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Effect of Different Levels of Mineral Fertilization and Phenological Stage on Growth and Biomass Production of *Paspalum plicatulum*

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ABSTRACT

The direct effect of six levels of mineral fertilization with NPK (17-17-17) on the growth and biomass production of Paspalum plicatulum was evaluated at different phenological stages at the Bareng Agronomic Research Station at the Fouta Djallon Central Plateau (Middle Guinea). A factorial design comparing six doses of nitrogen fertilizer (0; 50; 100; 150; 200 and 250 kg N/ha) and three phenological stages (bolting, flowering and after seed set) on plots of 8 m² (4 x 2 m) in four replicates, for a total of 72 experimental plots was used. At each phenological stage, 64 plants were collected per treatment for measurements of heights and diameters. Stem, leaf and whole plant biomass assessment was done on each plot based on nitrogen fertilizer level and phenological stage. The results obtained showed that the mineral fertilization and the phenological stage influence in a positive way (P <0.05) the height and the diameter of P.plicatulum. Regardless of the phenological stage, the highest height and diameter were obtained with a dose of 200 kg N/ha. In addition, the biomass of stems and whole plants of P. plicatulum was increased (p <0.05) with the phenological stage regardless of the level of fertilization. The highest leaf biomass was obtained at bolting (4.12 t DM/ha). The results obtained show that under the agro-ecological conditions of the Central Plateau of Fouta djallon where the test was conducted, the direct effect of fertilization at a rate of 200 kg N/ha makes it possible to obtain the highest growth. P. plicatulum plants were elevated in height, diameter and biomass produced. Plants in the 150 and 200 kg N/ha fertilizer plots had the highest leaf-to-stem ratios (p<0.05) at bolting. Regardless of the level of fertilization, the best leaf-to-stem ratios of P. plicatulum were obtained at bolting.

Keywords: *Paspalum plicatulum, growth, biomass, mineral fertilization, phenological stage;*

INTRODUCTION

In the humid tropics, the need to feed an ever-growing population is now forcing farmers to expand their arable land at the expense of rangelands (Musco et al., 2016; Tendonkeng et al., 2018). This situation results in the narrowing of rangelands and the exacerbation of conflicts between farmers and pastoralists (Pamo et al., 2007, Pamo et al., 2008).

The animals are thus pushed back to the marginal lands with low fertility. An improvement in animal productivity can be achieved not only by controlling production systems, but also by intensifying the production of high-yielding forage species (Pamo et al., 2007, Tendonkeng et al., 2011).

Among the main species introduced to the Fouta Djallon Central Plateau, *Paspalum plicatulum*, a perennial bunchgrass has been well received by ruminants (Ngampongsai and Chanjula, 2009). However, the main factors influencing the growth, yield, and nutritional value of this grass as well as many other grasses are climate, soil, and harvesting (Tendonkeng et al., 2011). *P. plicatulum* is proposed to be used profitably use not only in the improvement of natural pastures but also in green or preserved fodder (Cook et al., 2005). Without fertilization, any form of exploitation of forage plants leads to a decrease in the stock of soil nutrients in general and nitrogen in particular especially when it comes to tropical grasses (Obulbiga and Kaboré-Zoungrana, 2007; Tendonkeng et al., 2011).

However, the misuse of land in agrarian systems in the Central Plateau of Fouta Djallon has contributed to their gradual depletion of nutrients (nitrogen, phosphorus and potassium) (Lauga-Sallenave, 1996). Fodder growing there is very low in biomass and is of very low nutritional value, particularly at the end of the rainy season and throughout the dry season (DNE, 1994).

Various studies have shown that mineral fertilization based on nitrogen fertilizers accelerates plant growth, spreads fodder production over time and leads to a significant increase in biomass (Pamo, 1991, Morot-Gaudry, 1997, Lawlor et al., 2001). If in Cameroon in the same altitude zone as the Central Plateau of Fouta djallon, works by Tendonkeng et al. (2011) have shown that nitrogen fertilization can help to improve the biomass yield of *Brachiaria ruziziensis*, no research has yet been conducted in the Central Plateau of Fouta Djallon on the determination of the optimal level of fertilizer (NPK), and its effect on growth and biomass production of *Paspalum plicatulum* at different phenological stages. The objective of this study is therefore to determine the effect of different levels of mineral fertilization at nitrogen and the phenological stage on the growth and biomass production of *Paspalum plicatulum*.

