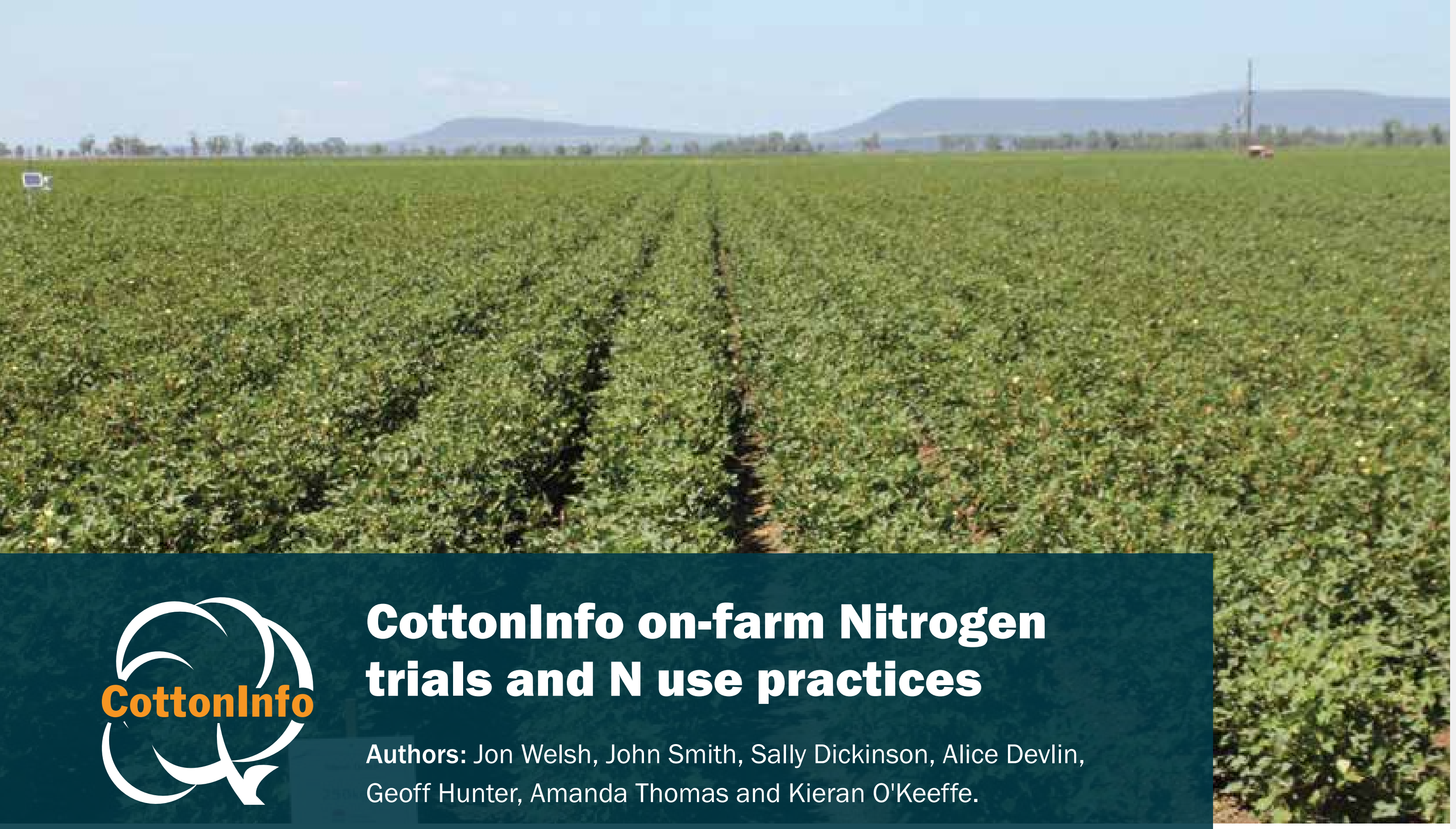
CottonInfo

2017

CottonInfo on-farm Nitrogen trials and N use practices

CottonInfo is a joint initiative of Australian Government Cotton Research and Development Corporation, CSD Cotton Seed Distributors, Cotton Australia

Best Practice



CottonInfo on-farm Nitrogen trials and N use practices

Authors: Jon Welsh, John Smith, Sally Dickinson, Alice Devlin, Geoff Hunter, Amanda Thomas and Kieran O'Keeffe.

Take home messages

Irrigated cotton lint yield response to applied Nitrogen (N) fertiliser has been consistent in on-farm trials across 5 regions in eastern Australia. A summary of key findings;

- Based on the trial results undertaken across a range of industry sites, N rates have been applied in excess of plant requirements necessary to achieve high yields;
- Little or no yield response to applied nitrogen occurred between applied N treatments, timing or application methods, meaning factors other than N from fertiliser influence cotton yield;
- Petiole N testing through the growing season was found to be a useful tool to track apparent soil nitrate-N availability and guide in-crop applications of N during peak demand;
- Petiole testing highlighted similar end-of-season levels regardless of N treatment suggesting significant loss of N from the higher N applications;
- Where a significant amount of nitrogen is drawn from the soil organic N pool, the efficiency of large amounts of applied N is generally poor;
- The zero-N treatments in the Murrumbidgee Valley achieved an impressive 11 b/ha yield with a starting soil N of 164kg N/ha, providing a valuable insight into the contribution of residual soil N and mineralised N at below optimum fertiliser rates; and
- Measured crop removal and post-harvest soil tests at each of the sites also showed a large proportion of total available N was lost or unaccounted for.

Introduction

Nitrogen is the most difficult nutrient to manage in irrigated cotton production; it has more impact on yields, crop maturity and lint quality than any other primary plant nutrient. N can originate from a range of sources; mineralisation, atmospheric fixation and applied N in the form of fertiliser. Nutrient mobility and chemical processes occurring throughout the season can create challenges for farm managers. Further to this, nitrogenous fertiliser use efficiency is becoming increasingly scrutinised by environmental policy makers worldwide. Environmental concerns include nitrate in ground water and run-off, and the production of nitrous oxide – a highly potent greenhouse gas. Major cotton apparel brands and retailers in the textile industry are also encouraging farmers to demonstrate a reduction in the environmental impacts of their management practices and among them, lowering of the carbon footprints of their crops. Life Cycle Assessments has shown fertiliser production and nitrous oxide emissions make up two-thirds of the carbon emissions of cotton fibre at the farm gate. Therefore, identifying ways to improve nitrogen use efficiency and reduce the carbon footprint of cotton fibre helps build sustainability credentials with an increasingly environmentally aware consumer. Industry survey results show that on average cotton growers are using more nitrogen fertiliser than industry best practice recommends. Although Net Present Value (NPV) calculations show granular urea is at historical lows, considerable per hectare savings can still be made by optimising nitrogen rates. Figure 1 shows the cyclical nature of urea prices; where at certain times has achieved NPVs over $1,000/t - compared with current day prices circa $420/t.

