Article

DMPP nitrification inhibitor in the fertilization of forage corn in the Comarca Lagunera

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Abstracts

The Comarca Lagunera produces more than 2 343 million liters of milk per year from a herd of more than 465 thousand head of dairy cattle. The contamination of groundwater by nitrates and the emission of greenhouse gases (NO_2) are the most serious major environmental problems in intensive agriculture. The objective of this research was to evaluate the effect of fertilizers with nitrification inhibitor on yield, forage quality and foliar nutritional concentration. The research was conducted in 2017 at the La Laguna Experimental Field (INIFAP). Five fertilization programs with and without DMPP nitrification inhibitor plus a regional control with conventional fertilization were evaluated. The treatment that received 240 kg N ha^{-1} (regional control) produced the highest yield in green forage and dry matter (41.5 t ha^{-1} and 13.88 t DM ha^{-1} respectively). However, these values were statistically equal to the dose of 120 kg N ha^{-1} + IN DMPP. The highest grain yield (6.05 t ha^{-1}) was achieved with the treatment of 240 kg of N ha^{-1} + IN DMPP. The highest concentration of N in the foliage (2.43 and 2.32%) was achieved with the highest doses of N (360 kg ha^{-1}) without DMPP IN and with MPP IN respectively. Regarding the foliar nutritional concentration of Mg, S, Fe and Zn there was no significant difference between treatments. Forage quality analyzes indicate that the highest crude protein content (8.95%) was recorded with the 360 kg treatment of N ha^{-1} + IN DMPP. It is concluded that fertilizers with nitrification inhibitor can reduce the doses of N in feed corn.

Keywords: DMPP, foliar nutritional concentration, nitrification inhibitor.

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Introduction

The growth rate of the world population (8.5 billion in 2030) generates a high demand for high quality animal protein, cow's milk production is the main source to meet this need. However, the focus on increasing GBL productivity has resulted in inappropriate use of agricultural inputs, especially nitrogen fertilizers and pesticides that, when handled improperly and inefficiently, will 'filter' into the environment, affecting the quality of water, soil and the atmosphere (Groot and Van't Hooft, 2016).

In Mexico, the Comarca Lagunera is the main dairy basin in the country. It produces more than 2 343 million liters of milk per year from a herd of more than 465 thousand head of dairy cattle (GBL) (SIAP, 2017). The dairy herd in the region demands high amounts of quality forage throughout the year, so that in 2017 55 000 ha of forage corn (35 000 ha of gravity irrigation and 20 000 ha of pumping) were established in two cycles agricultural, spring-summer and autumn-winter. Feed corn is the main crop in this type of production system. The silo of this forage has a high concentration of soluble carbohydrates, is an important source of energy and has a high degradation in the rumen of the animal (NRC, 2001).

High yields and acceptable forage quality are related to biotic, abiotic factors and the supply of nutritional elements to the plant. Nitrogen (N) is the chemical element that is most related to performance, development and quality. In addition, it exerts a strong influence on the chemical composition of the grain, especially in the amino acid content, which translates into better forage quality (Szymanek and Piasecki, 2013). The inorganic compounds of N ($N\text{-}NO_3^-$ and $N\text{-}NH_4^+$) constitute less than 5% of the total nitrogen in the soil and are the main chemical ways in which N is absorbed by plants.

One of the main characteristics of soils in arid areas such as the Comarca Lagunera is its low content of organic matter (% OM) and N available ($N\text{-}NO_3^-$ and $N\text{-}NH_4^+$), so all crops require the application of organic and inorganic fertilizers to maintain an optimal nutritional condition that manages to project the maximum yield and quality potential of the hybrids used (Cueto *et al*., 2006).

When nitrogen fertilizers are applied to the soil they are directly absorbed by plants or transformed into various chemical forms in the oxidation process. When making applications without technical criteria based on crop demand, expected yield and supply (supply) of the soil, crops tend to be overfertilized (Figueroa *et al*., 2010). N ($N\text{- }NO_3^{-3}$) that is not absorbed by plants is lost in ionic or gaseous form (NO_x) in chemical and bacteriological processes such as leaching, volatilization and denitrification (Wei *et al*., 2014).