MATERIAL AND METHODS

Study Zone

The study was carried out at the agronomic research station of Bareng in the Central Plateau of Fouta Djallon, located between 12 ° 70 'and 12 ° 04' west longitude and between 10 ° 55 'and 11 ° 68' north latitude with an average altitude of 925m. This work was conducted from May 2014 to January 2015. The original vegetation of this region is that of a grassy savannah and wooded in places. The rainfall varies between 1600 and 2000 mm per year. The climate of this region is characterized by a rainy season extending from May to November, followed by a cold dry season from December to February and a hot dry season from March to April. March is hottest and records a maximum temperature of 30 ° C. The months of December and January are very cold with a minimum of 7 ° C. The soil of the study zone is of ferralitic type under anthropic pressure through food crops and vegetables in all seasons.

Experimental Design

A factorial design comparing six doses of nitrogenfertilizer (0; 50; 100; 150; 200 and 250 kg N / ha) in the form of NPK (17-17-17) and three phenological stages (bolting, flowering and after seed set) on plots of 8 m² (4 x 2 m, spaced 0.5 m apart) in four replicates, for a total of 72 experimental plots was used. Soil samples (n = 5) were collected from the experimental site in the 0-20 cm horizon before soil preparation and plantation of stump fragments. The soil analysis was carried out at the Laboratory of the Training and Research Unit for Soil Analysis and Environmental Chemistry (UFRASCE) of the University of Dschang following the method describe by Pauwel et al. (1992). This analysis shows that this soil is very acidic sandy-loam (pH<5) with medium porosity. It is poor in major nutrients assimilable (0.13% for nitrogen, 0.53 meq / 100g for potassium and 8.3% for phosphorus) and organic matter (2.53%). This soil requires a fertilizer supplement for intensive forage production. The average organic carbon content (2.53%). The value of the C/N ratio > 20 indicates that the mineralization is blocked or momentarily blocked (Sys et al., 1991). The exchangeable base content was moderate (7.30 meq / 100g). According to Beernart and Bitondo (1992), the Cation Exchange Capacity of 11.5 would be described as low (<20 meq / 100 g). These observations show that this soil cannot retain the ions for the nutrition of the plants, proper characteristics of the oxisols. An improvement of the CEC so that any widespread fertilizer is retained to be made available to the plants is therefore necessary (Tendonkeng et al., 2011).

Soil Preparation, Plantation of Plants and Fertilization

The experimental site was plowed with a tractor and plantation of the plots was done manually. The previous cultural site prior to the implementation of the trial was a fallow of 5 years after two successive years of fonio (*Digitaria exilis* Stapf). The same amount (80g) of phosphate fertilizer in the form of single superphosphate was applied per plot (including controls) as a bottom fertilizer. Young plant of *P. plicatulum* were removed from the fodder base of the Bareng Agricultural Research Station (Fouta Djallon Central Plateau). Theheight of the roots and leaves (dressing) of these young plants was reduced and transplanted on each plotat 4 cm deep and spacing of 25cm x 25cm (160,000 plants / ha). One month after planting, a control cut was made at 20 cm above the soil and the plots fertilized once at different fertilizer doses. The maintenance of the plots consisted of the manual removal of the weeds and the cleaning of the alleys between the different blocks and parcels.

Data Collection

At each of the three phenological stages, 16 plants were randomly collected in each replicate at each fertilization level for a total of 64 (16 plants × 4 replicates) per treatment for the height measurements which was take form the soil to end of the extremity of the highest leaf and the diameter of the stem was take before the first internode. The height of the plants was measured using a tape measure graduated to the centimeter and the diameter using an electronic caliper set to the millimeter.

During the cutting periods (24 plots cut for each phenological stage, ie 6 fertilization levels x 4 replicates) and to avoid edge effects, the clumps of *P. plicatulum* were harvested at 5 cm above the ground and at the center of the plot on a useful surface of 2 m² (2 x 1 m) and weighed. A representative sample of 500g of whole plants taken from biomass measurements was separated into leaves and stems and dried in an oven at 60 ° C to constant weight for dry matter determination and yield assessment. Their proportion has been expressed in dry matter (Tendonkeng et al., 2011).

Statistical Analysis

Data collected on height, diameter, and biomass produced were subjected to multi-factorial analysis using the General Linear Model (GLM). When differences existed between different treatments, the means were separated by Duncan multiple range test at 5% significance level (Steel and Torrie, 1980).

