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Original article

# Response of Congo Grass (*Brachiaria ruziziensis* L. Germain and Evard) to Nitrogen Fertilization on an Oxisol in Western Highlands Agro-ecological Zone of Cameroon

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**Abstract**

In the context of climate change, sustainable fertilization management can be achieved by the use of minimum external agricultural inputs capable of generating both economic and environmental benefits. In this regard, a study conducted in western highlands agro-ecological zone of Cameroon revealed the response of *Brachiaria ruziziensis* (an important cover crop and forage) to a range of nitrogen levels (0, 50, 100, 150, and 200 kgN.ha-1) combined with a constant level of P2O5 (100 kgN.ha-1) and K2O (50 kg/ha) evaluated using a randomized complete block design. The findings showed that in a regularly cultivated soil, Congo grass is capable of meeting its mineral needs by searching for them in strata of the soil below the cultural profile (0-25 cm). As a result, in comparison to non-fertilized units (27.75 t.ha-1), fertilized units did not provide a significant dry matter yield (P > 0.05). Despite the lack of a significant difference, the yield increased with the addition of nitrogen until it reached 100 kg/ha, and then decreased until it reached 200 kg N.ha-1. As a result, Congo grass should be used as a biological pump, bringing lixiviated minerals to the surface to favor soil fertility replenishment and shorten fallow period.

**Keywords:** Fertilization, Agricultural inputs, Congo grass, Dry matter, Fallow.

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## INTRODUCTION

The need to meet the ever-increasing nutritional demands of the world's growing population has raised sustainable agriculture and agro-based sectors to the frontline of environmental and social development issues in Sub-Saharan Africa. Soils are an important part of agriculture and serve as a support for a variety of ecological, biological, physical, and chemical processes (Zhenghong et al., 2020). Its wide range of applications in the upkeep of human live activities makes the overburdening of soils a paramount issue (Omotayo and Chukwuka, 2008). Soil productivity has become a constant challenge for farmers and agriculturists in Africa. Indeed, low soil fertility inevitably leads to low agricultural productivity, since agricultural development is fundamentally affected by the productivity status of land resources. In recent decades, unsustainable land cultivation practices have led to accelerated depletion of the natural soil base available for food production, global warming and climate change. The need for proper soil management to achieve optimum productivity becomes imperative when considering issues regarding soil fertility improvement in SSA (Omotayo and Chukwuka, 2008; Ansong et al., 2018; Silveira and Kohmann, 2020).

Fallowing is a cultural practice used by farmers to help overworked and exhausted soils recover their fertility. It is commonly referred to as a resting period for agricultural land between two cropping cycles during which soil fertility is restored. However, this natural management is a long-term fallow that usually lasts approximately ten years (Abdoulaye et al., 2013). Under intensified rotations, natural fallows show considerable limitations characterized by soil and vegetation degradation and by species replacement from woody to herbaceous species. Herbaceous species are seldom able to produce large amounts of good-quality biomass and restore soil fertility quickly. A desirable step in agricultural intensification is, therefore, to plant fallow species that improve soil systems more efficiently than natural fallows.

Employing certain species as cover crops, especially *Brachiaria ruziziensis* in the fallow period represents a promising way of restoring the fertility of degraded soils (Calonego et al., 2017). Indeed, their introduction in sole or intercropped with other crops in the tired plots, makes it possible to restore the fertility of the soil, especially in a very short time: 2 to 3 years maximum (Abdoulaye et al., 2013).

The genus *Brachiaria* consists of herbaceous, perennial or annual, erect or decumbent species belonging to the short-lived perennial grass family. Commonly grown for pastures in the tropics, it presents approximately one hundred species. Among *Brachiaria* species, *Brachiaria ruziziensis* also known as Congo grass, is one of the most important plant belonging to the C4 plants because of its high palatability, grazing support, and high dry matter production (6 to 15 t/ha) (Damaceno et al., 2019). It tolerates drier conditions and more light exposure than many other plants (Watson and Dallwitz, 2008).Congo grass has a dense system of bunched, quickly growing roots that can go down to a depth of 1.8 m (Husson et al., 2008). Grasses with deep root systems help pump nutrients from the deeper layers to the surface soil horizons, and their biomass extracts nutrients from the deeper layers, which are gradually released (Crush, et al., 2005).Therefore, *B. ruziziensis*is commonly used to shorten the fallow period and prevent the loss of soil fertility in subtropical agricultural regions. In addition, recent studies have concluded that the use of *B. ruziziensis* as a cover crop contributes to improving the quality of the chemical and physical attributes of soils (Nascente et al., 2013; Seidel et al., 2017). Knowing that plants respond differently to the amount of nitrogen during fertilization, there is a lack of detailed information on the effect of nitrogen fertilization on the growth and mineral accumulation in *B. ruziziensis.* Thus, there is a need to investigate the response of Congo grass to nitrogen fertilization. This study was conducted to evaluate the response of *Brachiaria ruziziensis* to different nitrogen fertilization rates in an Oxisol type.