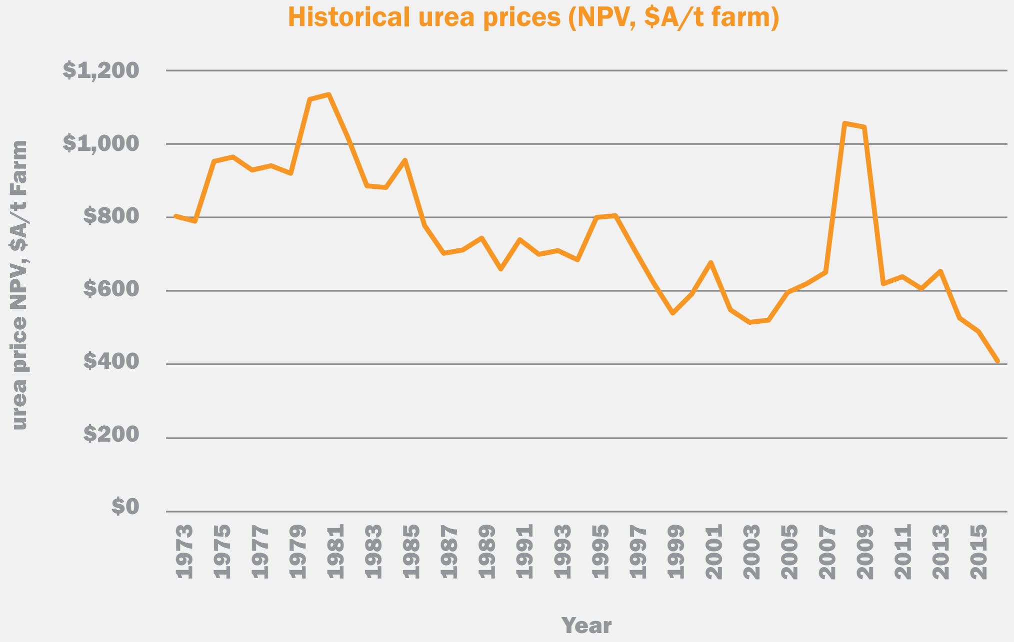


Figure 1 Historical NPV up-country urea price: 1973-2016. Source: ABARE (2016), Powell (2015), Mercardo (2016) and Reserve Bank of Australia (2016)

A doubling of urea prices, similar to the global surge in energy prices in 2008-09 could potentially have detrimental effects on crop gross margins and overall profitability. The CottonInfo regional nitrogen trials aim to work with growers to understand the relationship between N application rate, timing, yield and to demonstrate methods such as petiole testing to improve confidence and better manage this key input.

Results

A summary of the main findings from the 2015-16 season trials in each valley is provided in this section

Macintyre

Sally Dickinson

Trial Design: 3 replications of 4 N fertiliser treatments (36 x 1m x 710m rows).
Two treatments ended up the same because an in-season treatment did not go ahead.

The Macintyre trial found that overall, applied N did not seem to be a limiting factor on any of the treatments. Lower rate treatments maintained lint yield showed very good fertiliser efficiency (24.5 kg lint/ kg applied N). The key things we were exploring were not just about the fertiliser applied but also the role or contribution of mineralisation and the management of losses out of the system. Some losses occur by leaching, however in this field it is unlikely to be deep drainage losses due to the precise irrigation management and freshly lasered fields minimising the watering time for each irrigation and minimising the amount of drainage.

The starting soil N mineral was 74kg N/ha (0-80 cm) and 20 kg/ha of N (starter fertiliser contribution) applied pre-plant. The different rates of N didn't show differences in lint yield but showed that the combination of pre-season and in-crop application can achieve the same outcome, albeit with different fertiliser rate and NFUE outcomes. Figure 2 shows that we can grow our expected yields on no pre-plant N applications where there was 74kg/ha starting soil N. Our highest yield came from a treatment that had 150 kg/ha N applied in crop.

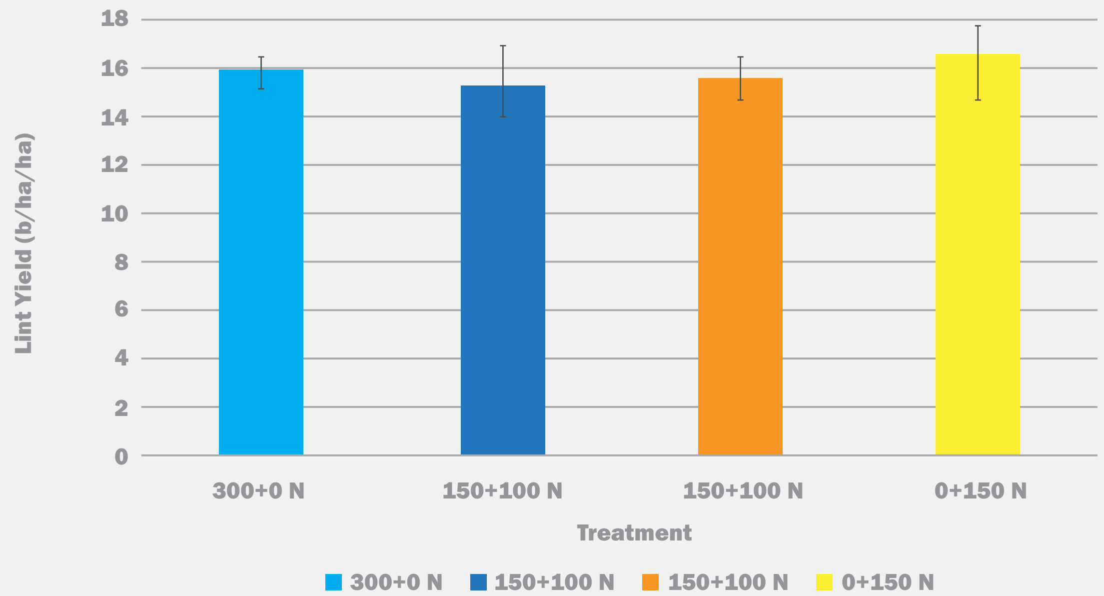


Figure 2 Post-ginning yield results of nitrogen fertiliser treatments of Sicot 74BRF in 2015-16 at "Yattlewondai", Lint yield results of the N fertiliser management trial at Mungindi in the Border Rivers area. Means of three replicates represented with standard deviation/plotted around the means of the treatments with the least significant difference of 2.7 ba/ha.