Groundwater contamination by ($N\text{-}NO_3^-$) of agricultural origin is one of the most serious environmental and human health problems in modern intensive agriculture. It can cause serious consequences for public health especially in certain population groups such as infants and pregnant women. This environmental problem is derived from an excess in the application of nitrogen fertilizers and the inadequate disposition of manure in dairy and livestock farms (Fernández and Soria, 2012).

According to current estimates in Mexico, agricultural activities are the third cause of greenhouse gas (GHG) generation with a contribution of 12% of emissions in the country. Most of these emissions are generated by the use of nitrogen fertilizers, enteric fermentation (methane generated in the digestion of ruminants and monogastrics) and manure management (Saynes *et al*., 2016).

By adding IN as the DMPP to nitrogen fertilizers it is possible to reduce the nitrification rate in which ammonium ($N\text{-}NH_4^+$) is transformed to nitrate ($N\text{-}NO_3^-$) while maintaining a greater proportion of the fertilizer applied in the soil, decreasing from this way N losses due to leaching and denitrification (Hu *et al*., 2013). The IN are highly selective, since they only act on nitrifying microorganisms (*Nitrosomas* spp. and *Nitrobacter* spp.) and not on other types of soil microorganisms. The IN are very effective in sandy soils, to avoid leaching $N\text{-}NO_3^-$ and in saturated soils, to avoid denitrification (NO_x).

The nitrification rate can be controlled by keeping the N in the form of ($N\text{-}NH_4^+$), which is retained by the clay complex of the soil due to its positive charge, thus avoiding leaching. Nitrification inhibitors (IN) are compounds with bacteriostatic effect that delay the formation of $N\text{-}NO_3^-$ by suppressing the activity of the bacteria of the genus *Nitrosomas* spp. The objective of the present investigation was to evaluate a fertilizer with the IN DMPP (3.4 Dimethyl Pyrazole Phosphate) in the yield of green, dry and grain fodder, forage quality and nutritional concentration.

Materials and methods

Description of the experimental site

The experiment was carried out in the summer cycle of 2017 in lot 13 of the Experimental Field of La Laguna (CELALA) belonging to the National Institute of Forestry, Agricultural and Livestock Research (INIFAP) located in Matamoros, Coahuila, Mexico. The municipality of Matamoros Coahuila, is located in the southwest of the state, at coordinates 103° 13’ 4” west longitude and 25° 31’ 41’’ north latitude, its height is 1 110 meters above sea level, it has an average annual rainfall of 258 mm

Prior to planting a sampling was carried out to characterize the soil physically and chemically. 6 random samples were taken at a depth of 0.30 m, these sub samples were mixed to form a composite sample which was sent to the soil laboratory of the Experimental Field (CELALA) for further analysis. The physical and chemical characteristics of the soil of the experimental site are shown in Table 1.

Table 1. Main characteristics of the soil of the experimental site.

Property	Units	Value
Sand	(%)	46.9
Silt	(%)	21.8
Clay	(%)	31.3
Textural class	--	Clay loam

Property	Units	Value
pH		8.4
Electric conductivity	dS m^{-1}	0.52
Organic material	(%)	1.1
Nitric nitrogen	mg kg^{-1} of soil of $N\text{-}NO_3$	9.4
Ammoniacal nitrogen	mg kg^{-1} of soil of $N\text{-}NH_4$	12.7
Available phosphorus	mg kg^{-1} of soil of P	12.9
Zinc (Zn^{2+})	mg kg^{-1}	0.72

It is a free soil with a tendency to sandy soil (47%), alkaline, non-saline pH, low in organic matter, low in phosphorus and available nitrogen.

Treatments and experimental design

A completely randomized block design was used, six treatments were evaluated with four repetitions per treatment. The experimental plots had an area of 60.8 m^2 (10 m long and 6.08 m wide). Within each plot, eight rows were formed at a distance of 0.76 m between each one, Table 2 refers.

