

# Alternative N application strategies for reduced N<sub>2</sub>O emissions in flood-furrow irrigated cotton

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## Abstract

The large inputs of N fertiliser needed for high-yielding irrigated cotton can potentially lead to substantial emissions of the greenhouse gas, nitrous oxide (N<sub>2</sub>O). We compared the impact on N<sub>2</sub>O emissions of three alternative strategies for applying the required amount of N to a commercial flood-furrow irrigated cotton crop. Compared to applying all N fertiliser pre-sowing, splitting the application between pre-sowing and in-season applications led to temporal differences in the N<sub>2</sub>O emitted, but there was no cumulative difference over the whole season. Similarly, altering the placement of the pre-sowing N fertiliser band from the non-irrigated side of the hill to the irrigated side of the hill led to a spatial difference in the N<sub>2</sub>O emission pattern, but no cumulative effect was observed. Almost all N<sub>2</sub>O emissions occurred in response to the first three of eight irrigation events, with the emissions after the second and third irrigations only observed where additional N was applied as water-run urea. The mostly low-intensity rainfall during this growing season had little impact on N<sub>2</sub>O emitted. Future research should focus on minimising N<sub>2</sub>O losses from the first irrigation, either through further reducing pre-plant N rates or by using a nitrification inhibitor with the pre-plant N application.

## Key Words

Nitrous oxide, cotton, irrigation

## Introduction

Flood-irrigated cotton systems aim to produce the maximum possible lint yield using applied water and nutrients, particularly nitrogen (N). With average irrigated cotton yields now around 10 bales/ha (Cotton Australia, 2016) and individual paddock yields reaching >15 bales/ha (Roth Rural, 2015), the mean N fertiliser application is now >240 kg N/ha across the industry (Roth Rural, 2014). The use of these high N rates in a flood-furrow irrigation system has the potential for large emissions of the greenhouse gas nitrous oxide (N<sub>2</sub>O) from the soil. Nitrous oxide emissions occur during soil nitrification and denitrification processes, which are governed by soil water content, soil mineral N concentration, labile carbon and temperature.

Flood-furrow irrigation commonly involves running water down every second furrow, with every other furrow wet only by water 'subbing' through the raised soil bed occupied by the cotton plant. With a typical plant-row spacing of 1 metre, this means that there is a 2 metre-wide "repeating unit" within the field. There are a large range in soil water contents and soil mineral N concentrations in various positions across this 2 metre unit. In order to investigate the potential impacts of varying N applications and irrigation strategies on N<sub>2</sub>O emissions, we need to measure gaseous emissions in a manner that captures the range in conditions and likely emissions rates from each plot.

Some 40% of cotton growers have adopted the practice of water-run urea irrigations as a means of adding supplementary fertiliser N to that applied to the soil prior to cropping (Roth Rural, 2014). This brings further variability to the distribution of mineral N, water and aeration conditions within the "repeating unit" that must be captured in sampling to aid understanding of the location, magnitude and duration of N<sub>2</sub>O emissions from the system. We selected 4 key areas within the unit to locate manual chambers for gas measurements.

This paper compares the impact of three N application strategies on the N<sub>2</sub>O emissions during key post-irrigation periods within a commercially managed cotton crop near Gunnedah, northwest NSW, Australia. Higher frequency gas emissions data is also presented to demonstrate the seasonal variation in N<sub>2</sub>O fluxes from two of the three treatments. These results may demonstrate that subtle changes in N application strategies can continue to deliver high yields as well as reduce the environmental impact of the crop.

