NITROGEN DYNAMICS IN A SOIL AMENDED WITH RAW AND TREATED PIG SLURRY IN AN ALMOND ORCHARD, CARTAGENA SE SPAIN

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1 INTRODUCTION

Due to the intensive farming in SE Spain, great amounts of pig slurries are generated which suppose a problem of management to avoid damages to the environment. Pig slurry is a source of many nutrients and specially rich in nitrogen. So the use of this effluent as fertilizer is a common practice that in the correct dose is a good amendment and essential for sustainable development, but in excess can be a risk of soil and water pollution, and damage of crops.

We can find different ways of managing pig slurries that help to reduce its volume and quantity of pollutants. The most important ones are those that allow a use of these residues without damaging the environment. The application of slurries directly to the soil as an organic amendment is one of the best ways of management, especially after phase-separation by applying both the solid and liquid phase, composting, biological treatments, etc. (González, 2003). Therefore, one of the best ways of acting is the use in agriculture as organic fertilizer taking into account the doses and the availability of crops near the farm (Daudén and Quilez, 2003).

Due to the high quantity of nitrogen in the slurries, the possibility of nitrate leaching arises, causing groundwater pollution. As a consequence, the quantity of slurry allowed to apply is limited to 210 kg N ha^{-1} $year^{-1}$ and to 170 kg N ha^{-1} $year^{-1}$ in nitrate vulnerable zones (Council Directive 91/676/EEC), where our study area is located. The main objective of this study is to determine changes in nitrogen dynamics resulting from organic amendments applied after different treatments and doses in an almond orchard.

2 MATERIALS AND METHODS

The experimental area is an almond orchard located in the village of La Aljorra, belonging to the municipality of Cartagena in the Murcia Region (SE Spain). The climate of the area is semiarid Mediterranean with mean annual temperature of 18ºC and mean annual rainfall of 275 mm. A total of 10 plots (12 m x 30 m) were designed, one of them being the control without fertilizer. Three different treatments were applied, raw slurry, the effluent obtained after solid-liquid separation and solid manure, all of them in three doses being the first one of 170 kg N/ha, and the others two and three times the first one. The first dose is determined by the Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources adopted by the Commission on 19 December 1991. Application of the different fertilizers was carried out in February 2009. Three surface soil samples (0-25 cm) were randomly collected from each plot in September 2009 (7 months after the application).

The soil is a Thypic Haplocalcid (Soil Survey Staff, 2010) with clay loam to loam texture. Soil characteristics are given in Table 1.

TABLE 1 **Soil Characterization (values are mean, n = 3)**

Treatment	Doses	pH	EC[a] (dS/m)	OM[b] (%)	$CaCO_3$ (%)	Texture[c] (% sand, silt, clay)
Control		8.25	0.46	3.13	15.36	Clay-Loam (34, 33, 33)
Raw Slurry	1	7.99	0.45	2.79	24.55	Clay-Loam (29, 39, 32)
	2	7.79	1.37	2.85	21.76	Clay-Loam (25, 44, 31)
	3	8.12	1.23	2.86	25.85	Clay-Loam (28, 42, 30)
Liquid Slurry	1	8.08	0.48	2.93	23.71	Clay-Loam (26, 39, 35)
	2	7.84	0.59	3.55	25.16	Clay-Loam (29, 36, 35)
	3	7.92	1.06	2.95	30.43	Clay-Loam (29, 39, 32)
Solid Manure	1	7.93	0.79	3.58	27.87	Loam (34, 39, 27)
	2	8.17	0.58	3.62	32.18	Loam (38, 37, 25)
	3	8.17	0.70	3.59	28.22	Loam (36, 40, 24)

[a] EC: electrical conductivity
[b] OM: organic matter
[c] Sand: 2-0.05 mm; silt: 0.05-0.002 mm; clay: <0.002 mm.

