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The nitrogen to potassium ratio affects the growth of Mavuno grass

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ABSTRACT
Nitrogen (N) and potassium (K) are nutrients that act together for plant development, acting mainly in photosynthesis and plant cell division processes. This work aimed to evaluate the effect of different N: K ratios on the morphogenic, structural, and productive characteristics of Mavuno grass (*Urochloa* sp.) grown in a greenhouse. A completely randomized design with four replications was used. The treatments used were a control (without application of N and K) and five N: K ratios (75:0, 0:75, 75:75, 150:75, and 300:150 kg ha^{-1}). Urea was used as nitrogen fertilizer and potassium chloride as potassium fertilizer. Two production cycles were carried out, lasting 28 days each. The leaf appearance rate when fertilization was carried out with both nutrients was higher (P<0,05) than the other treatments being the highest for 75:75 ratio. The same effect was observed for the leaf elongation rate. The population density of tillers was greater (p<0.05), as the N: K ratio was increased, with the ratio 300:75 differing approximately 128%, 97%, and 80% from the ratios 0:0, 75:0 and 0:75. Dry matter production showed a difference (p<0.05) between treatments, where the relationships that included both nutrients showed higher productivity. The proportion of leaf blade differed between the N: K ratios (p<0.05), with a greater proportion of this component being observed in the absence of one of the nutrients. Therefore, fertilization with N and K favors the development and productivity of Mavuno grass, where observed that the 75:75 ratio presented better production and growth rates in Mavuno grass, being an efficient solution for the grass.

Key words: fertilization, forage, macronutrients, morphogenesis, productivity

A relação nitrogênio e potássio afeta o crescimento do capim Mavuno

RESUMO
O nitrogênio (N) e o potássio (K) são nutrientes que agem em conjunto para o desenvolvimento vegetal, atuando principalmente em processos de fotossíntese e divisão celular da planta. Este trabalho teve como objetivo avaliar o efeito de diferentes relações N:K sobre as características morfogênicas, estruturais e produtivas do capim-Mavuno (*Urochloa* sp.) cultivado em casa de vegetação. Foi utilizado um delineamento inteiramente casualizado e quatro repetições. Os tratamentos utilizados foram uma testemunha (sem aplicação de N e K) e cinco relações N:K (75:0, 0:75, 75:75, 150:75 e 300:150 kg ha^{-1}). A ureia foi utilizada como adubo nitrogenado e o cloreto de potássio como adubo potássico. Foram feitos dois ciclos de produção, de 28 dias cada. A taxa de aparecimento foliar quando feita adubação com os dois nutrientes foi maior (p<0.05) do que os outros tratamentos, sendo maior na relação 75:75. O mesmo efeito foi observado para a taxa de alongamento foliar. A densidade populacional de perfilhos foi maior (p<0,05), conforme a relação N:K era aumentada, chegando à relação 300:75 diferir aproximadamente 128%, 97% e 80% das relações 0:0, 75:0 e 0:75. A produção de matéria seca apresentou diferença (p<0,05) entre os tratamentos, onde as relações que contaram com os dois nutrientes apresentaram maiores produtividades. A proporção de lâmina foliar diferiu entre as relações N:K (p<0,05), sendo observado uma maior proporção desse componente na ausência de um dos nutrientes. Portanto, a adubação com N e K favorece o desenvolvimento e a produtividade do capim Mavuno, onde se observou que a relação 75:75 apresentou melhores taxas de produção e crescimento no capim Mavuno, sendo uma solução eficiente para o capim.

Palavras-chave: adubação, forragem, macronutrientes, morfogênese, produtividade

INTRODUCTION

Pasture degradation is a common phenomenon in agricultural systems and represents a significant challenge to the productivity and sustainability of the agricultural sector (Barbieri and Féres, 2021). In this context, the availability of essential nutrients, such as nitrogen (N) and potassium (K), performer a crucial role in the recovery and maintenance of pasture quality (Yarborough et al., 2017a; Cunha et al., 2021). Recent studies have show a positive response of mavuno grass (*Urochloa hybrida*) to nutrients, increasing its productivity, the proportion of leaves, and population density of tillers (Pereira et al., 2021; Prudencio et al., 2023).