Table 2. Treatments evaluated.

Treatment	Commercial product	kg N ha^{-1}	kg fertilizer ha^{-1}
1	Conventional urea (46% N)	120	261
2[2]	Conventional urea (46% N)	240	522
3	Conventional urea (46% N)	360	782
4[1]	Novatec Solub® (45% N)	120	267
5[1]	Novatec Solub® (45% N)	240	534
6[1]	Novatec Solub® (45% N)	360	800

[1]= treatments with IN DMPP (3,4 Dimethyl, Pyrazole phosphate); [2]= regional control.

Variables evaluated

Five variables were evaluated: green forage (FV), dry forage (FS) and grain yield. Foliar nutrient concentration (CNF) and forage quality (bromatological).

Statistical analysis of the data

Statistical analysis of the data was performed using the InfoStat® student version software (vIS 11-09-017). When there was a significant difference between treatments, a test of comparison of means by minimum significant difference (DMS) was performed.

Soil preparation

Prior to the experiment in the total experimental area, an unfertilized forage oat crop was established with the objective of 'bleaching' the soil. The land was leveled with Laser Plane® equipment to make irrigation more efficient. The plotting of plots, borders and roads was made. The land was fallow with vertical plow, two cross-barking steps were made to later form the plots of the plots and the support edges for the multi-port irrigation system.

Sowing and fertilization

The sowing was done dry on June 28, 2017 with a Gaspardo® precision pneumatic seeder. The seeded hybrid was Pioneer® P3966W which is a white grain corn, double purpose and resistant to finishing. One day before sowing, the seed was treated with 500 ml of Tiamethoxam (350 g l^{-1} of ia) per 100 kg of seed to avoid damage to the seed by the attack of soil pests. The planting density was 105 000 ha^{-1} plants (8 seeds per meter and 0.76 cm distance between rows).

Nitrogen fertilization of all treatments was divided into two, 50% at the time of planting and 50% prior to the first aid irrigation. Phosphorus fertilization (P) was the same in all treatments, consisting of 90 kg ha^{-1} of P_2O_5 using phosphoric acid (H_3PO_4, 52% P_2O_5) as a source of P. At 28 days after sowing (dds) carried out a crop or flush with landfills in order to break the 'crust' of the soil prior to the second fertilization (50% remaining) and the first aid irrigation.

Watering

The total irrigation sheet (LR) was 89 cm. Immediately after sowing and fertilization, the sowing irrigation was applied through the multi-port irrigation system, an irrigation envelope was made at 7 dds to help the seed to emerge and five irrigation risks as shown in Table 3.

Table 3. Irrigation frequency, periodicity and irrigation sheet.

Type of irrigation	Date	Days after planting (dds)	Irrigation sheet applied (cm)	Accumulated irrigation sheet (cm)
Sowing irrigation	Junio 28	0	18	18
Over irrigation	Julio 05	7	09	27
1er Assistance	Julio 26	28	12	39
2^{o} Assistance	August 9	42	14	53
3^{o} Assistance	August 25	58	12	65
4^{o} Assistance	September 8	72	13	78
5^{o} Assistance	September 26	90	11	89

Pest and weed control

Periodic inspections and monitoring of plots in the plots were carried out periodically, especially during critical periods (emergency, flowering and grain filling). The plague that presented with greater incidence was the cogollero worm (*Spodoptera frugiperda*), observing presence and damage from the emergence of the plants. A 'salereada' application of granulated Permethrin (0.4% GR) applied directly to the bud when the crop was 13 dds was made, then three applications of 44.5% Ethyl Chlorpyrifos CE were made. For the control of the same pest at 21, 31 and 59 days, the applications were carried out with backpack sprinkler and the applied dose was 500 mL ha^{-1}.

