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Nitrogen and Potassium Topdressing in Maize Intercropped with *Brachiaria Ruziziensis*

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Abstract

Maize has been intercropped with different forage species, especially *Brachiaria* spp., for different purposes and at different times: after maize harvest, as a food source for cattle; and exclusively for the production of straw to maintain a no-tillage system, which is the main purpose of intercropping in western Paraná. The objective was to investigate the effects of different rates of nitrogen (N) and potassium (K) topdressing on grain yield and components of yield for maize intercropped with *Brachiaria ruziziensis*. The experiment was conducted in Paraná State, Brazil. The experiment used a completely randomized block factorial design (4 × 3) with four replications. Treatments for the first factor consisted of sowing maize intercropped with *Brachiaria ruziziensis* with four rates of N topdressing (0, 80, 100 and 120 kg ha^{-1}) applied as urea. For the second factor were rates of K topdressing (0, 30 and 50 kg ha^{-1}), applied in the form of potassium chloride. During at sowing fertilization was performed with of 30, 26 and 50 kg ha^{-1} of N, phosphorus and K, respectively. The following variables were evaluated: plant height, first ear height, stem diameter, number of tillers per plant, mass of 1,000 grains, grain yield. The results showed that application of N topdressing promoted increased grain yield of maize intercropped with *Brachiaria ruziziensis* until N rate of 85 kg ha^{-1}. Isolated application of K did not influence the variables studied.

Keywords: conservation system, foliar fertilization, integrated system, nutrient interactions

1. Introduction

In recent years, the methods used to grow maize in Brazil have undergone major technological changes, resulting in significant increases in grain yield. Among these changes, the use of fertilizers applied to gain high yields, disease control and improvements in field management were aimed at improving the quality of the soil; other new practices included crop rotation and no-tillage cultivation (Coelho et al., 2007) and intercropping between cultures (Cruz et al., 2009).

The cultivation of maize intercropped with forage species, especially those of the genus *Brachiaria*, has been used for different purposes and at different times: after maize harvest, as a food source for cattle; and exclusively for the production of straw to maintain a no-tillage system (Crusciol et al., 2010), which is the main purpose of intercropping in western Paraná. The use of plants intercropped with maize promotes soil biological activity; this results in increased soil organic matter, and because intercropped plants have a high C/N ratio, soil cover is guaranteed for a longer period so that erosion is reduced (Borghi et al., 2006). Forage *Brachiaria* species are excellent for use in intercropping with maize materials; these species provide a good amount of dry matter production ensuring good coverage for no-tillage cultivation (Silva et al., 2005).

The demand for nutrients will increase in intercropped systems, requiring greater care in handling them. Nitrogen (N) is taken up in greater quantities by maize, which influences grain yield more strongly than other changes. Approximately 75 % of the available soil N is translocated to grains, concentrating N at the rate of approximately 20 kg N ha^{-1} per ton of harvested grain (Sousa & Lobato, 2004).

In Brazil, Silva et al. (2006 a) reported that the main factors contributing to low grain yield of maize were the mishandling of N fertilizers and the insufficient application of it. Meanwhile, Duete et al. (2008) reported that the amount of the nutrient used in the cultivation of maize in Brazil averages 60 kg ha^{-1}, while the averages in

China (130 kg ha^{-1}) and the United States (150 kg ha^{-1}) were much higher.

After N, maize also absorbed large quantities of potassium (K), whereas, an average of 30 % of applied N is exported into the grain. While potassium is not part of any organic compound within the plant, it is important in the synthesis and metabolism of carbohydrates and also contributes to greater photosynthetic activity (Prado 2008). Potassium improves the quality and nutritional value of food products. A study by Rodrigues et al. (2014) used fertilization doses of potassium chloride coated pellets; they observed an increase in chlorophyll content with an increasing dosage of potassium oxide. When K is in the form of K^+ ions in plant tissue, it returns to the soil very quickly after the death of plants (Pavinato, 2008).

Although N is the most important nutrient, it does not work independently in the nutrition of plants; for example, the shortage of phosphorus, K and sulfur can alter the efficiency of N application, reducing grain yield (Usherwood & Segars 2001). There is a positive correlation between nitrogen and potassium, because the potassium acts on the activation of the nitrate reductase enzyme (Venkajesan & Ganapathy, 2004; Silva et al., 2011).

