Original scientific paper

Effects of tillage systems in irrigated crops on microbiological parameters of soil in different crop rotations

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Abstract
Nitrogen (N) is the main limiting factor in crop productivity and thereby soil management systems may change the mineralization and nitrification rates. The objective of this study was to calculate the net mineralization and nitrification rates of soil N and the correlation with soil pH under management systems in irrigated crops. Randomized complete block design was used, in split-split plots, with four replications, with tillage system as main factor, crop rotations as sub-factor and fertilization as sub-sub factor. The tillage systems used were conventionally (CT) and zero or no till (NT). Crop rotation were Maize-Maize-Maize, Maize-Soy Bean-Wheat, Maize-Sorghum-Wheat. The present study was conducted to determine the effect of tillage systems on nitrogen mineralization after one year of soil management in maize crop. 96 soil samples were studied by incubation at different times (five weeks) and depths (six depths). Sampling depth was ranged from 0-100cm, at intervals of 10cm. Mineralization capacity of nitrogen was higher at the soil surface while that mineralization and availability of nitrogen decreased with deeper layers in CT and NT systems. Net mineralization was higher in thee first cm of soil under NT than CT, however, higher processing capacity of nitrogen between 20-40cm was found under CT than NT due to management soil. A first order kinetic model (R_2 = 0.79) of net nitrogen mineralization was created and the rate of mineralization (k) was obtained. The model results indicated that the rate of mineralization (k) and potentially mineralized nitrogen increased and decreased respectively with depth.

Key words: Soil mineralizable N, tillage, crop rotation, Net Nitrogen Mineralization

Materials and methods

The field experimental was established in April 2011 at the Zamadueñas Experimental Station (Valladolid, Spain). The soil of the studied area is a Cambisol with higher clay and silt loam texture and water holding capacity. The climate is a typical Continental Mediterranean with cold winter and war summers. Mean annual temperature is 12.6° C and annual precipitation is 424.7 mm.

The experimental design is a split-split-plot with four replications where the main factor is the system of tillage (CT, moldboard plow, cultivator and sowing and NT, herbicide and sowing), the second factor is the crop rotation (Maize-Maize-Maize, Maize-Soy Bean-Wheat, Maize - Sorghum-Wheat) and the third factor is the fertilization (conventional (FC) and adjusted (FR)). The study covered a total of forty-eight 240 m^2 elementary plots. In this study only results after harvest of maize crop from the first year are presented. Soil samples were collected on November 2011 (after maize harvest) at three sites on each elementary plot to obtain a composite sample per plot from 16 plots at a depth of 0-10, 10-20, 20-30, 30-40, 40-60 and 60-100 cm (total 96 samples, 4 plots x 4 replications x 6 depths). The composite samples were sealed in plastic bags and transported to the laboratory for analysis. Nitrogen mineralization of soil samples was determined by aerobic incubation without leaching. The 96 soil samples were incubated during 36 days at 60% moisture and 28°C temperature conditions, then the ammonia nitrogen (easily mineralizable) and nitrogen oxide was determined. Ammonia nitrogen extraction was determined by Keeny y Nelson (1982) method. Ammonia nitrogen determination was obtained with Nelson (1983) method. Soil nitrate extraction and nitrate from soil extracts were analyzed by Official Methods of Soils Analysis MAPA (1993) and (Norman, R.J.; Edberg, J.C. y Stucki, J.W., 1985) methods respectively.

Data analyses showed a normal distribution which was established using the Wilk–Shapiro normality test, and therefore used over parametric statistics. Spearman (Kumar, Indrayan, and Chhabra, 2012) and Pearson (Galton, 1880) correlations were made to observe the degree of association or independence between variables. These correlations were supplemented with graphs represented by linear and nonlinear regression.

The exponential: $f(y) = \alpha * e\hat{}(\beta * x)$ model was used.

Data were statistically analyzed using R programme applying Student's or the LSD Means test with $p< 0.05$.