## MATERIALS and METHODS

### Experimental location

The study was conducted at the experimental farm located at the Dschang subdivision (Latitude 5° 26' 38" N, Longitude: 10° 03' 11" E, 1500 meters above sea level), Menoua division, West Cameroon, and took place from 16 August to January 2019. The site is characterized by a wet season that lasts from March to November and a dry season that lasts from November to March. The average annual precipitation is 1800mm. The average annual temperature is approximately 20.03°C, with maximum temperatures ranging from 25°C to 28°C in April and minimum temperatures ranging from 14 to 16 °C in December. The average daily sunshine hours is 4.75.

### Soil characterization

The experiment was carried out on a well-drained red ferritic soil (oxisol). These soils are acidic, and high in organic matter, but low in phosphorus and potassium (Beernaert and Bitondo, 1992). The previous crop in the experimental area was cabbage (*Brassica olearacea*). Soil samples were randomly collected from the soil surface to a depth of 25 cm in the experimental area which were composited, mixed thoroughly, and processed, and 1 kilogram of soil was submitted for analysis in the Soil Science Laboratory of the University of Dschang. Dry sieving was used to obtain the sand fraction. The slit and clay extractions were carried out in the Robinson Pipette. The pH-$H_2O$ was determined using an electrode in a soil-water (1:2.5) suspension and the pH-KCl in a soil-KCl (1:2.5) 1 N suspension. The reversible acidity was extracted using a 1M KCl solution and then measured using titration. The percent of total organic carbon (TOC %) was determined using the Walkley and Black method, and the total nitrogen was determined using the Kjeldahl method. The organic matter percentage (OM %) was calculated using the formula OM % = TOC percent x 1. 724. The exchangeable bases were determined after extraction with a 1N solution of ammonium acetate at pH 7. The total amount of potassium and sodium was determined by flame photometry while the total amount of magnesium and calcium in the soil was obtained by complexometry. The extractable phosphorus was obtained by the Bray 2 method.

**Plant material**

The seeds of the species *B. ruziziensis* were provided by the Institute of Agricultural Research for Development (IRAD) in Cameroon. The average germination rate of the seed lot that was used was 5%.

**Experimental design and treatments**

The experimental area was laid out in a randomized complete block design (RCBD) with five treatments and three replications. Each block consisted of 5 experimental units corresponding to the different treatments. Each treatment plot had dimensions of 1.8m x 1.8m separated by 1 m alleyways. The sowing density was 30cm x 30cm. Each pocket had an average of 5 plants and five doses of nitrogen (T1, T2, T3, T4 and T5) were applied as follows:

T1: 0 kg N + 100 kg $P_2O_5$ + 50 kg $K_2O.ha^{-1}$

T2: 50 kg N + 100 kg $P_2O_5$ + 50 kg $K_2O.ha^{-1}$

T3: 100 kg N + 100 kg $P_2O_5$ + 50 kg $K_2O.ha^{-1}$

T4: 150 kg N + 100 kg $P_2O_5$ + 50 kg $K_2O.ha^{-1}$

T5: 200 kg N + 100 kg $P_2O_5$ + 50 kg $K_2O.ha^{-1}$

**Setting up of the experiment**

The experimental plot was initially plowed with hoes at a depth of approximately 25 cm, followed by a second pass consisting of breaking up the soil clods to form the experimental units. *B. ruziziensis* was sown in pockets of 30 cm apart and with an average depth of 1 cm, and then covered with a light layer of soil. Because of the low germination rate (5%), 45 kg of seeds were used per hectare. Depending on the treatments, a single fertilizer application was applied and administered 44 days after sowing. To eliminate weed competition in the early phases of Congo grass development, two manual weedings were performed 28 and 42 days after seeding.