Soil total nitrogen (Nt) was assessed by the Kjeldahl method according to Duchaufour (1970); soluble nitrogen (N_{sol}) by Sims and Haby (1971), analyzed by a TOC analyzer (TOC-V- CSH Shimadzu). Soil microbial biomass nitrogen (MBN) was determined by the fumigation–extraction method by Vance *et al.* (1987). Urease activity was analysed according to Tabatabai and Bremner (1972) and modified by Nannipieri *et al.* (1978).

The fitting of the data to a Normal distribution for all properties measured was checked with the Kolmogorov–Smirnov test. We carried out a one-way ANOVA to investigate the differences between treatments and doses. The separation of means was made according to Tukey's honestly significant difference at $P < 0.05$. Relations between soil properties were studied using Pearson correlations.

3 RESULTS AND DISCUSSION

No significant differences were found in TN for any of the applications, ranging from 0.14 to 0.22 % (Figure 1). This is contrary to the results reported by Fernández *et al.* (2009) in barley crops amended with sewage sludge in a three years period. N_{sol}, urease activity and MBN showed the same trend with highest values in doses 2 and 3 in raw pig slurry and dose 3 in liquid slurry. No significant differences were found between control and the rest of the treatments and doses (Figure 1). The values obtained for urease activity are significantly higher than the values reported by Zornoza *et. al* (2009) in non amended almond orchards in SE Spain, under similar climatic and edaphic conditions. This is likely due to pig slurry application in our study area as a common procedure for years, since we found values of urease activity near 5 times higher for the control samples. The similar values obtained in TN in the different treatments and doses are due to the mineralization of N after 7 months of the application of fertilizers. In contrast, the differences found in N_{sol} are due to the liquid phase of the treatments (raw and liquid slurry) in the highest doses in which there are high quantities of soluble organic matter.

We found positive significant correlations between urease and MBN ($r = 0.61$; $P<0.001$) and N_{sol} ($r = 0.60$; $P<0.001$). Regarding NBM, significant correlations were found with N_{sol} ($r = 0.79$, $P<0.001$), as Li *et al.* (2008) also found in soils amended with mineral fertilization and pig manure. No correlations between urease, MBN, N_{sol} and organic carbon were found ($P>0.05$). There was a significantly negative correlation between pH and urease activity ($r = -0.59$, $P<0.001$) and NBM ($r = -0.53$, $P<0.01$), the same that Li *et al.* (2008) obtained in application of mineral fertilization plus swine manure in a wheat-maize rotation crop.

The fact that we found the same pattern in MBN, urease activity and N_{sol}, together with correlation between them, indicates that N_{sol} controls microbial populations, which increase their numbers owing to increases in labile organic matter, easy to decompose. To carry out the degradation of these labile compounds, microorganisms release to the soil higher amounts of enzymes, reflected in the increased activity in urease. Hence, organic matter amendement had an effect on soil microbial community size and activity resulting in an increase in microbial biomass, enzyme activities and N mineralization as previously observed by several authors (Kizilkaya *et al.,* 2005;

Stark *et al*., 2008; Bastida *et al.,* 2009). The changes in biochemical properties observed in this study were also, in part due to organic matter application induced changes in soil pH. Our data indicates that most parameters determined in this study are significantly negatively correlated with soil pH values. This has been reported very often, since organic matter presents acid functional groups that decrease pH.

With all these results, we can infer that most organic N mineralizes to soluble forms like soluble organic compounds and NH_4^+ or NO_3^-. Thus, doses are crucial to avoid leaching of soluble nitrogen that can be rapidly mineralised likely provoking pollution of groundwater by nitrates.

