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SCIENTIFIC NOTE/ NOTA CIENTÍFICA

LEACHING OF NITROGEN IN COLUMN IN REGARDING SOIL PARTICLE SIZE

LIXIVIAÇÃO DE NITROGÊNIO EM COLUNA EM FUNÇÃO DA GRANULOMETRI-A DO SOLO

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ABSTRACT

The quantity of nitrogen that can be leachate is principally influenced by factors that determine the flow of water on the soil, like the texture and structure, as well by the concentration and form of the nitrogen present in the soil. This work has as objective to evaluate the leaching of nitrogen regarding the soil particle-size. The experimental adopted was entirely randomized with arrangement factorial 5 x 2, with five soils (three Ultisol, one alfisol and one oxisol) with different particle-size (37.5; 132.5; 315.0; 491.2 e 546.0 g kg^{-1} of clay), collected in the region north of the Paraná State, and two nitrogen sources (potassium nitrate and ammonium sulphate) with four repetitions. One treatment witness without nitrogen was included to allow additional statistical tests. The soil were packed in columns of PVC with 25 cm of height and 4 cm of diameter, and posteriorly irrigated until the field capacity. The sources of nitrogen were applied in the quantity equivalent to 65 kg ha^{-1} of N and afterwards, was applied 150 cm^3 of distilled water, corresponding to a precipitation of 180 mm. The use of KNO3, potassium nitrate resulted in higher N losses by leaching, compared to ammonium sulfate, presenting a negative correlation with clay content.

Key-words: texture of soil; ammonium sulphate; potassium nitrate.

RESUMO

A quantidade de nitrogênio que pode ser lixiviado é influenciada principalmente pelos fatores que determinam o fluxo de água no solo, como a textura e estrutura, bem como pela concentração e forma do nitrogênio presente no solo. Este trabalho teve como objetivo avaliar a lixiviação de nitrogênio em função da granulometria do solo. O delineamento experimental adotado foi inteiramente casualizado com arranjo fatorial 5 X 2, com cinco classes de solo (três argissolos, um nitossolo e um latossolo) de diferentes granulometrias (37,5; 132,5; 315,0; 491,2 e 546,0 g kg^{-1} de argila), coletados na região norte do estado do Paraná, e duas fontes de nitrogênio (nitrato de potássio e sulfato de amônio) com quatro repetições. Um tratamento testemunha sem nitrogênio foi incluído para permitir testes estatísticos adicionais. Os solos foram acondicionados em colunas de PVC com 25 cm de altura e 4 cm de diâmetro, e posteriormente, umedecidos até a capacidade de campo. As fontes de nitrogênio foram aplicadas na quantidade equivalente a 65 kg ha^{-1} de N e em seguida aplicou-se 150 cm^3 de água destilada, correspondente a uma precipitação de 180 mm. O uso de nitrato de potássio resultou em maiores perdas de nitrogênio por lixiviação, em comparação com a fonte sulfato de amônio, apresentando correlação negativa com o teor de argila.

Palavras-chave: textura do solo; sulfato de amônio; nitrato de potássio.

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INTRODUCTION

For the correct conservationist planning of any area of interest, there is the necessity of detailed studies that provide success and whether can use natural resources without aggress, in a degrading way, the environment (Mello et al., 2006).

Second Kitamura et al. (2007), for the environmental planning, it has a fundamental importance the knowledge of soil physical attributes, involving principally those related with their particle-size distribution which influence directly the surface flow and the water movement of in the soil.

The dynamic of N in soil involves processes of physical, chemical and biological nature, which will determine if the N will remain fixed in the agriculturical soil layer, or if it will absorbed by plants or lost by denitrification (Franco et al., 2008; Chantigny et al., 2001), volatilization (Lara Cabezas & Souza, 2008; Da Ros et al., 2005; Basso et al., 2004), surface drainage (Guadagnin et al., 2005) or moves in the soil, until achieving deeper layers (Rocha et al., 2008a).

The leaching of nitrate into the soil can achieve great magnitude if this anion is present in the soil in quantities above the absorption capacity by the culture and when the irrigation or rain exceeds the water storage capacity of the soil (Rocha et al., 2008b).