## Methods

### *Field experiment*

A randomised, replicated field experiment was conducted during the 2015-16 summer within a commercial cotton farm near Gunnedah, New South Wales, Australia. There were 3 treatments and 3 replicates giving 9 plots, each of which was 8 m wide (8 rows of cotton plants at a 1 m row spacing) and 560 m long (paddock length). The treatments used were: (T1) 100 kg N/ha of anhydrous ammonia injected into the non-irrigated side of the hill before sowing plus two applications of 30 kg N/ha as urea applied to the water used for irrigations 2 and 3 (out of a total of 8 irrigations). Treatment 2 (T2) was similar to T1 except the ammonia was injected into the irrigated side of the hill. Treatment 3 (T3) had all fertiliser N for the season applied as ammonia prior to sowing (160 kg N/ha) and none applied as water-run urea. The ammonia for T3 was injected into the non-irrigated side of the hill, as in T1. Ammonia was injected on the 16/9/2015. The cotton crop was sown on 1/10/2015 and harvested on 20/4/2016.

### *Nitrous oxide measurements- semi-auto chambers*

The semi-automated system featured 4 polycarbonate chambers (0.5 m x 0.5 m x 0.15 m) secured to a stainless steel base that was pushed 0.1 m into the soil. At the programmed time of sampling (9 am AEST), the lid of each chamber automatically closed and headspace sampling commenced from each chamber using a pump and a syringe injecting the sampled gas into 12 mL exetainers. Each chamber was sampled 3 times during a closure of 1 h, after which the lids automatically reopened. These chambers were located on planted hills only and included cotton plants. The chamber height was increased to 0.65 m on 11/12/2015 to accommodate growing plants. The 4 chambers sampled 2 reps of treatments T1 and T3 on a bi-weekly frequency from fertiliser application until harvest, with a total of 65 sampling times during the trial. Cumulative N<sub>2</sub>O emissions were calculated by linear interpolation between measurement days, while the N<sub>2</sub>O emission factor was calculated as the proportion of applied N emitted as N<sub>2</sub>O-N over the season.

### *Nitrous oxide measurements- manual chambers*

The manual chamber system consisted of cylindrical chambers of 0.15 m diameter and 0.15 m height that were secured at the time of sampling to a base pushed 0.1 m into the soil. Chambers were located in a mid-field transect across all 9 plots. Each plot had 4 chambers: (1) on the irrigated side of the hill, (2) on the non-irrigated side of the hill, (3) in the irrigated furrow, and (4) in the non-irrigated furrow. Separate sets of measurements from 12 chamber positions across one 'repeating unit' (not shown) found that these 4 positions measured the extremes of N<sub>2</sub>O emissions and gave a representative average of the whole unit. Following the 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup>, 4<sup>th</sup> and 5<sup>th</sup> irrigations, we sampled 1, 2, 4 and 7 days after the end of the irrigation. The 2<sup>nd</sup> and 3<sup>rd</sup> irrigations contained urea at a concentration calculated to provide 30 kg N/ha (T1 and T2, not T3). At each sampling time, starting at 9 am (AEST), chambers were secured to their base and headspace samples (25 mL) were collected immediately, then again after 60 min. Each sample was injected into a pre-vacuumed 12 mL glass exetainers (Labco, UK) for later analysis of N<sub>2</sub>O by gas chromatograph. The difference in N<sub>2</sub>O concentration between the 60 minute sample and the 0 minute sample was divided by the measurement time to give the slope (assuming a linear response). This slope was used to calculate the N<sub>2</sub>O flux using gas flux formulae corrected for air temperature and barometric pressure. The flux rate is presented as g N<sub>2</sub>O-N/ha/d.

### *Other measurements*

Rainfall and temperature at the site were logged hourly using a WM3000 weather station (Envirodata, Australia). Bi-daily barometric pressure data was obtained for Gunnedah from the Bureau of Meteorology.