The hypothesis of this study when is intercropping *B. ruziziensis* with maize will result in an increased demand for N and K, and that increased doses of these elements will result in an increase in maize yield. The object of this study was to investigate the effects of different rates of N and K topdressing on grain yield and yield components of maize intercropped with *B. ruziziensis*.

2. Material and Methods

The experiment was carried out during season 2012/13 in the experimental field on the UNIOESTE, in Marechal Cândido Rondon municipality, Paraná State, Brazil at 24°31'S, 54°01'W at an elevation of 420 m. Soil was classified as typic oxisol (Perferic Red Latossol). The particle size determination performed according to the hydrometer Bouyoucos. The results were: Clay 763 g kg^{-1}, silt, 136 g kg^{-1}, and sand 101 g kg^{-1}, according to the methodology of EMBRAPA (2006). Before the experiment, soil samples were collected in the 0–0.10 m and 0.10–0.20 m soil layers (Table 1). The solution for extraction of phosphorus was Mehlich-1, and to aluminum, calcium and magnesium the extractor was KCl. The methodology used to determine organic matter was Walkley-Black.

Table 1. Chemical characterization of the Oxisol soils at depths of 0–0.10 m and 0.10–0.20 m

Depth	pH	P	MO	H+Al	$Al^{(2)}$	K^+	Ca^{+2}	Mg^{+2}	SB	CTC	V	Al
m	$CaCl_2$	mg dm^{-3}	g dm^{-3}	-------------------------- $cmol_c$ dm^{-3} ---------------------							------ % ------	
0-0.10	4.62	12.62	27.34	6.72	0.20	0.45	3.69	1.44	5.58	12.30	45.37	3.46
0.10-0.20	4.81	9.05	24.61	5.79	0.15	0.30	4.09	1.48	5.87	11.66	50.34	2.49

The experiment was a completely randomized block factorial (4 × 3) design with four replications. Treatments consisted of sowing maize intercropped with pasture (*B. ruziziensis*) with four rates of N topdressing (0, 80, 100 and 120 kg ha^{-1}), applied in the form of urea (45 % N). The second factor included three rates of K topdressing (0, 30 and 50 kg ha^{-1}), applied in the form of potassium chloride (60 % K_2O). The size of the plot per treatment was 4.5 x 7 meters, totaling 31.5 m^2.

Hybrid maize seeds were sown mechanically in a no-tillage system and spaced 0.90 m between rows and 0.20 m between plants. At the moment of sowing were applied a base fertilization at dose de 300 kg ha^{-1} of a formulated 10–20–20 with nitrogen, phosphate and potassium oxide, respectively. *Brachiaria ruziziensis* was sown manually in line between maize rows on the same day of maize sowing, using 8.0 kg ha^{-1} of encrusted seeds.

When the maize reached the developmental stage five sheets developed at 25 days after emergence, proceeded to the topdressing with manual application of nitrogen and potassium in the form of urea and potassium chloride, respectively. Weeds were manually removed where necessary, and fungicides and insecticides were applied to prevent diseases and insect damage, according recommendations. Not irrigations were applied during the whole season of the crop.

At the silking stage, 10 plants in the middle rows were randomly selected from each plot and measurement of growth characteristics as follows: stem diameter, measured to the nearest centimeter (cm) at 1/3 the base of the maize plant; plant height, the maize plant measured to the nearest centimeter from the base to top; and first ear height. The number of tillers per plant was also determined.