Black & Waring (1979), has observed that the properties of soil that most increased the leaching of the nitrate of the soil were particle-size, organic matter and pH. The dynamics of NH_4^+ and NO_3^- is oriented by their electric charge. Both are adsorpted the colloids cargoes, but are easily exchangeable with other ions of soil solution (Meurer et al., 2000). Due the predominance of negative charges (pH in KCl 1 mol dm^{-3} – pH in water) in layer arable of soil (Sangoi et al., 2003) it is insignificant the adsorption electrostatics of NO_3^- in this layer (Meurer, et al., 2000), while for NH_4^+ the adsorption is significantly high (Luchese et al., 2002).

When an ion has low adsorption in the surface of the colloids, it is susceptible at the loss by leaching (Sangoi et al., 2003). The water movement along the soil profile has high correlation with the leaching ions fee, which has been studied by several authors (Costa et al., 1999; Amaral et al., 2004; Matos et al., 2004; Ferreira et al., 2006). Wruck (1996) verified that the volume and distribution of the pores are important factors that affect the water mobility in the ground, however, among the factors, the authors observed that the macroporosity are related with the higher leaching intensity of ions in the profile.

According to Camargo et al. (1989) the higher water storage capacity of clay soils reduces the water percolation velocity in the profile, therefore reducing the drag of nitrate to lower layers. Kitamura et al. (2007) report that the nutrients and water retention capacity have positive correlation with the clay soil levels. In sandy soil, the management of water and nitrogen fertilization (parceling) minimizes the nitrate loss by leaching (Sanchez, 2000).

In this context this work has as objective to evaluate the leaching of nitrogen regarding the soil particle-size.

MATERIAL AND METHODS

The experiment was conducted in the fertility soil laboratory of the University of Londrina (PR). There were selected five soils of the north of the Paraná State, with distinct physic-chemical characteristics in layer of 0 - 20 cm (Table 1).

TABLE 1 – Granulometric characteristics[(1)] and rpH[(2)] of the soil used in the experiment

Soil samples	Clay	Silt	Sand	rpH
	-----------------------g kg^{-1}----------------------			
Ultisol 1	37.5	62.5	900.0	- 1.30
Ultisol 2	132.5	130.0	737.5	- 0.50
Ultisol 3	315.0	292.1	393.7	- 1.00
Alfisol	491.2	228.7	280.0	- 0.80
Oxisol	546.2	122.1	332.5	- 1.00

(1) Determined by the method of pipette as EMBRAPA (1997),

(2) Determined by the difference between the pH in KCl and the pH in water.

The experimental adopted was entirely randomized, in factorial arrangement 5 x 2, in that factors there were five soils (Ultisol 1, Ultisol 2, Ultisol 3, Alfisol, and Oxisol) and two sources of N (potassium nitrate and ammonium sulphate) with four repetitions. For each soil, it was conducted a witness (without the addition of nitrogenated fertilizer), with three repetition, totalized 55 parcels.

For the experiment installation it was collected samples of soils in the municipalities of Londrina, Rolandia and Porecatu of surface layer (0 - 20 cm) of each soil, due be the layer where the highest proportion of the root system of plants is located, and therefore occurs greater absorption of nitrogen. The samples collected were dried at air, manually ground sieved (0,4 cm) and homogenized and it was collected samples for particle-size analysis (EMBRAPA, 1997) and for the fertility evaluation (Pavan et al., 1992). The soils were corrected through the use of $CaCO_3$ (P. A.) to raise the index of base saturation of each soil to 70%, maintaining the soils incubated for five days to 60% of the maximum capacity of water retention. After incubated it was determined the rpH (Table 1) for the evaluation of cargo net soil.

The different soils were placed in columns, constituted of PVC tubes with 4 cm of diameter and 25 cm of height, with volume of 314.2 cm^3. The columns of soil were dampened to achieve the maximum capacity of water retention. Then, each column of soil was fertilized with 10 mg of N, using the potassium nitrate (KNO_3) and ammonium sulphate ($(NH_4)_2SO_4$) in the form of salts P. A. (pure for analysis). The salts have been applied in the soil surface. This dose is equivalent to fertilization at 65 kg ha^{-1} of N, which is the recommended dose for corn with expectation to harvest 8 tons ha^{-1} in a soil of mean response class (Raij & Cantarella,1997).