Results

Effect of Different Levels of NPK Fertilization (17-17-17) on Plant Height and Diameter of *Paspalum plicatulum* at Different Phenological Stages

The height of *P. plicatulum* increased with fertilization up to the 200 kg N / ha at bolting, flowering and after seed set(Table 1). At these stages, the height of the plants in the fertilized plots was significantly high ($p < 0.05$) than the plants in the unfertilized plots (controls). Fertilization at a dose of 200 kg N / ha permit, whatever the phenological stage, to have plants having a height greater ($p < 0.05$) than that of other plants. Plant heights of plots fertilized at doses 150 and 200 were not significantly different ($p > 0.05$) at bolting. Similarly, the plant heights of the plots receiving 100 and 150 kg N / ha at flowering were statistically comparable ($p > 0.05$).

Table1. *Effect of different levels of NPK fertilization (17-17-17) on the height (cm) of plants of Paspalum plicatulum at different phenological stages.*

Levels of fertilization (kg N/ha)	Phenological stages		
	Bolting	Flowering	After seed set
0	45.83^{a}	63.81^{a}	67.64^{a}
50	59.10^{b}	75.97^{b}	81.33^{b}
100	70.60^{c}	96.41^{de}	103.08^{d}
150	77.26^{d}	97.55^{e}	103.24^{d}
200	84.03^{e}	108.45^{f}	114.11^{e}
250	75.68^{d}	91.92^{c}	97.03^{c}
SEM	0.986	1.432	1.489
Prob	0.001	0.001	0.001

a, b, c, d, e, f: Means with the same letters in the same column are not significantly different at the 5% level. SEM: Standard Error of the Mean; Prob: Probability.

The diameter of the plants increased with the level of fertilization up to the dose of 200 kg N/ha before decreasing then with the dose of 250 kg N/ha (Table 2). At the time of spawning, fertilization made it possible to obtain plants with greater diameter ($p < 0.05$) than plants of unfertilized plots. Plants in plots fertilized at a dose of 200 kg N/ha were greater in diameter ($p < 0.05$) than other plants. The plant diameters of the plots fertilized at doses of 150 and 250 kg N/ha were comparable ($p > 0.05$) at the bolting. At flowering, the diameter of the plants in the fertilized plots was greater ($p < 0.05$) than that of the control plots. In addition, the plant diameter of the plots fertilized at the 100 kg N/ha dose was comparable ($p > 0.05$) to that of the plants in the plots that received the dose of 150 kg N/ha at flowering. At the after seed setstage, the diameter of plants in all fertilized plots were higher ($p < 0.05$) than that of the plants in the unfertilized plots. Plants in plots fertilized at doses of 150 and 250 kg N/ha respectively, were not significantly different ($p > 0.05$) at the after seed setstage. The highest plant diameter was obtained with plots fertilized at a dose of 200 kg N/ha regardless of the phenological stage.

Table2. *Effect of different levels of NPK fertilization (17-17-17) on the diameter (cm) of plants of Paspalum plicatulum at different phenological stages.*

Levels of fertilization (kg N/ha)	Phenological stages		
	Bolting	**Flowering**	**After seed set**
0	0.38[a]	0.47[a]	0.47[a]
50	0.45[b]	0.56[b]	0.56[b]
100	0.48[c]	0.66[c]	0.68[c]
150	0.57[e]	0.71[c]	0.72[d]
200	0.61[f]	0.77[d]	0.81[e]
250	0.53[d]	0.69[c]	0.74[d]
SEM	0.008	0.011	0.010
Prob	0.001	0.001	0.001

a, b, c, d, e, f :Means with the same letters in the same column are not significantly different at the 5% level. SEM: Standard Error of the Mean; Prob: Probability.

Influence of the Phenological Stage on the Height and Diameter of *Paspalumplicatulum*

The height of *P. plicatulum* increased (p <0.05) with the phenological stage (Figure 1). The heighest plant height was observed at the after seed setstage.

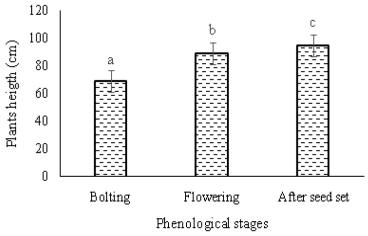

Figure1. *Influence of phenological stage on plant height of Paspalum plicatulum*

a, b: averages with different letters are significant at the 5% level.