Nitrogen is a nutrient most required by crops, and its absorption by the plant is dependent on several soil and climate factors (Jardim et al., 2018). However, K is often neglected during fertilization stages, leading to nutrient depletion in the soil (Zhang et al. 2010). Losses of nutrients in the system are inevitable causes of occurrence, therefore, the nutritional reestablishment of the soil through fertilization practices must be corrected annually (Spiess, 2011). The lack of nutrient replacement compromises crop yield, reducing biomass production in the following year, and consequently the pasture support capacity (Campiglia et al., 2014).

In studies with *Panicum sp*., it is seen that fertilization with N and K together has better responses than when applied individually (Kering et al., 2012). This is because K participates in protein synthesis during nitrogen metabolism, therefore, N fertilization increases protein synthesis in the plant, accelerating plant development (Zahoor et al., 2017; Makino; Ueno, 2018). However, it is necessary to correctly meet the need for both nutrients, so that they do not become limiting for each other (Kering et al., 2012).

Based on this, the combined effect of N and K in tropical grasses, such as mavuno grass, can increase the tiller population and grass productivity, due to rapid leaf recovery after defoliation. Furthermore, nutrients tend to increase the leaf dynamics of mavuno grass, due to the accelerated process of cell division in meristematic tissues (Lima et al., 2019; Cunha et al., 2022).

To this end, we objected to determining the effect of different N: K ratios on the morphogenic, structural, and productive characteristics of mavuno grass.

MATERIAL AND METHODS

A study was conducted in Igarapé-Açu, Pará, Brazil (1°07'44''S, 47°36'24''W), under greenhouse conditions from November to April 2021. The E horizon of a Yellow Oxissol was collected and used in the vases for cultive. The soil was analyzed for chemical characteristics (pH in water = 5.99; P Mehlich = 5 mg dm^{-3}; K = 0.4 mmol dm^{-3}; Ca^{2+} = 8.0 mmol dm^{-3}; Mg^{2+} = 4.0 mmol dm^{-3}; H + Al = 43 mmol dm^{-3}, SB: 22%). The maximum and minimum temperature observed in the experimental period were 30.7 and 24.2 °C, respectively.

The treatments were six combinations of nitrogen (N) and potassium (K), 0:0; 75:0; 0:75; 75:75; 150:75, and 300:150 kg of N and K $ha^{-1,}$ respectively, distributed in a completely randomized design with four replications. The experimental units were vase (25 cm in diameter and 30 cm in height) filled with approximately 10 kg of soil. Ten seeds of *Urochloa sp.* cv. Mavuno in each vase. After 14 days, the seedlings were thinned, leaving only three per pot. The plants remained growing for 45 days after thinning so that they all had similar initial growth.

After the growth period, the forage mass was cut 35 cm above ground. Afterwards, all pots received the equivalent of 90 kg of P_2O_5 ha^{-1}, and the corresponding doses of N and K. The source of N applied was urea and the source of K applied was potassium chloride. Fertilization was calculated and applied to the soil surface. The fertilized were applied only at the beggining of the experiment. The evaluations were conducted in two cycles of 28 days. The average of cycles was used.

To evaluate the morphogenic and structural characteristics, three tillers per pot were identified. Morphogenic assessments began five days after the application of treatments. The three marked tillers were evaluated every three days with records of leaf appearance, ligule exposure, length of expanded, expanding, and senescent leaves, and the number of living leaves per tiller. The evaluations were: Leaf appearance rate (LAR) – leaves day^{-1}; Leaf elongation rate (LER) – cm of leaf day^{-1}; Phyllochron (number of days for the appearance of two consecutive leaves) – days $leaf^{-1}$; Leaf senescence rate (LSR) – cm leaf day^{-1}; Leaf life span (LLS) – days; Stem elongation rate (SER) – cm of stem day^{-1}; Final leaf size (FLS) – cm; Number of living leaves per tiller (NLL); Tiller population density (TPD), by counting all tillers contained in the pot (tillers $vase^{-1}$). The height of the canopy was measured from the ground to the apex using a ruler graduated in centimeters, without extending the leaves, on the day of defoliation.

The collected fresh mass was weighed, and the morphological components (leaf blade, stem, and dead material) were separated. Samples were weighed and dried at 65 °C for 72 hours to determine dry matter. From the dry weight, it was possible to calculate: Dry matter production (kg DM^{vase-1}), proportion of leaf blade (g kg^{-1}), proportion of the stem (g kg^{-1}), the proportion of dead material (g kg^{-1}) and the leaf blade: stem ratio.

