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Nitrogen leaching from the root zone of sugarcane and bananas in the humid tropics of Australia

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ABSTRACT

Loss of nitrogen in deep drainage from agriculture is an important issue for environmental and economic reasons, but limited field data is available for tropical crops. In this study, nitrogen (N) loads leaving the root zone of two major humid tropical crops in Australia, sugarcane and bananas, were measured. The two field sites, 57 km apart, had a similar soil type (a well drained Dermosol) and rainfall (~2700 mm year^{-1}) but contrasting crops and management. A sugarcane crop in a commercial field received 136–148 kg N ha^{-1} year^{-1} applied in one application each year and was monitored for 3 years (first to third ratoon crops). N treatments of 0–600 kg ha^{-1} year^{-1} were applied to a plant and following ratoon crop of bananas. N was applied as urea throughout the growing season in irrigation water through mini-sprinklers. Low-suction lysimeters were installed at a depth of 1 m under both crops to monitor loads of N in deep drainage. Drainage at 1 m depth in the sugarcane crops was 22–37% of rainfall. Under bananas, drainage in the row was 65% of rainfall plus irrigation for the plant crop, and 37% for the ratoon. Nitrogen leaching loads were low under sugarcane (<1–9 kg ha^{-1} year^{-1}) possibly reflecting the N fertiliser applications being reasonably matched to crop requirements and at least 26 days between fertiliser application and deep drainage. Under bananas, there were large loads of N in deep drainage when N application rates were in excess of plant demand, even when applied fortnightly. The deep drainage loss of N attributable to N fertiliser, calculated by subtracting the loss from unfertilised plots, was 246 and 641 kg ha^{-1} over 2 crop cycles, which was equivalent to 37 and 63% of the fertiliser application for treatments receiving 710 and 1065 kg ha^{-1}, respectively. Those rates of fertiliser application resulted in soil acidification to a depth of 0.6 m by as much as 0.6 of a unit at 0.1–0.2 m depth. The higher leaching losses from bananas indicated that they should be a priority for improved N management.

1. Introduction

As agriculture expands and intensifies across the globe, and particularly in the tropics, it is becoming increasingly important that fertilisers be used efficiently (Drigo, 2005; Wadley et al., 2006). Insufficient or excessive use of fertilisers decreases profitability and can degrade health of the soil and surrounding environment. Excessive use of nitrogen fertilisers can lead to soil acidification (Helyar and Porter, 1989) and loss of nitrate by leaching to groundwater and hence surface water, particularly in humid environments (Aulakh and Malhi, 2005). Fertiliser rate trials are the first step in determining economic optimum application rates. While many fertiliser rate trials have been carried out, they continue to be necessary as combinations of crop type and environment evolve. However, from an environmental perspective, even more important is quantification of nutrient losses. For nitrogen fertilisers in humid environments, the main loss pathway is nitrate in deep drainage (e.g. Banabas et al., 2008; Moody et al., 1996). However, there is limited information on leaching loss of nitrogen under different cropping practices in the humid tropics, particularly over multiple years.

In the humid tropics of northeast Australia, agriculture is the dominant land use on non-mountainous areas, and loss of nutrients is of particular concern as these areas drain into the aquatic and marine ecosystem of the World Heritage-listed Great Barrier Reef and its catchments (Brodie et al., 2008). Sugarcane (193,600 ha) and bananas (11,100 ha) are the major intensive crops in the Wet Tropics Bioregion, which has an average annual rainfall of 1850 mm (McDonald and Weston, 2004). Both crops are reliant on fertiliser N with current mean annual rates of 138 kg ha^{-1} for sugarcane

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Table 1
Some soil properties for the sugarcane and banana sites.

Depth (m)	pH (1:5 water, 4A1)[a]	OC (%, 6A1)[a]	ECEC ($cmol_c\ kg^{-1}$, 15J1)[a]	CS (%)	FS (%)	Silt (%)	Clay (%)
Sugarcane							
0–0.1	5.5	0.9	2.7	2	23	32	43
0.1–0.2	5.5	0.7	2.3	2	24	30	44
0.2–0.3	5.8	0.4	2.0	2	23	32	43
0.3–0.6	5.2	0.3	1.4	2	32	28	39
Banana							
0–0.1	5.6	1.72	9.7	3	32	25	40
0.1–0.2	5.6	1.74	9.0	1	33	26	40
0.2–0.3	5.6	1.80	8.8	1	33	23	43
0.3–0.6	4.9	1.10	3.5	<1	26	33	41

[a] Method codes for Rayment and Higginson (1992); OC, organic carbon (Walkley and Black); ECEC, effective cation exchange capacity; CS, coarse sand; FS, fine sand.

and 310 kg ha^{-1} for bananas in this region (Incitec Pivot Ltd., pers comm.; S. Lindsay pers comm.). The average annual N application in the banana industry was 520 kg^{-1} ha^{-1} in 1995, at which time no replicated N fertiliser trials had been conducted on bananas in Australia (Daniells, 1995). However, high concentrations and loads of N from sugarcane and banana production have been reported in streams and groundwater in the Johnstone and Tully River catchments within the Australian humid tropics (Armour et al., 2009; Hunter and Walton, 2008; Rasiah et al., 2005, 2010; Thorburn et al., 2003).

