Program Overview

More Profit from Nitrogen (MPfN): enhancing the nitrogen use efficiency of intensive cropping and pasture systems

The nation-wide MPfN Program is a partnership between Australia’s four major intensive users of nitrogenous fertilisers: cotton, dairy, sugar and horticulture. Nitrogen (N) is a significant input cost to producers and a substantial contributor to the environmental footprint of each industry.

The Program aims to bring about increased farm profitability and reduced environmental impact by increasing N use efficiency (NUE) across the four industry sectors, resulting in a reduction of the amount of N required to produce each unit of product.

N is essential for plant growth and is vital in producing high yielding, quality crops, produce and pasture. Calculating the optimum amount to apply is difficult for farmers as the N cycle is complex and there are regional uncertainties associated with the contribution of mineralisation in the soil, the decomposition of organic matter that releases N contained in those compounds into forms that are plant-accessible. N availability is also affected by factors including soil type and condition, climatic variability, paddock management history, irrigation management practices and applied fertiliser formulation, timing, placement and prevailing conditions at the time of application.
The MPfN Program is undertaking research and trial to deliver enhanced NUE, improving profitability and sustainable use, through better understanding the influence of the contributing factors. It is striving to:

- Generate a greater knowledge and understanding of the interplay of factors to optimise N formulation, rate and timing across industries, farming regions and irrigated/ non-irrigated situations;
- Generate a greater knowledge and better understanding of the contribution (quantifying rate and timing) of mineralisation to a crop or pasture’s nitrogen budget; and
- Generate a greater knowledge and understanding of how enhanced efficiency fertiliser (EEF) formulations can better match a crop or pasture’s specific N requirements.

The Program is also providing a platform for cross industry collaboration on N management, the results of which is fostering unprecedented information and knowledge exchange amongst Australia’s leading scientists in NUE.

**Methodology**

The MPfN Program is managed by Cotton Research and Development Corporation (CRDC) in close collaboration with Dairy Australia (DA), Sugar Research Australia (SRA) and Horticulture Innovation Australia (Hort Innovation). Ten projects are being delivered under the Program’s umbrella through the following lead agencies:

- NSW Department of Primary Industries
- University of Southern Queensland - National Centre for Engineering in Agriculture
- Queensland University of Technology
- University of Melbourne
- Queensland Government - Department of Environment and Science
- Queensland Government - Department of Agriculture and Fisheries
- Northern Territory Government - Department of Primary Industry and Resources
- University of Tasmania - Tasmanian Institute of Agriculture

A further eleven collaborating research organisations and commercial companies are involved providing financial and in-kind contributions.

A total of [35 field based trials](https://www.crdc.com.au/more-profit-nitrogen#field-based-trials) (click for Google map) have been established in the first eighteen months located on both research and commercial farms in Tasmania, Victorian, NSW, Queensland, South Australia and the Northern Territory. This in-field research is supported by leading laboratory experimentation, analysis, simulation and modeling technologies.

**Extending the outcomes**

The MPfN Program is continuously extending ongoing findings and outcomes to science, extension, service provider and farming audiences by supporting:

- Field days and workshops
- Publication of research project and whole-of-program based articles in leading industry circulars and agricultural media
- Creating opportunities for commercial, agency and peak body organisations of industry to collaborate on NUE
- PhD and Post Doctorate research positions
- Publication of peer reviewed articles/ papers in leading Australian and international science journals
- Presentation of research findings at major Australian and international conferences
- Preparation of industry guidelines and fact sheets to expedite research findings into the adoption of NUE best management practice on Australian farms.

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More Profit from Nitrogen: enhancing the nutrient use efficiency of intensive cropping and pasture systems is supported by funding from the Australian Government Department of Agriculture and Water Resources as part of its Rural R&D for Profit program.
Smart blending of enhanced efficiency fertilisers to maximise sugarcane profitability

Application rates of nitrogen (N) fertiliser to sugarcane crops generally range from 130 to 250 kg N/ha, approximately half of which may be lost through gaseous emissions, leaching and/or runoff following large rainfall or irrigation events. The N losses not only impact upon environmental assets, but also substantially decrease farm profit.

Enhanced efficiency fertilisers (EEFs), such as polymer-coated urea (PCU) and nitrification inhibitor-impregnated urea, can increase nitrogen use efficiency (NUE). However, the N release pattern of PCU may differ from crop N uptake dynamics and the high cost of EEFs can impede their use by farmers.

Led by the Queensland Department of Environment and Science and involving four partner research organisations, this project aims to investigate optimal blending ratios of EEFs with conventional urea, under various soil and seasonal conditions.

The Research Questions

- Can fertiliser N application rates be significantly reduced by properly blending PCU and conventional urea?
- Can blended use of PCU and urea increase fertiliser NUE compared to using a single product?
- How much can farm profitability be improved from the use of blended fertilisers compared to the use of a single product?
- How to select the most suitable products and work out the optimal blending ratios for a specific farm?

Methodology

The following research is being undertaken using replicated on-farm field trials in the major sugarcane growing regions of Innisfail, Tully, Ingham, Mackay and Bundaberg:

- Different blends of commercially available fertiliser formulations (conventional urea, PCU, or nitrification inhibitor-coated urea) assessed at the recommended and sub-optimal rates.
- Soil samples collected and analysed to monitor ammonium and nitrate N dynamics and movement in the soil profile.
- Sugar yield and crop nitrogen uptake measured and profitability analysed to assess the most profitable fertiliser management strategies in relation to soil, site and seasonal conditions.

Project Achievements

- First year crops have been harvested across the six field research sites.
- Soil and plant samples were taken and analysed for mineral N and total N content.
- Field days, site tours and workshops have been conducted at sites by local partners for grower input and feedback.