Immediately after fertilization, each column of soil received 150 cm^3 of distilled water by dripping (5 to 6 drops per minute), simulating a volume of water equivalent to 180 mm, being usually the average monthly rainfall occurred in the state during the summer months (Caviglione et al., 2000).

After 24 hours the leachate contents of each column was collected and subsequently analyzed according to the method described by Tedesco (1995) to determine concentrations of NO_3^- and NH_4^+.

The data obtained have been subjected to variance analysis, and the averages compared by the Tukey test ($P < 0.05$). It was also held analysis of the correlation between the leaching of N and clay contents of the samples.

RESULTS AND DISCUSSION

The results presented in Figure 1 indicate that occurred differences ($P < 0.01$) in the quantity of N leachate between the sources studies. The tubes that received application of potassium nitrate showed greatest leaching of NH_4^+ + NO_3^- when compared to the ammonium sulphate and the witness (without the addition of nitrogen), in the different particle-sized. It was verified a significant negative correlation ($r = -0.97$, $P < 0.01$) between the quantity of N leached and the clay content in the treatments fertilized with potassium nitrate, indicating that the greatest loss of nitrate occurred in samples with lower levels of clay (Figure 1), corroborating with Lund et al. (1974). Probably this behavior of nitrate anion is associated with a fewer positive charges of the sandy soils and especially the infiltration speed of the water.

However, no was observed leaching ($p > 0.05$) of NH_4^+ and NO_3^- between the witness and the treatment that received ammonium sulfate. Being ammonium a cation, it was possibly adsorbed negative electrical charges from the soil (Luchese et al., 2002) and the dose of 10 mg of N was not sufficient to permit its leaching in the columns of soil, what explains the not difference for the nitrate ion.

Analyzing separately the leaching of the NO_3^- and NH_4^+ between sources and in each sample of soil (Table 3) it may be noted that it was found higher quantity of NH_4^+ in leachate only in the Ultisol 1, and alfisol. In Ultisol 2, the content of NH_4^+ found, was similar to Alfisol, but not different from the witness, for it possibly contain higher levels of NH4 than the Alfisol. However, despite this last sample displays differences ($P<0.01$) in relation to the witness, 0.64 mg of N leachate by column of soil is insignificant before 10 mg of N applied. In the Ultisol 1, the greater leaching of ammonium may have occurred due the lower cation exchange capacity (Table 2), and more porous spaces between sand particles of these samples, which increased the water infiltration rate as observed by Wruck (1996), loading the non-adsorbed ions.

TABLE 2 – Chemical characteristics(3) of soils used in experiment

Soil	O.M.(4)	P	pH	Al+H	K	Ca	Mg	Al	CEC(5)
- g kg^{-1} Clay -	g kg^{-1}	mg dm^{-3}		------------------------cmol$_c$ dm^{-3}-------------------					
Ultisol 1	5.36	4.61	6.13	1.98	0.13	1.63	0.71	0.04	4.44
Ultisol 2	6.70	3.60	4.61	3.62	0.13	1.27	0.86	0.18	5.87
Ultisol 3	18.76	15.10	5.74	4.54	0.77	7.05	0.18	0.03	12.35
Alfisol	11.39	0.09	4.36	7.35	0.14	1.85	0.36	0.41	9.70
Oxisol	16.24	1.21	4.37	7.60	0.34	2.30	0.53	0.37	10.78

(3) Methodology adopted by IAPAR (Pavan et al.,1992). (4) Organic matter. (5) Cation exchange capacity.

TABLE 3 - Quantities of nitrate and ammonium leachate after fertilized with 10 mg of N in columns of soil with potassium nitrate and ammonium sulphate in soils with different particle-sized

Source of N	Soil									
	Ultisol 1		Ultisol 2		Ultisol 3		Alfisol		Oxisol	
	NH_4^+	NO_3^-	NH_4^+	NO_3^-	NH_4^+	NO_3^-	NH_4^+	NO_3^-	NH_4^+	NO_3^-
	mg $column^{-1}$									
Witness	0.08 b	1,23 b	0.34 a	0.10 b	0.14 a	3.02 b	0.15 b	2.86 b	0.10 a	2.14 b
KNO_3	0.17 b	7.57 a	0.56 a	5.90 a	0.21 a	6.63 a	0.31 ab	5.30 a	0.11 a	5.11 a
$(NH_4)_2SO_4$	1.73 a	1.28 b	0.64 a	0.27 b	0.24 a	4.32 b	0.64 a	2.87 b	0.23 a	2.14 b

NH_4^+: C.V.(%) = 10.38, MSD = 0.46 mg; and NO_3^-: C.V.(%) = 9.05, MSD = 1,57 mg. Averages followed by the same letter in column do not statistically differ among themselves by the Tukey test to 5%.

