Sugar Research Australia

Milestone Report 15a

Final Report

Project Title:	Nitrogen fertiliser requirements for representative soils of the Lower Burdekin cane growing district
Project Number:	RP20/14C
Chief Investigator:	Julian Connellan
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Statistical analyses of data presented in this report was provided by Dr Vivi Arief, Research Officer, The University of Queensland.

This project was originally conceived by local Burdekin canegrower Mr David Defranciscis who along with other industry representatives approached the Department of Environment and Heritage Protection to fund a number of trials across the Burdekin. Throughout the project Mr Defranciscis provided support and assistance has been greatly appreciated. In the later stages of this project Mr Defranciscis devoted considerable time and effort to promoting the outcomes of this work and was the major driver for the delivery of the findings to the sugarcane industry in the Burdekin.

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Summary of key findings

The SIX EASY STEPS guidelines aim to achieve both productive and profitable outcomes for Australian sugarcane growers, while limiting the loss of nutrients from sugarcane farms. In 2009, regulations were introduced that were derived from procedures outlined in the SIX EASY STEPS method to determine nitrogen inputs. After concern was expressed about the impact of the regulations on sugarcane production, the project 'Nitrogen fertiliser requirements for representative soils of the Lower Burdekin cane growing district' was conceived to validate the SIX EASY STEPS method to determine appropriate nitrogen (N) application rates. Since the beginning of the project in 2011, 23 large-scale strip trials were established on commercial sugarcane farms in the Burdekin Delta and the Burdekin River Irrigation Area (BRIA).

The trials were setup to compare the performance of the SIX EASY STEPS N rates (DYP 150 and DYP 180) with higher N rates (grower N rate and high N rate) that were generally applied by local farmers. To enable successful comparisons, a multitude of data were collected from trial sites throughout the project and included:

- General plant growth and pest pressure
- Plant nutrient status via leaf analyses
- Sugarcane biomass accumulation
- Irrigation water quality
- Soil mineral nitrogen pre planting and post-harvest
- Sugarcane yield, commercial cane sugar (CCS) content and calculated sugar yield.

Analyses were completed to determine whether differences in production and profitability were statistically significant. Significance implies confidence that differences in production or profitability between the treatments is due to the amount of N applied. Three types of statistical analyses were undertaken: (1) for each crop harvest; (2) for all crops harvested from each site over a crop cycle, and; (3) for all crops harvested across all sites.

Production results for each crop harvested identified two sites/years where there were significantly higher cane yields at N application rates greater than that recommended by the SIX EASY STEPS method when using the district yield potential (DYP) of 180 tonnes cane per hectare (tch). In both cases only one crop class at each of the two different sites (2nd and 4th ratoon) showed responses to N rates above that recommended by the SIX EASY STEPS method. At one of these sites there was a significant decline in CCS and as a result there was no significant difference in tonnes of sugar produced per hectare. At the other site, the Grower and High treatments produced significantly more cane and sugar than the SIX EASY STEPS treatments. The reason for this response was not clear and warrants further investigation.

When examining each site over all crop classes, five of the twenty-three sites showed that the High and/or Grower N rate treatments had significantly higher cane yield than the DYP 150 treatment, but not the DYP 180 treatment. Six sites showed that the DYP 150 and/or DYP 180 treatments had significantly higher CCS than the High treatment, and in some cases the Grower treatment. There were no consistent trends found with sugar yields.

Analysis of data pooled overall sites over all crops classes showed that the Grower and High N rate treatments had significantly higher cane yields than the DYP 150 and DYP 180 treatments (1.8 and 4.5 tch respectively). However, the Grower and High N rate treatments had significantly lower CCS than the DYP 150 and DYP 180 treatments (0.3 and 0.2 units respectively). Although there was a response to N application rates above that recommended by the SIX EASY STEPS method the associated decline in CCS had a negative impact on potential sugar yields and as a result there were no significant difference in sugar yields between the DYP 180 N rate treatment and the Grower and High N rate treatments. The DYP 150 N rate treatment produced significantly less (0.3 tsh) sugar than the DYP 180, Grower and High N rate treatments.

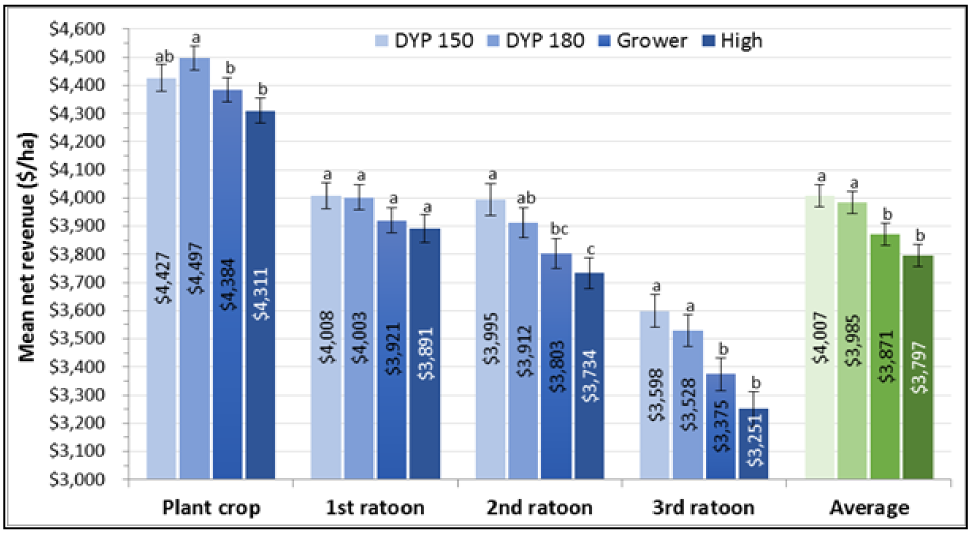
Economic analysis was undertaken to compare the profitability of the different N rate treatments in each crop, at each trial site and across all trial sites.

To quantify the economic benefit accruing to the grower, gross revenue was calculated from production data, while subtracting costs that varied between the treatments, such as fertiliser and harvesting costs. This method ensured the treatments were compared on an equitable basis.

While there was variation between years and sites, the economic results indicated that the SIX EASY STEPS treatments maximised profitability in the vast majority of cases. For example, a SIX EASY STEPS treatment attained the highest mean profitability in 86% of the harvested crops. This is further evidenced, when comparing the profitability of each treatment over all crops harvested from each site. A SIX EASY STEPS treatment achieved the highest mean profitability at all sites that had more than one crop harvest, although results from only two sites reached significance.

An analysis was also undertaken that drew upon all the economic data from all the sites. This evaluation showed that both of the SIX EASY STEPS treatments were significantly more profitable than the higher N rate treatments (see graph below). Importantly, the relative performance of each N rate treatment changed between crop classes. Nevertheless, the higher N rate treatments had lower mean profitability during every crop class, which suggests a negative relationship between profitability and the amount of N applied above the SIX EASY STEPS guidelines.

This project has validated the SIX EASY STEPS method for determining appropriate N application rates in the Lower Burdekin cane growing district.



Above graph taken from report (see Figure 41).

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1 Introduction

In October 2009, the *Great Barrier Reef Protection Amendment Act* was passed by the Queensland Parliament under the *Environmental Protection Act of 1994*. The amendment was aimed at reducing the risk of nutrients, chemicals and sediments from farming activities reaching the Great Barrier Reef lagoon. In order to achieve their objective in the sugar industry, the Department of Environment and Heritage Protection (DEHP), formerly the Department of Environment and Resource Management (DERM), decided to regulate the method for determining nitrogen (N) and phosphorus (P) inputs for sugarcane production in all areas from the Plane Creek mill area northward.

In response to the introduction of the regulated method for determining N input which is derived from procedures outlined in the SIX EASY STEPS (Queensland Government 2009), some canegrowers in the Burdekin district (which produces approximately 25% of Queensland's sugarcane) expressed concern that sugarcane yields could be negatively affected by the permissible N application rates. Sugarcane growers and Wilmar (the milling company that operates in the Burdekin region) were also of the opinion that additional research was needed to ensure that any regulated N application would not compromise the profitability and/or supply security of the local sugarcane industry.

As a result, DEHP contracted Sugar Research Australia (formerly BSES Limited), to undertake a series of demonstration trials (Project No. RP20C) across the Burdekin district to determine the adequacy of the regulated N for sugarcane production. Sugar Research Australia (SRA) initially established 15 replicated and randomised large-scale strip trials on the major soil types found in the Burdekin region to demonstrate to growers that by following the SIX EASY STEPS method to determine the appropriate N application rate they would be able to maintain productivity and improve profitability. Ten trial sites were established in 2011, three were established in 2012, one was established in 2013 and four were established in 2014. With the extension of the project as RP20/14C another four sites were established in 2015.

This project was overseen by a technical management group (involving SRA and the Department of Science, Information Technology and Innovation (DSITI)). The technical management group was responsible for ensuring that the research was conducted in a scientifically sound manner.

The replicated strip trials were located on commercial farms in the Delta area and in the Burdekin River Irrigation Area (BRIA), so that the major soil types in each area was represented in the project. The sites were selected after considering a number of factors such as block size, shape, soil uniformity, irrigation systems employed and pest control measures. Consideration was also given to yield history of the blocks.

The profitability (net revenue) of each N application rate treatment has been calculated for each crop harvest and for the complete crop cycle and presented in this report. Also, the profitability of each rate across all trial sites has been evaluated. The optimum N application rates that maintain the profitability of sugarcane production were identified.

2 Method

2.1 Strip trial site establishment

At the beginning of the project, protocols were developed in partnership with the Department of Environment and Heritage Protection (DEHP). These protocols provided guidelines on research activities which have taken place since the beginning of this project (refer to Appendix 1).

Sites were initially identified through contacts made at grower group meetings, via local grower David Defranciscis and through the local cane grower organisations such as Canegrowers, Burdekin. Once sites were identified a site inspection was undertaken with the grower to determine if the site was a prospective candidate for the trials.

Once suitable sites were identified they were mapped using electrical conductivity resistivity measurements (Veris 3100). These maps were used to provide a general guide to changes in soil type and salinity/sodicity levels across blocks. This information was used to develop comprehensive soil sampling strategies for each site. Potential trial sites were broken up into zones and soil sampled independently according to the results of the EC survey by the Veris 3100. Soil samples were collected to a depth of 1 metre in each zone, with sub-samples from 0-20 cm, 20-40 cm, 40-60 cm, 60-80 cm and 80-100cm depths being collected (Figure 1.) and analysed for nutrient status separately. The results of the analysis from each zone for the 0-20cm samples were put through the SIX EASY STEPS method to determine if there was any significant change in the recommended nitrogen application rate for each zone.

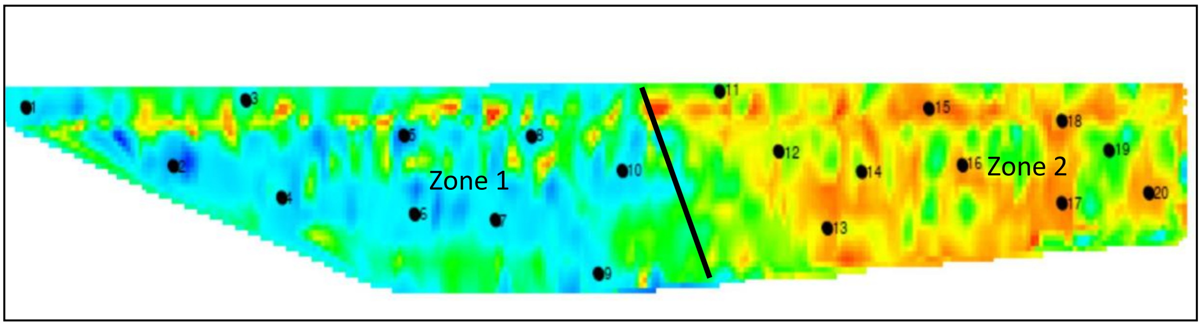

Figure 1: A 'soil' map generated from the electrical conductivity / resistivity measurements showing identified zones and soil sampling points

Generally fertiliser (approx. 50 kg N/ha) was applied to each trial site during the planting process by a planter box which was owned by the grower or supplied by a contractor. The planter boxes were calibrated at each site to determine the amount of nitrogen applied at this stage of crop establishment.

Figure 2: Calibration of a planter box

In most cases prior to row closure strips were established using a fertiliser box supplied as part of the project, however at several farms due to farming practice growers own equipment was used to establish the strips. For each treatment the fertiliser boxes were recalibrated to apply the desired rate of nitrogen via granular fertiliser.

Figure 3: Fertiliser box supplied as part of the project being used to establish strips

The fertiliser box supplied as part of the project also had load cells allowing for a record of the amount of product applied (kg) to each strip. This allowed for a comparison to the calibrated rate and in some cases was used to identify equipment malfunctions or errors in calibration calculations, which would otherwise be undetected when using standard fertiliser boxes.

At one trial site (Site 22) which is located in the Clare area of the Burdekin, Liquid One Shot fertiliser products were used at planting and approximately three months following planting to establish the trial. These products were supplied by Wilmar specifically for the trial and at no cost to the grower.

Figure 4: Liquid One Shot fertiliser products applied at planting (left image) and again 3 months following planting (right image).

Over the period of the project factors such as crop establishment, irrigation management, and pests and disease management were monitored and recorded.

From planting, water samples were collected and tested for nutrient content by DSITI. Water is sourced from bores or a channel system for the trial sites. In the Delta, water sources are generally bores, and in the BRIA, generally channels. However, in both areas a mixture of both water sources are sometimes used.

Information gathered from soil analyses were used to establish the treatments/nitrogen rates for individual sites.

Each trial contained three or four N treatments which were randomised and replicated three or four times.
The treatments include:

- Treatment 1: An N application rate based on a District Yield Potential of 150 tch (only applied to the 10 sites established in 2011 and some ratoon sites in 2015) for the particular soil type

- Treatment 2: An N application rate based on a District Yield Potential of 180 tch for the particular soil type

- Treatment 3: An N application rate comparable to that traditionally used by growers

- Treatment 4: A higher N rate than treatment 3.

Site and treatment information was used to design a randomised trial layout for each of the twenty three sites.

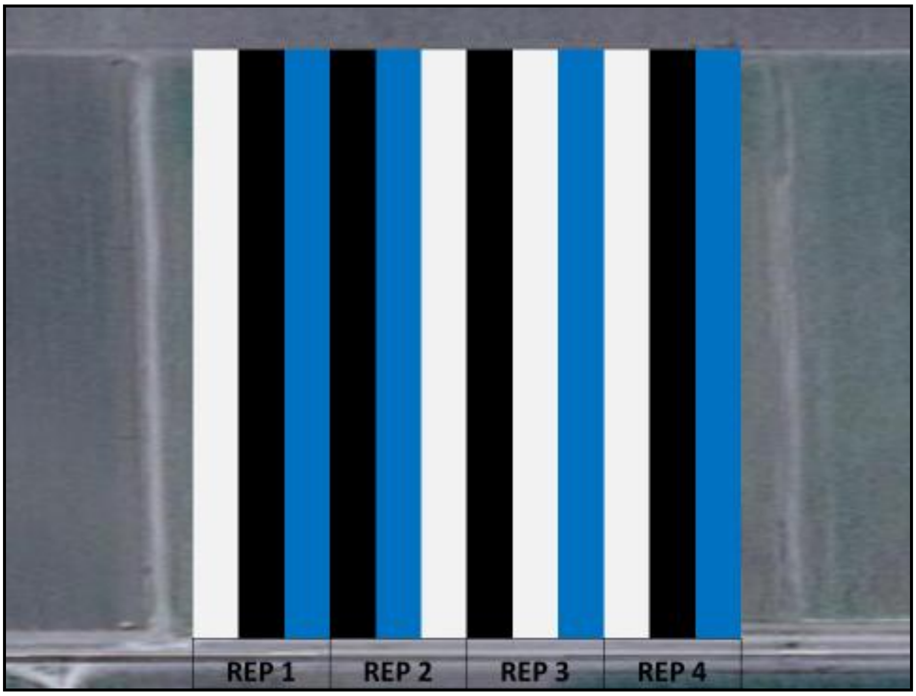

Figure 5: Google earth image of a trial block overlaid with a typical trial design

The number of sites established in each area over the duration of the project is shown in Figure 6.

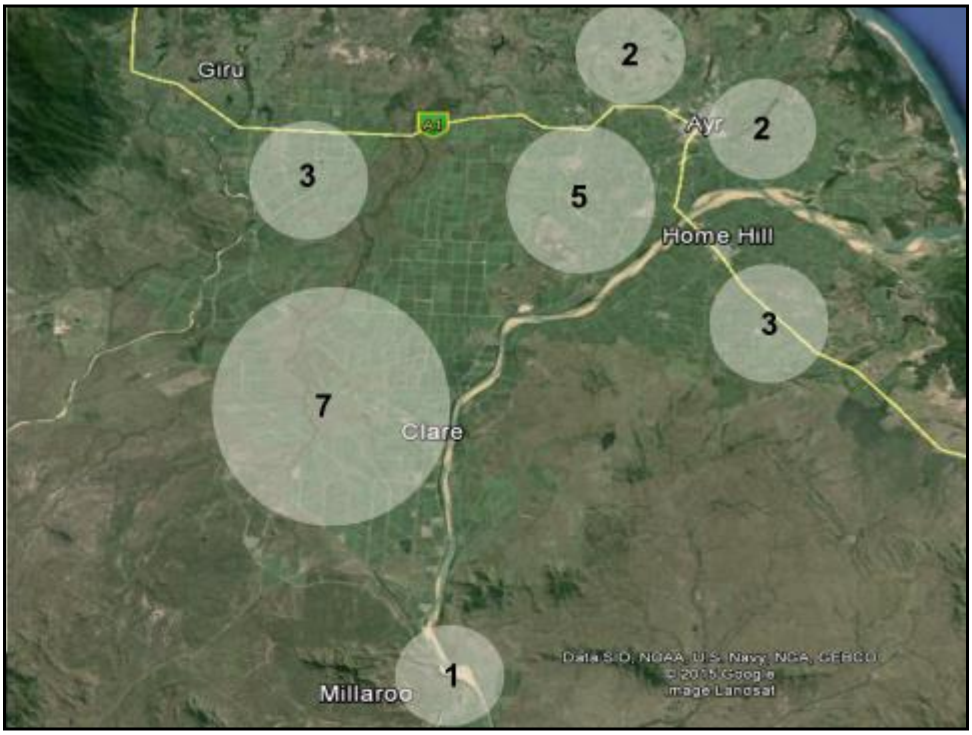

Figure 6: Approximate location and number of trial sites established in each area

Following the establishment of the sites the following parameters were monitored over the duration of the project:

- General plant growth and pest pressure
- Plant nutrient status via leaf analyses
- Sugarcane biomass accumulation
- Irrigation water quality

- Soil mineral nitrogen pre planting and post-harvest
- Sugarcane yield, commercial cane sugar (CCS) content and calculated sugar yield.

2.2 Small plot trial establishment

In order to better understand the sugarcane crop N requirements and how it's partitioned within the plant at various stages of development, a small plot trial was established on an SRA farm in the Burdekin. This trial was established in addition to the strip trials undertaken on local farms. The protocols for establishing and sampling this trial are included in Appendix 2. A paper was developed from data collected and published by the Australian Society for Sugarcane Technologists (ASSCT) in 2016 (see Appendix 5). As part of this work a second paper is currently in development and will investigate the accumulation of macronutrients at various stages of crop development in the above and below ground biomass.

Figure 7: Small plot trial biomass assessment at 6 months after planting

2.3 Calculating a partial nitrogen budgets

A partial nitrogen budget can be used to account for the major inputs and outputs from a block or farm. It can be used to identify where there may be excessive N applications and can be used to develop a better understanding of crop N requirements. For example a nitrogen budget is considered to be in balance where inputs and outputs are equal, however, if N inputs exceed crop requirements then losses to the environment are likely.

By utilising data obtained from plant biomass sampling at nine months following planting/ratooning, and knowing nitrogen inputs such as the initial soil mineral nitrogen pool, kilograms of nitrogen applied as fertiliser and the amount of mineral nitrogen remaining in the soil profile following harvest, a partial nitrogen budget (Figure 8.) can be developed for sugarcane over a number of seasons for a range of varieties and crop classes. This can be used as a tool to improve the understanding of the fate of nitrogen in sugarcane.

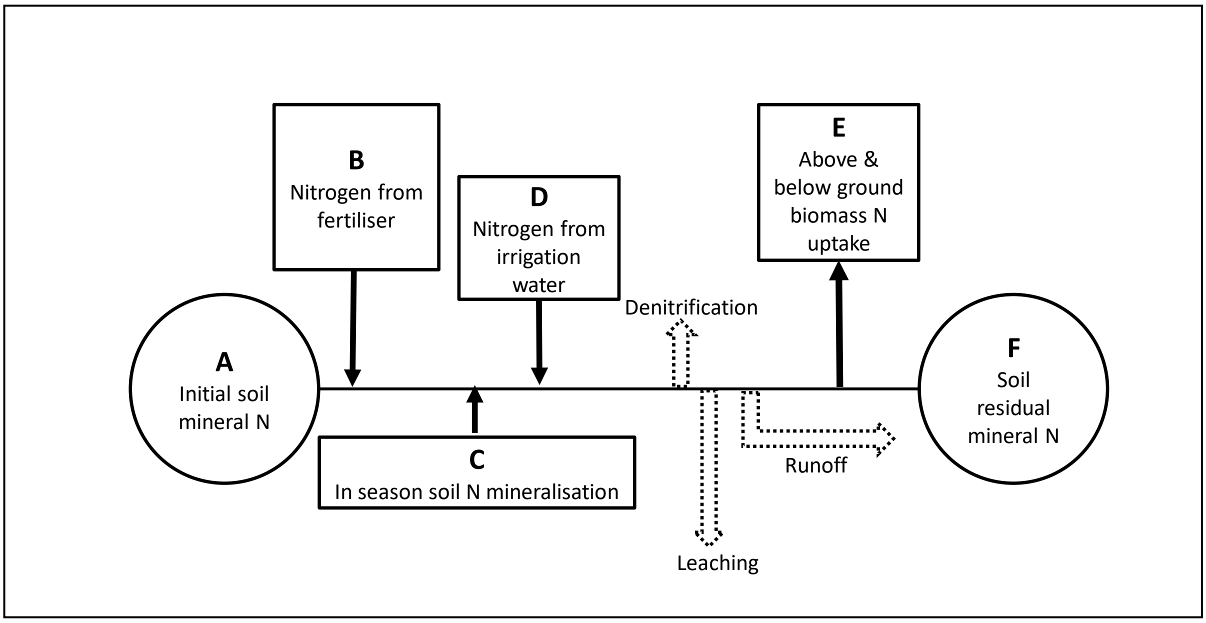

Figure 8: Nutrient inputs and outputs for a partial nitrogen budget for sugarcane grown in the Burdekin

The input components of the partial nitrogen budget are:

1. Initial soil mineral N **(A)** – determined by taking soil samples prior to planting and calculating the total amount of nitrate N (kg/ha) and ammonium N (kg/ha) in the top 60cm of the soil profile.

