RAHMANN G & AKSOY U (Eds.) (2014) Proceedings of the 4th ISOFAR Scientific Conference.
'Building Organic Bridges', at the Organic World Congress 2014, 13-15 Oct., Istanbul, Turkey (eprint ID 23586)

Nitrogen management in organic horticultural rotation

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Key words: Organic agriculture, compost, field incubation, green manure, nitrogen

Abstract

A field crop rotation with a cover crop of hairy vetch (Vicia sativa, L.) and rye (Secale cereale, L.) followed by potato (Solanum tuberosum, L.) and lettuce (Lactuca sativa L.) was set up with the aim of improving nitrogen (N) management for organic agriculture. N mineralization was determined by field incubation in response to green manure and increasing rates of compost (20 e 40 t ha^{-1}) and organic commercial fertilizer (1 e 2 t ha^{-1}). N mineralization in compost occurred throughout crop rotation, but most of the organic fertilizer was mineralized in the first days after soil application. Consequently, N availability and potato crop yield was increased with 2 t ha^{-1} of organic fertilizer in comparison to 20 t ha^{-1} of compost whereas lettuce yield increased with compost application in comparison to organic fertilizer.

Introduction

Organic farming practices for management of soil organic matter and nutrient availability include crop rotation, cover cropping and soil amendments with composts and/or manures. Nitrogen (N) is usually the limiting nutrient because it depends on the decomposition of organic matter and crops require it in large quantities. If not properly managed, N supply does not match with crop demand (Brito, 2001) and N recovery by crops decreases whilst N loss increases (Jarvis, 1996).

Incubations under controlled laboratory conditions gives us insights into soil potential to mineralize N. However it is unlikely that this approach will accurately reflect the rates of mineralization that occur in the field, due to soil perturbations (storing, mixing and sieving) and the lack of temperature and soil moisture fluctuations (Lomander et al., 1998). Here, N mineralization was determined by field incubation in order to evaluate the availability of mineral N in comparison to crop demand, with the final aim of improving fertilizer recommendations.

Material and methods

A field crop rotation with rye (*S. cereale* L.) consociated with hairy vetch (*V. sativa* L.) as green manure, over the autumn and winter, followed by potato (*Solanum tuberosum* L. cv. Desirée) and lettuce (*Lactuca sativa* L. Maravilla de verano) was set up on a sandy loam soil in the NW of Portugal, as a randomized block design with four replicate plots per treatment. Treatments applied before potato crop included: (i) incorporation of rye and vetch green manure (GM); (ii) and (iii) incorporation of GM with 20 and 40 t ha^{-1} (FM) of compost (C20 and C40); (iv) and (v) incorporation of GM with 1 and 2 t ha^{-1} of a commercial organic fertilizer certified for organic agriculture based on poultry fermented and granulated feathers (OF1 and OF2), and (vi) a reference treatment without soil amendments (T0). The compost was collected from a pile of cow manure aged for 7 months and turned twice.

Chemical properties and composition of compost, organic fertilizer and green manure are shown in table 1. Total N in the soil, composts and crops were measured by molecular spectrophotometry after digestion with sulfuric acid; mineral N from samples of fresh soil and composts was extracted with KCl 1M 1:5 solution and determined by molecular absorption spectrophotometry using a continuous flow auto-analyser. Soluble C and N were extracted with $CaCl_2$ 0.01M 1:10 solution and measured in an elementary analyser.

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Table 1: Organic matter content (OM), dry matter content (DM) and chemical properties (mean and standard deviation) of compost, organic fertilizer and green manure (rye and hairy vetch)

Nutrients	Compost	Organic fertilizer	Green manure
DM (%)	25.9	91.5	20.0
pH (H_2O)	8.0 ± 0.05	6.6 ± 0.1	
EC (ds m^{-1})	4.3 ± 0,3	5.9 ± 0.02	
OM (g kg^{-1} DM^a)	589 ± 63	831 ± 13	
N (g kg^{-1} DM^a)	19.8 ± 0.7	118.7 ± 3.8	21.0 ± 0.9
C/N	17 ± 2.4	3.9 ± 0.1	23 ± 1.1
NH_4^+-N (mg kg^{-1} FM^b)	69 ± 16	7272 ± 545	268 ± 22
NO_3^--N (mg kg^{-1} FM^b)	134 ± 38	2.1 ± 1.0	98 ± 4.8
Soluble C* (mg kg^{-1} DM^a)	7363 ± 489	42704 ± 3002	62418 ± 3773
Soluble N* (mg kg^{-1} DM^a)	1367 ± 3.1	36585 ± 2854	3243 ± 244

