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Tillering dynamics of Tanzania guinea grass under nitrogen levels and plant densities

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ABSTRACT. This study evaluated the influence of nitrogen levels (N) and plant density (D) on the tillering dynamics of Tanzania guinea grass (*Panicum maximum* Jacq.). Treatments were arranged in a completely randomized block design with 12 treatments and two replicates in a factorial scheme (4 × 3) with four levels of N (0, 80, 160 or 320 kg ha^{-1} N) and three plant densities (9, 25, and 49 plant m^{-2}). Higher number of tillers was observed in the treatment with 9 plants m^{-2} and under higher levels of N, especially in the second and third generations. Still, the N influenced quadratically the appearance rate of basal and total tillers, which were also affected by plant density and interaction N × D. However, the appearance rate of aerial tiller was not influenced by factors evaluated. The mortality rate of total tiller was influenced quadratically by the nitrogen levels and plant densities. The mortality rate of basal tiller responded quadratically to plant density, whereas the mortality rate of aerial tiller increased linearly with fertilization. Pastures with low or intermediate densities fertilized with nitrogen, presented a more intense pattern of tiller renewal.

Keywords: light interception, *Panicum maximum*, tiller, appearance rate, mortality rate.

Dinâmica de perfilhamento do capim-tanzânia sob doses de nitrogênio e densidades de plantas

RESUMO. Objetivou-se com este trabalho avaliar o efeito de doses de nitrogênio (N) e densidades de plantas (D) sobre a dinâmica de perfilhamento do capim-tanzânia (*Panicum maximum* Jacq.). O delineamento foi em blocos casualizados, com 12 tratamentos e duas repetições em esquema fatorial 4 × 3, com quatro doses de N (0, 80, 160 ou 320 kg ha^{-1} ano^{-1}) e três densidades de plantas (9, 25 ou 49 plantas m^{-2}). O número de perfilhos foi maior na densidade de 9 plantas m^{-2} e nas maiores doses de N, principalmente na segunda e terceira gerações. O N influenciou quadraticamente as taxas de aparecimento de perfilhos basilares e totais, que também foram influenciadas pela densidade de plantas e pela interação N × D. A taxa de aparecimento de perfilhos aéreos, no entanto, não foi influenciada pelos fatores avaliados. A taxa de mortalidade de perfilhos totais foi influenciada de forma quadrática pelas doses de N e pelas densidades de plantas. A taxa de mortalidade de perfilhos basilares respondeu quadraticamente à densidade de plantas, enquanto a taxa de mortalidade de perfilhos aéreos aumentou de linearmente com a adubação. Pastos implantados em densidades baixas ou intermediárias adubados com nitrogênio apresentam padrão mais intenso de renovação de perfilhos.

Palavras-chave: interceptação luminosa, *Panicum maximum*, perfilho, taxa de aparecimento, taxa de mortalidade.

Introduction

The pastures yield is a result from a dynamic process where the forage accumulation is characterized by the positive balance between emergence and mortality of tillers. As the persistence of pastoral systems depends on the emergence of new tillers, it is important to seek management strategies that favor the forage tillering, a key feature in the sustainability of pastures.

The study on these strategies may allow identifying management practices that increase the pasture productivity by simply favoring the natural cycle of replacement and renewal of tillers (VALENTINE; MATTHEW, 1999), which according to Santos et al. (2006) is the main way to reduce the negative effect of excessive development of stems and flowering on the nutritional value and morphological composition of the forage.

The tillering in tropical grasses is a structural characteristic that determines the morphological plasticity, which is influenced by combinations of nutritional, environmental and management factors (GARCEZ NETO et al., 2002). It is known that the nitrogen fertilization stimulates both the emergence and renewal of tillers, important to ensure the sustainability of pastures (FAGUNDES et al., 2006; GARCEZ NETO et al., 2002; MARTUSCELLO et al., 2006; MORAIS et al., 2006).