With a lower incidence it was presented: eloterous worm (*Helicoverpa* Zea), red spider (*Tetranychus urticae*) and diabrotic (*Diabrotic* spp.). An application of Betacyflutrim (8.4%) + Imidacloprid (19.60%) was performed at a dose of 500 mL ha^{-1} for the control of eloterous and diabrotic worm at 50 dds. For the control of the red spider, an application of Abamectin (18 g ia L^{-1}) was carried out at a dose of 1 000 mL ha^{-1} with a backpack spray gun.

Weed management and control was mainly manual with hoes. However, two herbicide applications were made. The first application was made at 34 dds, the product used was Dimethyl amine (2,4 D 49.4% S) for the control of broad leaves at a dose of 1 L of the product in solution in 100 L of water. The second application was made at 51 dds, the product used was nicosulfuron (4.21%) for the control of narrow leaves especially Johnson grass (*Sorghum halepense*) and wide leaves, mainly quelite (*Amaranthus hybridus*).

Soil sampling

A soil sampling was carried out prior to planting. Sampling was carried out by means of a box auger. Five random samples were made inside the experimental site at 30 cm depth to obtain a composite sample, the sample was spread over the cardboard bag and allowed to dry in the environment. Subsequently, the sample was ground until it passed through a 2 mm opening sieve. In the soil laboratory of the Experimental Field of La Laguna it was determined: texture, electrical conductivity, pH and the concentration of nitric nitrogen, ammonia and total inorganic nitrogen in extract obtained from 1M KCl and distilled by steam entrainment with MgO and Devarda alloy (Cueto *et al*., 2018).

Foliar sampling

At 65 days (September 1) when the crop was in the flowering stage, leaf sampling was carried out. 20 plants were taken randomly within each useful plot, two opposite leaves were taken from the cob of each plant which by convention is used for the assessment of the nutritional status of corn. The samples were dried in a forced air oven at a temperature of 65 °C until constant weight was reached. The N was analyzed by the Kjeldahl method. P by the molybdate-vanadate method in visible range spectrophotometer. K, Mg, Fe, Cu, Mn and Zn were analyzed by atomic absorption. The total samples were analyzed in 2018 at the National Soil Fertility and Plant Nutrition Laboratory of the Bajio Experimental Field.

Harvest

When the crop had 104 dds (October 11, 2017), a dry matter content of approximately 33% and the grain was in a phenological state known as a third of the milk line, the experiment was harvested. In each of the plots the four central grooves were harvested, a linear meter was left in each header to eliminate the edge effect such that the useful plot had an area of 24.32 m^2.

After harvesting the scale and weighing the harvested plants on the useful plot, the total plants, normal plants and hour plants were counted. Five plants were taken from each plot which were labeled and weighed at the time. Subsequently, the plants were sent to the laboratory of the experimental field of La Laguna where they were dried in an oven at 65 ºC until a constant weight was achieved, with this information the percentage of dry matter was calculated. dry matter (%)= dry weight/fresh weight x 100.

Results and discussion

Green forage and dry matter yield

The results of the statistical analyzes in the evaluated treatments showed differences only with respect to the treatment of 120 kg N ha^{-1} with conventional urea without IN DMPP. The treatment that received 240 kg N ha^{-1} in the form of conventional urea without IN DMPP (regional control), was the one that produced the highest yield of green fodder (41.5 t ha^{-1}) and dry matter (13.88 t ha^{-1}). However, it was statistically equal to the treatment that only received 120 kg N ha^{-1} + IN DMPP. The effect of 3, 4-dimethylpyrazole phosphate (DMPP) on the efficiency of ammonia fertilization in sweet orange and found that the treatment supplemented with IN DMPP improved the efficiency of nitrogen fertilization for the yield and foliar nitrogen concentration variables.

Nelson and Huber (2001) indicate that the potential benefit of the application of IN depends on specific site factors such as soil type, climate, cultural practices and N management programs and that the highest probability of yield response occurs in excessively or poorly drained soils due to losses of N from leaching and denitrification respectively. The results and comparison of means by significant minimum difference are shown in Table 4.

Table 4. Green forage yield.