2. Nitrogen from fertiliser **(B)** – Kg N applied/ha.

3. In season soil mineralisation **(C)** - the SIX EASY STEPS estimate of soil N mineralisation potential based on Walkley-Black organic C (0-20cm).

4. N in irrigation water **(D)** - water samples were collected from all sites over the crop cycle, these samples were tested for oxidised N. The amount of irrigation water applied to each site was not captured as part of this project, however an average figure of 10 ML which is a typical volume applied per hectare over the growing season is used along with the water sample results from each site to estimate the contribution of N to the crop from irrigation water.

The output components of the partial nitrogen budget are:

1. Crop N uptake **(E)** – this is the amount of nitrogen captured by the above and below ground crop biomass. The measurement of above ground biomass took place when the crop was approximately nine months of age, at which point the crop had accumulated the maximum amount of N required for crop development. Below ground biomass is based on an estimate from the findings of Connellan and Deutschenbaur, 2016 (Appendix 5).
2. Soil residual mineral N following harvest (F) – soil samples were collected from treatments at each site and nitrate and ammonium N in the top 60cm of the soil profile was measured.

2.4 Leaf analysis

Leaf analysis is the method of choice to enable growers to check on the adequacy of fertiliser recommendations by checking the nutrient status of the plant when it is between 3 and 7 months of age. This information is then used to identify if any remedial actions are required to correct any problems found within the season, or provide guidance to adjust fertiliser rates the following season.

Leaf samples (third leaf) have been taken according to SRA leaf sampling guidelines over the duration of the project. Samples were taken from all trials sites and each treatment. Results are presented in Appendix 3.

2.5 Economic analysis

A crucial requirement of the economic investigation is to take into account all variables that impact on the profitability of each N rate treatment. A fundamental variable in this study is cane yield. By applying higher quantities of N, growers expect to attain higher yields to increase revenue. Another central variable is CCS, cane with a higher CCS content delivers relatively higher revenues for the grower. However, variables associated with revenue are not the only variables that impact on the economic outcome. Fertilising costs, harvesting costs and levies also impact on the profitability of different treatments. Higher fertiliser rates require a relatively higher spend for growers and are examined accordingly. Harvesting costs and levies are influenced by each treatment's particular combination of cane yield and CCS. A benefit of growing cane with comparatively higher CCS content is that harvesting costs and levies do not increase proportionately, unlike growing cane with comparatively higher yields. This interaction affects the relative cost and profitability of each treatment for the grower. For this reason, both harvesting costs and levies are included in the investigation, in addition to fertiliser costs.

For this economic analysis, the inclusion of the aforementioned variables is necessary to accurately evaluate the impact on grower profitability. In particular, the analysis of production data and applicable costs at the replicate scale is required to ensure a true representation of treatment profitability and to account for variability. The cane yield and relative CCS measures used to calculate net revenue were obtained from mill data for each replicate.

To quantify the relative economic benefit accruing to the grower, this report applies a method that has been used consistently in past literature to calculate the net revenue or 'partial net return'[1] from applying each of the N rate combinations. This method first involves calculating the payment a grower receives for one tonne of cane under the current cane payment formula for the Burdekin (see Equation 1 - Mackintosh, 2000). The result is then multiplied by the number of tonnes yielded per hectare to calculate gross revenue on a per hectare basis (see Equation 2). In order to compare the economic efficiency of each N rate, the gross revenue net of harvesting costs, levies and the cost of fertiliser is calculated for each replicate (see Equation 3). Accordingly, Equations 4 and 5 describe the methods used to calculate harvesting costs plus levies and fertiliser costs. Equation 6 presents the formula to calculate relative CCS. The N rate treatment with the highest of the resultant calculations is deemed to have the greatest economic benefit.

[1] For instance, Schroeder, Hurney, Wood, Moody and Allsopp (2010) compared returns relating to the application of nitrogen under the SIX EASY STEPS guidelines and the usual nutrient practice of a grower. The same method was also used in later papers to compare the economic efficiency of several different nutrient practices (Schroeder, Moody, & Wood, 2010; Skocaj, Hurney, & Schroeder, 2012).

Equation 1: cane payment formula = (sugar price x 0.009 x (relative CCS – 4)) + mill constant

Equation 2: gross revenue ($/ha) = cane payment formula x cane yield (tch)

Equation 3: net revenue ($/ha) = gross revenue ($/ha) – [fertiliser cost ($/ha) + harvesting costs ($/ha) + levies ($/ha)]

Equation 4: harvesting costs plus levies ($/ha) = cane yield (tch) x (harvesting cost + levies ($/t))

Equation 5: fertiliser costs for each product ($/ha) = current price of fertiliser product ($/kg) x fertiliser rate applied (kg/ha)

Equation 6: Relative CCS = Actual CCS – daily pool CCS + seasonal pool CCS

A number of other parameters need to be estimated to carry out the economic analyses. To focus the analyses on the specific changes in question, the prices listed below are standardised so the results are not influenced by short term changes in prices.

The economic analysis uses the five-year average net sugar price between 2011 and 2015, which is likely to be almost equal to the 2012-16 average given that the 2016 forecasted price (~$515 per tonne[2]) is very similar to the 2011 price ($518 per tonne). A five-year period corresponds to the length of an average crop cycle (plant to 3rd ratoon plus fallow). This is important given that growers would not plough-out their crops after one year to chase high sugar prices due to high planting costs and contracts with millers. All input prices (e.g. fertiliser and chemical) were sourced from local suppliers.

The following information outlines some assumptions required for the analysis:

- Sugar price = $424/tonne of sugar
- Harvesting cost + levies = $7.30/tonne + $0.81/tonne = $8.11/tonne of cane
- Mill area constant[3] for the Burdekin = 0.662

Apart from taking into account differences in harvesting costs, fertilising costs and levies, the analysis assumes that all other variable growing expenses, such as those expended on cultivation, planting, irrigation, pest control and fixed growing expenses, are the same for all fertiliser rate treatments. The collection of data on these aspects of the production system would be useful to explain differences between trial sites (e.g. quantity of irrigation water applied). Unfortunately, the inclusion of this data was not possible in this project but should be an objective for future research.

2.6 Economic risk analysis

It is critical for farm managers to consider commodity and input prices when making fertiliser management decisions. For example, over the course of the trials (2011-16) the sugar prices that Queensland cane farmers received for their sugar fluctuated within a certain range. In 2011, the sugar price rose to $518 per tonne, while in 2015 the price fell to $382 per tonne.

Consequently, sensitivity analyses were undertaken to explore if the economic outcomes in the trials were sensitive to fluctuations in the price of sugar and fertiliser. Given the variations in the sugar

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[2] QSL Harvest pool - Queensland Sugar Limited (June, 2017) QSL Pool Price Matrices - 2016 Season. Retrieved from: http://www.qsl.com.au/pricing/pricing-products/2016-season/qsl-pool-price-matrices-2016-season#harvest_pool_2016

[3] The mill constant is needed to calculate the cane price using the cane payment formula.

price that were discussed above, the boundary conditions for the sugar price sensitivity analysis were set at \$380 (minimum) and \$520 (maximum) per tonne.
However, the rolling five-year average sugar price over the past 20 years has ranged between \$270 and \$452 per tonne, so the likelihood of attaining a five-year average price above \$450 is low.

Considering the trial sites were fertilised between 2011 and 2015, monthly urea price data during this time period was used to determine the sensitivity of the economic outcomes to fluctuations in the fertiliser price. Specifically, the analysis compares the 2015 average urea price with the minimum and maximum prices for urea between 2011 and 2015 to determine the percentage differences. In April 2014 the urea price was 13% lower than the 2015 average, while in May 2012 it was 38% higher. Consequently, the range set for the fertiliser price sensitivity analysis was between 85% and 140% of the fertiliser price in 2015.

2.7 Statistical analysis

A statistical analysis of the production and economic data observations has been undertaken to examine whether there is a statistically significant difference (e.g. in sugar yield or net revenue) between the various nitrogen rate treatments. Three different types of models were used to carry out the analyses using the ASREML-R package. Table 1 describes the specific models employed for each type of analysis, while Table 2 outlines the purpose of fitting each parameter into the models.

The null hypothesis assumes that, on average, the mean values (e.g. sugar yield or net revenue) of all the treatments are equal. To test the null hypothesis for the crop class and trial site analyses, F-tests were employed to assess whether the mean value of any N rate treatment was significantly higher or lower than any of the other treatments at a 5% significance level (α=0.05). For the analysis of all trial sites, Wald tests were used to test the significance level of the fixed terms at a 5% significance level. Furthermore, pairwise comparisons were carried out by comparing the means of each treatment together with the 95% least significant difference (LSD) using the Bonferroni procedure to correct for multiple comparisons.

Treatment means for each analysis have been graphed along with 95% LSD bars to visually display treatment variability. Letters (a, b, c, etc.) have also been positioned above each 95% LSD bar to indicate statistical significance. These are assigned based on the results of the Bonferroni adjusted LSD tests. Common letters indicate that differences in mean values between the particular treatments are not statistically significant and vice versa.

Table 1: Description of analyses and models

<table>
<tr><th></th><th>Trials/crops examined</th><th>#</th><th>Model</th><th>Fitted model function</th><th></th></tr>
<tr><td>I.</td><td>Each crop class</td><td>33</td><td>ANOVA (fixed)</td><td>$y \sim \mu + R + N + e$</td><td rowspan="3">Where:
y= cane yield, CCS, sugar yield or net revenue
R= replicate
N = treatment
T = trial
C = crop class
e = residual</td></tr>
<tr><td>II.</td><td>Each trial site[4] - including all crops from the site</td><td>12</td><td>Split-plot across time (fixed)*</td><td>$y \sim \mu + R + N + NR + C + CR + NC + e$</td></tr>
<tr><td>III.</td><td>All trial sites - including all crops from all sites</td><td>1</td><td>Split-plot across time and space (mixed model[5])*</td><td>$y \sim \mu + T + R(T) + N + NT + NR(T) + C + C(T) + CR(T) + NC + NC(T) + e$</td></tr>
</table>

* For models II and III, a first order autoregressive model was fitted to take into account yield relationships that might occur over successive crop classes. For six of the trial sites the residual was not modelled as modelling trials with data from less than two ratoon crops causes' singularities.

[4] Some sites cannot be analysed with a multi-crop model as data was only collected from one harvest.
[5] Crop class, treatment and crop class x treatment were fitted as fixed effects, while trial and replication were fitted as random effects.

Table 2: Purpose of model parameters

Model parameters	Purpose - to account for variability attributed by:
Replication	• Placement of plots in the field (spatial effects[6])
Treatment	• Nitrogen rate effects
Crop class	• Time effects[7]
Trial	• Environmental factors at each trial site (e.g. soil type, management practices)
Parameter x parameter	• Interactions between two parameters. For example ○ NR - nitrogen rate performance in each replication ○ CR - spatial and time interactions ○ NC - nitrogen rate performance in each crop/ period ○ NT - nitrogen rate performance in each trial
Residual	• Any remaining variability (e.g. model II. = Crop x Treatment x Replication)

2.8 Limitations

While every action was taken to ensure that the highest quality standards were maintained, some aspects of the trials do have limitations. A key limitation of carrying out strip trials on commercial sugarcane farms is the number of plots (or strips) available for the trial. For example, each plot has to be of sufficient size to ensure the mill is able to measure the CCS level of the harvested cane.
Depending on the size of the paddock, this may limit the number of plots available across a cane paddock for the trial. Plot availability influences the design of the trial, particularly around the quantity of treatments and replicates available for investigation and subsequent statistical analysis. Given that the quantity of treatments and replicates influences degrees of freedom, care should be taken when interpreting the individual crop statistical results at some of the trial sites. Importantly, degrees of freedom tend to increase when analysing data across multiple harvests and trial sites.

[6] For example, effects from variations in soil type and drainage.
[7] Includes a range of effects brought about by climate variations between years as well as accumulated damage from harvesting and pests.

3 Background information

3.1 Burdekin soils

A range of soil types exist in the Delta and Burdekin River Irrigation Area (BRIA). A requirement of this project was that the major soil types were to be included to ensure that findings of this project were applicable to all sugarcane growers in the Burdekin. The soil groups (and soil types) and the sugarcane area they represent in the Burdekin are listed in Table 3.

Table 3: Soils groups included and the cane growing area they represent in the Burdekin.

Area	Soil group/order	QDPI Soil Types*	Area (ha)	Number of trial sites
BRIA	Vertosol	2Ugd	5233	4
	Sodic Duplex	2Dyb	4491	3
		6Drc	2045	3
	Non Sodic Duplex	6Dbg	1010	1
Delta	Dermosol	BUfc	10747	3
		BUmd	1354	1
		Cufc	1354	1
		Bufb	2807	2
		BGnb	188	1
		BGnc	279	1
	Vertosol	RUgb	6354	2
		RUgd	849	1

QDPI soil type descriptions sourced from the Queensland Government Soils Globe.

3.2 Soil organic carbon levels pre-planting

A critical component of the SIX EASY STEPS method for determining nitrogen application rates is the organic carbon levels found in the top 20cm of the soil profile. Intensive soil sampling (refer to Appendix 1. for sampling procedure) at each site followed by detailed laboratory analysis provided site specific information which combined with the appropriate District Yield Potential (DYP) provided a recommendation for the appropriate nitrogen application rate for each site.

Figure 9: Soil sampling prior to planting

3.3 Soil mineral nitrogen levels pre-planting

Soil mineral nitrogen (nitrate nitrogen and ammonium nitrogen) in the top 60cm of the soil profile was also measured (refer to Appendix 1.) prior to planting. Soil sampling was undertaken in 20cm increments down to 1m (Figure 9.), however nitrogen levels are reported for the top 60cm. Details of mean soil mineral nitrogen levels for each site prior to planting are presented in the results.

The method used to calculate mineral nitrogen is as follows:

Mineral N (kg/ha) = Value (mg/kg) x sampling depth (cm) x bulk density (g/cm^3) x 0.1

An assumed bulk density value of 1.21 was used for all samples to calculate mineral N.

3.4 Nitrate nitrogen levels in irrigation water

Irrigation water in the Delta area of the Burdekin is supplied predominately from bores which tap into the local groundwater systems. However, some Growers in this area also utilise channel water. Water used in the BRIA is predominantly surface water supplied via an irrigation network. For the duration of this project water samples were taken (refer to Appendix 1. for sampling procedure) at random intervals from the bores or supply channels which were used to irrigate trial sites. Water samples were tested for the presence of oxidised nitrogen as N. Mean oxidised nitrogen levels found each season in water samples are presented in the results.

Figure 10: Irrigation following planting of a trial site

3.5 Post harvest soil analysis

Post-harvest soil samples were collected from sites following the 2012, 2013, 2014, 2015 and 2016 harvests. Soil samples were taken in 20cm increments (0-20cm, 20-40cm, 40-60cm, 60-80cm, 80-100cm) from each strip and all sites (if possible). Sampling took place in the centre of the hill in most cases (Figure 11). However, at Site 6 following the 2012 harvest of the plant crop soil samples were also taken from the shoulder of the hill which corresponded with the general location of the side dressed application of nitrogen fertiliser.

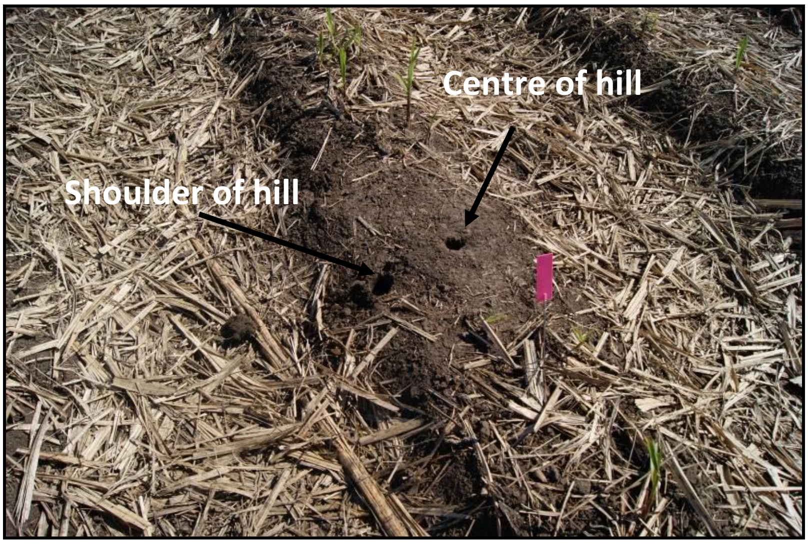

Figure 11: Post-harvest soil sampling positions at Site 6

Mean mineral nitrogen levels in the top 60cm of the soil profile for each site following each harvest were calculated and are presented in the results. The method used to calculate nitrogen in the soil profile was the same as that used to calculate soil mineral nitrogen levels pre-planting as described in Section 3.3.

In many cases the levels of ammonium nitrogen and nitrate nitrogen found at each depth were below the laboratory limit of detection. In order to calculate a value for kg of mineral N per hectare the reported value of <2 mg/kg was substituted with the value of 1. This may have resulted in the overestimation of mineral nitrogen per hectare. The level of N detection was improved for the 2016 post-harvest soil samples and no substitution was required to calculate mineral N.

4 Results

4.1 Harvest data capture and interpretation

Over the duration of the project cane yield and CCS results were supplied by the local Wilmar sugar mills for each trial site. Sugar yield was calculated from this. The results were analysed to identify if there were any differences in cane and sugar yields which could be attributed to higher nitrogen application rates. To quantify the economic return to the grower, the 'net revenue' was calculated for each replicate, which is gross revenue (calculated from cane yield and relative CCS using the cane payment formula) net of fertiliser costs, harvesting costs and levies.

Figure 12: Harvesting of a trial site in the BRIA

Harvest results and an economic analysis for each site are presented along with background information such as location, soil type, organic carbon levels, water supply, variety, row width, soil mineral nitrogen pre-planting and post-harvest and general comments about grower practices observed over the duration of the trials.

4.2 Site specific results

Site 1 – Brandon, Delta

Site characteristics

Variety:	Q208⁽ᵇ⁾	Row width:	1.52 m	Water source:	Bore

Soil characteristics (0-20cm)

% Sand (fine):	31
% Sand (coarse):	39
% Silt:	17
% Clay:	13

Type:	Dermosol
Texture:	Loam
QDPI:	BUfb

% Organic carbon:	0.89
Soil pH (1:5 Water):	6.7
Cation exchange capacity:	7.6

Crop establishment

Planting date:	3/05/2011

Harvest date

Harvest -Plant:	20/09/2012

Site overview

This trial site was generally well managed. The crop was established with few gaps and weed management was good over the development of the plant crop. In general irrigation management appeared to be adequate, however crop vigour appeared to vary considerably throughout the block. This was particularly evident at harvest with areas of smaller cane still standing whilst areas with larger cane were lodged. In general areas with the smaller cane tended to have a subsoil with a high percentage of coarse sand.

Yield and return

Yields at this site showed no response to higher N application rates as there were no statistically significant differences between the treatments in regards to production or economics (Table 4). The N rate with the highest mean net revenue was the lowest (130kg N/ha) N application rate. Using the DYP of 150 tch in the SIX EASY STEPS method to determine an appropriate N application rate at this site appears to have provided adequate levels of N for maximum cane and sugar yield and the greatest financial return for the grower.

Table 4: Mean cane and sugar yield, CCS and gross revenue, costs and net revenue

Crop stage	N rate Kg N/ha	Cane yield tch	CCS units	Sugar yield tsh	Net revenue $/ha
Plant	130 – ~DYP 150	125	15.4	19.2	$4,035
	170 – ~DYP 180	118	15.6	18.5	$3,832
	210 – grower	128	15.2	19.5	$3,914
	250 – high	132	15.2	20.2	$3,995
	p-value	0.079	0.322	0.173	0.648
	95% LSD	17.3	0.9	2.6	$644

Pre-plant soil N

Prior to planting on average across the trial site a total of 23(±5) kg/ha of mineral N was found in the top 60cm of the soil profile. This included 12(±3) kg/ha of nitrate N and 11.0 (±3) kg/ha of ammonium N.

Nitrate nitrogen levels in irrigation water

Irrigation water applied to this trial site was supplied from a bore. During the growth of the plant crop water samples were taken from the fluming as the trial site was being irrigated. Mean levels of oxidised nitrogen as N, were measured and found to be 7.0 (±0.9) mg/L.

Post-harvest soil N

Following the harvest of the plant crop soil mineral N levels in the top 60cm of the soil profile were calculated in all treatments. Nitrate and ammonium levels and total mineral N are presented in Table 5. Soil sampling in all strips following harvest indicated that mineral N levels in the profile were low. Higher rates of applied N did not result in higher levels of mineral N in the soil profile following harvest indicating that the majority of N not utilised by the crop had either been converted to another form which is no longer immediately available to the crop or had moved out of the profile due to leaching, runoff, denitrification or via a combination of these loss pathways.