Petioles were tested in each of the treatments through the season. Adequate nitrogen levels should range from 20,000 to 40,000 mg/kg at 500 day degrees, 10,000 to 22,500 mg/kg at 1000 day degrees and decline to 2,500 to 10,000 mg/kg at 1500 day degrees. Petiole nitrate-N samples taken at three growth stages during the season showed all treatments inside the satisfactory range, with the exception of the nil up-front treatment. In-season application of 150kg N/ha boosted petiole nitrate-N levels, returning the treatment into the satisfactory range at the end of season. The sample summary of four treatments is shown in Figure 3.

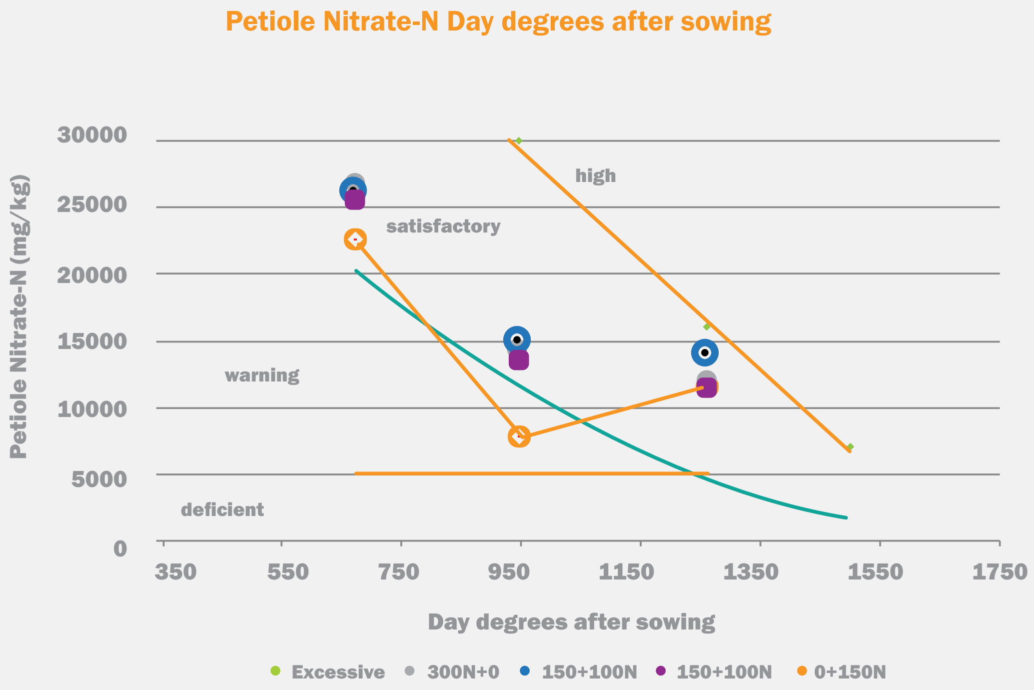


Figure 3 Petiole nitrate-N results of nitrogen fertiliser treatments of Sicot 74BRF in 2015-16 at "Yattlewondai" Mungindi in the Border Rivers area.

Field history on "Yattlewondai" was long-fallow from wheat in 2014. Important to note, the field was also laser-levelled prior to sowing in the spring of 2015, enhancing irrigation application efficiency. The N budget summary in Table 1 shows very little separation in yield response, N removal and finishing soil N from the various treatments. The lowest treatment rate of N (0+150N) has had higher efficiency. In contrast, the pre-plant treatment of 300N shows similar removal and low finishing soil N suggesting a significant portion of N remains unaccounted for. At this site most application strategies lay within the preferred target NFUE range of 13 -18.

Table 1 N budget summary for treatments of Sicot 74BRF at "Yattlewondai" Mungindi in 2015-16.

	N Treatment (kg N/ha)				Sample range
	300+0 N	**150+100N**	**150+100N**	**0+150N**	**150 kg/N/ha**
Starting soil N	74	74	74	74	0 kg/N/ha
Total available N	374	324	324	224	150 kg/N/ha
Finishing soil N	40	26	26	31	14 kg/N/ha
Crop N removal	175	181	169	171	12 kg/N/ha
Lint Yield (b/ha)	15.7	15.4	15.6	16.2	0.8 b/ha
NFUE (kg lint/ kg applied N	11.9	13.9	14.2	24.5	12.6

Gwydir

Alice Devlin

Trial Design: 3 replications of 2 N fertiliser treatments (12 x 1m x 710m rows).

The trial conducted at "Milo", Moree measured two treatments with different pre-applied rates of N and a uniform in-crop application of N occurring at three stages through the season. In this case 185 kg N/ha was applied across three irrigations as water run N26. The planned side dress in-crop treatment at first flower was unfortunately not able to be applied. Nonetheless, with only two treatments, the treatment receiving higher pre-plant N (as Ammonia) in September yielded slightly higher, however, this was not statistically significant. The yield response of the 2 treatments is shown in Figure 4.