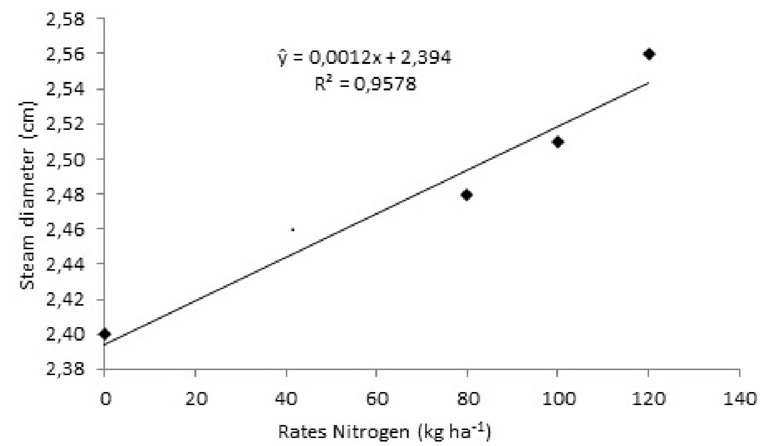
The ears of maize were harvested by hand at 16 weeks after plants. In each plot were harvested plants of floor area, and was discarded 0.5 m in the bedside of each installment and the two side lines, harvesting the two central lines of each plot. The ears of maize were conducted for laboratory and dried in the shade; then, 10 ears were randomly chosen to evaluate the ear diameter and ear length. After, the ears of maize were threshed manually to evaluate the mass of 1,000 grains and grain yield. The mass of 1,000 grains was determined using an average of eight samples of 100 randomly selected grains. The yield per plot was determined by weighing the grain on a semi-analytical balance, correcting for wet weight for 130 g kg^{-1} of weighing and then estimating the grain yield in kg ha^{-1}.

Data were subjected to analysis of variance ($p<0.05$) using SAEG statistical software and with significant differences noted in rates of N accumulated; regression analysis was performed using the analysis of variance option in the SAEG statistical program (SAEG 2007).

3. Results and Discussion

The results of this study showed that application of different rates of nitrogen topdressing significantly affected ($p < 0.05$) the stem diameter, ear height, mass of 1,000 grain and grain yield; and no statistical difference was observed for first ear height, number of tillers and ear diameter. Regarding the effect of nitrogen rates in topdressing the stem diameter and ear height, the data set were adjusted a first-degree regression equation. The linear increase in steam diameter and ear height was observed with increased nitrogen fertilization, which shows that the dose of 120 kg ha^{-1} was not enough to achieve the maximum these characteristics (Figure 1 a and b).

(a)



(b)

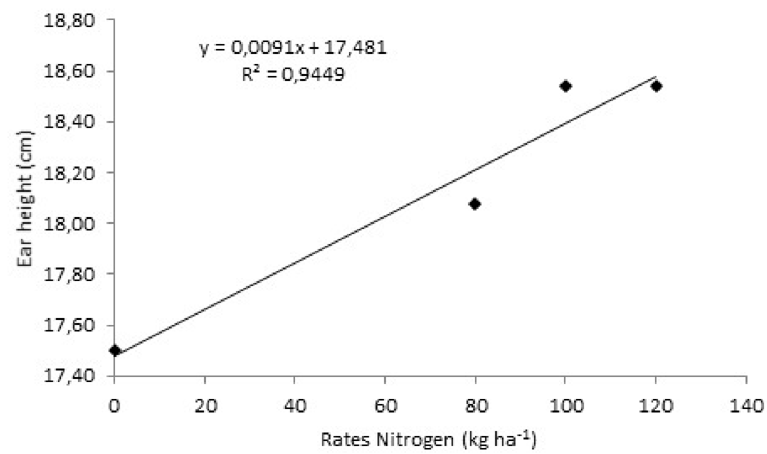
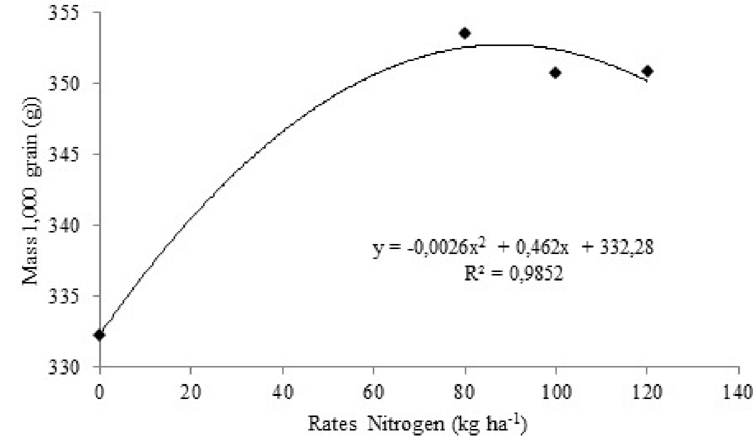


Figure 1. Stem diameter (a) and ear height (b after application of nitrogen on topdressing in the maize intercropped with *Brachiaria ruziziensis*

The effect of nitrogen rates in topdressing the mass of 1,000 grains and grain yield, the data set were adjusted a quadratic regression model. The estimate of the maximum mass of 1,000 grains (353 g) was obtained with application of 89 kg ha^{-1} of N topdressing and the estimate of the maximum grain yield (8,580 kg ha^{-1}) corresponded the application of 85 kg ha^{-1} of N topdressing (Figure 2 a and b).

