Effect of nitrogen over corn-grass association in the renovation of pastures at piedmont of the Llanos Orientales of Colombia

Efecto del nitrógeno sobre la asociación maíz–pastos en la renovación de praderas del piedemonte de los Llanos Orientales colombianos

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ABSTRACT

In the piedmont of the Eastern Plains of Colombia, was established the association of corn with the grasses *B. decumbens*, Mulato and Toledo, to renovate degraded pasture. The effect of the N was evaluated with 100 and 200 kg ha^{-1} applied to the corn to the 15 and 35 days after the sowing (das). The available N in the soil in nitrate form remained N in 42 and 43 kg ha^{-1} to the 15 and 35 das respectively, coinciding with the fertilization of N applied to the corn, but to the 60 days it reducing to 11.9 kg N ha^{-1}. The available N in ammonium form was of 82, 84 and 72 kg ha^{-1} to the 15, 35 and 60 das, respectively. To the beginning of the flowering, the N leaf in the corn associated with *B. decumbens* and with the grass, Toledo was respectively of 2.9 and 2.83%, while in the association with grass Mulato was of 2.66%. The N leaf in the grasses Mulato and Toledo was respectively of 3.31 and 3.20%. In the phase of filled grain of corn, the N leaf in the corn didn't present significant differences when being associated with the three grasses, being obtained an average of 2.59%. The treatments with 100 and 200 kg N ha^{-1} applied to the corn didn't affect the content of N in the leaves of corn and grass, so much in the moment of the flowering like in the one filled of the grain.

Key words: yield, nitrate, ammonium, *Brachiaria*.

RESUMEN

En el piedemonte de los Llanos Orientales colombianos, se estableció la asociación de maíz con los pastos *B. decumbens*, Mulato y Toledo como medio para renovar praderas degradadas. Se evaluó el efecto del nitrógeno (N) con 100 y 200 kg ha^{-1} aplicados al maíz a los 15 y 35 días después de la siembra (dds). El N disponible en el suelo en forma de nitrato permaneció en cantidades de 42 y 43 kg ha^{-1} a los 15 y 35 dds respectivamente, coincidiendo con la fertilización nitrogenada aplicada al maíz; no obstante, a los 60 días el N disminuyó a 11,9 kg ha^{-1}. El N disponible en forma de amonio fue de 82, 84 y 72 kg ha^{-1} a los 15, 35 y 60 dds, respectivamente. Al inicio de la floración, el N foliar en el maíz asociado con *B. decumbens* y con pasto Toledo fue de 2,9 y 2,83% respectivamente, mientras que en la asociación con pasto Mulato fue de 2,66%. El N foliar en los pastos Mulato y Toledo fue de 3,31 y 3,20%, respectivamente. En la fase de llenado de grano, el N foliar en el maíz no presentó diferencias significativas por estar asociado con los tres pastos, obteniéndose un promedio de 2,59%. Los tratamientos con 100 y 200 kg N ha^{-1} aplicados al maíz, no afectaron el contenido de N en las hojas de maíz y pasto, tanto en el momento de la floración como en el llenado del grano.

Palabras clave: productividad, nitrato, amonio, *Brachiaria*.

Introduction

Nitrogen (N) is required in the synthesis of nucleic acids, proteins, hormones, chlorophyll and other compounds essential for plant growth and which promotes the greatest increases in dry matter production (Orozco, 1999). Bueno *et al*. (2004) considered the most important element in tropical forages, the response in biomass production and protein content, important factors that determine the meat and milk yields. The soils of the Colombian Llanos, between one of its limitations in fertility, low organic matter content, source of N for pasture production in this region. This deficiency is most apparent organic matter in soils of the Altillanura who have had a larger process of weathering and leaching of nutrients (Rincón, 2007; Mejia, 1996).

The low contribution of N to soils of the Llanos produces a low vigor, low regrowth capacity, high susceptibility to pests of pastures. The previous aspects translate into a pasture degradation manifested in the invasion of other species of low forage value and the loss of animal productivity by more than 70% (Martha Junior *et al*., 2004; Rincón, 1999). To resolve this problem, the integration of pasture crops provides an alternative high viability in the farm (Vilela *et al*., 2003; Sans *et al*., 1999).