Treatment	Green forage (t ha^{-1})	Dry material (%)
240 kg N ha^{-1} conventional urea	41.5 A	33.39 A
360 kg N ha^{-1} conventional urea	39.8 A	33.22 A
[1]360 kg N ha^{-1} Novatec Solub (45%N)	39.71 A	31.15 A
[1]240 kg N ha^{-1} Novatec Solub (45%N)	39.49 A	32.53 A
[1]120 kg N ha^{-1} Novatec Solub (45%N)	35.85 A	33.51 A
120 kg N ha^{-1} conventional urea	29.2 B	33.36 A

Means with a common letter are not significantly different (p> 0.05); [1]= fertilizer with IN DMPP.

Dry forage yield (FS)

Because the calculation of the FS yield is obtained by multiplying the green forage yield by the dry matter by 100, the results are similar to those of PV. The performance of FS was statistically equal between the regional control (240 kg N ha^{-1} UC) and the treatments with the dose of (240 kg N ha^{-1} + IN DMPP) and high (360 kg of N ha^{-1} UC and + DMPP). These results agree with the data obtained by Cueto *et al*. (2006) who in 1998 in a research on forage maize on the effect of population density and nitrogen fertilization found that the best yields of FS were achieved with the dose of 250 and 375 kg of N ha^{-1}.

It should be noted that there is only a difference of 1.89 t ha^{-1} DM between the regional control (240 kg N ha^{-1}) and the treatment with DMPP IN of 120 kg ha^{-1}. Barrientos (2016) conducted an investigation on the effect of the DMPP nitrification inhibitor on N dynamics, yield and quality of forage corn, finding that the best yield was obtained with the dose of 244 kg of N ha^{-1} with the IN DMPP and foliar applications of micronutrients and biological compounds.

It should be noted that there was a difference of 2.2 t ha^{-1} between the treatment with the lowest dose of N (120 kg ha^{-1}) with the DMPP IN compared to the treatment with the same dose of N, but without the IN DMPP. The results of the statistical analysis and the means comparison test are shown in Table 5.

Table 5. Dry forage yield.

Treatment	Dry forage (t ha^{-1})	Dry material (%)
240 kg N ha^{-1} conventional urea	13.88 A	33.39 A
360 kg N ha^{-1} conventional urea	13.22 A	33.22 A
[1]240 kg N ha^{-1} Novatec Solub (45%N)	12.82 A	31.15 A
[1]360 kg N ha^{-1} Novatec Solub (45%N)	12.4 A	32.53 A
[1]120 kg N ha^{-1} Novatec Solub (45%N)	11.99 A B	33.51 A
120 kg N ha^{-1} conventional urea	9.78 B	33.36 A

Means with a common letter are not significantly different ($p > 0.05$); [1]= Fertilizer with IN DMPP.

Grain yield

The treatment based on 240 kg N ha^{-1} + IN DMPP was the one that obtained the highest yield (6.05 t ha^{-1}) surpassing the regional control (240 kg N ha^{-1} without IN DMPP) by 550 kg ha^{-1}. The increase in grain yield when using fertilizers with the IN DMPP is consistent with the results obtained by Pasda *et al*. (2001) who evaluated the effect of IN DMPP on the quality and yield of wheat, corn, potatoes and sugar beets. These authors point out that by using the IN DMPP and dividing it into two applications in the cultivation of winter wheat they managed to increase the yield of grain up to 250 kg ha^{-1}.

Similar results were obtained by Linares *et al*. (2012) who evaluated the effect of fertilization with conventional urea treated with IN in the state of Carabobo in Venezuela. They found that in the treatments where IN DMPP was added they obtained differences of up to 1.2 t ha^{-1} with respect to the others, observed in Table 6.

Table 6. Grain yield.

Treatment	Grain yield (t ha^{-1})
[1]240 kg N ha^{-1} Novatec Solub (45%N)	6.05 A
240 kg N ha^{-1} conventional urea	5.5 A B
[1]120 kg N ha^{-1} Novatec Solub (45%N)	5 A B
[1]360 kg N ha^{-1} Novatec Solub (45%N)	4.88 A B
360 kg N ha^{-1} conventional urea	3.95 B C
120 kg N ha^{-1} conventional urea	2.83 C

Means with a common letter are not significantly different ($p > 0.05$); [1]= Fertilizer with IN DMPP.