Table 5: Mean and coefficient of variation of soil (0-60cm) nitrate, ammonium and total N in each treatment following harvest of the plant crop

Crop Stage	Treatment (kg/ha)	NO3 (kg/ha)	NH4 (kg/ha)	Total N (kg/ha)
Plant	130	15	16	31 (41%)
	170	15	16	31 (16%)
	210	10	19	29 (28%)
	250	8	15	23 (34%)

Nitrogen exported to the mill

During the harvesting of trial sites stalk samples were taken at random locations from within each strip to estimate the amount of N exported to the mill (Table 6). Stalk N concentration appears to increase with higher rates of applied N.

Table 6: Mean N in stalk exported to the mill (kg/ha) and kg of N in stalk/tonne of stalk for each treatment for the plant crop

Crop Stage	N Rate (kg/ha)	Mean Yield (tch)	N in Stalk Exported to Mill (kg/ha)	Kg of N in Stalk/tonne of Stalk
Plant	130	125	68a	0.54
	170	118	75a	0.64
	210	128	82a	0.64
	250	132	90a	0.68

P<0.05, means followed by a common letter are not significantly different at the 5% level

Partial N budget

The two N budgets show the major inputs and outputs for the SIX EASY STEPS method recommended N application rate when using the DYP of 150 tch and the growers preferred N application rate for the plant crop. The DYP of 150 tch was chosen for the budget due to a lack of response to N rates above this DYP.

Budget 1. SIX EASY STEPS (Mean yield: 125 tch)

Inputs (kg/ha)		Outputs (kg/ha)	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**130**	1. Crop N uptake	**110**
2. Pre plant soil mineral N	**23**	2. Soil residual mineral N	**31**
3. In season soil N mineralisation estimate	**20**		
4. N in irrigation water	**70**		
Total Inputs	**243**	**Total Outputs**	**141**

Estimate of N in attached dead leaf and below ground biomass used in calculation of crop N uptake. Estimate of N in components is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
102

There was a considerable amount of unaccounted N in this budget.

Budget 2. Grower N rate (Mean yield: 128 tch)

Inputs (kg/ha)		Outputs (kg/ha)	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**210**	1. Crop N uptake	**165**
2. Pre plant soil mineral N	**23**	2. Soil residual mineral N	**29**
3. In season soil N mineralisation estimate	**20**		
4. N in irrigation water	**70**		
Total Inputs	**323**	**Total Outputs**	**194**

Estimate of N in attached dead leaf and below ground biomass used in calculation of crop N uptake. Estimate of N in components is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
129

With the higher N application rate there was considerably more N unaccounted, however there appears to be a considerable increase in the amount of N accumulated by the crop. There was no increase in yield at the higher N application rate, indicating that there may have been some luxury N uptake.

*Unaccounted for N = Total Inputs – Total Outputs

Site 2 – Millaroo, BRIA

Site characteristics

Variety:	KQ228⁽ᵈ⁾	Row width:	1.60 m	Water source:	Channel

Soil characteristics (0-20cm)

% Sand (fine):	64
% Sand (coarse):	17
% Silt:	12
% Clay:	7

Type:	Non Sodic Duplex
Texture:	Sand
QDPI:	6Dbg

% Organic carbon:	0.35
Soil pH (1:5 Water):	6.5
Cation exchange capacity:	3.4

Crop establishment

Planting date:	1/05/2011

Harvest dates

Harvest -Plant:	10/09/2012
1st ratoon:	31/07/2013
2nd ratoon:	12/08/2014
3rd ratoon:	9/09/2015
4th ratoon:	

Site overview

This trial site was generally well managed over the duration of the crop cycle. The crop was established with few gaps. The incidence of weeds was low to moderate. The difficulty for the grower at this site is its very sandy, low organic carbon soil, which is prone to leaching, has poor water holding capacity and a very low cation exchange capacity which limits the ability of the soil to hold on essential nutrients such as potassium, calcium and magnesium. Due to the remote location of this site there were no viable options for importing organic material such as mill mud to improve organic carbon levels.

Yield and return

There appeared to be a response to higher N application rates in the plant crop at this site (Table 7). The low rate which is 20 kg N/ha less than that recommended by the SIX EASY STEPS method when using a DYP of 150 tch produced significantly less cane than the highest rate. In the ratoon crops there were no statistically significant differences in tonnes of cane, CCS, tonnes of sugar or net revenue. In terms of profitability, the DYP 180 treatment had the highest mean net revenue in the plant and 1st ratoon, while the DYP 150 had the highest average in the 2nd and 3rd ratoons.

Table 7: Mean cane and sugar yield, CCS and gross revenue, costs and net revenue

Crop stage	N rate Kg N/ha	Cane yield tch	CCS units	Sugar yield tsh	Net revenue $/ha
Plant	130 – ~DYP 150*	135 b	15.2 a	20.6	$4,284
	170 – ~DYP 180	141 ab	15.1 a	21.3	$4,368
	210 – grower	144 a	15.0 a	21.6	$4,353
	p-value	0.035	0.042	0.104	0.613
	95% LSD	7.9	0.2	1.4	$337
1st ratoon	170 – ~DYP 150*	107	15.3	16.5	$3,318
	210 – ~DYP 180	113	15.3	17.3	$3,433
	250 – grower	114	15.0	17.2	$3,303
	p-value	0.084	0.429	0.638	0.824
	95% LSD	8.8	0.6	2.6	$1,359
2nd ratoon	170 – ~DYP 150	108	15.2	16.3	$3,193
	210 – ~DYP 180	106	15.1	16.0	$3,041
	250 – grower	106	15.0	15.9	$2,946

Crop stage	N rate Kg N/ha	Cane yield tch	CCS units	Sugar yield tsh	Net revenue $/ha
	p-value	0.852	0.435	0.681	0.195
	95% LSD	12.3	0.5	1.8	$438
3rd ratoon	170 – ~DYP 150	99	16.5	16.4	$3,336
	210 – ~DYP 180	102	16.4	16.6	$3,285
	250 – grower	101	16.0	16.2	$3,070
	p-value	0.837	0.132	0.892	0.484
	95% LSD	17.0	0.9	3.3	$845

* According to the SIX EASY STEPS method the recommend N application rate for this site with a DYP of 150 tch is 150 kg N/ha for a plant crop and 190 kg N/ha for a ratoon crop.

In general, yields declined dramatically across treatments after the plant crop, however the ratoons maintained similar yields over the duration of the remaining crop cycle. Factors which may have impacted on ratoon crop yields include:

- Limited access to irrigation water due to supply issues, this was particularly evident in the 3rd ratoon crop.
- It was the opinion of the grower that nematodes impacted ratoon crop yields, although no testing was undertaken to confirm their presence.
- The sandy, low organic carbon soil had low fertility which may have contributed to the rapid decline in productivity.

The grower at this site reported that dramatic decline in productivity after the plant crop is a normal occurrence at this site.

Figure 13 presents the statistical results for an analysis over the full crop cycle (plant cane through to third ratoon). The results indicate that there were no significant differences in cane yield, CCS, sugar yield or net revenue between the treatments. Consequently, we cannot be confident (at the 95% significance level) that differences between the treatments are attributable to the amount of N applied.

How to interpret the graphs below?

The columns indicate the means for each treatment, while the errors bars show the 95% least significant difference (95% LSD bars). Overlapping error bars signify that the differences between the treatments are not statistically significant, while non-overlapping bars indicate a significant difference. Letters (a, b, c, etc.) have also been positioned above each 95% LSD bar with common letters signifying that there is not a significant difference, and vice versa. The blue spotted column in the graphs point out the N rate treatment specified by the SIX EASY STEPS guidelines which is most likely to be appropriate for this site.

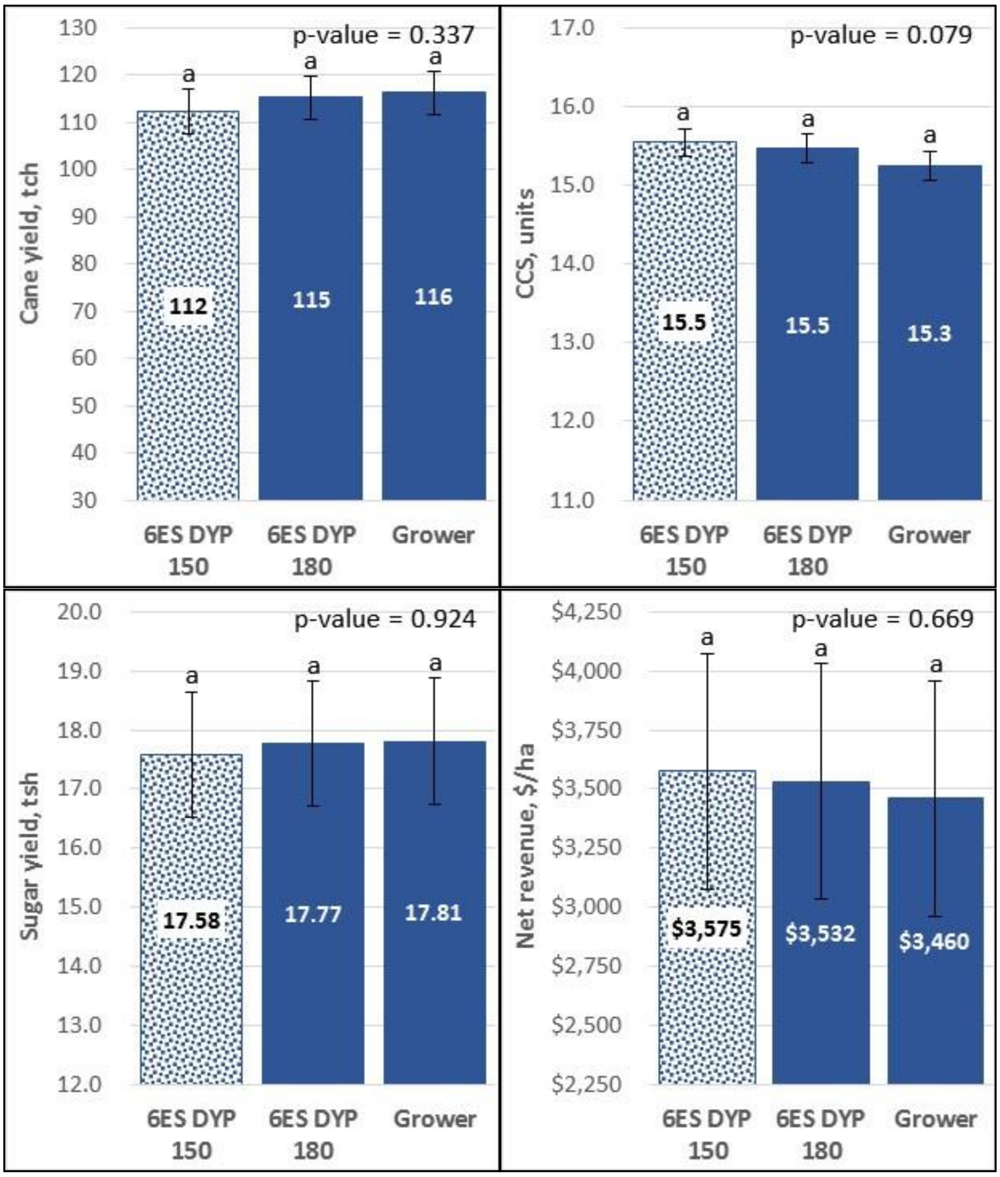

Figure 13: Average over crop cycle – cane yield, CCS, sugar yield and net revenue

The sensitivity analysis revealed that the economic outcome over the crop cycle was sensitive to fluctuations in the price of sugar (see Figure 14 below). Results show that the DYP 180 treatment would attain the highest mean net revenue if the sugar price was above $490 per tonne (assuming all other variables remained the same). The economic outcome was not found to be sensitive to fertiliser prices between the ranges considered (85% to 140% of fertiliser prices in 2015).

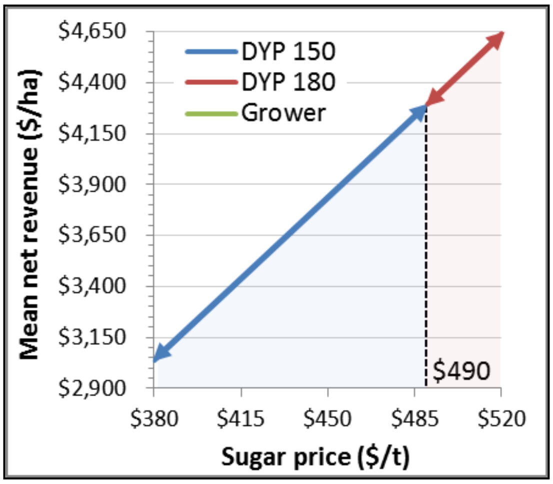

Figure 14: Sensitivity of mean net revenue over crop cycle to the sugar price

Pre-plant soil N

Prior to planting, on average across the trial site, a total of 41(±1) kg/ha of mineral N was found in the top 60cm of the soil profile. This included 40(±1) kg/ha of nitrate N and 1(±0.4) kg/ha of ammonium N.

Nitrate nitrogen levels in irrigation water

Irrigation water applied to this trial site was supplied via a channel. The source of the channel water was the Burdekin River. Mean levels of oxidised nitrogen as N were <0.05 mg/L over the duration of the trial.

Post-harvest soil N

Following the harvest of each crop soil mineral N levels in the top 60cm of the soil profile were calculated in all treatments. Soil nitrate and ammonium levels and total mineral N are presented in Table 6.

Prior to planting there was some nitrate present in the top 60cm of the soil profile, however ammonium levels were very low. Following each harvest soil mineral N levels (Table 8) remained very low in each treatment. Higher rates of applied N did not result in higher levels of mineral N remaining in the soil profile following harvest indicating that the majority of N not utilised by the crop had been converted to another form which was no longer immediately available to the crop or had moved out of the profile. The most likely loss pathway at this site being leaching due to the sandy nature of the soil.

Table 8: Soil (0-60cm) nitrate, ammonium and total mineral N in each treatment following harvest of each crop stage

Crop Stage	Treatment (kg/ha)	NO3 (kg/ha)	NH4 (kg/ha)	Total mineral N (kg/ha)
Plant	130	-	-	-
	170	-	-	-
	210	-	-	-
1st Ratoon	170	12	7	19
	210	12	7	19
	250	7	7	14
2nd Ratoon	170	7	7	14
	210	7	12	19
	250	7	7	14
3rd Ratoon	170	7	7	14
	210	7	7	14
	250	7	7	14

Nitrogen exported to the mill

During harvesting of trial sites stalk samples were taken at random locations from within each strip to estimate the amount of N exported to the mill (Table 9). In the second ratoon, N in stalk exported to the mill increased significantly at the highest N rate (250 kg N/ha) in comparison to the two lower N rates. There was no additional yield produced at the highest N application rate indicating that some luxury consumption of N by the crop had taken place.

Table 9: Mean of N in stalk exported to the mill (kg/ha) and kg of N in stalk/tonne of stalk for each treatment and crop stage

Crop Stage	N Rate (kg/ha)	Mean Yield (tch)	N in Stalk Exported to Mill (kg/ha)	Kg of N in Stalk/tonne of Stalk
1st Ratoon	170	107	88 a	0.82
	210	113	-	-
	250	114	104 a	0.91
2nd Ratoon	170	108	84 b	0.78
	210	106	97 b	0.92
	250	106	118 a	1.1
3rd Ratoon	170	99	73 a	0.74
	210	102	98 a	0.96
	250	101	106 a	1.1

P<0.05, means followed by a common letter are not significantly different at the 5% level

Partial N budget

The two N budgets show the major inputs and outputs for an N application rate 20 kg N/ha less than the SIX EASY STEPS method recommended N application rate when using the DYP of 150 tch and the Growers preferred N application rate for the 2nd ratoon crop. The lowest N rate was chosen for the budget due to a lack of response to N at higher application rates.

Budget 1. SIX EASY STEPS – 20 kg N/ha (Mean yield: 108 tch)

Inputs (kg/ha)		Outputs (kg/ha)	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**170**	1. Crop N uptake	**148**
2. Soil mineral N remaining after 1st Ratoon harvest	**19**	2. Soil residual mineral N	**14**
3. In season soil N mineralisation estimate	**0**		
4. N in irrigation water	**0**		
Total Inputs	**189**	**Total Outputs**	**162**

*Estimate of N in below ground biomass used in calculation of crop N uptake. Estimate is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
27

This budget was close to being in balance with little N unaccounted. Although the N application rate is 20 kg N/ha lower than that recommended by the SIX EASY STEPS there was still some N unaccounted.

Budget 2. Grower N rate (Mean yield: 106 tch)

Inputs (kg/ha)		**Outputs (kg/ha)**	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**250**	1. Crop N uptake	**160**
2. Soil mineral N remaining after 1st Ratoon harvest	**14**	2. Soil residual mineral N following harvest	**14**
3. In season soil N mineralisation estimate	**0**		
4. N in irrigation water	**0**		
Total Inputs	**264**	**Total Outputs**	**174**

*Estimate of N in below ground biomass used in calculation of crop N uptake. Estimate is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
90

With the higher N application rate more N is unaccounted, the majority of the addition N applied at the higher rate was not utilised by the crop. The crop appears to have taken up more N, however this has not translated into additional yield.

*Unaccounted for N = Total Inputs – Total Outputs

Site 3 – Airville, Delta

Site characteristics

Variety:	KQ228⟨ᵈ⟩	Row width:	1.52m	Water source:	Bore

Soil characteristics (0-20cm)

% Sand (fine):	59
% Sand (coarse):	3
% Silt:	20
% Clay:	18

Type:	Dermosol
Texture:	Loam
QDPI:	BUfc

% Organic carbon:	0.9
Soil pH (1:5 Water):	7.4
Cation exchange capacity:	13.5

Crop establishment

Planting date:	6/5/2011

Harvest dates

Harvest -Plant:	24/8/2012
1st ratoon:	17/7/2013
2nd ratoon:	4/8/2014
3rd ratoon:	2/7/2015
4th ratoon:	7/7/2016

Site overview

This trial site was generally managed according to best management principles. The crop was established with few gaps and weed management was good over the five seasons. Good farm management practices combined with good soil fertility and in general good irrigation management has allowed this grower to achieve consistent cane and sugar yields over the duration of the trials.

Yield and return

The only yield response to higher N application rates occurred in the 4th ratoon crop (Table 10), which showed a significant increase in yield (tch and tsh) at the Growers preferred N application rate. Net revenue was also highest at this application rate, though pairwise comparisons indicated no statistically significant differences between treatments.

In general, yields declined from the plant crop onwards, however the 4th ratoon yielded the highest of all the crop stages. The reason for this is not clear, however anecdotally the farmer believes that the significantly improved yields of the 4th ratoon was a response to a change in irrigation practice and the application of lime to the block, which he believed improved soakage.

Table 10: Mean cane and sugar yield, CCS and gross revenue, costs and net revenue.

Crop stage	N rate Kg N/ha	Cane yield tch	CCS units	Sugar yield tsh	Net revenue $/ha
Plant	130 – ~DYP 150	153 a	13.5 a	20.7	$4,427
	170 – ~DYP 180	157 a	13.2 ab	20.8	$4,318
	210 – grower	163 a	12.8 ab	21.0	$4,201
	250 – high	163 a	12.6 b	20.6	$3,991
	p-value	0.024	0.026	0.899	0.167
	95% LSD	10.7	0.9	2.1	$658
1st ratoon	170 – ~DYP 150	151 a	14.3	21.5	$4,500
	210 – ~DYP 180	153 a	14.2	21.8	$4,446
	250 – grower	159 a	13.9	22.1	$4,382
	290 – high	163 a	13.5	21.9	$4,137
	p-value	0.033	0.090	0.691	0.233
	95% LSD	12.2	1.1	2	$638
2nd ratoon	170 – ~DYP 150	143	15.2	21.9	$4,573
	210 – ~DYP 180	146	15.2	22.1	$4,545

Crop stage	N rate Kg N/ha	Cane yield tch	CCS units	Sugar yield tsh	Net revenue $/ha
	250 – grower	151	15.1	22.7	$4,564
	290 – high	154	14.9	22.9	$4,485
	p-value	0.279	0.355	0.472	0.949
	95% LSD	20.7	0.8	2.8	$636
3rd ratoon*	170 – ~DYP 150	156*	12.8*	19.9*	$4,489*
	210 – ~DYP 180	146*	12.7*	18.5*	$4,042*
	250 – grower	143*	12.6*	18.0*	$3,821*
	290 – high	143*	12.3*	17.5*	$3,540*
	p-value	n/a	n/a	n/a	n/a
	95% LSD	n/a	n/a	n/a	n/a
4th ratoon	170 – ~DYP 150	167 b	11.7	19.6 b	$4,093 a
	210 – ~DYP 180	167 b	11.8	19.8 b	$4,106 a
	250 – grower	180 a	11.8	21.2 a	$4,360 a
	290 – high	181 a	11.7	21.2 a	$4,298 a
	p-value	0.001	0.810	0.001	0.025
	95% LSD	8.6	0.5	0.9	$287

*Data from one strip only presented for each treatment due loss of rake data

Figure 15 presents the statistical results for an analysis over the crop cycle (plant cane through to fourth ratoon, however the third ratoon results could not be included as too many data points were missing). The results indicate that there were statistically significant differences in cane yield and CCS between the treatments but not in sugar yield or net revenue. The high N rate treatment was found to have significantly higher cane yield than the DYP 150 treatment but significantly lower CCS than both SIX EASY STEPS treatments.

