Valorisation of organic wastes in agriculture. Compostage supply for the use of organic matters as background nitrogen fertilizer.

Essais de valorisation des déchets en agriculture. Apport du compostage à l'utilisation d'amendemnets de matières organiques comme engrais azotés de fond.

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Abstract

Several experiments have been carried out in order to evaluate the compostage impact on organic matters and its influence on the nitrogen mineralization ability. Double-walls thermostated columns, kept at constant temperature and moisture (respectively 28°C and 75%), were used to study the nitrogen mineralization within 16 weeks, with various organic wastes added to two soils of different textures. A first attempt was investigated to compair the nitrogen mineralization after application of sewage treatment plant sludges and the same sludges composted with green materials. A second attempt allowed the comparison between chemical nitrogen fertilizer and lavender-straw compost, at two different total nitrogen ratios.

Keywords *: nitrogen, sludge, compost, fertilizer, lavender, mineralization, nitrate.*

Résumé

Plusieurs essais ont été réalisés afin d'évaluer l'impact du compostage sur les matières organiques et son influence sur le potentiel de minéralisation de l'azote. Des colonnes thermostatées, à doubles parois, maintenues à température et à humidité constantes (respectivement 28°C et 75%), sont utilisées pour étudier la minéralisation de l'azote pendant 16 semaines, dans deux sols de textures différentes, et après apports d'amendements d'origines diverses. Un test a permis de comparer la minéralisation de l'azote après épandage de boues brutes de station d'épuration, et de ces mêmes boues compostées avec des déchets verts. Un deuxième test a permis la comparaison des apports engrais chimiques azotés et compost de paille de lavande, à deux doses différentes d'azote total. Ces essais comparatifs ont mis en évidence la minéralisation de l'azote au cours des 16 semaines avec apparition des formes minérales de l'azote.

Mots-clés : azote, boue, compost, engrais, lavande, minéralisation, nitrate.

1. Introduction

To face with the coming out of new constraints and more strict making of rules bound to wastes elimination, the valorisation of organic matters in agriculture represents a more and more promoting solution but which had to resolve few querys. Estimated models of the organic matters evolution, and especially for the nitrogen in the soil, are important and essential to manage the amendments valorisation. Thus, Campbell (1988) has verified nitrogen mineralization function of temperature and moisture. The same variables allowed Gunnar et al. (1990) to simulate the nitrogen dynamic in the soil. On the other hand, Serna (1992) has established an available nitrogen pattern function of the type of sludge and Douglas (1991) has studied the rate of available nitrogen to the crop growth, depending on soil characteristics, organic residues, time influence and application method of these residues. In our study, the bioavailability of organic amendments (sludges, composted sludges and straw-lavender compost) will be compared with chemical fertilizers in order to estimate the quantities to apply to compensate the nutrients losses. The implementation of accelerated mineralization experiments in thermostated lysimetric columns allow in a first time to compare the different amendments and to follow up in particular the composting influence. Another lysimetric experiments allow the comparison of the nitrogen biodisponibility in normal mineralization conditions, with wheat crop.

2. Materials and methods

2.1. Treatments

In accelerated mineralization conditions, organic amendment used is a straw-lavender compost being in a rustic composting maturation during six months on a pile of 2.000 tonnes. This amendment will be compared with chemical fertilizer (ammo-nitrate) and the nitrogen rates applied were chosen in accordance with agricultural methods practised in the region : 15 $t.ha^{-1}$. The amendments quantities have been estimated for a same total N (2 mg/g dry matter) application for the columns “concentrated chemical fertilizer” and “concentrated compost”. As regards the amendments containing sludges : sludges composted with green materials (noted BIOT), raw sewage sludge (BBA) and the same composted sewage sludges (CA) have been selected. The application rate was 20 $t.ha^{-1}$ of dry matter.

