

## Nitrogen's Balance in the soil-plant system with guinea-grass (*Panicum maximum* Jacq) in tropical dry forest

M.F. Pirela<sup>1</sup>, T. Clavero<sup>2</sup>, L. Fernández<sup>2</sup> L. Sandoval<sup>2</sup>

<sup>1</sup>Instituto Nacional de Investigaciones Agrícolas (INIA). Estación Local Carrasquero.

<sup>2</sup>Universidad del Zulia, Facultad de Agronomía, Maracaibo.

### Abstract

In order to study the nitrogen balance on the soil-plant system with guinea grass (*Panicum maximum* Jacq), an essay was carried out in the western part of Venezuela. The area belongs to a Tropical dry Forest, with an average annual precipitation of 1200mm with average temperatures of 28°C. An experimental design with randomized blocks was used with five replications and three nitrogen levels  $N_0 = 0 \text{ kg ha}^{-1}\cdot\text{year}^{-1}$ ,  $N_1 = 100 \text{ kg ha}^{-1}\cdot\text{year}^{-1}$  and  $N_2 = 200 \text{ kg ha}^{-1}\cdot\text{year}^{-1}$ . The data was processed using Pearson's correlation analysis. Se evaluó el contenido de nitrógeno (N-Total) en la planta, las pérdidas de nitrógeno por efecto de la precolación, escorrentía, el contenido de nitrógeno en el suelo y el aporte de nitrógeno por la lluvia. Los resultados obtenidos muestran que la distribución porcentual del nitrógeno en la planta resultó en un 55% en la biomasa removida, un 35% en la biomasa residual y un 10% en la biomasa radicular. Las pérdidas por percolación ocurrieron en un 80% como  $\text{N}-\text{NO}_3^-$  y en un 20% como  $\text{N}-\text{NH}_4^+$ . Las pérdidas por escorrentía resultaron muy pequeñas con valores que no excedieron  $1 \text{ kg ha}^{-1}\cdot\text{año}^{-1}$ . Del nitrógeno en el agua de lluvia el  $\text{N}-\text{NH}_4^+$  se constituye en el mayor aporte con  $8,4 \text{ kg ha}^{-1}\cdot\text{año}^{-1}$  mientras tanto, el  $\text{N}-\text{NO}_3^-$   $8,4 \text{ kg ha}^{-1}\cdot\text{año}^{-1}$  mientras un 66,8% y 33,2% respectivamente. Were evaluated nitrogen's content (Total-N) in the plant, nitrogen's lost by effect of percolation, run-off, and nitrogen's content in the soil and the nitrogen's provision by rain. The obtained results show that the percentage distribution of nitrogen in the plant was of 55% in the removed biomass, 35% on the residual biomass and 10% on the radicle biomass. Lost by percolation occurred in 80% as in  $\text{N}-\text{NO}_3^-$  and 20% as  $\text{N}-\text{NH}_4^+$ . Lost by run-off were not too much, with values that did not exceed  $1 \text{ kg}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$ . Of the nitrogen if the rain water  $\text{N}-\text{NH}_4^+$  constitutes the highest contribution with  $8.4 \text{ kg ha}^{-1}\cdot\text{year}^{-1}$  meanwhile,  $4.16 \text{ kg N}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$  showing 66.8% and 33.2% respectively.

**Key words:** Nitrogen, guinea grass, dynamic

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Author email: mpirela@inia.gov.ve

## Introduction

On Pasture production, nitrogen is one of the most important nutriment which characterizes by being submitted to a permanent transformation dynamic and biochemical synthesis in the soil-plant system, where profits and lost of the element are shown on relatively short periods.

From the point of view of pasture's mineral nutrition, nitrogen is one of the conditional elements of limitations in the plant's development, on this matter; Delgado *et al.* (8) mention the importance of studying nitrogen in the soil since its incorporation is almost compulsory at any fertilization plan in the different crops.

There are lots of aspects that influence this profit and lost process as the type of soil, cover, doses and

source of nitrogen, quantity and time of rains, infiltration velocity, and removal rate of pasture among other aspects (2). This evidences the importance of handling rationally the nitrogen fertilizers through the diagnose and knowledge of the response of forage species by means of the profit and lost processes of nutriment that take place on the soil-plant system.