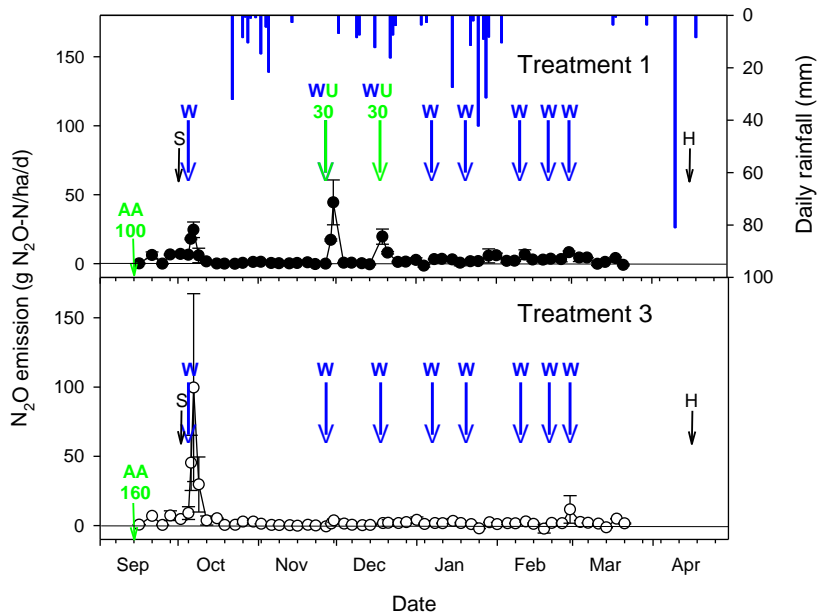
## Results

### *Seasonal N<sub>2</sub>O emissions (semi-auto chambers)*

Regular measurements of N<sub>2</sub>O emitted from the plant beds showed several distinct peaks of emission activity occurring during the season (Figure 1), most in response to the first 3 irrigations. Emissions during the remainder of the season were low to negligible. After the initial injection of anhydrous ammonia, the lack of rainfall kept N<sub>2</sub>O emissions to low levels until directly after the first irrigation, when N<sub>2</sub>O flux increased dramatically in both treatments, with one of the two chambers in T3 recording a peak daily emission of 167 g N<sub>2</sub>O-N/ha/d two days after the irrigation ended.

Emissions quickly subsided in T1 but continued for an additional week in T3, which had the larger initial N rate. Emissions during the remainder of October and most of November were negligible, despite several

rainfall events in this period. The application of additional N fertiliser to T1 as urea in irrigations 2 and 3 led to distinct peaks in N<sub>2</sub>O emission lasting for a week on each occasion. Irrigations 2 and 3 in T3 used water only and caused only a small short-lived increase in emissions. Further N<sub>2</sub>O emissions in response to either rainfall or irrigation water (irrigations 4–8) were subtle from both treatments, although emissions in one of the two chambers in T3 increased to 22 g N<sub>2</sub>O-N/ha/d after the final irrigation, double that recorded in either chamber of T1. There was no significant difference in cumulative N<sub>2</sub>O emissions between these treatments T1 and T3 (mean = 688 g N<sub>2</sub>O-N/ha) or N<sub>2</sub>O emission factor (mean = 0.43%).



**Figure 1. Daily N<sub>2</sub>O emissions, measured bi-weekly, using semi-auto chambers located on hill positions; in relation to irrigation, daily rainfall and N fertiliser addition in treatments 1 and 3. Arrows indicate dates of anhydrous ammonia (AA), sowing (S), water irrigation (W), water-run urea irrigation (WU), and harvest (H).**