Besides that, the plant density also affects the pasture structure, since it determines the intensity of the intraspecific competition for food resources and nutrients. The plant density or tillers on the pasture also changes the quality and quantity of radiation that penetrates the forage canopy, which will modify the Tiller size/density compensation tradeoff between the size and density of tillers and the ability to produce new tillers (SBRISSIA; DA SILVA, 2008).

Given the above, this study evaluated the influence of nitrogen fertilization and plant density on the tillering dynamics of Tanzania-grass harvested when the canopy intercepted 95% of light.

Material and methods

The experiment was conducted in the Setor de Forragicultura from the Departamento de Zootecnia at Universidade Federal de Viçosa, from November 2007 to March 2008. Viçosa is located in the region of 'Zona da Mata' of Minas Gerais State, at 651 m altitude, at geographic coordinates 20º 45' 40" S and 42º 51' 40". The climate is subtropical (subtype Cwa), with mild, dry winter, and marked rainy and dry seasons (KÖPPEN, 1948). The mean annual rainfall is 1,340 mm, the relative air humidity is around 80% and the maximum and minimum temperatures are 27.3 and 14.9ºC, respectively (Figure 1).

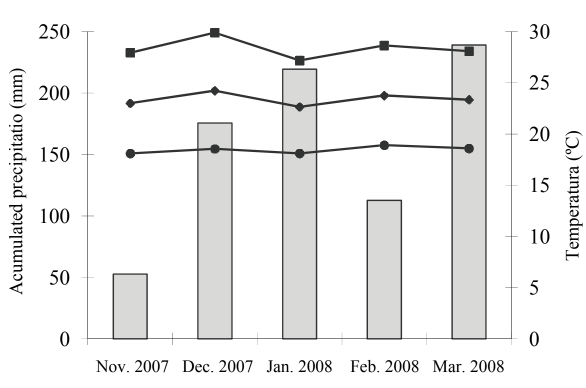


Figure 1. Monthly accumulated precipitation (Prec.) and maximum (Tmax), medium (Taverage) and minimum (Tmin) temperatures observed during the study.

It were used plots with 9 m^2 (3 × 3 m) of guinea grass cv. Tanzania (*Panicum maximum* Jacq.) established since December 2005, when studies on the establishment stage of Tanzania-grass were made by Magalhães et al. (2011). Treatments were arranged in factorial scheme (4 × 3), corresponding to four levels of nitrogen (0, 80, 160 or 320 kg ha^{-1}) and three plants densities (9, 25 or 49 plants m^{-2}), totaling 12 treatments. The design used was the completely randomized block with two replicates, established perpendicular to the slope of the area.

The soil classified as paleudult soil (EMBRAPA, 1999) has clayey texture. Before the start of the experiment (October 2007), soil samples were taken at the depth 0-20cm, which presented the following chemical attributes: pH in water (1:2.5 ratio) = 5.88; P-Mehlich^{-1} = 2.25 mg dm^{-3}; K-Mehlich^{-1} = 47 mg dm^{-3}; Ca^{2+} = 3.4 $cmol_c$ dm^{-3}; Mg^{2+} = 0.88 $cmol_c$ dm^{-3}; Al^{3+} = 0.0 $cmol_c$ dm^{-3}; H + Al = 3.59 $cmol_c$ dm^{-3}, base saturation (V) = 55%; and organic matter (OM) = 1.67 dag kg^{-1}. According to these results, we applied the equivalent of 200 kg ha^{-1} of P_2O_5 in the form of simple superphosphate (18% of P_2O_5).

The nitrogen (N) levels were divided into three applications: the first soon after standardization cut held on November 4th, 2007; and the other after the second and third cut in each plot (experimental unit). It was also applied 150 kg ha^{-1} K_2O, divided into two applications, one soon after standardization cut, and the second after the cut in each plot. The sources of N and potassium (K) were urea (44% N) and potassium chloride (58% K_2O), respectively.