(a)



(b)

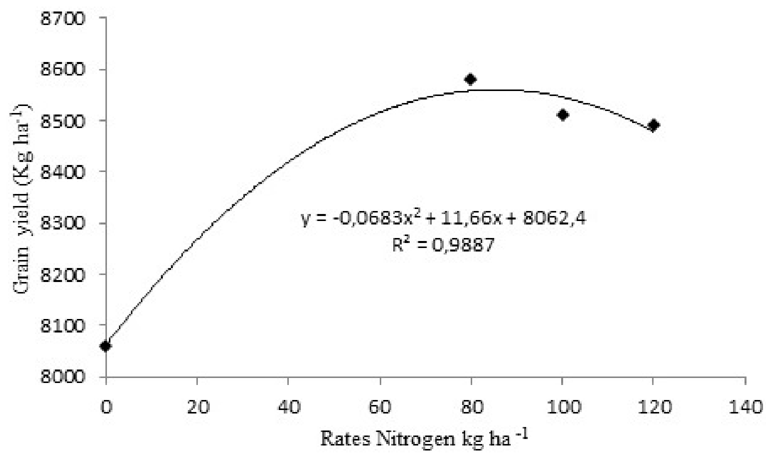


Figure 2. Mass of 1,000 grains (a) and grain yield (b) after application of nitrogen on topdressing in the maize intercropped with *Brachiaria ruziziensis*

Analyzing the data it was found that the application of nitrogen on topdressing promoted an increase of 6.10 % in mass 1,000 grains and 6.43% at grain yield. Remember that were applied as base fertilization 30 kg ha^{-1} of nitrogen, then the total nitrogen was 119 and 115 kg ha^{-1} for mass 1,000 grain and grain yield, respectively, which is consistent with previously published literature, therefore, the consortium *Brachiaria ruziziensis* with maize not demanded greater amounts of N, by maize.

When the isolated effect of K application rates was analyzed, no significant differences were found in the variables studied here. In Table 2 the average results for stem diameter, ear height, mass of 1,000 grains and grain yield after application of potassium on topdressing in the maize intercropped with *Brachiaria ruziziensis*. The results yield components are presented in Table 2.

Table 2. Average results for stem diameter (a), ear height (b), mass of 1,000 grains and grain yield after application of potassium on topdressing in the maize intercropped with *Brachiaria ruziziensis*

K rates on topdressing	Stem diameter	Insertion height of the ear	Number of tillers	Ear diameter	Ear height	Mass 1,000 grains	Grain yield
(kg ha^{-1})	(cm)	(cm)		(cm)	(cm)	(g)	(kg ha^{-1})
0	2.46^{ns}	127.15^{ns}	32.18^{ns}	5.13^{ns}	18.21^{ns}	344.77^{ns}	8366^{ns}
30	2.49	127.87	29.68	5.16	18.03	346.82	8416
50	2.52	128.28	30.18	5.15	18.25	348.90	8467

Analyzing the data for effect of interaction N × K verified only significant difference ($p<0,05$) for first ear height. The maize response for interaction was adequately represented by the polynomial second degree regression model. When not applied potassium top dressed the maximum ear height was achieved with the application of N at rates of 127 kg ha^{-1}. When applied potassium top dressed at rates 30 e 50 kg ha^{-1} the maximum ear height was achieved with the application of N at rates of 88.4 and 72 kg ha^{-1}, respectively (Figure 3). An interaction between N and K was also observed by Stromberger et al. (2008), who found that an increase in the K application rate promoted more vigorous growth in plants when those plants received doses of N.