Results

Because data analysis revealed that soil NO_3^- and NH_4^+ had non significant differences between tillage systems results were not presented. Table 1 showed the soil total nitrogen and mineral nitrogen NO_3^- and NH_4^+ accumulation along the incubation period at different depths. Soil total nitrogen was very low and decreasing with depth. Data indicated that NO_3^- content was increasing over time and decreasing with depth layers while NH_4^+ accumulated values were similar over time but decreasing with depth. NO_3^- content had major influence than NH_4^+ on the mineralization rate.

Table 1. Mineral nitrogen forms accumulation along the incubation period and soil total nitrogen (STN)

		Incubation time (NO_3^- mg kg^{-1})				**Incubation time (weeks) (NH_4^+ mg kg^{-1})**		
Depth	**N t (%)**	0	2	3	5	0	2	3
0-10 cm	0.084	7.56	26.60	42.65	70.27	13.60	13.80	13.95
10-20 cm	0.083	7.07	24.20	41.07	63.97	14.49	14.67	14.84
20-30 cm	0.079	7.20	23.29	38.39	57.09	12.67	12.86	13.00
30-40 cm	0.068	6.60	23.01	34.55	52.58	11.02	11.22	11.33
40-60 cm	0.056	8.98	23.43	32.84	47.95	10.33	10.53	10.65
60-100 cm	0.050	9.66	21.51	29.98	45.51	9.88	10.19	10.33

Figure 1a shows mineral nitrogen NO_3^- and NH_4^+ evolution along 35 days of incubation. Nitrate content increased progressively from 6.5 to 18 mg Kg^{-1} at the end of the incubation time however, ammonium, NH_4^+, was transformed and decreased during the first incubation period (day 1 to day 14) as a result of volatilization and oxidation of $N\text{-}NO_2$ and NO_3^- potential forms, influenced by the basic pH soil. In this study net mineralization nitrogen was significantly correlated with soil pH as observed in Figure 1b. These results are consistent with findings reported by (Barberis and Nappi, 1995) and (Harmsen et al., 1955).

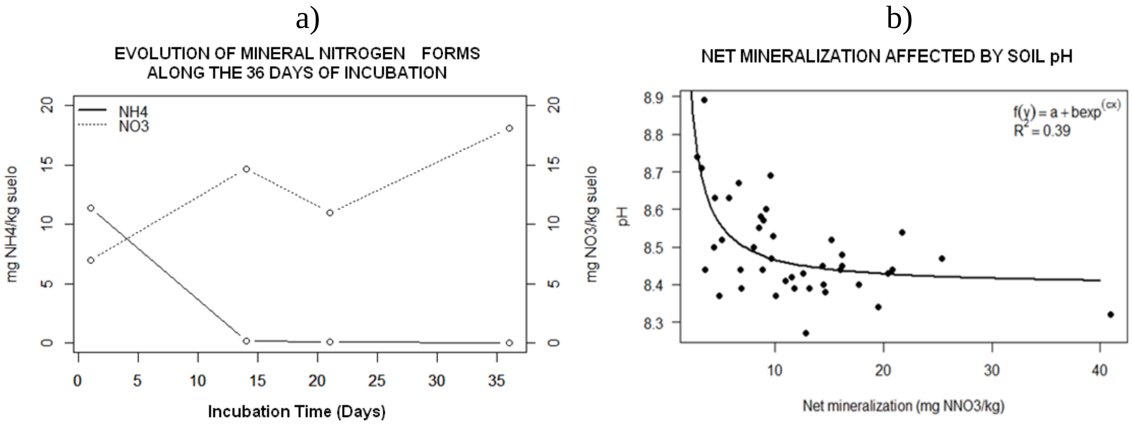

Figure 1. Mineral nitrogen forms evolution during the incubation period (a) and correlation model between nitrogen mineralization and soil pH (b)

Net mineralization nitrogen evolution at different depths along five weeks is presented in Figure 2. Results indicated that incubation time and profile depth had an important effect on net mineralization nitrogen which was higher for the shallow layers, mainly at 0-10 cm depth while for the deeper layers, 40-60 and 60-100 cm, net mineralization was lower from two weeks of incubation.

