

THE IMPACT OF REDUCED NITROGEN FERTILISER APPLICATION RATES ON NITROGEN LOADS TO SURFACE WATER

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KEYWORDS: Nitrogen Replacement, Runoff, Fertiliser, Urea.

Abstract

NITROGEN losses to water from farming systems have the potential to negatively impact human and ecosystem health. Environmental damage to the Great Barrier Reef as a result of extra nitrogen inputs since European settlement is becoming increasingly apparent. Sugarcane is the dominant intensive landuse in Great Barrier Reef catchments, and consequently this industry's nitrogen management practices are coming under increasing scrutiny and pressure to implement nitrogen management practices that reduce losses of nitrogen to the environment. An experiment was conducted in sugarcane on the Wet Tropical coast of Australia to measure nitrogen losses from two different rates of nitrogen fertiliser to surface water. Results show that substantial decreases in nitrogen application rate reduced nitrogen lost to surface water by 34%. Between 10 and 15 kg N/ha/y was lost in runoff water as total nitrogen, which is agronomically insignificant, but aggregated over the whole sugarcane industry, may be detrimental to the health of the Great Barrier Reef. For the sugarcane industry to reduce losses of nitrogen for improved water quality, reducing fertiliser rates is an appropriate management option that can deliver lower nitrogen contributions to downstream ecosystems.

Introduction

Nitrogen is an essential element for plant growth, providing good returns on investment in agricultural cropping systems (FAO, 2006). However, nitrogen can be mobile in the crop-soil system, and has been detected in water downstream of agriculture (e.g. Mitchell *et al.*, 2001).

In Australia, elevated levels of nitrogen, likely to be originating from agricultural fertiliser use, have been detected in the rivers draining to the World Heritage listed Great Barrier Reef (Mitchell *et al.*, 2001; Bramley and Roth, 2002). This extra nitrogen is a cause for concern, possibly causing degradation of the Great Barrier Reef (Brodie *et al.*, 2005); and potentially lowering the reefs resilience to climate change (Wooldridge, 2009).

Sugarcane (*Saccharum* spp.) is by far the dominant cropping landuse in catchments draining to the Great Barrier Reef, occupying c. 380 000 ha (Canegrowers, 2009). In Australia, sugarcane receives annual nitrogen fertiliser applications of 150+ kg nitrogen per hectare (Calcino *et al.*, 2000); however, not all of the applied nitrogen is used by the crop (Thorburn *et al.*, 2003). Australian sugarcane is also grown with high water input from either high rainfall in the wet tropics or in supplementary or full irrigation in drier catchments. The majority of sugarcane grown in Great Barrier Reef catchments is grown on the coastal lowlands, floodplains and deltas close to estuaries,

creeks and river mouths. This proximity to the end of catchments means there are very short residence times for water draining from sugarcane farms to the Great Barrier Reef lagoon, providing little opportunity for in-river processes to remove nitrogen from the flow (Furnas and Mitchell, 2001). This unique combination of high fertiliser nitrogen input, high water input, proximity to the end of catchments and, by virtue of being the dominant landuse, means it is important to manage sugarcane to minimise nitrogen losses from the paddock to protect the sensitive ecosystems of the Great Barrier Reef.

Nitrogen losses from sugarcane production systems to ground water have been extensively investigated (e.g. Ng Kee Kwong and Deville, 1984; Ghiberto *et al.*, 2009; Stewart *et al.*, 2006; Bohl *et al.*, 2000). While nitrogen lost to leaching is an economic imposition on the farm manager, the environmental consequences of this nitrogen on surface water are uncertain (Rasiah *et al.*, 2005). The few studies of nitrogen losses in surface water suggest losses may be small, in the range of a few up to approximately 20 kg N/ha (Ng Kee Kwong *et al.*, 2002; Bengtson *et al.*, 1998) but, given sugarcane's proximity to the Great Barrier Reef, virtually all nitrogen lost in surface water flow from cane lands will enter the reef lagoon (Furnas and Mitchell, 2001). Additionally, when these agronomically small nitrogen losses are aggregated across the entire sugarcane industry, they could be contributing a substantial increase in nitrogen flow to the Great Barrier Reef.

Furthermore, there is little evidence as to what contribution changing management practice may have on reducing nitrogen losses to surface water. For this reason, we measured nitrogen losses to surface water from two application rates of nitrogen fertiliser over two years to determine if nitrogen fertiliser application rate management can be a useful tool for reducing surface water nitrogen losses and ultimately benefit the Great Barrier Reef.