After the standardization cut, the light interception (LI) was monitored in the plots by using the SunScan canopy analysis system (Delta-T Devices, Cambridge, UK). The readings were taken every three days up to readings close to 90%, then the readings were performed daily, up to 95% LI, when the forage was cut with the aid of a brush cutter and then removed. Regardless of canopy height, the cut was made at 25 cm from the ground level.

Tillering dynamics and the respective appearance and mortality rates of tiller were evaluated in two clumps per plot (experimental unit). At the beginning of experimental period, all the tillers in the clump were counted and marked with plastic-coated wire of different colors. With each new sampling, at 28 days-intervals, new tillers were marked with different colors. Thus, it was determined the dynamics of tiller population of all generations (different colors), which allowed monitoring the evolution of the number of tillers (NT) per clump. The data of each replicate were used to estimate the mean NT for each treatment and to construct area charts of the tillering dynamics. This information was evaluated descriptively.

With the NT of each generation throughout the assessment period, it was possible to estimate the mean rates of appearance and mortality throughout the experimental period. The rates were calculated as follows:

$$\%\,TAp = \frac{TIL_{NEW}}{TIL_{TOTAL}} \times 100$$

$$\%\,TMo = \frac{TIL_{TOTAL} - TIL_{SURVIVORS}}{TIL_{TOTAL}} \times 100$$

where:

TAp: tiller appearance rate (%);

TMo: tiller mortality rate (%);

TIL_{NEW}: new tillers emerged in the last marking performed;

TIL_{TOTAL}: sum of the number of tillers of all generations identified before the last marking;

$TIL_{SURVIVORS}$: sum of the number of tillers of previous generations that remained alive in the last marking performed.

The tillers appearance and mortality rates were calculated for each class of tillers (total, basal and aerial), in each of the two clumps and in every generation evaluated. Then the mean value was calculated among the generations and between the two clumps to determine the observation value of the experimental plot.

The data were subjected to analysis of variance and regression analysis using the basic model:

$$\hat{Y} = \hat{\beta}_0 + \hat{\beta}_1 \times N + \hat{\beta}_2 \times N^2 + \hat{\beta}_3 \times D + \hat{\beta}_4 \times D^2 + \hat{\beta}_5 \times (N \times D)$$

where:

N = nitrogen level;

D = plant density.

The remaining degrees of freedom for the treatments were grouped as 'lack of fit'. The models were selected based on the significance of the parameters described above, adopting 0.05 as the critical level for probability of type I error. For the case of significance of 'lack of fit', we evaluated an alternative model to that described above so that there was an appropriate adjustment to the data.

All statistical analyses were performed by the procedures PROC GLM, PROC REG and PROC NLIN implemented in SAS (Statistical Analysis System).

Results and discussion

In the descriptive analysis of the tillering dynamics throughout the study, it was observed that the increase in density resulted in reduced number of tillers per clump (Figure 2). Despite that, the NT of the plots with 25 plants m^{-2} was lower than those with 49 plants m^{-2}, in plots fertilized with 80 and 320 kg ha^{-1} of N. This result was not expected since the condition of 49 plants m^{-2} represents greater competition, which reduces the NT as a function of the increased number of clumps. The initial number of tillers (generation 1) was very similar among treatments involving the density of 9 plants m^{-2}, but in the other treatments, it was quite variable. The density of 9 plants m^{-2} had the higher NT, since due to its low plant density there was greater tillering to fill empty space. Under conditions of less dense canopy, more light penetrates to the lower strata, resulting in more tillering.

At higher levels of N (160 and 320 kg ha^{-1} N) there was an increase in NT in the second generation, because the treatments had been applied since the standardization cut, which means that these plots received higher doses of N and thus presented increase in NT (Figure 2). On the other hand, the plots that did not receive or received the lowest dose had maintained the NT or presented a slight increase. This increase may have been caused by the application of phosphorus and potassium, which was standardized for all treatments, and also due to the occurrence of conditions favorable to tillering, such as higher rainfall and temperature.