The nitrate leaching was always greater when used the potassium nitrate as source, regardless of the proportion of clay in the samples of the soil studied (Table 3). The KNO_3 is rapidly dissociated in water, releasing K^+ and NO_3^-, and the nitrate ion in soils with negative charge (DpH<0) tends to leaching. Similar results were obtained by Guedes (1974).

Considering the application of ammonium sulfate source, the nitrate level in leachate was similar to the witness, in all soils studied, possibly because not there was sufficient time (24 hours) so that occur the process of nitrification. Losses by volatilization and denitrification were disregarded by the short experimental period.

These results could be potentiated in field conditions where the soil is not limited to just one rain. Accordingly also the leaching of N in 20 cm in the soil, could limit their availability to crops in the initial phase of development.

CONCLUSIONS

The use of potassium nitrate (KNO_3) resulted in higher N losses by leaching, compared to ammonium sulfate, presenting negative correlation with clay content.

REFERENCES

1. AMARAL, A. S. et al. Movimentação de partículas de calcário no perfil de um cambissolo em plantio direto. **Revista Brasileira de Ciência do Solo**, v. 28, n. 2, p. 359-367, 2004.
2. BLACK, A. S.; WARING, S. A. Adsorption of nitrate, chloride and sulphate by some highly weathered soils from South-East Queensland. ***Australian Journal of Soil Research,*** v. 17, n. 2, p. 271-282, 1979.
3. BASSO, C. J. et al. Perdas de nitrogênio de dejeto líquido de suínos por volatilização de amônia. **Ciência Rural**, v. 34, n. 6, p. 1773-1778, 2004.
4. CAMARGO, P. B. et al. Destino do N de fertilizantes – N^{15} (uréia e aquamônia) aplicados na cultura da cana-de-açúcar. I. deslocamento no solo. In: CONGRESSO BRASILEIRO DE CIÊNCIA DO SOLO, 22., 1989, Recife. **Resumos...** Recife: SBCS, 1989. p. 70-71.
5. CAVIGLIONE, J. H. et al. **Cartas climáticas do Paraná**. Londrina: Instituto Agronômico do Paraná, 2000. CD-ROM
6. CHANTIGNY, M. H.; ROCHETTE, P.; ANGERS, D. A. Short-term C and N dynamics in a soil amended with pig slurry and barley straw: a field experiment. **Canadian Journal of Soil Science**, v. 81, n. 2, p. 131-137, 2001.
7. COSTA, S. N. et al. Mobilidade de nitrato em colunas de solo sob condições de escoamento não permanente. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v. 3, n. 2, p. 190-194, 1999.
8. DA ROS, C. O.; AITA, C.; GIACOMINI, S. J. Volatilização de amônia com aplicação de uréia na superfície do solo, no sistema plantio direto. Ciência Rural, v. 35, n. 4, p. 799-805, 2005.
9. EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA (EMBRAPA). **Manual de métodos de análise de solo**. 2. ed. Rio de Janeiro: Centro Nacional de Pesquisa de Solos, 1997. 212 p.
10. FERREIRA, P. A. et al. Transporte no solo de solutos presentes na água residuária de café conilon. **Acta Scientiarum *Agronomy,*** v. 28, n. 1, p. 29-35, 2006.
11 FRANCO, H. C. J. et al. Aproveitamento pela cana-de-açúcar da adubação nitrogenada de plantio. **Revista Brasileira de Ciência do Solo,** v. 32, n. especial, p. 2763-2770, 2008.
12. GUADAGNIN, J. C. et al. Perdas de solo, água e nitrogênio por erosão hídrica em diferentes sistemas de manejo. **Revista Brasileira de Ciência do Solo,** v. 29, n. 2, p. 277-286, 2005.
13. GUEDES, G. A. de A. **Contribuição ao estudo do movimento dos íons nitrato e amônio em colunas de material de solos do triângulo mineiro e de pirapora**. 1974. 39 f. Dissertação (Mestrado em Ciência do Solo) - Universidade Federal de Viçosa, Viçosa, 1974.
14. KITAMURA, A. E.; CARVALHO, M. P.; LIMA, C. G. R. Relação entre a variabilidade espacial das frações granulométricas do solo e a produtividade do feijoeiro sob plantio direto. **Revista Brasileira de Ciência do Solo**, v. 31, n. 2, p. 361-369, 2007.
15. LARA CABEZAS, W. A. R.; SOUZA, M. A. Volatilização de amônia, lixiviação de nitrogênio e produtividade de milho

