

Assessing controlled release and deep placement N fertilizer technologies in subtropical sugarcane

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Abstract

Maintaining adequate nitrogen (N) nutrition in sugarcane requires matching supply with demand. The NSW sugarcane system predominantly grows sugarcane over 2 years, with fertiliser N supplied within a couple of months after planting cane or harvesting the previous crop and ratooning. We evaluated alternate N fertiliser technologies; a) that supply N deeper into the soil profile (ca. 50-200mm) via ultra-high pressure, and b) slow release products. Preliminary results indicate that polymer coated urea is able to lower nitrous oxide (N₂O) emissions during peak events, presumably by limiting mineral N in soil at any given time. This lower soil NO₃⁻ was observed at site 1 in the 2015/16 season only. The N fertiliser based on a modified charcoal pellet gave lower cumulative N₂O emissions than farmer practice urea (matching N rate) at only one of six field sites. The emissions of N₂O did not appear to depend upon the dose of fertiliser N applied, but were site specific, and highly dependent upon rainfall events.

Key Words

Nitrous oxide, polymer coated urea, charcoal granule, ultra-high pressure injection

Introduction

The NSW sugarcane industry comprises around 35,000 ha of plantation with 15-20,000 ha harvested annually. Over 1.5 million t of sugarcane was crushed in 2014 with a value to the NSW economy of over \$230 million. An estimated 9,000-14,000 t of urea is applied annually to these systems to maintain the high biomass productivity (generally over 100t/ha at harvest). The northern NSW systems overlying acid sulfate soils can be high GHG emitters, with up to 21% of applied N being converted to N₂O (Denmead et al. 2008). Whilst these emissions are clearly not typical, sugarcane soils are often exposed to long periods of wet weather soon after N fertiliser application (typically applied in October) resulting in the exposure of N to both denitrification and physical loss pathways. In a review of N use efficiency in sugarcane, Bell et al., (2015) surmise that N use efficiency, especially following high fertiliser application, tends to be poor. By limiting both the quantity and availability of N to these loss pathways, it may be possible to lower the overall emissions of N₂O with the goal of increasing the crop N availability. However, simply lowering inputs of N fertiliser may not achieve a satisfactory outcome for growers, with reduced yield and depletion of soil N stocks by the end of the growing season.

To address this opportunity for limiting the availability of N in period following its application, we evaluated a range of technologies in-field, assessing loss pathways via production of N₂O, and fertiliser N-use efficiency. Ultra-high pressure (UHP) N injection is ideally suited to sugarcane production as it can place the N fertiliser with precision into the crop root zone. This potentially increases crop N uptake and lowers mineral N in soil outside the root zone (which is available to be denitrified). It is also suitable for multiple "split" applications of N throughout the cane growing season. The second N-delivery technique was a new low-cost slow release N fertiliser using modified activated charcoal (see theory in Yao et al., 2015). Like UHP injection, this can be precision applied, the hypothesis being that the slow release characteristics avoid large soil mineral N concentrations in soil, especially shortly after fertiliser application.

Methods

Establishment of field trial in 2014

Six field sites were established in October 2014 in Northern NSW using planted cane (ie paddock coming out of fallow into sugarcane), and ratoon (sugarcane regrowth after harvest). At all sites, two experimental N treatments were applied, matching total N addition with farmer practice urea application (control). Plots were

50m in length and consisted of 3 rows of sugarcane, with the centre row being used for all analyses. In addition, there was an area within each field site where nil N was applied to evaluate background greenhouse gas emissions for Emission Factor (EF) testing. Plots were arranged in a randomised block design with 3 replicates per treatment. Dosage of N onto each site varied from 71 kg N/ ha (planted sugarcane going into an incorporated legume break) to 300 kg N/ ha in ratooned sugarcane. These N doses were based on farmer practice for each site, based on the industries Six Easy Steps guidelines and farmer experience. Fertiliser application technology varied between sites, from incorporation during stool splitting, to surface application, but were consistent with farmer practice at each site. Fertiliser treatments included ultra-high pressure application of urea ammonium nitrate (UAN) using the Aqua-till N injection system set at 25,000 psi injection pressure; and a slow release N fertiliser based on a charcoal matrix developed as part of a DAFF filling the research gap project.