Losses of N by deep drainage, which depend mostly on hydrology and fertiliser practice, have been measured by lysimeters, both disturbed and undisturbed, or estimated using models calculating hydrology and N movement (e.g. Goss and Ehlers, 2009; Thorburn et al., 2005, 2011). Under sugarcane, losses of nitrate to groundwater have ranged from <1 to 70 kg N ha^{-1} crop^{-1} in Australia, Brazil and Mauritius (Ng Kee Kwong and Deville, 1984; Bohl et al., 2001; de Oliveira et al., 2002; Gihberto et al., 2009; Rasiah et al., 2005, 2010; Thorburn et al., 2011; Webster et al., 2012). Under bananas, deep drainage is particularly variable spatially and temporally because of redistribution of rainfall by the canopy, especially re-direction into stem flow. Under the banana stem, drainage can be 6–24 times higher than in areas such as in the row away from the stem, and in the inter-row (Cattan et al., 2007; Sansoulet et al., 2008). Furthermore, stemflow as a proportion of rainfall changes as the plants develop (Sansoulet et al., 2007). Loads of N in deep drainage under bananas ranged from 116 kg N ha^{-1} in 14 months (306 kg N ha^{-1} applied, Wakelin et al., 2011) to ~210 kg ha^{-1} year^{-1} (~420 kg N ha^{-1} applied, Muñoz-Carpena et al., 2002). Thus losses of N from the root zone have a large range in sugarcane but are high in bananas.

The aim of the work reported here was to quantify the leaching losses of N from a range of fertiliser practices over several seasons in sugarcane and bananas in the humid tropics of Australia. This was the first replicated N fertiliser experiment on bananas in the Australian humid tropics.

2. Methods

2.1. Commercial sugarcane site (Gordonvale)

2.1.1. Location and crop management

Losses of N in deep drainage were measured in a commercial field from 2007 to 2010. The study site (Fig. 1) has a humid tropical climate with an average annual rainfall at the nearby Mulgrave Sugar Mill of 1958 mm. Most rain falls in a distinct wet season between December and May. The soil type is an Acidic, Dystrophic, Brown Dermosol (Table 1; Isbell, 1996). The sugarcane crop

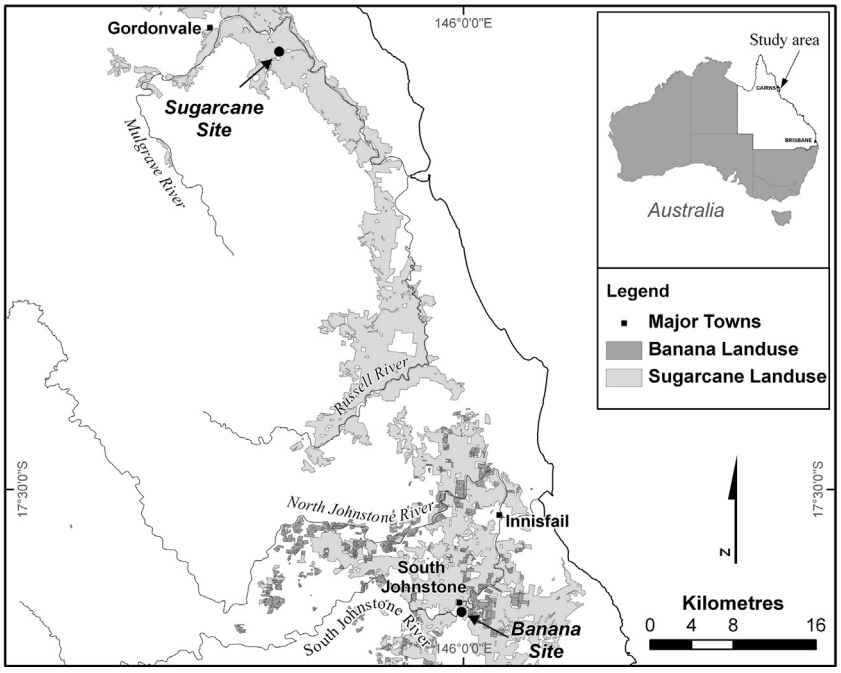

Fig. 1. Site locality map.