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Nitrogen mineralization rates in soils amended with different poultry manures

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Application of organic wastes and by-products on agricultural land has received considerable attention in recent years, not only because of increased energy requirement for synthetic fertilizer production, but also because of the costs and environmental problems associated with their disposal. Many organic wastes could be recycled through application to agricultural land as a source of plant nutrients, specially nitrogen (N), as well as a soil amendment to enhance the future crop production by improving soil quality. Adding organic wastes to the soil can increase total N, organic matter, microbial population, enzyme activity, moisture retention, pH buffering capacity and crop yields (Dick and Christ 1995). It is important to identify the rates of application that maximize crop yields while minimizing the leaching of nitrate to groundwater.

Laboratory studies provide information about N availability under ideal conditions and in the absence of field studies, provide the best quantitative information on N availability.

Poultry manure (PM) commonly has a N concentration ranging 20-80 g N/kg on dry weight basis, with 72-88% of the N in organic form (Korkmaz 2008). Organic N in poultry manure mineralizes faster than the organic N in the other manures and sewage sludge (Delgado *et al.* 1999). Serna and Pomar (1993) have shown that the chemical composition of animal manure can affect the amount of net N mineralized from manure.

Keeping these in view, an incubation experiment was carried out with two different poultry manures: broiler's poultry manure (PMB) and hen's poultry manure (PMH) to evaluate the potential rates of mineralization and nitrification normally used in agriculture in two different soils. Chemical analyses were carried out on poultry manures and soils (Table 1).

The soils were taken from an upland field (0-20 cm) in central Spain (40º 30' N, 3º 52' W), air dried and sieved through a 2 mm mesh sieve. The soils samples used in this experiment were characterized as sandy loam in texture (700 and 655 g sand/kg; 190 and 180 g silt/kg; 110 and 165 g clay/kg of soil A and soil B, respectively.)

Triplicate samples of 100g air-dried soils were placed in a glass lysimeters tubes and were incubated in the dark as a constant temperature of 25ºC during 47 week period.

Soils were leached at 0, 2, 4, 8, 12, 16, 22, 30, 36, 43, and 47 week after the addition of PM, by adding 100 mL of $CaCl_2$ and 25 mL of N-free nutrient solution to obtain the extract for measure the inorganic nitrogen mineralized. Potential N mineralization laboratory incubations were conducted using sequential leaching techniques (Stanford and Smith 1972).

The mineral N contents of the extract were determined using the steam distillation and titration method of Bremner (1965) and total mineral nitrogen was calculated as ammonium-N + nitrate–N (NH_4^+ – N + NO_3^-–N).

The total inorganic nitrogen (mg N/kg soil) of untreated and PM treated soils was calculated by adding the initial inorganic N to total nitrogen mineralized (TNM) accumulated in samples.

The percentage of organic N mineralized from the PM (net nitrogen mineralized rate) was calculated by:

$$\%\ ONm = \frac{(INt - INc)}{ONpm} \times 100$$

where, %ONm, Percentage of organic N mineralized; INt, Inorganic N in treated soils; INc, Inorganic N in control soil; ONpm, Organic N added from PM.

Descriptive analysis of dates was done (mean, variance, standard deviation, standard error (SE), graphic). One-way analysis of variance using the general lineal model (GLM) procedure of the statistical Analysis System Programme, (SAS, Release 9.3) was used to compare the rates and PM in each soil.

Data (Fig 1) show that in soil A (SA) there was a slow mineralization in the first four weeks of incubation but in soil B (SB) there was only a slow mineralization in the first two weeks. After these first weeks there was a phase with high mineralization between the fourth and the twenty-second week in SA and between the second and the thirtieth week in SB, and finally a third phase with a slow mineralization. When the rate increased, the duration of the second phase increased too, because there were more labile compounds to mineralize.

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Table 1 Chemical properties of broiler poultry manure (PMB), hen poultry manure (PMH) and soils

	pH 1:2.5 H_2O	Electrical conductivity (dS/m 25°C)	N kjeldahl (%)	N-NH_4^+ (mg/kg)	N-NO_3^- (mg/kg)	Organic carbon (%)	C/N
PMB	8.24	9.31	3.48	7064.33	363.85	33.37	9.61
PMH	7.76	9.47	4.03	11319.71	462.42	31.02	7.71
Soil A	6.87	0.09	0.05	2.71	2.34	0.33	7.33
Soil B	8.42	0.17	0.09	2.81	2.27	0.41	4.51

The control soils released a maximum of 95 and 117 mg N/kg in soils A and B respectively. In case of 6 tonnes/ha PM application the maximum values were 109 and 149 mg N/kg PMB and 143 and 171 mg N/kg PMH in soil A and soil B, respectively.

