Does split-nitrogen application reduce nitrous oxide emissions from irrigated cotton compared with all nitrogen applied pre-season?

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Key findings

- Nitrous oxide (N_2O) emissions at the Gunnedah site were approximately three times higher than at the Emerald site, probably because of the heavier clay soil at Gunnedah.
- High and highly variable N_2O emissions occurred at both sites during the week following the first irrigation event after the pre-planting nitrogen (N) application. There was no significant effect from the amount of N applied at pre-planting on these first emissions, nor overall at Gunnedah. At Emerald, overall N_2O losses were greater from the split N treatment.
- N_2O emissions were low–negligible following the subsequent 4–5 irrigation events, except where N was water-run, which caused small and temporary increases in N_2O.
- The greatest N_2O emission came from the soil above the pre-plant N fertiliser bands. More was emitted from the non-irrigated side of the plant bed, even when both sides of the bed had been fertilised (Emerald).
- Cotton lint yield was not affected by N timing treatment, however, plant biomass was smaller and more N-concentrated from the split N treatment at Gunnedah.
- The 2015–16 weather conditions did not favour either N-timing treatment agronomically or environmentally, but different rainfall patterns in other years may be more influential.

Nutrition and soils

Introduction

Nitrogen fertiliser is a major input required for high-yielding irrigated cotton cropping systems, but its use has environmental consequences in the form of increased soil N_2O emissions. Farmers across the northern Australian irrigated cotton region use a range of N fertiliser application products, application placement and timing strategies to produce high-yielding crops, but the effects of the different strategies on N_2O emissions are not well known. While the in-season N uptake into the cotton plant follows an established pattern of very slow accumulation during the initial two months followed by a period of rapid N uptake, farmers often apply all of the crop's N fertiliser into the soil several weeks to months before planting occurs. In contrast, other farmers apply part of the season's N requirement pre-planting, with the remainder applied in-crop, either by side-dressing, broadcasting ahead of irrigation, or dissolved in the irrigation water used in one or more post-establishment irrigation events.

This paper describes experiments at two locations (Emerald and Gunnedah) that aimed to assess the effect that N fertiliser timing (all applied pre-planting vs pre-planting + in-crop) had on soil N_2O emissions and cotton production.

Site details

Experiment 1. Emerald

Location	'Wills Road', Emerald
Co-operator	Cam Geddes
Soil type	Brown vertosol (clay–loam) with 35% clay, 53% sand, and 11% silt at 0–30 cm soil depth.
Rainfall and irrigation	There was 39 mm of rain during the 75 day pre-planting period between N application and planting, then another 401 mm rainfall during the cropping season from planting to picking. Of this, 335 mm fell in the 45 days before picking. The crop was irrigated nine times, including a pre-planting irrigation on 7 July 2015.

Trial design	Randomised complete block design with three replications of three treatments – only two treatments are discussed in this paper (T1 = split N; T3 = all N applied pre-planting). Each plot was 12 rows, planted on 1 m row spacing, and 1500 m long (paddock length).
Sowing date and variety	10 September 2015. Sicot 75RRF
Harvest (picking) date	3 February 2016

Treatments

Treatment 1 (T1, split N) = 180 kg N/ha pre-planting N applied on 27 June 2015 as urea drilled into both sides of every hill, then three in-crop applications of 20 kg N/ha as UAN applied in the 4th, 5th and 6th irrigations.

Treatment 3 (T3, all pre-planting) = 240 kg N/ha pre-planting N applied on 27 June 2015 as urea drilled into both sides of every hill.

Site details

Trial 2. Gunnedah

Location	'Ruvigne', Gunnedah
Co-operator	Rod Smith
Soil type and nutrition	Black vertosol (medium clay) with 65% clay, 9% sand and 26% silt at a soil depth of 0–30 cm.
Rainfall and irrigation	There was no rainfall during the 15 day pre-planting period between N application and planting, but there was 405 mm rainfall during the cropping season. The crop was irrigated eight times with approximately 7 ML/ha applied in total.
Trial design	Randomised complete block design with three replications of three treatments – only two treatments are discussed in this paper (T1 = split N; T3 = all N applied pre-planting). Each plot was eight rows, planted on 1 m row spacing, and 560 m long (paddock length).
Sowing date and variety	1 October 2015. Sicot 74BRF
Harvest (picking) date	8 May 2016

Treatments

Treatment 1 (T1, split N) = 100 kg N/ha as anhydrous ammonia injected pre-planting on 16 September 2015 into the hill on the non-irrigated side, then two in-crop applications of 40 kg N/ha applied as water-run urea in the second and third irrigations.