The diameter of the stems of *P. plicatulum* increased with the phenological stage regardless the level of fertilization (Figure 2). Stem diameter ofplants at post-seeding stagewas greater (p <0.05) than that at bolting and flowering. Similarly, the plants at flowering showed the higher diameter of the stems (p <0.05) than at the bolting.

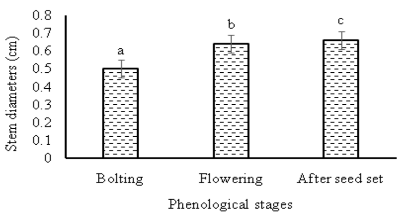

Figure 2. *Influence of the phenological stage on stem diameter of Paspalum plicatulum*

a, b: averages with different letters are significant at the 5% level.

Effect of Different Levels of NPK Fertilization (17-17-17) on Biomass Production (T MS / Ha) of *P. Plicatulum* at Different Phenological Stages

The evolution of the whole plant biomass, leaves and stems of *P. plicatulum* as a function of phenological stages showed that the biomass increased (p <0.05) with the level of fertilization to reach maximum production in plots fertilized at the rate of 200 kg N/ha at the bolting (Table 3). In fact, at this vegetative stage, the biomass of the leaves was greater than that of the stems, regardless of the level of fertilization. On the other hand, the biomasses of whole plants, leaves and stems produced in plots fertilized at doses 150; 200 and 250 kg N/ha were comparable (p>0.05). It was observed at a dose of 250 kg N/ha, a decrease in biomass of about 10% for the whole plant, 11.65% for the leaves and 7.74% for the stems compared to fertilization at the dose 200 kg N/ha. Plant biomasses from fertilized plots were higher (p <0.05) at bolting than those from unfertilized plots.

The whole plant biomass (11.05 t MS/ha), leaves (4.03 t MS/ha) and stems (7.02 t MS/ha) of *P. plicatulum* plants cut at flowering on the plot fertilized at the dose of 200 kg N/ha was higher (p <0.05) than those collected from the unfertilized plots (Table 3). Similarly, at the level of fertilized plots, the highest biomass (p <0.05) of whole plants, leaves and stems was obtained with fertilization at a rate of 200 kg N/ha. In contrast to the bolting stage, the stem biomass at flowering was higher than leaf biomass, regardless of the level of fertilization. As well as during the bolting, a decrease of biomass was observed in plots fertilized at a rate of 250 kg N/ha of the order of 16.65%; 17.86% and 16% respectively for the whole plant, leaves and stems compared to that of plots fertilized at a dose of 200 kg N/ha. At this phenological stage, no significant difference (p>0.05) was observed between whole, leaf and apical biomasses of *P. plicatulum* plants produced in plots fertilized respectively at doses of 150 and 250 kg N/ha. In addition, plant biomasses from fertilized plots were higher (p <0.05) than those from unfertilized plots. At this phenological stage, the biomass produced by the plants of plots fertilized at 150 and 250 kg N/ha were comparable (p>0,05).

At the after seed setstage, stem biomass was more than double than that of leaves, regardless of the level of fertilization applied. In addition, fertilization at the dose of 200 kg N/ha givethe highest biomass of whole plant (11.47 t MS/ha), leaves (3.56 t MS/ha) and stems (7.92 t MS/ha) ($p < 0.05$) at this phenological stage. On the other hand, the biomass of the plants from the plots receiving thedose of 50 kg N/ha was comparable ($p > 0.05$) to that from the unfertilized plots. Similarly, the biomasses of whole plants, leaves and stems of *P. plicatulum* that received 150 and 250 kg N/ha were not significantly ($p > 0.05$) different at the after seed setstage.

As in the previous stages, at the after seed setstage, a decrease of biomass in plots fertilized at a dose of 250 kg N/ha of about 16.65%; 21.34% and 14.14% respectively for the whole plant, leaves and stems compared to that of plots fertilized at the dose of 200 kg N/ha was observed. In general, mineral fertilization at the dose of 200 kg N/ha increased the biomass of stems, leaves and therefore the whole plant of *Paspalumplicatulum* whatever the phenological stage.