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Maize cultivation requires large amounts of N. Such as this element greatly affects yield is required adequate diagnosis of their availability in the soil. Corn needs about 20 to 25 kg ha^{-1} of N per ton of grain produced (Sanchez, 1976). The determination of the amount and timing of fertilizer application should seek greater amount of grain produced per unit of nutrient applied and greater economic benefit (Mengel and Barber, 1974; Varvel *et al*., 1997).

Plants take up and use two forms of soil nitrogen, ammonium (NH_4) and nitrate (NO_3) in proportions dependent on the species, stage of development, carbohydrate availability, soil pH and environmental factors (Deane and Glass, 1983). Absorbed nitrate can be stored or reduced, in some species is reduced in the root system (Oaks, 1992; Andrade *et al*., 2001). High levels of ammonia in the plant are toxic and cause damage to the cell membrane, which is why all the generated ammonia is rapidly absorbed or assimilated or stored in the vacuole of the cell (Menezes, 2004; Orozco, 1999).

Cramer and Lewis (1993) showed that crops use significant amounts of ammonia, if present in the soil. Certain corn hybrids have a high requirement for ammonium uptake of N in this way helps to increase grain yield. Salinas (1985) assessed the development of the grass *B. humidicola, B. dictyoneura* and *B. decumbens*, using nitrogen fertilizer as nitrate and ammonium. All three species had a higher form of development when N was nitrate, however, to provide N as ammonium, the growth of *B. humidicola* not inhibited as if it happened in the *B. decumbens* and *B. dictyoneura*. According to quoted by Rao *et al*. (1998) and Miles *et al*. (2004) the grass *B. brizantha* cv. Marandú can take only small amounts of N-NH_4, however *B. humidicola* able to absorb both forms of N.

As a strategy to improve the availability of good quality forage biomass and contribute to the improvement of livestock productivity in the piedmont plains. This research was based to renovate a pasture of *B. decumbens* degraded through the association with maize. The rational use of nitrogen is one of the most important factors to obtain high yields of maize grain and fodder. This will contribute to greater profitability and sustainability of agropastoral systems in the Llanos Foothills (Piedmont).

Materials and methods

The study was carried out between August and September; the soil belongs to an Oxisol located in a terrace at Corpoica La Libertad Research Station in Villavicencio (Meta, Colombia): 9° 6' N and 73° 34' W at 330 m.a.s.l. The last 30 years annual average rainfall is 2.900 mm and the mean temperature 26°C. The relative humidity is 85% in the rainfall season and 65% in the dry season.

The soil where the experiment was established is very acidic with aluminum saturation of 71.7% while the base saturation was 24.7% (Tab. 1). Were more deficient nutrients phosphorus (1.0 ppm), calcium (0.37 me 100g^{-1}) and magnesium (0.11 me 100g^{-1}) in both the clay loam texture and bulk density presented a value of 1.5 g cm^{-3} before tillage and 1.3 g cm^{-3} after tillage.

TABLE 1. Chemical characteristics of soil where the experiment was established.

Parameter	Value
pH	4.4
M.O. (%)	2.4
P (ppm)	1.0
Ca (me 100 g^{-1})	0.37
Mg (me 100 g^{-1})	0.11
K (me 100 g^{-1})	0.10
Na (me 100 g^{-1})	0.26
Al (me 100 g^{-1})	2.10
Fe (ppm)	126
B (ppm)	0.15
Cu (ppm)	0.80
Zn (ppm)	0.50
CIC efectiva	3.44
Base saturation (%)	24.70
Aluminum saturation (%)	71.70
Calcium saturation (%)	12.50
Magnesium saturation (%)	3.70
Potasium saturation (%)	3.36

In a degraded pasture was established simultaneously, the cultivation of hybrid corn "Master" in association with the grasses *Brachiaria* hybrid cv. "Mulatto", *Brachiaria brizantha* cv. "Toledo" and *Brachiaria decumbens*. To determine the effect of N on the development and production of corn grain and grass biomass were evaluated doses of 100 and 200 kg N ha^{-1} applied to the groove in fractions of corn, at 15 and 35 days after planting of the association.