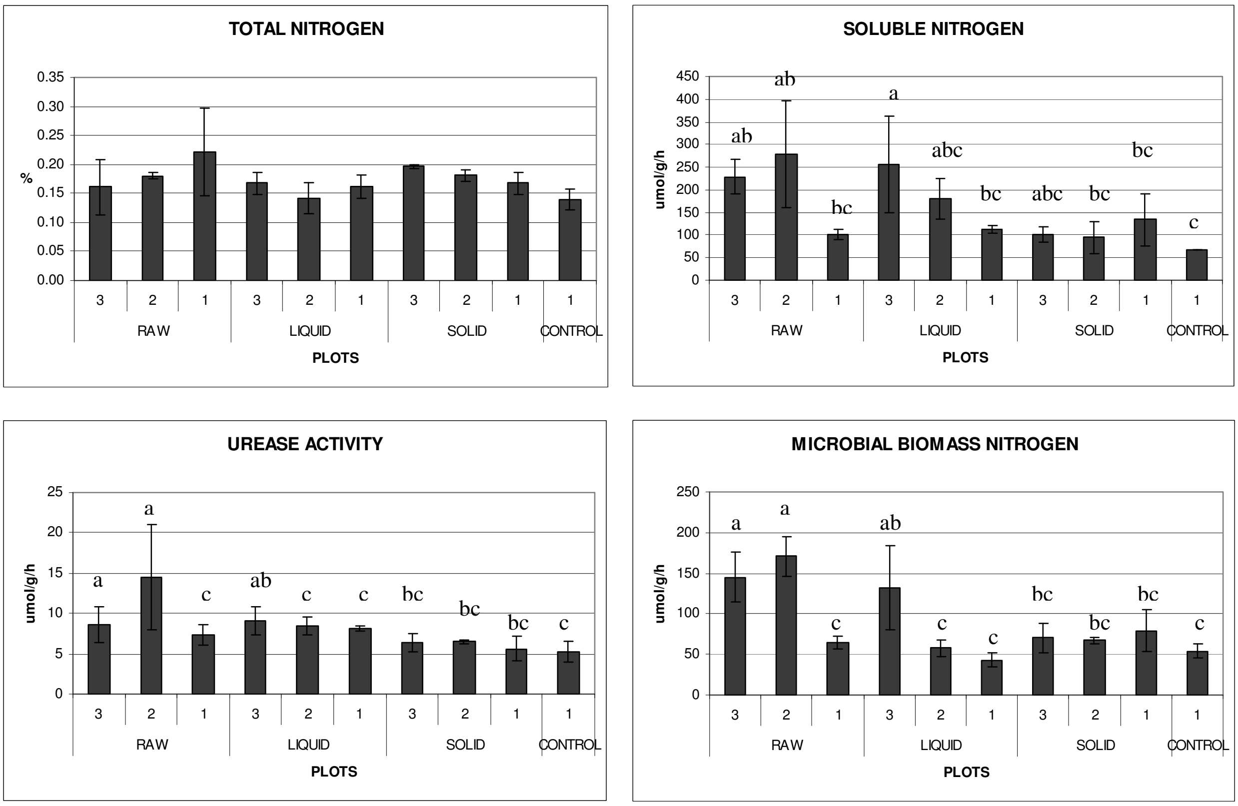

FIGURE 1 **Mean values and standard deviation for Soil Total Nitrogen, Soluble Nitrogen, Urease Activity, Microbial Biomass Nitrogen. 1, 2 and 3 denoted the three different doses. Different letters indicate mean values significantly different after Tukey's honestly significant difference at P<0.05.**

4 CONCLUSIONS

We can conclude that the use of pig slurry as organic fertilizer incorporates great amounts of nitrogen to the soil in its different forms, mainly as soluble and microbial biomass. Doses are important so it is a factor that has to be taken into account before applying these fertilizers because soluble nitrogen could be leached and rapidly mineralised which may lead to possible pollution of groundwater by nitrates; however more research is needed to confirm this assertion. This research also evidences the importance of analyzing biochemical parameters when studying nitrogen cycle, as they have been proved to be more sensitive to the different treatments and doses applied than total nitrogen.

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