Optimizing N fertiliser use and N fertiliser use-efficiency

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Introduction

Nitrogen losses can be high from irrigated cropping soils, but these losses can be minimised with careful attention to N fertiliser management. N is lost principally where nitrate is converted to N gases (denitrification), but also with nitrate leaching. These losses account for 30% of the N fertiliser applied to irrigated cotton on average; these losses can be doubled in extreme cases where poorly-structured soils become waterlogged. Because some fertiliser N is lost as nitrous oxide (N_2O), an extremely potent greenhouse gas, inefficient N fertiliser use has become an environmental issue that the cotton industry is addressing with research and improved N fertiliser management practices.

Most cotton crops require N fertiliser inputs to maximise gross margins (i.e. most crops respond to N fertiliser application). However, few growers manage to apply the appropriate quantity of N fertiliser, thereby wasting N and foregoing some profit and risking environmental damage. Crop demand for N should be closely matched with the supply from the soil and fertiliser.

Recent examination of N fertiliser experiments and commercial cotton fields has shown that crop N use-efficiency can be quickly and easily estimated to provide some feedback that indicates where N fertiliser management should be revised.

Minimising N fertiliser losses from soil

By adopting appropriate N fertiliser management practices, losses of N fertiliser from the cropping system can be minimised. Recommendations to improve N fertiliser management practices include:

- *Timing N fertiliser application*: This involves matching the crop's demand for N with the supply. Compared with applying all N before sowing, side-dressing or water-run in-crop applications will help avoid some losses and enable N to be better utilised by the crop.

- *Optimal N fertiliser rate*: Avoid over- or under-fertilising – you cannot force cotton crops to take up more N than they need, in the hope of producing more yield! See the N fertiliser response curves for cotton (Figure 5). Growers should aim to optimise N fertiliser rate to avoid waste and inefficient use of this resource.

- *Monitoring N in soil* (using laboratory analyses) – Extension material such as NutriLOGIC and NUTRIpak can assist interpreting soil analyses. Guidelines have been published on the CRC website and by O'Halloran et al (2005).

Determining Crop N use-efficiency

Crop N use-efficiency describes how well crops convert the N they accumulate into yield. It can be most conveniently defined as lint yield (kg/ha) divided by crop N uptake (kg/ha). This measure has been used in experiments at Narrabri to monitor NUE over the past 5 years. It shows that those crops that receive optimal amounts of N fertiliser (as identified by the curves shown in Figure 4) produce close to 12 kg lint/kg N uptake (Figure 1).

Very conveniently, this measure of crop N use-efficiency can also indicate where excessive or inadequate N fertiliser has been applied.

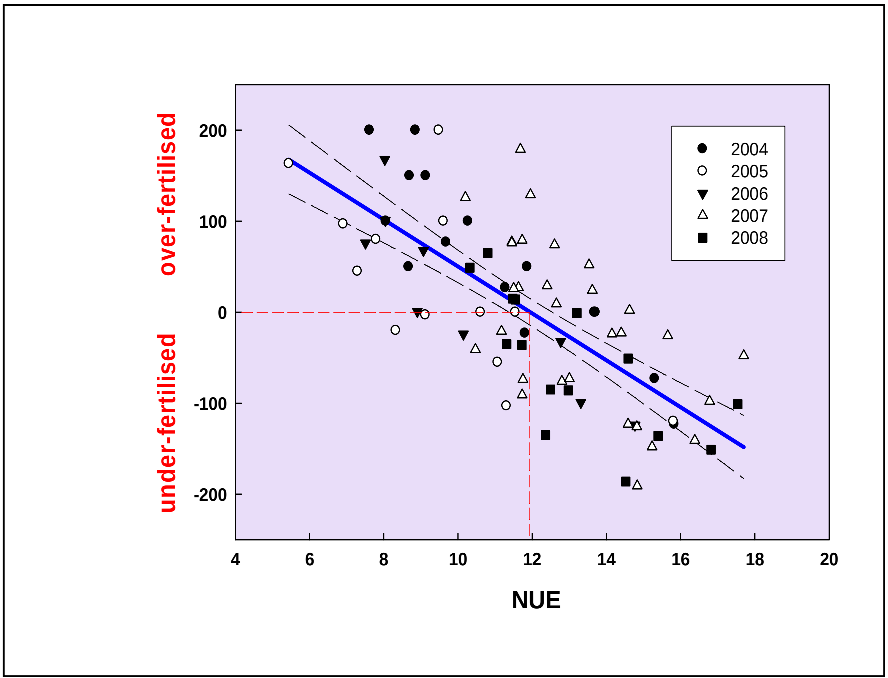


Figure 1. Crop N use efficiency is closely related to how N fertiliser is managed in cotton crops.