The characteristics of the different amendments are resumed in table 1.

	organic C	total N	NTK	organic N	$N\text{-}NH_4^+$	$N\text{-}NO_3^-$
Straw-lavender compost	139	23,2	23	22,45	0,46	0,034
Chemical fertilizer	/	364	208	/	208	35,226
Biotechna	171,5	19,51	16,65	16,64	0,003	2,84

compost						
Arles compost	214,0	26,90	26,63	26,55	0,077	0,27
Raw sewage sludges from Arles	181,6	/	27,09	/	/	/

Results expressed as mg.g^{-1} of dry matter

Table 1
Chemical characteristics of the materials

2.2. Experimentation method

The study device of the nitrogen accelerated mineralization was constituted by double-walls thermostated columns (height = 25 cm and area of 0,0104 m^2) allowing by warm water circulation to stay at a constant temperature. Essays with wheat crop, after application of straw-lavender compost, were conducted in normal conditions of temperature and at a constant moisture (75 % of the field total capacity). Through simulation models, temperature and moisture have been identified as being the decisive factors for the soil nitrogenous mineralization. Each column was kept at constant temperature, 28°C ± 1°C, and at a constant moisture corresponding to 75 % of the field total capacity, by regular watering. These values represent the optimal activity conditions for the microbial populations involved in the nitrogen cycle.

Treatments of straw-lavender compost and chemical fertilizer were studied on a soil coming from the Valensole plateau (Alpes de Haute-Provence, France). Samples of 20 g core soil (minimum amount required for the total chemical analyses) were removed every 3 weeks for 16 weeks. The sample was taken on the total heignt of the column, providing a representative soil sample. (Table 2 : soil column constitution).

Thermostated column	Amendment $t.ha^{-1}$	total N mg
1:Reference soil	0	0
2:Concentrated fertilzer	1,5	568
3:Fertilizer	0,15	56,8
4:Concentrated compost	50	1206,4
5:Compost	5	120,6

Column with wheat crop	Amendment g of dry matter
T : Reference soil	0
L : Straw-lavander compost	15,6
E : Fertilizer	0,47
LF : Straw-lavander compost with fowl droppings*	9,4

* Straw-lavander compost with fowl droppings 37,25 mg g^{-1} of NTK.

Table 2
Soil column constitution

Amendments from sewage sludges were compared on a soil representative of the brown mediterranean soils (cultivated site of Beaurecueil, Provence Alpes Côte d’Azur, France). Samples of soil were removed on the upper tenth centimetre, for 16 weeks. These 10 cm corresponded to the vegetal sample area.

2.3. Steady parameters

All chemical analysis (table 3) were carried out on dry (60°C for 24h) and mixed samples. Results are expressed as $mg.g^{-1}$ of dry matter.

Parameter	Extraction	Technique
pH	Water. Ratio 1/5 (m/V)	pHmeter
NTK	Kjeldahl mineralization method	Acid-basic titration
NH_4^+	Water. Ratio 1/5 (m/V)	Colorimetrie λ = 630 nm
NO_3^-/ NO_2^-	Water. Ratio 1/5 (m/V)	Ionic chromatography
organic C	Anne mineralization method	Redox titration
organic N	Difference between NTK et NH_4^+	
UV spectra	Water. Ratio 1/5 (m/V)	200 to 350 nm, eye of 1 cm

Table 3
Analysis methods

3. Results and discussion

3.1. Sewage sludges and composted sewage sludges comparison

Appearance of the nitrogen most mineral form, nitrate ion, occurred after 3 weeks of experimentation and the follow up of the NH_4^+ ion evolution showed a decrease of the concentration during the same time (results not given). Increasing of nitrate in soil was observed particularly in the BBA column, and lower in BIOT. In BIOT, a great increasing of nitrate was observed between the third and the sixth week, followed by a decreasing. The reference soil column marked a small increasing in the time of experimentation, showing that the mineralization was effective even though no organic matter was applied. The different structure in each column according to the type of amendment, could explain the different behaviour in the soil. Morel (1989) explain that the texture is bound to the structural qualities of the soil, which govern the mineralization process. Thus, compost particles formed dense aggregats in the BIOT column, conversely the mixture in the BBA column seemed to be more homogeneous. There was in this way a better mineralization in the BBA column, leading to a visible appearance of the nitrate ions.

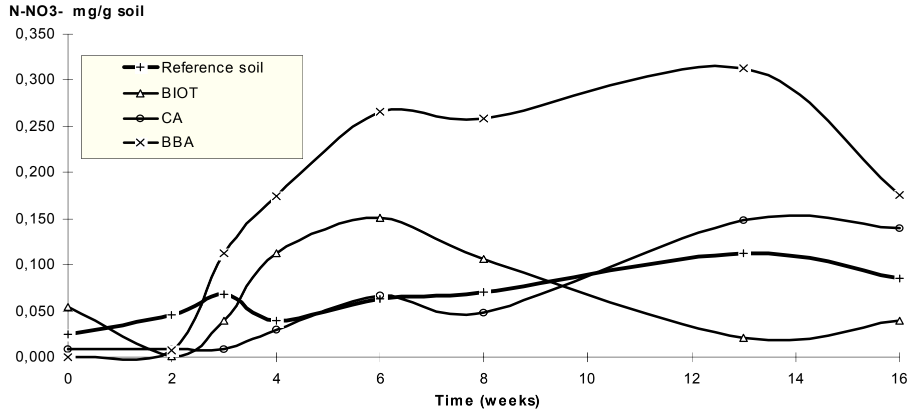

Figure 1
Evolution of the nitrate with time ($N\text{-}NO_3^-$ $mg.g^{-1}$ of soil)