**Dry biomass and macronutrients determination**

Plants were harvested 104 days after sowing by cutting the tillers 10 cm from the ground using a sharp sickle. Samples were collected from an area of 3.24 $m^2$ in each experimental unit. Subsequently, these samples were weighed directly in the fields to measure fresh weights. To determine the dry weight, subsamples weighing 500 g of each of the harvested grasses were collected, oven dried at 65 °C until a constant weight was attained, and used to calculate the dry matter percentage. Dry matter yield was calculated as the percentage of dry matter multiplied by the fresh weight harvested from each plot and extrapolated to tonnes/ha. After dry matter yield estimation, the dried grass samples were milled using a hammer mill, and allowed to pass through a 1 mm sieve screen for chemical analysis of the total nitrogen (N), phosphorus(P), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe) and sodium (Na).

**Statistical analysis**

Statistical analyses were performed using R version 3.5.1 software. Analyses of variance (ANOVA) were used with LSD (least significant difference) to test differences among treatments ($P$ = 0.05). In all cases, residuals were tested for normality with Shapiro-Wilk's test and homogeneity of variance Bartlett's test) at the 5% threshold.

## RESULTS and DISCUSSION

### Agroclimatic conditions

The initial soil analysis presented in table 1 shows that the experimental area has a clayey- sandy loam texture. Total nitrogen has an average content of 0.13% but the C/N ratio (39) indicates a lack of nitrogen for the bacteria responsible for mineralization. The soil is weakly acidic with a water pH value of 5.4. The cationic balance is largely unbalanced, due to a lack of calcium and magnesium (64/7/22). Indeed, the calcium content is low, and the magnesium content is very low. The CEC is moderate, and the saturation rate is low. Similarly, the rate of available phosphorus was low (6.36mg/kg). The potassium content (1.18 mEq%) is high and average for sodium (0.29 mEq%). Thus, the results obtained show that the soil has an average level of chemical fertility overall, but a low level of physical fertility because its texture contains more inert elements (sand) than reactive ones (silt and clay).

**Table 1:** Mineralogical and granulometric fraction values of the experimental area before sowing.

| Characteristics | Mineralogical and granulometric fraction values | | | |
|---|---|---|---|---|
| | Block 1 | Block 2 | Block 3 | Mean |
| Sand (%) | 59 | 57 | 56 | 57 |
| Slit (%) | 18 | 23 | 23 | 21 |
| Clay (%) | 23 | 20 | 21 | 21 |
| pH $H_2O$ | 5.4 | 5.6 | 5.3 | 5.4 |
| pH KCl | 4.7 | 4.7 | 4.3 | 4.5 |
| ΔPh | -0.7 | -0.9 | -1 | -0.86 |
| Calcium (mEq %) | 3.20 | 3.60 | 3.60 | 3.46 |
| Magnesium (mEq %) | 0.40 | 0.40 | 0.40 | 0.40 |
| Potassium (mEq %) | 2.15 | 0.71 | 0.69 | 1.18 |
| Sodium (mEq %) | 0.38 | 0.25 | 0.25 | 0.29 |
| S (mEq %) | 6.13 | 4.96 | 4.93 | 5.34 |
| CEC (mEq %) | 25.92 | 21.12 | 23.52 | 23.52 |
| V (%) | 24 | 23 | 21 | 22.67 |
| TOC (%) | 5.71 | 4,95 | 5,33 | 5.33 |
| OM (%) | 9.85 | 8.54 | 9.19 | 9.19 |
| Total Nitrogen (%) | 0.14 | 0.14 | 0.13 | 0.13 |
| C/N ratio | 42 | 35 | 40 | 39 |
| P bray II (mg/kg) | 6.95 | 5.41 | 6.72 | 6.36 |

**TOC:** Total organic carbon, **OM**: Organic matter

The total monthly rainfall that occurred throughout the conduct of the study ranged from 0 to 226 mm with an average annual precipitation of 79 mm (Table 2).

**Table 2.** Rainfall (mm) that occurred during the conduct of the study.

| Rainfall | Distribution of rainfall during the trial | | | | | |
|---|---|---|---|---|---|---|
| | August | September | October | November | December | January |
| Rainfall records | 07 | 24 | 13 | 05 | 01 | 00 |
| Rainfall (mm) | 56 | 226 | 101 | 74 | 17 | 00 |

The average amount of rainfall obtained was 22.8 times lower than the average estimated annual precipitation of 1800mm.Such a wide range variation in rainfall could probably be one of the consequences of climate change. The total amount of rainfall of 79 mm in the 104 day growth period was not adequate for the growth and development of Congo grass which needs rainfall ranging from 1000 to >3000 mm year$^{-1}$ (Cook et al., 2005) for its development.