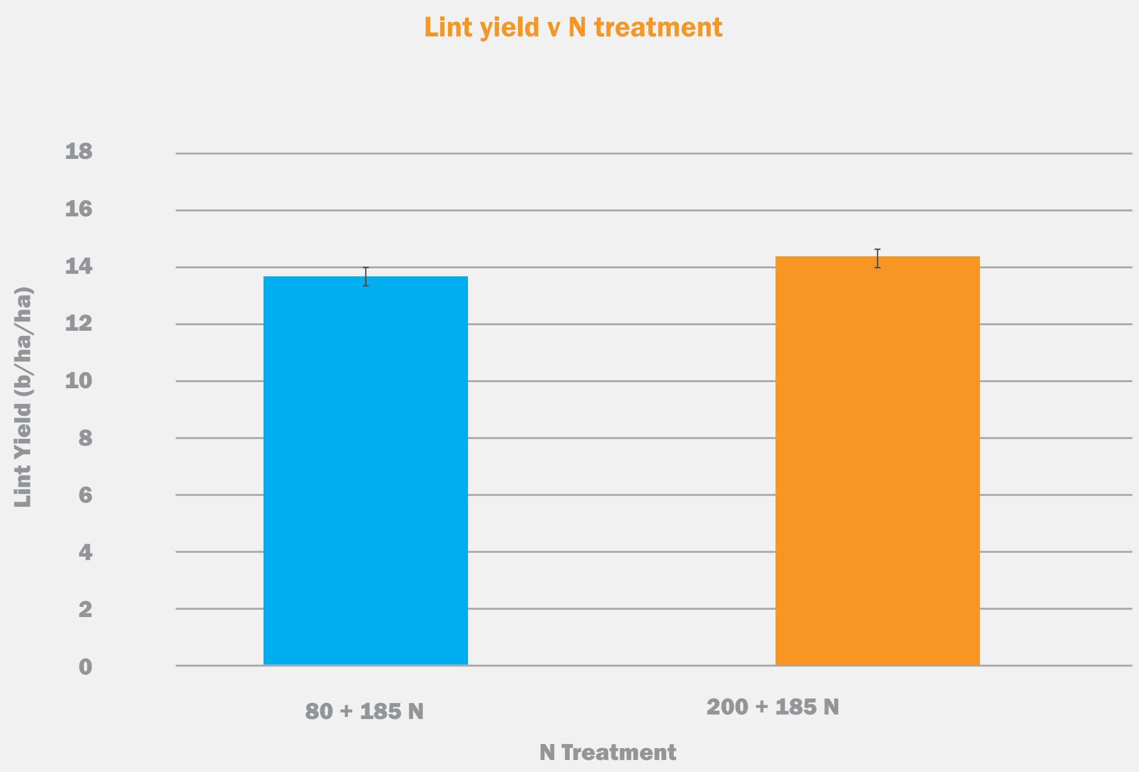


Figure 4 Post-ginning yield results of nitrogen fertiliser treatments of Sicot 74BRF in 2015-16 at "Milo", Moree in the Gwydir Valley.

The soil N budget summary in Table 2 shows an unusually high amount of starting soil mineral N (233 kg/ha) on this particular trial site. The total soil mineral and fertiliser N available to the crop was 488kg N/ha and 608kg N/ha respectively. The crop was only able to remove 144 kg N/ha and 195 kg N/ha respectively. The field history is long-fallow out of wheat in 2014. Unfortunately the zero-N strip planned did not occur due to unforeseen circumstances on the farm. However, the N budget summary shows a relatively low N use when considering crop removal and yield when compared to other sites -. At the end of the crop, a large proportion of N is unaccounted for and has potentially been tied up in unmeasured N pools or lost from the soil.

Table 2 N budget summary for treatments of Sicot 74BRF at "Milo" Moree in 2015-16.

	N Treatment (kg N/ha)		Sample range
	80+185N	**200N+185N**	**120 kg/N/ha**
Starting soil N	223	223	0 kg/N/ha
Total available N	488	608	120 kg/N/ha
Finishing soil N	50	92	42 kg/N/ha
Crop N removal	144	195	51 kg N/ha
Lint Yield (b/ha)	13.6	14.3	0.7 b/ha
NFUE (kg lint/ kg applied N	11.6	8.4	3.2

Namoi Valley

Geoff Hunter

Trial Design: 2 replications of 4 N fertiliser treatments (24 x 1m x 600m rows).

The biggest impact this trial made on the grower came from the plant leaf and petiole tests observed on the nil-N strip. Unfortunately results are not available for this treatment due to hail and chemical damage (situated on the edge of the field), which at no time through the year showed any deficiencies of nitrogen and grew strongly throughout the growing season. The grower actually chose not to apply 40 units of water run N26 in crop due to increased confidence in monitoring nitrate levels. The duration of the flowering period was only around 30 days and although being short by industry standards, it shows 11 bales/ha crop can be achieved with the right climatic conditions and adequate nutrition. Figure 5 shows yield results for each treatment. Statistical analysis found no significant difference between treatments (P=0.46, lsd = 1.04 b/ha).

Petiole nitrate-N tests through the crop growth stages revealed high and satisfactory levels for all treatments. The 270N up-front treatment showed a reading in the 'high' range. Not included in Figure 6 is the nil strip (zero N) treatment. Although not published, petiole nitrate-N results for the nil strip commenced in the optimum range at 900 day degrees and only dipped into 'warning' level at cut-out.