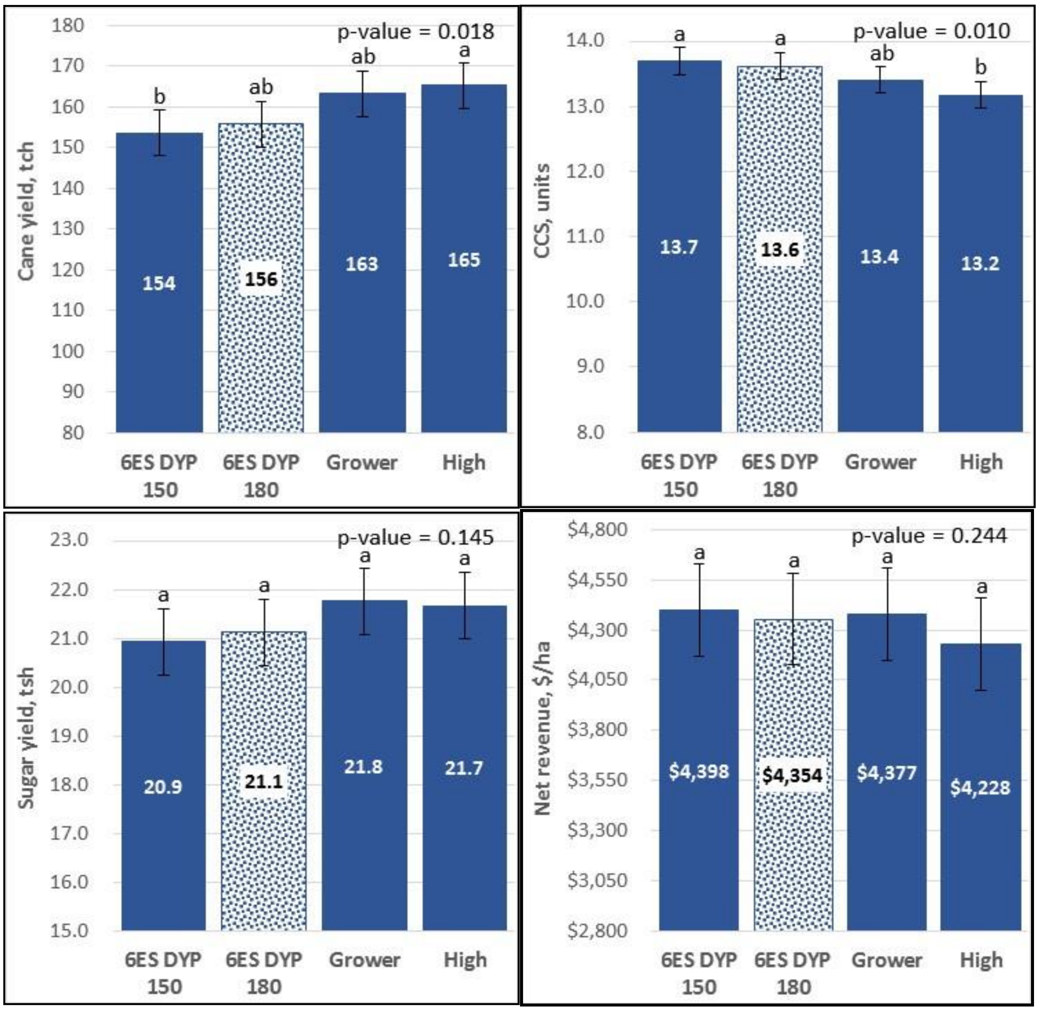

Figure 15: Average over crop cycle – cane yield, CCS, sugar yield and net revenue

Sensitivity analysis revealed that the economic outcome over the crop cycle (P, 1R, 2R & 4R, but not including 3R) was sensitive to fluctuations in the price of sugar (see Figure 16). Results show that the DYP 150 treatment would attain the highest mean net revenue if the average sugar price was below $473 per tonne (assuming all other variables remained the same). The economic outcome was not found to be sensitive to fluctuations in fertiliser prices between the ranges considered.

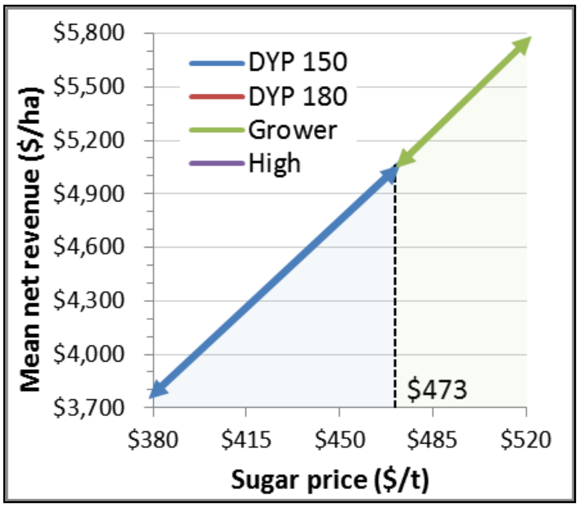

Figure 16: Sensitivity of mean net revenue over crop cycle to the sugar price

Pre-plant soil N

Prior to planting on average across the trial site a total of 23 kg/ha of mineral N was found in the top 60cm of the soil profile. This included 12 kg/ha of nitrate N and 11 kg/ha of ammonium N.

Nitrate nitrogen levels in irrigation water

Irrigation water applied to this trial site was supplied from a bore. During the crop cycle water samples were taken from the fluming as the trial site was being irrigated. Mean levels of oxidised nitrogen as N, measured for each crop stage are presented in Table 11.

Table 11: Mean and standard error of oxidised nitrogen as N in irrigation water

Crop Stage	Oxidised nitrogen as N (mg/L)
Plant	5.2 (±0.38)
1st Ratoon	4.75*
2nd Ratoon	4.18 (±0.85)
3rd Ratoon	3.53*
4th Ratoon	3.78 (±0.27)

* Result based on one sample

Post-harvest soil N

Following the harvest of each crop soil mineral N levels in the top 60cm of the soil profile were calculated in all treatments. Mean nitrate and ammonium levels and total mineral N are presented in Table 12. Prior to planting mineral N in the top 60cm of the soil profile was uniformly low (Table 12). Following each harvest soil mineral N levels remained low in each treatment. Higher rates of applied N did not result in higher levels of N remaining in the soil profile following harvest indicating that the majority of mineral N not utilised by the crop had either been converted to another form which was no longer immediately available to the crop or had moved out of the profile due to leaching, runoff, denitrification or a combination of these loss pathways.

Table 12: Mean and coefficient of variation (plant crop only) of soil (0-60cm) nitrate, ammonium and total mineral N in each treatment following the harvest of each crop stage

Crop Stage	Treatment (kg/ha)	NO3 (kg/ha)	NH4 (kg/ha)	Total mineral N (kg/ha)
Plant	130	8	7	15 (9%)
	170	10	15	25 (10%)
	210	7	12	19 (25%)
	250	8	16	24 (20%)
1st Ratoon	170	15	17	31
	210	12	19	31
	250	10	15	24
	290	15	15	29
2nd Ratoon	170	7	17	24
	210	7	22	29
	250	7	15	22
	290	7	19	27
3rd Ratoon	170	7	15	22
	210	7	17	24
	250	17	17	34
	290	7	17	24
4th Ratoon	170	12	20	32
	210	13	19	33
	250	8	20	29
	290	12	18	30

Nitrogen exported to the mill

During the harvesting of trial sites stalk samples were taken at random locations from within each strip to estimate the amount of N exported to the mill (Table 13). In the first ratoon crop N in stalk exported to the mill increased significantly at the highest N rate (290 kg N/ha) in comparison to the two lower N rates. There was no additional yield produced at the highest N application rate indicating that some luxury consumption of N by the crop had taken place. In the second ratoon there was a significant increase in N accumulated by the crop at the 210 kg/ha N rate and above. There was no significant increase in crop yield indicating that some luxury consumption of N had taken place.

Table 13: Mean of N in stalk exported to the mill (kg/ha) and kg of N in stalk/tonne of stalk for each treatment and crop stage

Crop Stage	N Rate (kg/ha)	Mean Yield (tch)	N in Stalk Exported to Mill (kg/ha)	Kg of N in Stalk/tonne of Stalk
Plant	130	153	96 a	0.63
	170	157	117 a	0.75
	210	163	123 a	0.75
	250	163	118 a	0.72
1st Ratoon	170	151	96 b	0.64
	210	153	97 b	0.63
	250	159	-	-
	290	163	130 a	0.8
2nd Ratoon	170	143	82 b	0.57
	210	146	118 a	0.81
	250	151	128 a	0.85
	290	154	122 a	0.79
3rd Ratoon	170	156*	105 a	0.67
	210	146*	116 a	0.79
	250	143*	125 a	0.87
	290	143*	144 a	1.01

***** 3rd Ratoon yield data is based on data from one strip only for each treatment
P<0.05, means followed by a common letter are not significantly different at the 5% level

Partial N budget

The four N budgets show the major inputs and outputs for the SIX EASY STEPS method recommended N application rate when using the DYP of 180 tch and the Grower N application rate for the plant crop and the 4th ratoon crop.
The 4th ratoon crop was included to gain a better understanding of the N inputs and outputs where a response to N was found at the Grower and High N rate treatments.

<u>Plant Crop</u>

Budget 1. SIX EASY STEPS (Mean yield: 153 tch)

Inputs (kg/ha)		Outputs (kg/ha)	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**170**	1. Crop N uptake	**223**
2. Pre plant soil mineral N	**23**	2. Soil residual mineral N	**25**
3. In season soil N mineralisation estimate	**20**		
4. N in irrigation water	**52**		
Total Inputs	**265**	**Total Outputs**	**248**

*Estimate of N in attached dead leaf and below ground biomass used in calculation for crop N uptake. Estimate of N in components is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
17

This budget was close to being in balance with little N unaccounted.

Budget 2. Grower N rate (Mean yield: 163 tch)

Inputs (kg/ha)		Outputs (kg/ha)	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**210**	1. Crop N uptake	**239**
2. Pre plant soil mineral N	**23**	2. Soil residual mineral N	**19**
3. In season soil N mineralisation estimate	**20**		
4. N in irrigation water	**52**		
Total Inputs	**305**	**Total Outputs**	**258**

*Estimate of N in attached dead leaf and below ground biomass used in calculation of crop N uptake. Estimate of N in components is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
47

With the higher N application rate more N was unaccounted with little additional yield obtained from the additional 40 kg/ha of applied N.

***Unaccounted for N = Total Inputs – Total Outputs

4th Ratoon Crop

Budget 1. SIX EASY STEPS (Mean yield: 167 tch)

Inputs (kg/ha)		Outputs (kg/ha)	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**210**	1. Crop N uptake	**190**
2. Soil mineral N following harvest of 3rd ratoon	**24**	2. Soil residual mineral N	**33**
3. In season soil N mineralisation estimate	**20**		
4. N in irrigation water	**38**		
Total Inputs	**292**	**Total Outputs**	**223**

*Estimate of below ground biomass used in calculation of crop N uptake. Estimate of N is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
69

This budget indicates that there was a considerable amount of N unaccounted.

Budget 2. Grower N rate (Mean yield: 180 tch)

Inputs (kg/ha)		Outputs (kg/ha)	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**250**	1. Crop N uptake	**222**
2. Soil mineral N following harvest of 3rd ratoon	**34**	2. Soil residual mineral N	**29**
3. In season soil N mineralisation estimate	**20**		
4. N in irrigation water	**38**		
Total Inputs	**342**	**Total Outputs**	**251**

*Estimate of below ground biomass used in calculation of crop N uptake. Estimate of N is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
91

With the higher N application rate more N was unaccounted, however there was a significant increase in yield of 13 tch at the Grower N rate in comparison to the SIX EASY STEPS N rate. The reason for the response remains unclear.

*Unaccounted for N = Total Inputs – Total Outputs

Site 4 – Brandon, Delta

Site characteristics

Variety:	Q200⌽	Row width:	1.52 m	Water source:	Bore

Soil characteristics (0-20cm)

% Sand (fine):	55
% Sand (coarse):	6
% Silt:	20
% Clay:	19

Type:	Dermosol
Texture:	Loam
QDPI:	BUmd

% Organic carbon:	0.99
Soil pH (1:5 Water):	7.0
Cation exchange capacity:	13

Crop establishment

Planting date:	4/05/2011

Harvest dates

Harvest -Plant:	14/09/2012
1st ratoon:	22/08/2013

Site overview

The plant crop at this trial site was managed according to best management principles. The crop was established with few gaps, weed and irrigation management were also good; however, there was a change in the ownership of this trial site following the harvest of the plant crop which resulted in a change in management practices employed for the ratoon crop. Observation during the development of the ratoon crop revealed that the crop was not watered with the same frequency as previously and weed management was generally considerably poorer.

Yield and return

There appeared to be no yield response to higher rates of applied N in the plant or ratoon crops at this site (Table 14). The ratoon crop yield dropped by approximately 20 tch in all treatments. The likely reason for the significant decline is due to a change in irrigation and weed management practices employed by the manager of the farm at this time.

Table 14: Mean cane and sugar yield, CCS and gross revenue, costs and net revenue.

Crop stage	N rate Kg N/ha	Cane yield tch	CCS units	Sugar yield tsh	Net revenue $/ha
Plant	120 – ~DYP 150	143	14.9	21.2	$4,261 a
	160 – ~DYP 180	145	15.0	21.7	$4,355 a
	220 – grower	139	14.8	20.6	$3,968 a
	280 – high	144	14.8	21.2	$4,026 a
	p-value	0.262	0.333	0.177	0.038
	95% LSD	11	0.5	1.7	$432
1st ratoon	160 – ~DYP 150	118	15.6	18.4	$3,681
	200 – ~DYP 180	118	15.4	18.1	$3,493
	260 – grower	114	15.4	17.6	$3,265
	300 – high	125	15.2	18.9	$3,402
	p-value	0.368	0.158	0.454	0.152
	95% LSD	20.6	0.7	2.9	$597

Figure 17 presents the statistical results for an analysis over both the plant cane and first ratoon. The results indicate that there was a statistically significant difference in CCS between the treatments but not in cane yield, sugar yield or net revenue. Both of the SIX EASY STEPS treatments were found to have significantly higher CCS than the High N rate treatment.

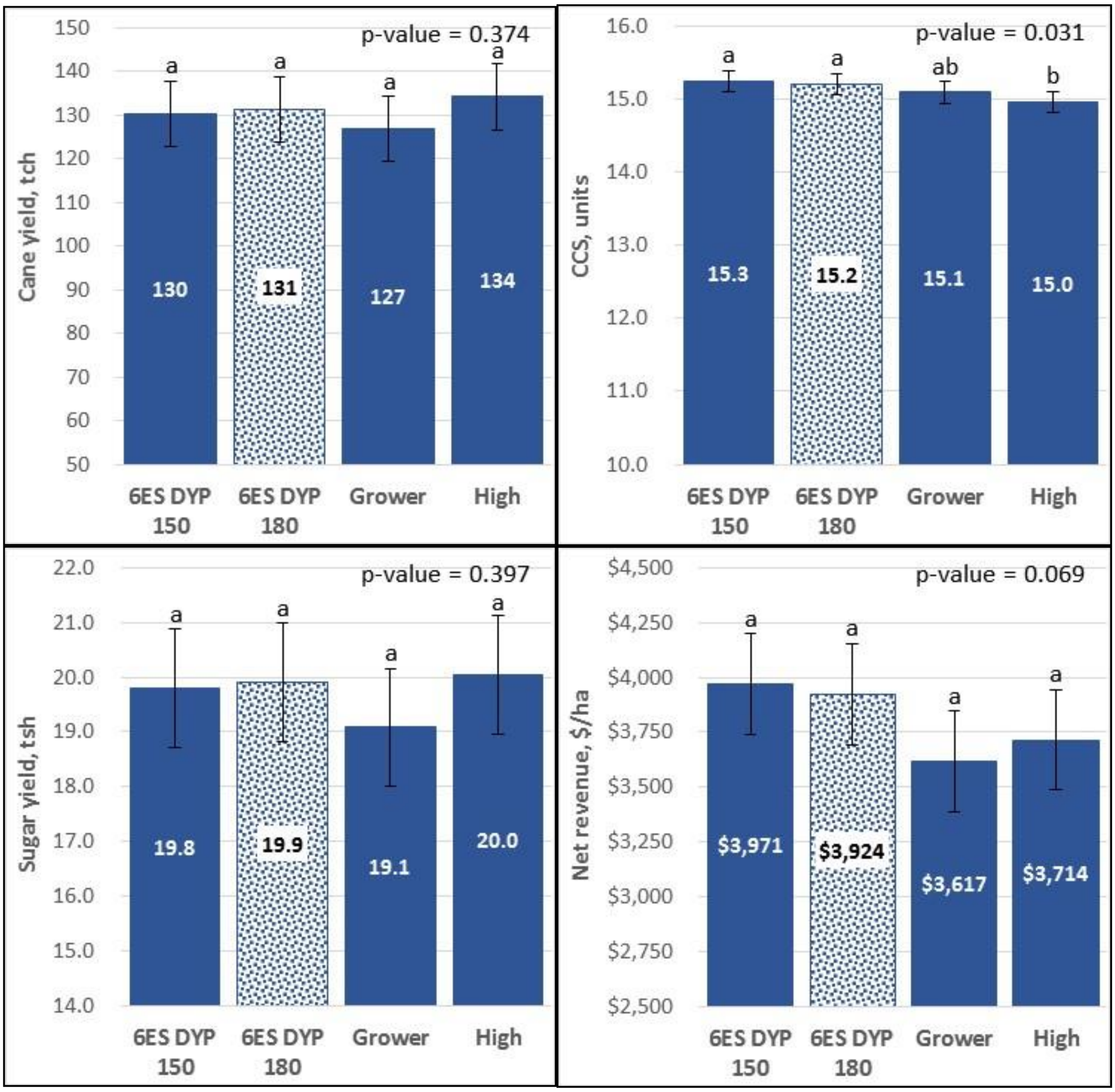

Figure 17: Average over crop cycle – cane yield, CCS, sugar yield and net revenue

Sensitivity analyses reveal that the economic outcome over both the plant cane and first ratoon was not sensitive to fluctuations in the sugar price or fertiliser price within the considered ranges.

Pre-plant soil N

Prior to planting on average across the trial site a total of 21(±2) kg/ha of mineral N was found in the top 60cm of the soil profile. This included 9(±1) kg/ha of nitrate N and 12(±1) kg/ha of ammonium N.

Nitrate nitrogen levels in irrigation water

Irrigation water applied to this trial site was supplied from a bore. During the plant and ratoon crops water samples were taken from the fluming as the trial site was being irrigated. Mean levels of oxidised nitrogen as N, measured for each crop stage are presented in Table 15.

Table 15: Mean and standard error of oxidized nitrogen as N in irrigation water

Crop Stage	Oxidised nitrogen as N (mg/L)
Plant	2.8(±0.5)
1st Ratoon	2.7(±0.5)

Post-harvest soil N

Following the harvest of each crop soil mineral N levels in the top 60cm of the soil profile were calculated in all treatments. Mean nitrate and ammonium levels and total mineral N are presented in Table 16.

Prior to planting mineral N in the top 60cm of the soil profile was uniformly low. Following each harvest soil N levels remained low in each treatment. Higher rates of applied N did not result in higher levels of N remaining in the soil profile following harvest indicating that the majority of mineral N not utilised by the crop had either been converted to another form which was no longer immediately available to the crop or had moved out of the profile due to leaching, runoff, denitrification or a combination of these loss pathways.

Table 16: Mean and coefficient of variation (plant crop only) of soil (0-60cm) nitrate, ammonium and total mineral N in each treatment following hearvest of the plant and ratoon crops

Crop Stage	Treatment (kg/ha)	NO3 (kg/ha)	NH4 (kg/ha)	Total mineral N (kg/ha)
Plant	120	9	23	32(16%)
	160	7	23	30(9%)
	220	7	27	34(4%)
	280	7	21	28(13%)
1st Ratoon	160	10	10	20
	200	12	15	27
	260	24	15	39
	300	12	15	27

Nitrogen exported to the mill

During the harvesting of trial sites stalk samples were taken at random locations from within each strip to estimate the amount of N exported to the mill (Table 17). In the plant crop N in stalk exported to the mill increased significantly at the 280 kg N/ha N rate in comparison to the two lowest N rates. There was no additional yield produced at the highest N application rate indicating that some luxury consumption of N by the crop had taken place.

Table 17: Mean of N in stalk exported to the mill (kg/ha) and kg of N in stalk/tonne of stalk for each treatment in the plant and 1st ratoon crop

Crop Stage	N Rate (kg/ha)	Mean Yield (tch)	N in Stalk Exported to Mill (kg/ha)	Kg of N in Stalk/tonne of Stalk
Plant	120	143	89 b	0.62
	160	145	89 b	0.61
	220	139	109 ab	0.78
	280	144	117 a	0.81
1st Ratoon	160	118	93 a	0.79
	200	118	-	-
	260	114	111 a	0.97
	300	125	126 a	1.00

P<0.05, means followed by a common letter are not significantly different at the 5% level.

Partial N budget

The two N budgets show the major inputs and outputs for the SIX EASY STEPS method recommended N application rate when using the DYP of 180 tch and the growers preferred N application rate for the plant crop.

Budget 1. SIX EASY STEPS (Mean yield: 143 tch)

Inputs (kg/ha)		Outputs (kg/ha)	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**160**	1. Crop N uptake	**195**
2. Pre plant soil mineral N	**21**	2. Soil residual mineral N	**30**
3. In season soil N mineralisation estimate	**20**		
4. N in irrigation water	**28**		
Total Inputs	**229**	**Total Outputs**	**225**

*Estimate of N in attached dead leaf and below ground biomass used in calculation of crop N uptake. Estimate of N in components is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
4

This budget was close to being in balance with little N unaccounted.

Budget 2. Grower N rate (Mean yield: 139 tch)

Inputs (kg/ha)		Outputs (kg/ha)	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**220**	1. Crop N uptake	**229**
2. Pre plant soil mineral N	**21**	2. Soil residual mineral N	**34**
3. In season soil N mineralisation estimate	**20**		
4. N in irrigation water	**28**		
Total Inputs	**289**	**Total Outputs**	**263**

*Estimate of N in attached dead leaf and below ground biomass used in calculation of crop N uptake. Estimate of N in components is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
26

With the higher N application rate slightly more N was unaccounted. The crop appears to have captured more N at the higher N application rate without any yield increase.