Initial Outcomes

- The nitrification inhibitor (DMPP) increased ammonium (a stable mineral nitrogen form) accumulation and/or reduced nitrate (a mobile nitrogen form) accumulation in soil in the first 1-2 months after application.
- Mineral N release and accumulation from PCU were markedly slower than conventional urea in the first 3 months after application, which may potentially decrease N loss after rainfall.
- Significant movement of fertiliser N to deep soil (> 60 cm depths) were recorded in the normal urea treatment in well-drained soils. However, such movement was not evident in PCU fertiliser treatments or in poorly drained soils.
- Most fertiliser N that was released into soil disappeared within 2.5-3 months after application. The quick depletion of urea N (with or without DMPP) at the early crop growing season demonstrated the risk of substantial N loss.
- The above benefits of EEFs in conserving N in soil did not translate into significantly higher sugar yield in most cases in the first year. The research team are examining the long term performance of EEFs.
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This project is supported by funding from the Australian Government Department of Agriculture and Water Resources as part of its Rural R&D for Profit program, the Queensland Government (Department of Environment and Science, Department of Agriculture and Fisheries), Sugar Research Australia, Herbert Cane Productivity Services Limited, Farmacist Pty Ltd, ICL Specialty Fertilisers and Incitec Pivot Ltd
New technologies and managements: transforming nitrogen use efficiency in cane production

Fertiliser is a major determinant of profit margin for cane growers. This project, led by the Queensland Government Department of Agriculture and Fisheries, seeks to investigate new novel formulations and management techniques to optimise nitrogen (N) application to cane crop requirements.

Past research has found uptake of fertiliser nutrients to crops is extremely poor, with only 50% efficiency across many production systems. Mass balances indicate annual N inputs consistently exceed harvested exports by 40% to 60%, resulting in substantial loss to the environment. Impacts of poor nitrogen use efficiency (NUE) are being closely monitored in the Great Barrier Reef (GBR) catchment, where a major source of nutrient discharge is from agriculture, including the sugar industry.

This project has commenced with “proof of concept” laboratory based studies devised to economically test the characteristics of a large range of N fertiliser formulations, under varying simulated management and environmental conditions, prior to narrowing the selection to those considered most appropriate for more costly field based trials. The aim is to develop more targeted N formulations to better match N release to cane crop demands, throughout seasons, by controlling N transformation and solubility, and combating N “leakiness” to the environment. To do so, the research team has designed innovative equipment to rapidly test characteristics influencing optimal N application for cane crops of singular or combinations of enhanced efficiency fertilisers (EFFs).

The Research Questions

- Through novel fertiliser formulations is it possible to deliver nitrogen to meet ideal crop requirements throughout the season without excess soluble nitrogen during periods of low requirement?
- Is it possible to intercept runoff nitrogen losses close to sources of nutrient intensive crop production, prior to flow convergence, and significantly decrease the magnitude of these losses?

Methodology

The project is conducting research through these key activities:

- Laboratory component: The application of innovative micro-scale dialysis techniques, in addition to batch processes, is providing real time investigation of process kinetics in ‘typical’ sugar farming systems, with and without plants. Other loss pathways are being monitored in real-time and on-line using a custom-automated suite of Cavity Ring-Down Spectrophotometers, Fourier Transform Infra-Red Spectrometers and Quantum Cascade Lasers.
- Growth accelerator trials: Rapid growth pot trials and cost-effective screening is being undertaken of a wide range of prototype fertiliser formulations using advanced mechatronics technologies to carefully control the environment of the experiments. Robotics are used to schedule and apply water whilst taking 3D images to measure growth rates and N soil and plant content.
- A purpose built off-site rainfall simulator and flume has been constructed to carry-out evaluation of transport mitigation managements.
- Field investigations (final year): Focus will be on completing field trials with a limited number of evidence-based EFF formulations from laboratory and simulation studies. Production system representative fertiliser field-trials will be established in the GBR catchments of Herbert / Wet Tropics and Burdekin to undertake nutrient capture and formulation research. System nutrient losses will be monitored.
- Supporting mathematical modeling and evaluation will use an over-arching conceptual framework to compare fertiliser formulation performances and to place the research data into context with previous sugar agronomic studies.

Project Achievements

- New laboratory based experimental processes have been developed to rapidly test a large number of EFF formulations using a cutting edge ensemble including computer integration and automated 32 channel manifolds, reaction vessels plumbed with gas lines, probes previously used to measure brain fluid chemistry, a robot controlled plant growth accelerator (with 3D cameras), a rainfall simulator with automated sampling, and a bank of spectrophotometers.
- Initial studies have commenced on testing the characteristics of over 30 EFF formulation possibilities.
- Planning has commenced in collaboration with the MPFN project conducted by the Queensland Department of Environment and Science to collocate field based studies.
Initial Outcomes

Already producing results, to date this approach has identified:

- An inhibitor treatment that can decrease runoff nitrate losses from the rainfall simulator by about 50%.
- Two inhibitor formulations that can increase plant nitrogen uptake after 12 weeks under highly leached but otherwise controlled conditions. This is a good early success as decreased initial fertiliser vulnerability to loss followed by mid-season availability is one of the key research targets.
- A novel inhibitor formulation that increases plant nitrogen uptake for the period from germination to 20 weeks in a model plant.
- Six novel inhibitor formulations capable of significantly decreasing nitrogen leaching losses.

Extending the outcomes

The project is already providing a number of opportunities for sugar farmers, service providers and extension staff to connect with ongoing findings and has plans for future activities, including:

- Demonstration days conducted at field trial locations
- Workshops aimed at early adopters of new technology
- Preparation of fact sheets on formulation options resulting from project findings
- Articles and videos for Sugar Research Australia (SRA) avenues, including the industry’s CaneConnection magazine.
- Conference presentations and proceedings at key events, including the 2017 Fertiliser Australia Conference.
- Peer reviewed journal publications on both field experiments and laboratory work.

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This project is supported by funding from the Australian Government Department of Agriculture and Water Resources as part of its Rural R&D for Profit program, Queensland Government (Department of Agriculture and Fisheries) and Sugar Research Australia. It is also supported by research collaborators, University of Queensland and AgResearch New Zealand.
Improved nitrogen use efficiency through accounting for deep soil and mineralisable N supply, and deployment of enhanced efficiency fertilisers (EEF) to better match crop N demand

NSW Department of Primary Industries (NSW DPI) leads this project which seeks to advance fertiliser technologies that enable subtropical sugar farmers to better match nitrogen (N) supply with crop N demand to improve N use efficiency (NUE) and reduce N loss to the environment. To achieve this, the project is assessing N stores in soil to improve understanding of N supplied from soil organic matter (mineralisation) and is investigating optimal use of EEFs, such as poly coated urea (PCU), to better match N demand from the crop with N supply. A dose response model for urea and PCU, considering soil type and soil organic N supply, will develop improved practice management options leading to better environmental outcomes and grower profitability.