In order to understand better the process of mineralization-immobilization during the incubation of these poultry manures, we studied the amount of NO_3^--N released and the percentage of organic N mineralized by one-way analysis of variance to compare the differences between rates of application at 8 and 47 weeks of the incubation.

Data (Table 2) show that the amount of NO_3^-–N released into the soils was higher SB than SA. In case of PMH, between rates 3 and 6 tonnes/ha, there were significant differences in both soils; SA (p=0.0042, p=0.0001) and SB (p=0.0014, p=0.0001) for 8 and 47 weeks respectively, when the rate increased, the amount of NO_3^-–N released increased too. But in PMB there were not significant differences when the rate increased from 6 to 12 tonnes/ha, due to PMB had straw in their composition. Some forms of organic N, like urea, proteins and amino acids, are readily mineralized to inorganic forms, while others are chemically or structurally protected in plant tissues, for example in lignin, a recalcitrant source of N (Chadwick *et al.* 2000).

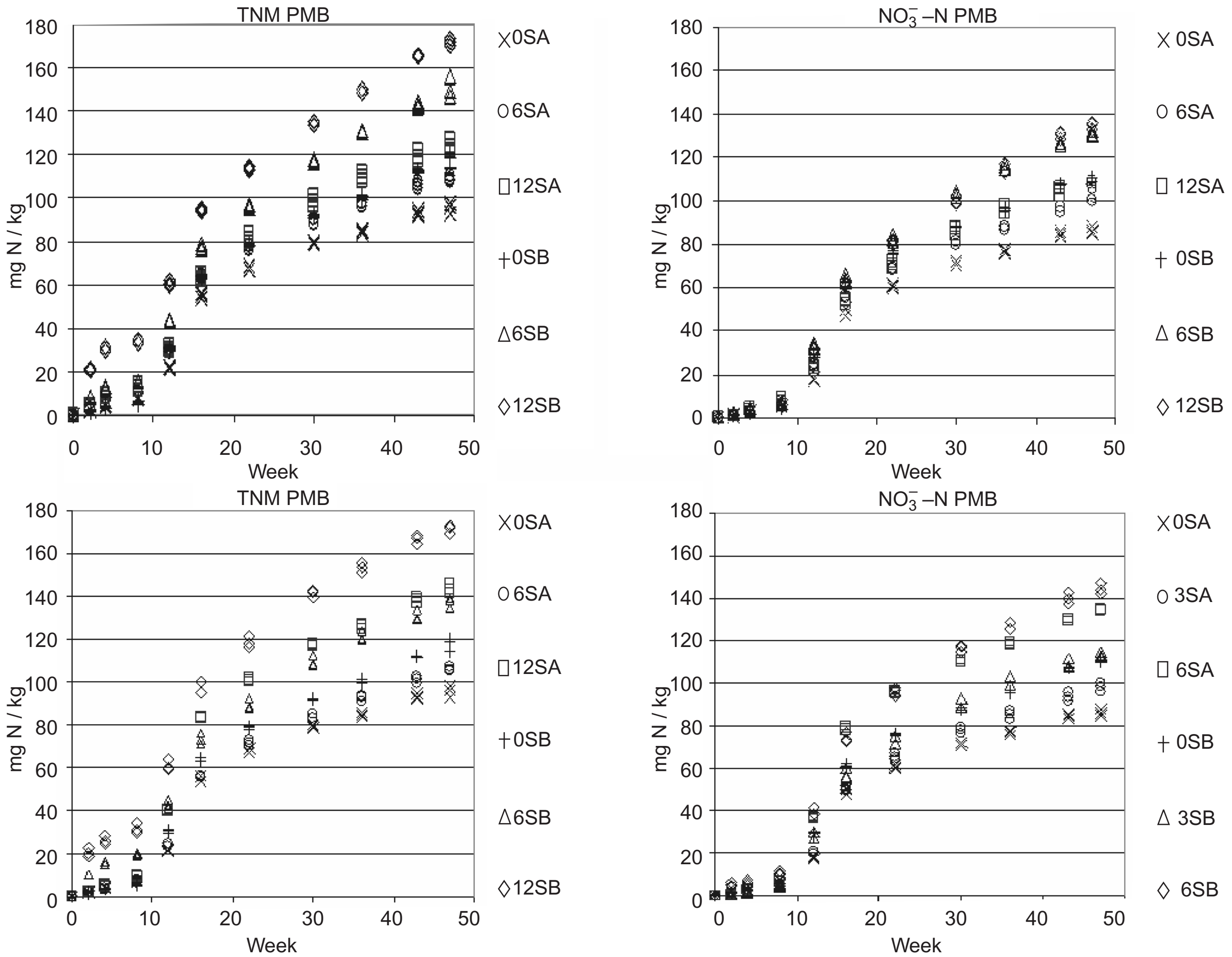

Fig 1 Amounts of total nitrogen mineralized (TNM) and NO_3^-–N mineralized in soil A and soil B from broiler poultry manure (PMB) with the rates 6 and 12 tonnes/ha and from hen poultry manure (PMH) with the rates 3 and 6 tonnes/ha

Table 2 Amount of NO_3^-–N (N mg/kg soil) released into the soils

Soil	Time	PMB		PMH	
	(week)	6 tonnes/ha	12 tonnes/ha	3 tonnes/ha	6 tonnes/ha
	8	7.67±0.1	7.6±0.82	5.2±0.29	6.7±0.07
SA	47	109.83±0.6	114.2±1.91	104.1±1.15	140.2±0.33
	8	6.61±0.3	6.1±0.39	4.7±0.34	10.5±0.65
SB	47	137.11±0.5	140.2±1.88	118.3±0.83	152.3±1.45

PMB is broller poultry manure and PMH is hen popultry manure. Mean ± SE.

Table 3 Organic nitrogen mineralized (%) at different time of incubation

Soil	Time	PMB		PMH	
	(week)	6 tonnes/ha	12 tonnes/ha	3 tonnes/ha	6 tonnes/ha
	8	6.61±0.74	4.8±0.62	1.21±0.27	3.11±0.68
SA	47	33.03±2.93	23.66±1.18	39.52±2.81	85.64±2.43
	8	20.81±0.58	18.01±0.65	46.07±2.41	54.22±2.14
SB	47	66.68±1.56	45.6±0.36	65.71±3.92	99.21±2.37

PMB is broller poultry manure and PMH is hen popultry manure. Mean ± SE.