*Unaccounted for N = Total Inputs – Total Outputs

Site 5 – Giru, BRIA

Site characteristics

Variety:	Q200⁽ᵇ⁾	Row width:	1.60 m	Water source:	Channel

Soil characteristics (0-20cm)

% Sand (fine):	36
% Sand (coarse):	17
% Silt:	23
% Clay:	24

Type:	Sodic Duplex
Texture:	Loam
QDPI:	6Drc

% Organic carbon:	0.87
Soil pH (1:5 Water):	7.2
Cation exchange capacity:	12.6

Crop establishment

Planting date:	10/09/2012

Harvest dates

Harvest -Plant:	2/10/2013
1st ratoon:	7/10/2014
2nd ratoon:	19/10/2015
3rd ratoon:	20/11/2016

Site overview
The crop was established with some gaps throughout the trial site, the gaps were large enough to have negatively impacted yields to some degree. The incidence of gaps was randomly distributed across the block. Weed management was reasonable, however the incidence of weeds did increase in later ratoons. Irrigation management was fair, however there were periods where irrigation frequency was less than optimum to achieve maximum cane yield at this site.

Yield and return
There appeared to be no yield response to higher rates of applied N in the plant or ratoon crops at this site, however higher rates of N did appear to have a negative impact on CCS in the plant crop, with the highest N rate having a significantly lower CCS than the two lower N rates (Table 18). The plant crop at this site was a late plant which may have impacted on the plant crop yield. For the third ratoon crop it was decided to lower the N rates in line with the DYP of 150 tch and to trial the use of ENTEC urea at an even lower rate of 150 kg N/ha. There was no significant difference in yields with the three N rates in the third ratoon. In terms of profitability, the High N rate treatment had lower mean net revenue in the plant crop, for which the difference was statistically significant. No statistically significant differences in net revenue were identified in the ratoon crops.

Table 18: Mean cane and sugar yield, CCS and gross revenue, costs and net revenue

Crop stage	N rate Kg N/ha	Cane yield tch	CCS units	Sugar yield tsh	Net revenue $/ha
Plant	170 – ~DYP 180	94	15.4 a	14.5	$2,817 a
	210 – grower	95	15.4 a	14.7	$2,811 a
	250 – high	96	15.2 b	14.7	$2,711 b
	p-value	0.110	0.005	0.284	0.015
	95% LSD	3.1	0.1	0.4	$89
1st ratoon	210 – ~DYP 180	132	14.8	19.5	$3,755
	250 – grower	135	14.6	19.7	$3,696
	290 – high	135	14.8	20.0	$3,696
	p-value	0.498	0.218	0.540	0.739
	95% LSD	10.4	0.3	1.5	$335
2nd ratoon	210 – ~DYP 180	123	15.9	19.5	$3,995
	250 – grower	125	15.8	19.7	$3,943
	290 – high	121	15.7	19.0	$3,666
	p-value	0.857	0.373	0.695	0.244
	95% LSD	24.1	0.5	3.4	$694
3rd ratoon	150 – ENTEC	95	15.2	14.4	$2,535
	170 – ~DYP 150	95	15.0	14.3	$2,509
	210 – ~DYP 180	90	14.9	13.5	$2,275
	p-value	0.392	0.154	0.305	0.159
	95% LSD	11.5	0.4	1.9	$417

Figure 18 presents the statistical results for an analysis over the crop cycle (plant cane through to second ratoon – the third ratoon was not included because it did not examine an N rate above SIX EASY STEPS). The results indicate that there were no significant differences in cane yield, CCS, sugar yield or net revenue between the treatments.

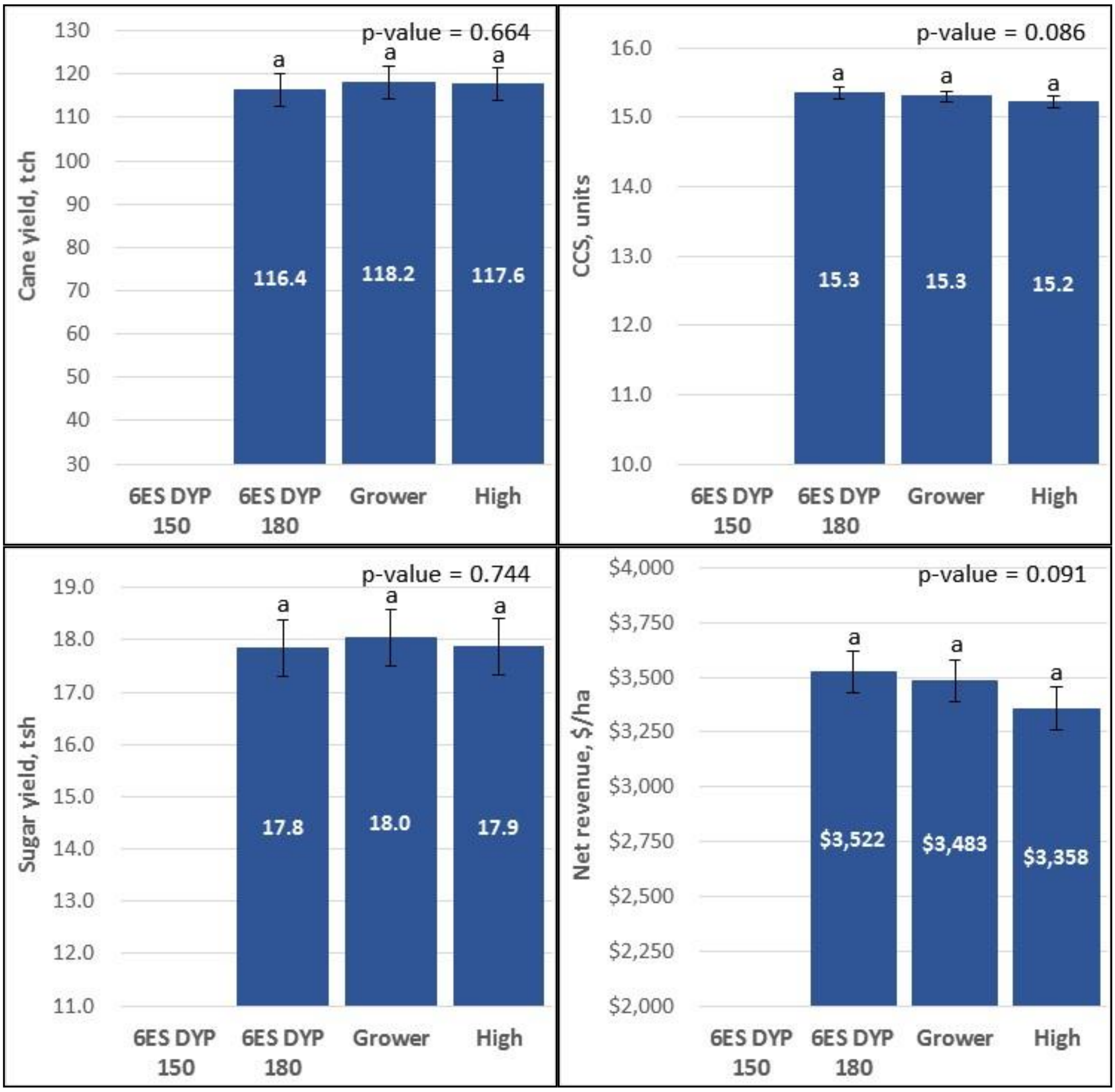

Figure 18: Average over crop cycle – cane yield, CCS, sugar yield and net revenue

Sensitivity analyses reveal that the economic outcome over the crop cycle was not sensitive to fluctuations in the sugar price or fertiliser price within the considered ranges.

Pre-plant soil N

Prior to planting on average across the trial site a total of 39(±0.4) kg/ha of mineral N was found in the top 60cm of the soil profile. This included 21(±1) kg/ha of nitrate nitrogen and 18(±0.4) kg/ha of ammonium nitrogen.

Nitrate nitrogen levels in irrigation water

Irrigation water applied to this trial site was supplied via a channel. Mean levels of oxidised nitrogen as N were <0.05 mg/L over the duration of the trial.

Post-harvest soil N

Following the harvest of each crop soil mineral N levels in the top 60cm of the soil profile were measured in all treatments. Nitrate and ammonium levels and total mineral N are presented in Table 19. Soil N levels remained low in each treatment.

Higher rates of applied N did not result in higher levels of N remaining in the soil profile following harvest indicating that the majority of mineral N not utilised by the crop had either been converted to another form which is no longer immediately available to the crop or had moved out of the profile due to leaching, runoff, denitrification or a combination of these loss pathways.

Table 19: Soil (0-60cm) nitrate, ammonium and total mineral N in each treatment following harvest for each crop stage

Crop Stage	Treatment (kg/ha)	NO3 (kg/ha)	NH4 (kg/ha)	Total mineral N (kg/ha)
Plant	170	7	12	19
	210	12	12	24
	250	7	15	22
1st Ratoon	210	10	17	27
	250	7	19	27
	290	10	19	29
2nd Ratoon	210	7	24	31
	250	7	22	29
	290	7	17	24
3rd Ratoon	150	7	21	28
	170	6	28	34
	210	5	23	29

Nitrogen exported to the mill

During the harvesting of trial sites stalk samples were taken at random locations from within each strip to estimate the amount of N exported to the mill (Table 20). In the first ratoon N in stalk exported to the mill increased significantly at the highest N rate (290 kg N/ha) in comparison to the two lower N rates. There was no additional yield produced at the highest N application rate indicating that some luxury consumption of N by the crop had taken place.

Table 20: Mean of N in stalk exported to the mill (kg/ha) and kg of N in stalk/tonne of stalk for each treatment and crop stage.

Crop Stage	N Rate (kg/ha)	Mean Yield (tch)	N in Stalk Exported to Mill (kg/ha)	Kg of N in Stalk/tonne of Stalk
Plant	170	94	66 a	0.7
	210	95	-	-
	250	96	60 a	0.63
1st Ratoon	210	132	72 b	0.55
	250	135	81 b	0.61
	290	135	98 a	0.73
2nd Ratoon	210	123	77 a	0.63
	250	125	113 a	0.90
	290	121	82 a	0.68

$P<0.05$, means followed by a common letter are not significantly different at the 5% level.

Partial N budget

The two N budgets show the major inputs and outputs for the SIX EASY STEPS method recommended N application rate when using the DYP of 180 tch and the growers preferred N application rate for the plant crop.

Budget 1. SIX EASY STEPS (Mean yield: 94 TCH)

Inputs (kg/ha)		Outputs (kg/ha)	
Component	**Result**	**Component**	**Result**
1. Nitrogen from fertiliser	**170**	1. Crop N uptake	**138**
2. Pre plant soil mineral N	**39**	2. Soil residual mineral N	**19**
3. In season soil N mineralisation	**20**		
4. N in irrigation water	**0**		
Total Inputs	**229**	**Total Outputs**	**157**

*Estimate of N in below ground biomass used in calculation. Estimate is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
72

This budget indicates that there was a considerable amount of unaccounted N.

Budget 2. Grower N rate (Mean yield: 95 TCH)

Inputs (kg/ha)		Outputs (kg/ha)	
Component	**Result**	**Component**	**Result**
1. Nitrogen from fertiliser	**210**	1. Crop N uptake	**134**
2. Pre plant soil mineral N	**39**	2. Soil residual mineral N	**24**
3. In season soil N mineralisation	**20**		
4. N in irrigation water	**0**		
Total Inputs	**269**	**Total Outputs**	**158**

*Estimate of N in below ground biomass used in calculation. Estimate is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
111

With the higher N application rate more N was unaccounted, there was no additional N accumulated by the crop.

*Unaccounted for N = Total Inputs – Total Outputs

Site 6 – Clare, BRIA

Site characteristics

Variety:	Q183⁽ᵇ⁾	Row width:	1.52 m	Water source:	Channel

Soil characteristics (0-20cm)

% Sand (fine):	27	Type:	Sodic Duplex	% Organic carbon:	0.77
% Sand (coarse):	3	Texture:	Clay	Soil pH (1:5 Water):	8
% Silt:	24	QDPI:	2Dyb	Cation exchange capacity:	19.4
% Clay:	46				

Crop establishment

Planting date:	16/05/2011

Harvest dates

Harvest -Plant:	20/06/2012
1st ratoon:	26/06/2013
2nd ratoon:	3/11/2014
3rd ratoon:	7/07/2015

Site overview

This trial site was generally well managed. The crop was established with few gaps and weed management was good over the four seasons. Irrigation management appeared to be generally adequate.

Yield and return

The second ratoon was the only crop stage which appeared to respond to higher rates of applied N (Table 21) with the 210 kg N/ha rate (SIX EASY STEPS, DYP 180 tch) producing significantly more tonnes of cane than the lower N rate of 170 kg N/ha (SIX EASY STEPS, DYP 150 tch). However the higher N rates had a negative impact on the CCS, with levels declining significantly once N rates reached the Grower N rate of 250 kg/ha. This negative impact on CCS resulted in no significant differences is tonnes of sugar or net revenue for any of the treatments.

Yields in the 3rd ratoon were dramatically lower than the previous crop stage due in part to the crop being harvested when it was approximately eight months of age.

Table 21: Mean cane and sugar yield, CCS and gross revenue, costs and net revenue

Crop stage	N rate Kg N/ha	Cane yield tch	CCS units	Sugar yield tsh	Net revenue $/ha
Plant	130 – ~DYP 150	106	13.7	14.4	$3,653
	170 – ~DYP 180	111	13.3	14.8	$3,629
	210 – grower	113	12.8	14.5	$3,434
	250 – high	113	12.8	14.9	$3,453
	p-value	0.160	0.180	0.387	0.104
	95% LSD	12.1	1.3	0.9	$347
1st ratoon	170 – ~DYP 150	112 a	15.0 a	16.8	$3,817
	210 – ~DYP 180	122 a	14.8 ab	18.1	$4,065
	250 – grower	126 a	14.2 b	17.8	$3,843
	290 – high	124 a	14.3 ab	17.8	$3,802
	p-value	0.046	0.011	0.181	0.275
	95% LSD	14.4	0.7	1.9	$525
2nd ratoon	170 – ~DYP 150	108 b	17.4 a	18.8	$3,975
	210 – ~DYP 180	111 ab	17.3 ab	19.2	$4,009
	250 – grower	116 ab	16.5 b	19.1	$3,781
	290 – high	117 a	16.6 b	19.4	$3,830
	p-value	0.027	0.008	0.485	0.222
	95% LSD	9.3	0.8	1.6	$432
3rd ratoon	170 – ~DYP 150	80	14.7	11.7	$2,402 a
	210 – ~DYP 180	75	14.7	11.0	$2,167 a
	250 – grower	76	14.3	10.8	$2,015 a
	290 – high	76	14.0	10.7	$1,910 a
	p-value	0.63	0.113	0.294	0.049
	95% LSD	14.3	1	2	$531

Figure 19 presents the statistical results for an analysis over the crop cycle (plant cane through to third ratoon). The results indicate that there were statistically significant differences in cane yield and CCS between the treatments but not in sugar yield or net revenue. While the unprotected F-test for net revenue had a p-value less than 0.05, protected pairwise comparisons (using the Bonferroni method) did not indicate significant differences between the treatments. The high and grower treatments were found to have significantly higher cane yield than the DYP 150 treatment but also significantly lower CCS than both of the SIX EASY STEPS treatments.

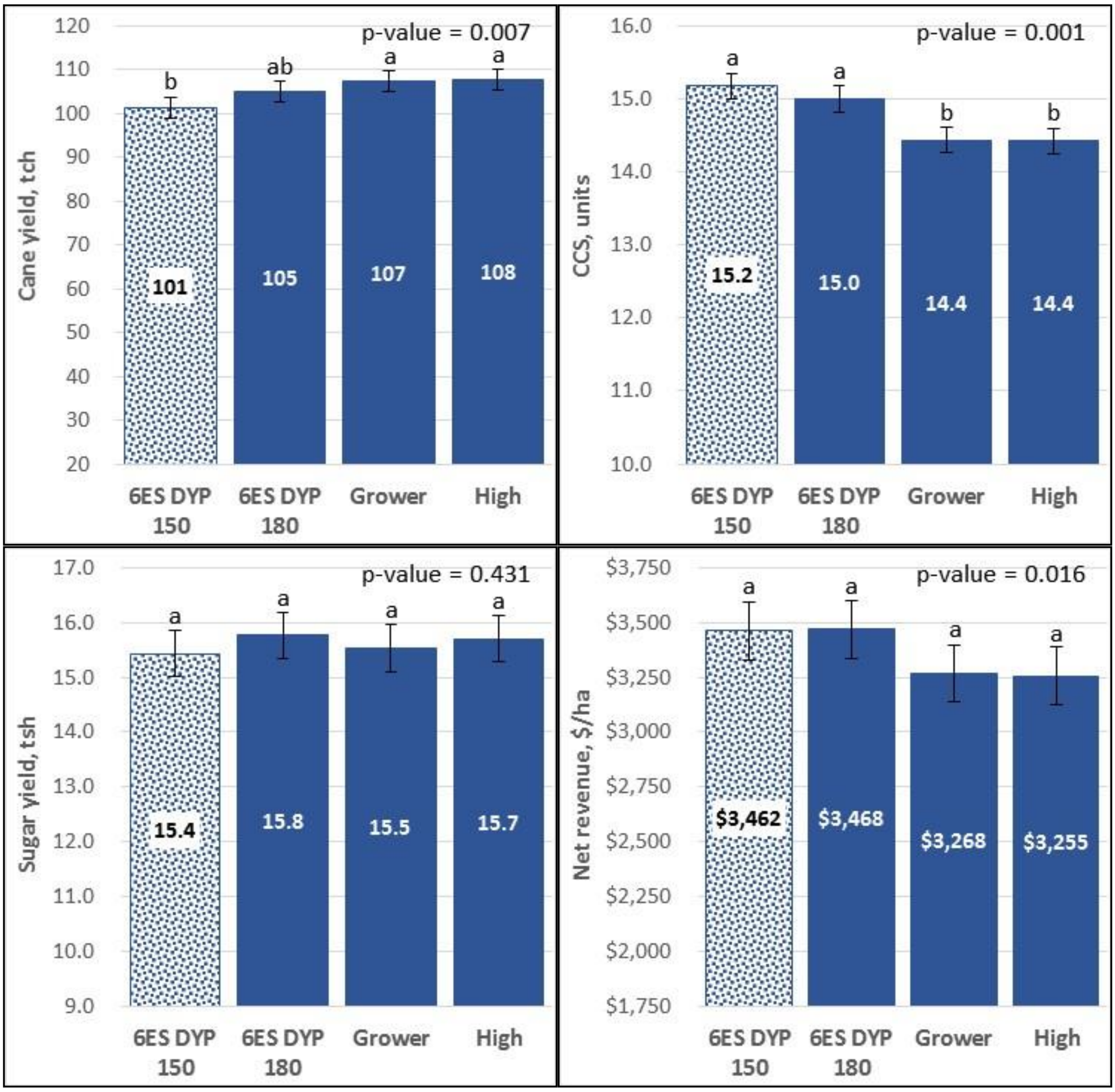

Figure 19: Average over crop cycle – cane yield, CCS, sugar yield and net revenue

The sensitivity analysis revealed that the economic outcome over the crop cycle was sensitive to fluctuations in the prices of sugar and fertiliser (see Figure 20 below). Results show that the DYP 150 treatment would attain the highest mean net revenue if the sugar price was below $400 per tonne or if fertiliser prices were 10% higher than 2015 prices.

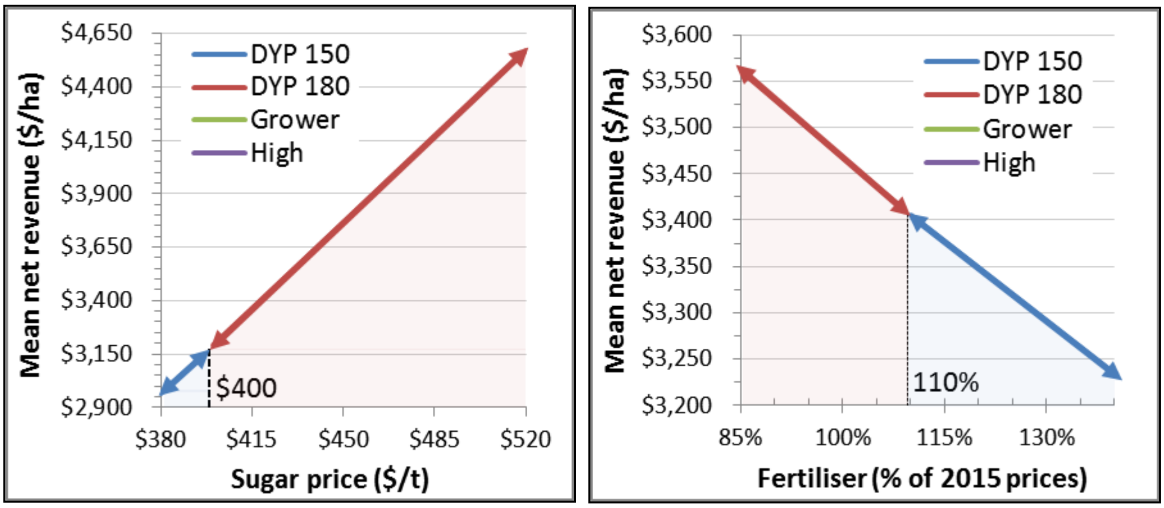

Figure 20: Sensitivity of mean net revenue over crop cycle to sugar and fertiliser prices

Pre-plant soil N

Prior to planting on average across the trial site a total of 32(±3) kg/ha of mineral N was found in the top 60cm of the soil profile. This included 5(±1) kg/ha of nitrate nitrogen and 27 (±4) kg/ha of ammonium nitrogen.

Nitrate nitrogen levels in irrigation water

Irrigation water applied to this trial site was supplied via a channel. Mean levels of oxidised nitrogen as N were <0.05 mg/L over the duration of the trial.

Post-harvest soil N

Following the harvest of each crop soil mineral N levels in the top 60cm of the soil profile were measured in all treatments. Mean nitrate and ammonium levels and total mineral N are presented in Table 20. Soil mineral N levels remained low in each treatment, higher rates of applied N did not result in higher levels of N remaining in the soil profile following harvest indicating that the majority of mineral N not utilised by the crop had either been converted to another form which is no longer immediately available to the crop or had moved out of the profile due to leaching, runoff, denitrification or via a combination of these loss pathways.