The follow up of the organic nitrogen variations with the time (un published results), showed that the composted sewage sludges tend to immobilise nitrogen in an organic form. An increasing of the organic nitrogen was indeed observed in these columns at the eighth week while the concentration decrease in the BBA mixture. Sims (1990) has also done the similar observation with a study conducted with different composted sewage sludges, the nitrogen immobilisation noted in this case had repercussions on the growth crop studied. Composting could therefore reduce the available nitrogen rate but it could be used to provide slow organic fertilizers, since a nitrate increasing was observed in the mixture with composted sewage sludges after the twelfth week, while the concentration increase in a significant way in the BBA column. This increasing was probably due to a differed mineralization after a stage of immobilisation.

UV spectra study of the sewage sludges and composted sewage sludges showed in a global way an elevated absorbance value between 200 and 230 nm due to the presence of functional group and nitrates coming from mineralization (figure 2), and a shoulder between 230 and 280 nm, characterising the organic matter (Thomas et al., 1993).

The organic matter amount seemed to be more important in the Arles compost and in the raw sewage sludges while it was not detected in the Biotechna compost. The peak at 200-230 nm and the shoulder near 280 nm in the spectra of Biotechna compost extraction showed that this product was at an advanced mineralization level before its incorporation to the soil. This result is along the same line as the observations done in figure 1 where a nitrate swift decrease was observed (sixth week), decrease probably due to a lack of nitrogen. The Biotechna compost study, constituted from sewage sludges composted with green materials and bark shaving, confirm the experiments of Epstein (1978) who proved that composting with bark shaving decrease the mineralization ability.

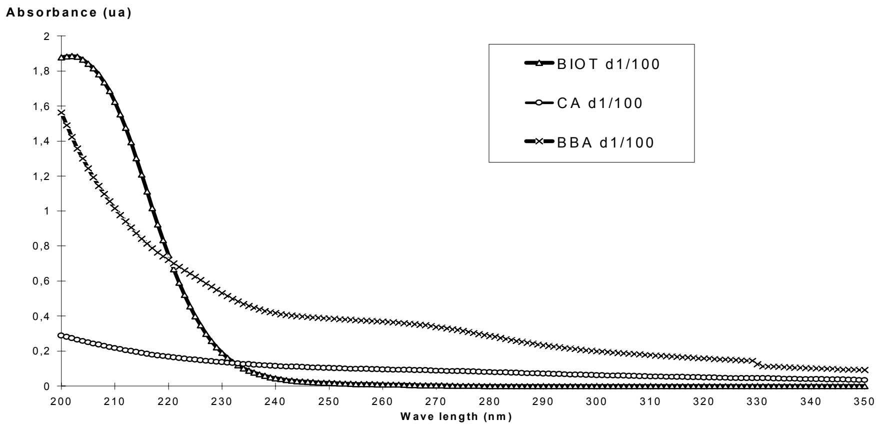

Figure 2

UV spectra of the different organic matters applied (d : dilution)

An increasing of the absorbance values with the time was noted in the absorption UV spectra of the soil mixtures extractions (figure 3a and 3b). The peak evolution in the low wave length was in connection with the nitrate concentrations and confirmed the observations of the figure 1. With the time, the shoulder decrease near 280 nm showed clearly the organic matter disappearance and therefore the organic matter mineralization.