Experimental design

Statistical design used a randomized complete block with split plot arrangement with three replications. The main plot consisted of each of the three grasses in an area of 3 ha subplot by the two levels of nitrogen in an area of 1 ha.

Establishment of the experiment

For crop establishment was used one pass of harrow, and then made a hard chisel; who worked at a depth of 25 cm was then applied to the soil with a lime, a mixture of dolomitic lime, phosphate rock, agricultural gypsum and joined with one pass of harrow.

For doses of amendments and fertilizers applied, we took into account the chemical analysis of soil and the nutritional requirements of maize in acidic soils. The agricultural amendment were applied to dolomite lime, rock phosphate and gypsum, to reduce the saturation of aluminum and to correct deficiencies of calcium, phosphorus, magnesium and sulfur in these soils. These were incorporated and mixed into the soil to 45 days before planting corn. The application of rock phosphate deficiency due to high phosphorus (P) and the need to have a reserve in the soil for subsequent use of pasture, since by its slow solubility, P would not be available to meet the needs of cultivation of maize, which was applied diammonium phosphate (DAP), P fertilizer readily available.

Fertilization was applied to corn-pasture association consisted of 1,500 kg ha^{-1} of dolomitic lime (399 kg of Ca, Mg 88.5 kg), 400 kg ha^{-1} of phosphate rock (50 kg P, 99.6 kg of Ca), 300 kg ha^{-1} agricultural gypsum (55 kg of Ca, S 44.4 kg) 150 kg ha^{-1} diammonium phosphate (29 kg P, 27 kg N), 150 kg ha^{-1} potassium chloride (75 kg K), 20 kg ha^{-1} Borozinco (3,000 g Zn, 100 g Cu, 500 g of B and 1,200 g of S). According to these input quantities, the dose per hectare was 555 kg of Ca, Mg 88 kg, 79 kg P, 75 kg K and 44 S.

The only source of variation in fertility was the level of nitrogen applied (100 and 200 kg ha^{-1} of N), using urea as a source. Split into two equal parts of nitrogen fertilization at 15 and 35 days after seeding. At the time of sowing was applied to all treatments 27 kg N ha^{-1} contained in 150 kg ha^{-1} applied DAP.

Was used 22 kg ha^{-1} plant density in furrows 80 cm apart and 5 plants per linear meter. The seed drill and fertilizer planted the seed to a depth of 3 cm and fertilizer (phosphorus + potassium + zinc) in the same row of corn, at a depth of 5 cm. Forage grasses were planted immediately after corn planting to 4 kg ha-1 plant density in rows 50 cm apart and perpendicular to the planting of corn.

Evaluations

For determine the N content in soil and plant, were evaluated flowering and grain filling of corn crop (35 and 60 das, respectively).

Ammonium and nitrate in the soil at 15, 35 and 60 das of maize-pasture association, by the method of AOAC (1995), by sampling soil at a depth of 20 cm.

Total-N content of leaves was determined by a modified micro-Kjeldahl to 35 and 60 das in corn and grass. We sampled maize leaves and grass in the middle third of the plant and dried in an oven at a temperature of 70°C for 72 h.

The data were subjected to analysis of variance to determine significance and comparison of means was determined by Tukey's comparison test using SAS™ version 9 and the coefficients of determination and regression were calculated using the Excel™ program.

Results and discussion

Ammonium and nitrate in the soil

Before starting the tillage was measured nitrate in the soil, being an average value of 0.10 mg kg^{-1} (0.05 kg ha^{-1} of N), while the N in ammonium form was of 7.5 mg kg^{-1} (11.6 kg ha^{-1} N). This deficiency of N in the soil, chlorosis and

TABLE 2. Ammonium and nitrate in the soil established the association of corn with three grasses and two levels of N.

Association of corn with three grasses:	**Nitrate (mg kg^{-1})**			**Ammonium (mg kg^{-1})**		
	15 dds[1]	35 dds	60 dds	15 dds	35 dds	60 dds
B. decumbens	90.1	93.3	18.7	55.2	60.7	42.0
Mulato	93.4	93.3	28.0	53.3	52.3	51.3
Toledo	95.3	102.7	32.7	51.3	51.7	46.7
Mean	92.9	96.4	26.5	53.3	54.9	46.7
Nitrogen:						
100 kg ha^{-1}	79.5	99.5	28.6	46.6	46.7	43.5
200 kg ha^{-1}	93.4	93.3	24.9	62.1	62.2	49.8
Mean	86.5	96.4	26.8	54.4	54.5	46.7
cv (%)	28.2	19.3	26.4	42.3	46.2	27.2
Significance	NS	NS	NS	NS	NS	NS

[1] dds: days after seeding.