The poultry manure, in general, has a great amount of N in inorganic form corresponding 21% to PMB and 29% to PMH, and in case of ammonia the losses to emission could be important (Moore *et al*. 2011). Also, regarding PMH, there is a high percentage of labile organic compounds as urea that can be mineralized easily and quickly over time, i.e. in the first 8 weeks PMH released the 70% of total N applied, due to the high microbial activity generated by the ambient conditions and the concentration of nutrients. Ruiz *et al*. (2008) had reported similar values but in first two weeks of incubation, these differences over time could be due to differences in incubation conditions.

After 8 weeks of incubation there were not significant differences ($p<0.05$) between rates of application for each soil and poultry manure in the percentage of organic N mineralized (Table 3), but after 47 weeks of incubation there were significant differences. The percentage of organic N mineralized in the PMB was higher in 6 tonnes/ha than 12 tonnes/ha, this percentage was lower according to increase the rate in both soils with $p=0.0245$ in SA and $p=0.0002$ in SB. However the PMH increased the percentage of organic N mineralized according to the increase rates of application with $p=0.0002$ in SA and $p=0.0019$ in SB. The rate of 6 tonnes/ha of PMH showed the highest percentage of organic N mineralized.

The animal manures as PMH composed of faeces and urine without added bedding material, are usually considered to be the wastes that contain the largest proportions of potentially mineralizable nitrogen (Nicholson *et al*. 1996). There are big differences between this PM and the composted PM, where about 40% of the organic N became available to crops during the first year and 6-12% during each subsequent year (Whitmore 2007). Under the condition of incubation the N released as inorganic form in one year was 99% and 66% of organic N added to soil through PMH and PMB, respectively.

Thus the rate and timing of PM applications need to consider the N requirements of the given crop to ensure the efficient use of these products. It is imperative that landholders can manage the application of organic amendments to soil through accurate knowledge of their maturity status and thus nutrient release characteristics.

SUMMARY

The Nitrogen (N) availability from field-applied poultry manure for crop production is influenced by a number of complex processes. Keeping these in view, an experiment was conducted to evaluate the decomposition of poultry manure by analysing the nitrogen mineralization. Thus the rate and timing of PM applications need to consider the N requirements of the given crop to ensure the efficient use of these products.

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