A survey of commercial fields in the past two seasons has shown that most (2/3) of the fields examined had been over-fertilised by an average of 40 kg N/ha for all the fields tested, but up to 120 kg N/ha in excess of what was required in one crop. This degree of over-use of N fertiliser has cost the industry directly about $10M/annum in recent years. The indirect effects of over-fertilising (yield reduction, delayed maturity, defoliation problems, growth regulators etc) have cost the industry many times this amount.

Field-by-field measurement of Crop N use-efficiency

The measurement of crop NUE can be facilitated by analysing seed sampled from modules in the field. This is much quicker, simpler and less expensive than measuring crop N uptake at crop maturity. Seed N% is closely related to crop NUE and the over- or under-use of N fertiliser (Figure 2). Fuzzy seed can be very quickly assayed for N using a non-destructive technique. Seed cotton samples could be collected in the field, or fuzzy seed collected/analysed at the gin.

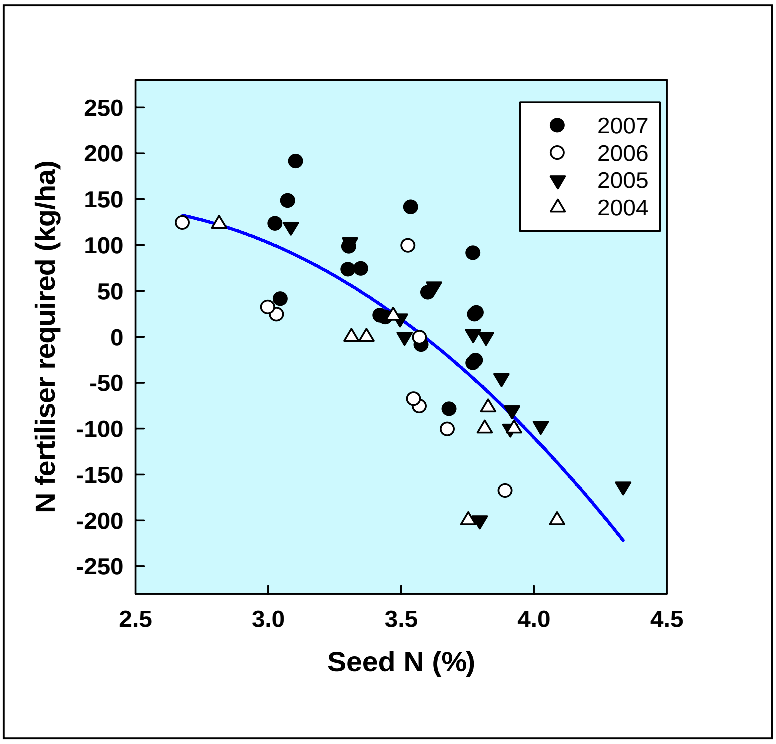


Figure 2. The relationship between seed N% and the amount of N fertiliser applied to cotton crops, relative to the optimal amount. Negative values indicate too much N fertiliser was applied.

Further, by allowing for the large range of lint yields obtained in this data, a more precise estimate of N fertiliser requirement can be obtained.

Cycling of soil and fertiliser N by soil microbes

Fertiliser N is quickly transformed to nitrate where ammonium fertilisers are applied. This nitrate is then available for uptake by soil micro-organisms and crops. However, where high levels of nitrate persist in the soil, substantial N losses can occur. The soil microbial biomass takes up a substantial amount of nitrate-N from the soil, particularly early summer as the soil warms and stubble breaks down. Crops take up most of the N they need when soil nitrate levels are low (Figure 3). At this time, soil nitrate is derived from organic-N sources. Organic-N is made available to the crop through microbial activity which rapidly recycles soil N.

