ESTIMATING THE EFFECT ON NITROGEN MINERALIZATION FROM ORGANIC RESIDUES APPLIED TO DEGRADED SOILS

Teixeira T., Cordovil C.M.d.S.
Instituto Superior de Agronomia, TU Lisbon, Tapada da Ajuda, 1349-017 Lisboa, Portugal.
cms@isa.utl.pt

1 INTRODUCTION

Nitrogen (N) is the nutrient most likely to be limiting for plant and animal production. Also, increasing world population, is giving rise to the need for more food production, in quantity and quality enough to supply man's needs. It is therefore necessary to supply more and more nutrients to the soil in order to achieve the production levels required to reduce world hunger. Intensive and somewhat indiscriminate 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.

Simultaneously, intensification of agriculture, as well as the development of industry, has been leading to the increasing production of organic residues such as manure, municipal solid waste, crop and forest waste, food industry waste, among others (Sims, 1995). Their application to agricultural land is a good solution for recycling, can increase soil organic matter content, and to provide plant nutrients such as N, as a good alternative to commercial fertilizers (Cordovil, 2004).

The application of organic residues to agricultural soils as a source of N needs a better understanding of the processes involving the mineralization of organic N compounds. A good prediction of the amounts of N mineralized from the residues is an interesting issue, and also a valuable tool for the sustainable and rational use of these sources of nutrients for plant growth, while reducing the environmental impact. More than 90% of the N in soils is in organic forms. Available N is considered to be a fraction of easily mineralizable organic N that can be estimated based on the mineral N released during incubation of soil at an appropriate temperature. However, incubation procedures are time consuming, and several chemical methods have been developed as substitutes for incubations by several authors. Thus, the development of a rapid, accurate and cost-effective method for the prediction of N supply both from soil organic matter and the application of organic waste materials is of great interest.

2 RESEARCH OBJECTIVES

Nitrogen mineralization is not yet fully understood. Having in mind that N is one of the most important elements for crops, it becomes of major importance to study its behaviour.
The objective of the present work was therefore to increase our understanding of mineralization, and find if it's possible to predict by the use of a quick and easy method, its availability from organic residues applied to soil.

2.1 Organic Residues

The organic residues chosen for this experiment were:

- Secondary pulp mill sludge (S) – This material is mostly water, biosolids and fibres. Presenting a high content in organic matter, they are rich in N, P and Mg (Cordovil, 2003; Costa, 1993). They have almost all of the nutrient elements. Potentially toxic metals are present in these materials in quantities so small that problems are not to be expected as long as the applications are not excessive (Costa, 1993).
- Poultry manure (PM) – this material is considered one of the best organic fertilizers. It contains large amounts of N, P, and K as well as secondary and trace elements combined with little moisture (Moore et al., 1998). In addition, it builds soil organic matter reserves. The organic matter benefits crop production as it increases soil water-holding capacity, water infiltration rates, cation exchange capacity, structural stability, and improves soil tilth (Moore et al. 1998).

3 METHODOLOGY

A quick and easy-to-perform waterlogged incubation experiment was developed by Kokkonen et al. (2006) to investigate the evolution of mineralization of N compounds in several different soils. This methodology was used in soils with and without application of two different organic residues (PM and S). The soils tested differed in texture, organic matter content as well as in 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 hour digestion at 100ºC was correlated to the incubation results, to try to predict N mineralization in a laboratory routine.

3.1 Soil and Residues

Twenty different soils and two different residues were used in this experiment. Both soils and residues are representative of Portuguese soils and Mediterranean climates, and of the animal and industrial activities related to the agricultural practices in such region. Soils were collected in regions between the latitudes 37º05'N and 40º71' N and respective longitudes 8º06' W and 7º89' W. Soil samples from 20 different locations in Portugal were dried and ground to pass through a 2 mm mesh, and then analysed to determine sand, loam and clay fractions (Póvoas and Barral, 1992).

The organic residues studied were also analysed, for some chemical characteristics (Table 1).

TABLE 1 **Characteristics of the residues used in the experiment.**

	Poultry Manure	Secondary Pulp Mill Sludge
pH (H_2O)	8.35	6.75
Dry Matter (g kg^{-1})	856.50	893.20
Organic Matter (g kg^{-1})	765.80	874.80
Total organic C (g kg^{-1})	444.20	507.40
N Kjeldahl (g kg^{-1})	40.13	33.59
NH_4-N (g kg^{-1})	10.48	1.03
NO_3-N (g kg^{-1})	0.36	0.41
C:N ratio	12.51	12.65

3.2 Development of incubation method

Samples of each dry soil weighing 5 g were placed into 36 bottles. 12 contained only soil, 12 were mixed with PM and the other 12 were mixed with S. The amounts of organic residues added to each one of the soils, corresponded to applications of 200 kg N ha^{-1}. To each one of the bottles, an amount of 50 mL of distilled water was then added and the air inside removed. All the bottles were placed in a shaker for 1 hour, and immediately after the shaking, each suspension was incubated at 37 ºC. After, the extraction suspensions were further incubated at 37ºC for 10 days and sampled over this period, for mineral N content.

3.3 Determination of mineral nitrogen

Mineral N (NH_4-N and NO_3-N) was determined in all the soils tested. Both soils and soil/residue mixtures were analysed. 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 taking them to shake for 1 hour. After shaking, the suspension was centrifuged for 10 minutes at a speed of 3500 rpm, and the supernatant was taken to N determination by segmented flow spectrophotometry.