Table3. *Direct effect of six levels of NPK fertilization (17-17-17) on biomass production (t DM/ha) of Paspalum plicatulum at different phenological stages*

Levels of fertilization (kg N/ha)	Phenological stages								
	Bolting			Flowering			After seed set		
	PE	F	T	PE	F	T	PE	F	T
0	2.17^a	1.17^a	1.00^a	4.55^a	1.62^a	2.94^a	5.14^a	1.54^a	3.60^a
50	3.50^b	1.94^b	1.57^b	6.21^b	2.30^b	3.93^b	6.60^b	1.80^a	4.80^b
100	5.26^c	2.94^c	2.31^c	8.01^c	3.02^c	4.98^c	8.22^c	2.30^b	5.91^c
150	6.93^d	3.95^d	2.98^d	9.09^d	3.41^c	5.68^d	9.75^d	3.02^c	6.73^d
200	7.22^d	4.12^d	3.10^d	11.05^e	4.03^d	7.02^e	11.47^e	3.56^d	7.92^e
250	6.50^d	3.64^d	2.86^d	9.21^d	3.31^c	5.90^d	9.57^d	2.80^c	6.80^d
SEM	0.364	0.207	0.159	0.289	0.108	0.184	0.338	0.102	0.236
Prob	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

a, b, c, d, e, f : Means with the same letters in the same column are not significantly different at the 5% level. PE = whole plant; F = Leaves; T = stems. SEM = Standard Error of the Mean; Prob = Probability.

Effect of Phenological Stage on Biomass Production (T DM / Ha) of *Paspalum plicatulum*

The evolution of the biomass of the whole plant, leaves and stems of *P. plicatulum* as a function of the phenological stage showed that the biomass of the whole plant was higher ($p < 0.05$) at flowering and after seed setcompared to that obtained at the bolting (Table 4). In addition, no significant difference ($p > 0.05$) was observed between the biomass of the whole plant obtained at flowering and after seed set. The leaf biomass was comparable ($p > 0.05$) regardless of the phenological stage. On the other hand, the biomass of the stems has increased ($p < 0.05$)with the phenological stage.

Table4. *Effect of phenological stage on biomass production (t DM / ha) of Paspalum plicatulum*

Phenological stages	Biomass (t DM/ha)		
	Whole plant	Leaves	Stems
Bolting	5.26^a	2.96^a	2.30^a
Flowering	8.02^b	2.94^a	5.07^b
After seed set	8.45^b	2.50^a	5.95^c
SEM	0.623	0.19	0.262
Prob	0.001	0.154	0.001

a, b,: Means with the same letters in the same column are not significantly different at the 5% level. SEM: Standard Error of the Mean; Prob: Probability.

Effect of Different Levels of NPK Fertilization (17-17-17) on the Leaf/Stem Ratio of *Paspalum plicatulum* at Different Phenological Stages

The leaf/stem ratios of *P. plicatulum* plants at bolting were higher ($p < 0.05$) than those at flowering and after seed set (Figure 3). Plants in plots fertilized at 150 and 200 kg N/ha had the highest leaf/stem ratios ($p < 0.05$) at bolting. At floweringand after seed set, ratios decrease to almost 50% regardless of the level of fertilization. At the after seed setstage, the doses of 150 and 200 kept more leaves than the other doses.

At the flowering stage, we observed a beginning of senescence and the fall of the first leaves formed. This decrease was more pronounced at the after seed setstage, regardless of the level of fertilization.

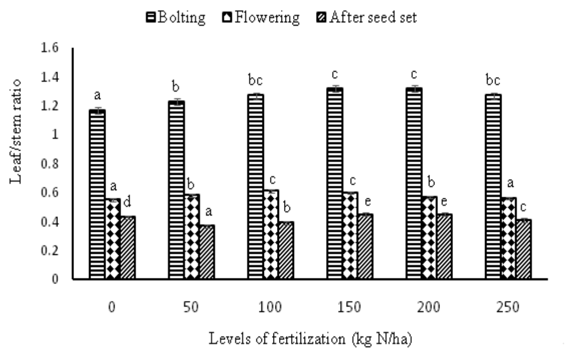

Figure3. *Effect of different levels of fertilization on the leaf/stem ratio P. plicatulum at different phenological stages.*

a, b, c: The averages carrying the same in different doses are not significantly different at the level of 5%.