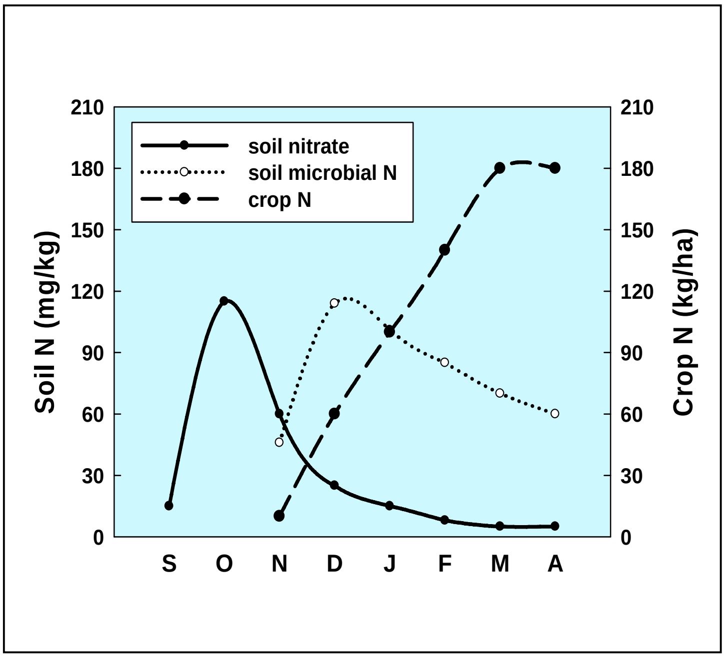


Figure 3. Soil nitrate and crop N uptake throughout a cropping season. Urea was applied in September at 150 kg N/ha.

Optimising crop N uptake

Most commonly, lint yield is limited by factors other than N. For any level of lint yield, there is a minimum amount of crop N uptake (Figure 4). Lint yield is often limited by constraints such as water stress or poor insect management etc. Lint yield can be limited by many factors (including soil structure, insect and water management etc) but in practice, it is not often limited by N nutrition. Thus, applying more N fertiliser may not improve lint yield nor increase crop N uptake; it only results in less efficient use of N fertiliser. Figure 4 shows that lint yield was increased by improved soil health with legume cropping. However, lint yield levelled off in both the legume or non-legume systems when N uptake reached 200 kg N/ha. Water and insect management probably limited yield in these crops. In 2008, higher lint yields were achieved with similar crop N uptake to previous years, due to better irrigation management in the milder season. The data presented here indicates that little increase in lint yield is achieved by taking up more than 200 kg N/ha. The dashed line (Figure 4) indicates that with excellent insect and water management and healthy soil, yields of more than 15 bales/ha (6 b/ac) can be achieved with only 200 kg N/ha N uptake.

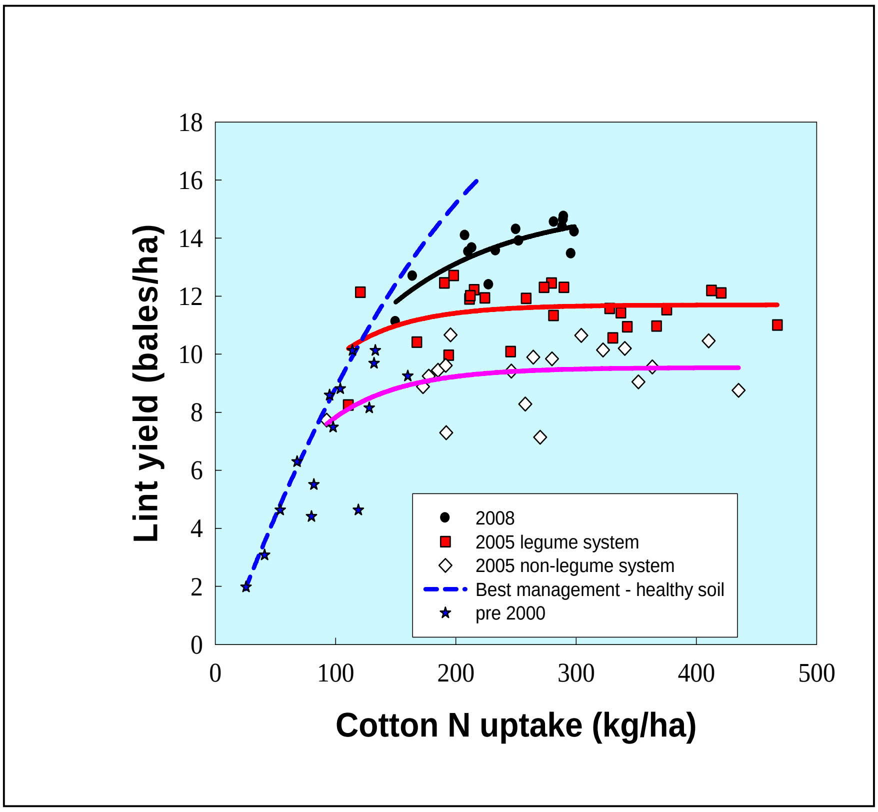


Figure 4. Relationships between lint yield and crop N uptake.