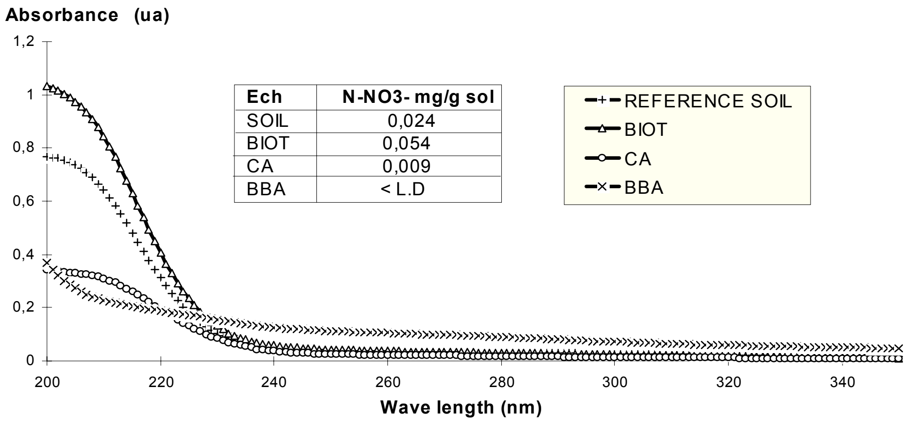

Fig 3a

Absorption UV spectra of the water soil mixtures extractions at initial time

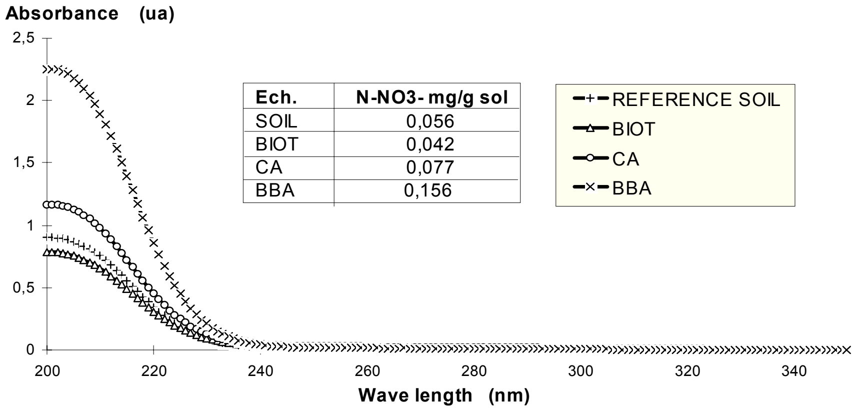

Fig 3b
Absorption UV spectra of the water soil mixtures extractions after 10 weeks

3.2. Straw-lavender compost and chemical fertilizer comparison

Accelerated mineralization

The experiment could be divided in two parts, mainly conditioned by the ammonium ions evolution. During the first period, the ammonium concentration remained high, providing sufficiently materials for nitrifying bacteria. Further 9 weeks, in spite of a 95% decrease of $N\text{-}NH_4^+$ in the 5 columns, a nitrate concentration increasing was observed. This appearance of nitrate, differed with the time, could be attributed to a more or less rapid synthesis dynamic of this ion, according to the environment conditions.

After the nine first weeks, nitrate concentration decreased in favour of the organic compartment, in the "concentrated chemical fertilizer", "chemical fertilizer" and "concentrated compost" columns. The decrease of the necessary material for nitrification (NH_4^+), preventing the bacteria activity to continue the nitrification chain in a significant way, could not explain by itself the nitrification standstill. The presence of an important nitrate amount seemed to be one of the parameters responsible of the mineral nitrogen immobilisation in an organic form. Indeed, the results, showed the mineralization continuation beyond the 9 weeks in the "reference soil" and "chemical fertilizer" columns, which contain a small quantity of nitrate (respectively 0,036 and 0,037 $mg.g^{-1}$). In the other three columns, the nitrate ions evolution increased until the ninth week, then followed by a significant decrease. In the columns containing chemical fertilizer, this decrease was explained by the high initial nitrate concentration. As for the "concentrated compost", a different behaviour was observed. While its nitrate concentration was close to the ones "reference soil" and "compost", a great nitrate concentration was noted during the first nine weeks, allowing to reach a high value (0,243 mg.g-1 of $N\text{-}NO_3^-$), close to the initial value measured in the column containing concentrated chemical fertilizer (0,252 $mg.g^{-1}$). The addition of a sufficient quantity of compost led to a good aeration, favouring the mineralization. After nine weeks, this aeration was no longer able to compensate the high nitrate rate, and then a significant loss of nitrate was observed.

