Nitrogen Release from Poppy Waste and Biosolids at Low Temperature

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Abstract

An incubation experiment was conducted over 56 days at 12.5° C and constant soil moisture to compare nitrogen mineralisation between organic soil amendments available to the agricultural industry in Tasmania. Treatments incorporated with soil were poppy mulch (PM, seed head and stem residues after alkaloid extraction), poppy seed waste (PSW, seed residue after oil extraction), anaerobically digested biosolids (ADB), lime amended biosolids (LAB), lime and an unamended control. At day 28, mineralisation of the total nitrogen applied in the ADB, PSW and LAB treatments was 29%, 36% and 44% respectively. Values increased to 35%, 48% and 62% respectively at day 56. However, the PM treatment (and to a lesser extent the lime and control treatments) exhibited a drawdown of nitrate over the same period.

Key Words

Poppy waste, biosolids, nitrogen mineralisation

Introduction

Many organic soil amendments used in agriculture are a source of both carbon and plant available nutrients. However, amendment availability and logistical limitations rather than the demand for nutrients and organic matter often determine application timing and rate for agriculture use (Bünemann *et al.* 2006). Inorganic fertiliser contains nutrient formulations for direct uptake by plants. Conversely, prediction or calculation of plant available nutrients in organic amendments is more problematic because they are generally waste products with a variable and dynamic composition. In Tasmania, lime amended biosolids (LAB), anaerobically digested biosolids (ADB), poppy mulch (PM) and poppy seed waste (PSW) are available for agricultural use. Total nitrogen for each product is generally 3 %, 4.6 %, 1.6 % and 5.1 % respectively, most of which is in organic form. The Tasmanian state biosolids guidelines (Dettrick and McPhee 1999) suggest that only 25 % of the organic nitrogen contained in biosolids is mineralised in the first twelve months following application. Calculated application rates are based on this assumption. However, a study conducted by Eldridge *et al.* (2008) in NSW found up to 50 % of total N in land applied biosolids was mineralised in the first 2 months after application. They further suggested that a one size fits all model may not be appropriate for biosolids mineralisation calculations (Eldridge *et al.* 2008). No published research has been found on the mineralisation rates of PM and PSW as they are waste products of a primary industry that provides alkaloids for pharmaceuticals, and seeds for edible oil, culinary purposes and in the manufacture of paints and cosmetics.

Incubation experiments have been conducted by Flavel and Murphy (2006), Burgos *et al.* (2006) and Hseu and Huang (2005) to investigate N mineralisation of various soil-applied organic amendments. Incubation temperatures (and times) used for the amended soils were 15°C (142 days), 28°C (280 days) and 30°C (336 days) respectively. Although these studies were conducted between 20 and 48 weeks, most changes occurred within the first 4 weeks following incorporation. N mineralisation studies conducted specifically on biosolids-amended soil by Smith *et al.* (1998) concluded that biosolids type, soil temperature and time from incorporation were dominant factors in determining release rate and nitrate formation. The incubation temperature in this experiment was 25°C, with subsequent biosolids studies by Smith and Durham (2002) and Rouch *et al.* (2009) using 25°C and 20°C respectively. Aside from the study by Flavel and Murphy (2006) the temperatures in the other studies mentioned ranged between 20 and 30°C, temperatures most favourable for the nitrification process (Brady and Weil 1999).

However, in cool temperate climates, soil preparation for crop production or pasture renovation traditionally occurs in autumn or spring at which time soil amendments are also applied and incorporated. Therefore, the objective of this study was to determine the rate of N release from amended soils at a temperature more typical of this climate at these times of year.