Reapplication of fertiliser in 2015

Two sites were harvested in November 2015, and N was reapplied post-harvest (December) to the ratoon cane. For these two sites, a second generation of the bonded charcoal matrix N fertiliser was utilised, and due to the unavailability of the UHP equipment at the time, we utilised polymer coated urea (PCU). Sites 1 and 2 had 118 and 150 kg N applied/ ha, respectively.

Manufacture of charcoal based N fertiliser

Wheat straw was pre-reacted with phosphoric acid, urea, ferric and ferrous sulfate before being heated to 600°C. The activated charcoal was further reacted with urea and ammonium sulfate at 80-130°C before being pelletised using bentonite as a binder. The pelletised charcoal based fertiliser had an N concentration of 13%, and a total carbon content of 13%. The N was distributed evenly across the surface and within pores of the matrix (Fig 1).

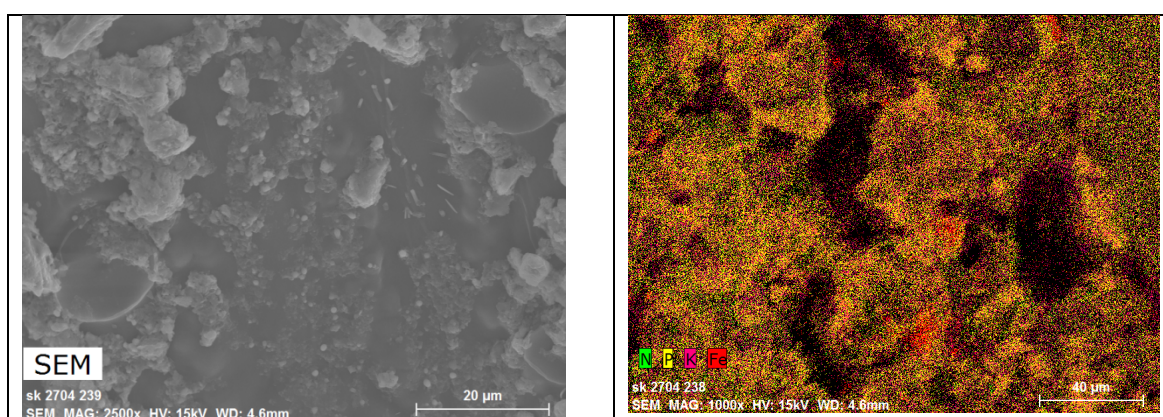


Figure 1. SEM image of the surface of the pellet and an EDS map of the distribution of NPK and Fe on the surface

Soil and greenhouse gas sampling

GHG sampling used a static chamber methodology (Morris et al., 2013) with 3 chambers per row and 2 chambers per furrow per plot. Chambers were closed then sampled immediately and at 60 min exactly. Preliminary testing confirmed N₂O and CO₂ flux was linear for the described incubation period under the conditions experienced in this field trial (data not shown). Soil gas samples were extracted from the chambers and transferred to pre-evacuated 12-mL Exetainer® vials. GHG concentrations were determined using an Agilent 7890A gas chromatograph (Agilent Technologies, Santa Clara, USA) with flux calculations detailed in Van Zwieten et al. (2010). Soil mineral N contents (0-50mm) were evaluated from each plot (on-row) at similar times to the soil GHG sampling using an in-field extraction/ sample preservation methodology.

Results and Discussion

Greenhouse gas emissions (from 27 sampling events) for the first 200 days following application of N fertilizer in 2014/2015 are presented in Table 1. There is clear site-to-site variability in both the amount of fertilizer N applied and the corresponding emissions. Interestingly, while Site 1 had the lowest fertilizer N application dosage, it had the greatest emissions. This is also evidenced from the nil-N control plots (EF

controls). This site had a legume break crop incorporated just prior to planting of cane, supplying a labile C and N supply to the soil. This soil also had the highest soil organic C content (data not shown) and overlies acid sulfate. The responses to the slow release N pellet and also the UHP injection varied between sites, with no clear benefit of either technology, except at Site 5 where significant mitigation was observed. Cumulative emissions across the sampling period consistently showed the effect of N application on N₂O emissions, albeit for Site 6 where N fertiliser gave only very minimal increases in N₂O emissions compared to the control.