It is necessary to carry out a research to try to explain all processes that occur in the agro-systems when nitrogen is applied as a fertilizer. This research constitutes a slight approximation on the nitrogen's dynamic and its main objective is: to do a balance of nitrogen in order to show the importance and nature of lost in the soil-plant system with guinea grass (*Panicum maximum* Jacq).

## Materials and methods

The study took place at El Laberinto, Jesús Enrique Lossada municipality, Zulia state. The predominant weather and vegetation in the area under study are classified as Tropical dry Forest (16). The average annual precipitation is of 1200mm with a bimodal regimen with two rainy periods (May-June and September-November), and two drought periods (December-April and July-August). Monthly mean temperatures for maximum and minimum values are 36.6°C and 22.1°C respectively (17). Soils have formed through materials coming

from the formation "El Milagro", with an argillite horizon that is presented at 50 cm. The content of organic matter is inferior to 2%. Soils were grouped on the taxonomical unit Ultic paleustalf (5). The essay was designed in plots with a surface of 1125m of land sowed with guinea grass. For the processing of the experimental information, was used Pearson's correlation analysis (20). The experimental design used was randomized blocks with 5 replications and 3 treatments applied at random (0-100-200 kg N.ha<sup>-1</sup>.year<sup>-1</sup>).

Each experimental unit was

constituted by plots of 75 m<sup>2</sup>. At the same time, these were divided in sub-plot A of 3m x 15 m 75 m<sup>2</sup>, where were evaluated nitrogen in the soil, plant and its leaching. Sub-plot B of 2 m 15 m (30 m<sup>2</sup>) of length, where nitrogen's measurements in the water were done by run-off.

Urea was used as a source for levels of nitrogen fertilization, as well as a standard dose of phosphorus by means of 100 kg of P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup>.year<sup>-1</sup>. A cut with rotary was done before to uniform grass.

The foliar mass was submitted to 11 cuts every 35 days, and 3 plants were sampled per experimental unit. Plants were divided in three sections: residual biomass, which belonged to the part of the plant that was in a height from 0 to 40cm; removed biomass, at a superior height of 40cm and radicle biomass. A total of 90 sampled/cut were analyzed. Grass sampled were put on plastic bags and dried at 60°C for 48 h. The content of Total-N was determined by the Kjeldahl's method (1).

Samples of soil were taken per plot in a depth from 0 to 20 cm, just immediately alter each of the programmed cuts. Samples dried at 55°C. Once dried, it was proceeded to determine the content of total nitrogen (total-N), ammoniacal

nitrate ((N-NH<sub>4</sub><sup>+</sup>) and nitric nitrogen (N-NO<sub>3</sub>) using Kjeldahl's method (4), Magnesium oxide and Devarda respectively (3).

The lysimeter methodology (13) was used to evaluate the leached nitrogen, putting two lysimeters in two depths (from 0 to 20 cm and from 0 to 40 cm) for each treatment in all 5 replications, with the aim of knowing the development of leaching. Lysimeters were built with PVC (polyvinyl chloride) tubes of 15.25 cm diameter. For their install, these were pushed from the soil's surface to down the land. Collected samples were measured with a graduated cylinder and 5 ml of toluene was applied per each liter of percolated water in order to avoid its decomposition caused by microorganisms. Analysis to determine N-NH<sub>4</sub><sup>+</sup> and N-NO<sub>3</sub><sup>-</sup> were done by duplicate, using the Magnesium oxide (MgO) method and Devarda respectively (4).

Nitrogen by run-off was determined in sub-plots B, on the base of the methodology (10). The content of N-NH<sub>4</sub><sup>+</sup> N-NO<sub>3</sub><sup>-</sup> (4) in samples was analyzed by duplicated.

A rain gauge was installed on the study area, to measure precipitation and quantify by duplicate the provisions of N-NH<sub>4</sub><sup>+</sup> and N-NO<sub>3</sub><sup>-</sup> to the system (4).

## Results and discussion

Accumulation and distribution of Nitrogen in the plant.

