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NITROGEN MINERALIZATION IN SOIL WITH CONVENTIONAL AND ORGANOMINERAL FERTILIZATION PRACTICES

M. Tejada,[1,*] C. Benitez,[2] and J. L. Gonzalez[2]

[1]Departamento de Cristalografía, Mineralogía y Química Agrícola, E.U.I.T.A. Universidad de Sevilla, Carretera de Utrera, km. 1, Sevilla 41013, Spain
[2]Departamento de Química Agrícola y Edafología, Facultad de Ciencias, Universidad de Córdoba, Campus de Rabanales, Edificio C-3, Crta N-IV-a, km 396, Córdoba E-14014, Spain

ABSTRACT

Nitrogen (N) mineralization in soil treated with no fertilizer (U), conventional fertilizer (C), organic + conventional fertilizer (OC), and organomineral fertilizer (OM) was studied. The net N mineralization rate and mineralization half time for the different treatments were determined. The final values suggest that the mineralization was found to be more extensive at 25°C than at 15°C, independently of the treatment fertilizer effected. Similar comments could be made for the losses of gaseous N. Also the final

*Corresponding author. E-mail: mtmoral@us.es

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gaseous N losses were higher slightly with the conventional (C) and organomineral (OM) fertilizers that in the soil treated with no fertilizer (U) and organic + conventional fertilizer (OC). The treatment with organic + conventional fertilizer (OC) exhibited the greatest residual effect. The statistical treatment of changes in the inorganic N content during the incubation period showed the organic + conventional fertilizer (OC) to contain two types of N fractions with a mineralization half time of 1 day (conventional fraction) and 243 days (organic fraction, respectively). On the other hand, the organomineral fertilizer (OM) was found to contain a single N fraction the mineralization half time of which was 3 days. On the other hand, the cumulative C-CO_2 evolution was significantly greater for organic matter-amended than for non-organic matter-amended soils. Also, the temperature was markedly influential in the evolution of C-CO_2, highlighting the biggest values to 25°C and for the treatment OC, independently of the used temperature, due mainly to the presence of labile organic N presents in the treatment OC. The manufacturing process of the organomineral fertilizer (in a reactor at a high temperature) may favor of the more resistant N fractions, which are initially integrated in the organic fraction.

INTRODUCTION

A common feature of Mediterranean arable soils is their low content of organic matter as a result of mineralization due to climate and farming methods. This process negatively affects soil properties with an increase in physical, chemical, and biological degradation and the subsequent increase of soil losses due to erosive phenomena, causing a decrease in soil fertility.[1,2]

The use of organomineral fertilizers in agricultural practices has grown steadily in recent years. In addition to the organic matter they contribute, organomineral fertilizers provide appropriate amounts of mineral nutrients to ensure early crop development—in contrast, organic matter in fertilizers must be mineralized before such minerals can be released. As a result, the use of stable organomineral fertilizers has some advantages other than the obvious improvement in the physical properties and nutritional potential of soils;[2] in fact, unlike mineral and organic fertilizers, which require at least two applications, organomineral fertilizers need only be used once and have thus an advantage over the previous two.[3–6]

The purpose of this work was to study the mineralization and nitrification of N in fertilizer treatments as a special instance of organic matter mineralization on account of its lesser complexity. While N mineralization can be determined by various methods,[7–10] soil incubation is by far most commonly used as it allows one to quantify net mineralization—in fact, both ammonification and nitrogen immobilization by incorporation into organic substances and formation of microbial protoplasm take place simultaneously.

MATERIALS AND METHODS

Soil and Fertilizers

The experiment was conducted with soil samples taken from the arable layer (0–25 cm) of an Alfisol with Inceptisol intergradations.[11] The general properties of this soil appear in Table 1. In the experiment we used three types of fertilizer, namely: an organic fertilizer containing 2.5% humic extract, commercially available in suspended form (Humifluide, from Agrifluide S.A.); an organomineral fertilizer with a 5:2.2:8.3 N–P–K formula and 2.5% of humic extract, marketed as a suspension by Agrifluide S.A. under the trade name Bioplus; and a conventional fertilizer. In this fertilizer of commercial origin, the same raw materials were used as in conventional (urea, monoammonium phosphate and potassium chloride) and organic fertilizers (humic substances extracted from black peat, using 1 mol of KOH for each kg of humic extract desirable in the fertilizer). This method used to manufacture organic and organomineral fertilizers carbon was described in a previous paper.[12]

Incubation Procedure

The mineralization process was studied by incubating triplicate soil samples treated with no fertilizer (U), conventional fertilizer (C), organic + conventional

Table 1. General Properties of the Soil Surface Horizon (0–25 cm); The Analysis Are Effectuated by M.A.P.A. Methods[13]

pH (H_2O) = 6.70	K available (ppm) = 189.10
CO_3 (%) = traces	C.E.C. (meq/100 g) = 10.77
N (%) = 0.085	Conductivity (mS/cm) = 0.84
C (%) = 0.69	Soil texture: Clay loam
C/N = 8	Bulk density (g cm^{-3}) = 1.1
O.M. (%) = 1.19	Porosity (%) = 58
P available (ppm) = 16.50	

fertilizer (OC), and organomineral fertilizer (OM) at 15 or 25 ± 0.1°C and a soil moisture content of 18 ± 0.5% for 120 days. Moisture losses were monitored by weighing and corrected by the addition of distilled water every week. The difference between treatment OC and OM is: that treatment OC includes an organic fertilizer in suspension and a solid conventional fertilizer, whereas treatment OM includes only an organomineral fertilizer in suspension. Samples were incubated in a stove at controlled temperature and photoperiod (8 hours/day), with periodic wetting with de-ionized water in order to maintain moisture within the above-mentioned range.

Samples were placed in porcelain dishes containing 500 g of soil mixed with the same amount of sand. The conventional fertilizer was applied at 75 kg N ha^{-1} (0.027 g N kg^{-1} soil), 33 kg P ha^{-1} (0.012 g P kg^{-1} soil) and 125 kg K ha^{-1} (0.045 g K kg^{-1} soil). The same rates of conventional fertilizer plus 1500 kg ha^{-1} (0.545 g kg^{-1} soil) of the organic fertilizer were used to prepare the organomineral fertilizer. Therefore, the addition that is effectuated to the soil appears in the Table 2.