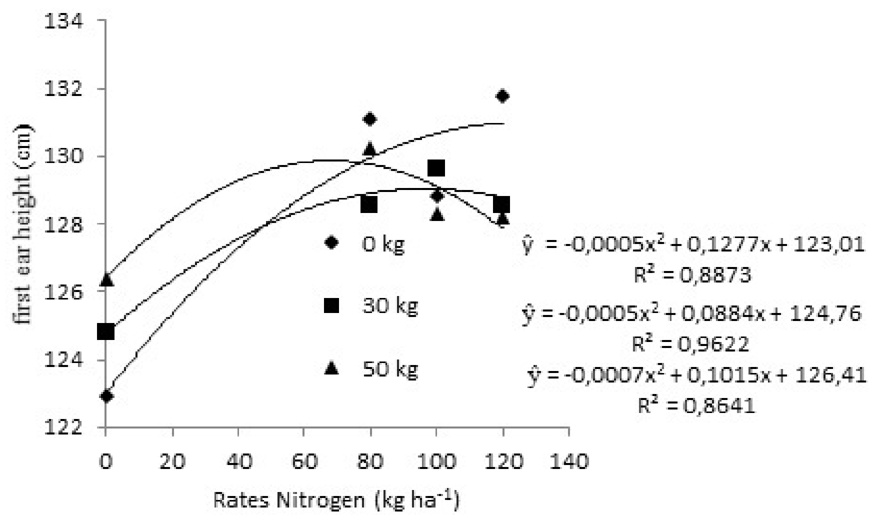


Figure 3. Ear height and maize stem diameter as a function of nitrogen and potassium application rates during intercropping of maize with *Brachiaria ruziziensis*

4. Discussion

These results suggest that the application of N influenced the stem diameter, because the availability of nitrogen is directly involved in cell division and growth and photosynthesis.Grains yield had increase because the application of nitrogen fertilizer in plants affects the absorption of other nutrients. This is because the nitrogen increases number of new roots, and these in turn increases the absorption of n end all nutrients and dry matter production (Dovale et al., 2012). The positive effect of nitrogen on productivity was explained by the linear increase in leaf N content (Valderrama et al., 2011). N while not limited by other factors, the greater n availability increases the potential of the plant to define increasing grain mass (pöttker & wiethölter 2004).

Similar effects of N rates on the grains yield were reported by Bravin et al. (2014), but the maximum was obtained with the dose of 165 kg ha^{-1}. Fernandes et al. (2005) studied N accumulation rates for six maize cultivars and found no significant differences for the variables of stem diameter and ear height, but obtained similar results for the mass of 1,000 grains and grain yield. The maximum grain yield was obtained with a N application rate of 110 kg ha^{-1} in the current experiment. Furthermore, Silva et al. (2006 b), worked with N fertilizer application rates in crops seeded prior to planting maize and also reported an increase in ear height up to dose of 203 kg ha^{-1}.

The results show low efficiency in the use of nitrogen fertilization coverage on the grain yield maize. This response is related to the high productivity observed in the treatment that received at sowing, only a base fertilizer 30 kg ha^{-1} N; and none N on topdressing, but was able to maintain a high grain yield (8060 kg ha^{-1}). This result indicated that the soil had a good natural stock of N and soil conditions and climate were favorable to mineralization in no-tillage system. According to Souza et al. (2008), maize in low nutrient supply conditions is capable of increasing nutrient use efficiency. Lara-Cabezas and Pádua (2007), working with N efficiency applied on topdressing in the maize intercropped with Brachiaria ruziziensis found that the consortium did not negatively affect the assimilation of N, but promoted a synergy in nitrogen uptake, and for better understanding of this indeed further studies should be conducted in the rhizosphere.

Corroborating the result Deparis et al. (2007), whose study employed thirteen different doses of N and seven doses of K; they also found significant differences for mass of 1,000 grain and grain yield although differences in doses of N and K did not affect the position of ear insertion. They reported that the response N fertilization for mass of 1,000 grain and grain yield was linear up to150 kg ha^{-1}.

One explanation why there were no effects of potassium fertilization on components of production and maize productivity is that the potassium content in the soil at depth of 0-0.10 m was considered high (> 0.4 cmolc dm^{-3}), as shown in Table 1; especially in no-tillage systems that favors the maintenance of the straw and the increase of K. In review, other authors also found no significant differences for K doses (Ceretta & Pavinato, 2003; Brunetto et al., 2005; Pavinato et al., 2008; Valderrama et al., 2011)

5. Conclusions

The application of nitrogen topdressing promoted increased grain yield of maize intercropped with *Brachiaria ruziziensi*s until N the rate of 85 kg ha^{-1}. Isolated application of K did not influence the variables studied here.

Acknowledgments

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