Standard practice was to soil sample in the centre of the hill following harvest, however the grower at this trial site expressed interest in sampling the shoulder of the hill to see if mineral N levels were any different. From the limited sampling conducted there appeared to be no difference in mineral N levels in the two locations on the planting hill (Table 22).

Table 22: Mean and coefficient of variation (plant crop only) of soil (0-60cm) nitrate, ammonium and total mineral N in each treatment following the harvest of each crop stage

Crop Stage	Treatment (kg N/ha)	NO3 (kg/ha)	NH4 (kg/ha)	Total mineral N (kg/ha)
Plant (centre of the planting hill)	130	10	10	20 (24%)
	170	10	14	24 (17%)
	210	12	18	30 (9%)
	250	12	13	25 (7%)
Plant* (shoulder of planting hill)	130	8	18	26 (11%)
	170	9	18	27 (16%)
	210	7	10	17 (8%)
	250	7	12	19 (21%)
1st Ratoon	170	12	15	27
	210	15	24	39
	250	17	19	36
	290	17	22	39
2nd Ratoon	170	7	19	27
	210	7	17	24
	250	7	36	44
	290	7	22	29
3rd Ratoon	170	7	24	31
	210	7	27	34
	250	7	41	48
	290	7	27	34

*Soil samples taken from the shoulder of the hill for comparison with soil samples taken from the centre of the hill.

Nitrogen exported to the mill

During the harvesting of trial sites stalk samples were taken at random locations from within each strip to estimate the amount of N exported to the mill (Table 23). In the 1st ratoon crop N in stalk exported to the mill increased significantly at the 210 kg/ha N rate and the 290 kg/ha N rate.

There was no significant increase in yield at either of these two N application rates indicating that some luxury consumption of N by the crop had taken place.

Table 23: Mean of N in stalk exported to the mill (kg/ha) and kg of N in stalk/tonne of stalk for each treatment and crop stage

Crop Stage	N Rate (kg/ha)	Mean Yield (tch)	N in Stalk Exported to Mill (kg/ha)	Kg of N in Stalk/tonne of Stalk
Plant	130	106	-	-
	170	111	-	-
	210	113	-	-
	250	113	-	-
1st Ratoon	170	112	59 c	0.53
	210	122	72 b	0.64
	250	126	-	-
	290	124	97 a	0.78
2nd Ratoon	170	108 b	52 c	0.48
	210	111 ab	74 b	0.67
	250	116 ab	92 a	0.79
	290	117 a	88 ab	0.75
3rd Ratoon	170	80	48 a	0.60
	210	75	51 a	0.68
	250	76	58 a	0.76
	290	76	51 a	0.67

$P<0.05$, means followed by a common letter are not significantly different at the 5% level

Partial N budget

The two N budgets show the major inputs and outputs for the SIX EASY STEPS method recommended N application rate when using the DYP of 150 tch and the Grower preferred N application rate for the plant crop. The DYP of 150 tch was chosen for the budget due to a lack of response to N rates above this DYP.

Budget 1. SIX EASY STEPS (Mean yield: 106 tch)

Inputs (kg/ha)		Outputs (kg/ha)	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**130**	1. Crop N uptake	**108**
2. Pre plant soil mineral N	**32**	2. Soil residual mineral N	**24**
3. In season soil N mineralisation estimate	**10**		
4. N in irrigation water	**0**		
Total Inputs	**172**	**Total Outputs**	**132**

Estimate of N in attached dead leaf and below ground biomass used in calculation of crop N uptake. Estimate of N in components is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
40

This budget was close to being in balance with 40 kg N/ha unaccounted.

Budget 2. Grower N rate (Mean yield: 113 tch)

Inputs (kg/ha)		Outputs (kg/ha)	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**210**	1. Crop N uptake	**141**
2. Pre plant soil mineral N	**32**	2. Soil residual mineral N	**30**
3. In season soil N mineralisation estimate	**10**		
4. N in irrigation water	**0**		
Total Inputs	**252**	**Total Outputs**	**171**

Estimate of N in attached dead leaf and below ground biomass used in calculation of crop N uptake. Estimate of N in components is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
81

With the higher N application rate more N was unaccounted. It appeared that the crop accumulated more N, however this did not translate into significantly higher yields.

*Unaccounted for N = Total Inputs – Total Outputs

Site 7 – Home Hill, Delta

Site characteristics

Variety:	Q208⁽ᵇ⁾	Row width:	1.52 m	Water source:	Bore

Soil characteristics (0-20cm)

% Sand (fine):	48	Type:	Dermosol	% Organic carbon:	0.58
% Sand (coarse):	7	Texture:	Loam	Soil pH (1:5 Water):	8.1
% Silt:	19	QDPI:	CUfc	Cation exchange capacity:	14.9
% Clay:	26				

Crop establishment

Planting date:	19/05/2011

Harvest dates

Harvest -Plant:	26/10/2012	3rd ratoon:	8/11/2015
1st ratoon:	13/09/2013		
2nd ratoon:	14/10/2014		

Site overview

This trial site was generally managed according to best management principles. The crop was established with few gaps and weed management was good over the four seasons. Good farm management practices combined with fair soil fertility has allowed this grower to achieve consistent cane and sugar yields over the duration of the trials.

Yield and return

Higher rates of applied N did not result in any additional production of cane or sugar at this site over the duration of the trial (Table 24). A general decline in productivity was observed in the ratoons, however higher N rates did not have any effect on tonnes of cane or sugar produced. In the 1st ratoon, the DYP 150 treatment was found to have significantly higher net revenue than the High treatment by almost $400/ha. A similar outcome also occurred in the 3rd ratoon with both SIX EASY STEPS treatments having significantly higher net revenue than the High treatment (ranging between $260/ha and $410/ha) and the DYP 150 having almost $300/ha more than the Grower treatment.

Table 24: Mean cane and sugar yield, CCS and gross revenue, costs and net revenue

Crop stage	N rate Kg N/ha	Cane yield tch	CCS units	Sugar yield tsh	Net revenue $/ha
Plant	130 – ~DYP 150	150	15.6	23.5	$4,797
	170 – ~DYP 180	152	15.5	23.5	$4,703
	210 – grower	-	-	-	-
	250 – high	151	15.2	23.0	$4,434
	p-value	0.932	0.477	0.814	0.325
	95% LSD	14.9	1.1	2.8	$859
1st ratoon	170 – ~DYP 150	124	16.1	19.9	$4,208 a
	210 – ~DYP 180	-	-	-	-
	250 – grower	-	-	-	-
	290 – high	120	15.9	19.1	$3,818 b
	p-value	0.517	0.464	0.264	0.048
	95% LSD	16	0.7	1.9	$384
2nd ratoon	170 – ~DYP 150	128	15.6	20.0	$4,207
	210 – ~DYP 180	125	15.6	19.4	$3,989
	250 – grower	125	15.4	19.2	$3,867
	290 – high	125	15.3	19.2	$3,785
	p-value	0.503	0.070	0.338	0.057
	95% LSD	10	0.4	1.9	$475
3rd ratoon	170 – ~DYP 150	111	17.2 a	19.1	$4,151 a
	210 – ~DYP 180	111	17.0 ab	18.9	$4,003 ab
	250 – grower	112	16.7 ab	18.7	$3,858 bc
	290 – high	111	16.6 b	18.4	$3,740 c
	p-value	0.978	0.021	0.297	0.001
	95% LSD	10.3	0.5	1.2	$191

Figure 18 presents the statistical results for an analysis over the crop cycle (plant cane through to third ratoon). Unfortunately, as data was not collected for the grower treatment in the plant and first ratoon crops and the DYP 180 treatment in the first ratoon crop, the statistical analysis was unable to predict mean values for the grower and DYP 180 treatments. The results indicate that there were statistically significant differences in CCS and net revenue between the treatments but not in cane yield or sugar yield[8]. The SIX EASY STEPS DYP 150 treatment was found to have significantly higher CCS and net revenue than the high N rate treatment by almost $400/ha per crop, which adds up to almost $1,600 over the crop cycle (all four crops – plant to 3rd ratoon).

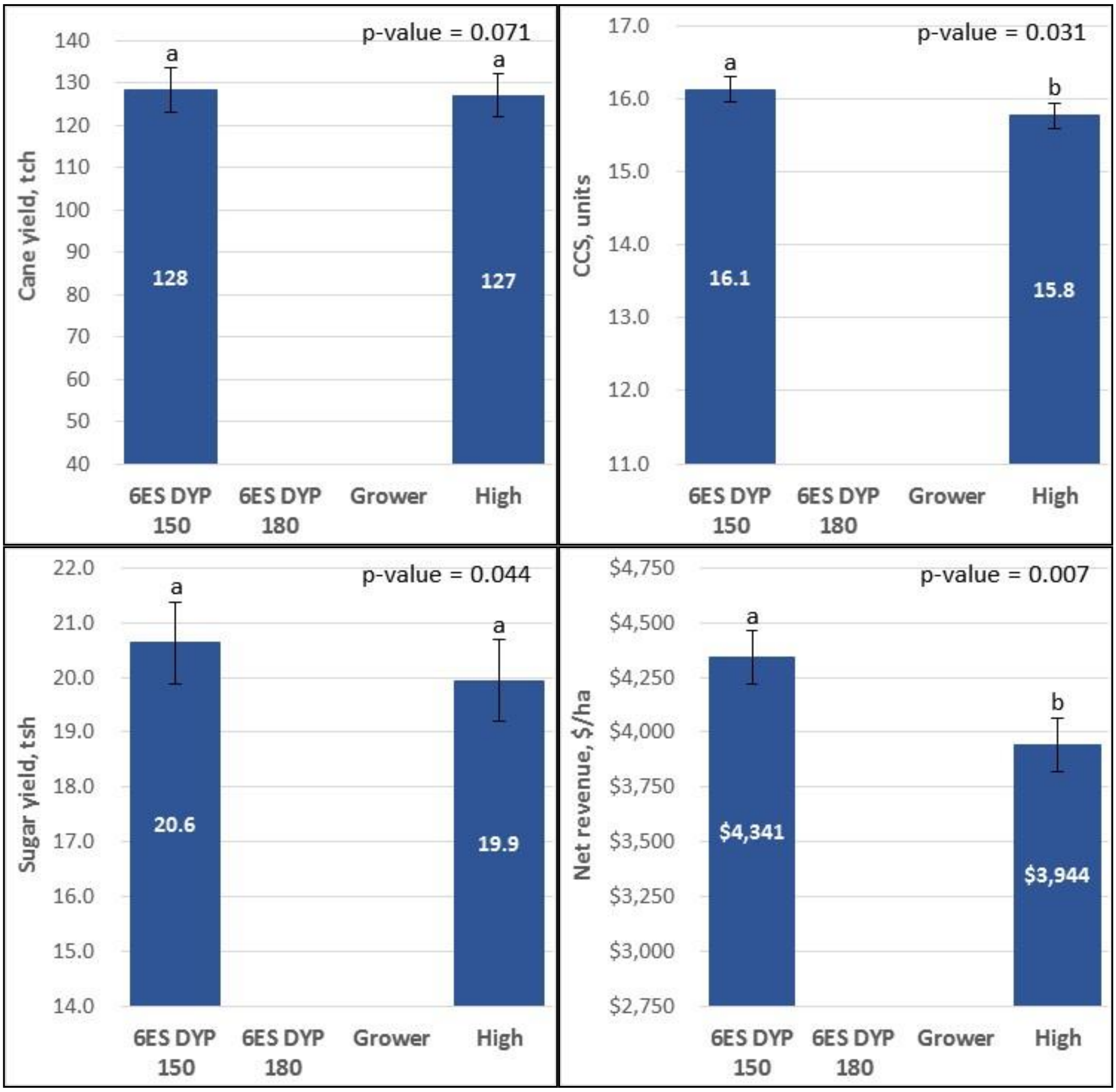

Figure 21: Average over crop cycle – cane yield, CCS, sugar yield and net revenue

Sensitivity analyses reveal that the economic outcome over the crop cycle was not sensitive to fluctuations in the sugar price or fertiliser price within the considered ranges.

Pre-plant soil N

Prior to planting on average across the trial site a total of 16(±5) kg/ha of mineral N was found in the top 60cm of the soil profile. This included 11 (±6) kg/ha of nitrate nitrogen and 5(±0.4) kg/ha of ammonium nitrogen.

[8] While the unprotected F-test for sugar yield had a p-value less than 0.05, protected pairwise comparisons (using the Bonferroni method) did not indicate significant differences between the treatments.

Nitrate nitrogen levels in irrigation water

Irrigation water applied to this trial site was supplied from four separate bores. The water from these bores was often mixed. The site was also irrigated with water supplied from a creek, however this was infrequent. Water samples were taken from each source and tested for oxidised nitrogen as N and are presented in Table 25.

Table 25: Mean and standard error of oxidized nitrogen as N for each water source

Crop Stage	Oxidised nitrogen as N (mg/L)
Bore 1	0.74*
Bore 2	3.2 (±0.77)
Bore 3	6.2 (±0.21)
Bore 4	5.3 (±0.08)
Creek	<0.05#

*Result based on one sample
Result based on two samples

Post-harvest soil N

Following the harvest of each crop soil mineral N levels in the top 60cm of the soil profile were calculated in all treatments. Mean nitrate and ammonium levels and total mineral N are presented in Table 26. Soil N levels remained low in each treatment. Higher rates of applied N did not result in higher levels of N remaining in the soil profile following harvest indicating that the majority of mineral N not utilised by the crop had either been converted to another form which is no longer immediately available to the crop or had moved out of the profile due to leaching, runoff, denitrification or via a combination of these loss pathways.

Table 26: Mean and coefficient of variation (plant crop only) of soil (0-60cm) nitrate, ammonium and total mineral N in each treatment following harvest of each crop stage

Crop Stage	Treatment (kg/ha)	NO3 (kg/ha)	NH4 (kg/ha)	Total mineral N (kg/ha)
Plant	130	21	11	35 (18%)
	170	29	15	44 (10%)
	210	31	15	46 (14%)
	250	21	20	41 (10%)
1st Ratoon	170	12	7	19
	210	-	-	-
	250	-	-	-
	290	17	12	29
2nd Ratoon	170	-	-	-
	210	-	-	-
	250	-	-	-
	290	-	-	-
3rd Ratoon	170	7	7	15
	210	7	15	22
	250	7	17	24
	290	7	15	22

Nitrogen exported to the mill

During the harvesting of trial sites stalk samples were taken at random locations from within each strip to estimate the amount of N exported to the mill (Table 27).

In the plant crop N in stalk exported to the mill increased significantly at the highest N rate (250 kg N/ha) in comparison to the lowest N rate (130 kg N/ha).

There was no significant increase in yield produced at the highest N application rate. In the second ratoon crop there was a significant increase in N exported to the mill at the highest N rate (290 kg N/ha) in comparison to the two lowest N rates. In both the plant and second ratoon crops there is evidence of luxury consumption of N by crops.

Table 27: Mean of N in stalk exported to the mill (kg/ha) and kg of N in stalk/tonne of stalk for each treatment and crop stage

Crop Stage	N Rate (kg/ha)	Mean Yield (tch)	N in Stalk Exported to Mill (kg/ha)	Kg of N in Stalk/tonne of Stalk
Plant	130	150	98 b	0.67
	170	152	108 ab	0.68
	210	-	-	-
	250	151	120 a	0.79
1st Ratoon	170	124	81 a	0.65
	210	-	-	-
	250	-	-	-
	290	120	90 a	0.75
2nd Ratoon	170	128	91 b	0.71
	210	125	86 b	0.69
	250	125	98 ab	0.78
	290	125	111 a	0.89
3rd Ratoon	170	111	76 a	0.68
	210	111	77 a	0.69
	250	112	82 a	0.73
	290	111	78 a	0.70

P<0.05, means followed by a common letter are not significantly different at the 5% level

Partial N budget

The two N budgets show the major inputs and outputs for the SIX EASY STEPS method recommended N application rate when using the DYP of 180 tch and the growers preferred N application rate for the plant crop.

Budget 1. SIX EASY STEPS (Mean yield: 150 tch)

Inputs (kg/ha)		Outputs (kg/ha)	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**170**	1. Crop N uptake	**152**
2. Pre plant soil mineral N	**16**	2. Soil residual mineral N	**44**
3. In season soil N mineralisation estimate	**10**		
4. N in irrigation water	**39^**		
Total Inputs	**235**	**Total Outputs**	**196**

Estimate of N in attached dead leaf and below ground biomass used in calculation of crop N uptake. Estimate of N in components is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
39

This budget was close to being in balance with 39 kg N/ha unaccounted.

Budget 2. High N rate (Mean yield: 151 tch)

Inputs (kg/ha)		Outputs (kg/ha)	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**250**	1. Crop N uptake	**184**
2. Pre plant soil mineral N	**16**	2. Soil residual mineral N	**46**
3. In season soil N mineralisation estimate	**10**		
4. N in irrigation water	**39^**		
Total Inputs	**315**	**Total Outputs**	**230**

Estimate of N in attached dead leaf and below ground biomass used in calculation crop N uptake. Estimate of N in components is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
85

With the higher N application rate more N was unaccounted. It appears that the crop has accumulated more N, however this has not translated into additional yield.

**Unaccounted for N = Total Inputs – Total Outputs*
^ Estimate of N in irrigation water is based on the average concentration of oxidised N in the four bores monitored

Site 8 – Clare, BRIA

Site characteristics

Variety:	Q208⟑	Row width:	1.65 m	Water source:	Channel

Soil characteristics (0-20cm)

% Sand (fine):	33
% Sand (coarse):	4
% Silt:	26
% Clay:	38

Type:	Sodic Duplex
Texture:	Clay loam
QDPI:	2Dyb

% Organic carbon:	0.6
Soil pH (1:5 Water):	7.4
Cation exchange capacity:	16.2

Crop establishment

Planting date:	16/05/2011

Harvest dates

Harvest -Plant:	8/09/2012
1st ratoon:	6/09/2013
2nd ratoon:	16/10/2014
3rd ratoon:	5/10/2015
4th ratoon:	

Site overview

The plant crop was established with few gaps and weed management was good over the four crop stages. Prior to planting gypsum was applied to this block at a rate of 5 tonnes/ha. Soil moisture monitoring data collected during the development of the 3rd ratoon crop along with general observations over the duration of the trial indicated that irrigation management practices could be adjusted to improve productivity at this site.

Yield and return

A statistically significant response to higher rates of applied N was only seen in the 2nd ratoon with more cane produced by the High N rate treatment in comparison to the DYP 150 N rate treatment (Table 28). Importantly, the improved yield did not follow through to higher profitability with the High N rate treatment attaining the lowest mean net revenue in the 2nd ratoon, while the DYP 150 treatment produced the highest.

Table 28: Mean cane and sugar yield, CCS and gross revenue, costs and net revenue

Crop stage	N rate Kg N/ha	Cane yield tch	CCS units	Sugar yield tsh	Net revenue $/ha
Plant	130 – ~DYP 150	126 a	15.9	20.0	$4,005
	170 – ~DYP 180	131 a	15.5	20.3	$3,943
	210 – grower	134 a	15.6	20.9	$4,019
	250 – high	136 a	15.6	21.2	$4,017
	p-value	0.035	0.560	0.224	0.953
	95% LSD	9.8	1	2.1	$601
1st ratoon	170 – ~DYP 150	79	16.2	12.8	$2,354
	210 – ~DYP 180	82	16.2	13.3	$2,384
	250 – grower	84	16.2	13.6	$2,392
	290 – high	85	16.0	13.6	$2,305
	p-value	0.290	0.697	0.298	0.729
	95% LSD	11.1	0.8	1.6	$320
2nd ratoon	170 – ~DYP 150	79 b	17.3	13.7	$2,971
	210 – ~DYP 180	82 ab	17.1	14.0	$2,933
	250 – grower	81 ab	17.2	14.0	$2,859
	290 – high	86 a	16.9	14.4	$2,841
	p-value	0.024	0.259	0.125	0.344
	95% LSD	5.7	0.8	1	$288
3rd ratoon	170 – ~DYP 150	84	18.1	15.1	$3,068
	210 – ~DYP 180	81	18.2	14.7	$2,946
	250 – grower	85	18.0	15.4	$3,003
	290 – high	85	17.9	15.3	$2,880
	p-value	0.157	0.259	0.289	0.146
	95% LSD	7.1	0.5	1.2	$270

Figure 22 presents the statistical results for an analysis over the crop cycle (plant cane through to third ratoon). The results indicate that there was a statistically significant difference in cane yield between the treatments but not in CCS, sugar yield[9] or net revenue. The SIX EASY STEPS DYP 150 treatment was found to have significantly lower cane yield than the High N rate treatment by 6 tch per crop.

[9] While the unprotected F-test for sugar yield had a p-value less than 0.05, protected pairwise comparisons (using the Bonferroni method) did not indicate significant differences between the treatments.