**Dry mass production**

The effect of different levels of nitrogen fertilizer on the dry matter yields of Congo grass is shown in Figure 1. A linear regression obtained from the results showed that the dry biomass yield is linked to the different doses of nitrogen by a cubic function written in the form:

$Y = 27.4 + 9.7 \times 10^{-4}X^2 – 5.06 \times 10^{-6}X^3$ ($R^2$= 93.65%; probability = 0.03173),

With Y = dry biomass yield (t DM/ha) and X = nitrogen doses (kg.ha$^{-1}$).

This function admits an optimum corresponding to 31.98t/ha of dry yield when the nitrogen fertilizer rate is applied at 150 kg N/ha. Similarly, Costa et al. (2012) found a linear effect of nitrogen fertilization on the biomass yield of *B. brizantha* with the application of up to 160 kgN.ha$^{-1}$. However, the maximum value was estimated with the application of 145.9 kg of N/ha. It was also observed that between 0 and 150 kg N/ha, the dry biomass yield increased as the levels of nitrogen applied increased. However, the dry biomass yield decreased when the rate of nitrogen fertilizer application ranged from 150 to 200 kgN.ha$^{-1}$.

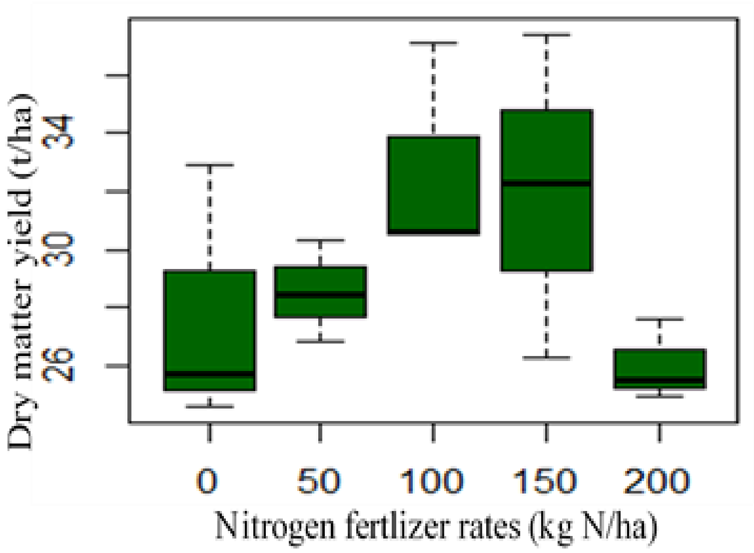


**Figure 1.** Effect of nitrogen fertilization rate on dry mass production of Congo grass.

Nitrogen fertilization positively enhanced the dry biomass production of *B. ruziziensis*. The increase in dry biomass forage with the level of nitrogen fertilization observed during this test is in agreement with the observations of many authors (Obulbiga and Kaboré-Zoungrana 2007; Pamo et al, 2008; Silva et al., 2013; Paiva et al., 2019). However, the dry biomasses of Congo grass obtained with the fertilization levels of 50, 100, 150, and 200 kg N/ha showed no significant difference ($P$>0.05) compared to the control treatment where no nitrogen was supplied to the soil. This result is different from the results obtained by Pamo (1991) and Zanine et al. (2020) who obtained significant differences when comparing dry biomass obtained from nitrogen fertilized plots with unfertilized plots in the case of *B. ruziziensis* and *Brachiaria brizantha*, respectively. However, the dry biomass obtained with fertilized as well as unfertilized experimental units was greater than those reported by Appadurai and Goonawardene (1973), who fertilized *B. ruziziensis* with 224 kg N.ha$^{-1}$ and 366 kg N.ha$^{-1}$ and obtained 22.03 t DM.ha$^{-1}$ and 25.60 t DM.ha$^{-1}$, respectively. This disparity can be explained by the plot's high fertility at the time of the study. Indeed, the organic matter content of the soil at the beginning of the experimental period (9.19%) may have influenced the responses of Congo grass, since total nitrogen in the soil is a component of the soil organic matter and has its dynamics associated with it (Nunes et al. 2011).

The decrease in yield observed with fertilization rates ranging from 150 kg N.ha$^{-1}$ to 200 kg N.ha$^{-1}$ is consistent with the findings of Olsen (1982), who demonstrated that supplying nitrogen at a dose that exceed the plant's demands for prospective growth no longer increases forage yield. Maurice et al. (1985) have shown that nitrogen fertilization at dosages that exceed the plant's potential growth demands causes a decline in biomass production owing to ammonium toxicity.