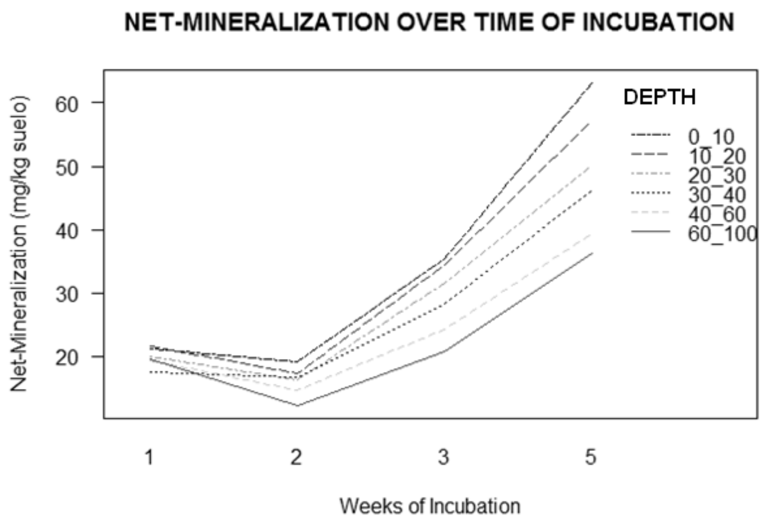

Figure 2. Mineral nitrogen evolution at different depths along 5 weeks of incubation

Net mineralization was significantly different between tillage systems; NT had 50% higher mineralization than CT at 0-10 cm depth (Figure 3). From 10 cm to 50 cm depth, tillage system behavior was opposite; CT had higher mineralization than NT. These results were due to management tillage. Surface layer had more nutrients and organic matter in NT as many researchers concluded (Lopez-Fandó and Pardo, 2009; Sombrero and de Benito, 2010) and mineralization was higher in this layer. However, in CT systems, soil organic matter and nutrients were increasing with depth (Gal et al., 2007) due to moldboard plowing and soil overturning and therefore net nitrogen mineralization was greater in these layers. Other authors also concluded that soil management alters the processes in which the microbial population is involved, such as nitrogen mineralization (García et al., 1992; Benintende et al., 2008).

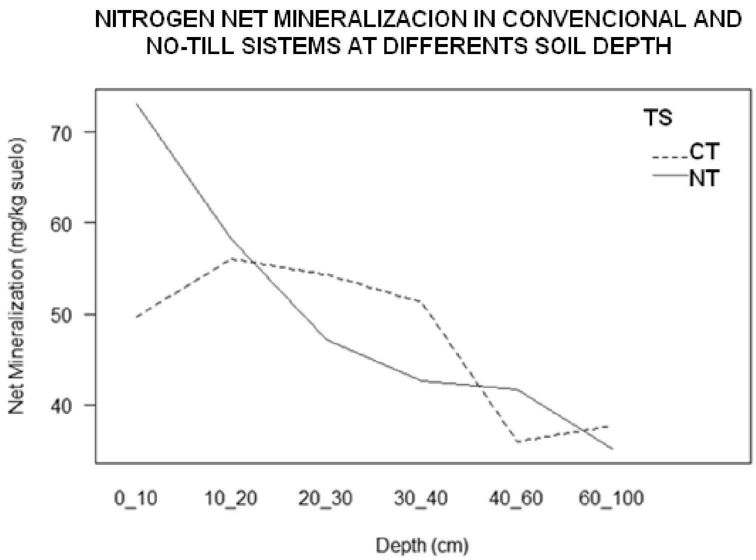

Figure 3. Net mineralization evolution along the soil profile. This was differentiated by tillage systems

Measurements of soil nitrogen were performed in function of time, therefore, the data obtained at different incubation periods follow the behavior of a kinetic model (Standford and Smith, 1972). In this model, a first order kinetic used a nonlinear regression analysis by the method of least squares (Smith et al., 1980). Mineralized nitrogen is linearly related to the square root of time (figure 4). The model followed this kinetic type: $N_m = N_o\ (1\text{-}e^{-kt})$, where N_m is the amount of mineralized nitrogen, N_o is potentially mineralized nitrogen (mg kg^{-1}), k is the constant of the first order of mineralization ($time^{-1}$) and t is the incubation time. N_o x k is the mineralized nitrogen per unit time.