Treatment 3 (T3, all pre-planting) = 180 kg N/ha as anhydrous ammonia injected pre-planting on 16 September 2015 into the hill on the non-irrigated side.

Measurements

Nitrous oxide measurements (both sites)

Nitrous oxide emissions were measured during 5–6 separate 7-day campaigns with samples collected 1, 2, 4, and 7 days after early–mid season irrigation events including pre-planting irrigation.

Results from the 2014–15 season indicated negligible N_2O emissions from mid–late season irrigations. Each plot had four chambers: two in the furrows and two on the plant beds. The concentrations of N_2O in air sampled at 0 and 60 minutes after sealing the chamber with a gas-tight lid were determined using a laboratory gas chromatograph. Hourly emission rates were calculated from the increase in N_2O concentration with time over the time of chamber closure, then extrapolated to a daily flux result. Cumulative losses across the 5–6 sampling events were determined by linear extrapolation between sampling days. Days outside the sampling events were not included in the cumulative totals.

Other measurements

Treatment effects on cotton crop production were evaluated by 3 × 1 m length biomass cuts per plot peak biomass, and machine harvesting by commercial cotton picker in the middle six rows of each plot.

Results

Emerald site

The highest daily emissions of the whole season, and most variable, were measured two days after the initial pre-planting irrigation in both treatments. These high fluxes occurred in the non-irrigated hill position (T1 and T3), and in the non-irrigated furrow position (T1 only). The emissions after subsequent irrigation events were smaller and tended to be higher in the non-irrigated hill and furrow positions. Emissions from the irrigated furrows in all treatments were low across the whole season.

The cumulative emission of N_2O during the six sampling events was significantly greater from T1 than from T3 when all sampling events and chamber location results were combined into a total cumulative N_2O loss (122 vs 88 g N_2O-N/ha) (Figure 1). N_2O loss from a 7-day sampling event was greater from T1 during irrigations 4, 5 and 6 when water-run UAN was applied. Sampling position significantly affected net N_2O loss, especially after the first irrigation, with the greatest loss from the non-irrigated side of the hill, then the non-irrigated furrow, then the irrigated hill and irrigated furrow positions.

Results from the hand-cut biomass assessments showed no treatment differences in plant population, boll number, dry matter or dry matter N content. Likewise, there was no N treatment effect on lint yield or seed N content. Overall, the lint yield was down on expectations due to heavy rainfall in the last weeks before picking, with yields averaging 11.0 bales/ha across these two treatments.