The statistical model adopted was: $Yij = \mu + Pi + Ɛij$; onde: Yij, dependent variables; μ, mean value common to all observations; Pi, fixed effect of N:K ratio applied; Ɛij, random error of each observation.

All data were analyzed for normality and homogeneity of variance following the Shapiro-Wilk and Levene tests, respectively. Analysis of variance (ANOVA) was performed, and when significant, the means were compared using the Tukey test ($p<0.05$). All statistical analyses were performed using the statistical program R (version 4.4.2; R Core Team, 2023).

RESULTS

Effects of N:K ratios on LAR, LER, phyllochron, LSR, and LLS were observed ($P<0.05$). Higher values of LAR and LER are observed in the 75:75 ratio (Table 1), however, it is seen that only potassium fertilization causes a decrease in the rate of leaf development. The phyllochron, which is the inverse of LAR, showed the lowest values in the 75:75 ratio, with a time of approximately eight days for the appearance of two consecutive leaves.

The relationship is also evident in LSR, where 75:75 fertilization presents a higher rate of leaf senescence than the others. However, the 300:150 relationship showed that LLS is lower when fertilizer levels increase, even decreasing in up to two days the LLS in relation to relations with the absence of any of the nutrients. Stem elongation rate was not affected (p=0.12) by the different N:K ratios.

The NLL per tiller was higher (p<0.05) when fertilization is not carried out, while the increase in N: K levels caused a low NLL (Table 2).

The TPD increased (p<0.05) as the levels of the N:K ratio increased, with an increase of 128.6, 96.9, and 80.3% being observed in the tiller population of the 300:150 ratio 0:0, 75:0 and 0:75 ratio, respectively. No variation was observed in FLS values and plant height (p=0.181).

Table 1. Morphogenic characteristics of mavuno grass fertilized with different N:K ratios.

Variable	Relation N:K						SEM	p-value
	0:0	75:0	0:75	75:75	150:75	300:150		
LAR (leaf day^{-1})	0.10 b	0.11 ab	0.10 b	0.13 a	0.12 ab	0.12 ab	0.02	<0.01
LER (cm of leaf day^{-1})	4.23 bc	3.92 bc	3.76 c	4.87 a	4.58 ab	4.39 ab	0.80	<0.01
phyllochron (day leaf^{-1})	10.57 a	10.50 a	11.26 a	8.05 b	8.69 ab	9.09 ab	2.59	<0.01
LSR (cm of leaf day^{-1})	0.78 c	1.63 bc	1.72 bc	3.11 a	2.11 ab	3.05 a	0.06	<0.01
LLS (days)	20.63 a	20.72 a	20.45 a	19.10 b	19.67 ab	18.56 b	1.56	<0.01
SER (cm of stem day^{-1})	0.32	0.29	0.28	0.38	0.26	0.24	0.156	0.12

Means with different lowercase letters in the line differ from each other using the Tukey test (p<0.05). LAR: Leaf appearance rate; LER: Leaf elongation rate; LSR: Leaf senescence rate; LLF: Leaf life span; LER: Leaf elongation rate; SER: Stem elongation rate; SEM: standard error of the mean.

Table 2. Structural characteristics of mavuno grass fertilized with different N:K ratios.

Variable	Relation N:K						SEM	p-value
	0:0	75:0	0:75	75:75	150:75	300:150		
FLS (cm)	21.591	21.618	21.118	24.008	22.247	23.376	3.845	0.181
NLL	5.017 a	4.467 ab	4.200 b	4.633 ab	4.267 b	4.033 b	0.651	0.001
Height (cm)	47.750	53.400	53.200	51.000	46.800	52.200	10.67	0.089
TPD (tiller vase^{-1})	11.2 c	13.0 c	14.2 c	18.8 b	22.5 ab	25.6 a	3.69	<0.001

Means with different lowercase letters in the line differ from each other using the Tukey test (p<0.05). FLS: Final leaf size; NLL: Number of living leaves; TPD: Tiller population density; SEM: standard error of the mean; p: p-value.

The production of dry matter per vase was affected by the applied N:K ratio, with the highest production being observed in the 75:75 ratio, while the lowest were observed where fertilization with N and K was not carried out. The morphological components showed a significant effect (p<0.05) for the N:K ratio. The LB proportion, and the stem propotion were higher when the N:K ratio was 0:0. On the other hand, the proportion of DM was lower on this treatment, being higher at the ratio 75:75. The LB:S ratio was not influenced by the N:K ratio (p>0.05).