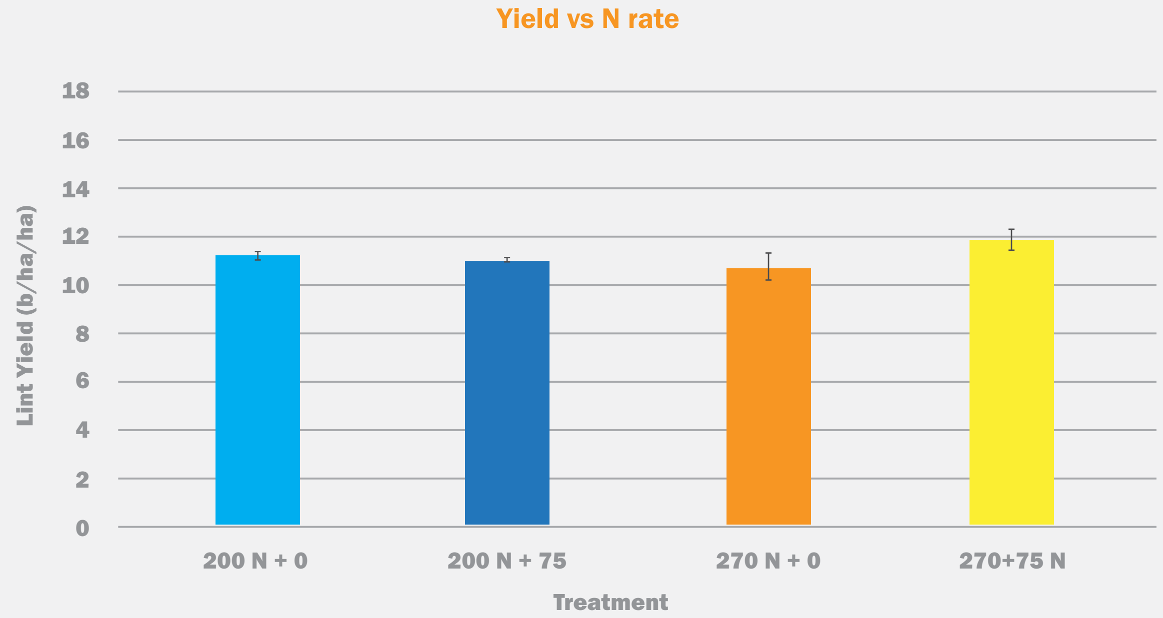


Figure 5 Post-ginning yield results of nitrogen fertiliser treatments of Sicot 74BRF in 2015-16 at "Bellevue" Harparary in the Lower Namoi Valley. Error bars represent the standard error of the mean of between 3 and 5 modules (LSD=1.04 b/ha).

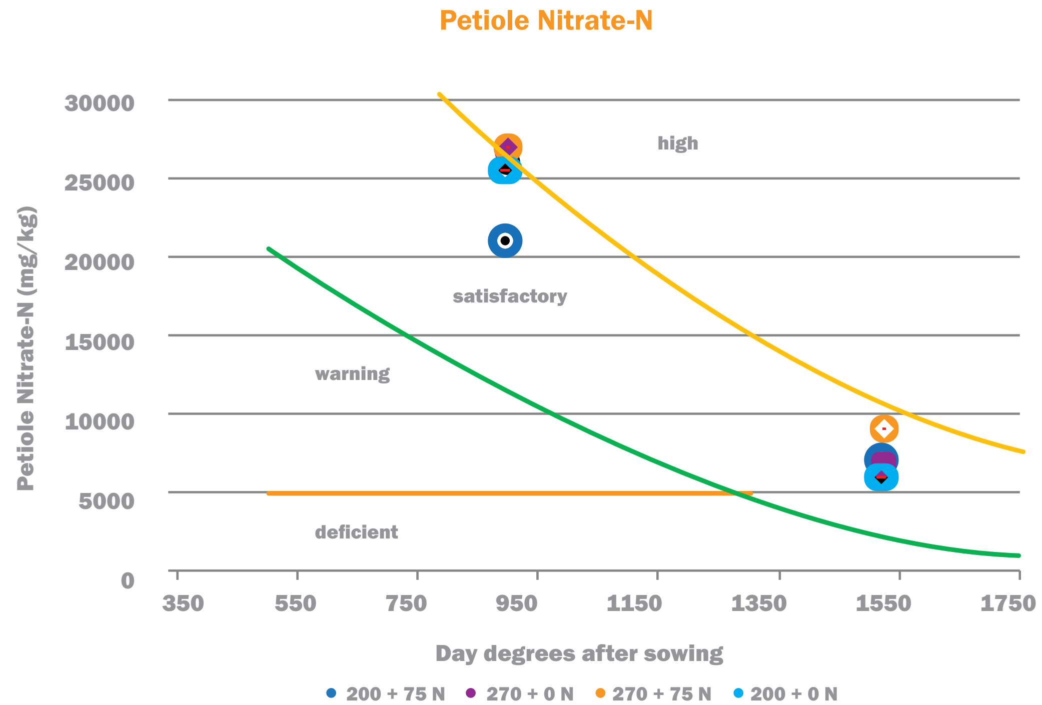


Figure 6 Petiole nitrate-N for treatments of Sicot 74BRF at "Bellevue" Harparary, Lower Namoi in 2015-16.

The nitrogen balance summary for the various treatments is summarised in Table 3. The field history was long-fallow out of wheat in 2014. Despite a difference in N treatments of 145kg N/ha the small difference in finishing soil N between the lowest N treatment (200N+0) and the highest N treatment (270N+75N) illustrates large amounts of N unaccounted for when considering removal, applied N and lint yield. Industry research to better quantify mineralised N is underway to help understand this contribution and estimated N losses from the system. The 200+0 application strategy was the only treatment to reach the target NFUE range of 13 -18.

Table 3 Soil nitrate summary for N treatments of Sicot 74BRF at "Bellevue" Harparary, 2015-16.

	N Treatment (kg N/ha)				Sample range
	200N+0	**200N+75N**	**270N+0**	**270N+75N**	**145 kg/N/ha**
Starting soil N	86	86	86	86	0 kg/N/ha
Total available N	286	361	356	431	145 kg/N/ha
Finishing soil N	68	65	79	79	14 kg/N/ha
Crop N removal	136	134	133	146	12 kg N/ha
Lint Yield (b/ha)	11.6	11.3	11.1	11.8	0.7 b/ha
NFUE (kg lint/ kg applied N	13.1	9.3	9.3	7.8	5.3

Macquarie Valley

Amanda Thomas

Trial Design: 4 replications of 6 N fertiliser treatments (16 x 1.5m x 870m rows).

The key findings of the trial show that the pre-season soil nitrogen can be used in your nitrogen budgeting to refine applied N rate. By looking at the removal rates from the zero upfront treatments, it became clear that mineralisation is playing an important role in providing nitrogen to the crop.

The message for growers in the Macquarie is to find out what your crop is using by pre and post season soil testing and making sure that your applied nitrogen can be used by the crop. Setting the crop up to reach its full potential is not only about applied nitrogen, you need to mitigate against stress factors such as waterlogging and heat stress to be able to make the most of any inputs, including N into the crop. The results in Figure 7 show that there was no significant difference between any of the treatments. We can conclude that in this trial nitrogen was not a limiting factor across any of the treatments - highlighting the need to treat each season as it comes.