The third generation was characterized by maintenance or small reduction in the NT in most treatments (Figure 2), which can be explained by the maintenance of fertilization levels through top-dressing fertilization. Besides that during this period it was also observed a high mortality, which was balanced by the emergence of new tillers. This pattern of intense renewal may be due to the increased availability of resources and the higher mortality of tillers caused by the more frequent defoliation. This response pattern was not observed in the plots that were not fertilized with N or received the equivalent to 80 kg ha^{-1}. In these plots, both the reduction of NT as the emergence of new tillers were less intense, except for the plots of treatments with fertilization of 80 kg ha^{-1} and densities of 9 and 49 plants m^{-2}. Probably after the third generation, these plants had already received at least two portions of fertilization, which favored this trend from the third and fourth generations.

The fourth generation in the plots that received 320 kg ha^{-1} N was characterized by a remarkable reduction in NT. Probably this decrease was caused by the occurrence of dry spell during the rainy season in February. The reduction in rainfall associated with greater leaf area of plants fertilized with 320 kg ha^{-1} N may have implied in a more severe stress to these plants. In this occasion, the plants would also have received all the portions of fertilization and thus have not maintained the same pattern of previous generations.

The fifth generation was characterized by the maintenance of the NT in most treatments and increase in the plots that received 320 kg ha^{-1} N (Figure 2). This observation confirms the possibility of damages caused by the little rainfall in February, because in March, with more rainfall, there was a substantial increase of NT in these plots.

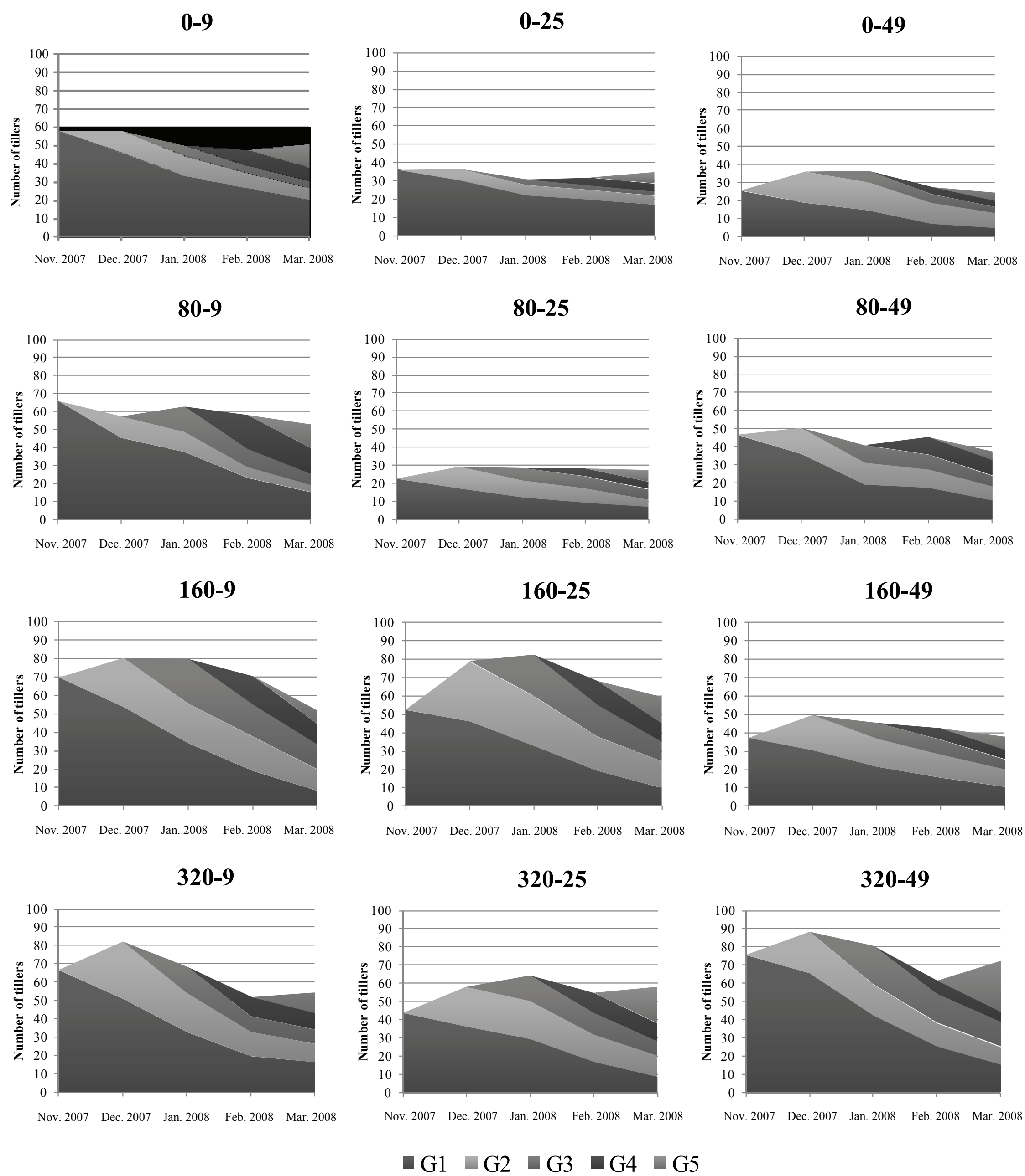
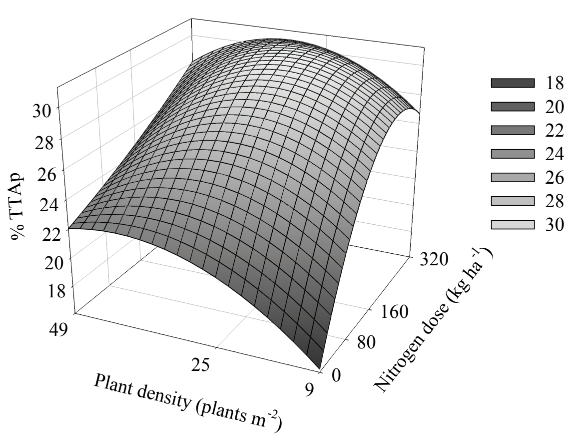