Studying the nitrogen's accumulation and distribution in the plant (table 1), is seen that

independently of levels, more than 50% of nitrogen in the plant is over 40 cm of height, agreeing to those reported by Joffre (1990). This finding must be considered at the moment of

**Table 1. Content of accumulated nitrogen (kg.ha<sup>-1</sup>) and percentage distribution in the removed biomass, residual biomass and radicle biomass for the different treatments.**

Levels	N in the biomass					
	Removed (%)	Residual (%)	Radicle (%)	Plant		
0 kg N ha <sup>-1</sup>	102.75 (51.6)	73.89 (37.1)	22.35 (11.3)	198.98		
100 kg N ha <sup>-1</sup>	151.88 (56.5)	89.18 (33.1)	27.59 (10.4)	268.65		
200 kg N ha <sup>-1</sup>	189.81 (55.1)	116.87 (33.9)	37.48 (11.0)	344.16		

establishing the adequate grazing height for animals, for the best handle of guinea grass. Comparing nitrogen's removal for three levels, it is observed that the non application of nitrogen in the plant is able to remove the quantity in the soil-plant system of 198.9 kg N.ha<sup>-1</sup>.year<sup>-1</sup>.

This removal might be the result of a contribution to the system by free fixation or a contribution coming from the deep layers of the soil due to the contribution of rain. Even though, when 100 kg.N.ha<sup>-1</sup> was applied, the removed quantity increased to 268.6 kg N.ha<sup>-1</sup>.year<sup>-1</sup> which represents an increased of 26% in relation to the lack of nitrogen. For treatment of 200 kg N.ha<sup>-1</sup>, a removal

of 344.1 kg N.ha<sup>-1</sup>.year<sup>-1</sup> is observed, representing an increment of 42.2% in relation to the witness.

Similar results report Sistani *et al.* (19) in a research about the dynamic of nutrients in the soil with three meadow grass cultivars (*Cynodon dactylon* (L) Pers.). It is important to mention the marked effect of treatments' levels, which is understood as a considerable increased in the nitrogen's removal, maybe due to the capacity of nitrogen of accelerating the growth's rate in the plant through transformations and synthesis of biochemical aspect that occur on it (2, 7).

#### **Nitrogen and the production of dry matter:**

The correlation analysis done

**Table 2. Correlation between the nitrogen's content in the plant and the production of dry matter.**

Dry matter	Nitrogen's content in the plant		
	Removed	Residual	Radicle
MS-Removed	0.86*	-	-
MS-Residual	-	0.81*	-
MS-Radicle	-	-	0.95*

\*(P<0.01)

(table 2), shows a high positive correlation ( $r=0.86$   $P<0.01$ ) between the nitrogen's content and the production of dry matter on the removed biomass of the plant. Likewise, in the production of dry matter of the residual biomass and on the dry matter of the radicle biomass similar correlations appeared ( $r= 0.81$ ;  $P<0.001$ ), ( $r= 0.95$ ;  $P<0.01$ ) respectively. These results agree to those reported by Coto *et al.* and McLaughlin *et al.*, who found a high positive correlation between the nitrogen's content in the plant and the production of dry matter.

### Nitrogen in the soil.

The nitrogen's content in the soil for the treatment of  $0 \text{ kg N}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$  (table 3), shows a progressive reduction in the time on each of the evaluated ways (Total N,  $\text{N-NH}_4^+$  and  $\text{N-NO}_3^-$ ), emphasizing a low relation  $\text{N-NH}_4^+ / \text{N-NO}_3^-$ , which increases gradually at the time that passes the time, predominating the presence of the ammonium ion. The variation of the Total N on the superficial layer 0-20 cm is of  $40 \text{ kg ha}^{-1}$ , which is under the extraction of  $198.98 \text{ kg}\cdot\text{N}\cdot\text{ha}^{-1}$  done by the plant, which evidences the probability of an active free fixation, and a participation of deep layers of the soil on the nitrogen nourishment of the plant. A similar situation is presented in other treatments.

The average values for treatments of  $100$  and  $200 \text{ kg N}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$  are showed on tables 4 and 5 respectively. There is seen a similar tendency to the one observed with treatment  $0 \text{ kg N}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$ . At the same time, a predominance of ammonium on

the nitrates is observed during the entire essay.

This predominant situation of  $\text{N-NH}_4^+$  might be due to the interchange of nitrogen that happens between the soil and the atmosphere. On this matter, Hanawalt (9) says that the soil absorbs enough quantity of nitrogen as ammonium of the atmosphere, which allows maintaining the fertility during an undefined period. Of nutrients of the soil, nitrogen has been the focus of different research; however, there are aspects that have not been totally elucidated. For example, lost and gain of nitrogen are still topic of discussion.