Soil samples were subjected to the following analyses at 0, 3, 7, 15, 30, 45, 60, 90, and 120 days of incubation. The analyses carried out on the soil samples during the experimental were 1) analysis of total N by the Kjeldahl method:[13] soil NO_3^--N, NO_2^--N, and NH_4^+-N was extracted with 2 *M* KCl (250 mL) on an orbital shaker for 2 h; the suspension was filtered and stored at −15°C until analysis; the concentration of NO_3^--N and NO_2^--N in the extracts was determined by the colorimetric method of Griess and Illosvay as modified by Barnes and Tolkard[14] and Bremner;[15] the concentration of NH_4^+-N in the extracts was determined by the colorimetric method of Kempers;[16] 2) inorganic N: calculated as the combined amounts of NH_4^+-N, NO_2^--N and NO_3^--N; 3) organic N: obtained as the difference between total N and inorganic N; 4) N losses: calculated as the difference between initial total N in the samples and total N at each sampling date; 5) net inorganic N: calculated as the difference between inorganic N in each sample and its content in the unfertilized soil.

Statistical Methods

The end values of nitrogen fractions were subjected to multiple analyses of variance based on the LSD criterion (least significant differences between means using Student's t), and fertilizer treatment and temperature were used as the variable independent.

On the other hand, an interactive procedure based on the Marquardt-Levenberg algorithm, included in the Statgraphics 5.0 software package,[17] was used to calculate the amount of mineralized nitrogen ($N_{miner} = NH_4^+\text{-N} + NO_3^-\text{-N} + NO_2^-\text{-N}$) as a function of the incubation time, among other parameters.

Table 2. Addition Effectuated to the Soil

	N				P		K	
	Organic (g/kg Soil)	Form	Inorganic (g/kg Soil)	Form	(g/kg Soil)	Form	(g/kg Soil)	Form
Conventional	0.022	Solid	0.005	Solid	0.012	Solid	0.045	Solid
Organic + conventional	0.022	Solid	0.005	Solid	0.012	Solid	0.045	Solid
	0.00054	Suspension			0.00001	Suspension	0.022	Suspension
Organomineral	0.02254	Suspension	0.005	Suspension	0.01201	Suspension	0.067	Suspension

The program provided the non-linear regression coefficients for the experimental and theoretical curves obtained. To this end, three different types of mathematical expressions (*viz.* linear, single exponential and double exponential equations) were tested. The linear equation used was of the following form:[7]

$$N_t = N_i + kt$$

The single exponential form was of the following type:[7]

$$N_t = N_0 \times (1 - e^{-kt}) + N_i$$

Finally, the double exponential expression tested, which conforms quite well to soils containing two N fractions with a different mineralization rate, was as follows:[18,19]

$$N_t = N_0 \times S \times (1 - e^{-kt}) + N_0 \times (1 - S) \times (1 - e^{-ht}) + N_i$$

In the three equations above, N_t denotes the amount of inorganic N at incubation time t; N_0 potentially mineralizable nitrogen; N_i the combined amount of nitrogen in all inorganic forms prior to incubation; k and h the mineralization rate constants for the two nitrogen fractions; and S and $(1 - S)$ the nitrogen fractions mineralizing at a different rate (k and h, respectively).

The mineralization half-times for potentially mineralizable N were calculated from the following equations:

$$N_t = N_0 \times S \times (1 - e^{-kt})$$

$$\frac{N_t}{N_0 \times S} = 1 - e^{-kt}$$

$$\frac{\frac{1}{2}N_0}{N_0 \times S} - 1 = -e^{-kt}$$

if S = 1 for that it is considered the non dependence of the two fractions,

$$\frac{1}{2} - 1 = -e^{-kt}$$

$$\frac{1}{2} = e^{-kt}$$

$$\ln\frac{1}{2} = -kt$$

$$t = \frac{\ln\frac{1}{2}}{-k}$$

$$t_{S_{1/2}} = \frac{0.693}{k}$$

On the other hand,

$$N_t = N_0 \times (1 - S) \times (1 - e^{-ht}) + N_i$$

$$\frac{N_t}{N_0 \times (1 - S)} = 1 - e^{-ht}$$

$$\frac{\frac{1}{2} N_0}{N_0 \times (1 - S)} - 1 = -e^{-ht}$$

if $(1 - \mathrm{S}) = 1$ for that it is considered the non dependence of the two fractions,

$$\frac{1}{2} - 1 = -e^{-ht}$$

$$\frac{1}{2} = e^{-ht}$$

$$\ln \frac{1}{2} = -ht$$

$$t = \frac{\ln \frac{1}{2}}{-h}$$

$$t_{(1-S)_{1/2}} = \frac{0.693}{h}$$

in the one that the non dependence of the two mineralization processes is assumed and it is suppressed of the calculation the value N_i in order to that the values have a physical sense with independence of the initial state of the soil.

Finally, the same statistical program and the parameter values obtained at 120 days of incubation were used to perform a multifactor analysis of variance with the temperature and fertilizer treatment as variables.

Soil Microbial Biomass

Soil microbial biomass was estimated using the $CHCl_3$ fumigation-extraction method.[20] Samples of most soil (10 g) were used, and K_2SO_4-extractable C was determined using dichromate digestion. On the other hand, soil respiration was measured by incubation in all treatments. In this respect, C-CO_2 is produced by microorganisms during respiration process. Total C-CO_2 collected in the NaOH flasks was determined by the addition of an excess of 1.5 *M* $BaCl_2$ followed by tritation with standardized HCl using a phenolphthalein indicator.[21,22]

RESULTS AND DISCUSSION

Nitrogen Dynamics

Figure 1 shows the changes in organic N at 15 and 25°C, during the incubation period (120 days). As can be seen, the content in this nitrogen fraction decreased during the first few days as an effect of mineralization. Subsequent changes were much more gradual, which shows that net mineralization was more emphasized at the early incubation stage. On the other hand, the soil samples treated with organic matter (OC and OM treatments) exhibited higher final organic N contents than the rest; differences among treatments were statistically significant at $p < 0.05$ (Table 3). Consequently, these two types of fertilizer, especially at 25°C, have a greater residual effect (particularly OC), as previously noted by Buchanan and Gliessman,[23] and consistent with the results of Gonzalez et al.[3] and Benitez et al.[24] in crops. This increased residual effect of N in the treatments using greater amounts of organic matter is very important since mineralization in subsequent years will contribute more inorganic N to the soil and hence increase its availability to crops.[25–28] Also, it minimizes nitrogen losses during the first year.[29]