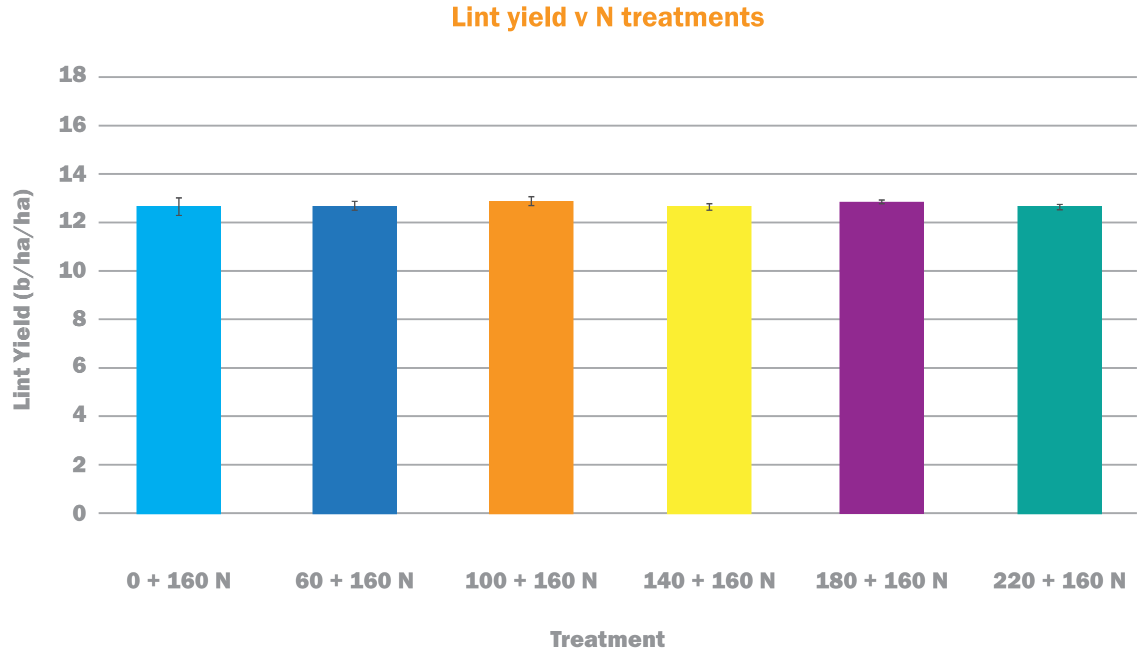


Figure 7 Post-ginning yield results of nitrogen fertiliser treatments of Sicot 74BRF in 2015-16 at Auscott, Warren in the Macquarie Valley. Error bars represent the standard error of the mean of six modules (LSD=0.48 b/ha).

The petiole nitrate-N concentrations found in samples done early in the season were much lower than expected, however at the time of the first petiole test there had been no in-crop N application, with the first water run urea applied until December, so it is indicating differences between the upfront fertiliser application rates. Cooler and cloudy climatic conditions at the time may have also contributed to the low-levels of plant nitrate in the early sample. The crop experienced a slow start prior to the first sample at 500 day degrees. The crop progressed well into the “satisfactory” zone late in the season. Figure 8 provides a summary of the sampling results of the various treatments.

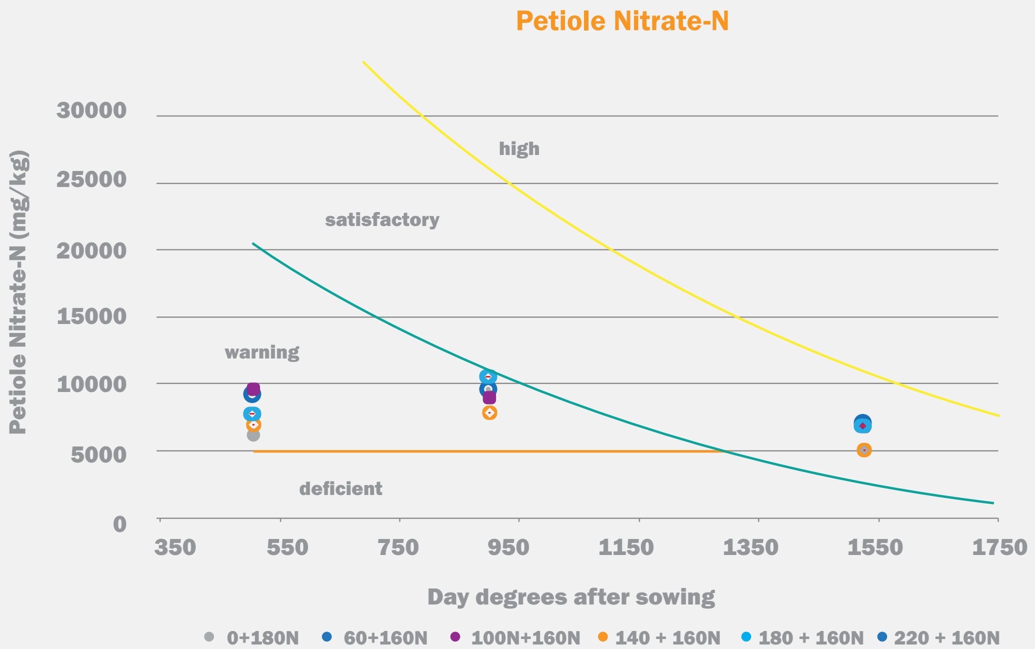


Figure 8 Petiole nitrate-N results of nitrogen fertiliser treatments of Sicot 74BRF in 2015-16 at Auscott, Warren in the Macquarie Valley

The crop N budget summary in Table 4 shows crop removal within a 12kg N/ha range and final soil N within a 23 kg N/ha range. However, wide-ranging differences in applied N (240kg N/ha) shows a large proportion of the applied N is unaccounted for, potentially lost from the system. The 160+0 and 60+160 application strategies were the only treatment to reach the target NFUE range of 13 -18.

Table 4 Crop N budget summary for treatments of Sicot 74BRF at Auscott, Warren for 2015-16 season.

	N Treatment (kg N/ha)						Sample range
	0+160	60N+160N	100N+160N	140N+160N	180N+160N	220N+160N	240kg/N/ha
Starting soil N	126	126	126	126	126	126	0 kg/N/ha
Total available N	286	346	386	426	446	506	220kg/N/ha
Finishing soil N	74	73	80	87	90	96	23 kg/N/ha
Crop N removal	145	141	153	144	149	145	12 kg/N/ha
Lint Yield (b/ha)	12.7	12.7	12.9	12.7	12.9	12.7	0.2 b/ha
NFUE (kg lint/ kg applied N	18	13.1	11.3	9.6	8.6	7.6	10.4

Murrumbidgee Valley

Kieran O'Keeffe

Trial Design: 3 replications of 5 N fertiliser treatments (6 x 2m x 800m rows).