The research questions

- Can the quantification of mineral N from soil and N from organic matter be used to lower application rates of fertiliser N?
- Does slow release N fertiliser (PCU) increase N supply in soil, reduce N losses and increase fertiliser use efficiency?
- Is there potential for PCU to extend the supply of fertiliser N later into the crop cycle (ie. second year) resulting in greater yields?

Methodology

1. 30 representative paddocks in northern NSW were sampled to determine the extent of subsoil (deep) N reserves. The soils were used in incubation studies to determine the rate of N mineralisation, with data being used to develop new tools (MIR/NIR) to rapidly predict soil mineralisable N

2. An assessment of the potential of PCU to better match soil N supply with crop demand is currently being assessed at three field sites in the Tweed, Richmond and Clarence catchments, NSW.

3. Results will be used to:
   a. Derive N response curves for urea and PCU to enable the development of a simple model to predict the economic returns of using an EEF product based on the differential pricing of each product at any given time in the future.
   b. Determine N leaching losses on the lighter textured soils to demonstrate benefits of PCU in maintaining N levels in surface soils.
   c. Inform \(^{15}\)N stable isotope studies to assess the contribution of fertiliser vs native soil N to crop N uptake in soils that differ in base soil N levels, and to derive NUE indices.

Project achievements

- Two field trials were established in October 2016 (Tweed Valley & Richmond Valley, NSW) to evaluate an N-response curve from urea and PCU (9 month product). The sites are laid out in a randomised complete block design of 6 rates of each fertiliser, with 3 replicates (33 plots with controls).
- The Tweed Valley field site was harvested as 1 year sugarcane in October 2017, while the Ballina field site is continuing as 2-year cane.
- Residual N from deep soil cores (1m) (control, 300 units urea and 300 units PCU cores to 1m at 0-20, 20-40, 40-60, 60-80 and 80-100cm) were taken post- harvest to assess the role of residual N from PCU vs urea at the Tweed Valley site in 2017.
- Nitrification assays of the cores have been undertaken using the Queensland Department of Environment and Science (QDES) 14 day N mineralisation method and have also been analysed by NSW DPI’s MIR/NIR equipment to develop algorithms for estimating N-mineralisation potential.
- UAV/ NDVI/ red edge evaluation of the plots is continuing at a higher frequency (every 6 months) than first anticipated, now by NSW DPI’s internal capacity.
- 27 sugarcane paddocks have been sampled and analysed in NSW, at varying depths, for deep soil N.
Initial outcomes

Tweed and Richmond Valley sites:

- Some soils have significant stores (ca 200 kg ha\(^{-1}\)) of ammonium-N to 1m depth, with little evidence of nitrification.
- Sugarcane roots were also detected in these cores to depth suggesting plants can access deep N stores.
- Both field sites showed a leaf-N response curve to N fertiliser (using 6 fertiliser doses), with more N in biomass from matching doses of N coming from PCU.
- Mineralisable N assay data, completed for the deep soil N cores, are being used to inform an MIR/NIR algorithm for predicting potentially mineralisable N in soils. To date, variation was observed between soil types and field locations.
- Year 1 findings demonstrated that nearly 50 kg ha\(^{-1}\) of mineralisable N was released from the 0-40cm soil profile at the Richmond Valley site, while the much heavier soil at the Tweed Valley site released less at 22 kg ha\(^{-1}\).

Extending the outcomes

- Workshops/field days/briefings with advisors, extension officers (eg Sunshine Sugar Agricultural Services), and farmer groups.
- A model is being developed for incorporation into the industry “Six-Easy Steps Guidelines” and will contribute to the development of a Decision Support Model for the use of EEFs in sugarcane production.
- Rapid mineralisable N methodologies will be made available for commercial adoption.
- Scientific outputs including results for the stable isotope methodologies will be presented in Industry workshops, science conferences, and journal publications.

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This project is supported by funding from the Australian Government Department of Agriculture and Water Resources as part of its Rural R&D for Profit program, NSW Department of Primary Industries and Sugar Research Australia. It is also supported by research collaborators Southern Cross University and Sunshine Sugar Agricultural Services.
Enhancing nitrogen use efficiency & improving phosphorus nutrition in cotton

This project is undertaking research into both nitrogen (N) and phosphorus (P) and is led by NSW Department of Primary Industries (NSW DPI). It aims to increase understanding of the intricate relationship between soil and fertiliser N & P supply, fertiliser placement, fertiliser timing, and irrigation strategy to achieve greater nitrogen use efficiency (NUE) and improved phosphorus soil nutrition.

Optimising NUE can be complex as fertiliser type, application strategy and irrigation management can influence N availability to the plant and N loss to the environment under different farm practice scenarios. Under certain conditions, N losses to the atmosphere, deep subsoil and surface water can be substantial, leading to poor NUE. In addition to applied fertilisers, N mineralised from soil organic matter is also a major source for cotton crops and is subject to the same loss pathways.

In parallel, the project is undertaking research into the dynamics of P uptake by cotton plants from both topsoil and subsoil, and the patterns of crop P accumulation, to better understand trends of long-term P supply throughout the soil profile. The research is investigating long term depletion rates of deep soil P reserves under different soil management strategies in irrigated farming systems.

The findings will aid in the development of informed N and P management strategies to increase efficient and effective N and P use by farmers.

The Research Questions

- What is the current status of N fertiliser knowledge from previous research in irrigated Australian cotton systems?
- What is the significance of ammonia volatilisation as an N loss pathway in furrow irrigated cotton systems?
- How does the interaction of irrigation management and N fertiliser timing affect N use efficiency in cotton?
- How does irrigation management affect mineralisation of N from soil organic matter in furrow irrigated cotton systems?
- How does the method of in-crop N fertiliser application affect N use efficiency in cotton?
- Is there long term P stratification or decline in cotton farming systems?
- How much P is being taken up by cotton plants from surface and subsoil layers?
- Is the response of P affected by varied irrigation and N management?
- Does P movement in runoff pose a risk to on-farm dams in cotton farms?

