NITROGEN MINERALIZATION IN SOILS AMENDED WITH ORGANIC BY-PRODUCTS OF OLIVE OIL AND SUGARBEET PROCESSING INDUSTRIES

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Summary: Mineralization of organic-N supplied to two different types of soils by an alpechín (olive-oil mill waste water)-compost and a beet vinasse after three consecutive years was studied. Results were compared with those obtained for a mineral fertilizer treatment and a control (unfertilized). N-mineralization can be described by a first order kinetic model. Both organic residues produced an important increase in the organic-N loading of the soils which is slowly released over a time.

Keywords: N-mineralization; potentially mineralizable-N; olive-waste-water, vinasse.

INTRODUCTION

Agricultural use of "alpechín" (olive oil mill waste water) and vinasse (a by-product from sugar industries), both with a high organic load, is recognized environmentally and economically, as a desirable method of disposal.[1, 2]

Soils receiving organic residues for several years are likely to have relatively high N-supplying capacities.[3,4] The quantity of residue-N in soils available to plants, is influenced by the application rate and residue characteristics.[3,5] However, information on the rate and extent of N mineralization is necessary to achieve optimum crop yields while avoiding potential pollution of groundwater.[4, 6, 7]

The aim of this paper is to study the mineralization pattern of the organic-N supplied to soils by an alpechín-compost and a vinasse after three years of treatment, comparing results to those obtained using a mineral fertilizer and a control (unfertilized).

MATERIALS AND METHODS

Soil samples were collected from containers (0.42 m² and 50 cm depth), filled with two different soils, where comparative studies were carried out for three consecutive years[8] on the yield and nutritional state of ryegrass (*Lolium multiflorum*) for different soil treatments: **(AC) alpechín**

compost (50000 kg ha^{-1}); (**V**) **concentrated and depotassified beet vinasse** (9370 kg ha^{-1}); (**MF**) **mineral fertilizer** (1.200 kg ha^{-1} of a NPK fertilizer 15-15-15 complex and 130 kg ha^{-1} of urea 46% N as sidedress applied twice); and (**C**) **control** (unfertilized). The experiments were carried out in a glasshouse using a six replications randomized design. Original soil properties of soils (**S1**, loam-clay-sandy Xerorthent; and **S2**, sandy Xeropsamment) and residue characteristics are shown in Table 1.

The soils, sampled at the plow layer (0-20 cm), were air dried, passed through 2 mm and analysed for total Kjeldahl-N (TKN, mg kg^{-1}); organic matter (O.M.) and C/N ratio. Results were analysed using ANOVA and the means were compared by the Tuckey's test (P< 0.05).[8] Triplicate samples of each soil and treatment were then

Table 1. Characteristics of original soils and residues used.

	SOILS		RESIDUES	
PROPERTIES	*S1*	*S2*	*AC*	*V*
pH (1:5)	*7.90*	*8.45*	*7.67*	*5.3*
CaCO3 (%)	*27.0*	*8.60*	*20.2*	*---*
O.M. (%)	*0.53*	*0.14*	*22.06*	*39.8*
TKN (%)	*0.05*	*0.04*	*0.90*	*3.25*
E.C. (1:5) dSm^{-1}	*0.20*	*0.10*	*2.85*	*20-30*
C/N	*5.69*	*2.32*	*12.3*	*7.10*
Sand (%)	*57.6*	*89.9*	*---*	*---*
Silt (%)	*21.1*	*2.5*	*---*	*---*
Clay (%)	*21.3*	*7.6*	*---*	*---*

incubated from 0 to 40 weeks, at constant moisture (15%) and temperature (30ºC) by an aerobic and non-leaching process.[16] Exchangable ammonium (extracted with 2M KCl) and nitrate (extracted with deionized water) were monitored periodically using ion-selective electrodes.[10, 11]

Statistical analysis of N-mineralization results

A non-linear regression approach described by Smith *et al*[12] and the Marquart-Levenberg algorithm were used to fit data to the first order equation: $N_m = N_o (1-e^{-kt}) + N_i$; where: N_m is the mineralized-N in a specific time (t), being expressed as sum of NH_4^+-N and NO_3^-; N_o is the potentially mineralizable N defined[13] as the fraction of the organic-N pool that is susceptible to mineralization; k is the first order rate constant and N_i the amount of mineralized-N at time t=0.

RESULTS AND DISCUSSION

Nitrogen mineralization

The evolution of total accumulative mineralized-N (NH_4^+ + NO_3^-) during the time of incubation is depicted in Figure 1 (A and B) for soils S1 and S2. In general, a rapid initial release of inorganic-N is observed, followed by a slower and relatively constant mineralization, especially in treatments MF and C, in which total mineralized-N tends to constant values after 16 and 8 weeks in soils S1 and S2 respectively. However, AC and V treated soils do not reach a plateau during the 40 weeks of incubation.
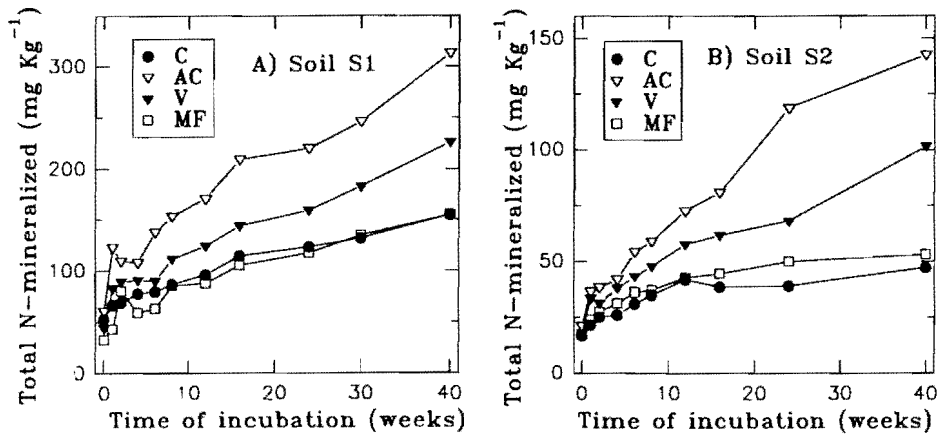
Figure 1. Evolution of total mineralized−N with time of incubation
in soil S1 (A) and soil S2 (B).