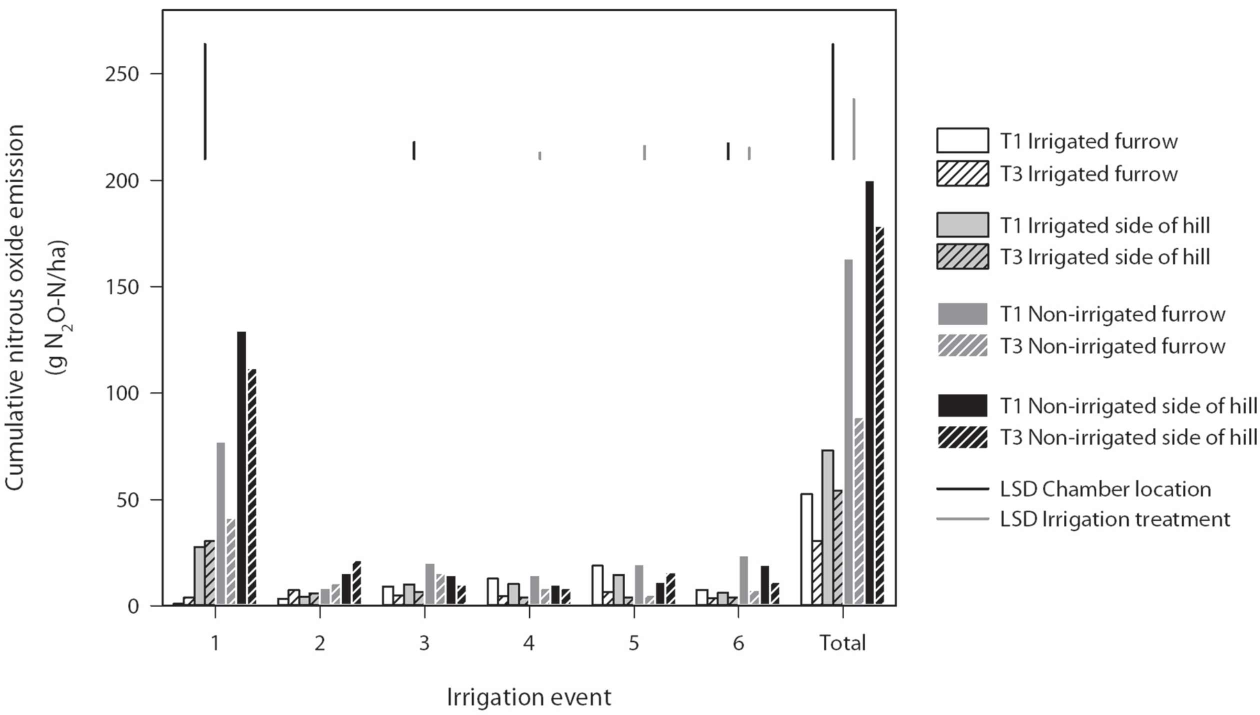

Figure 1. Cumulative nitrous oxide emitted during each 7-day sampling event at the Emerald site as influenced by N treatment and sampling chamber location.

Nutrition and soils

Gunnedah site

High and highly variable N_2O emissions occurred following the first irrigation event, with one chamber in T3 recording a flux of 768 g N_2O-N/ha/d on the first day after irrigation. The highest fluxes were measured in chambers located above the N fertiliser band, while fluxes from the other positions were much lower and not significantly different (Figure 2). The high fluxes from the fertiliser band location decreased after four days but, unlike the other chamber positions, had not yet reached the baseline emission level even after seven days post-irrigation.

In T1, moderate N_2O emissions occurred in response to the water-run urea applied in irrigations 2 and 3. The highest fluxes in T1 were found in the non-fertilised hill position (on the irrigated side). There were negligible N_2O emissions in response to irrigations 4 and 5 (T1), and to irrigations 2–5 for T3. Cumulative emissions across the five sampling occasions showed no significant difference between the N treatments, but the fertilised band position was clearly the greatest overall source of N_2O emitted.

There was no statistical difference in plant population, boll number, biomass N content, commercially-harvested lint yield (14.2 bales/ha) or lint quality attributable to the N treatments. However, there was a significant treatment effect on the maximum plant biomass (dry matter) produced, with plants in T1 smaller than those in T3. There was also a treatment effect on N concentration of the biomass, with T3 (1.75%) statistically less than T1 (1.99%).