Figure 2 shows the average changes, referred to on oven dry basis, in NH_4^+-N during the incubation period at the temperatures studied. The first remarkable difference among incubations originated from temperature. In fact, the peak amounts of NH_4^+-N were detected at 15 and 3 days of incubation at 15 and 25°C, respectively; the organomineral treatment (OM) produced the greatest amount of NH_4^+-N in both cases. Also, the decrease in the NH_4^+-N content beyond its peak level was slower and more gradual at 15 than at 25°C, consistent with previous results of Benitez.[30] The highest NH_4^+-N final contents were measured at 15°C. The previous results reveal a significant influence of temperature ($p < 0.1$) on nitrogen mineralization (Table 3), coinciding with the results given by Antonopoulos,[31] but the influence of fertilizer treatments is not significant.

Figure 3 shows the changes in the mean NO_2^--N content for the different fertilizer treatments studied. This nitrogen fraction exhibited a similar behavior to that of NH_4^+-N in relation to temperature. Thus, the peak NO_2^--N levels at 15°C were recorded at 15 days of incubation, whereas those at 25°C were observed at only 3 days; the conventional fertilizer treatment produced the largest amounts of nitrous N in both cases,[32] thus confirming that the nitrification rate increased with increasing temperature, coinciding with the results given by

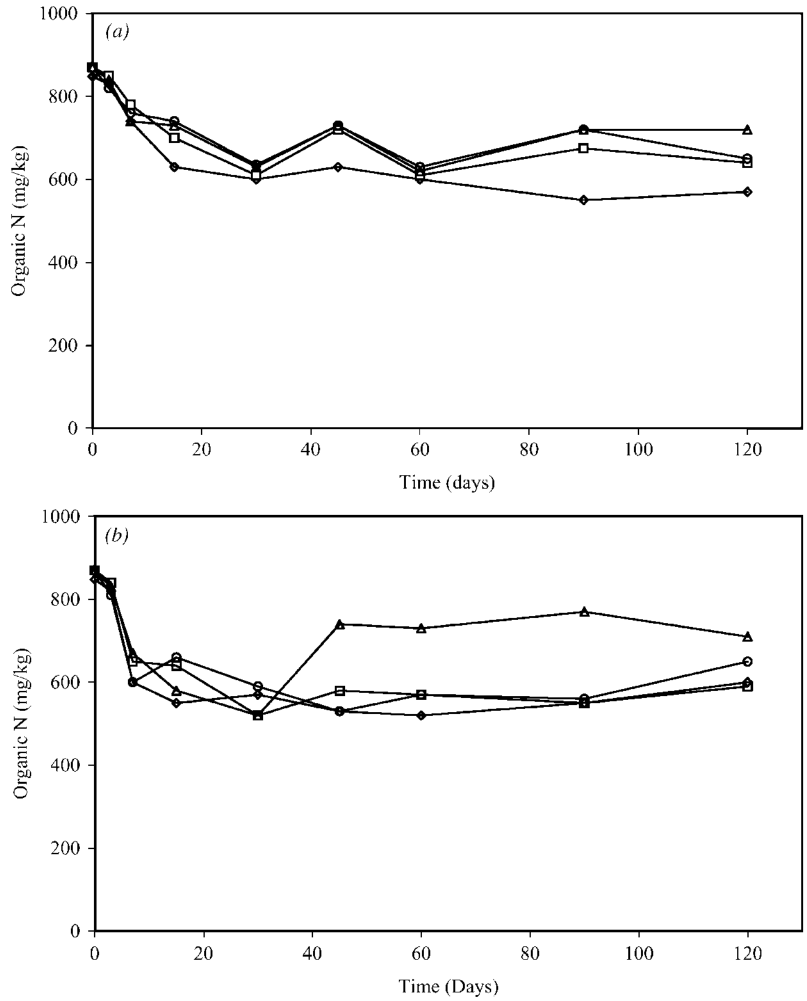


Figure 1. Organic N content during incubation at 15°C (a) and 25°C (b). Legend symbols: treatment U (rhomb), treatment C (square), treatment OC (triangle), and treatment OM (circle).

Antonopoulos,[31] likewise, the NH_4^+ to NO_2^- transformation is very extensive in this soil, independently of fertilizer treatment, because the peak of NH_4^+-N contents occur in the same date. Also, the final NO_2^--N contents were greater at 25°C than at 15°C, which again reflects the significant influence ($p < 0.05$) of temperature on this fraction (Table 3).

Table 3. Multifactor Analysis of Variance of the Final Parameter Values Obtained in the Different Incubations

	Temperature		Fertilizer Treatment	
	F	S	F	S
Organic N	9.14	—	42.29	**
Ammonia N	10.90	*	0.49	—
Nitrous N	25.54	**	0.16	—
Nitric N	5.16	—	0.86	—
Inorganic N	12.41	*	20.99	*
Net inorganic N	13.27	*	21.38	*
Total N	1.71	—	14.71	—
N loss	1.71	—	14.71	—

S: significance level; $*p < 0.1$, $**p < 0.05$, $***p < 0.01$, $***p < 0.001$.

Figure 4 shows the changes in the mean NO_3^--N contents for the different fertilizer treatments at 15°C and 25°C. Whichever the temperature, the unfertilized soil (U) always contained the smallest amount of nitrate N. The nitrate contents at the start of the incubation period are consistent with a higher initial net nitrification rate in the soil treated with conventional fertilizers (C and OC) than in that treated with the organomineral fertilizer (OM), both at 15 and 25°C. The decreased contents of nitrate N in the soil to which the organomineral fertilizer was applied, particularly at 15°C, were a result of the increased NH_4^+-N levels, which diminished the nitrification rate. However, at 25°C the organomineral fertilizer (M) contributes amounts of nitrate at 120 days of incubation similar to those of the conventional (C) and organic + conventional (OC) treatments, but not in 15°C. On the other hand, the results obtained indicate that the transformation $NO_2^- \rightarrow NO_3^-$ slower than transformation $NH_4^+ \rightarrow NO_2^-$ in this soil at both temperatures.