The quantities of organic amendments applied were governed by the farming methods in the region where the soil sample were taken, this explain the use of the “chemical fertilizer” column as a reference. The high degree of nitrate decrease which occurred in the column containing ten times more chemical fertilizer, could be a sign for a similar risk in a field. It is therefore important to not apply a too high quantity of mineral chemical fertilizer. The wanted objective is then no more reached and there would be a risk to obtain the opposite effect : a significant loss of bioavailable nitrogen, i.e. nutritive substances. However, this observation has to be tempered since the presence of crop in fields consume generally all or a part of the nitrates.

Cultivated columns

In the columns with wheat crop, an experiment cut in two phases was also observed since the ammonium ions decreased significantly after the nine first weeks. At this experimentation level, a change of the nitric ions was as well detected (figure 4). In fact, the nitrate concentration decreased in a significant way for the cultivated columns, while this parameter remained at a constant level in the non-cultivated columns. The results showed a different mineralization dynamic according to the presence or absence of a vegetal cover. The nitrate appearance was indeed more late in the columns without crop, as if the crop presence would have “boost” the mineralization.

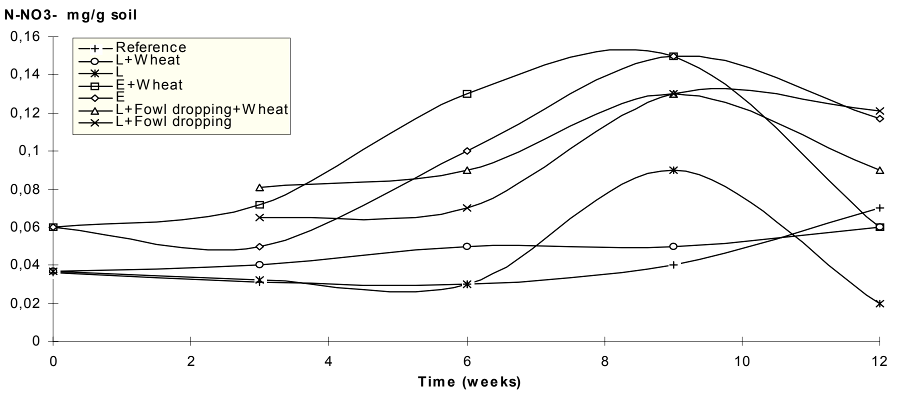

Figure 4
Nitrate evolution with the time in cultivated columns

This experimental period (9 weeks) seems important since it corresponds both at a period of nitrogen plant uptake, and at a mineralization slowing down. The results show the importance of the amendment period choice. The perfect knowledge of the mineralization phenomenon is therefore important to perform the organic matters application and avoid any risk of ground water pollution or nutritive substances losses.

The addition of fowl-droppings to straw-lavender compost didn't entail any change of the nitrogen mineralization dynamic. This co-product would even so provide a complement since the mineral nitrogen quantities were more important, the graph of the straw-lavender compost with addition of fowl droppings column was always higher as the graphs corresponding of the straw-lavender compost column. So, the application of fowl-droppings with straw-lavender compost could offset the defects of straw-lavender compost by an useful great supply of nitrates.

4. References

Campbell C.A., Jame Y.W. & De Jong R., 1988. Predicting Net Nitrogen Mineralization over a Growing Season : Model Verification. *Can. J. Soil Sci.*, August, 68, 537-552.

Douglas B.F. & Magdoff F.R., 1991. An Evaluation of Nitrogen Mineralization Indices for Organic Residues. *J. Environ. Qual.*, Vol.20, April-June, 368-372.

Epstein E., Keane D.B., Meisinger J.J. & Legg J.O., 1978. Mineralization of Nitrogen from Sewage Sludge and Sludge Compost. *J. Environ. Qual.*, Vol.7, N°2, 217-221.

Gunnar Ch. Borg, Per-Erik J. & Börje L., 1990. Simulated and Measured Nitrogen Conditions in a Manured and Fertilised Soil. *Plant & Soil*, 121, 251-267.

Morel R., 1989. Les sols cultivés. *Technique & Documentation. Lavoisier*.

Serna M.D., Pomares F., 1992. Nitrogen Mineralization of Sludge-Amended Soil. *Bioresource Technology*, 39 : 285-290.

Sims J.T., 1990. Nitrogen Mineralization and Elemental Availability in Soils Amended with Cocomposted Sewage Sludge. *J. Environ. Qual.*, 19, 669-675.

Thomas O., Théraulaz F., Domeizel M., Massiani C., 1993. UV spectral deconvolution : a valuable tool for waste water quality determination. Environmental Technology, 14, 1187-92.