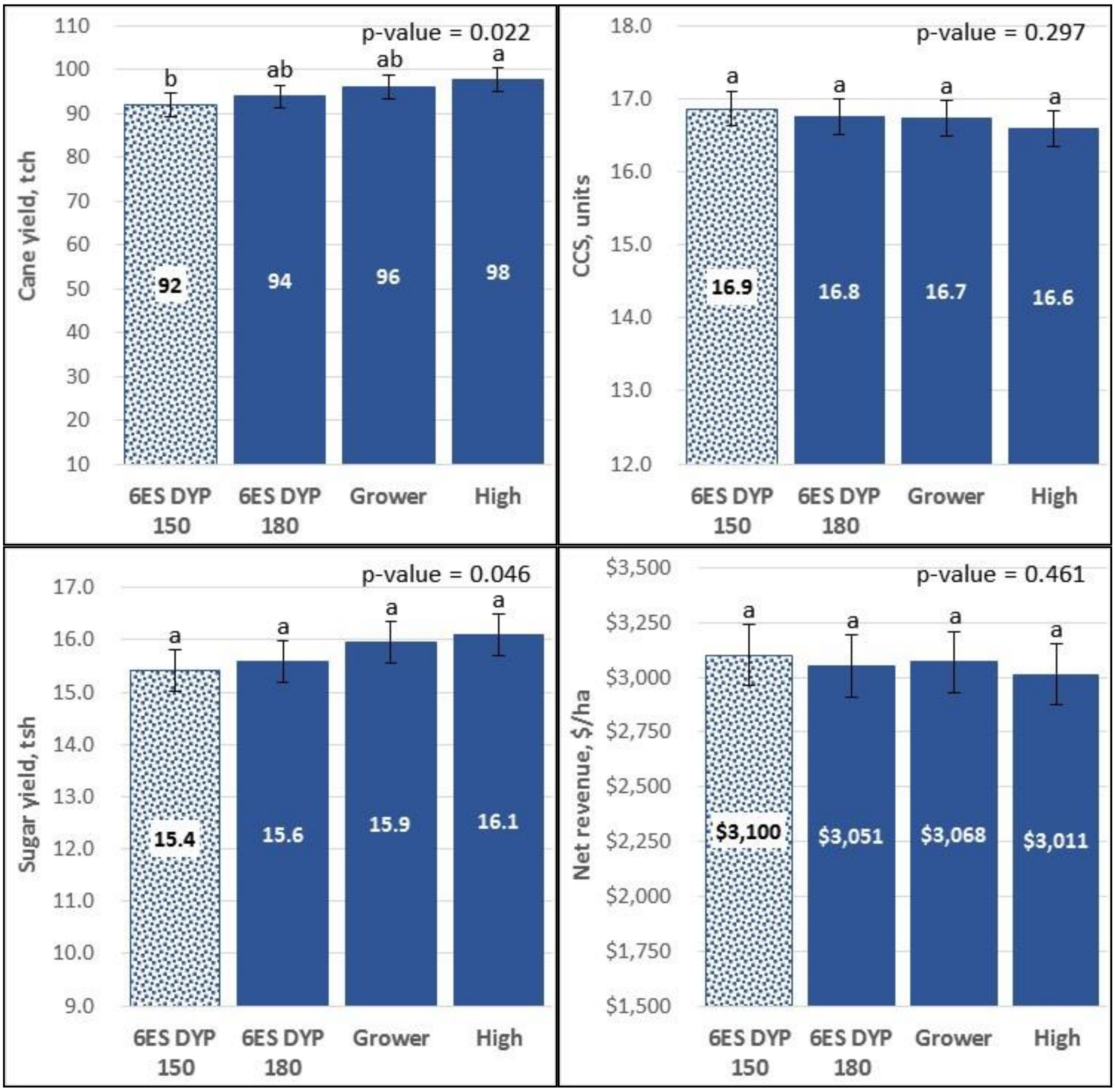

Figure 22: Average over crop cycle – cane yield, CCS, sugar yield and net revenue

Sensitivity analyses reveal that the economic outcome over the crop cycle was not sensitive to fluctuations in the sugar price or fertiliser price within the considered ranges.

Pre-plant soil N

Prior to planting on average across the trial site a total of 31(±13) kg/ha of mineral N was found in the top 60cm of the soil profile. This included 17(±10) kg/ha of nitrate nitrogen and 14(±3) kg/ha of ammonium nitrogen.

Nitrate nitrogen levels in irrigation water

Irrigation water applied to this trial site was supplied via a channel. Mean levels of oxidised nitrogen as N were <0.05 mg/L over the duration of the trials.

Post-harvest soil N

Following the harvest of each crop soil mineral N levels in the top 60cm of the soil profile were calculated in all treatments. Mean nitrate and ammonium levels and total mineral N are presented in Table 29. Soil mineral N levels were low in each treatment. Higher rates of applied N did not result in higher levels of N remaining in the soil profile following harvest, indicating that the majority of mineral N not utilised by the crop had either been converted to another form which is no longer immediately available to the crop or had moved out of the profile due to leaching, runoff, denitrification or via a combination of these loss pathways.

Mean and coefficient of variation (plant crop only) of soil (0-60cm) nitrate, ammonium and total mineral N in each treatment following the harvest of each crop stage

Table 29: Mean and coefficient of variation (plant crop only) of soil (0-60cm) nitrate, ammonium and total mineral N in each treatment following the harvest of each crop stage

Crop Stage	Treatment (kg N/ha)	NO3 (kg/ha)	NH4 (kg/ha)	Total mineral N (kg/ha)
Plant	130	7	19	26 (5%)
	170	7	17	24 (10%)
	210	9	19	27 (5%)
	250	8	24	33 (26%)
1st Ratoon	170	7	12	19
	210	7	15	22
	250	7	15	22
	290	7	15	22
2nd Ratoon	170	7	19	27
	210	7	19	27
	250	7	17	24
	290	7	24	31
3rd Ratoon	170	7	27	34
	210	7	22	29
	250	7	24	31
	290	7	24	31

Nitrogen exported to the mill

During the harvesting of trial sites stalk samples were taken at random locations from within each strip to estimate the amount of N exported to the mill (Table 30). In the plant, 1st and 2nd ratoon crops there was a trend for increased concentration of N in stalks with higher N application rates. In the plant crop N in stalk exported to the mill increased significantly at the 210 and 250 kg/ha N rates in comparison to the two lowest N rates (130 and 170 kg/ha). There was no significant increase in yield produced at the higher N application rates indicating luxury N consumption by the crop.

Table 30: Mean of N in stalk exported to the mill (kg/ha) and kg of N in stalk/tonne of stalk for each treatment and crop stage

Crop Stage	N Rate (kg/ha)	Mean Yield (TCH)	N in Stalk Exported to Mill (kg/ha)	Kg of N in Stalk/tonne of Stalk
Plant	130	126	60 b	0.48
	170	131	57 b	0.44
	210	134	73 a	0.54
	250	136	82 a	0.60
1st Ratoon	170	79	41 a	0.52
	210	82	47 a	0.57
	250	84	-	-
	290	85	51 a	0.60
2nd Ratoon	170	79	45 a	0.57
	210	82	46 a	0.56
	250	81	50 a	0.62
	290	86	51 a	0.59
3rd Ratoon	170	84	51 a	0.61
	210	81	65 a	0.80
	250	85	56 a	0.66
	290	85	59 a	0.69

$P<0.05$, means followed by a common letter are not significantly different at the 5% level

Irrigation management

Soil moisture monitoring was conducted at this site in the 3rd ratoon crop using a PR2 profile probe and a HH2 hand logging device.

Readings began in December 2014 approximately one and a half months after harvest and ceased in June 2015. Readings were conducted approximately weekly over the monitoring period. The access tube for the probe was placed in the centre of the bed approximately 50 meters from the top of the block. Data collected from the site is presented in Figure 23 and shows some of the recorded irrigations and a rainfall event.

From December to March there was little change in soil moisture levels apart from an increase due to a rainfall event in January 2015 which increased soil moisture in the top 30cm of the profile. From mid-March onwards soil moisture levels began to decline throughout the profile, at this time the crop was five months of age and had a high requirement for soil moisture. Irrigation events temporarily increased soil moisture in the top 30 cm of the soil profile, however there was an overall trend of declining soil moisture levels in this part of the soil profile. At 40, 60 and 100cm soil moisture levels also declined steadily from mid-March onwards. In a well-managed block it would be expected that soil moisture levels would fluctuate at 40 cm as a result of increased soil moisture from irrigation events and from extraction by the crop. In general the soil moisture data indicates that from March onwards irrigation events were not able to meet crop demand, which would have had a negative impact on productivity.

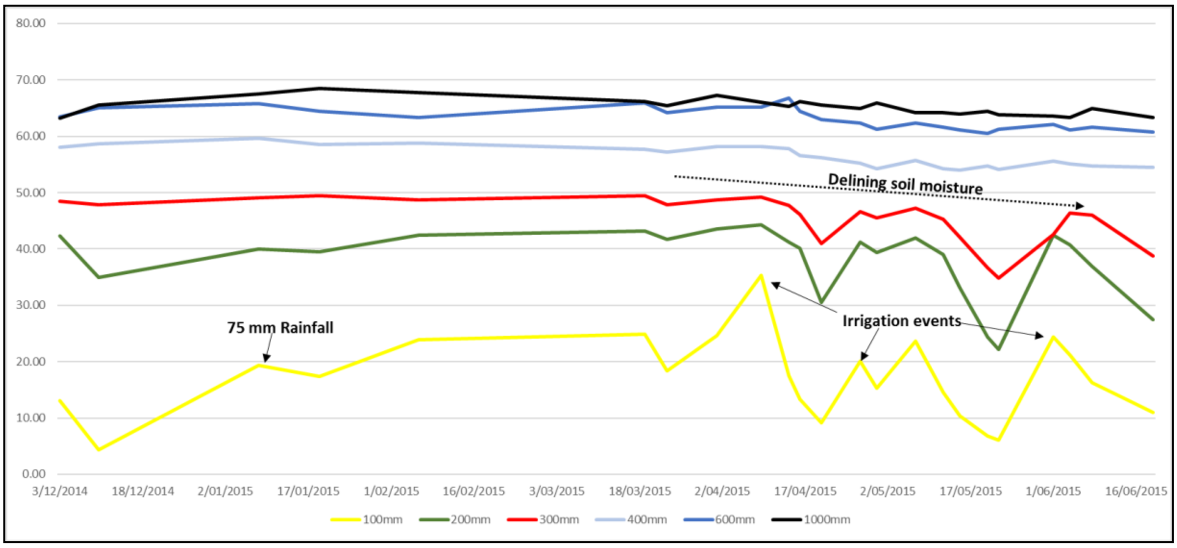

Figure 23: Soil moisture data collected during the 3rd ratoon crop

Partial N budget

The two N budgets show the major inputs and outputs for the SIX EASY STEPS method recommended N application rate when using the DYP of 150 tch and the growers preferred N application rate for the plant crop. The DYP of 150 tch was chosen for the budget due to a lack of response to N rates above this DYP.

Budget 1. SIX EASY STEPS (Mean yield: 126 tch)

Inputs (kg/ha)		Outputs (kg/ha)	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**130**	1. Crop N uptake	**88**
2. Pre plant soil mineral N	**31**	2. Soil residual mineral N	**26**
3. In season soil N mineralisation estimate	**10**		
4. N in irrigation water	**0**		
Total Inputs	**171**	**Total Outputs**	**114**

Estimate of N in attached dead leaf and below ground biomass used in calculation crop N uptake. Estimate of N in components is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
57

This budget indicates that there was 57 kg N/ha unaccounted.

Budget 2. Grower N rate (Mean yield: 134 tch)

Inputs (kg/ha)		Outputs (kg/ha)	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**210**	1. Crop N uptake	**173**
2. Pre plant soil mineral N	**31**	2. Soil residual mineral N	**27**
3. In season soil N mineralisation estimate	**10**		
4. N in irrigation water	**0**		
Total Inputs	**251**	**Total Outputs**	**200**

Estimate of N in attached dead leaf and below ground biomass used in calculation of crop N uptake. Estimate of N in components is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
51

At the Grower N application rate the crop accumulated considerably more N, however this did not translate into significantly higher yields. There appeared to be a significant amount of luxury N uptake.

*Unaccounted for N = Total Inputs – Total Outputs

Site 9 – Clare, BRIA

Site characteristics

Variety:	KQ228⁽ᵇ⁾	Row width:	1.65 m	Water source:	Channel

Soil characteristics (0-20cm)

% Sand (fine):	27	Type:	Vertosol	% Organic carbon:	0.59
% Sand (coarse):	6	Texture:	Clay	Soil pH (1:5 Water):	6.7
% Silt:	23	QDPI:	2Ugd	Cation exchange capacity:	16.8
% Clay:	45			Sodium % Cations (ESP)	8.5

Crop establishment

Planting date:	23/05/2011

Harvest dates

Harvest -Plant:	23/10/2012
1st ratoon:	10/09/2013

Site overview

The crop was established with a considerable number of gaps randomly distributed throughout the block. Weed management was fair over the duration of the trial at this site. Prior to planting gypsum was applied to this block at a rate of 5 tonnes/ha. Production at this site was constrained by the high levels of sodium and access to sufficient volumes of irrigation water.

Yield and return

Higher rates of applied N did not improve yields (tch or tsh) at this site in the plant or ratoon crop (Table 31). Plant crop yields were low, however with the high CCS values, sugar production levels were fair. First ratoon yields were very low by Burdekin standards.

Table 31: Mean cane and sugar yield, CCS and gross revenue, costs and net revenue

Crop stage	N rate Kg N/ha	Cane yield tch	CCS units	Sugar yield tsh	Net revenue $/ha
Plant	130 – ~DYP 150	90	16.7	15.0	$2,855
	170 – ~DYP 180	96	17.0	16.3	$3,133
	210 – grower	95	16.7	15.9	$2,942
	250 – high	96	16.8	16.1	$2,957
	p-value	0.059	0.247	0.078	0.194
	95% LSD	7.5	0.6	1.7	$434
1st ratoon	170 – ~DYP 150	59	16.2	9.5	$1,838
	210 – ~DYP 180	60	16.2	9.7	$1,822
	250 – grower	60	16.0	9.7	$1,752
	290 – high	61	16.1	9.8	$1,727
	p-value	0.743	0.224	0.078	0.457
	95% LSD	8.7	0.3	1.4	$294

Figure 24 presents the statistical results for an analysis over both the plant and first ratoon crops. The results indicate that there were no significant differences in cane yield, CCS, sugar yield or net revenue between the treatments.

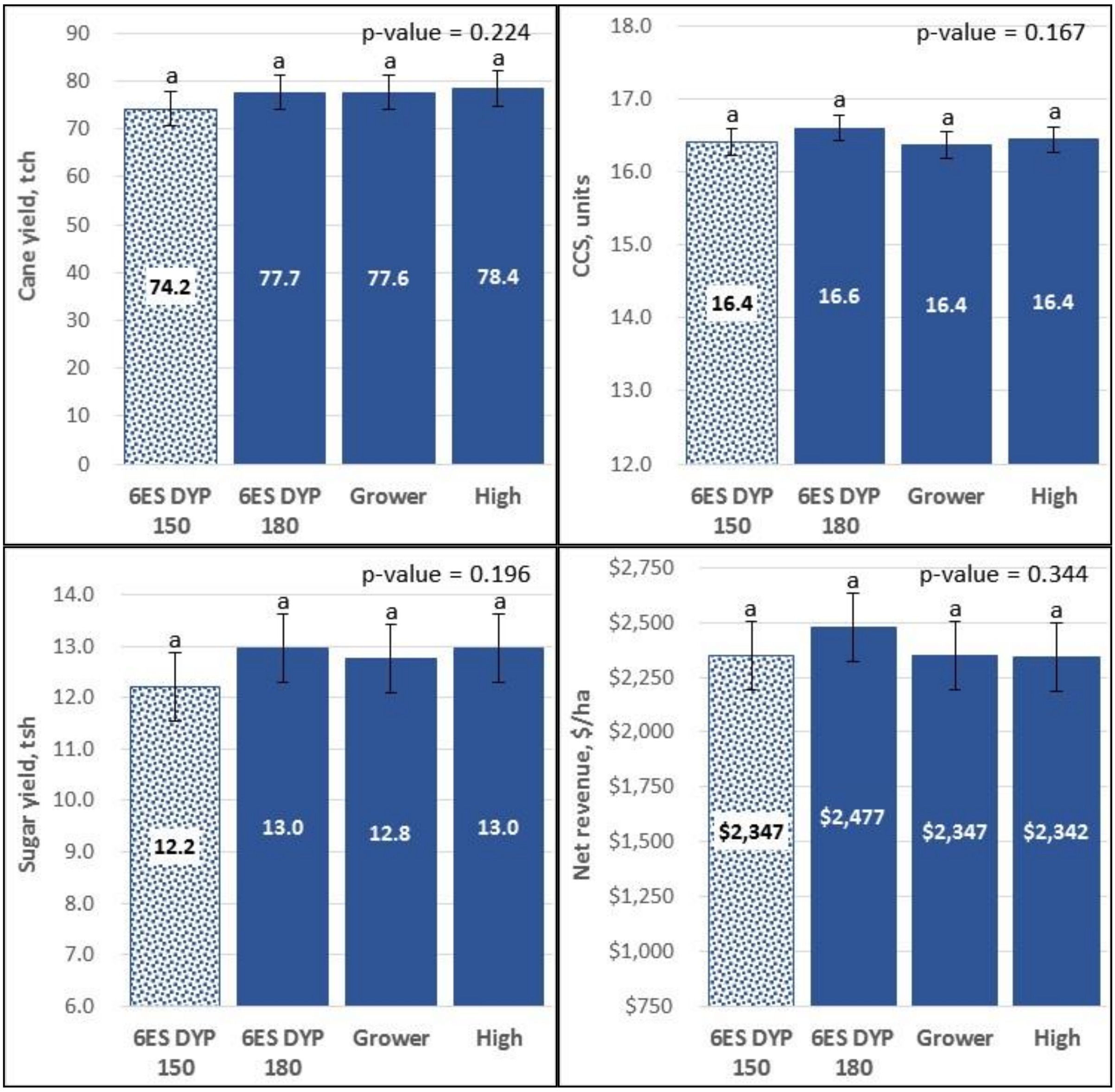

Figure 24: Average over crop cycle – cane yield, CCS, sugar yield and net revenue

Sensitivity analyses reveal that the economic outcome over both the plant and first ratoon crops was not sensitive to fluctuations in the sugar price or fertiliser price within the considered ranges.

Pre-plant soil N

Prior to planting on average across the trial site a total of 28 (±6) kg/ha of mineral N was found in the top 60cm of the soil profile. This included 11 (±3) kg/ha of nitrate nitrogen and 17 (±3) kg/ha of ammonium nitrogen.

Nitrate nitrogen levels in irrigation water

Irrigation water applied to this trial site was supplied via a channel. Mean levels of oxidised nitrogen as N were <0.05 mg/L over the duration of the trial.

Post-harvest soil N

Following the harvest of each crop soil mineral N levels in the top 60cm of the soil profile were calculated in all treatments. Mean nitrate and ammonium levels and total mineral N are presented in Table 32. Soil mineral N levels remained low in each treatment. Higher rates of applied N did not result in higher levels of N remaining in the soil profile following harvest indicating that the majority of mineral N not utilised by the crop had either been converted to another form which was no longer immediately available to the crop or had moved out of the profile due to leaching, runoff, denitrification or via a combination of these loss pathways.

Table 32: Mean and coefficient of variation of soil (0-60cm) nitrate, ammonium and total mineral N in each treatment following the harvest of the plant crop

Crop Stage	Treatment (kg N/ha)	NO3 (kg/ha)	NH4 (kg/ha)	Total mineral N (kg/ha)
Plant	130	7	18	25 (7%)
	170	7	17	24
	210	7	23	31 (23%)
	250	7	21	28 (5%)

Nitrogen exported to the mill

During the harvesting of trial sites stalk samples were taken at random locations from within each strip to estimate the amount of N exported to the mill (Table 33). In the plant crop N in stalk exported to the mill increased significantly at the 210 kg/ha N rate in comparison to the lower N rate of 170 kg /ha. There was no significant increase in yield produced at the higher N application rate indicating luxury N consumption by the crop.

Table 33: Mean of N in stalk exported to the mill (kg/ha) and kg of N in stalk/tonne of stalk for each treatment and crop stage

Crop Stage	N Rate (kg/ha)	Mean Yield (TCH)	N in Stalk Exported to Mill (kg/ha)	Kg of N in Stalk/tonne of Stalk
Plant	130	90	63 bc	0.70
	170	96	57 c	0.61
	210	95	74 a	0.78
	250	96	71 ab	0.74
1st Ratoon	170	59	38 a	0.64
	210	60	34 a	0.57
	250	60	-	-
	290	61	36 a	0.59

$P<0.05$, means followed by a common letter are not significantly different at the 5% level

Survey of gaps within trial site

Following the establishment of the plant crop it was noted that there was a considerable number of gaps throughout the block. Due to the concern that this may have biased the trial results a survey of gaps was undertaken. Where a gap of >50cm between stalks was observed the gap was measured and the length recorded (Table 34). This assessment was conducted for the lowest N rate (130 kg N/ha) and the highest N rate (250 kg N/ha). The incidence of gaps appeared to be random and the percentage of area lost in each strip does not appear to vary greatly between the two treatments. However, the total area lost due to gaps was considerable and potentially impacted yields.

Table 34: Percent of strip area in each replicate not producing cane due to gaps

Treatment (kg N/ha)	Replication	% of strip area with gaps
130	1	9
	2	12
	3	9
250	1	11
	2	12
	3	13

Partial N budget

The two N budgets show the major inputs and outputs for the SIX EASY STEPS method recommended N application rate when using the DYP of 150 tch and the growers preferred N application rate for the plant crop. The DYP of 150 tch was chosen for this budget as yields were very low and there appeared to be no response to N at higher application rates.

Budget 1. SIX EASY STEPS (Mean yield: 90 tch)

Inputs (kg/ha)		**Outputs (kg/ha)**	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**130**	1. Crop N uptake	**137**
2. Pre plant soil mineral N	**28**	2. Soil residual mineral N	**25**
3. In season soil N mineralisation estimate	**10**		
4. N in irrigation water	**0**		
Total Inputs	**168**	**Total Outputs**	**162**

Estimate of N in attached dead leaf and below ground biomass used in calculation of crop N uptake. Estimate of N in components is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
6

This budget was close to being in balance with little N unaccounted.

Budget 2. Growers preferred N rate (Mean yield: 95 tch)

Inputs (kg/ha)		**Outputs (kg/ha)**	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**210**	1. Crop N uptake	**170**
2. Pre plant soil mineral N	**28**	2. Soil residual mineral N	**31**
3. In season soil N mineralisation estimate	**10**		
4. N in irrigation water	**0**		
Total Inputs	**248**	**Total Outputs**	**201**

Estimate of N in attached dead leaf and below ground biomass used in calculation of crop N uptake. Estimate of N in components is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
47

With the higher N application rate more N was unaccounted. The crop appeared to accumulate more N, however this did not translated into higher yields.