Figure 5 shows the changes in the inorganic N nitrogen content during the incubation period. As can be seen, treatment U produced the lowest levels of this fraction at both temperatures. Also, the temperature was markedly influential on the incubation process ($p < 0.05$, Table 3), coinciding with the results given by Bernal and Roig[28] and Antonopoulos.[31] In fact, the highest inorganic N levels at 25°C were detected at 3 days whereas those at 15°C were observed at 15 days. The decrease in the inorganic N content beyond its peak level was slower and more gradual at 15 than at 25°C. The decreases in inorganic N were probably due to microbial immobilization, since nitrogen losses by ammonia volatilization are negligible when the organic material is homogeneously mixed with soil.[28,33] Witter[34] also observed a decrease in inorganic N in soil amended with poultry

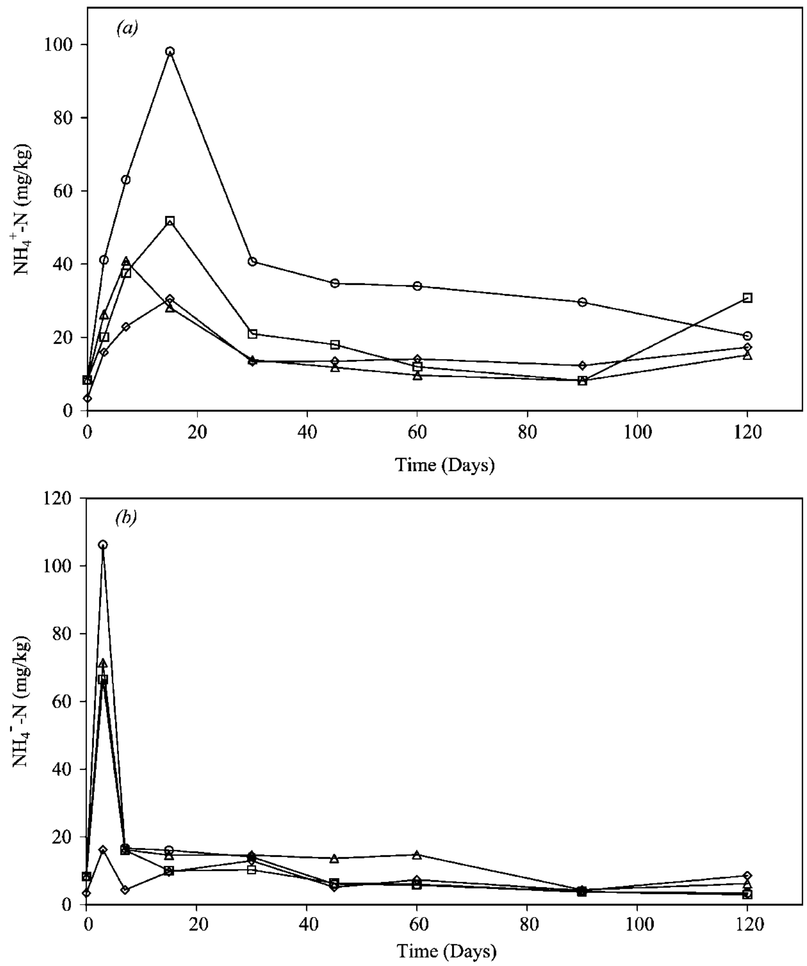


Figure 2. NH_4^+-N content during incubation at 15°C (a) and 25°C (b). Legend symbols: treatment U (rhomb), treatment C (square), treatment OC (triangle), and treatment OM (circle).

manure, suggesting that part of that N was retained in the clay fractions as non-exchangeable-N. The largest amounts at both temperatures and at 15 days were produced by the organomineral treatment (OM). However, the final values show that at 15°C the conventional fertilizer treatment originated the largest contents in inorganic-N, but at 25°C these values aren't influenced for fertilizer treatment.

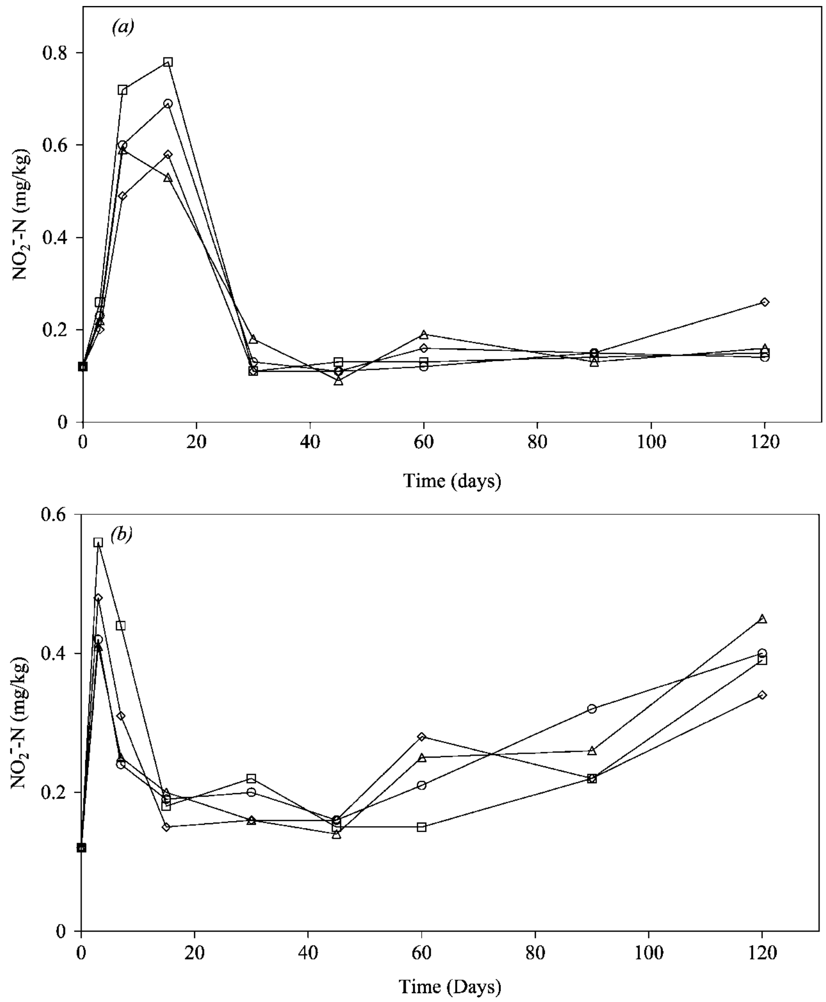


Figure 3. NO_2^--N content during incubation at 15°C (a) and 25°C (b). Legend symbols: treatment U (rhomb), treatment C (square), treatment OC (triangle), and treatment OM (circle).