Methodology

The project is undertaking a literature review of previous research into N fertiliser use efficiency in parallel with in-field research:

1. A core trial site is located at the Australian Cotton Research Institute (ACRI), Narrabri, NSW, consisting of a fully replicated and randomised plot design subject to a range of N application strategies including:
   - Product and form of application (solid granular urea and dissolved solutions of UAN, urea and ammonia);
   - Timing of application (all applied in-crop vs varying amounts pre-plant : in-crop);
   - Rate of application (Zero N, Optimal N, High N (optimal + 100 kg N/ha));
   - Use of enhanced efficiency fertiliser (EEF) products (including urease inhibitor and nitrification inhibitor); and
   - Irrigation schedule (initially focus on 50 or 70 mm deficits).

2. A single summer campaign to measure ammonia volatilisation from in-crop applied N fertiliser, using open path laser concentration sensors, is also to be undertaken.

3. In-crop N mineralisation is assessed through mineral N analysis of soils collected by sequential in-season soil coring inside and outside of root exclusion tubes.

4. N losses in selected irrigation and in-crop N management treatments is being studied in greater depth using $^{15}$N mini plots at the core site.
5. Two satellite site experiments, establish on commercial farms near Gunnedah and Moree in 2017, have incorporated replicated and randomised treatments from the core site, selected through discussions with local grower groups.

6. Evaluations are undertaken at each of the experiment sites on N plant uptake, cotton lint yield, N content in irrigation runoff, and residual N soil under the various scenarios.

The P component of the project also includes a literature review of nutrition research in cotton farming systems followed by in-field P research:

1. Historical samples from several long-term cotton trials are analysed for CaCl2-P, Colwell-P, BSES-P and PBI to assess the development of soil P stratification and/or P decline over time.
2. P utilization, from various depths in the soil at different growth stages, are being investigated using P-isotopes.
3. Irrigation and N management interactions, and their implications for improving P use efficiency, are being investigated in field experiments quantifying P uptake response.
4. Irrigation water samples are monitored for total and reactive P to quantify cotton farming system practices that minimise the risk of P loss.

Project Achievements

- A paddock-scale (8 ha) irrigated cotton core site trial was conducted at ACRI in years 1 & 2 with 15-24 treatments imposed, including irrigation scheduling and N fertiliser product/application type/application timing treatments.
- Comprehensive measurements of the treatment effects on soil, water, and plant properties were made both throughout the season, and of cotton lint and seed yield and N uptake at harvest.
- Successful use of individual-plot N-fertigation systems has allowed side-by-side comparisons of water-run N application with broadcast and side-dress treatments.
- Two replicated and randomised on-farm experiments have been established in year 2 near Moree and Gunnedah (NSW) with treatments imposed and in-season soil, plant and irrigation water sampling underway. Lint and seed yield measurements will be made within the plots, both by hand sampling and with commercial pickers. Both trials are investigating the potential benefits of using a nitrification inhibitor directly injected with anhydrous ammonia when applied at a range of N rates pre-plant.
- Soil P status has been assessed in archived samples from 5 long-term cotton tillage and rotation trials. Samples collected from both the beginning and end (or most recent sampling where the trials are on-going) of each trial were analysed according to outlined methodology.
- N and P uptake within the ACRI core site trials is also being assessed, as is N and P in irrigation water inflow and runoff from all the imposed treatments.

Initial Outcomes

- Irrigating to a 70 mm deficit (9 irrigations) increased lint yield and fertiliser N use efficiency, compared to irrigating to a 50 mm deficit (12 irrigations), despite the plants in the 50 mm deficit being taller and of greater biomass.
- A more-than-adequate supply of N from soil + fertiliser meant that varying the N application timing or N fertiliser product used did not affect lint yield or NUE, despite the plants in plots where more of the fertiliser N was applied early having taller plants.
- N loss in tail drain runoff was substantial from the water-run treatments, ranging from 23–31% of the fertiliser N applied as either ammonia, UAN or urea, compared to just 5–6% when urea was either broadcast or side-dressed prior to irrigation.
- Excess soil + fertiliser N remained in the soil profile as nitrate after picking, but had leached to between 30 cm and 60 cm depth.
- Soil P levels at four of the five long-term sites was adequate for continued cotton production without P deficiency, but over the years of the trials showed a declining trend towards lower levels at all depths to 60 cm.
- At the other long-term site, initial soil P indicated possible P deficiency for cotton, so fertiliser P was used during the trial, which had increased soil P by the conclusion of that trial.
- Crop rotation treatments at the P-deficient site appeared to affect final soil P levels, with legume-rotations showing the highest soil P increase.
Extending the outcomes

The project is providing a number of opportunities for the industry to connect with the ongoing findings outcomes. These include:

• Presentations at cotton industry and scientific conferences, including the Australian Association of Cotton Scientist Conference.
• Presentations at cotton industry grower workshops such as the 2018 CottonInfo Optimising Irrigation and Nitrogen Researchers Tour.
• Field days/farm walks at the trial sites.
• Support of two PhD positions through the University of Queensland and the University of Melbourne.
• Regular article contributions to the Spotlight on Cotton R&D magazine and CottonInfo e-newsletter.
• Updating of CottonINFO resource materials for growers.
• Scientific journal articles will focus on the key research questions in years 3-4.

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This project is supported through funding from the Australian Government Department of Agriculture and Water Resources as part of its Rural R&D for Profit program, the Cotton Research and Development Corporation and the NSW Department of Primary Industries. Research collaborators include the CSIRO, The University of Melbourne (nitrogen component), and The University of Queensland (phosphorus component).
Optimising nitrogen and water interactions in cotton

By better understanding how to optimise nitrogen (N) supply to cotton crops from organic matter in soil, this two-year project, led by the University of Southern Queensland, aims to build cotton grower’s confidence to change current practices in applied N fertiliser rates. Nitrogen mineralisation is dynamic and difficult to predict because microbial activity, responsible for mineralising soil organic N into plant available forms, is reactive to the extent of soil drying between irrigation or rainfall events.