Mineralization-Immobilization turnover represents a dynamic system where a continuous exchange of soil N takes place.[14,15] Initially, the availability of easily mineralizable-N (e.g. dead microbiomass tissue) results in a net increase of mineralized-N. Afterwards, decomposition of residual organic-N dominates the process[16]; this would account for the maintained increase of the mineral-N observed over the last weeks of incubation for AC and V (Figure 1), whose O.M. contents exceed those of C and MF (Table 2).

Table 2. Organic matter content; TKN and C/N relation in soils S1
and S2 after three years of treatment with AC. V, MF, and C.

VAR.	UNIT	TREATMENTS			
		AC	V	MF	C
		SOIL S1			
O.M.	%	2,88 b	1,21 a	1.17 a	1,11 a
TKN	mg Kg-1	1359 c	748 ab	655 ab	574 a
C/N	--	12,3 a	9,4 a	10,4 a	11,2 a
		SOIL S2			
O.M.	%	1,67 b	0,63 a	0.53 a	0,51 a
TKN	mg Kg-1	898 b	299 a	263 a	236 a
C/N	--	10,8 a	12.2 a	11,7 a	12,5 a

Mean values in rows followed by the same letter are not significantly different (P<0.05)

For each treatment, maximum values of total mineralized-N after 40 weeks of aerobic incubation are higher in soil S1 than in S2: 313.6 and 142.4 mg N kg^{-1} for AC; 224.4 and 101.6 mg N kg^{-1} for V; 155.2 and 79.3 mg N kg^{-1} for MF; and 155.2 and 69.4 mg N kg^{-1} for C. Differences between soils seem to be related to soil characteristics; for example clay, O.M. and TKN contents of S1 are higher than in S2 (Table 2). In fact, there is ample evidence of the influence of these properties on the mineralization process: Cuevas et al[17] note these kind of influences in soils treated with sewage sludge, Griffing et al[4] in soils fertilized with different organic manures, Hérbert et al[18] in soils treated with composted manures and López[8] in mineralization of AC and V added to different soils.

In each soil, N-mineralization is different for each treatment, following the trend AC>>V>MF>C, the same sequence being observed for the soil O.M. and TKN contents. These results agree with those found by several authors,[4,18] who reported a positive relationship between soil O.M. and TKN content and the N mineralization process. The highest values for mineralized-N correspond to AC treated soils receiving 150000 kg ha^{-1} in three years, giving rise to the highest soil O.M. and TKN contents (Table 2). A similar tendency was observed in soils treated with liquid alpechín.[19,20] In these soils O.M. and organic-N supplied by alpechín persist a long time after application.

Kinetics of mineralization

The high values of the non-linear determination coefficient, r^2, obtained in all cases (Table 3) after adjustment of the experimental data to a first order kinetic equation, confirm this as one of the best models for the N mineralization pattern.[4,13,16]

In each soil the amount of potentially mineralizable-N, N_o, (Table 3) for the different treatments follows a trend similar to that found for TKN content; the higher the reserves of organic N in soils the greater the quantities of N susceptible to mineralization. Therefore, treatments AC and V have the highest values of N_0 in each soil.

The improvement in N-supplying capacities of soils due to the use of organic fertilizers (such as alpechín compost or beet vinasse) is more obvious if the N_0/NTK * 100 ratio is analysed (Table 3). In soil S1 these values range between 24 and 29 for treatment AC, MF and C, being twice as high for beet vinasse. In soil S2, with a sandier texture, the differences between organic and mineral fertilizer are even more pronounced: N_0/NTK * 100 values for treatments AC and V are respectively about two and four times as high as treatments MF and C. The nature of the O.M. of vinasse, simpler than that of AC[21], might account for the easier evolution of residual organic-N in vinasse treated soils.

N-mineralization rate constants, k, (Table 3) for both AC and V treatments are similar in the two soils, and lower than those for treatments MF and C, especially in the sandy soil, S2. A general trend of mineralization rate decreasing as TKN increases has been also observed by Magdoff[5].

Tabla 3. *Mineralization kinetic parameters.*

VAR.	UNIT	TREATMENTS			
		AC	V	MF	C
		SOIL S1			
N_i	mg Kg^{-1}	89	68	44	60
N_o	mg Kg^{-1}	392	356	154	138
N_o/NTK	%	29	48	24	24
$k * 10^3$	week^{-1}	20	14	31	27
$t_{1/2}$	days	243	347	157	180
r^2		0.95	0.96	0.95	0.98
		SOIL S2			
N_i	mg Kg^{-1}	26	27	20	18
N_o	mg Kg^{-1}	189	138	33	27
N_o/NTK	%	21	46	13	11
$k * 10^3$	week^{-1}	24	19	102	121
$t_{1/2}$	days	202	255	48	40
r^2		0.96	0.96	0.99	0.94

The slower mineralization process in soil S1 than in soil S2 might be the result of the formation in soil S1 (with high clay content) of organo-mineral complexes involving the organic fraction. This results in a higher protection of the O.M. and the soil biomass making them inaccessible to the heterotrophic microorganisms responsible for the mineralization.[5,18,22]

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