Figure 2. Number of tillers per generation in Tanzania guinea grass subjected to different nitrogen levels and plant density where the number above each graph correspond to the combination between nitrogen level and plant densitys evaluated in five generations of tillers (G1 to G5).

A significant effect ($p < 0.05$) was detected of the nitrogen level, plant density and interaction between these effects on the total tillers appearance rate (TTAp), which was quadratically affected by both factors (Figure 3).

The TTAp was low in the absence of N, especially in the density of 9 plants m^{-2}. When the plants were established in density of 49 plants m^{-2}, the response of the TTAp to the application of N was not significant in relation to the others, so that the rates of 22.0, 23.3 and 24.7% were observed for the absence of N and for the levels of 80 and 160 kg ha^{-1}, respectively. In the density of 25 plants m^{-2}, the TTAp increased from 20.9 to 29.7% with the application of 160 kg ha^{-1}, and in the density of 9 plants m^{-2}, the TTAp increased from 16.2 to 26.8%, values close to the maximum TTAp estimated. This result can be related to the effect of dense plant communities in promoting higher competition for nutrients. Garcez Neto et al. (2002) verified a significant effect of nitrogen supply on the total number of tillers, with a 21%-increase in the population. According to these authors, the tillering in grasses is a structural characteristic that determines the morphological plasticity of the plants, which is strongly influenced by combinations of nutritional, environmental and management factors. Furthermore, another factor that may have contributed to the lower TTAp at high plant densities is the self-shading caused by the accelerated development of plants fertilized with N (SACKVILLE-HAMILTON et al., 1995).



$$\hat{Y} = 12.2808 + 0.10288N - 0.000218N^2 + \\ + 0.4929D - 0.00599D^2 - 0.000037ND^2 + \\ + 0.000000097N^2D^2 (R^2 = 0.8356)$$

Figure 3. Total tillers appearance rate (TTAp) in Tanzania guinea grass fertilized with nitrogen (N) in different plant densities (D).