3.4 Statistical procedure

A kinetic model was applied to the data obtained in the anaerobic incubations in order to predict the amounts of N mineralized. This was made using the first order equation proposed by Stanford and Smith (1972):

$$Nm = N_0\,(1-e^{-kt})$$

In this equation, N_m represents cumulative N mineralization over time t, k it's the mineralisation constant and N_0 represents potentially mineralizable N.

3.5 Development of chemical method

Samples of soil alone and soils mixed with each residue weighing 3 g were placed in glass tubes adaptable to a Skalar 5620/40 digestor, and 20 mL of 2M KCl solution were added to each one. The suspensions were digested for 4 hours at a temperature of 100ºC. After cooling at room temperature, the suspensions were centrifuged for 10 minutes at a speed of 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.

4 RESULTS AND DISCUSSION

The greatest mineralization percentages were observed in soils with the greatest 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. The amounts of N mineralized from soil organic matter, were better 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. The 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. The application of PM to the 20 soils tested, showed that the mineralization pattern was maintained regardless of the soil characteristics. However, N mineralization prediction was less reliable than with the S application. In fact, less favorable results were obtained for soil with PM, and this effect was particularly visible in soils with less sand. On the contrary, when S was added to the soils, almost 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 mineralization.

Correlation between the values of the anaerobic incubations and the values predicted by the model was better when the soil/S mixture was tested. The r values obtained by the correlation in soil/LS mixture averaged between 0.82 and 0.94 and were higher for soils with sandy textures. The soil/poultry manure mixture revealed poorer r values, which ranged between 0.40 and 0.70, but once again the greatest values were obtained in soils with large amounts of sand.

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 (Table 2). Once again, the best correlations were once again obtained for soils with large amounts of sand.

TABLE 2 **Average N obtained trough chemical method and r^2 values between the values obtained through the Stanford and Smith model and through the chemical method.**

		Nmin (mg/kg)					
	Soils	**Soil**	**r^2**	**Soil + poultry manure**	**r^2**	**Soil + Secondary Pulp mill sludge**	**r^2**
1	Pegões	276,7	0,848	166,1	0,982	79,7	0,050
2	Viseu	67,9	0,283	130,3	0,467	65,6	0,266
3	Vila Viçosa	25,5	0,581	94,9	0,848	37,7	0,001
4	Cacém	72,9	0,156	199,4	0,074	97,1	0,880
5	Mira Sintra	182,9	0,0003	272,9	0,827	183,9	0,989
6	Sobral Monte Agraço	60,6	0,218	156,2	0,069	79,6	0,950
7	Bencatel	9,0	0,997	117,6	0,012	22,5	0,656
8	Évora	25,2	1,000	105,5	0,411	35,0	0,423
9	Escoural 1	29,8	0,950	160,9	0,603	46,5	0,994
10	Escoural 2	19,6	0,649	118,8	0,931	39,2	0,739
11	Albufeira	9,1	0,683	42,6	0,390	9,6	0,102
12	Alcácer	83,8	0,985	128,7	0,859	54,3	0,310
13	Comporta	15,9	0,275	102,4	0,999	20,2	0,191

Soils		Nmin (mg/kg)					
		Soil	r^2	Soil + poultry manure	r^2	Soil + Secondary Pulp mill sludge	r^2
14	Portalegre	70,8	0,385	183,9	0,015	92,9	0,995
15	Pegões 2	90,7	0,011	138,9	0,170	94,1	0,070
16	Montemor 1	69,9	0,044	126,3	0,549	59,9	0,354
17	Reguengo	73,8	0,009	207,1	0,881	87,6	0,999
18	Montemor 2	108,8	0,340	151,3	0,957	71,1	0,287
19	Montemor 3	49,9	0,983	163,8	0,692	31,9	0,032
20	Montemor 4	27,3	0,874	117,6	0,040	45,4	0,003

5 CONCLUSIONS

Nitrogen mineralization of the soils and mixtures fitted well to polynomial equations and was better fitted for soil and the S mixture. The initial N content of soils was also correlated to the N mineralization pattern. This simple incubation procedure was effective in stimulating the release of the easily mineralizable organic N, both from soil and residues. However, a greater potential for N mineralization exists from both residues tested.

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 2003. Previsão da disponibilidade de azoto para as plantas a partir da mineralização de resíduos orgânicos aplicados ao solo. Doutoramento em Engenharia Agronómica. Instituto Superior de Agronomia – Universidade Técnica de Lisboa. Lisboa. 188 p.

Costa J B 1999. Caracterização e constituição do solo. Fundação Calouste Gulbenkian. Lisboa. 527 p.

Kokkonen A, Esala M, Aura E 2006. Acceleration of N mineralization by release of enzymes and substrates from soil mineral particles with phosphates. Soil Biol. Biochem. 38: 504-508.

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

Póvoas I, Barral M F 1992. Métodos de análise de solos. Comun. IICT Sér. Ciênc. Agrárias n10. 61 p.

Santos J Q 1995 Fertilização e poluição: Reciclagem agro-florestal de resíduos orgânicos. Author's edition. Pp 70-83.

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 e Smith SJ 1972. Nitrogen Mineralization Potentials of Soils - Soil Sci Soc Am J 36, 465-472.