Table 1. Cumulative N₂O emissions from the 200 days following N fertilizer application in October 2014. Units are kg N₂O-N/ ha with SEs in parentheses.

| | Site 1 | Site 2 | Site 3 | Site 4 | Site 5 | Site 6 |
|------------------------------|-----------------------------|-------------------------|-------------------------|-----------------------------|----------------------------|-----------------------------|
| <i>Fertiliser N dose</i> | <i>71 kg N/ ha</i> | <i>300 kg N/ ha</i> | <i>150 kg N/ ha</i> | <i>230 kg N/ ha</i> | <i>230 kg N/ ha</i> | <i>155 kg N/ ha</i> |
| <i>Soil and agronomy</i> | <i>Hydrosol, plant cane</i> | <i>Hydrosol, ratoon</i> | <i>Hydrosol, ratoon</i> | <i>Hydrosol, plant cane</i> | <i>Tenosol, plant cane</i> | <i>Dermosol, plant cane</i> |
| *EF Control (nil N) | 42 (17) | 8.0 (11) | 4.3 (3) | 10 (10) | 7.7 (12) | 14 (4) |
| Farmer practice urea | 70 (12) | 17 (9) | 10 (2) | 23 (7) | 60 (8) ^b | 12 (2) ^a |
| Slow Release Charcoal pellet | 88 (12) | 20 (9) | 9.3 (2) | 35 (7) | 37 (8) ^a | 14 (2) ^a |
| UHP injection | 69 (12) | 31 (9) | 12 (2) | 31 (7) | 45 (8) ^a | 29(2) ^b |
| | P=0.2 | P=0.5 | P=0.5 | P=0.2 | P=0.002 | P=0.002 |

For all sites, high soil NO₃⁻ (>50mg/kg) coincided with higher emissions of N₂O. As the crop grew, and N dissipation mechanisms commenced (ie January-March 2015), NO₃⁻ concentrations returned to below 10mg NO₃⁻/kg soil across all treatments; and were indistinguishable from the nil N-control plots. Our work has observed that ground undulation has affected the cutting performance and injection efficiency of the prototype UHP platform as close ground contact is required to avoid dissipation of the water jet. A revised and updated platform has now been installed, incorporating a parallelogram based ground engagement system and leading press-wheel that maintains the cutting nozzle at a constant distance from the soil surface and compresses any loose stubble immediately in front of the cutting stream.

Sites 1 and 2 were harvested as 1-year old sugarcane in September 2015 and no differences were detected in yield between N treatments (using a sub plot harvest method- data not shown). The remaining sites are due for harvest in September 2016 as 2-year cane.

N fertiliser was reapplied at sites 1 and 2 into ratooned sugarcane, and intensive sampling for GHG emissions recommenced over the 2015/16 summer. The flux of N₂O and soil NO₃⁻ concentrations is presented in Figure 2. While we have yet to biometrically analyse the data, it is particularly evident from Site 1 that Polymer Coated Urea does not have the same magnitude of peak emissions as either urea or charcoal N fertiliser. In the second major emissions event at site 1 (end of March 2016) driven by a large rain event commencing on March 1, 2016, PCU had a slightly higher emission than either urea or charcoal N fertiliser suggesting that it maintained a greater total fertiliser applied N content in soil later into the season. This was however not supported by NO₃⁻ analysis from surface soils.

Site 2 had an emission event in January 2016 recording similar fluxes to Site 1, but the second event in March recorded much greater N₂O emissions than Site 1. Interestingly, the March event at Site 2 had a corresponding level of soil nitrate below 0.02 mg/g NO₃⁻, yet maintained a high production of N₂O during the March rainfall event. At this site, as with Site 1, polymer coated urea had lower peak emissions of N₂O. Collection of data will continue until harvest in September 2016, when we will calculate net cumulative emissions and provide statistical inferences.