The maximum TTAp (31%) was estimated for the combination between the density of 27 plants m^{-2} and the level of 260 kg ha^{-1} N. This result converges with the increase observed in the plots with densities between 25 and 49 plants m^{-2} fertilized with 160 and 320 kg ha^{-1} N.

In the absence of nitrogen fertilization, the TTAp increased with the density of plants up to 25 plants m^{-2}, remaining constant. However with the application of N, an increase with the density was verified up to values close to 25 plants m^{-2}, from which it decreased. Despite this, under high fertilizations, the differences between plant densities were less marked (Figure 3). This fact suggests that the high availability of N may partially compensate the self-shading caused by high plant density. The results of Carvalho et al. (2006) do not support our results, since according to these authors, the tillering dynamics of elephant-grass managed under rotational stocking was not affected by the height of the stubble, which also increase the shading inside the canopy.

The basal tillers appearance rate (BTAp) was influenced quadratically by N levels ($p < 0.05$), with no effect of plant densities and interaction between these factors ($p > 0.05$; Figure 4). The maximum basal tillering of Tanzania guinea grass (BTAp of 33%) was estimated for the level of 257 kg ha^{-1} N. This value is quite close to the maximum total tillering and is a result of the greater participation of basal tillers on total number.

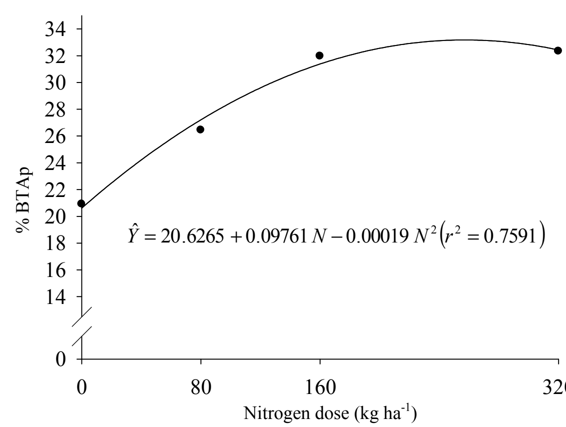


Figure 4. Basal tillers appearance rate of (BTAp) in Tanzania guinea grass fertilized with nitrogen (N).

The increases in the BTAp obtained with the application of 80, 160 and 320 kg ha^{-1} N were 32, 52, and 57%, respectively. The effect of this nutrient on the BTAp can be associated with its ability to stimulate the formation of new tillers not only by increasing the number of buds, but also by the increase in the development of basal buds.

According to Davies (1974), the number of leaves formed on the tiller axis determines the maximum potential for appearance of new tillers and the occupation or development of these buds is called 'site filling'. In this way, Morais et al. (2006) verified a linear effect of nitrogen levels on the basal tillering of pastures of *Brachiaria decumbens* cv. Basilisk during the dry and water-dry transition periods, and related this effect to the increase in the appearance of leaves reported in these periods.

The quadratic trend of the BTAp to the N levels also can be due to the self-shading caused by the greater production of leaves. According to Skinner and Nelson (1992), in dense canopies the tillering is usually lower than the potential determined by the leaf appearance rate, which characterizes the effect of strong competition for assimilates and light, and defines the concept of 'site usage'.