Foliar nutrient concentration

Total nitrogen

The highest concentrations of total nitrogen (% NT) in the plant (2.43 and 2.32%) were obtained with the high doses of N (360 kg N ha^{-1} UC and 360 kg N ha^{-1} IN DMPP). A close relationship is observed between the N applied per hectare and the concentration of foliar NT regardless of the inclusion of the IN DMPP. Similar results were obtained by Shintate *et al* (2016) in an investigation carried out in Selvira, Brazil where they evaluated in corn the yield and foliar diagnosis in relation to nitrogen fertilization and inoculation of bacteria found that the increase in the fertilization rate with N influenced the concentration of N, P and S, regardless of the source of fertilization used.

Phosphorus, potassium and calcium

In the case of phosphorus, the highest concentration was achieved with the high N dose (360 kg N ha^{-1}) without the nitrification inhibitor, treatments 1, 4, 5 and 6 were statistically the same. It should be noted that all treatments were low in the content of this element since the sufficiency range is from 0.31 to 0.5%. In the case of potassium (K) all treatments had a sufficient concentration (2.1 to 3.1%) with the exception of treatments with the low dose of N (120 kg ha^{-1}) with and without IN DMPP.

In calcium concentration there was no significant difference between treatments. The concentration of this element was high in all treatments due to the origin of the soils since the sufficiency range is between 0.26 and 0.8%, in Table 7.

Table 7. Foliar nutrient concentration of N, P, K and Ca at 65 dds.

Treatment	Total N (%)	Treatment	P (%)	Treatment	K (%)	Treatment	Ca (%)
360 kg N (UC)	2.43 A	360 kg N (UC)	0.21 A	360 kg N (S45)	2.22 A	240 kg N (UC)	0.99 A
360 kg N (S45)	2.32 A	240 kg N (S45)	0.19 AB	240 kg N (UC)	2.19 A	120 kg N (UC)	0.97 A
240 kg N (S45)	2.27 AB	360 kg N (S45)	0.18 AB	120 kg N (UC)	2.17 A	120 kg N (UC)	0.394 A

Treatment	Total N (%)	Treatment	P (%)	Treatment	K (%)	Treatment	Ca (%)
240 kg N (UC)	2.25 AB	120 kg N (UC)	0.15 AB	240 kg N S45)	2.11 A	360 kg N (UC)	0.94 A
120 kg N (UC)	2.02 B	120 kg N (S45)	0.15 AB	120 kg N S45)	2.08 A	120 kg N (S45)	0.91 A
120 kg N (S45)	1.67 C	240 kg N (UC)	0.15 B	360 kg N UC)	1.93 A	360 kg N (S45)	0.89 A

Means with a common letter are not significantly different (*p*> 0.05); UC= conventional urea. S45= Novatec Solub 45®.

Foliar nutrient concentration

Magnesium, sulfur, iron and zinc

There was no significant difference between treatments in the concentration of Mg, S and Fe. The concentration of Mg and S in all treatments was low. The sufficiency range for magnesium is 0.61 to 0.9% and 0.16 to 0.61% for sulfur. The iron concentration in all treatments was high, the sufficiency range of this element is 31 to 121 ppm. The highest concentration of Zn (54.8 ppm) was presented in the regional control. The zinc concentration in all treatments was sufficient (Table 8).

Table 8. Nutritional concentration of Mg, S, Fe and Zn at 65 dds.