The Research Questions

- How do N fertiliser formulations and wet-dry cycles affect within-season patterns of mineral N and dissolved organic N in the soil?
- How well can a rapid soil test, based on water extraction, quantify the pool of potentially available organic N?

Methodology

In the second and final year, two research trial plots have been established in overhead irrigated paddocks on a commercial cotton farm in Jondaryan (Queensland).

Key project activities at the trial sites include:

- Two fertiliser treatments (urea and DMPP-treated urea) and a zero-N control applied in 4 replicated plots;
- Soil samples taken from inside and outside 300 mm depth root-exclusion tubes after significant wetting events; and
- Field-moist soil analysed after sampling for water and KCl-extractable mineral N, and water-extractable total dissolved N.

Project achievements

- Monitoring of concentration and form of N sampled from within and outside root exclusion tubes placed within the fertiliser band was completed for the 2016/17 cotton season at both experimental sites. Soil samples were subject to chemical analyses and experimental data from the season was statistically analysed.
- Extension: Experimental results were presented at the Australian Association of Cotton Scientist Conference in Canberra in August 2017 and as a partner in the 2018 CottonInfo Optimising Irrigation and Nitrogen Researchers Tour.

Initial outcomes

- DMPP-treated urea significantly increased the concentration of ammonium-N recovered from soil samples from within the tubes. Throughout the season, nitrate-N concentrations were consistently higher for the standard urea treatment.
- No consistent yield benefits were observed with the use of N fertilisers treated with nitrification inhibitors. Low response to DMPP-treated urea may be explained by preferential uptake of nitrate. Further work into the physiology and mechanisms of NH$_4$/NO$_3$ uptake by cotton, as affected by fertiliser formulation, is therefore required.

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This project is supported by funding from the Australian Government Department of Agriculture and Water Resources as part of its Rural R&D for Profit program, the University of Southern Queensland and the Cotton Research and Development Corporation.
Increasing nitrogen use efficiency in dairy pastures

This project is aiming to increase nitrogen use efficiency (NUE) in dairy pasture systems where direct loss of N has been measured at levels as high as 40%. Previous farm scale work has suggested that small improvements in NUE can provide substantial productivity and profit gains for farm businesses. Past research in N cycling and loss processes have identified a number of options to increase NUE in dairy systems and this project is testing and validating a number of these opportunities. Led by Queensland University of Technology (QUT) and assisted by the NSW Department of Primary Industries (NSW DPI), the project has commenced to demonstrate how improved NUE practices, together with greater water use efficiency (WUE), can provide win-win opportunities for farmers in both environmental and business sustainability improvement.

The research aims

The project aims to test and validate practices to improve NUE and WUE whilst reducing the carbon footprint and increasing the productivity and profitability of Australian dairy farms. Research is:

- Investigating the interactions between nitrogen, mineralisation and irrigation management to develop best management practices (BMP).
- Increasing industry understanding of N losses, particularly from denitrification, and the potential for precision irrigation management to optimise NUE and WUE.
- Developing efficient strategies for reducing denitrification and total soil N losses and optimising synthetic fertiliser inputs.
- Producing recommendations for farmers detailing the optimal application timing and rates of enhanced efficiency fertilisers (EEFs) based on prevailing and climatic conditions.

Methodology

The project is conducting two key activities:

1. Establishment of two core replicated trial sites – one each in the subtropical and hot/dry dairy regions of NSW and several satellite farmer based demonstration and research sites:
   - The core sites have used existing research infrastructure operating at Casino (QUT) and Camden (NSW DPI) including variable rate irrigation, intensive soil moisture monitoring equipment and automated chambers.
   - The sites are providing a testbed for BMPs and accurate quantification of N loss pathways under a suite of different nitrogen, irrigation and EEF management practices.
   - Under different N treatments, determination is taking place of the key processes in N cycling (mineralisation, denitrification and total N recoveries) using $^{15}$N labelled fertilisers to trace N movements from soil and plant recoveries, and field based mass spectrometer readings. Pasture yield is being measured under each treatment.
   - Quantification of total denitrification losses ($N_{2}O$ and $N_2$) using highly enriched (99%) $^{15}$N fertiliser and total GHG’s using automated chamber technology.

2. Use data and process understanding from activity 1 to test potential BMPs and develop industry benchmarks for NUE by:
   - Measuring N cycling and efficiency over 2 years; and
   - Measuring agronomic efficiency with outputs in units of pasture DM/kg N/L water.
**Project Achievements**
In the first year several experiments have been completed examining the impact of irrigation on N losses in the subtropical and warm temperate dairy regions of QLD and NSW. The outcome of this research was presented at the project’s farmer field day held in November 2017 at the Casino trial. The topics of NUE, N losses, EEFs and remote sensing technologies were presented by the researchers.

**Initial Outcomes**
While research is still ongoing, initial results of 2017 indicated a clear threshold in soil water saturation at which losses of N accelerate, creating implications for improving both the optimal rate and spatial efficiency of irrigation. Interestingly, irrigation effects also carry-over to impact upon losses following rain events, emphasising the need to account for short-term rainfall predictions in irrigation scheduling.

**Extending the outcomes**
Findings will be disseminated to the research, industry and agronomy communities through scientific papers and conference presentations. Progressive outcomes are already being extended to farmers at on-farm field days as well as through the general media and Dairy Australia’s programs and resources.

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This project is supported by funding from the Australian Government Department of Agriculture and Water Resources as part of its Rural R&D for Profit program, Queensland University of Technology, Dairy Australia and the NSW Department of Primary Industries.
Quantifying the whole farm systems impact of nitrogen best practice on dairy farms

The dairy industry has used whole farm system analysis as a cost-effective research tool to assess the potential of a range of N management interventions on dairy farms. This capability can be confidently used to assess the value-proposition of research into new technology and practices at a reduced cost and time relative to field experiments.

Over the last 20 years average annual N fertiliser use on dairy farms has increased more than four-fold, now approximately 100 kg N/ha per annum to over 250 kg N/ha per annum on some farms. When all sources of N input are accounted for, higher stocked farms would be cycling between 400 and 600 kg N/ha annually. The average annual N usage cost per farm is approximately $40,000.