#### *Key N<sub>2</sub>O emissions (manual chambers)*

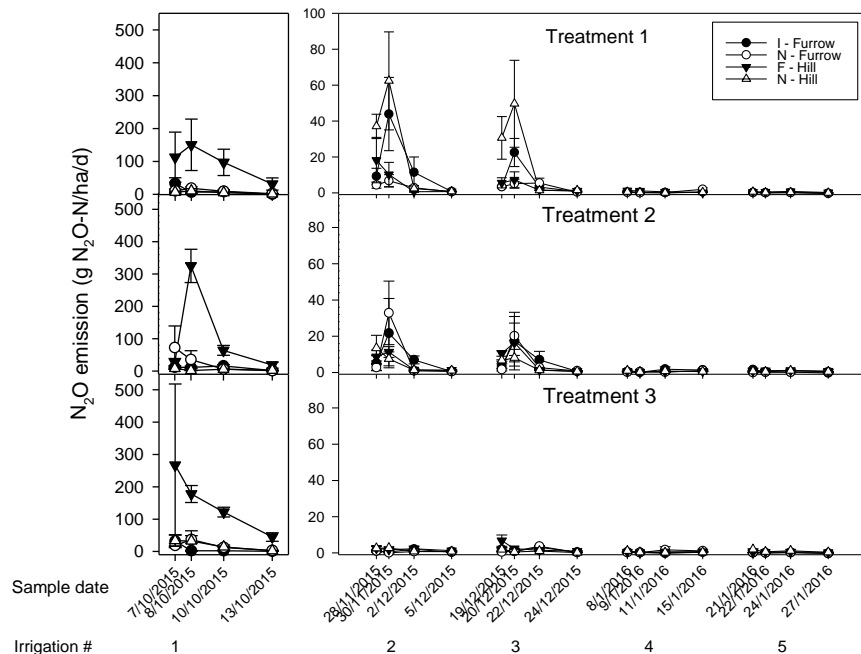
The manual chambers allowed greater detail of the influence of location within the “repeating unit” on N<sub>2</sub>O emitted (Figure 2). Highest emissions occurred following the first irrigation event, with one chamber in T3 recording a flux of 768 g N<sub>2</sub>O-N/ha/d one day after irrigation. This and other high fluxes were measured in chambers located on the fertiliser band, while fluxes from the other positions were much lower and not significantly different. The high fluxes from the fertiliser band location decreased after 4 days, but, unlike the other chamber positions, did not reach the baseline emission level by 7 days after irrigation.

In T1 and T2, moderate N<sub>2</sub>O emissions occurred in response to the water-run urea applications in irrigations 2 and 3. Highest fluxes in T1 were found in the non-fertilised hill position (next to the irrigated furrow). By contrast, fluxes in T2 were not affected by chamber position. There were negligible N<sub>2</sub>O emissions in response to irrigations 4 and 5 (T1 and T2) and irrigations 2–5 for T3. Cumulative emissions across the 5 sampling occasions showed no significant difference between the three treatments, but the fertilised band position was clearly the greatest overall source of N<sub>2</sub>O emitted.

#### **Conclusion**

The current practice of applying the majority of N pre-sowing followed by several in-season applications as water-run urea produces N<sub>2</sub>O emissions lasting up to a week in response to each N application/irrigation event, particularly the first irrigation. The predominantly dry conditions kept N<sub>2</sub>O losses to a minimum between irrigation events, despite occasional rainfall and high concentrations of nitrate in the soil for the first 4 months of the growing season (data not shown). The older practice of applying the whole season’s N pre-sowing focussed N<sub>2</sub>O emissions on just the first irrigation event, with little additional N<sub>2</sub>O lost during subsequent irrigations. Future N<sub>2</sub>O reduction strategies should investigate methods of minimising losses from the first irrigation, either by further reducing pre-plant N rates, or by applying a nitrification inhibitor with the pre-plant N. There was no significant difference between treatments in cumulative N<sub>2</sub>O emitted for the season. Further information on indirect N<sub>2</sub>O emissions from N-laden runoff water would be useful to better define the environmental impact of these alternatives.

Irrigating the furrows close to the fertiliser band rather than those on the other side of the hill from the fertiliser band did increase the initial intensity of N<sub>2</sub>O released after the first irrigation, but there was no net difference in N<sub>2</sub>O emitted. Following the water-run urea applications, N<sub>2</sub>O emissions were greater from the non-fertilised hill of T1 than T2, but were similar elsewhere. Overall, there was no net difference in total N<sub>2</sub>O emitted between the three treatments when losses for the five key irrigation measurement periods were combined.



**Figure 2.** Daily N<sub>2</sub>O emissions during the week after each of the first 5 irrigation events (note difference in scale for irrigation 1). Mean ± standard error shown for each of the 4 positions within a 2 m ‘repeating unit’. Irrigations 2 and 3 in treatments 1 and 2 were water-run urea.

## References

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