NS: no significant differences in mean according to the Tukey test ($P > 0.05$).

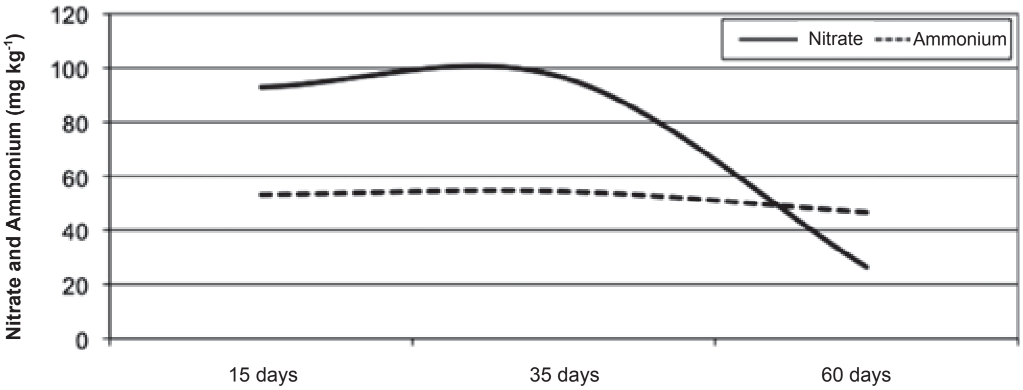

FIGURE 1. Ammonium and nitrate from the first nitrogen fertilization (15 dap) to grain filling (60 dap) on the ground set with the corn-grass association.

contributed to the lack of vigor of the grass *B. decumbens* it was before starting treatment. After completion of the tilling and before planting, we determined the content of ammonium and nitrate in the soil, obtaining values of 46.6 mg kg^{-1} (72.5 kg ha^{-1} N) and 74.6 mg kg^{-1} (33.6 kg ha^{-1} of N) respectively, generating an increase in available N with soil tillage, favoring the decomposition of organic matter (Kluthcouski and Stone, 2003). The evaluations were carried out at 15 and 35 das, after the second fertilization with urea and 60 dap when maize was at grain filling, no differences ($P> 0.05$) in both the content of nitrates and ammonium (Tab. 2).

The average crop of 92.9 mg kg^{-1} of NO_3 arranged at the age of 15 d when the corn was in good vegetative growth and of 96.4 mg kg^{-1} at 35 d, at which time started flowering, coinciding with the fractional nitrogen fertilization in these two epochs. However, the values of NO_3 in the soil decreased to 26.5 mg kg^{-1} at 60 d (Fig. 1), coinciding with the beginning of grain filling and high demand for N for a good harvest. However, the amount of N that moves from vegetative tissues to the cob during the filling process varies considerably from a range of 20 to 60% of total grain N derived from uptake by the roots before anthesis, deposited in the stem, and then moved into the cob. The amount of N mobilized depends on the cultivar, the amount and timing of application of N fertilizer (Lafitte, 2002).

The ammonium content in the soils was kept steadily during the 60 d of evaluation, with an average of 50 mg kg^{-1} (Fig. 1). The N in the form of nitrate is absorbed by most plants and is also easily carried deeper soil layers because of its negative charge is not retained in the soil exchange complex (Sims *et al*., 1998, Cabral da Silva *et al*., 2005). Whereas the ammonium positive charge if it is retained in the cation exchange sites of clays and organic matter, this explains the stability of ammonium in the soil while nitrate have decreased over time.

