Effects of land application of two different biosolids on plant growth and nitrogen mineralisation in a red ferrosol soil in subtropical Australia

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Abstract

Land application of biosolids can help to improve declined soil fertility and soil health in intensive agricultural systems. Understanding the fate of the nitrogen (N) applied is the key to take advantages of such application and minimise the possible side effects. A study was carried out to investigate the effects of land application of aerobically and anaerobically digested biosolids at the Nitrogen Limited Biosolids Rate on plant growth and the mineralisation of the applied N in biosolids in a red feresol soil planted with maize in subtropical Australia. Plant maximum biomass production and grain yields were significantly higher from the biosolids treated plots (14.2-14.9 t/ha for maximum biomass production and 8.3-8.9 t/ha for grain yields) than from the unfertilised and fertilised plots (10.6-12.6 t/ha for maximum biomass production and 6.8-7.2 t/ha for grain yields). Six weeks after application, ammonium N in biosolids treated plots (478 kg/ha for aerobically and 408 kg/ha for anaerobically digested biosolids) accounted for more than half of the applied organic N (632 kg/ha for aerobically and 730 kg/ha for anaerobically digested biosolids), suggesting that significant amount of the applied N could be lost through volatilisation. The total mineralised N recovered from the plant and the top 1200 mm soil profile was 21% for aerobically and 30% for anaerobically digested biosolids. No leaching of the mineralised N was found below the top 1200 mm soil profile.

Media summary

Biosolids applied to a red ferrosol soil increased biomass production and grain yields. Most applied organic N was in the ammonium form in first 6 weeks after application.

Key words

Biosolids, nitrogen, mineralisation, volatilisation and maize.

Introduction

Agricultural land use could result in declined soil fertility, especially reduced soil organic carbon and soil N (Haynes *et al.*, 2003). Land application of biosolids has received increased attention in the last 2 decades (Robinson et al., 2002; During and Gath, 2002) and it could help to replenish the reduced soil organic matter, supply nutrients, such as N, P, K, S and essential micronutrients to plants, improve soil texture and water holding capacity, and have beneficial effects on microbial biomass and activity (Eriksen et al., 1999; Leifield et al., 2002).

The added mineral and organic N can affect N dynamics in soil-plant ecosystems. Transformations of the applied N need to be estimated for better N management strategies. It is well documented about the N mineralisation rate of biosolids, especially under controlled artificial conditions (Binder et al., 2002). However, the transformations of the applied N under field conditions largely depend on the composition of such applied materials, the climate conditions such as rainfall and temperature, the types and properties of soils used, as well as agricultural production systems. Mineralisation rate ranged between 15-55 % of biosolids sourced organic N during the first year after application (Binder et al., 2002; Keeney et al., 1976;

Robinson et al., 2002). However, there is limited information about the effects of land application on N transformations and plant growth in subtropical areas as most of mineralisation work has been conducted in areas of temperate climate and in the northern hemisphere.

The aims of this study are to investigate 1) the plant response to the application of the aerobically and anaerobically digested biosolids and 2) the mineralisation of organic N sourced from two different biosolids applied under field conditions.

Materials and procedures

The study was conducted in a red ferrosol soil at Kingaroy (26?33'S, 151?50 E), subtropical Australia. The experimental site is 430 metres above sea level. The average rainfall is about 780 mm, with 70% of the rainfall falling between October and March. The daily average temperatures are 22.6 ^{o}C in January and 11.1 ^{o}C in July.

Two biosolids products produced in southeast Queensland, Australia were used in this study: one aerobically digested biosolids and one anaerobically digested biosolids. Some of the selected soil and biosolids properties are listed in Table 1.

Table 1 Selected soil and biosolids properties

	pH[#]	EC	**Total N**	NH4-N	NO3-N	P	S	Sand	Silt	Clay
		mS/cm	%	mg/kg		mg/kg	mg/kg	%	%	%
Soil (0-100mm)	5.0	0.05	1.3	4.8	11	59[*]	300	22	19	60
Aerobic	6.2	2.5	5.2	2142	19	39000[$]	10000	-	-	-
Anaerobic	7.6	7.2	5.4	14107	55	24000[$]	15000	-	-	-

[#] 1:5 0.1M $CaCl_2$ extraction. [*] Extracted with 0.5M $NaHCO_3$. [$] Total P.

The experiment consisted of 4 treatments with 3 replications: unfertilised control, fertilised control (commercial fertiliser CK 700 at 200kg/ha, equivalent to 64.6 kgN, 16.6 kgP and 1.6 kgS/ha), aerobically digested biosolids and anaerobically digested biosolids. The two biosolids were applied at the Nitrogen Limited Biosolids Application Rate that in this study represented an N application rate equivalent to 180 kg mineral N/ha: 14 t/ha for aerobic biosolids and 20 t/ha for anaerobic biosolids. Each of the experimental plots had a size of 1m x 2m, with 1 m gap between the experimental plots.