The cropping history at "Benerembah" Griffith differs from other trial sites reported; the field has been double-long fallowed prior to the 2015-16 crop. The field was fallowed from the autumn of 2014 following the picking of the 2013-14 cotton crop. Hence significant stores of mineralised N were allowed to accumulate through the profile. The trial conducted near Griffith on a "beds in bays" bankless irrigation system included strips with zero applied N fertiliser. The zero strips were visible through the season with shorter bushes and less leaf material (see Photo 10 with light green strips). It was surprising to see the nil-strips yielded to 88 % of the highest yield. Following comprehensive pre-season soil tests, analysis through NutriLOGIC suggested that recommended N rates to be applied would be between 226 and 250 kg N/ha (treatment 2 - 60N+160N).

The site had a high mineral N level at the start with 164 kg N/ha present in the soil (0-60cm). The zero strip understandably had the greatest reduction in N during the season with 98 kg N/ha less than that measured pre-season. Figure 9 illustrates the yield differences between the treatments.

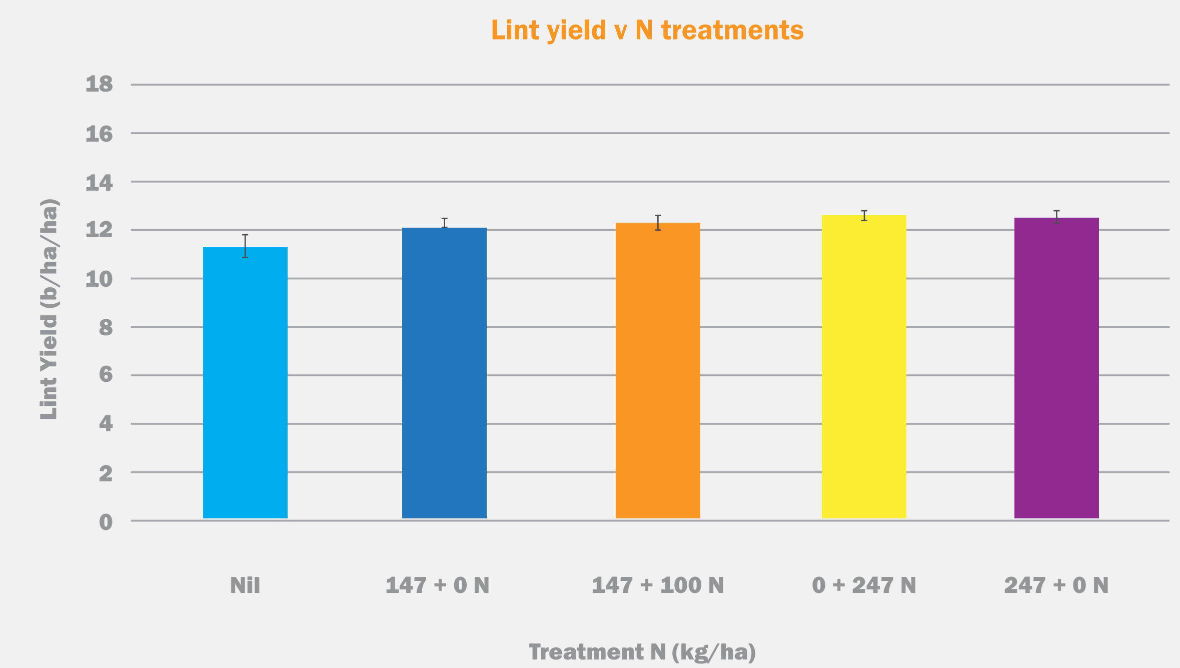


Figure 9 Post-ginning yield results of nitrogen fertiliser treatments of Sicot 74BRF in 2015-16 at "Benerembah" Griffith in the Murrumbidgee Valley, Southern NSW. Only the nil fertiliser treatment was significantly lower than any other treatment (LSD P=0.05, 0.81). Error bars are the standard error of the mean.

All of the treatments were in the adequate range through the season except the zero strips, which bordered on the 'warning' level of being too low. The petiole nitrate-N results for each treatment are shown in Figure 10.

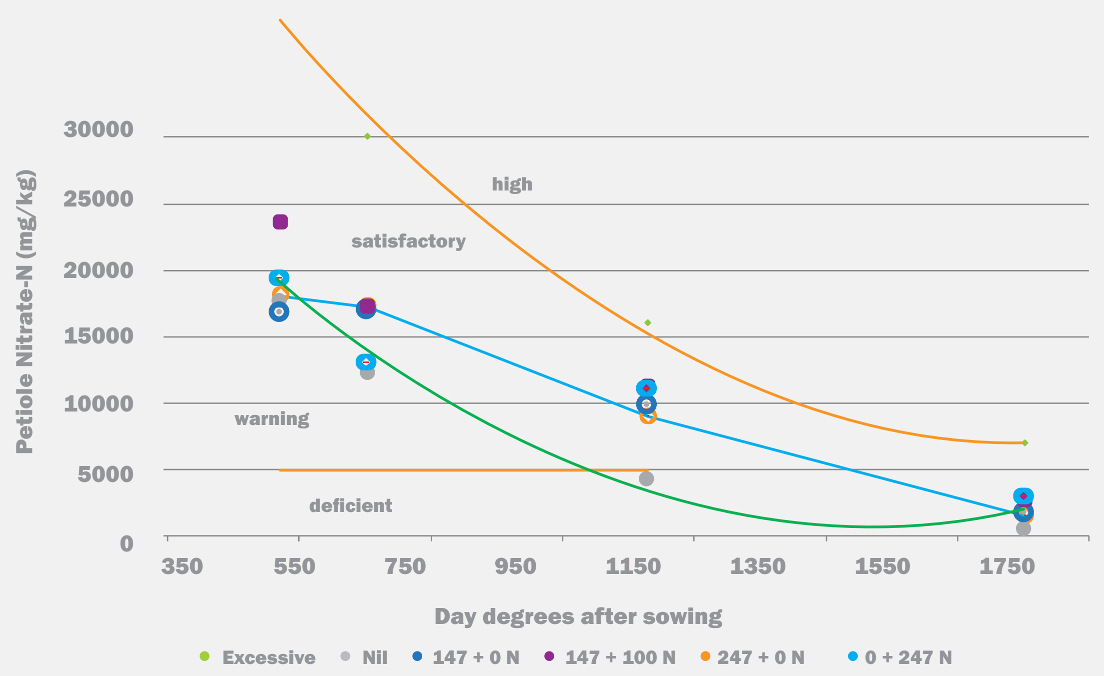


Figure 10 Petiole nitrate-N results of nitrogen fertiliser treatments of Sicot 74BRF in 2015-16 at Benerembah, Griffith in the Murrumbidgee Valley