* Extracted with $CaCl_2$, [a]DM: dry matter, [b]FM: fresh matter

The field incubation used during potato and lettuce crops was performed according to the methodology described by Hatch *et al*. (1990). At the beginning of each incubation period two samples of 5 cores each (15 cm long and 4 cm wide) were taken. Five subsamples were frozen and the remaining ones were enclosed in micro-perforated polyethylene bags, buried at 20 cm depth and incubated for 14 days. The difference between the amount of inorganic N in frozen and incubated samples was used to calculate N mineralization. The sum of N mineralized during each incubation provided an estimate of the total mineralized N in the tilled layer. Two models developed by Cabrera and Kessel (1988) and Bonde and Lindberg (1988) were fitted to the results, with either one or two mineralization pools.

$Nm = N_0 [1-\exp(-k_1t-k_2t^2)]$ and $Nm = N_1 [1-\exp(-k_1t)] + N_2 [1-\exp(-k_2t)]$

In both models Nm (mg kg^{-1} DM) represents accumulated mineralized N at time t; k (one pool model), k_1 and k_2 (two pool model) are mineralization constant rates, and the amount of potentially mineralizable N is given by N_0 (one pool model) and by N_1 and N_2 (two pool model).

Results

Potato yield was not statistically different between the treatments OF1 and OF2 (36 and 42 t ha^{-1} respectively) and C40 (36 t ha^{-1}). However, potato yield increased ($P< 0.05$) in treatment OF2 in comparison to treatments C20, GM and T0. Lettuce yield increased significantly ($P< 0.05$) for treatments C20 and C40 (18 and 19 t ha^{-1} respectively) in comparison to all other treatments (Fig. 1).

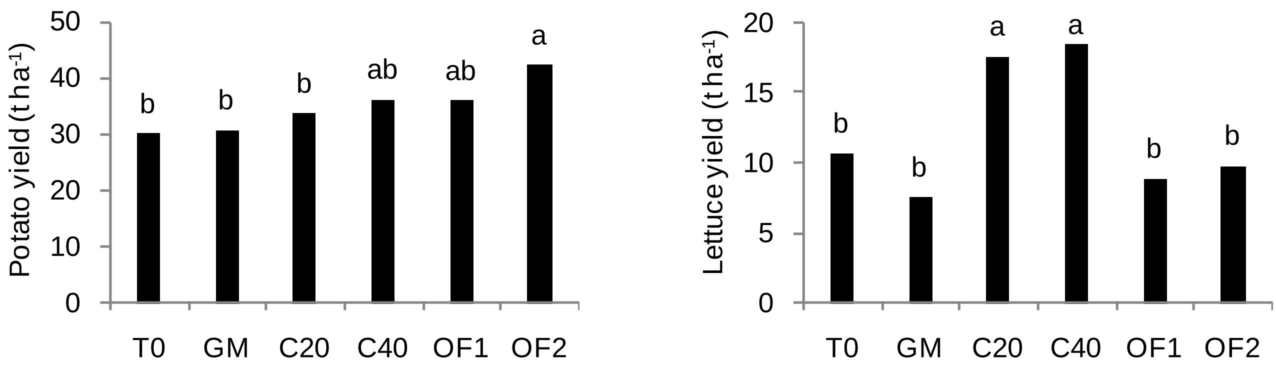

Figure 1. Potato and lettuce yield (t ha^{-1}) for the control treatment (T0) without soil amendments and in response to green manure (GM), GM and 20 or 40 t ha^{-1} of compost (C20 and C40), GM and 1 or 2 t ha^{-1} of organic fertilizer (OF1 and OF2).

The N mineralization of the organic fertilizer in the first 7 days of incubation, was 23 % and 49 % of the total N mineralized during the rotation, for 1 and 2 t ha^{-1} of fertilizer applied, respectively. On the other hand, the application of 40 t ha^{-1} of compost caused an initial N immobilization for 72 days probably due to increases in C (Reddy *et al*., 2008), and so, the N mineralization occurred throughout potato as well as lettuce growth period. N immobilization occurred with the application of green manure because C/N ratio was higher than 20 (Rosecrance *et al*, 2000) and a high content of soluble C (62418 mg kg^{-1}) in comparison to soluble N (3243 mg kg^{-1}) drived microorganisms into the immobilization of N from soil to decompose the soluble C from green manure (Fig. 2).