em resposta à aplicação de misturas de uréia com sulfato de amônio ou com gesso agrícola. **Revista Brasileira de Ciência do Solo,** v. 32, n. 6, p. 2331-2342, 2008.

16. LUCHESE, E. D.; FAVERO, L. O. B.; LENZI, E. **Fundamentos da química do solo**. Rio de Janeiro: Freitas Bastos, 2002. 182 p.
17. LUND, L. J.; ADRIANO, D. C.; PRATT, P. F. Nitrate concentrations in depp soil cores as related to soil profile characteristics. **Journal** Environment Quality, v. 3, n. 1, p. 78-82, 1974.
18. MATOS, A. T.; LEMOS, A. F.; BARROS, F. M. Mobilidade de nitrato em solos de rampas de tratamento de águas residuárias por escoamento superficial. **Engenharia na Agricultura**, v. 12, n. 1, p. 57-65, 2004.
19. MELLO, G.; BUENO, C. R. P.; PEREIRA, G. T. Variabilidade espacial das propriedades físicas e químicas do solo em áreas intensamente cultivadas. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v. 10, n. 2, p. 294–305, 2006.
20. MEURER, E. J; THENHEIMER, D.; BISSANI, C. A.. Fenômenos de superfície. In: MEURER, E. J. (Ed.) **Fundamentos de química do solo**. 1. ed. Porto Alegre: Gênesis, 2000. Cap. 5. p. 77-105.
21. PAVAN, M. A. et al. **Manual de análise química de solo e controle de qualidade.** Londrina: Instituto Agronômico do Paraná, 1992. 40 p. (Circular, 76).
22. RAIJ, B. van; CANTARELLA, H. Milho para grãos e silagem. In: RAIJ, B. van; CANTARELLA, H.; QUAGGIO, J. A.; FURLANI, A. M. C (Ed.) **Recomendações de adubação e calagem para o estado de São Paulo**. Campinas: Instituto Agronômico, 1997. 285 p. (Boletim Técnico, 100).
23. ROCHA, F. A. et al. Modelo numérico do transporte de nitrogênio no solo. parte I: desenvolvimento e teste do modelo. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v. 12, n. 1, p. 47–53, 2008a.
24. ROCHA, F. A. et al. Modelo numérico do transporte de nitrogênio no solo. parte II: reações biológicas durante a lixiviação. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v. 12, n. 1, p. 54–61, 2008b.
25. SANCHEZ, C. A. Response of lettuce to water and nitrogen on sand in the potencial for leaching of nitrate – N. **HortScience**, v. 35, n. 1, p. 73-77, 2000.
26. SANGOI, L. et al. Lixiviação de nitrogênio afetada pela forma de aplicação de uréia e manejo dos restos culturais de aveia em dois solos com texturas contrastantes. **Ciência Rural**, v. 33, n. 1, p. 65-70, 2003.
27. TEDESCO, M. J. Nitrogênio In: GINELLO, C.; BISSANI, C. A.; TEDESCO, M. J. (Ed.) **Princípios de fertilidade de solo**. Porto Alegre: UFRGS, 1995. p. 73-98.
28. WRUCK, F. J. Mobilidade de nitrato cobre e zinco, provenientes do efluente líquido de granja suinícola, no solo. 1997. 84 f. Dissertação (Mestrado em Fitotecnia -Produção Vegetal) - Universidade Federal de Viçosa, Viçosa, 1996.

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