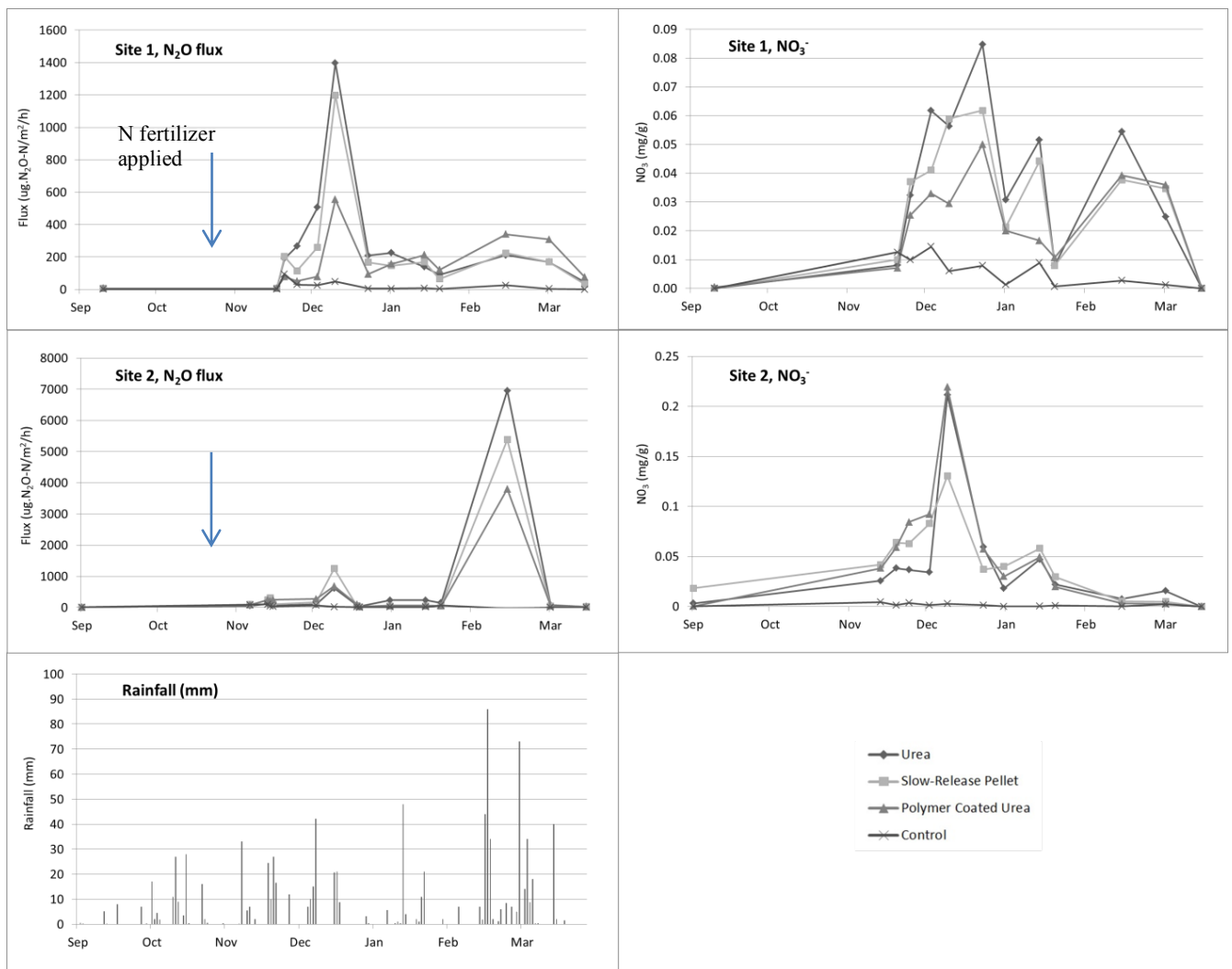


Figure 2. Flux of N₂O from sites 1 and 2, with corresponding soil surface (0-50mm) nitrate concentrations and regional rainfall from summer 2015/16 season. Note averages of 3 site reps (with 5 chambers per rep) are given.

Conclusion

Several novel N fertiliser technologies were applied into sub-tropical sugarcane in northern NSW, with polymer coated urea providing the greatest opportunity for mitigation of soil greenhouse gas emissions, particularly during major events following rainfall. The highest net cumulative emissions were from a sugarcane paddock coming out of a soybean break crop (Site 1) where residues were soil incorporated prior to planting. This site had the lowest fertiliser N dose, but cumulative emissions were much higher than other sites. Clearly the results demonstrate complexity in N cycling, being highly dependent upon the site, previous agronomic practices and weather events. While lower emissions were observed from peak emission events, the assessment of net cumulative emissions generally shows little statistical difference between treatments.

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