After the first nitrogen fertilization in the treatment with 100 kg ha^{-1} of N, N availability in the form of nitrate was 69.5 mg kg^{-1} (31.4 kg ha^{-1} of N) while treatment with 200 kg ha^{-1} N, was 93.4 mg kg^{-1} (42.2 kg ha^{-1} of N). In the second application of N at 35 d, the availability of nitrate in the soil

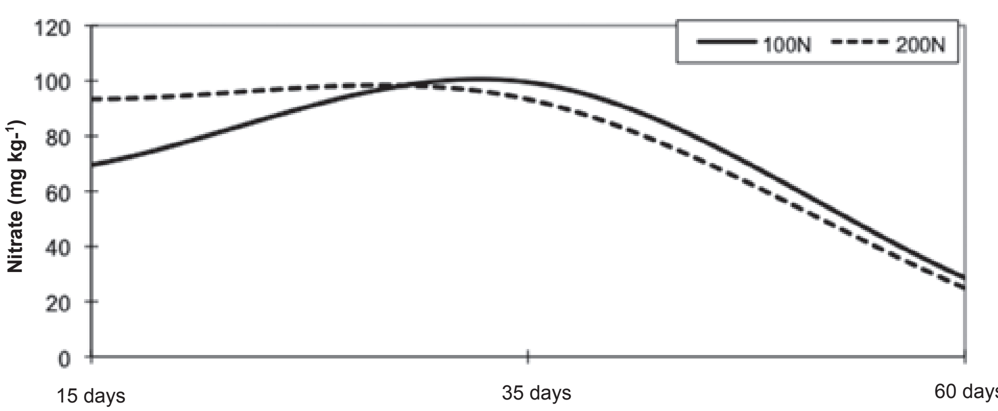

FIGURE 2. Nitrate content in soil with applications of 100 and 200 kg ha^{-1} N, in association corn - pastures.

was similar with both 100 and 200 kg ha^{-1} of N, yielding an average of 96.5 mg kg^{-1} (44.3 kg ha^{-1} of N as nitrate). At 60 dap, the availability of nitrate was reduced to 26.5 mg kg^{-1} (11.9 kg ha^{-1} of N) in the treatments with two levels of N applied (Fig. 2).

The availability of N in the form of ammonium in the soil, where treatment was applied 100 kg N ha^{-1} was stable at 46 mg kg^{-1} (71.5 kg ha^{-1} N) at 15 and 35 d, and 60 d there was a slight decrease to 43.5 mg kg^{-1}. At doses of 200 kg ha^{-1} of N, at 15 and 35 d was obtained contained 62 mg kg^{-1} of ammonium (96.4 kg ha^{-1} N) and 60 d was reduced to 50 mg kg^{-1} (77.7 kg ha^{-1} of N). As shown in Fig. 3, after the second application of N, the ammonium content in soil treated with both 100 and equated with the 200 kg ha^{-1} of N applied to corn-grass association.

Corn absorbs much of the N in nitrate form (Salvagiotti *et al*., 2000), therefore, in two important stages of development of this crop (at 15 and 35 d) had a total availability of 85.5 kg ha^{-1} from the nitrate (42 kg at 15 d and 43.5 kg at 35 d). In these periods of development of maize, we applied the two nitrogen fertilization treatments: 100 and 200 kg ha^{-1} of N as urea. At the time of planting corn-grass associations, we applied 27 kg ha^{-1} of N using diammonium phosphate source, with an efficiency of 60% fertilizer, the association had an availability of 16.5 kg N ha^{-1} to be used in the first 15 d of development of maize, along with 33.6 kg ha^{-1} of nitrate N available from the action of tillage.

Whereas the supply of N to plants, comes from nitrates available in the soil at the time of planting, the mineralization of organic matter (2 to 2.5% of N available for plants) and fertilizer (Montesano *et al*., 2003). It is considered that the efficiency of urea is about 60% in the treatment where it was applied 100 kg ha^{-1} at 15 and 35 das, the availability of N for plants from urea was 60 kg ha^{-1}. Moreover, with 2.4% organic matter, with a bulk density of 1.3 g cm^{-3} and a 2% annual mineralization, the availability of N to the crop from organic matter in this soil, was 31 kg ha^{-1}. Therefore, the total amount of N from fertilizer and organic matter mineralization was 91 kg ha^{-1}, number of close to 85.5 kg ha^{-1} of N available in the form of nitrate in the soil, to be taken by the crop at 15 and 35 das.