Methods

An incubation study was undertaken in a growth chamber over 56 days at a temperature equivalent to the 'autumn' and 'spring' season in Tasmania. A randomised complete block design with three replicates was used. Treatments included control (unamended), LAB, ADB, PM and PSW. Two other controls of $NaNO_3$ and NH_4Cl at 1% w/w soil were included for observing denitrification and mineralisation respectively (Rouch *et al*. 2009). A further control soil plus lime ($CaCO_3$ at 4% of LAB wet rate) was used to determine the effect (if any) of calcium on the release of nitrogen in the absence of the biosolids treatment (i.e. LAB). Each replicate included seven samples for removal and analysis at days 0, 3, 7, 14, 28, 42 & 56. Overall, there were 8 treatments x 3 replicates x 7 sample times. Treatment preparation was derived from Smith *et al.* (1998) with application rates based on treatments being incorporated in the soil to a depth of 10cm at a wet weight equivalent rate of 7.5 dry solid (DS) t/ha, assuming a bulk density of 1 g/cm^3. Although measured bulk density for this soil *in situ* was 1.4 g/cm^3, the lesser value was used to reflect the state of soil immediately following cultivation. Soil to a depth of 10cm was collected from an agricultural site near Cressy, Tasmania, sieved to < 4mm and stored at 4°C. The soil had been previously classified as a 'brown' Sodosol (Cotching *et al.* 2001). The gravimetric moisture content (GMC) of the soil at field capacity (FC) was determined using 'Haines' apparatus (Haines 1930) and calculated as 33%. 1.5 kg sub-samples of field moist soil (20% GMC $\approx$ 61% FC) were spread loosely at an even thickness on a 35 cm x 40 cm stainless steel tray. Each amendment was then evenly distributed over the soil samples at the required DS rate and mixed by hand using a broad spatula turning the soil in a uniform motion. Both biosolids products were mixed into a slurry with 40ml of distilled water before incorporating in the soil. 40 ml of distilled water was added to all other treatments (including control) to maintain a minimum of 70% field capacity. 7 x 50g samples for each replicate were weighed out in 125ml plastic bottles with loose fitted lids (for gaseous exchange) and incubated in the dark at an average of 12.5° C. The selected temperature was a calculated average of data obtained from http://www.bom.gov.au/climate/averages/ for 5 sites around Tasmania with similar soils: Cressy, Cambridge, Campbell Town, Ross and Palmerston. The treated and untreated soils were tamped down in the bottles (7 light taps on a bench) to achieve a similar bulk density (i.e. similar height in container). No additional water was added to the samples over the incubation period due to minimal moisture loss.

Samples from plots removed at each time period were frozen at -19 °C until analysis. Frozen samples were thawed to room temperature before weighing (10 – 15 g), drying at 105 °C for 24 hours, and reweighing to determine GMC. 5 g of each moist sample was also weighed into a 125 ml PPE screw top container and mixed with 2M KCl solution at a 1:10 ratio (w/v) for 1 hour. Extracts were then filtered through Whatman No. 42 filter paper, analysed colormetrically for NH_4 and NO_3, with results corrected for moisture using GMC. The total inorganic N content was calculated as the sum of NH_4 and NO_3 extracted from each sample throughout the incubation and the net mineralised N from the applied products was calculated as the difference between inorganic N in each treatment and the control soil (Burgos *et al*. 2006).

Results

The organic products used in the experiment were analysed prior to commencing the trial with results shown below in Table 1. The moisture results were used for final correction of samples prior to incubation. Brady and Weil (1999) suggest that the lower the C:N ratio of residues added to soil, the higher the microbial activity and subsequent mineralisation. Therefore mineralisation extent and rates should follow the sequence ADB > LAB > PSW > PM. They also suggest that if the C:N ratio exceeds 25:1, the microbes will source nitrogen from soil reserves, simulating the priming effect often associated with introduction of organic residues to soil (Brady and Weil, 1999).

Table 1. Characteristics of organic amendments and the soil

	Units (DMB)	LAB	ADB	PM	PSW	Soil
Moisture	% (w/w)	70.1	80.3	55.1	10.8	20.0
pH (H_20)		13	6.6	7.3	5.5	7.3
Organic C	% (w/w)	15.0	13.6	26.1	34.6	2.0
Ammonia	mg/kg	1300	4300	8.6	46	<1.0
Nitrate	mg/kg	1.7	1.2	<1.0	20	7.9
Nitrite	mg/kg	1.2	<1.0	1.6	6	<1.0
Total N	% (w/w)	3	4.6	1.6	5.1	0.15
Total N_{DS}*	kg/ha	225	345	120	383	1500
Total P	mg/kg	18000	11000	9300	15000	340
Ca	mg/kg	248000	20700	89400	23600	7790
C:N Ratio†		5:1	3:1	16:1	7:1	13:1

Total N_{DS}* - Total N in 7.5 dry solid tonnes / ha of organic amendment, C:N Ratio† - assumes total C ≈ organic C.

However, results in Figures 1 & 2 show the sequence to be PSW > LAB > ADB > PM and that even with a low C:N ratio of 16:1 (well below the suggested cap of 25:1), the PM treatment exhibited a nitrogen drawdown for 42 days of the 56 day incubation. The lime treatment was not significantly different to control.