Figure 6 shows the changes in the accumulative loss of N during the incubation period. The loss can be ascribed to gaseous N because experiments were conducted in porcelain dishes in order to avoid nitrogen losses through leaching. As a rule, whichever the temperature, gaseous nitrogen losses were quite substantial during the first few days of incubation, except at 25°C. There is a small

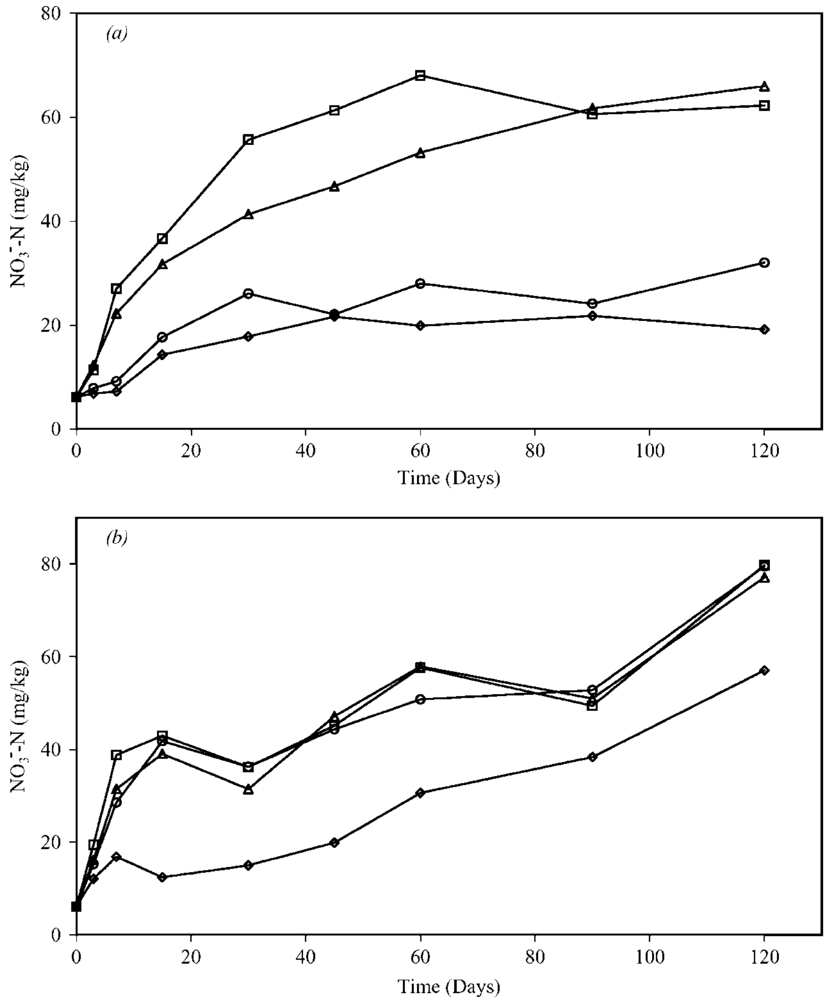


Figure 4. NO_3^--N content during incubation at 15°C (a) and 25°C (b). Legend symbols: treatment U (rhomb), treatment C (square), treatment OC (triangle), and treatment OM (circle).

gain in first three days—the period over which ammoniation was particularly intense—and leveled off after the seventh day. The descent in nitrogen losses values is due to nitrogen immobilization. On the other hand, N-losses represent approximately between 10%–25% of the initial N contents. The smaller final losses are produced with organic + conventional fertilizer treatments.

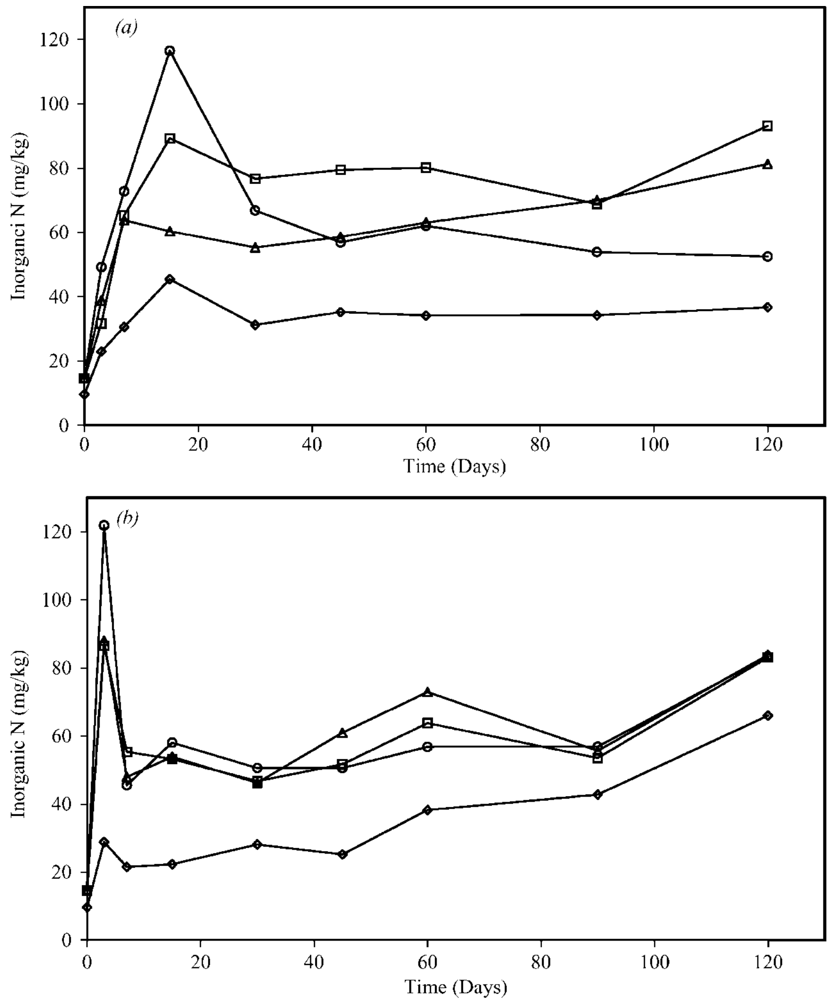


Figure 5. Inorganic N content during incubation at 15°C (a) and 25°C (b). Legend symbols: treatment U (rhomb), treatment C (square), treatment OC (triangle), and treatment OM (circle).