Treatment	Mg (%)	Treatment	S (%)	Treatment	Fe (ppm)	Treatment	Zn (ppm)
240 kg N (UC)	0.27 A	240 kg N (UC)	0.27 A	360 kg N (UC)	240.75 A	360 kg N (S45)	54.8 A
120 kg N (UC)	0.27 A	240 kg N (S45)	0.24 A	240 kg N S45)	237.5 A	120 kg N (UC)	51.13 AB
240 kg N (S45)	0.27 A	360 kg N (UC)	0.23 A	120 kg N (UC)	221.25 A	360 kg N (UC)	49.18 AB
120 kg N (S45)	0.26 A	120 kg N (S45)	0.21 A	240 kg N (UC)	203.25 A	240 kg N (UC)	47.48 AB
360 kg N (UC)	0.26 A	360 kg N (S45)	0.19 A	120 kg N S45)	199.75 A	240 kg N (S45)	47 AB
360 kg N (S45)	0.25 A	120 kg N (UC)	0.14 A	360 kg NS45)	187.75 A	120 kg N (S45)	40.9 B

Means with a common letter are not significantly different (*p*> 0.05); UC= conventional urea; S45= Novatec Solub 45®.

Forage quality

Crude protein (CP%)

It is called 'crude' since it is not a direct measurement of the protein, but an estimate of the total protein based on the foliar nitrogen content. It is calculated by multiplying the N x 6.25= crude protein. Crude protein includes true protein and non-protein nitrogen (NNP). The results only showed difference of all treatments with the dose of 120 kg N ha^{-1} without the IN DMPP. The treatment based on 360 kg N ha^{-1} with IN DMPP was the one that reached the highest percentage of CP due probably to a greater availability of inorganic N in the soil. The crude protein content of the treatment with only 120 kg N ha^{-1} was statistically equal to the treatment with 360 kg N ha^{-1}.

Acid detergent fiber (FDA)

It is a measure of quantification of lignin and cellulose. The higher the lignin content, the digestibility of cellulose decreases, so it correlates negatively with the total digestibility of the forage evaluated (Melendez, 2015). The treatment with the highest percentage of FDA was with the maximum nitrogen dose (360 kg ha with the IN DMPP) which was statistically equal to the treatment with 120 kg N with the IN DMPP. The treatments with the lowest lignin content were at doses of 240 and 120 kg N ha^{-1} without the IN DMPP and statistically the same.

Neutral detergent fiber (FDN)

The percentage of FDN is the measure of cellulose, hemicellulose and lignin represented in the fibrous part of the forages. The content of FDN in GBL diets correlates negatively with food consumption. The higher the FDN content, the less food consumption by livestock. The percentage of NDF in the treatments fluctuated between 39.23% (120 kg of N ha^{-1} without the IN DMPP) and 46.23% (360 kg N ha^{-1} with the IN DMPP). There was no significant difference between treatments. The results of the statistical analysis and the means comparison test are shown in Table 9.

Table 9. Crude protein (CP), acid detergent fiber (FDA) and neutral detergent fiber.

Treatment	CP (%)	Treatment	FDA (%)	Treatment	FDN (%)
360 kg N (S45)	8.95 A	120 kg N (UC)	29.93 A	120 kg N (UC)	46.23 A
120 kg N (S45)	8.75 A	360 kg N (S45)	28.73 A	120 kg N (S45)	43.33 A
360 kg N (UC)	8.6 A	120 kg N (S45)	27.58 AB	240 kg N (UC)	41.95 A
240 kg N (S45)	8.45 A	240 kg N (UC)	26.95 AB	360 kg N (S45)	41.5 A
240 kg N (UC)	8.4 A	240 kg N (S45)	25.13 B	240 kg N (S45)	39.93 A
120 kg N (UC)	7.3 B	360 kg N (UC)	24.2 B	360 kg N (UC)	39.23 A

Means with a common letter are not significantly different ($p > 0.05$); CP= crude protein; FDA= acid detergent fiber and FDN= neutral detergent fiber.

Conclusions

The use of IN DMPP presented a high potential to reduce the doses of nitrogen fertilizers minimizing in this way the contamination of bodies of water with nitrates and the atmosphere with gases derived from the denitrification process. No significant differences were found in the foliar concentration of nutrients or in the forage quality of the corn silo derived from the application of IN DMPP.

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