In late November 2002, the two biosolids were applied and incorporated into the top 100 mm soil. Seven weeks later, plant maize (variety C79) was planted at 1 row/m and was thinned to 7 plant/plot in a few weeks. Due to the serious drought experienced in the experimental area, the plots were irrigated at a rate equivalent to 50 mm rainfall after planting. One week later, 25 mm water was spayed to compensate the water loss due to the high evaporation rate in the field and no more irrigation was given thereafter.

Soil samples were collected 3, 6 and 15 weeks (0-100, 100-200 and 200-300 mm), and 28 weeks (0-100, 100-200, 200-300, 300-600, 600-900 and 900-1200 mm) after biosolids application. Soil samples were used for analysis of ammonium and nitrate after extracted using 2M KCl solution. Maximum biomass and grain samples were collected 3.5 months and 5 months after planting and the collected plant samples were oven dried at 55 ^{o}C. Ground plant samples were chemically analysed to determine the nutrient content.

Results and discussion

Maximum biomass production and grain yields

Maximum biomass production and grain yields were significantly higher from the biosolids treated plots (14.2-14.9 t/ha for maximum biomass and 8.3-8.9 t/ha for grain yields) than from the unfertilised and fertilised plots (10.6-12.6 t/ha for maximum biomass and 6.8-7.2 t/ha for grain yields) (Figure 1), attributed to the extra N added, and possibly the added phosphorous and other nutrients in the applied biosolids. No difference was found between the plots treated with different biosolids for both the maximum biomass production and grain yields. It was also observed that application of both biosolids had shortened the maize's silking time by about 1 week.

Nitrogen transformation

Six weeks after application, amounts of ammonium N from the biosolids treated plots were 396 kg/ha (anaerobic biosolids) and 460 kg/ha (aerobic biosolids), which accounted for more than 50 % of the applied organic N. The ammonium N then dropped to 40 kg/ka at 15 weeks and to < 20 kg/ha at 28 weeks (Figure 2 (a)). In contrast there was nearly constant level of the ammonium N in the unfertilised plots. The significant drop in ammonium N levels must have been caused by the volatilisation of ammonium N, as shown by Robinson and Roper (2003). They reported a 44-55 % volatilisation loss of the ammonium N applied in biosolids and expected the loss would have been higher if it had been warmer, drier and windier. Preliminary results from our other trials using different soil types and different crops indicated that up to 40-50 % N applied in biosolids was lost, due to volatilisation and/or denitrification (unpublished data).

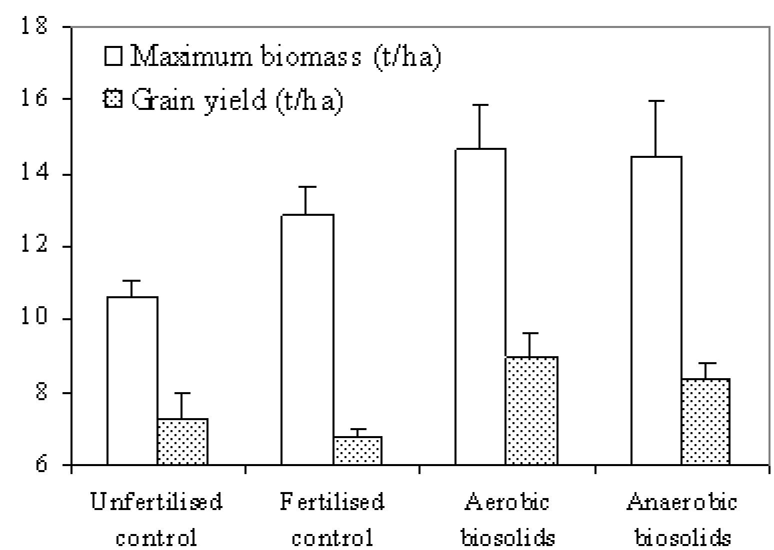

Figure 1. Maximum biomass production and maize grain yields as affected by the application of different biosolids at the Nitrogen Limited Biosolids Application Rate to a red ferrosol soil in subtropical Australia (the "T"s above the bars represent the standard errors of 3 replications)

(a)