Legume-based systems

N losses are minimised in these systems as little manufactured fertiliser N is normally required, as sufficient N is released from the legume residues in phase with cotton crop demand. Legume-based systems support a more vibrant level of soil biological activity that cycles nutrients quickly, as in natural ecosystems. Figure 5 shows little or no response to N fertilizer in legume-based systems.

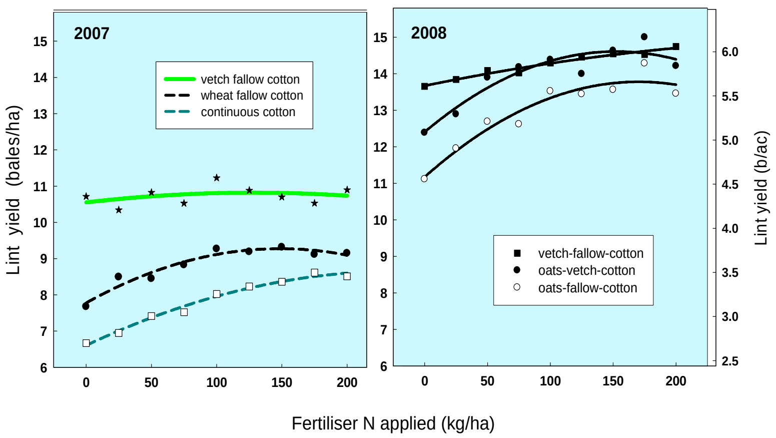
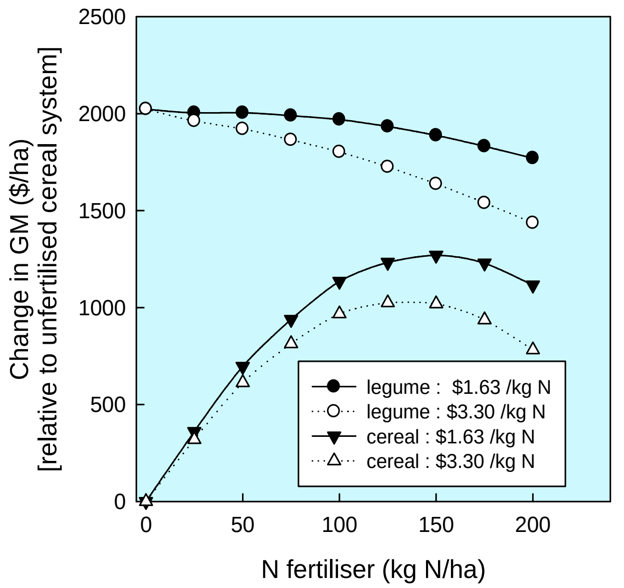


Figure 5. Lint yield responses to applied N fertiliser in 2007 and 2008 at Narrabri.

Rising cost of N fertiliser



The application of N fertiliser for cotton remains profitable even if the current cost of N fertiliser is doubled to $3.30/kg N. However, less N fertiliser is required to maximise profit in the comparisons shown in Figure 6.

Figure 6. Changes in cotton gross margins (relative to the

unfertilised cereal system) afforded by N fertiliser application in 2007 at Narrabri in cereal- and legume-based cotton systems. The N fertiliser responses for these two systems are shown in Figure 5.

Where legume-based rotation systems are adopted, much of the N required by cotton crops can be supplied by the legume. However, the greatest benefits come from the increased lint yields and profitability, compared with fertiliser-dependent cereal-based systems (Figure 6).

Conclusion

By adopting better N management practices discussed in this paper, the cotton industry can improve the efficiency of N fertiliser use, by minimising the opportunity for N to be lost from the soil and by ensuring that optimal amounts of N fertiliser are applied when they are best utilised by the cotton crop.

Legume rotation crops offer the opportunity to supply much of the N required by cotton crops. This will, to some degree, protect growers from future increases in the cost of manufactured N fertilisers.

Acknowledgments

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