### Nitrogen on percolated water

Accumulated values of lixiviated nitrogen during all year of evaluation show that the highest percentage is represented by  $\text{N-NO}_3^-$  compare to  $\text{N-NH}_4^+$  which is on an inferior percentage of 20%, table 6. These values are at a depth of 20 cm. There was no lixiviation on level 40 cm.

This situation is similar in all the applied levels. These results agree to those found by Johnson *et al.*, and Renck (12, 18) who mention that nitrogen's lost by lixiviation mainly occur as  $\text{NO}_3^-$  and  $\text{NH}_4^+$  is presented on insignificant quantities. This is logical since the ammonium is retained more intensely by the colloidal complex than ion  $\text{NO}_3^-$ .

Relating the lixiviated nitric-N with the reduction of nitric-N in the soil, is seen that the plant must absorb the nitric N and that nitrification is not active enough with pasture to compensate this reduction.

Doing the corresponding

**Table 3. Nitrogen's content (kg.ha<sup>-1</sup>) in the soil (0-20 cm) at the moment of each cut for level 0 kg.N.ha<sup>-1</sup>**

Cut	0	1	2	3	4	5	6	7	8	9	10	11
N-NO <sub>3</sub>	14.8	17.2	14.9	9.5	5.4	5.1	5.0	5.1	4.9	3.8	3.9	3.6
N-NH <sub>4</sub> <sup>+</sup>	13.3	15.4	13.9	5.4	4.9	8.3	9.1	7.4	7.2	7.3	7.0	6.3
A/N	0.8	0.8	0.9	0.5	0.9	1.5	1.8	1.4	1.4	1.9	1.7	1.7
NT	55.1	51.2	48.3	28.7	27.3	30.7	20.1	20.2	18.8	17.2	16.8	14.3

A/N= Relation N-NH<sub>4</sub><sup>+</sup>/N-NO<sub>3</sub>

NT= Total nitrogen

Cut 0= Initial-N

**Table 4. Nitrogen's content (kg.ha<sup>-1</sup>) in the soil (0-20 cm) at the moment of each cut for level 100 kg.N.ha<sup>-1</sup>**

Cut	0	1	2	3	4	5	6	7	8	9	10	11
N-NO <sub>3</sub>	14.8	21.4	27.7	24.2	20.4	11.1	8.3	7.9	6.0	7.1	5.2	5.1
N-NH <sub>4</sub> <sup>+</sup>	13.4	34.9	33.7	20.9	18.1	13.8	15.4	14.9	13.4	12.7	10.4	11.2
A/N	0.9	1.6	1.2	0.8	0.8	1.2	1.8	1.8	2.2	1.7	2.0	2.1
NT	60.0	83.8	80.1	58.3	52.1	49.4	40.1	32.2	30.1	32.8	22.4	21.3

A/N= Relation N-NH<sub>4</sub><sup>+</sup>/N-NO<sub>3</sub>

NT= Total nitrogen

Cut 0= Initial-N

Table 5. Nitrogen's content (kg.ha<sup>-1</sup>) in the soil (0-20 cm) at the moment of each cut for level 200 kg.N.ha<sup>-1</sup>

Cut	0	1	2	3	4	5	6	7	8	9	10	11
N-NO <sub>3</sub> <sup>-</sup>	14.7	60.3	60.9	62.4	53.6	32.3	17.1	9.4	7.8	13.9	6.6	5.9
N-NH <sub>4</sub> <sup>+</sup>	13.2	77.4	71.5	48.7	43.3	45.1	26.1	19.2	13.4	23.4	11.6	13.4
A/N	0.8	1.3	1.1	0.7	0.8	1.4	1.5	2.0	1.7	1.6	1.7	2.2
NT	55.6	178.0	146.7	132.7	109.2	102.7	55.9	48.7	39.8	53.3	27.4	30.8

A/N= Relation N-NH<sub>4</sub><sup>+</sup>/N-NO<sub>3</sub><sup>-</sup>

NT= Total nitrogen

Cut 0= Initial-N

correlation analysis (table 7), it is observed that N-NO<sub>3</sub><sup>-</sup> is positively correlated to the volume of percolated water ( $r=0.91$ ;  $P<0.01$ ), with the precipitation ( $r= 0.80$ ;  $P<0.01$ ) and with the content of N-NO<sub>3</sub><sup>-</sup> in the water of rain ( $r= 0.83$ ;  $P<0.01$ ). These relations agree to the information reported by Van Der Kruijs *et al.* (21), who mention that the N-NO<sub>3</sub><sup>-</sup> content in the percolation's water depends on the percolation's volume and on precipitation among other factors.