**Table 3.** Total content of macronutrient elements in *B. ruziziensis*.

| Treatments | Macronutrients content ($mg.kg^{-1}$) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Nitrogen | Phosphorus | Potassium | Calcium | Magnesium | Iron | Sodium |
| T1 | $343.7 \pm 67.4^{c}$ | $233.2 \pm 74.9^{b}$ | $1235.7 \pm 231.1^{b}$ | $5556.6 \pm 2641.6^{b}$ | $1880.8 \pm 1292.4^{a}$ | $25.6 \pm 7.8^{b}$ | $65.3 \pm 14.9^{a}$ |
| T2 | $333.4 \pm 24.3^{c}$ | $240.2 \pm 52.1^{b}$ | $1286.9 \pm 96.2^{b}$ | $5877.7 \pm 1265.8^{b}$ | $2028.8 \pm 1222.6^{a}$ | $25.8 \pm 5.5^{b}$ | $66.7 \pm 12.2^{a}$ |
| T3 | $499.9 \pm 199.1^{ab}$ | $312.2 \pm 15.0^{a}$ | $1408.3 \pm 83.1^{a}$ | $8199.1 \pm 1174.1^{a}$ | $1090.5 \pm 609.8^{b}$ | $31.3 \pm 9.8^{a}$ | $73.7 \pm 8.0^{a}$ |
| T4 | $597.8 \pm 192.9^{a}$ | $317.6 \pm 69.3^{a}$ | $1445.5 \pm 330.2^{a}$ | $7044.8 \pm 1560.0^{ab}$ | $2313.0 \pm 1432.3^{a}$ | $33.3 \pm 5.5^{a}$ | $72.7 \pm 17.8^{a}$ |
| T5 | $432.1 \pm 52.8^{ab}$ | $271.5 \pm 50.0^{a}$ | $1129.9 \pm 348.2^{b}$ | $6211.4 \pm 930.1^{b}$ | $1178.1 \pm 275.7^{b}$ | $27.2 \pm 8.9^{ab}$ | $58.1 \pm 17.6^{b}$ |

Data are the averages of three replications (mean ± standard deviation). Means followed by different letters in the same column are significantly different according to the protected least significant difference test at $P$ = 0.05.

The results showing the accumulation of macronutrients in *B. ruziziensis* in response to nitrogen fertilizer application are presented in Table 3. The macronutrients content of the plants ranged from 333.3 to 597.8 mg.kg$^{-1}$, 233.2 to 317.6 mg.kg$^{-1}$, 1129.9 to 1445.5 mg.kg$^{-1}$, 5556.6 to 8199.1 mg.kg$^{-1}$, 1090.5 to 2313.0, 25.6 to 33.3 g/kg, and 58.1 to 73.7 mg.kg$^{-1}$, for nitrogen, phosphorus, potassium, calcium, magnesium, iron and sodium, respectively. The T4 treatment, which included nitrogen fertilization at a rate of 150 kg N.ha$^{-1}$, resulted in greater nitrogen, phosphorus, potassium, magnesium, and iron accumulation. The T3 treatment, which included nitrogen fertilizer evaluated at a rate of 150 kgN.ha$^{-1}$, recorded the highest calcium and sodium accumulation in Congo grass. Therefore, no significant difference was observed when comparing the different nitrogen fertilization treatments with the control. This may be explained by the fact that the total quantity of minerals present on the surface and deep horizons of soil cannot cover the needs of the forage as soil grows. Therefore, with its large root volume, *B. ruziziensis* was able to go below the crop horizon (0-25cm) to pick up nutrients. Especially since, according to Husson et al. (2008), *B. ruziziensis* has a fasciculate root system composed of numerous roots that are dense and capable of developing at depths greater than 1.80 m.

## Conclusion

The soils of the western highlands agro-ecological zone of Cameroon, like most of the soils of sub-Saharan Africa, are overexploited, and most of the fertilizers used are leached. Congo grass has shown through this test its ability to draw nutrients beyond the crop horizon. Thus, the fertilized units did not lead to a significantly different yield ($P > 0.05$) from the unfertilized units. However, it is important to note that although there is no significant difference at the 5% threshold, the yield increases with the addition of nitrogen up to 100 kg N.ha$^{-1}$ and then decreases to 200 kg N.ha$^{-1}$.

## Conflicts of interests

The authors declare that there are no conflicts of interest.

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