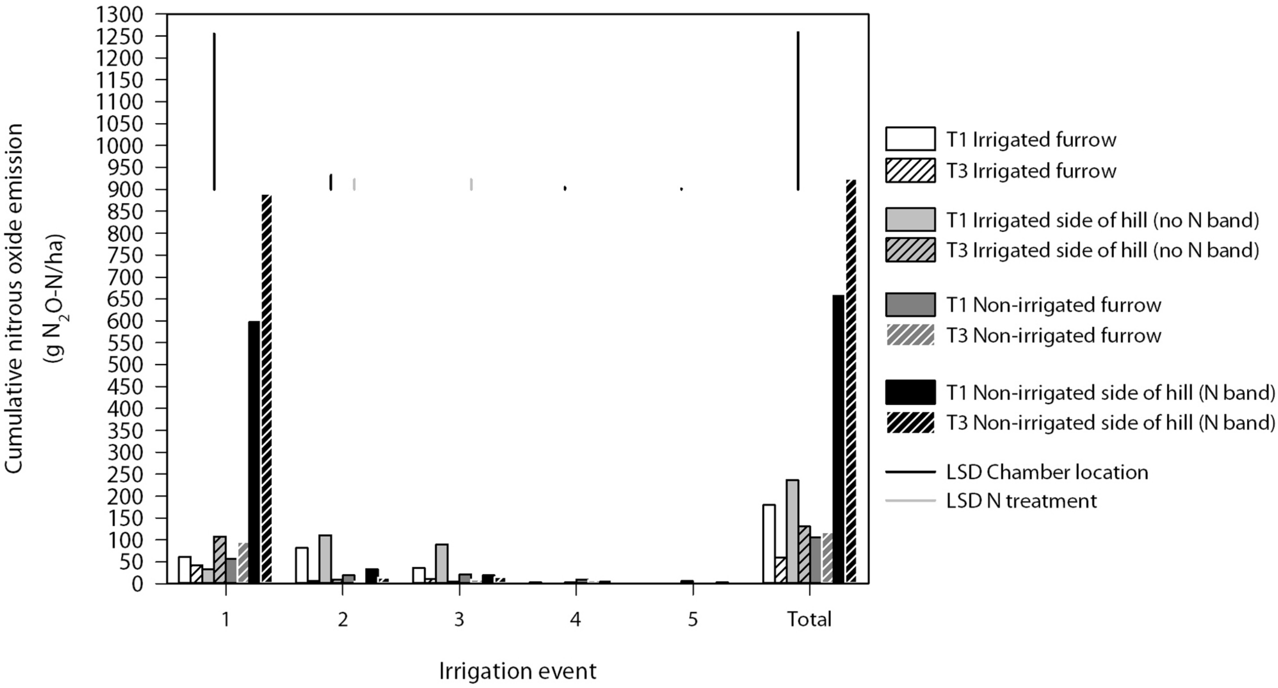

Figure 2. Cumulative nitrous oxide emitted during each 7-day sampling event at the Gunnedah site as influenced by N treatment and sampling chamber location.

Conclusions

Of the five or six week-long sampling campaigns following the early–mid season irrigations, the highest emission losses followed the first irrigation after pre-planting fertiliser had been applied. These high emissions were highly variable at both sites, so there was no statistically significant effect of the rate of pre-planting N applied on the amount of N_2O emitted over the following week. Subsequent irrigation events produced only small–negligible N_2O emissions from T3 where no further N was applied, while emissions in T1 were significantly greater only when N fertiliser was water-run. Total in-crop rainfall was high at both sites, but the majority fell late in the growing season after soil mineral N concentrations were depleted by plant N uptake, so rainfall-induced N_2O losses would have been minimal between irrigation events. At Emerald, total emissions of N_2O summed across the six sampling campaigns, were significantly greater when N applications were split than when applied all at pre-planting, whereas at Gunnedah there was no statistical effect of N application timing.

Nitrous oxide emissions differed hugely depending on sampling position within a plot. At the first irrigation, N_2O losses were highly concentrated from the soil directly above the N fertiliser application band. At Emerald, the N fertiliser was banded on both sides of every plant bed, yet emissions were much greater from the non-irrigated side of the bed than from the irrigated side, which could indicate that nitrate N has concentrated on this side of the plant bed as the irrigation water subbed across to the non-irrigated furrow. This pattern was reversed when water-run N fertiliser was applied, with more N_2O emitted from the irrigated sides of the plant bed at both sites. Initial N_2O losses at Gunnedah were predominantly from above the N banded position on the non-irrigated side of the plant bed. A more detailed 12 chamber sampling exercise (data not shown) found our choice of four chamber positions gave a satisfactory average of the whole plot when combined.

At Gunnedah, the N timing treatments caused significant differences in plant growth and N uptake, but at neither site did N treatment affect cotton lint yield, possibly due to the more-than-adequate N rates used.

From these experiments in this particular season, there was no clear choice of best N timing strategy for greater environmental or agronomic benefit. Years with wetter pre-sowing and early season conditions, such as 2016–17 would likely favour treatment T1 as there is less soil N at risk of loss in the period of up to five months before rapid plant N uptake by the crop.

Acknowledgements

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