Discussion

Lettuce yield increased with the application of compost because organic N in the organic fertilizer was mineralized earlier during the previous potato crop. This was probably due to the low C/N ratio (3.9) and a high content of soluble C and N (42704 and 36585 mg kg^{-1}, respectively) available in the organic fertilizer that increased microbial activity, thus releasing a high amount of mineral N in a short period of time. The amount of potentially mineralizable N (N_0) available for the lettuce crop was not enough for an acceptable lettuce yield for this variety. The largest amount of mineral N released during lettuce crop was 22 mg kg^{-1} DM (29 kg ha^{-1}), in a response to the addition of 40 t ha^{-1} of compost, because N remineralization occurred during potato as well as lettuce growth (Fig. 2). A mid-cycle potato (90-120 days) instead of the long-cycle potato (120-150 days) used in this experience could had been more advantageous. In the latter situation lettuce could had been planted earlier when a higher content of mineralizable organic N and higher temperatures would probably increase N mineralization and consequently N availability, thus leading to an increased lettuce yield.

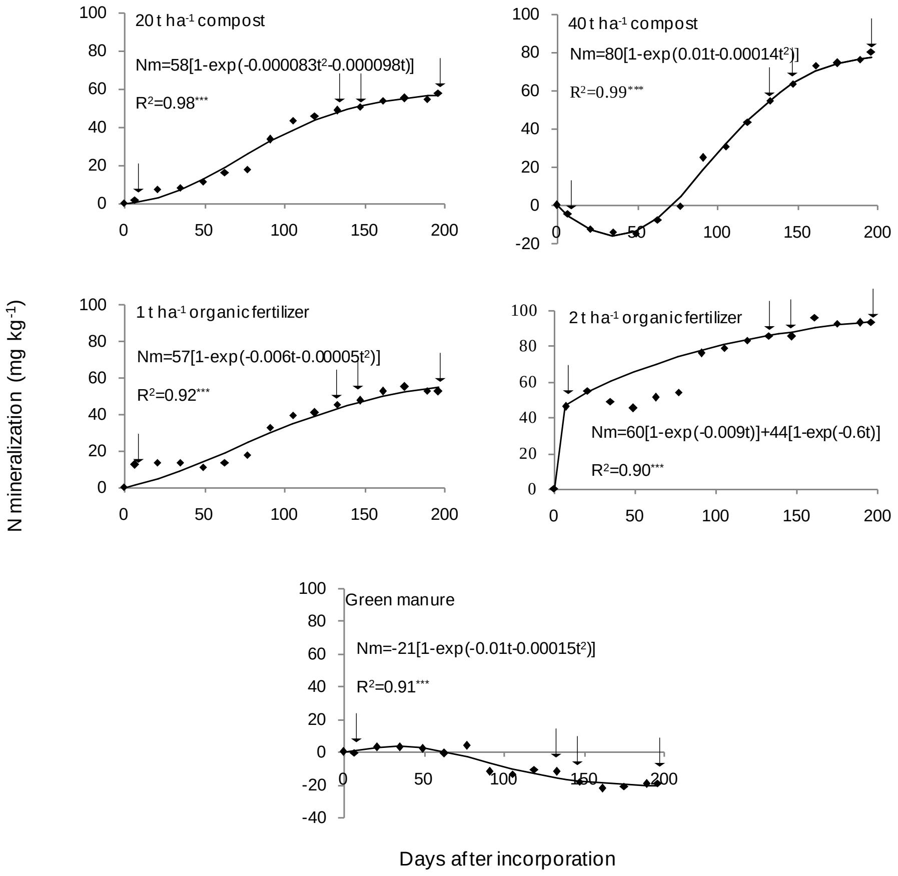

Figure 2. Accumulated mineralized N (mg kg^{-1} DM) from compost (20 and 40 t ha^{-1}), organic fertilizer (1 and 2 t ha^{-1}) and green manure in field incubation. Arrows represent the beginning and the end of crops. $^{*}P<0.05$ $^{**}P<0.01$ $^{***}P<0.001$.

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