Figure 7 shows the variation of the net inorganic N contents for the three fertilizer treatments studied. The figures include only three curves, corresponding to the conventional (C), organic (OC) and organomineral fertilizer (OM), because, as noted earlier, their values were obtained by difference with those for the unfertilized soil. The results reveal that mineralization was more rapid and intense

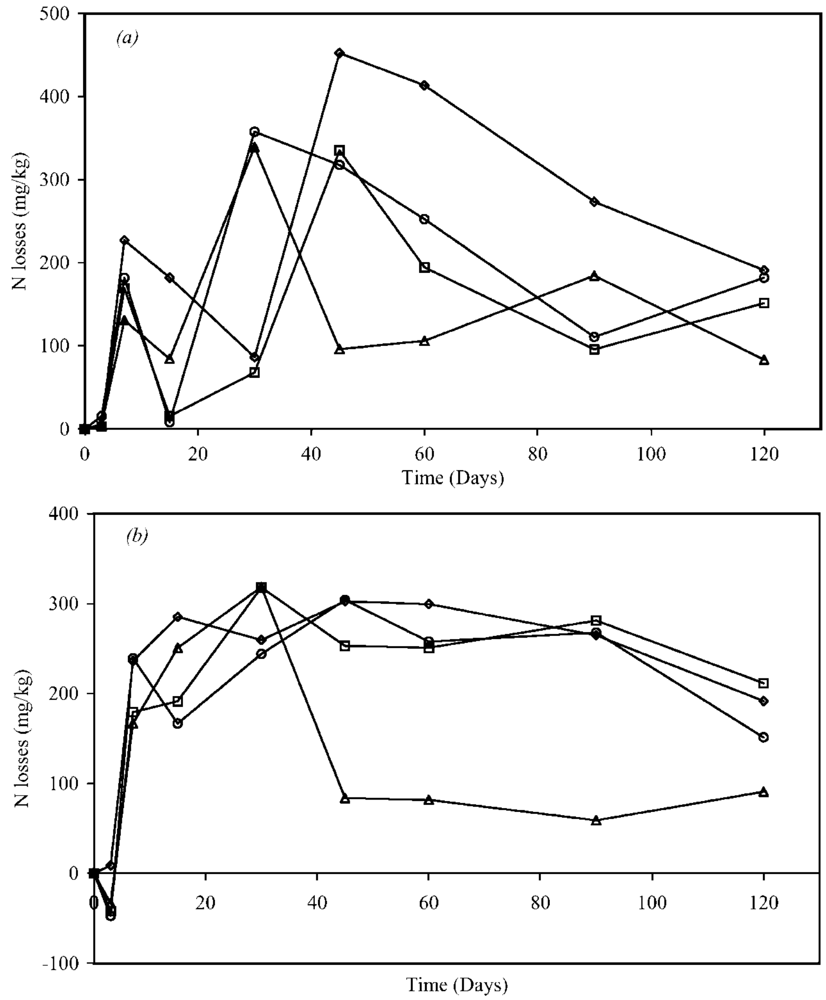


Figure 6. Variation of N losses during incubation at 15°C (a) and 25°C (b). Legend symbols: treatment U (rhomb), treatment C (square), treatment OC (triangle), and treatment OM (circle).

at the beginning, regardless of the fertilizer used. Also, the mineralization rate was especially high during the first few days in the soil treated with the organomineral fertilizer; however, the results obtained with this treatment were eventually similar to or smaller than those of the other fertilizer treatments during incubation owing to the losses of gaseous nitrogen, or nitrogen immobilization. Also, the temperature was markedly influential on the incubation process ($p < 0.05$, Table 3).