The volume of percolated water shows a significant correlation to the precipitation ( $r= 0.825$ ;  $P<0.01$ ). Superior or equal precipitations of 22 mm, are necessary to generate water flow on the profile of the soil from 0 to 20 cm depth, meanwhile superior or equal precipitations of 43 mm are necessary to produce water flow at a depth from 0 to 40 cm.

#### Nitrogen on run-off water

Generally, annual lost of nitrogen through run-off water (table 8) for the different levels of nitrogen applied resulted insignificant with values inferiors to 1 kg.N.ha<sup>-1</sup>.year<sup>-1</sup>. Likewise, it is observed that annual lost of N-NO<sub>3</sub><sup>-</sup> resulted to be similar to N-NH<sub>4</sub><sup>+</sup>. Similar results are reported by Maass *et al.* (13), who affirm that run-off is not the main cause of nitrogen's lost on pastures.

Table 9 show the correlation analysis between nitrogen contest in run-off water and the study variables. Data showed significant relationship between N-NO<sub>3</sub> with rainfall ( $r=0.69$   $P<0.01$ ), with the run-off water ( $r=0.75$   $P<0.01$ ) with N-NO<sub>3</sub> in rainfall ( $r=0.48$   $P<0.01$ ).

**Table 6. Nitrogen's content in the percolation's water for different treatments (kg N.ha<sup>-1</sup>) at 20 cm depth.**

Treatment	N-NO <sub>3</sub> <sup>-</sup>	(%)	NH <sub>4</sub> <sup>+</sup>	(%)
0 kg.N.ha <sup>-1</sup>	8.61	(87)	1.23	(13)
100 kg.N.ha <sup>-1</sup>	13.67	(83)	2.69	(17)
200 kg.N.ha <sup>-1</sup>	18.0	(84)	3.39	(16)

**Table 7. Correlation between nitrogen's content on the percolation's water and the studied variables.**

Variables	NH <sub>4</sub> <sup>+</sup>	N-NO <sub>3</sub> <sup>-</sup>
Precipitation	0.21 <sup>ns</sup>	0.80 *
N-NH <sub>4</sub> <sup>+</sup> on the water of rain	0.27 <sup>ns</sup>	-
N-NO <sub>3</sub> <sup>-</sup> on the water of rain	-	0.83*
Volume of percolated water	0.21 <sup>ns</sup>	0.91*

\*\* (P<0,01) ns= non significant

**Table 8. Nitrogen's content on the run-off water for different treatments (kg N.ha<sup>-1</sup>)**

Treatments	NH <sub>4</sub> <sup>+</sup>	(%)	N-NO <sub>3</sub> <sup>-</sup>	(%)
0 kg N ha <sup>-1</sup>	0.13	(50)	0.13	(50)
100 kg N ha <sup>-1</sup>	0.19	(49)	0.20	(51)
200 kg N ha <sup>-1</sup>	0.25	(54)	0.29	(56)

**Table 9. Correlation between nitrogen's content on the run-off water and the studied variables.**

Variables	NH <sub>4</sub> <sup>+</sup>	N-NO <sub>3</sub> <sup>-</sup>
Precipitation	0.38 <sup>ns</sup>	0.69*
NH <sub>4</sub> <sup>+</sup> on the water of rain	0.48 <sup>ns</sup>	-
N-NO <sub>3</sub> <sup>-</sup> on the water of rain	-	0.78*
volume of drained water	0.45 <sup>ns</sup>	0.75*

\*(P<0,01) ns = no significativo

### Nitrogen on precipitation's water

N-NH<sub>4</sub><sup>+</sup> becomes the highest contribution with 8.4 kg N.ha<sup>-1</sup>.year<sup>-1</sup> of the supplied nitrogen by rain, while N-NO<sub>3</sub> provides 4.1 kg N.ha<sup>-1</sup>.year<sup>-1</sup>, representing 66.8% and 33.2% of what was provided to the soil-plant system respectively (table 10). In the savannah of Venezuela, varied quantities that go from 2.6 to 19 kg N.ha<sup>-1</sup>.year<sup>-1</sup> are found as ammonium, mentioned by Medina (15).