DISCUSSION

The height and diameter of the plants increased with mineral fertilization level at NPK (17-17-17) to reach the maximum height and diameter with fertilization at a dose of 200 kg N/ha. This observation corroborates that made by Baumont et al. (2009) who argue that mineral fertilization with nitrogen fertilizer favors an increase in the growth rate of vegetation. Similarly, Machado (2013) observed an increase in leaf length of 46% in *Paspalum plicatulum* after the application of 100 kg N/ha compared to plants without fertilization, as a result of the influence of nitrogen (N) on cell division (Gastal and Nelson, 1994). Moreover, the same author noticed that nitrogen fertilization (100 kg N/ha) contributed to the increase in the diameter of the stems of *P. plicatulum* (0.55 mm in plants fertilized against 0.38 mm in plants without fertilization). The decrease in height and diameter with fertilization at 250 kg N/ha could be explained by the fact that at high doses, nitrogen becomes toxic for the plant by limiting its growth and production (Obulbiga and Kaboré-Zoungrana, 2007; Giovanni, 2008;Pamo et al., 2008; Tendonkeng et al., 2011). Indeed, we can think that beyond 200 kg N/ha, the nitrogen supplied by the compound fertilizer (NPK: 17-17-17) hydrolyzes rapidly in areas with high rainfall such as the Central Plateau Fouta djallon to give ammonia (NH_3) and ammonium (NH_4^+). Its effects, which are numerous and complex when they are in excess in the environment, are related to an acidification of the root environment and disturbances of the plant's hydromineral nutrition (Morot-Gaudry 1997, Tendonkeng et al., 2011), which would explain the decrease in size and diameter observed.

Nitrogen fertilization positively influenced biomass production (t MS/ha) of the whole plant of *P. plicatulum* and its different parts. This observation is consistent with the results of many research studies (Lawlor et al., 2001; Obulbiga and Kaboré-Zoungrana, 2007; Pamo et al., 2008; Tendonkeng et al., 2011). The variation in biomass obtained in this study is similar to the results obtained by Graminho et al. (2017), which showed that the biomass of hybrids *Paspalum sp*. ranged from 8 to 19 t DM/ha depending on the level of soil fertility and rainfall. Fertilization increases the rate of growth, which increases production for a given stage of development and reduces the time required to reach a defined yield (Lemaire et al 1999; Lawlor et al., 2001; Tendonkeng et al., 2011). In this study, we observed that biomass increased with the level of fertilization to a threshold above which it began to decline. These observations are in line with the results obtained by many authors (Limami et al., 2001; Lawlor et al., 2001; Tendonkeng et al., 2011). Moreover, this yield decrease is in agreement with the observations made in western Cameroon by Tendonkeng et al. (2011) who showed that an excessive nitrogen supply in *Brachiaria ruziziensis* culture became toxic to the plant and decrease its potential growth. For Maurice et al. (1985), mineral fertilization at nitrogen doses exceeding the potential growth requirements of the plant leads to a decrease in biomass production due to ammonium ion toxicity. Similarly, Lawlor et al. (2001) showed that when the nitrogen supply exceeds the plant's requirements, the efficiency of its use by the latter decreases because it becomes saturated.

The increase in *P. plicatulum* production with the phenological stage, observed in this study, corroborates well with that obtained with the work of Tendonkeng et al. (2011), in the western highland of Cameroon on *Brachiaria ruziziensis*. Indeed, during plant growth, there is an increase in the density of tillers, development of new buds, stems, and acceleration of leaf elongation (Lemaire, 1985). In fact, perennial grasses cut at the young stage are poor in dry matter and have a high water content. At flowering, nutrients are mobilized for seed formation and dry matter. Thus, the proportion of stems becomes greater, which increases biomass at flowering and after seed set (Tendonkeng et al., 2011).

In the bolting phase, *P. plicatulum* plants had very high leaf/stem ratios regardless of the level of fertilization. In the flowering phase, the ratios were 65%. According to Mauries (1994) the leaf/stem ratio decreases during a growing cycle and is directly related to biomass growth. The life of the organs produced by the plant cover, in particular that of the leaves, is limited. At a certain age, the leaves enter a process of senescence, which is characterized by the loss of their photosynthetic capacities, then by their necrosis, their return to the ground in the form of litter and finally by their decomposition (Roberge and Toutain, 1999).

Conclusion

The results of this study on the assessment of the direct effects of different levels of mineral fertilization on the growth and biomass production of *Paspalum plicatulum* at different phenological stages show that fertilization at the dose of 200 kg N/ha significantly increases the height, diameter and biomass production of *Paspalum plicatulum* regardless of the phenological stage. Beyond this dose, it has been observed a decline in growth and biomass production of this perennial bunchgrass in the edapho-climatic conditions of the Central Plateau of Fouta djallon. Regardless of the level of fertilization, *P. plicatulum* plants showed the best leaf/stem ratios at bolting.

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