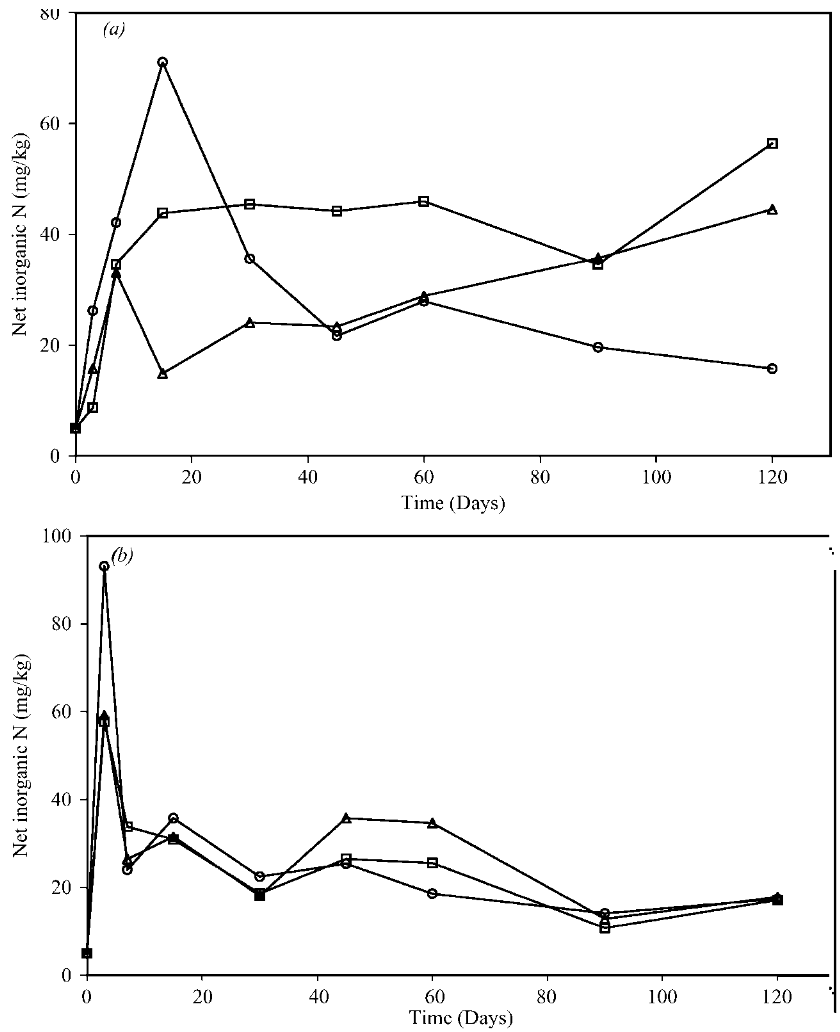


Figure 7. Net inorganic N content during incubation at 15°C (a) and 25°C (b). Legend symbols: treatment C (square), treatment OC (triangle), and treatment OM (circle).

Fitting of Nitrogen Mineralization Data Obtained for Treatments

The data were processed using the Statgraphics 5.0 software package, from Statgraphics 5.0,[17] in order to determine various expressions for inorganic nitrogen as a function of time. Similar treatments were carried out for the unfertilized soil (U).

Table 4 shows the results of fitting the nitrogen mineralization data obtained for the blank treatment (U) to the above-mentioned equations. The single exponential and double exponential curves provided the best fits at 15°C ($R^2 = 0.836$). The mineralization half time for potentially mineralizable nitrogen was 3 days in the more labile fraction and another 3 days in the more resistant fraction. The results obtained at 25°C did not fit a double exponential curve owing to the increased N losses observed in the first few days of incubation; in fact, the best fit was provided by the linear equation, with $R^2 = 0.848$. However, the large N_0 values obtained with the single exponential equation suggest that the mineralization potential increases with increasing temperature—at the expense of a longer mineralization half-time (243 days).

Table 4. Fitting of the Nitrogen Mineralization Data Obtained for the Blank Treatment (U) at Two Different Temperatures to Various Equations

	15°C			
Parameter	Unit	Value	R^2	$t_{1/2}$ (Days)
Linear equation				
N_i	mg/kg	26.75	0.200	
k	$week^{-1}$	0.75		
Single exponential equation				
N_i	mg/kg	9.19	0.836	
N_0	mg/kg	26.78		
k	$week^{-1}$	1.86		3
Double exponential equation				
N_i	mg/kg	9.19	0.836	
N_0	mg/kg	26.79		
k	$week^{-1}$	1.89		3
S	$week^{-1}$	0.25		
h	$week^{-1}$	1.81		3
	25°C			
Linear equation				
N_i	mg/kg	16.78	0.848	
k	$week^{-1}$	2.50		
Single exponential equation				
N_i	mg/kg	16.32	0.829	
N_0	mg/kg	133.36		
k	$week^{-1}$	0.02		243

Table 5 shows the results of the fit for the conventional fertilizer treatment (C). As can be seen, data only fitted the linear and single exponential equations, particularly the latter ($R^2 = 0.882$). Based on the fit, the potentially mineralizable concentration was 48.62 mg kg^{-1} and the mineralization half time 3 days. Similar values were previously reported by Deans et al.[19] and Lopez.[35] The results at 25°C only fitted the linear function owing to the massive nitrogen losses in the first few days of incubation, which are reflected in the negative value of k. (This may be mainly to the existent losses).

Table 6 shows the variation of the mineralized nitrogen content for the treatment with organic + conventional (OC). As can be seen, the data at 15°C fitted the double exponential function quite well ($R^2 = 0.812$); they reveal the presence of two nitrogen fractions one of which (78%) corresponds to the conventional fertilizer and mineralizes faster (1 day) than the other (22%), which corresponds to nitrogen in the organic fraction, of slow mineralization ($t_{1/2} = 243$ days). This reveals a substantial residual effect of this type of fertilizer on subsequent crops. This data is consistent with the results of Moliha et al.,[18] Deans et al.,[19] and Lopez[35] in soils treated with organic products. The data at 25°C fitted none of the three types of curves tested owing to the considerable nitrogen losses (reflected in the negative values of k and the fact that N_0 was smaller than N_i).

Table 5. Fitting of the Nitrogen Mineralization Data Obtained for the Conventional Treatment (C) at Two Different Temperatures to Various Equations

	15°C			
Parameter	Unit	Value	R^2	$t_{1/2}$ (Days)
Linear equation				
N_i	mg/kg	23.17	0.414	
K	week^{-1}	2.00		
Single exponential equation				
N_i	mg/kg	2.68	0.882	
N_0	mg/kg	48.62		
K	week^{-1}	1.12		3
	25°C			
Linear equation				
N_i	mg/kg	30.16	0.126	
k	week^{-1}	−0.96		

Table 6. Fitting of the Nitrogen Mineralization Data Obtained for the Treatment with Organic + Conventional Fertilizer (OC) at Two Different Temperatures to Various Equations

	15°C			
Parameter	Unit	Value	R^2	$t_{1/2}$ (Days)
Linear equation				
N_i	mg/kg	14.78	0.628	
K	$week^{-1}$	1.74		
Single exponential equation				
N_i	mg/kg	−0.42	0.578	
N_0	mg/kg	29.82		
K	$week^{-1}$	2.36		2
Double exponential equation				
N_i	mg/kg	−0.13	0.812	
N_0	mg/kg	85.77		
K	$week^{-1}$	5.00		1
S	$week^{-1}$	0.78		
H	$week^{-1}$	0.02		243
	25°C			
Linear equation				
N_i	mg/kg	30.27	0.059	
K	$week^{-1}$	−0.69		
Single exponential equation				
N_i	mg/kg	29.31	0.077	
N_0	mg/kg	1.16		
k	$week^{-1}$	−0.15		—

Table 7 shows the fits for the organomineral treatment. The regression coefficients were all very low owing to the N losses resulting from intense mineralization in the first few days of incubation.

