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PREDICTING NITROGEN MINERALIZATION FROM PULP MILL SLUDGE APPLIED TO SOILS

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ABSTRACT: Application of organic residues to agricultural and forest soils, and landscape areas, represents an effective outlet. Pulp mill sludge has been considered one of the most efficient residues, when used as fertilizer. Despite the attention that this subject has been given by the scientific community, there still remains a need for a better understanding of the decomposition of such added organic materials, namely nitrogen (N) mineralization. A quick and easy to perform waterlogged incubation experiment was performed, to investigate mineralization of N compounds in several (15) different soils, with and without application of poultry manure. Soils tested, differed in texture, organic matter content as well as in pH. A mild solubilizing agent (H_2O) was used to extract easily mineralizable N. After, the extraction suspensions were further incubated at 37ºC for 10 days and sampled over this period. A routine method for extraction of N from soils was used to predict N mineralization. N mineralization curve was well adjusted to polynomial equations and was better fitted for light texture soils. Prediction of N was efficient when the chemical routine method was used. Initial N content of soils was also correlated to N mineralization. This simple incubation procedure was efficient, on the simulation of the release of the easily mineralizable organic N, both from soil and residues.
Keywords: agriculture, nitrogen, residues, prediction.

INTRODUCTION

According to UN millennium goals, the need for more food production, in quantity and quality enough to supply man's needs, is a priority. One of the world's biggest challenges is to feed future generations. It is therefore necessary to supply more and more nutrients to the soil, to achieve production levels required to reduce world hunger. Also, low soil fertility is considered as one of the most important constraints on improved agricultural production. Intensive and somewhat indiscriminate growing use of commercial fertilizers is not environmentally sustainable, and excessive application of n, as mineral fertilizers, may lead to many environmental problems such as nitrate pollution of water resources, amongst others. On the other hand, intensification of agriculture, as well as the development of industry, has been leading to the increasing production of organic residues (Sims, 1995), thus, land application of organic residues, represents an effective outlet. Pulp mill sludge has been considered one of the most efficient residues, when used as fertilize, namely for nitrogen (N) fertilization. it ranks behind only carbon, hydrogen, and oxygen in total quantity needed and is the mineral element most demanded by plants, and the quantity of n in soils is intimately associated with organic matter levels, thus with soil quality. Application of organic residues to agricultural soils as a source of nitrogen needs a better prediction of the amounts of n mineralized from the residues. This can be a promising tool for the sustainable and rational use of these sources of nutrients to plants growth, while preserving the environment (Cordovil et al., 2005, 2007). The objective of the present work is therefore to know more about nitrogen mineralization, and finding if it's possible to predict by the use of a quick and easy method, its availability from organic residues applied to soil.

MATERIAL AND METHODS

A quick and easy to perform waterlogged incubation technique (Kokkonen et al., 2006), was used to investigate the evolution of n mineralization in 20 different soils with and without application of secondary pulp mill sludge. Soils tested, differed in texture, organic matter content and pH. A mild solubilising agent (H_2O) was used to extract easily mineralizable N. In addition, a quick chemical method, using a 2m KCl solution in a 4 hours digestion at 100ºC was correlated to the incubation results, to try to predict N mineralization in a laboratory routine (Cordovil et al., 2007).

Both soils and residue are representative of Portuguese soils and Mediterranean climates, and of an important industrial activity. Soils were collected between the latitudes 37º05'N and 40º71'N and respective longitudes 8º06' W and 7º89' W, and dried and ground to pass through a 2 mm mesh, and then analyzed to determine sand, loam and clay fractions (Póvoas and Barral, 1992). Pulp mill sludge studied was also analyzed for some chemical characteristics (table 1).Five g samples of each dry soil were placed into 24 bottles. Half the bottles was left with soil alone and the other half was mixed with secondary pulp mill sludge. The amount of sludge added to each one of the soils corresponded to an application of 200 kg N ha^{-1}. To each bottle, 50 ml of distilled water were added and the air inside removed. All the bottles were shaken for 1 hour and immediately after, they were incubated at 37 ºc for 10 days and sampled over this period, for mineral n content. After 0 (T0), 2 (T1), 5 (T2) and 10 (T3) days, 3 bottles from each soil preparation were analyzed, by adding 3.72 g of $KCl_{(s)}$ to each one and shaken for 1 hour. After, the suspension was centrifuged for 10 minutes at 3500 rpm, and the supernatant was taken to n determination by segmented flow spectrophotometry. Data from the incubation was fitted to a one pool kinetic model, to predict n mineralization (Stanford and smith, 1972):

$$N_m = N_0 (1-e^{-kt})$$

In this equation, Nn_m represents the mineralized and accumulated along time t, k is the mineralization constant and N_0 represents the potentially mineralizable n amount.

Three g of soil alone and of mixtures of soils and sludge were placed in Skalar 5620/40 digestor glass tubes, and 20 ml of KCl 2M solution were added to each one. Suspensions were digested for 4 hours at 100ºc. After cooling at room temperature, suspensions were centrifuged for 10 minutes at 3500 rpm, and the supernatant was taken to analysis. The N_{min} amounts determined by this method were then correlated to the N amounts calculated by the application of the equation described above.