Materials and methods

Data were obtained from an experimental site in the Saltwater Creek catchment, in the Mossman district of north Queensland (approximately 16°S, 145°E). This district is in the wet tropics bioregion and receives an average annual rainfall of 2018 mm/year (Bureau of Meteorology, 2009); however, the experimental site receives on average approximately 750 mm more per annum according to the farmer (S. McDonald, *pers. comm.*). The experimental site has a well drained soil formed on alluvium, described as dark greyish brown silty clay loam A horizon and yellowish brown silty clay loam to light clay B horizon with moderate fine blocky structure (Murtha 1994). Soil organic carbon is 1.2% in the top 20 cm.

The site has been growing sugarcane continuously since the mid 1970s, with the sugarcane stool being ploughed out, the block cultivated and replanted to sugarcane in the same year every four to six years. The site has been harvested green with the residue retained since the early 1980s. The site was last planted in August 2000 with the cultivar Q174^(b) and has been harvested in September of each subsequent year (achieving 64 tonnes/ha in 2001, 103 tonnes/ha in 2002, and 89 tonnes/ha in 2003).

The experimental program was initiated after the 2003 harvest (4th September 2003) with the site divided into six plots, each 13 rows wide (at 1.57 metre row spacing), a row length of approximately 175 metres, and a single row between each plot. One of two nitrogen rates was randomly assigned to plots, being either a) the normal nitrogen rate the farmer applies (N_{farm}), equalling 186 kg N/ha and b) a nitrogen rate based on replacing the nitrogen exported in the previous crop (N_{repl}), using a multiplier of yield in tonnes/ha (based on Thorburn *et al.*, 2004), equalling 102 kg N/ha (a multiplier of yield in tonnes multiplied by 1.15 to determine rate in kg N/ha was used). All fertiliser was applied as urea on the surface trash on 28th October 2003.

On 28th and 29th October 2003, two of the plots (one from each treatment) were instrumented to record water runoff volume and automatically sample runoff water during events. Each plot had a 9 inch Parshall flume (extended to capture runoff from 11 rows) equipped with a

monitoring station including an ISCO automatic water sampler which could collect up to 24 samples and store at 4°C prior to collection, a stage recorder located in a stilling well, and a pluviometer. The stage recorders, sample data and pluviometer were connected to a Campbell CR10X data logger, linked via telemetry to download hourly for remote monitoring. A ridge ran across the plots, with not all surface water running towards the sampling stations. Each plot was surveyed using total station surveying gear, with the N_{farm} rate draining an area of 3300 m² with a slope of 0.65%, and the N_{repl} rate draining an area of 2600 m² and a slope of 0.33%.

Over the 2003/04 wet season, water samples were collected after each triggered sampling event and retained frozen before being transported and analysed for total nitrogen.

During events, the Parshall flume stage height was recorded every minute, with stage height being converted to discharge for all of the stage data recorded over the six month wet season. Some corrections were necessary to the raw stage data when there was ponding of water in the base of flumes after small rainfall events. Flow weighted TN was calculated for each monitored event.

Results

The 2003/04 wet season's first runoff event was in the beginning of December 2003, and there were 20 monitored events through to the end of May 2004 (Figure 1). A total of 2868 mm of rain was recorded during this period (Figure 1). There were two distinct periods of heavy rainfall during the 2003/04 season, with 492 mm falling between 29th February 2004 and 3rd March 2004 and 465 mm falling on the 18th and 19th of March 2004. Flood events occurred during these two events where runoff water below the flume backed up into the flume, meaning accurate measurement of runoff discharge was not possible. Estimates of runoff discharge during these periods were made.