Soil Microbial Biomass

Table 8 shows the soil microbial biomass for all treatments measured as biomass-C ($\mu g\,C\,g^{-1}$ dry soil). As can be seen, this parameter was significantly greater for organic matter-amended than for non-organic matter-amended soils. Also, the temperature was markedly influential in the evolution of this parameter, highlighting the biggest values to 25°C. This result indicates that the proliferation

Table 7. Fitting of the Nitrogen Mineralization Data Obtained for the Organomineral Treatment (OM) at Two Different Temperatures to Various Equations

	15°C			
Parameter	Unit	Value	R^2	$t_{1/2}$ (Days)
Linear equation				
N_i	mg/kg	34.39	0.079	
k	week^{-1}	− 0.93		
Single exponential equation				
N_i	mg/kg	32.06	0.095	
N_0	mg/kg	0.27		
k	week^{-1}	− 0.25		3
	25°C			
Linear equation				
N_i	mg/kg	36.63	0.121	
k	week^{-1}	− 1.50		

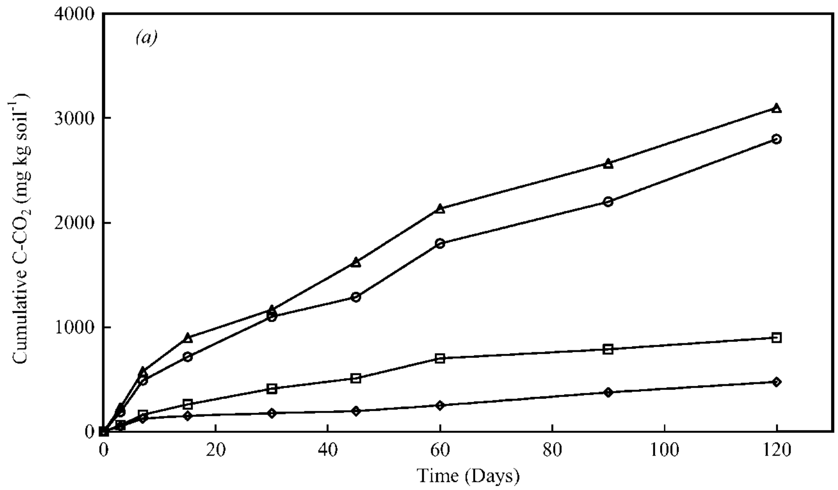
of microorganisms is bigger at 25 than to 15°C, that which implies a bigger value in the content of inorganic N (previously commented aspect).

On the other hand, Figure 8 shows the cumulative C-CO_2 evolution, or soil respiration, for the four fertilizer treatments studied. Also, this cumulative C-CO_2 evolution was significantly greater for organic matter-amended than for non-organic matter-amended soils. Significantly greater positive slopes of the C-CO_2

Table 8. Soil Microbial Biomass for All Treatments and Multifactor Analysis of Variance

	Biomass-C (μg C g^{-1} Dry Soil)	
Treatment	15°	25°C
U	1420	1454
C	1436	1498
OC	1702	1836
OM	1685	1794
	Biomass-C (μg C g^{-1} dry soil)	
	F	S
Treatment	20.72	***
Temperature	4.84	*

S: significance level; *$p < 0.1$ **$p < 0.05$ ***$p < 0.01$ ***$p < 0.001$.



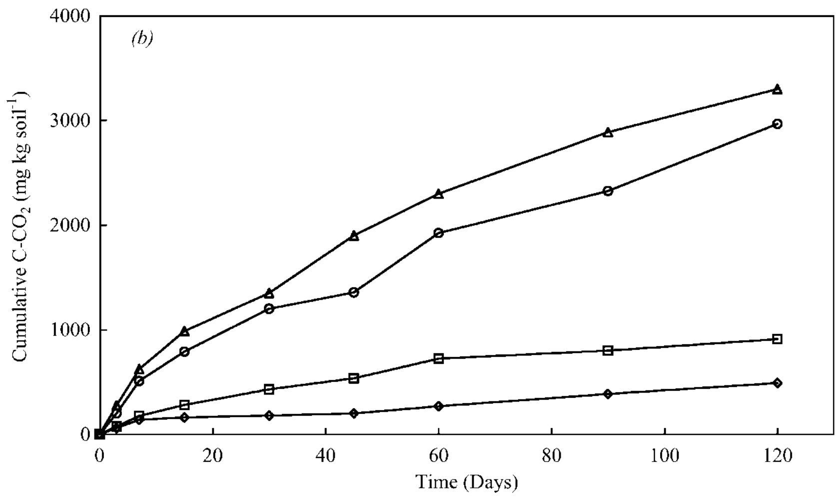


Figure 8. Cumulative C-CO_2 evolved for treatments during laboratory soil incubation at 15°C (a) and 25°C (b). Legend symbols: treatment U (rhomb), treatment C (square), treatment OC (triangle), and treatment OM (circle).

accumulation curves for the organic matter-amended soils reflect higher soil respiration rates than for non-organic matter-amended soils. The same as the previous case, the temperature was markedly influential in the evolution of C-CO_2, highlighting the biggest values to 25°C. This result indicates that the proliferation of microorganisms is bigger at 25 than to 15°C, that which implies a bigger value in the content of inorganic N (previously commented aspect). On the other hand, it is observed the biggest values in C-CO_2 for the treatment OC, independently of the used temperature, due mainly to the presence of labile organic N presents in the treatment OC. The manufacturing process of the organomineral fertilizer (in a reactor at a high temperature) may favor of the more resistant N fractions, which are initially integrated in the organic fraction.

In conclusion, increasing temperatures boost mineralization and N losses about 50% approximately of initial N-values of soil, whichever the fertilizer treatment used and consistent with previous findings of Benitez et al.[24] On the other hand, the treatment with organic + conventional fertilizer (OC) is seemingly that with the most significant residual effect in the soil; by contrast, the manufacturing process of the organomineral fertilizer (in a reactor at a high temperature) may favor of the more resistant N fractions, which are initially integrated in the organic fraction—hence their stronger mineralization at the early incubation stage their subsequent increased losses. Thus, it appears that soil microbial activity was more C limited than N limited, coinciding with the results given by Bending et al.[2]

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