Although research has defined guiding principles for the rate, source, timing and placement of N, there has been little validation of these best management practices (BMP) at a farm systems scale. It is well known that local factors influence the efficiency of N usage, however the effects on production, profitability, N cycling, and N losses at the whole of farm system level have not been well quantified.

This project, led by the University of Melbourne, is using modelling to validate current N BMPs at both the component and farm system level. An important aspect of the work is testing of the current dairy industry’s “Fert$mart” guidelines in key dairy regions of Australia. The modelling approach is proving to provide an effective link between high level component research and end users such as farmers, service providers and commercial advisors across regions and varying farming systems.

Assessing the potential for improvement in N use efficiency (NUE) will assist the industry in achieving both productivity and environmental targets, including improvements in home grown forage consumption, water use efficiency, cost effectiveness and greenhouse gas emissions efficiencies.

The research hypothesis

The project aims to use farm systems analysis and modelling to validate recommended dairy N BMPs and undertake new research emanating from the broader More Profit from Nitrogen project.

The key hypotheses are:

- Current BMPs in the Fert$mart guidelines will improve productivity and NUE, while minimising environmental N losses, when implemented in a whole farm systems context;
- N fertiliser rates and timing of application can be targeted to pasture needs if the contribution of soil N mineralisation can be estimated, leading to improved NUE, better production and reduced environmental N losses; and
- Combinations of irrigation management, fertiliser timing and enhanced efficiency fertiliser (EEF) can lead to improvement in production, profitability and NUE at a farm systems scale.

Methodology

The project is undertaking the following key activities:

- Establishing farm system simulations to model potential interactions between soil N mineralisation, N application rates, soil and climate for the major dairy regions of Australia;
- Modelling the interacting influences of irrigation management, fertiliser timing and EEF on potential pasture production and NUE;
- Identifying best combinations of irrigation, fertiliser timing and EEF type at a farm systems scale for enhancing dairy farm profitability whilst minimising environmental N losses; and
- Using the resource pool of the broader project to seek input into model development needs and conversely providing evaluation and extension of component level research across regions and farming systems.

The project has used previous farm systems model simulations at Ellinbank and Terang (Vic), Elliott (Tas), Mt Gambier (SA) and Taree (NSW) in initial studies. New model simulations are being established in 2018 at the trial sites of other MPfN dairy research projects including Allansford (SW Vic), Camden and Casino (NSW).
Project Achievements

Two major modelling studies have been completed (explained below) resulting in the publication of a conference paper and two peer reviewed journal articles in the first 18 months. The project has also been involved in the delivery of a number of field days for farmers and conducted two workshops on modelling for researchers and service providers.

Initial Outcomes

The first study examined the effect of a range of N fertilizer rates on pasture production for five dairy sites through south-eastern Australia over 18 years, under both cutting and grazing regimes. For most sites and seasons, current BMPs of applying between 20 and 50 kg N/ha post grazing will ensure efficient use of N applied, assuming soil moisture is not first limiting growth. The modelling therefore validated the current BMPs for the rate of N to apply for both irrigated and dryland systems, from Tasmania through to central NSW. However, the modelling has questioned the application of N in summer and autumn under dryland conditions in southern Australia, showing almost zero response to autumn N in 6 of the past 18 years at Ellinbank and 10 of the past 18 years at Terang. Only 22% of years at Ellinbank achieved summer N responses close to the economic break-even of 6:1 (i.e. 6 kg extra DM per kg N applied), with a range of between 0:1 and 12:1. These very poor pasture responses to N fertiliser in summer are mainly due to deep soil water limitations. Figure 1 is a comparison of a dryland site (Ellinbank) and irrigated site (Elliott), showing the far greater variability (uncertainty between years) in N response at the dryland site, especially in summer and autumn.

The modelling has therefore highlighted the risk of following a fixed recipe for applying N, particularly in summer and through the dry autumn period.

The second study used the same five dairy sites to compare the practice of applying a flat monthly rate of N fertiliser to increasing levels of strategic approaches to determine the rate and timing of N fertiliser. The study has found that more tactical/strategic application of N within season was more likely to result in economic pasture production response (as shown in study 1), a significant reduction in N application rates, reduced N losses and increased NUE. Moving beyond this initial step of a more strategic N application approach, to using increasing levels of precision technologies may incrementally improve NUE further.

Figure 1. The 18-year average pasture growth rate response to N fertilizer (kg DM/ha/day) at Ellinbank, Vic (dryland) and Elliott, Tas (irrigated) over each of the four seasons. Boxplots show the variability between years, being 25% and 75% of years in boxed, with whiskers representing 10% and 90% of years.

Figure 2. Total dry matter production (top left: t DM/ha/season), N fertiliser rates (top right: kg N/ha/season), total N loss (bottom left: kg N/ha) and NUE (bottom right: kg DM/kg N fertiliser), comparing a flat rate of 40 kg N/ha per month (FR) with strategic approaches and technology to determine the rate and timing of N fertiliser at Ellinbank. Bar colours are from bottom to top – autumn, spring, summer, winter. Coefficient of variation of the annual totals are given above the bars.

(ZR= Zero N applied; FR = Flat rate after each grazing 40 kgN/ha dryland & 50 kg N/ha irrigated; Seasonally modified (SM) = strategic application based on paper 1; Precision agriculture soil (Ps) = 30 kg/ha applied when soil N <20 mg/kg in the top 15cm and not applied for at least 21 days; Precision agriculture - plant (Pp): as per Ps; except applied when leaf N drops below 90% of optimum; Optimal N daily - plant (Dp): as for Pp except N applied daily; Optimal N daily - soil (Ds): as for Ps except N applied daily)
Extending the outcomes
The outcomes of this project are being extended through the following channels.

- **Science**
  - Published scientific papers on validating existing BMPs and evaluating potential of digital technologies in improving NUE.

- **Industry**
  - Workshops with regional dairy coordinators to update them on N BMPs for regions and farming systems.
  - Presentation of research findings at dairy industry and science conferences.
  - Presentation and discussion of research to farmers and advisors at regional field days and through industry publications.
  - Updating of the Fert$mart guidelines and publication of a fact sheet on key changes for the dairy industry.