The model describes a process of nitrogen mineralization to calculate the exponential and potentially mineralizable nitrogen (N_o) and constant of mineralization (k) representing the potential of mineralization. Nitrate amount per kg of dry soil that is mineralized weekly (N_o x k) was determined. Constants nitrogen mineralization for the samples studied was established by depth. Two models mineralization rate were created, the first corresponded to the soil layers between 0 and 30 cm and the second, from 30 to 100 cm depth.

The results showed that nitrogen mineralization potential decreased proportionally to the depth (Table 2). N_0 had 184.25 $mgkg^{-1}$ in upper layers (0-30 cm) while in deeper layers N_0 had 119.03$mgkg^{-1}$, results consistent with those of Benintende et al. (2008). Hadas et al. (1986) also determined that the N_o decreased with depth and had consistent relationship between depth and the rate of mineralization. The constant of mineralization (k) was lower at the soil surface and higher when depth increased. This parameter can be inferred on the time of potentially mineralizable nitrogen in which is degraded. K values found were similar to those determined by Benintende et al. (2008), Cassman and Munns (1980) and Hadas et al. (1986). Echeverría et al. (1994), found that the mineralization constant (k) had higher values in the deeper horizons than in the surface layers which suggested a different composition of the fraction likely to be mineralized in different layers. Stanford and Smith (1972), for a wide range of soils in USA, determined that mineralization rate was 0.054 + / - 0.009. Oyanadel and Rodriguez (1977) found a mean mineralization rate of 0.0058 + / - 0 01 in soils in Chile.

The kinetic model created allows to predict the value of NO_3-mineralized, under laboratory conditions, with a coefficient of determination of R^2 = 0.78 and 0.79, for 0-30 cm and 30-100 cm respectively.

Table 2. Parameters determining the rate of mineralization: N_o= potentially mineralized nitrogen (mg .kg^{-1}), k= constant of mineralization (time^{-1}) and t= the incubation time. N_o x k=mineralized nitrogen per unit time.

Parametres	**Depth**	
	0-30 cm	30-100cm
NN_o (mg N-NO_3^-.kg^{-1} dry soil)	184.25	119.03
k k (weeks^{-1})	0.04	0.08
NN_o x k (mg N-NO_3^-.kg^{-1} per week)	7.37	9.52
RR^2	0.78	0.79

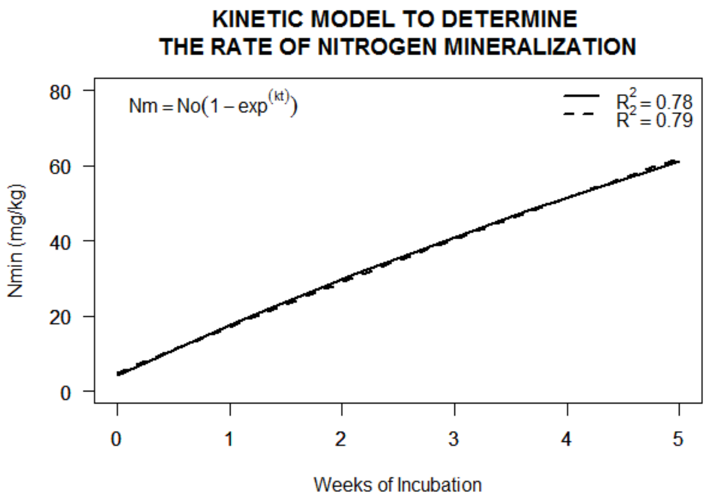

Figure 4. First-order kinetic model to determine the rate of nitrogen mineralization. R^2= 0.78 in depth 0-30cm; R^2= 0.79 in depth 30-100cm.

Conclusions

Management soil affected the net nitrogen mineralization in a year of conventional and no tilled system, NT had higher mineralization in the surface layer than CT which had higher values at deeper layers. Soil profile depth and incubation time determined the behavior of mineral forms of nitrogen. A model was created which allowed obtaining the rate of mineralization and nitrogen mineralization potential under controlled conditions with a high degree of confidence. CT caused more potentially mineralizable nitrogen accumulated in depth while NT showed greater amount of nitrogen on the surface.

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