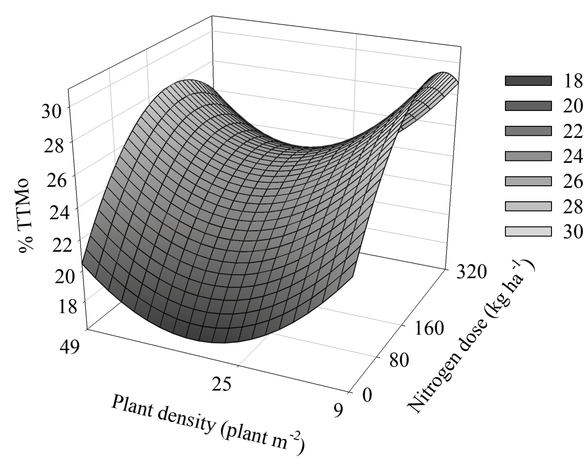
There was no influence from N levels, plant density and interaction between the factors on the aerial tillers appearance rate (ATAp), whose mean value was 22% of total aerial tillers present in each evaluation. The lack of effect can be attributed to the high coefficient of variation observed for the ATAp (65.7%). Nevertheless, it was expected that the ATAp was greater at higher levels of N, considering the effects of this nutrient on the tillering of forage grasses.

There are few studies in literature about the effect of plant densities and N on the aerial tillering. Giacomini et al. (2009), in an experiment with palisade grass cv. Marandu under intermittent stocking submitted to 95 or 100% of light interception and intensities of 10 and 15 cm of post-grazing residue, have observed increase in ATAp in the plants kept at 95% LI and 15 cm of post-grazing residue during the spring and summer. According to the authors, the production of aerial tillers could be a strategy for a rapid increase in the leaf area index of pastures. On the other hand, Difante et al. (2008) state that the increase in stem elongation due to flowering and the subsequent cut of these tillers can increase the ATAp by removing the apical meristem, which is also applicable to canopy with excessive development of stems.

The total tillers mortality rate (TTMo) was influenced quadratically, both by N levels and plant density, but there was no interaction between these factors (Figure 5). Regardless of the level of N applied, a reduction was detected in TTMo at intermediate density, which was not expected since the highest density (49 plants m^{-2}) leads to a stronger competition between tillers and therefore to a lower mortality. The lower mortality of tillers was registered for the density of 32 plants m^{-2}.

The maximum TTMo was estimated for the level of 212 kg ha^{-1} N. The mortality rates observed for the levels of 80, 160 and 320 kg ha^{-1} were similar and greater than that obtained without the application of N.

The increased mortality of tillers in the plants fertilized reflects the importance of tillers renewal during the growth period of the forage (SANTOS et al., 2006), especially under suitable availability of N. On the other hand, the lower TTMo in the absence of fertilization may be an indication that the guinea grass cv. Tanzania in N deficiency reduces the mortality of tillers as a survival strategy. In this way, first the plants reduce the propagation of new tillers to keep the growth of existing tillers under limiting growth conditions. Thus, Fagundes et al. (2006) observed an increase of population density of vegetative tillers and reduced density of dead tillers in pastures of signal grass fertilized with nitrogen during growth period.



$$\hat{Y} = 28.8677 + 0.0709N - 0.000167N^2 - $$
$$- 0.7375D + 0.01155D^2 \ (r^2 = 0.7701)$$

Figure 5. Total tillers mortality rate (TTMo) in Tanzania guinea grass fertilized with nitrogen (N) in different plant densities (D).

The basal tillers mortality rate (BTMo) was influenced quadratically by plant densities, with no effect of N and interaction between the factors ($p < 0.05$; Figure 6). The lowest BTMo was estimated for the density of 31 plants m^{-2}, but it was not expected a quadratic trend for this variable, so that higher densities tend to reduce mortality due to stress conditions represented by the competition for resources. Santos et al. (2011) improved the balance between the tiller appearance and tiller mortality rates of signal grass by reducing the sward height during the dry period. According to these authors, the improvement of environmental conditions represented by the height reduction in the dry period allowed a balance favorable to the appearance of tillers, which were younger when reached the growth period.