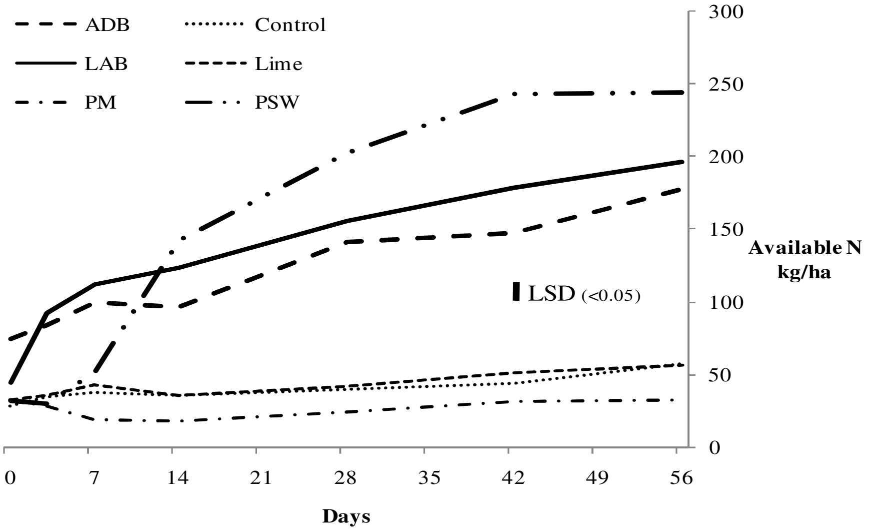

Figure 1. Total mineralised nitrogen from soil applied amendments

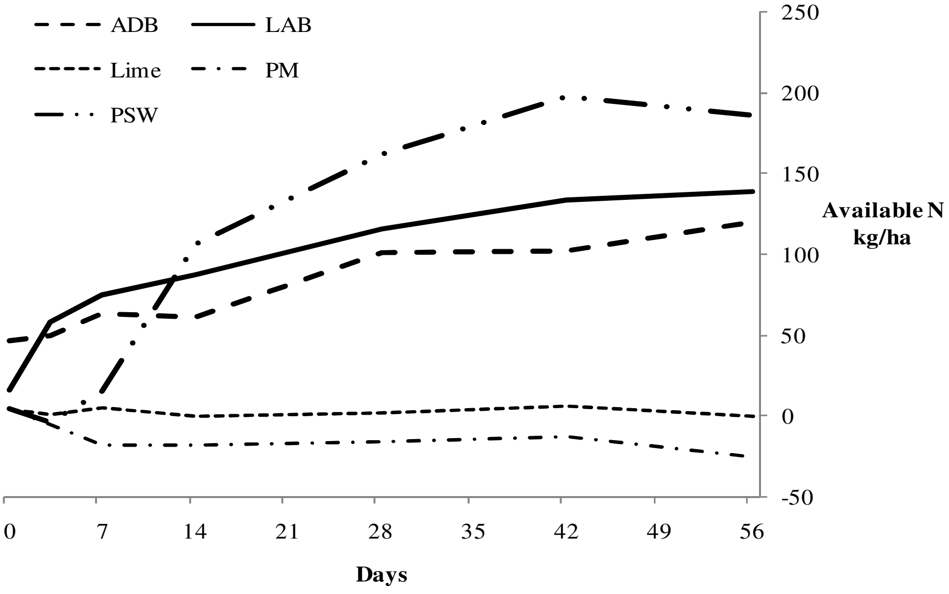

Figure 2. Mineralised nitrogen from soil-applied amendments relative to the control

After 28 days, the nitrogen mineralised from the PSW, LAB and ADB treatments was 162, 116 and 102 kg/ha greater than the control (Figure 2), representing 36 %, 44 % and 29 % of the total nitrogen applied with each organic amendment. Relative to the control, the available nitrogen increased to 186, 139 and 120 kg/ha by day 56 (48 %, 62 % and 35 % respectively) (Figure 2).

Conclusion

The results of this study confirm the suggestion by Eldridge *et al.* (2008) that one size does not fit all with respect to estimating nitrogen mineralisation, particularly from biosolids. The results also demonstrate that predictions of mineralisation extent and rates may not be reliably based on the C:N ratio of the applied product, which Griffin and Hutchinson (2007) found for compost. Although this study was conducted at a temperature less than the most conducive range for nitrogen mineralisation, the results show that plant available nitrogen can still be mineralised from amendments applied and incorporated in the soil in autumn and spring. If amendments were applied in the summer, the rate of mineralisation would probably be greater, at least initially. This indicates that timing of application is essential in ensuring that mineralisation of nitrogen coincides with plant requirements.

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