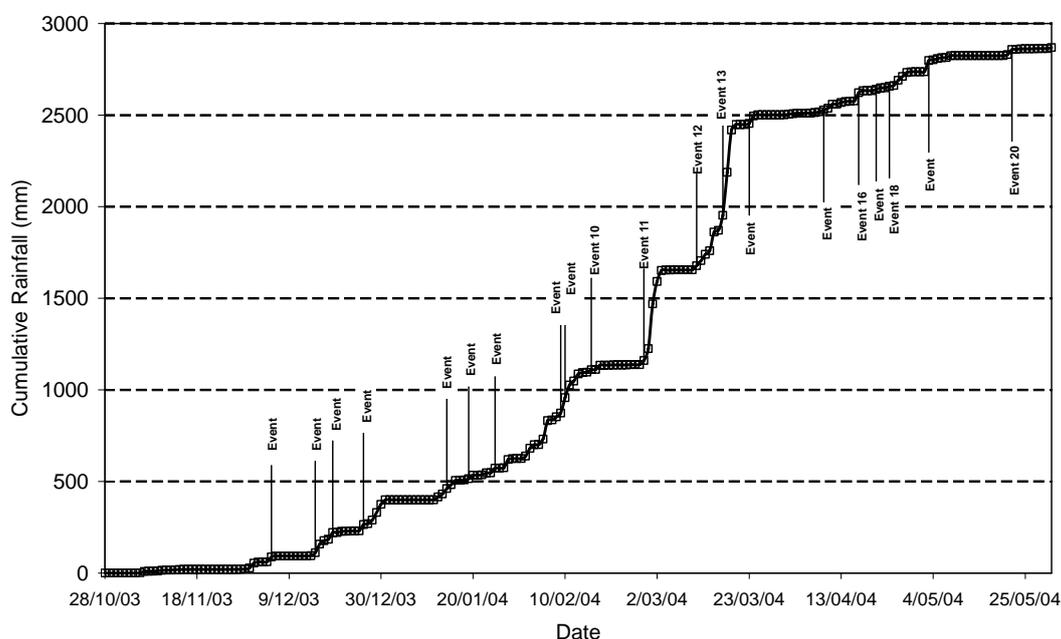


Fig. 1—Daily cumulative rainfall and monitored event times for the monitoring period during the 2003/04 wet season for Saltwater Creek experimental site.

Runoff coefficients varied between the events from 1 up to 76% of rainfall being monitored as runoff water. The total runoff coefficients for the two plots had a high level of agreement, with 23.9% for the N_{farm} plot and 24.9% for the N_{repl} plot.

The calculated event mean concentrations for the first events were the highest for the year (9.75 mg/L in the N_{farm} treatment and 3.87 mg/L in the N_{repl} treatment). Both treatments showed a steady decline in event mean concentration after the first event down to 0.93 mg/L in the N_{farm} treatment and 0.42 mg/L in the N_{repl} treatment. Calculated N loads (kg/ha) for total nitrogen delivery to surface water are presented in Table 1. TN loads are highest in the high runoff events, even though they have lower event mean concentrations.

Table 1—Loads of total nitrogen (TN) lost to surface water for all monitored events in the 2003/04 wet season from two rates of nitrogen fertiliser application.

Event	Event load (TN kg/ha)	
	N_{repl} (102 kg N/ha)	N_{farm} (186 kg N/ha)
1	0.05	0.13
2	0.40	1.00
3	0.22	0.77
4	1.88	1.95
5	0.33	0.47
6	0.11	0.18
7	2.30	3.24
8	0.07	0.13
9	0.78	1.03
10	0.06	0.07
11	2.14	2.51
12	0.28	0.33
13	1.25	2.86
14	0.01	0.03
15	0.05	0.11
16	0.05	0.10
17	0.03	0.06
18	0.04	0.09
19	0.03	0.07
20	0.03	0.08
Total	10.11	15.22

There was no significant difference between the two fertiliser treatments in yield (average 74 tonnes/ha), the amount of nitrogen in the above ground biomass (73 kg N/ha) or the amount of nitrogen exported from the plots (48 kg N/ha). There was, however, a significantly lower surplus (fertiliser nitrogen minus exported nitrogen) with the N_{farm} treatment having a surplus of 136 kg N/ha and N_{repl} a surplus of 57 kg N/ha.

Discussion

The most important finding in this paper is the confirmation that nitrogen losses from sugarcane to surface water can be reduced by lowering the nitrogen fertiliser application rate. Importantly, in these trials, the nitrogen fertiliser application rate was not too low to negatively impact on cane yield. Losses of total nitrogen to surface water from a sugarcane production system were reduced approximately 33% when fertiliser application rate was reduced from the growers normal rate of 186 kg N/ha to a nitrogen replacement rate of 102 kg N/ha.

The recorded total nitrogen losses to surface water over the 2003/04 wet season were 15 kg/ha when the N_{farm} application rate was used and 10 kg/ha with the N_{repl} application rate. These losses of nitrogen to surface water seem to be small (8 to 10% of applied nitrogen), and would not cause any significant agronomic impact, reflecting the findings of Ng Kee Kwong *et al.* (2002), who measured small losses of nitrogen to surface water and described the losses they found as ‘agronomically insignificant’. While this may be so, this contribution of nitrogen from sugarcane production to surface water may be contributing to the degradation of the Great Barrier Reef when

aggregated over the entire Australian sugarcane industry. Given the importance of nitrogen in surface water in Great Barrier Reef catchments, the 33% reductions reported here from lowering the nitrogen application rate could be highly environmentally significant.

There was a 38 day time lag between fertilisation date and the first event, probably allowing sufficient time for the urea fertiliser to hydrolyse and be immobilised into the soil organic matter. The first event did have the highest event mean concentration of total nitrogen, and this concentration reduced through the season.