- **Service Providers**
  - Annual professional skill development workshop with modellers, dairy consultants and dairy extension officers to share and enhance their modelling skills.

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This project is supported by funding from the Australian Government Department of Agriculture and Water Resources as part of its Rural R&D for Profit Program, The University of Melbourne, Tasmanian Institute of Agriculture and Dairy Australia.
Improving dairy farm nitrogen efficiency using advanced technologies

The science of Nitrogen (N) cycling in dairy systems can be poorly understood by dairy farmers and their agronomy advisors. Consequently N supplied to the pasture through mineralisation, and the variation in this supply over seasons, is not considered in fertiliser decision making.

Undertaken by the University of Melbourne, this project aims to gain a better understanding of the amount of N supplied through mineralisation to dairy pastures under dryland and irrigated conditions in one of dairy’s largest producing regions, South West Victoria. The findings will be utilised to develop a tool for farmers and advisors which will reliably estimate mineralised available N so that N fertiliser inputs can be adjusted accordingly. New N assessment technologies will also be investigated. The outcomes will provide opportunities to reduce costly N fertiliser inputs, N loss to the environment, and increase profit.

The Research Questions

- How much N is provided to high rainfall zone dairy pastures through mineralisation, and how does this vary over the year?
- Can new technologies, such as colour (NDVI) and hyperspectral imagery be used to predict N requirements of the pasture?
- Do these new technologies correlate with readily available field based tests?
- What is the benefit of using an enhanced efficiency fertiliser (EEF) program?
- Does irrigation lead to more effective utilisation of and more production of soil mineralised N?

Methodology

1. Small plot field experiments are being conducted at a commercial dairy farm located at Allansford, South West Victoria on irrigated and dryland areas. The experiment includes 5 N rates, Enhanced Efficiency Fertilisers (EEFs) and urine treatments over a 2.5 year period. Biomass, soil mineral N, N response and infield 15N measurements, soil moisture and temperature, and climate conditions will be measured at both sites.
2. Laboratory experiments are also taking place to understand mineralisation and N2 production – using different techniques including 15N labelling of N pools- at the university’s facilities at Parkville.
3. A range of technologies for predicting N supply are also being tested (test strips, hyperspectral cameras, mineralisation calculation).

Initial Outcomes

The dryland pasture growing season in 2017 was from late April through to the end of November (7 biomass harvests). Irrigation enabled increased annual production, with 12 biomass harvests. Preliminary results show that autumn N response curves are very flat. Between 77 and 95% of the N utilised by the pasture in autumn was sourced from the soil mineral N pool and fertiliser recovery for the same period was low (20%). These results suggest that reducing N inputs at this time of year would have little negative impact upon the productivity of both systems as the majority of N is derived from mineralised N. Autumn biomass production was greater in the dryland plots than in the irrigated plots reflecting the greater amount of stored soil profile N (76 kg N/ha compared to 47 kg N/ha over 80 cm depth respectively at the end of April).

Extending the outcomes

The project is providing opportunities for dairy farmers, service providers and extension staff to connect with ongoing outcomes via workshops and field days conducted in collaboration with local Dairy Australia programs. Initial findings were presented at a conference in the USA in 2017 and ongoing research will inform further conferer publication opportunities.

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This project is supported by funding from the Australian Government Department of Agriculture and Water Resources as part of its Rural R&D for Profit program, The University of Melbourne and Dairy Australia.
Optimising nutrient management for improved productivity and fruit quality in cherries

Undertaken by the Tasmanian Institute of Agriculture (TIA), an integrated approach is being used in this project to quantify plant nitrogen (N) demand and cycling through the soil-plant-atmosphere system of cherry crops. Research outcomes will be used to develop best management strategies for N use to increase quantity and quality of cherry yields and mitigate loss to the environment.

Cherries are a significant deciduous tree crop grown in cool temperate climates of Australia. N is essential for cherry tree development, fruit production and quality. Presently, only limited data is available for Australian cherry growing regions on the relative importance of soil N processes, total N loss from current management practices and tree N requirements.

The project is using the $^{15}$N stable isotope to quantify tree N demand, soil supply and current practice N use efficiency (NUE) to develop best management practices (BMP) for optimising N fertiliser use, including biological fertiliser options. The project aims to maximise NUE in the Australian cherry industry to increase productivity, profitability and good environmental management.

The Research Questions
What is the fate of fertilizer N post application and how can uptake be optimized to improve NUE in cherry cropping?
What is the dynamic of N throughout the plant-soil-atmosphere system across multiple seasons?
What is the measured utilisation, availability and timing of N released from crop residues and soil organic matter (SOM) mineralisation?
How do various biological fertiliser technologies perform under field conditions?

Methodology

The project activities are primarily field-based and are conducted on two commercial farms in Tasmania.

1. $^{15}$N and plant residue field trials are located at Wandin Valley Orchards in Gretna, southern Tasmania on ‘Lapins’ cultivar:
   - $^{15}$N is being used to quantify the inter-annual dynamics of N through the different parts of the cherry tree and soil profile including uptake, storage, and remobilisation.
   - $^{15}$N is also being used to determine plant residue N contribution to mineralisation.
   - Manual chambers are collecting $^{15}$N-N$_2$O and CO$_2$ produced from the residues and comparison being made with zero residue treatments to determine nitrification, denitrification and decomposition rates in the soil.

2. Fertigation field trials:
   - The application of biological fertilisers through drip irrigation is being used to ascertain BMPs for optimal fruit quality outcomes. This work is being undertaken across two sites on trees of varying maturity: Trial 1 is on young trees located in a relatively new commercial orchard at Jericho (Midlands Region) and on 5-year-old bearing trees at the Wandin Valley Orchards site.
Project achievements

- $^{15}$N and fertigation applications for the first season at both trial sites have been completed.
- Soil and leaf sampling to monitor N concentrations and treatment influences, are being undertaken.
- $\text{N}_2\text{O}$ and $\text{CO}_2$ gas sampling from pre-harvest fertigation trials were completed in late 2017.
- Fruit quality assessments will be completed on 2017/2018 harvested fruit to determine the influence of N treatments on productivity, quality and shelf-life.
- The $^{15}$N content in fruit will be analysed to determine the sink strength of the fruit relative to vegetative growth and the impact of pre-harvest fertigation on fruit quality outcomes.