On table 8 correlation analysis are described, between the nitrogen's content on the run-off water and the studied va-

riables, observing significant correlations between N-NO<sub>3</sub><sup>-</sup> with precipitation ( $r=0.69$ ;  $P<0.01$ ), with the run-off volume ( $r= 0.75$ ;  $P<0.01$ ), with N-NO<sub>3</sub><sup>-</sup> on the water of rain ( $r=0.48$ ;  $P<0.01$ ).

### Final balance of lost and gains

On table 11 is presented the general balance of enters and exits of nitrogen on the soil-plant system for the studied variables, where a positive balance can be seen for treatments with doses of 100 and 200 kg N.ha<sup>-1</sup>.year<sup>-1</sup> and a negative balance for the witness level. These results allow to infer the

**Table 10. Content of N-ammoniacal (ammoniacal) and N-nitric on the precipitation water (kg N.ha<sup>-1</sup>).**

Nitrogen	Quantity	%
N-NH <sub>4</sub>	8.4	66.8
N-NO <sub>3</sub>	4.1	33.2
Total	12.5	100

**Table 11. General balance of enters and exits of nitrogen on the soil-plant system (kg. N.ha<sup>-1</sup>).**

Enters	0 kg N.ha <sup>-1</sup> level	100 kg N.ha <sup>-1</sup> level	200 kg N.ha <sup>-1</sup> level
Initial N-soil	55,1	60,0	55,6
Fertilizer-N	0	100	200
N-precipitation	12,50	12,50	12,50
Total of enters	67,6	172,5	268,1
Exits			
Nitrogen on the removed biomass	102,0	151,88	189,81
Run-off	0,26	0,39	0,54
Lixiviation	9,84	16,36	21,39
Total of exits	112,1	168,6	211,74
Final balance	-44,5	3,9	56,36

necessity of fertilizing annually the evaluated soil-plant system, being the dose of 100 kg N.ha<sup>-1</sup>.year<sup>-1</sup> the nearest to the equilibrium of the system, considering the studied variables, and the importance of guaranteeing a quality pasture for animals.

The extraction of nitrogen by the plant constitutes the highest exit with a market effect of the applied doses, which is understood as a considerable increment in the nitrogen's removal by the plant, maybe due to the capacity of the nitrogen to accelerate the growth's rate in the

plant, through transformations and biochemical synthesis that happens on it.

Exits of nitrogen by lixiviation and run-off are few and moderate respectively to be considered important. The contribution of nitrogen by precipitation totalizes 12.5 kg N.ha<sup>-1</sup>.year<sup>-1</sup>.

The highest contribution of nitrogen by rains is presented as N-NH<sub>4</sub><sup>+</sup> as 8.4 kg N.ha<sup>-1</sup>.year<sup>-1</sup>, while N-NO<sub>3</sub><sup>-</sup> adds 4.1 kg N.ha<sup>-1</sup>.year<sup>-1</sup> representing 68.8% and 33.2% of the total of nitrogen supplied by the precipitation.

## Conclusions

Removal of N of plants constitutes the most important factor on lost of nitrogen in the evaluated soil-plant system. This elevated extraction of nitrogen suggests the necessity of applying nitrogen to the system through fertilizers, which proposes further studies regarding the dose, way of application and season.

Independently of treatments, more than 50% of the nitrogen content in the plant is over 40 cm height (removed biomass). On this matter, this height is recommended for a good handling of guinea grass.

The variation of total N on the superficial surface of the soil (0-20 cm) for the different treatments is under

the extraction done by the plant which evidences the probability that a fixation free of nitrogen and a provision of the depth surfaces of the soil participate on the nitrogen nourishment of the plant.

The quantity of nitrogen in the run-off water is established as the lowest contribution on the total lost of nitrogen on the evaluated system, without exceeding 1 kg.N.ha<sup>-1</sup>.year<sup>-1</sup>. Lost by lixiviation resulted minor; nevertheless, N-NO<sub>3</sub><sup>-</sup> constitutes the highest contribution to the total lixiviated compare to N-NH<sub>4</sub><sup>+</sup> which did not surpass 4 kg.N.ha<sup>-1</sup>.year<sup>-1</sup>. The contribution of nitrogen by precipitations resulted moderate.

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