Walton *et al.* (2000) investigated using tracer (KBr) losses to determine loss processes from sugarcane (KBr acts in a similar way to nitrate in water). Their study used rainfall simulation equipment, with simulated rainfall applied as soon as practical after tracer application. They reported high losses of the tracer and concluded nitrate losses from sugarcane to surface water could be significant. Comparing the results of Walton *et al.* (2000) with Ng Kee Kwong *et al.* (2002) and the results presented here suggests the time lag between fertiliser application and the first runoff event is a major determinant of the total nitrogen loss potential from sugarcane. This is consistent with the review of Daniels *et al.* (1998), who stated the amount, intensity and timing of the first runoff event after chemical application is the important determinant of losses.

In conclusion, we have shown that lowering N application rates will reduce N losses from sugarcane to the environment. Currently, losses of nitrogen in Great Barrier Reef catchments are too high (Brodie and Mitchell, 2005), and this study shows conclusively lower nitrogen fertiliser application rates will reduce the nitrogen load from sugarcane production systems to the Great Barrier Reef. The nitrogen replacement method (Thorburn *et al.*, 2004) of determining nitrogen application rate is appropriate for determining lower application rates that achieve the dual goals of maintaining yield and benefiting downstream ecosystems.

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L'IMPACT DE DOSES REDUITES D'ENGRAIS D'AZOTE SUR LES TENEURS EN AZOTE DES EAUX DE SURFACE

Par

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**MOTS-CLÉS: Substitution d'Azote,
Ruissellement, Engrais, Urée.**

Résumé

LES PERTES d'azote des systèmes de culture dans l'eau ont potentiellement un impact négatif sur la santé de l'homme et l'écosystème. Les dommages environnementaux sur les récifs de la Grande barrière dus aux apports supplémentaires d'azote consécutif à l'établissement des européens devient de plus en plus apparent. La canne à sucre est culture intensive dominante autour des captages de la grande barrière, et par conséquent les pratiques de gestion azotée de cette industrie sont de plus en plus examinées minutieusement et pressées d'établir des pratiques de gestion azotée qui réduisent les pertes en azote vers l'environnement extérieur. Un essai a été mené en canne à sucre sur la côte tropicale humide de l'Australie afin de déterminer les pertes d'azote vers les eaux de surface causées par deux apports différents d'engrais d'azoté. Les résultats montrent que les diminutions substantielles d'apports d'engrais azoté ont réduit de 34 % les pertes d'azote vers les eaux de surface. Entre 10 et 15 kilogrammes N/ha/an sont perdus par ruissellement, ce qui est agronomiquement insignifiant. Cependant, agrégés au niveau de l'industrie sucrière, ces pertes peuvent être nuisible à la santé de Grande Barrière. La diminution des apports d'azote est une stratégie appropriée qui peut améliorer la qualité de l'eau et entraîner des charges inférieures d'azote vers les écosystèmes en aval.

**EL IMPACTO DE LAS DOSIS REDUCIDA DE NITRÓGENO DE FERTILIZANTES EN
LOS NIVELES DE NITRÓGENO EN LAS AGUAS SUPERFICIALES**

Par

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Escorrentía, Abonos, Urea.****Resumen**

LA PÉRDIDA de nitrógeno desde los sistemas agrícolas hacia el agua tiene potencial para impactar negativamente sobre la salud humana y los ecosistemas. Daños ambientales en la Gran barrera de coral como resultado de las aportaciones de nitrógeno extra desde la colonización europea se está convirtiendo cada vez más evidente. La caña de azúcar es el intensivo uso de la tierra dominante en la Gran Barrera de Coral de las cuencas, y en consecuencia de este sector las prácticas de manejo de nitrógeno se encuentran bajo escrutinio cada vez mayor y la presión para implementar prácticas de manejo del nitrógeno, que reducir las pérdidas de nitrógeno al medio ambiente. Se realizó un experimento en la caña de azúcar en la costa tropical húmedo de Australia para medir las pérdidas de nitrógeno a partir de dos tipos diferentes de fertilizantes de nitrógeno a las aguas superficiales. Los resultados muestran que un descenso sustancial en la tasa de aplicación de nitrógeno reducido nitrógeno perdido en las aguas superficiales un 34%. Entre 10 y 15 kg N / ha / año se perdió en las aguas de escorrentía como nitrógeno total, que es insignificante punto de vista agronómico, sino agregados sobre la industria de la caña de azúcar entera, puede ser perjudicial para la salud de la Gran Barrera de Coral. Para la industria de la caña de azúcar para reducir las pérdidas de nitrógeno para mejorar la calidad del agua, la reducción de las tasas de abono es una opción de gestión apropiadas que pueden entregar las contribuciones más bajas de nitrógeno a los ecosistemas aguas abajo.