Previous nitrogen work has reported that up to 75% of nitrogen used by the crop is contributed by the soil. Further, other research has shown cotton can have a preference to uptake mineralised N over synthetic N (Grace et al., 2017). Therefore maintaining soil health and a large soil organic nitrogen pool is critical to maintaining production. Access to this nitrogen pool can be compromised by soil constraints such as compaction and sodicity so overcoming these problems results in more efficient production. The treatment N budget summary is listed in Table 5. The 147+0 application strategy was the only treatment to reach the target NFUE range of 13 -18.

Table 5 N budget summary for treatments of Sicot 74BRF at "Benerembah" Griffith in 2015-16.

	N Treatment (kg N/ha)					Sample range
	Zero N	**147+0 N**	**147+100N**	**247+0 N**	**0+247N**	**247kg/N/ha**
Starting soil N	164	164	164	164	164	0 kg/N/ha
Total available N	164	311	411	411	411	247 kg/N/ha
Finishing soil N	66	114	118	206	131	150kg/N/ha
Crop N removal	145	141	153	160	167	26kg/N/ha
Lint Yield (b/ha)	11.0	11.8	12.1	12.5	12.5	1.5 b/ha
NFUE (kg lint/ kg applied N		18.2	11.1	11.5	11.5	7.1

Discussion

Summary

On-farm nitrogen trials have been used successfully to extend industry research in the past. In September 2007, regional extension officers measured differences in NUE from Emerald to the Macquarie Valley. Based on research at that time, it concluded about 40kg N/ha too much N was applied (Rochester et al., 2007). In 2014, a meta-analysis of CottonInfo/CSD on-farm N trials found only 20 per cent of 147 irrigated sites planted back-to-back achieved optimum nitrogen fertiliser efficiency criteria (Smith et al., 2014). More recently, an examination of 2014-15 regional trial data by Dr Oliver Knox (2016) showed that there were few benefits of over-applying N. Soil testing and N accounting revealed excess N isn't being stored in the soil - with the majority being lost to the environment (Grace 2017).

The trial results in this analysis extend the value in calculating pre/post-plant N and crop removal to determine the fate of applied N. The range of removal of N through different treatments in this season was relatively small and inelastic in response to applied N rate. Therefore, N unaccounted for has most likely been lost from the system. Zero-N strips within rate trials were found to be particularly useful in demonstrating in-crop N mineralisation to growers. The Griffith site achieved a yield of 11 b/ha with no synthetic fertiliser. The different treatments of pre-plant and water-run N also found little yield response across all sites. However, there were no extended waterlogging periods resulting from irrigation and rainfall events coinciding, minimising suitable conditions for denitrification to occur. Splitting nitrogen application throughout the season to meet peak demand is acknowledged as a key risk management strategy to ensure N is not limiting and yield is optimised. Measuring plant nitrate status through petiole testing prior to peak crop demand was also found to be an effective tool to support other crop parameters to ensure the crop is adequately fertilised.

CottonInfo Nitrogen use workshops - what's the feedback saying?

From 2013-2017, CottonInfo, in conjunction with Back Paddock Company conducted a total of 29 crop nutrition workshops covering approximately 324,000ha of irrigable land. Feedback from those growers and advisors attending these sessions provided the following insights into nitrogen use practices;

- 57 per cent of those surveyed have already adopted best management practice on N use; right rate, right time, right place and right product;
- 82 per cent of attendees acknowledged best practice principles on soil testing, calculating mineralised N and refining crop rotations for higher Nitrogen Use Efficiency (NUE) offered benefits to their business;
- 98 per cent of growers and advisors are using a combination of up-front and in-crop application of N to meet peak crop demand and mitigate system losses from untimely rainfall events;
- 40-50 per cent of growers had used leaf/petiole testing in conjunction with soil tests when deciding on fertiliser rates; and
- Irrigation management (water application efficiency) and maintaining field slope was found to be a preferred strategy to mitigate applied N losses.

What's the latest N use research telling us?

A snapshot of the latest research on N use efficiency in irrigated cotton can help understand how to better manage this key input;

- Analysis of 8 years of experimental data, Rochester and Bange (2016) found crop uptake of N derived from the soil varied from 69 to 75 per cent, with the balance being met by fertiliser. Although crop uptake (kg N/ha) has increased over time with yields, the percentage of N in relation to organic N uptake has changed little. Lint yields may well be limited by the soil's ability to supply N as well as other nutrients.
- Experiments in the Upper Namoi region by Baird (2016) found losses of 50% of pre-applied N through tail water after the first irrigation. The study also found irrigation intensity also affected Water Use Efficiency (WUE) and NUE. The optimised management strategy for cotton productivity was concluded to be 250kg N/ha of applied N and the 70mm irrigation deficit.
- Consistent with the above findings, Macdonald et al. (2017) found over a 5-year period, the majority of dissolved organic N and nitrous oxide occurred between irrigations 1-4 and did not appear to be influenced by fertiliser timing or product.
- Fertiliser product and rate trials conducted by Grace et al. (2017) under furrow and centre pivot irrigation found no significant difference between treatments. The sites averaged 11.9 b/ha. The same study found 198kg N/ha was mineralised during the 2015-16 season from the top 100 cm of soil. 77% of the mineralised N was captured by the plant.
- Using a stable isotope (15N) technique to track the fate of fertiliser, Grace et al. (2017) found only 20% of the N taken up by the plant was derived from fertiliser. I.e. 80% is soil derived N

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