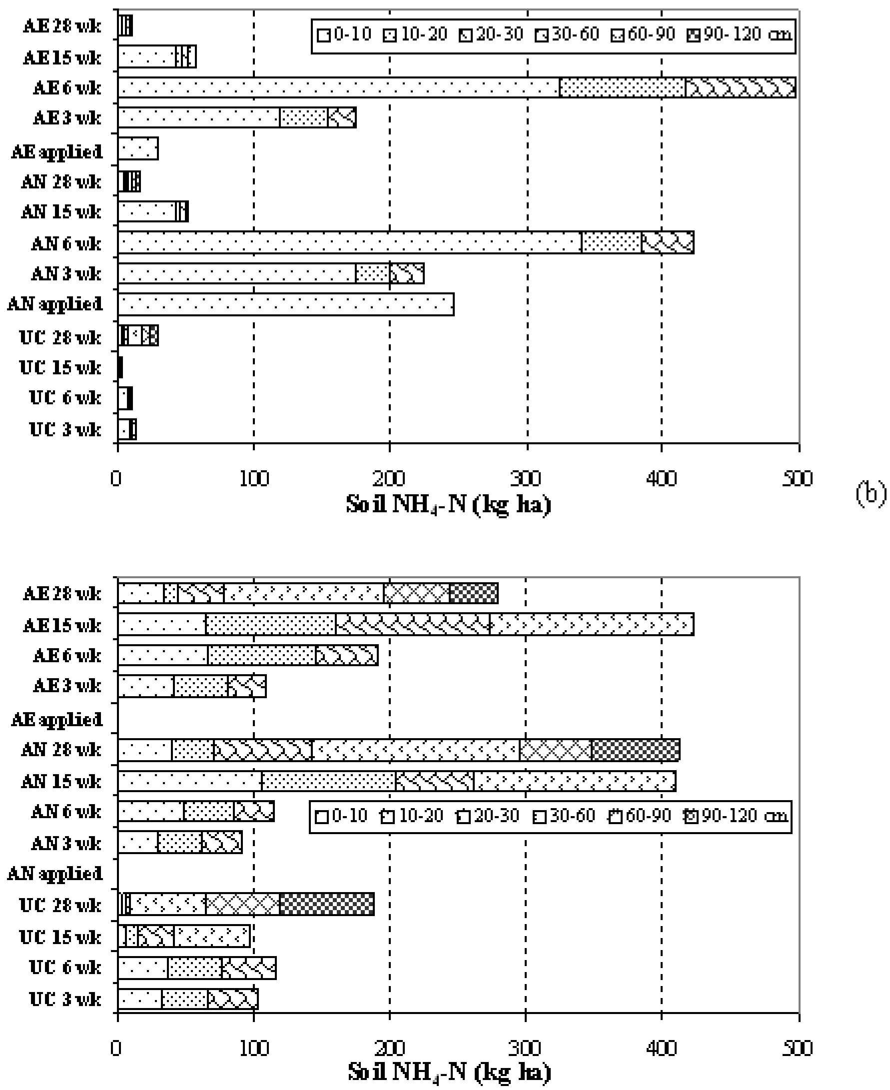

Figure 2. Ammonium nitrogen (a) and nitrate nitrogen (b) levels in the soil profile at different periods (3, 6, 15 and 28 weeks) after biosolids application at the Nitrogen Limited Biosolids Application Rate in subtropical Australia. UC: unfertilised control, AE: aerobic biosolids and AN: anaerobic biosolids.

Soil nitrate N in the top 300 mm soil was similar in the unfertilised (105 kg/ha) and in the anaerobic biosolids treated plots (120 kg/ha) in the first six weeks under the very dry conditions in the field (Figure 2 (b)). Higher nitrate N (170 kg/ha) was found from the aerobic biosolids treated plots, due probably to that the much higher water content found in the aerobic biosolids than in the anaerobic biosolids which could encourage the N mineralisation. Nine weeks late, nitrate N in the top 300 mm soil increased significantly for all biosolids treated plots (160-250 kg/ha). However, in the unfertilised plots nitrate N was nearly depleted (<30 kg/ha). Twenty-eight weeks after application, most mineralised N sourced from biosolids remained in the top 600 mm soil and there was no evidence that the mineralised N was leached below the 1200 mm soil profile. Much higher nitrate N was found in the anaerobic biosolids treated plots (250 kg/ha) than in the aerobic biosolids treated plots (160 kg/ha), suggesting that more ammonium N formed in the first 6 weeks could have been lost in the aerobic than in the anaerobic biosolids treated plots.

Our calculation showed that 21 % (aerobic) and 33 % (anaerobic) of the applied organic N were mineralised (either remained in the top 1200 mm soil profile or was picked up by plant) (Table 2).

However, the actual mineralisation rate could be much higher, considering that significant proportion of the formed ammonium N in the first 6 weeks could have been lost through volatilisation. Denitrification loss should be much less significant due to the well-drained soil used.

Table 2. Applied N, plant uptake N and soil mineral N in the soil profile (0-1200 mm) 28 weeks after biosolids application to a red ferrosol soil in subtropical Australia

	N applied to soil			Soil mineral N 28 weeks after application		Plant N uptake	Mineralised N recovered in plant and soil % applied organic N
	NH_4-N	NO_3-N	Organic N	NH_4-N	NO_3-N	-	
	kg N/ha						
Unfertilised control	-	-	-	30.0	187.6	127.4	-
Fertilised control	64.6 kgN, 16.6 kgP, 1.6 kg/ha			15.0	237.6	154.1	-
Aerobic biosolids	30.0	0.3	632.1	10.9	278.8	186.3	20.7
Anaerobic biosolids	282.1	1.1	729.6	16.5	412.5	178.9	30.3

Conclusions

Application of both aerobically and anaerobically digested biosolids increased both maximum biomass production and grain yields. More than half of the applied organic N sourced from both biosolids was transformed into ammonium N within six weeks and significant proportion of such formed ammonium N could be lost through volatilisation. The real mineralisation rate could be much higher, considering that significant proportion of the formed ammonium N would have been lost.

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