On 8 and September 28, 2007 when it was the application of urea (15 and 35 dap), precipitation did not exceed 7 mm. Fox *et al*. (1986) report that it is necessary to the occurrence of rainfall over 10 mm for the urea is incorporated into the soil profile, otherwise occurs in the form of NH3 volatilization. The soil moisture conditions and daytime temperatures of 31 °C during this month, may have contributed to the volatilization of urea, causing loss of N was not enough to be taken up by plants. This could happen in the treatment with twice the amount of applied N (200 kg ha^{-1}), at this dose, the plants should have 120 kg ha^{-1} of N from fertilizer and 31 kg ha^{-1} of N mineralization of organic matter produced for a total of 151 kg ha^{-1}. However, there were no significant differences in the levels of nitrate and ammonium in soils fertilized with 100 and 200 kg ha^{-1} of N, N losses apparently are higher when fertilization levels are higher. As they Barbieri and Echeverría (2003) determined the N-NH_3 losses to fertilize a pasture *Thinopirum ponticum* with 0, 90 and 180 kg ha^{-1} of N using urea as the source. Losses of N-NH_3 volatilization were 3, 14 and 63 kg ha^{-1}, respectively.

Recent studies have shown that high levels of N applied are no differences in corn production alone or in association with grasses, however, reduces efficiency and increases the nutrient losses as NO_3 or NH4 (Bundy and Andraski, 2005; Wachendorf *et al*., 2006; Zhao *et al*., 2006).

The availability of N-NH_4 in the soil, at 15 and 35 das corn association - grasses, was 83 kg ha^{-1}, while the availability

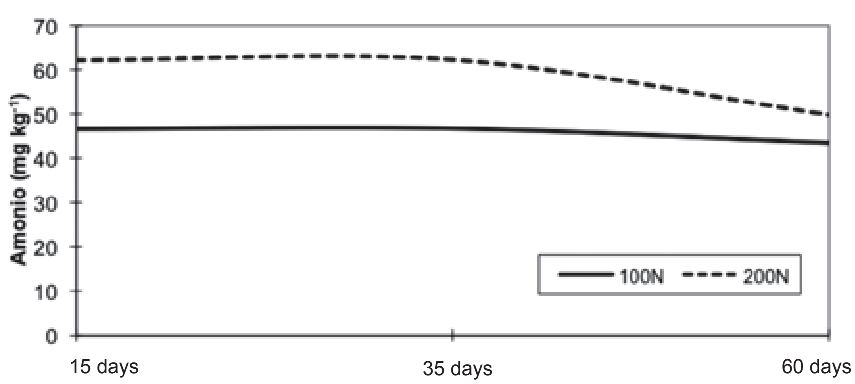

FIGURE 3. Ammonium content in soil with 100 and 200 kg ha^{-1} N, in association corn - pastures.

of NO_3-N was 43 kg ha^{-1}. These differences were extended to 6 times 60 das for the availability of NH4 (Tab. 3). It is important to book this present in the ammonium N stored in soil clays, which represents 70% of all inorganic N. Work performed by Cramer and Lewis (1993), showed that significant amounts of crops using ammonia, if this is present in the soil. Certain corn hybrids have a high requirement for ammonium uptake of N in this way helps to increase grain yield. One of the reasons that higher yields are obtained with the absorption of part of the N in ammonium form, is that the reduction of nitrate within the plant requires energy; nitrate is reduced to ammonia that then becomes amino acids in the plant. This energy is provided by carbohydrates, the same that could be used for growth and grain formation (Potash and Phosphate Institute, 1997).

Total nitrogen in maize leaves and grass

It was found that the onset of flowering, leaf N in maize associated with *B. decumbens* and corn Toledo associated with the grass was higher with 2.90 and 2.83% N respectively (Tab. 4), while in association with Mulato grass, corn presented a content of 2.66% of N leaves. On the grass *B. decumbens*, leaf N was significantly lower, while Mulato and Toledo pasture N concentration was 3.31% and 3.20%. It is generally observed at 35 dap, the leaf N in the grass showed levels higher than those found in corn.

