to the highest rate (Table 2). This amounted to an increase of 200% for *Setaria* and 82.4% for *Pennisetum* over the unfertilized control. The biomass of the legume *Tephrosia* was unresponsive to N ($P>0.05$).

3.2. Tussock Diameters

These measurements concerned only the grasses (*Pennisetum* and *Setaria*).The maximum tussock diameter was observed before the end of the rainy season.

***Table 2.** Effect of different nitrogen fertilizer rates on the total dry matter of native fodder species.*

Nitrogen rates (kg ha^{-1})	Fodder species		
	Pennisetum polystachion **(t ha^{-1})**	***Setaria sphacelata*** **(t ha^{-1})**	***Tephrosia pedicellata*** **(t ha^{-1})**
0 (control)	2.73 ± 1.12 b[1]	0.71 ± 0.25 c	0.99 ± 0.03 a
60	3.05 ± 0.70 b	1.55 ± 0.49 b	0.95 ± 0.08 a
120	4.98 ± 1.22 a	2.13 ± 0.48 a	1.10 ± 0.05 a
LSD (5%)	1.24	0.5	0.18
CV (%)	24.07	23.71	4.68

1 Values follow by the same letter are not significantly different based on Newman—Keuls test ($P<0.05$).LSD: Least significant Difference. CV: Coefficient of variation;

The highest tussock diameter with *Pennisetum* was registered at an N rate of 120 kg/ha (71.9±5.4 cm), whereas rates of 0 and 60 kg/ha produced values of 57.4 ± 9.3 cm and 51.3 ± 12.7 cm, respectively (Figure 1).

Setaria showed tussock diameters of 76.4 ± 9.9 cm and 63.3 ± 17.6 cm for N rates of 120 and 60 kg/ha, respectively against 38.6 ± 25.8 cm for the control plot ($P<0.05$).

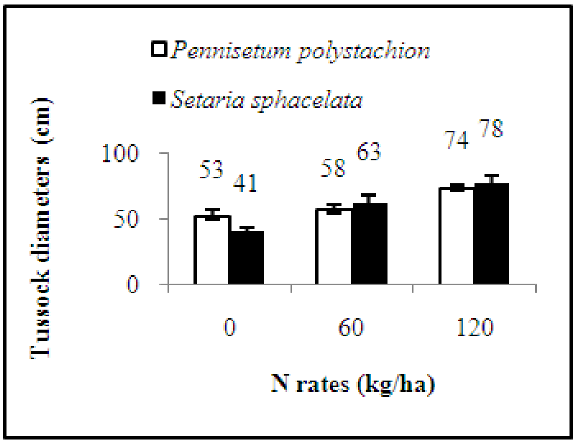

***Figure 1.** Effect of N-fertilizer on tussock diameter of two native grasses.*

3.3. Pods Production and Root Nodules

The effect of nitrogen fertilizer on number of *Tephrosia* pods and root nodules is presented in Table 3. The number of pods per plant showed a concavity trend with a significant decrease at 60 kg/ha.

***Table 3.** Effect of nitrogen fertilizer on the number of pods per plant and the number of root nodules of Tephrosiapedicellata.*

Nitrogen rates (kg/ha)	Number of pods per plant	Number of nodules per plant
0 (control)	35.75 ± 1.56 a[1]	21.50 ± 3.25 a
60	23.75 ± 1.76 b	28.00 ± 4.59 a
120	34.75 ± 2.54 a	20.50 ± 1.91 a
LSD (5%)	5.19	8.38
CV (%)	13.50	31.21

[1]values follow by the same letter are not significantly different based on Newman-Keuls test ($P>0.05$). LSD: Least Significant Difference; CV: Coefficient of variation

There was no significant impact of N fertilizer application on the number of root nodules perplant although at an N rate of 60 kg/ha, number of root nodules per plant was increased.

4. Discussion

The increasing dry matter production of the two native grass species depending positively on nitrogen level and soil inherent fertility is in accordance with data obtained in many other experimental fields [5, 10-13, 23-24].