RESULTS AND DISCUSSION

The highest mineralization rates were observed in soils with the highest organic matter contents, showing the presence of significant amounts of easily mineralizable compounds. Soils that were poorer in organic matter, had a low mineralization potential during the time of the experiment, as expected, due to the more recalcitrant nature of the organic matter itself. Thus, N mineralized from soil organic matter, was more related to organic matter content of soils than to the texture itself. Sand and clay contents were poorly correlated to the N mineralization potential in all the soils tested. Addition of organic residues to the soil enhanced the N mineralization potential as expected.

The model was better fitted to soils with lighter textures when the soils were incubated without residues (table 2). When secondary pulp mill sludge was added to the soils, several all r-squared values were good, leading to the finding that not only soil, but also the interaction of soil with the organic residue, drives the mineralization behavior. Residues characteristics are determinant in the mineralization behavior in soil, as long as the amount of clay in the soil is at a medium level (Cordovil et al., 2005). For some soils,

correlation between the values of the anaerobic incubation and the values predicted by the chemical model were better when the soil/secondary pulp mill sludge mixture was tested. The r-squared values obtained by the correlation in soil/sludge mixture, averaged between 0.82 and 0.94 in soils with sandy textures. However, in other experiments, the author observed a similar behavior of sludges mineralization in different texture soils. The correlation between the mineral N values extracted with the chemical method performed and the ones estimated by the fitting of the Stanford and Smith (1972) model were quite good for some soils and poor for others. Once again, the best correlation results were obtained for soils with high amounts of sand.

CONCLUSIONS

N mineralization behaviour of the soils and mixtures was well adjusted to the one pool kinetic model and was well fitted for soil and secondary pulp mill sludge mixture. Initial N content of soils was also correlated to N mineralization pattern. This simple incubation procedure was efficient, on the simulation of the release of the easily mineralizable organic N, both from soil and sludge. However, a greater potential for N mineralization exists from the residue tested. The chemical method was only efficient in the prediction of sludge mineralization in soils with low to medium clay content.

REFERENCES

Cordovil C. M. d. S. (2004). *Dinâmica do azoto na reciclagem de resíduos orgânicos aplicados ao solo*. Instituto do Ambiente. Lisboa. 56 p.

Cordovil C. M. d. S., Coutinho J., Goss M. and Cabral F. (2005). Potentially mineralizable nitrogen from organic materials applied to a sandy soil: fitting the one-pool exponential model. *Soil Use and Management* **21**, 65-72.

Cordovil C. M. d. S, Coutinho J., Goss M. and Cabral F. (2007). Comparison of chemical methods of assessing potentially available organic nitrogen, from organic residues applied to a sandy soil. *Communications in Soil Science and Plant Analysis 38*, 989-1006.

Kokkonen A., Esala M. and Aura E. (2006). Acceleration of N mineralization by release of enzymes and substrates from soil mineral particles with phosphates. *Soil Biollogy and Biochemistry* **38**, 504-508.

Moore P. A. Jr, Daniel T. C., Sharpley A. N. and Wood C. W. (1998). Poultry manure management. In: *Agricultural uses of municipal animal and industrial byproducts.* USDA, Agric. Res. Service, Conservation Research Report 44, pp 60-77.

Póvoas I. and Barral M. F. (1992). *Métodos de análise de solos*. Comun. IICT Sér. Ciênc. Agrárias n10. 61 p.

Sims J. T. (1995). Organic wastes as alternative nitrogen sources. In: *Nitrogen Fertilization in the environment*. Bacon P E (ed.). Marcel Dekker Inc. NY, USA. pp 487-520.

Stanford G. and Smith S. J. (1972). Nitrogen Mineralization Potentials of Soils. *Soil Science Society of America Journal* ***36***, 465-472.

Table 1. Characteristics of the pulp mill sludge used in the experiment.

pH (H_2O)	6.75	N kjeldahl (g kg^{-1})	33.59
Dry matter (g kg^{-1})	893.20	NH_4-N (g kg^{-1})	1.03
Organic matter (g kg^{-1})	874.80	NO_3-N (g kg^{-1})	0.41
Total organic C (g kg^{-1})	507.40	C/N ratio	12.65

Table 2. Average N content obtained by the chemical method and r^2 values of the correlation of this method and the model used.

Soils		Nmin (mg/kg)			
		Soil	r^2	Soil + pulp mill sludge	r^2
1	haplic arenosol	276.7	0.848	79.7	0.850
2	haplic (distric)	67.9	0.283	65.6	0.266
3	lithosol	25.5	0.581	37.7	0.001
4	haplic (eutric)	72.9	0.156	97.1	0.880
5	haplic (humic)	182.9	0.0003	183.9	0.989
6	calcaric cambisol	60.6	0.218	79.6	0.950
7	calcic chromic	9.0	0.997	22.5	0.656
8	rhodic luvisol	25.2	1.000	35.0	0.423
9	haplic luvisol	29.8	0.950	46.5	0.994
10	haplic luvisol	19.6	0.649	39.2	0.739
11	haplic (eutric)	9.1	0.683	9.6	0.102
12	arenosol	83.8	0.985	54.3	0.310
13	arenosol	15.9	0.275	20.2	0.191
14	haplic (distric)	70.8	0.385	92.9	0.995
15	haplic arenosol	90.7	0.011	94.1	0.070
16	haplic luvisol	69.9	0.044	59.9	0.354
17	haplic luvisol	73.8	0.009	87.6	0.999
18	haplic luvisol	108.8	0.340	71.1	0.287
19	haplic luvisol	49.9	0.983	31.9	0.032
20	haplic luvisol	27.3	0.874	45.4	0.003