Initial Outcomes
The initial outcomes of the first season will be available for release in early 2018.

Extending the outcomes

- The project is working directly through a steering committee comprised of commercial growers and will hold partner forums to directly engage with industry partners.
- Project activities and outcomes are promoted and extended at events including regional and national conferences, industry workshops, seminars and farmer focused field days.
- Research findings are communicated in scientific journals, industry magazines and agricultural media.

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This project is supported by funding from the Australian Government Department of Agriculture and Water Resources as part of its Rural R&D for Profit program, The University of Tasmania (Tasmanian Institute of Agriculture) and Hort Innovation Australia. In-kind support is also provided by Cherry Growers Australia Inc.
More Profit from Nitrogen

Optimising nutrient management for improved productivity and fruit quality in mangoes

This project is led by the Northern Territory Government Department of Primary Industry and Resources (NT DPIR) in partnership with Queensland University of Technology (QUT). It uses an integrated approach to quantify plant nitrogen (N) demand and cycling through the soil-plant-atmosphere system of mango crops. Management strategies will be developed to increase the quantity and quality of mango yields, whilst effectively mitigating loss of N to the environment.

Mangoes are a significant tree crop grown in tropical and subtropical climates of Australia. N is essential for mango tree development, fruit production and quality. Presently, only limited data is available for Australian mango growing regions on the relative importance of soil N processes, total N loss from current management practices and profitable use of N in the plant.

The research will use stable isotopes to quantify plant N demand, soil supply and current practice N use efficiency (NUE) to develop best management practices for optimising N fertiliser use, including enhanced efficiency fertilisers (EEFs). The project aims to maximise NUE in the Australian mango industry to increase productivity, profitability and good environmental management.

The Research Questions

- What is the dynamic of N concentrations in the different parts of the tree crop plant-soil-atmosphere system across multiple seasons? Where does the applied N go, how can we reduce losses and use N to drive profitable outcomes for mango growers?
- What is the measured utilisation, availability and timing of N released from crop residues and soil organic matter mineralisation? What’s the contribution of N mineralisation to the total N demands of mangoes? How does this impact overall mango nutrition? How does this differ between the regions and soils?
- What technologies can growers use to access better information regarding N dynamics and seasonal availability to inform their decisions for a better economic outcome?
- What is the cost effectiveness of EEFs for NT mango soils under a range of temperature and moisture conditions?

Methodology

The project activities are primarily field research based, located at the Coastal Plains Research Station outside Darwin and Katherine Research Station, as well as a number of commercial orchards across the Darwin and Katherine growing regions of the Northern Territory. Research is actively underway under the two following primary activities:

1. $^{15}$N and plant residue field trials:
   - Labelled fertiliser $^{15}$N is being used to quantify the inter-annual dynamics of N through the different parts of the mango tree and soil profile including uptake, storage, and remobilisation.
   - $^{15}$N is also used to determine plant residue N contribution to mineralisation.
   - Loss pathways are being measured with semi-automated chambers to collect N-N$_2$O, CH$_4$ and CO$_2$ produced from the residues and comparison analysis undertaken with a zero residue treatments to determine nitrification, denitrification and decomposition rates in the soil.

2. Field performance of EEFs and laboratory research:
   - Soils from mango orchards across Darwin and Katherine regions have been sampled.
   - Incubation experiments are testing the performance of a range of EEF’s for these soils under controlled laboratory conditions at QUT’s Institute for Future Environments, located in Brisbane.

Pictured:
NT DPIR mango NUE research team.
Project Achievements

- Research completed to develop and test a method for whole tree biomass harvests to trace N concentrations through mango tree parts. Subsequently, $^{15}$N labelled mango trees have been harvested to measure the above and below-ground biomass, quantify the amount of N derived from fertiliser and soil, and estimate the NUE of mango.
- Research completed to develop and test a method to infuse N directly into mango stems to achieve a high $^{15}$N enriched mango biomass that will be used for future decomposition studies.
- Initial field work in sampling mango soils in the Darwin and Katherine regions has been used for laboratory based incubation experiments including the performance of different EEFs.
- Studies have commenced into:
  1. Quantifying litter fall in mango; and
  2. Understanding plant available N forms (nitrate and ammonium) in the feeder root zone of soil.
- Establishment of first season of plant residue decomposition and soil N movement experiments as part of a PhD project.
- Two years of collaborative research has been undertaken with the University of New England to test if remotely sensed images can be used to predict orchard variability, and preparing mango growers for precision technologies.

Initial Outcomes

- Repeated whole tree extraction and partition is assisting to increase understanding of NUE, and the role of N in mango, by comparing the total N recovery in different tree parts, annual and inter-annual dynamics of N and differences between rates of N applied.
- Stem infusion is characterising N content and movement within mango trees at critical developmental times. It is helping to provide baseline data relative to current grower fertilisation practices.
- Litter fall measurements are contributing to the mango phenology calendar by capturing the impact of growers’ practices on recycling of nutrients on the overall nutrition of mangoes.
- Better understanding of NT mango soil physiochemical characteristics, coupled with evaluations of EEFs through incubation experiments, is providing valuable information to inform the project’s final recommendations on suitable N fertiliser forms for mango production.
- Mapping and remote sensing research is improving understanding on how the industry may benefit from a range of technology and expertise of partners in the greater MPfN project. These partners may have capability to deliver decision support tools to growers in the future.

Extending the outcomes

- In 2017, project research was presented at the Australian Mango Industry Association conference, Bowen, Queensland, and the International Mango Symposium, Guangxi, China.
- The project works with a reference group of commercial growers and produces periodic project updates which are distributed directly to mango growers.
- Project activities and outcomes are promoted and extended at events including regional and national conferences, industry workshops, seminars and farmer focused field days.
- Research findings are communicated in scientific journals, industry magazines and agricultural media.

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This project is supported through funding from the Australian Government Department of Agriculture and Water Resources as part of its Rural R&D for Profit program, the Northern Territory Government Department of Primary Industry and Resources, Queensland University of Technology’s Institute for Future Environments and Hort Innovation Australia.
In-kind support is also provided by the Australian Mango Industry Association Inc.