Some plant species can have high productivity due to good assimilation coefficients, good photosynthetic activity and well adapted root development, but yield cannot increase significantly on degraded soils without supply of fertilizer. In the Sudanian region of Benin, higher biomass of *Pennisetum polystachion* grass had been registered in old fields which have been fertilized for cash crop (cotton) production [7, 25]. As observed with food crops, the supply of nitrogen plays an important role in the grass biomass production. The improvement of soil fertility contributes also in the development of plant recovery.

Application of fertilizer to soils can also improve the nutritional quality of forage [9, 11-13]. Productivity and quality of forage is also based on the potential soil fertility. In Antilla, [26] increased *Digitaria pentzii* biomass by 150% by increasing the N fertilizer with on a clayed soil by 400%. This increase in yield was complemented by a high N and mineral nutrient content in the forage.

As *Setaria sphacelata* is a tussock grass, it has higher tussock diameter than *Pennisetum polystachion,* which is an annual. This is an interesting result, demonstrating that this grass like most perennial grasses that develop tussocks, can be used to protect soil against erosion under animal grazing. It can adapt itself to a broad range of soil conditions. In China's dry tropical rangelands, [27] showed that *Setaria sphacelata* established well on sandy soil achieving a density of 18 plants/m^{2}with mean yields of 0.3 t/ha DM at the establishment year on sandy soil and about 0.6 t/ha DM on a loamy soil. *Setaria* yields in the unfertilized plots in our experiment are similar to those obtained in China. *Setaria sphacelata* is encountered in Benin on lowland soils with a clay texture (flooded depression). This experiment has showed that it can adapt well to a sandy loam soil given adequate fertilization and rainfall. On sandy soils with low fertility and poor rainfall, yields of S*etaria sphacelata* can be reduced less than 25% in the first year production [27]. Reference [28] observed that, in the border line savanna forest, *Setaria sphacelata* can sustain a carrying capacity of 1.52 tropical livestock units per hectare, i.e. an animal live weight of 380 kg per hectare. Reference [29] demonstrated that *Setaria sphacelata* can be successfully grown on fertile soils with minimal fertilizer inputs (28 kg/ha P per 3 years). Our findings are at variance with this result as *Setaria* responded significantly to N supply even if P was applied.

Concerning *Tephrosia*, the reduced number of pods per plant was compensated by increasing in aerial biomass. This observation is in accordance with [28], who observed that nitrogen supply slowed down the relative development of legumes especially those which fix atmospheric nitrogen; accordingly, additional nitrogen fertilization reduces the pod production. Moreover, [15] found in the case of soybean cultivated in the northern Guinea and Sudan savanna of northeast Nigeria, that N fertilizer had no significant effect on seed yields or pods per plant while application of P fertilizer increased pods per plant by 40-66%; No significant interaction effect between N and P fertilizer on seed yield and pods plant^{-1} was also observed. As far as forage production is concerned, particularly in the Sudanian zone of Benin, it is wise to avoid the N fertilization for legume cultivation.

Application of N can reduce nodulation and N_2 fixation by legume species. In a study on an Alfisol in Nigeria, [30] showed that N_2 fixation on a well nodulated *Leucaena leucocephala* was reduced by 50% when 80 kg/ha N was applied.

In northern Benin, most cattle breeders are also farmers. It is better for them to sow grass forage species on fertilized soils or on soils which have been fertilized for cash crop. However, *Tephrosia* could be sown on impoverished soils.

Although in the tropics, improvement of indigenous plants is promising for forage production [31], criteria for evaluation of these forage species must include their ability to establish and produce under variable rainfall regimes [32].

5. Conclusion

From this study, it appears that nitrogen nutrition has a significant effect on the development and productivity of grass species. The additional N supply has increased significantly both total biomass and tussock diameter. As for food crops, nitrogen fertilization plays an important role in the improvement of forage species. The best increases in productivity of plants were obtained with an N rate of 120 kg/ha.

With the legume, applying nitrogen fertilizer slowed down the relative development of the plant and reduced the number of pods per plant. As far as seed production is concerned, it is wise to avoid nitrogen fertilization with *Tephrosia pedicellata* pasture.

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