At the stage of grain filling (60 das) leaf N content in maize were no significant differences being associated with the three grasses, yielding an average of 2.59%. The foliar N in maize was similar in flowering and grain filling (Tab. 3). Tropical grasses are characterized by decreased leaf N and increased fiber, when mature, however, Mulato grass remained the highest content of N with 2.58% at 60 d. In contrast, the N in the leaves of grass Toledo, was significantly lower (2.30%) compared to the other two grasses.

Treatments with 100 and 200 kg N ha^{-1} applied to corn, did not affect the N content in corn leaves and grass, both flowering and grain filling. At the time of flowering corn, the grass had higher leaf N content than corn, while in the grain filling, corn N content was higher in leaves than that found in the leaves of grass (Fig. 4).

The N in maize leaf showed little variation at 35 and 60 days of age, both with 100 and 200 kg ha^{-1} of N. At flowering, the average was 2.8% and grain filling of 2.6%, values that are in the lower range of 2.75% to 3.25% proposed by Malavolta *et al.* (1997), as appropriate. Meanwhile, pasture at 35 d had more than 3% of foliar N, 60 dds decreased to near 2.5%.

Conclusions

With a dose of 100 kg ha-1 of N was achieved an average yield of 5.3 t ha^{-1} grain of corn which it was confirmed that this crop requires 20 to 25 kg ha^{-1} of N for each ton of grain produced. Therefore do not justify application of 200 kg ha^{-1} of N to the corn association pasture in acid soil conditions of the middle terrace of the Piedmont plains. The content of nitrogen in the soil as nitrate remained stable up to 35 das, whereas in the form of ammonia, up to 60 das. Studies are needed to quantify specific loss of N as urea fertilization is done, taking into account the conditions of high rainfall and temperature, typical of the piedmont plains.

TABLE 3. Nitrogen (N) soil inorganic nitrogen fertilizer from the first until the beginning of grain filling in maize cultivation associated with pasture.

Stages (das*)	Nitrate			Ammonium			Soil inorganic N
	mg kg^{-1}	*kg ha^{-1}*	N (*kg ha^{-1}*)	*mg kg^{-1}*	*kg ha^{-1}*	N (*kg ha^{-1}*)	*kg·ha-^{1}*
15	93.0	186.0	42.0	53.2	106.4	82.7	124.7
35	96.4	193.0	43.5	54.9	109.0	84.7	128.2
60	26.4	53.0	11.9	46.6	93.2	72.4	84.3

* das: days after seeding.

TABLE 4. Nitrogen (N) inorganic nitrogen in maize and grass leaves.

Association of corn with grasses:	N at flowering of corn (35 d)		N at grain filling of corn (60 d)	
	Corn leaves	Grass leaves	Corn leaves	Grass leaves
B. decumbens	2.90 a	2.91 b	2.60 a	2.40 ab
Mulato	2.66 b	3.31 a	2.53 a	2.58 a
Toledo	2.83 ab	3.20 ab	2.65 a	2.30 b
cv (%)	4.9	6.8	5.6	6.7

Means with different letters in the same column indicate significant difference according to Tukey test ($P < 0.05$).

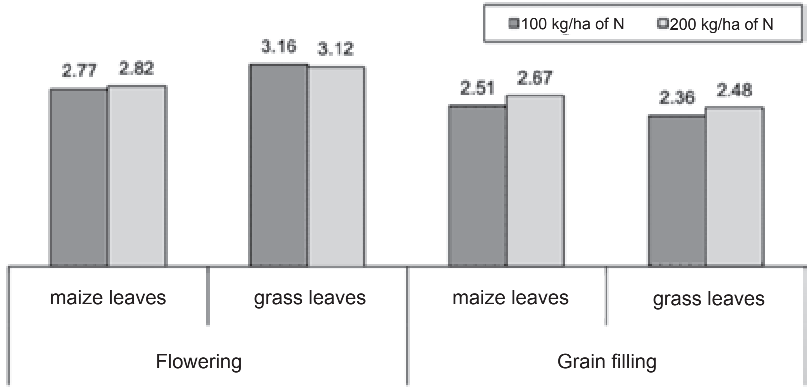

FIGURE 4. Foliar nitrogen (%) in corn-grasses association, in periods of flowering and grain filling of maize with two levels of nitrogen 100 and 200 kg ha^{-1}.

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