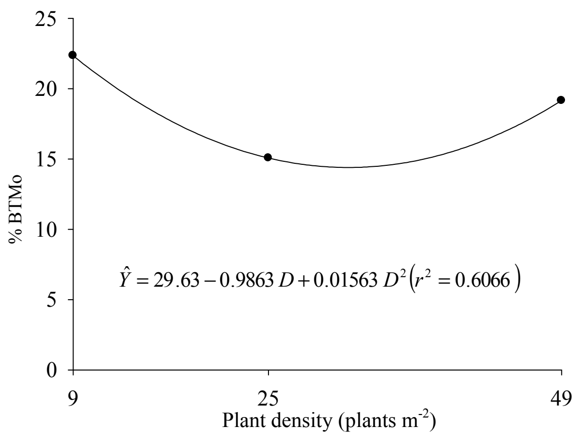


Figure 6. Basal tillers mortality rate (BTMo) in Tanzania guinea grass under different plant densities (D).

The levels of N influenced linear and positively the aerial tillers mortality rate ($p < 0.05$) (ATMo), but there was no effect of plant density or interaction between these factors on this variable (Figure 7).

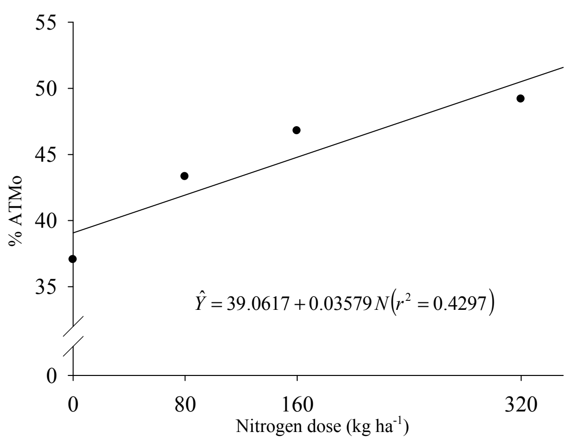


Figure 7. Aerial tillers mortality rate (ATMo) in Tanzania guinea grass fertilized with nitrogen (N).

The values of ATMo in the absence of N and at the level of 320 kg ha^{-1} were respectively 39 and 50%, corresponding to an increase of 29% in ATMo. The higher mortality of aerial tillers of plants fertilized with nitrogen can be associated with the increased frequency of cuts and to the effect of N on the elongation of stems of tropical forage. This may have increased the probability of removal of aerial tillers, above the post-grazing height, since not only senescent tillers were used to determine the mortality rate, but also the tillers not found in the following evaluation. A major cause of tiller mortality is the removal of apical meristem, especially of tillers at reproductive stage or in plants with caespitose growth, where the rapid elongation of internodes causes its elevation to the level of grazing or cutting (DIFANTE et al., 2008; FONSECA et al., 2010). Indeed, due to the upper level of insertion of aerial tillers there is high chance of removing the meristem or the tiller itself. Giacomini et al. (2009) observed increased mortality of aerial tillers during the growth period of palisade grass cv. Marandu and reduction in the autumn and winter, which suggest the occurrence of greater longevity of tillers under unfavorable conditions.

Beyond the effect of N on the renewal of plant tissue, the increased mortality observed in this study may be a result of the self-shading caused by the rapid development of forage canopy of fertilized plants. The ATMo was lower than BTMo, indicating more pronounced renewal of basal tillers.

Conclusion

The plant density and the nitrogen fertilization influenced the tillering dynamics of Tanzania guinea grass defoliated with 95% of light interception. The number of tillers per clump was higher in the plots with 9 plants m^{-2} and in those that received 160 or 320 kg ha^{-1} of nitrogen.

In plants of guinea grass cv. Tanzania fertilized with nitrogen, the appearance of total tillers is favored mainly at intermediate densities, while the mortality is reduced in intermediate and high plant densities; thus the pastures established with low or intermediate densities fertilized with nitrogen, presented a more intense renewal of tillers.

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