Table 3: Productive characteristics of mavuno grass fertilized with different N:K ratios.

Variable	Relation N:K						SEM	p-value
	0:0	75:0	0:75	75:75	150:75	300:150		
DMP (kg de MS vase^{-1})	5.10 c	5.32 c	6.20 bc	8.20 a	7.46 ab	7.56 ab	1.58	<0.01
LB (g kg^{-1})	760.42 a	754.33 a	784.55 a	708.69 ab	697.18 ab	653.16 b	9.94	<0.01
Stem (g kg^{-1})	226.20 a	196.77 ab	178.04 b	159.86 b	185.53 ab	146.56 b	2.32	<0.01
DM (g kg^{-1})	13.38 c	23.87 c	37.41 bc	131.45 a	117.29 ab	200.28 a	8.78	<0.01
LB:S	3.373	3.583	4.448	4.471	3.947	4.595	1.54	0.10

Means with different lowercase letters in the line differ from each other using the Tukey test (p<0.05). DMP: Dry matter production; LB: Leaf blade; DM: Dead material; LB:S: Leaf blade: stem ratio; SEM: standard error of the mean.

DISCUSSION

Potassium (K) acts as a metabolic regulator of nitrogen (N) in the plant, therefore, the combination of the two is necessary (Zahoor et al., 2017). From this, it can be explained that the rate of leaf appearance showed greater results when fertilization was carried out together between the nutrients, due to the applied N being metabolized more efficiently by the plant due to the presence of K. The leaf elongation rate is one of the variables that most respond to fertilization with N and K, since the deposition of nutrients in areas of elongation, where plant cell division occurs, especially nitrogen (Braz et al., 2011; Lima et al., 2019).

The effects observed on the rate of leaf senescence can be explained in the same way as the other variables since the metabolic rate of plants tends to accelerate as the N: K ratio is equalized. The potassium is a nitrogen metabolizing agent in plant cells, thus increasing cell division and the translocation of photoassimilates from older leaves to younger leaves (Zahoor et al., 2017; Oliveira et al., 2020; Cunha et al., 2022).

The reduction in leaf lifespan is explained by greater tissue renewal caused by the increase in the levels of N and K available in the soil (Cunha et al., 2022). The low supply of nutrients to the plant, especially N and K, keeps the leaves alive for longer. This effect is easily observed in the 75:75 ratio, where the appearance rate and leaf elongation rate are higher than in the others, while the phyllochron decreases.

The higher population density of tillers observed at higher N:K ratios is caused by the fact that N increases the chlorophyll content in the leaves, which in turn increases the availability of photoassimilates in the plant, favoring the development of basal and lateral buds (Bezerra et al. al., 2019).

Nitrogen fertilization can be limited by the absence of potassium, as can be seen in the production of dry matter, when N and K are in the same proportion, production reached its maximum, however, in ratios other than 1:1, production fell. The lower values in the absence of nutrients are because both participate in the synthesis of nutrients by the plant, resulting in a reduction in its productivity (Yarborough et al., 2017a; Yarborough et al., 2017b; Liu et al., 2018). Another important factor that may have contributed to the production of ratios 150:75 and 300:150 being lower is the fact that only one application of fertilizers was made, which can generate losses since the plant is unable to assimilate all the nutrients at once (Nascimento et al., 2020; Nascimento et al., 2021).

The higher LB proportion in the 75:75 ratio can be explained by the higher LAR observed in the same treatment, the accelerated rate of leaf appearance, together with a higher LLS maintains the production of leaf components in the forage canopy. On the other hand, the accelerated rate of senescence and the lower LLS in the highest ratios tended to increase the proportion of DM, thus decreasing the proportion of LB. The lack of effect on the LB:S ratio is due to the same reason as the drop in LB production, as the proportion of DM increased, the ratio between the LB and stem components tended to decrease, keeping all treatments with the same ratio.

CONCLUSION

The relationship between nitrogen and potassium favors the development of mavuno grass. However, this relationship can be observed from a sustainable perspective, since the increase in the N dose as a function of the K dose did not favor large increases in the morphogenic and structural characteristics of the forage. Therefore, determining an ideal relationship between N and K is more important than increasing the dose of nitrogen fertilizer. In the present study, the best ratio observed was 75:75, presenting adequate productivity with good growth of the cultivar.

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