*Unaccounted for N = Total Inputs – Total Outputs

Site 10 – Home Hill, Delta

Site characteristics

Variety:	Q208(d)	Row width:	1.58 m	Water source:	Channel/Bore

Soil characteristics (0-20cm)

% Sand (fine):	35	Type:	Vertosol	% Organic carbon:	0.84
% Sand (coarse):	17	Texture:	Clay loam	Soil pH (1:5 Water):	7.8
% Silt:	20	QDPI:	RUgb	Cation exchange capacity:	15.4
% Clay:	27				

Crop establishment

Planting date:	3/08/2011

Harvest dates

Harvest -Plant:	13/09/2012	3rd ratoon:	16/10/2015
1st ratoon:	2/08/2013		
2nd ratoon:	12/07/2014		

Site overview

This trial site was generally managed according to best management principles. The crop was established with few gaps and weed management was good over the four crop stages. Good farm management practices combined with reasonable soil fertility and in general good irrigation management has allowed this grower to achieve consistent cane and sugar yields over the duration of the trials.

Yield and return

A yield response to higher rates of applied N was observed in the plant and 2nd ratoon crops at this site, however there was also a statistically significant decline in CCS in the 2nd and 3rd ratoon crops with higher N rates (Table 35). In terms of profitability, no statistically significant differences in net revenue existed between the treatments in the plant crop, 1st ratoon or 2nd ratoon. In the 3rd ratoon, the DYP 180 treatment was found to attain significantly higher net revenue than the High rate treatment by just over $400/ha

Table 35: Mean cane and sugar yield, CCS and gross revenue, costs and net revenue

Crop stage	N rate Kg N/ha	Cane yield tch	CCS units	Sugar yield tsh	Net revenue $/ha
Plant	130 – ~DYP 150	122 b	15.5	18.9	$3,925
	170 – ~DYP 180	129 ab	15.2	19.7	$3,991
	210 – grower	130 ab	15.3	20.0	$4,004
	250 – high	133 a	15.1	20.1	$3,925
	p-value	0.035	0.554	0.101	0.870
	95% LSD	10.6	1	1.6	$477
1st ratoon	170 – ~DYP 150	117	15.4	18.0	$3,882
	210 – ~DYP 180	125	15.0	18.7	$3,901
	250 – grower	127	15.0	19.1	$3,931
	290 – high	133	14.8	19.6	$3,947
	p-value	0.065	0.201	0.062	0.901
	95% LSD	17.4	0.9	1.9	$371
2nd ratoon	170 – ~DYP 150	99 b	14.7 a	14.5	$3,172
	210 – ~DYP 180	102 b	14.3 ab	14.7	$3,069
	250 – grower	106 ab	14.0 bc	14.9	$3,008
	290 – high	113 a	13.5 c	15.3	$2,943
	p-value	0.002	0.002	0.186	0.157
	95% LSD	7.9	0.6	1.2	$337
3rd ratoon	170 – ~DYP 150	111	17.4 a	19.3	$3,994 ab
	210 – ~DYP 180	120	17.2 a	20.6	$4,165 a
	250 – grower	120	16.8 ab	20.2	$3,916 ab
	290 – high	122	16.5 b	20.1	$3,755 b
	p-value	0.071	0.007	0.165	0.035
	95% LSD	13.5	0.7	1.9	$393

Figure 25 presents the statistical results for an analysis over the crop cycle (plant cane through to third ratoon). The results indicate that there were statistically significant differences in cane yield and CCS between the treatments but not in sugar yield or net revenue. The high N rate treatment was found to have significantly higher cane yield but also significantly lower CCS than the DYP 150 treatment.

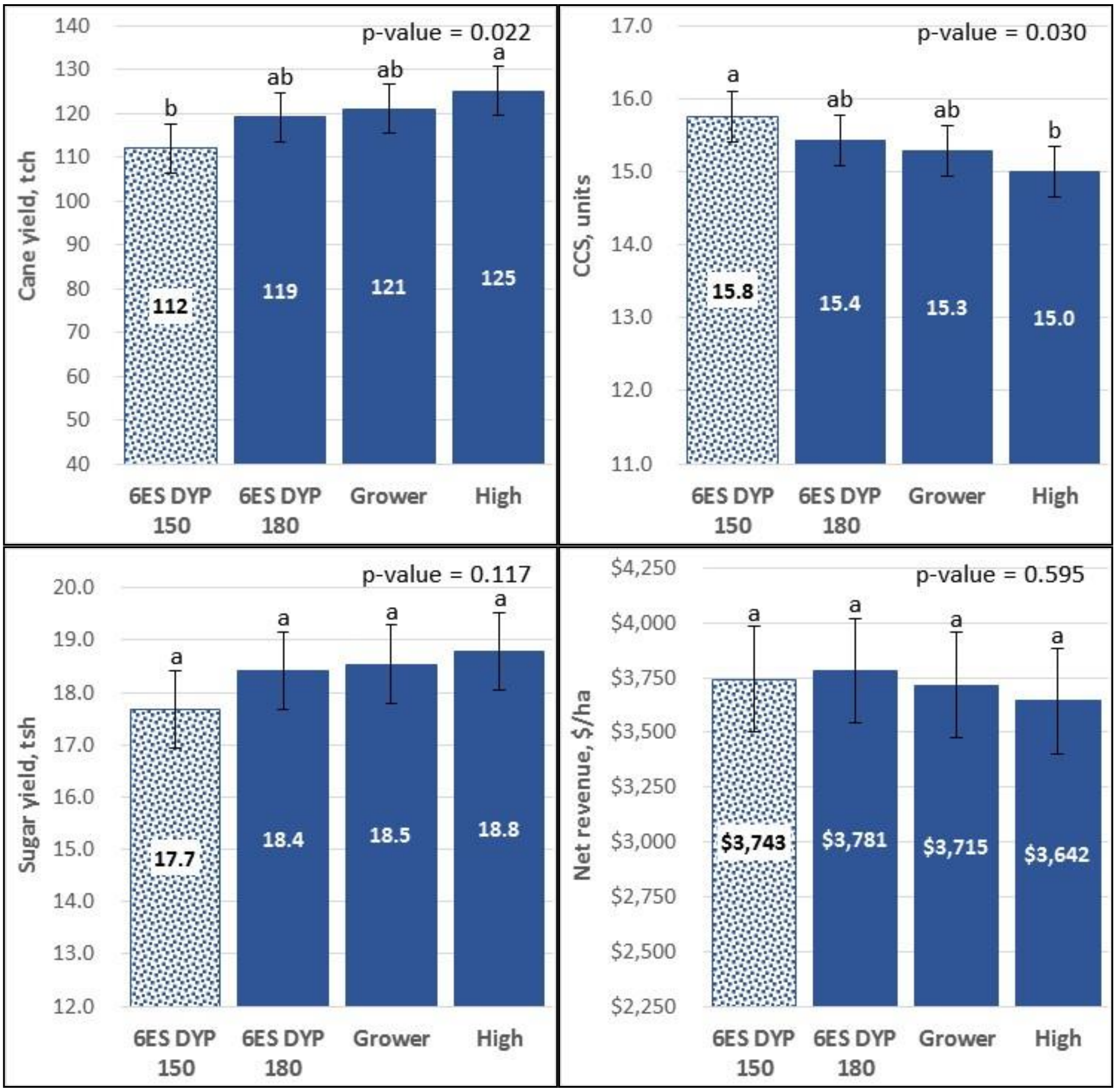

Figure 25: Average over crop cycle – cane yield, CCS, sugar yield and net revenue

Sensitivity analyses reveal that the economic outcome over the crop cycle was not sensitive to fluctuations in the sugar price or fertiliser price within the considered ranges.

Pre-plant soil N

Prior to planting on average across the trial site a total of 26(±1) kg/ha of mineral N was found in the top 60cm of the soil profile. This included 14(±1) kg/ha of nitrate nitrogen and 12(±1) kg/ha of ammonium nitrogen.

Nitrate nitrogen levels in irrigation water

Irrigation water applied to this trial site was supplied via a channel. Mean levels of oxidised nitrogen as N were <0.05 mg/L over the crop cycle.

Post-harvest soil N

Following the harvest of each crop soil mineral N levels in the top 60cm of the soil profile were calculated in all treatments. Mean nitrate and ammonium levels and total mineral N are presented in Table 36. Soil mineral N levels remained low in each treatment, there was no evidence of any significantly raised levels of N in the top 60cm of the soil profile.

Higher rates of applied N did not result in higher levels of N remaining in the soil profile following harvest indicating that the majority of mineral N not utilised by the crop had either been converted to another form which is no longer immediately available to the crop or had moved out of the profile due to leaching, runoff, denitrification or via a combination of these loss pathways.

Table 36: Mean and coefficient of variation (plant crop only) of soil (0-60cm) nitrate, ammonium and total mineral N in each treatment following the harvest of each crop stage

Crop Stage	Treatment (kg/ha)	NO3 (kg/ha)	NH4 (kg/ha)	Total mineral N (kg/ha)
Plant	130	10	16	26 (20%)
	170	10	17	27 (18%)
	210	10	19	29 (14%)
	250	10	17	27 (28%)
1st Ratoon	170	7	7	15
	210	7	7	15
	250	7	7	15
	290	7	19	27
2nd Ratoon	170	7	17	24
	210	7	10	17
	250	7	12	19
	290	7	17	24

Nitrogen exported to the mill

During the harvesting of trial sites stalk samples were taken at random locations from within each strip to estimate the amount of N exported to the mill (Table 37). At each crop stage there was a trend for increased concentration of N in stalks with higher N application rates.

In the plant crop, there was a significant increase in yield at the N application rate of 170 kg N/ha in comparison to the lower N application rate of 130 kg N/ha, however above this there was no further yield response. N in stalk exported to the mill increased significantly from 170 to 210 kg N/ha without a yield response indicating luxury N uptake by the crop.

In the 1st ratoon crop significantly more N in stalk was exported to the mill at the highest N application rate (290 kg N/ha) in comparison to the lowest N application rate (170 kg N/ha), however there was no increase in yield at any N application rate, indicating some luxury N uptake by the crop.

In the 2nd ratoon crop there was no significant difference in yield at 250 and 290 kg N/ha, however at 290 kg N/ha there was significantly more N in stalk exported to the mill than at the lower N application rate indicating some luxury N uptake by the crop.

In the 3rd ratoon crop significantly more N in stalk was exported to the mill at the highest N application rate (290 kg N/ha) in comparison to the lowest N application rate, however there was no significant increase in yield at any N application rate indicating that some luxury N uptake had taken place.

Table 37: Mean of N in stalk exported to the mill (kg/ha) and kg of N in stalk/tonne of stalk for each treatment and crop stage

Crop Stage	N Rate (kg/ha)	Mean Yield (tch)	N in Stalk Exported to Mill (kg/ha)	Kg of N in Stalk/tonne of Stalk
Plant	130	122 b	48 b	0.39
	170	129 ab	54 b	0.42
	210	130 ab	71 a	0.55
	250	133 a	81 a	0.61

Crop Stage	N Rate (kg/ha)	Mean Yield (tch)	N in Stalk Exported to Mill (kg/ha)	Kg of N in Stalk/tonne of Stalk
1st Ratoon	170	117	48 b	0.41
	210	125	57 ab	0.46
	250	127	-	-
	290	133	64 a	0.48
2nd Ratoon	170	99 b	47 b	0.47
	210	102 b	51 b	0.50
	250	106 ab	54 b	0.51
	290	113 a	72 a	0.64
3rd Ratoon	170	111	54 b	0.49
	210	120	67 a	0.56
	250	120	65 ab	0.54
	290	122	75 a	0.61

P<0.05, means followed by a common letter are not significantly different at the 5% level

Partial N budget

The two N budgets show the major inputs and outputs for the SIX EASY STEPS method recommended N application rate when using the DYP of 150 tch and the High N application rate for the plant crop. These treatments were chosen as there was a significant difference in yields.

Budget 1. SIX EASY STEPS (Mean yield: 122 tch)

Inputs (kg/ha)		Outputs (kg/ha)	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**130**	1. Crop N uptake	**105**
2. Pre plant soil mineral N	**26**	2. Soil residual mineral N	**26**
3. In season soil N mineralisation estimate	**20**		
4. N in irrigation water	**0**		
Total Inputs	**176**	**Total Outputs**	**131**

Estimate of N in attached dead leaf and below ground biomass used in calculation of crop N uptake. Estimate of N in components is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
45

This budget indicates that 45 kg N/ha was N unaccounted.

Budget 2. High N rate (Mean yield: 133 tch)

Inputs (kg/ha)		Outputs (kg/ha)	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**250**	1. Crop N uptake	**166**
2. Pre plant soil mineral N	**26**	2. Soil residual mineral N	**27**
3. In season soil N mineralisation estimate	**20**		
4. N in irrigation water	**0**		
Total Inputs	**296**	**Total Outputs**	**193**

Estimate of N in attached dead leaf and below ground biomass used in calculation of crop N uptake. Estimate of N in components is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
103

With the higher N application rate more N was unaccounted, the crop appeared to accumulate considerably more N at the High N rate. The mean yield of this treatment was significantly higher than the SIX EASY STEPS DYP 150 tch treatment.

*Unaccounted for N = Total Inputs – Total Outputs

Site 11 – Clare, BRIA

Site characteristics

Variety:	KQ228⁽ᵈ⁾	Row width:	1.5 m (Controlled traffic)	Water source:	Channel

Soil characteristics (0-20cm)

Type:	Sodic Duplex	% Organic carbon:	0.9
Texture:	Clay	Soil pH (1:5 Water):	7.3
QDPI:	6Drc	Cation exchange capacity:	

Crop establishment

Planting date:	5/05/2011

Harvest dates

Harvest -Plant:	19/08/2012
1st ratoon:	13/07/2013

Site overview

Row spacing at this site was 1.5m with a controlled traffic system in place as standard farming practice. The crop was established with few gaps and weed management was good over the duration of the trial. The plant crop yielded considerably better than the first ratoon crop, the change in productivity is likely due to a change in irrigation management at this site.

Yield and return

In the plant crop, the lowest N rate (130 kg N/ha) yielded significantly less tch than the two higher N rates (Table 38). Nevertheless, and while not significantly different, a general decline in CCS levels with higher N rates resulted in no significant differences between the treatments in tonnes of sugar produced. No significant differences in any of the production or economic measures were identified in the 1st ratoon.

Table 38: Mean cane and sugar yield, CCS and gross revenue, costs and net revenue

Crop stage	N rate Kg N/ha	Cane yield tch	CCS units	Sugar yield tsh	Net revenue $/ha
Plant	130 – ~DYP 150	127 b	15.6	19.8	$4,456
	170 – ~DYP 180	137 a	15.1	20.6	$4,504
	210 – grower	142 a	14.8	21.1	$4,516
	p-value	0.001	0.203	0.133	0.940
	95% LSD	5.5	1.3	1.9	$711
1st ratoon	170 – ~DYP 150	106	15.4	16.3	$3,562
	210 – ~DYP 180	111	15.0	16.7	$3,513
	250 – grower	114	14.8	16.8	$3,460
	p-value	0.065	0.109	0.474	0.676
	95% LSD	9.4	0.9	1.5	$435

Figure 26 presents the statistical results for an analysis over both the plant and first ratoon crops. The results indicate that there was a statistically significant difference in cane yield between the treatments but not in CCS, sugar yield or net revenue. The Grower and DYP 180 treatments were found to have significantly higher cane yield than the DYP 150 treatment. However, the higher yields did not translate into increased profitability with all treatments attaining very similar mean net revenue.

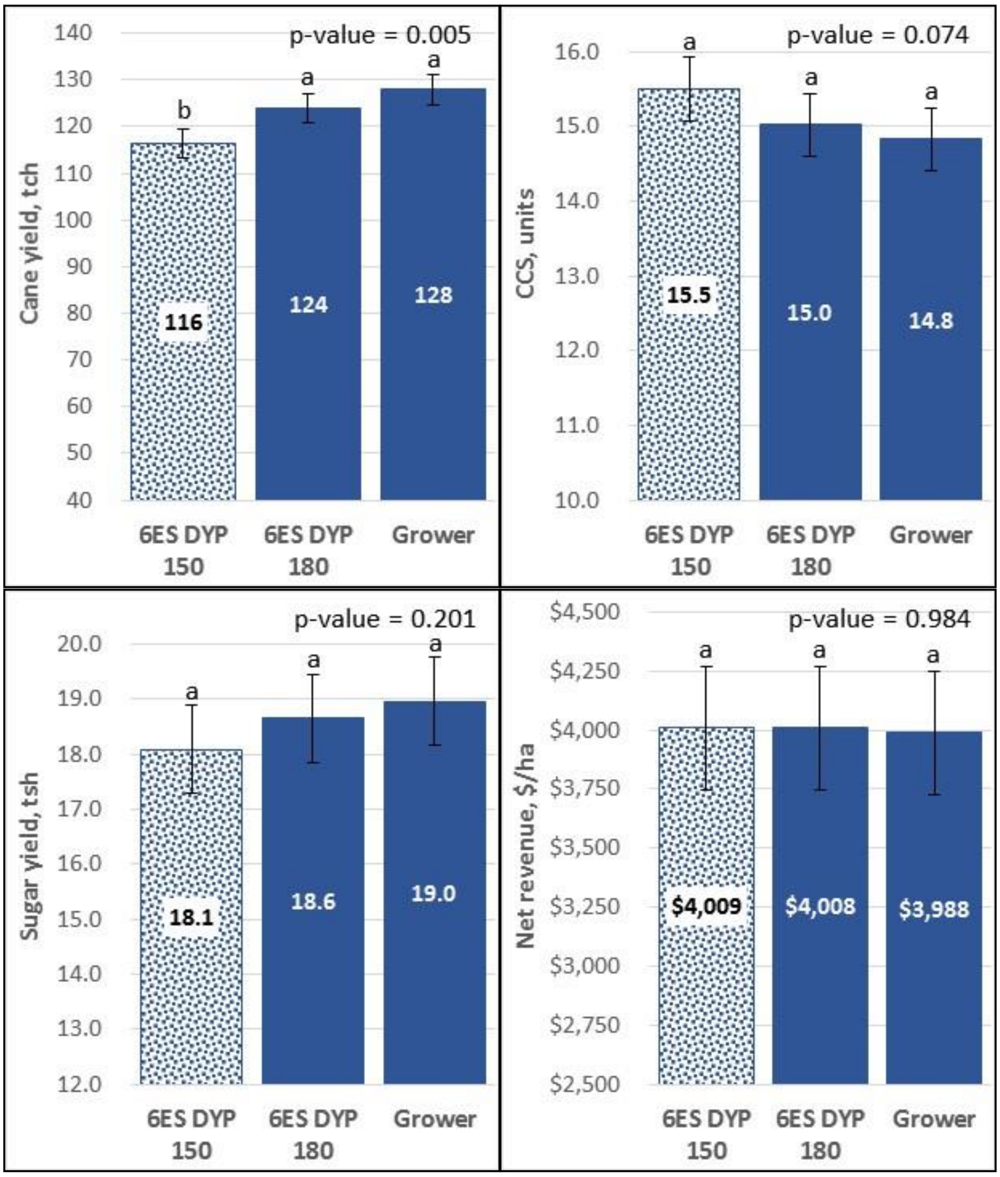

Figure 26: Average over crop cycle – cane yield, CCS, sugar yield and net revenue

The sensitivity analysis revealed that the economic outcome over both the plant and first ratoon crops was very sensitive to fluctuations in the prices of sugar and fertiliser (see Figure 27 below). Results show that the DYP 180 treatment would attain the highest mean net revenue if the average sugar price was above $430 per tonne or if fertiliser prices were more than 1% lower than 2015 prices. This sensitivity is due to the small difference in mean net revenue between the DYP 150 and 180 treatments.

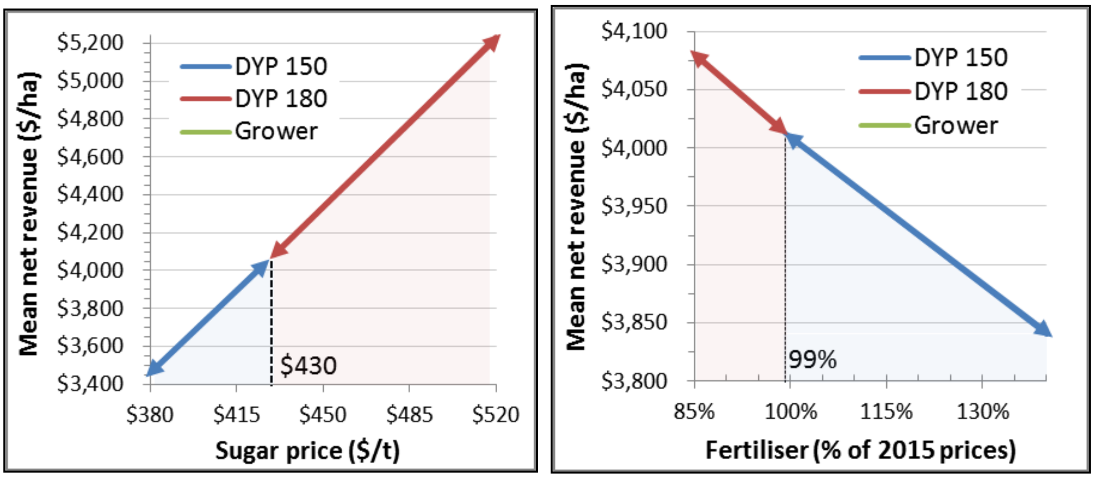

Figure 27: Sensitivity of mean net revenue over both crops to sugar and fertiliser prices

Pre-plant soil N

Prior to planting on average across the trial site a total of 27 kg/ha of nitrate N was found in the top 20cm of the soil profile. There was no data for nitrate levels below the top 20cm of the soil profile and no data for ammonium N in the top 60cm of the soil profile.

Nitrate nitrogen levels in irrigation water

Irrigation water applied to this trial site was supplied a channel. During the plant and ratoon crops water samples were taken from the fluming as the trial site was being irrigated. Mean levels of oxidised nitrogen as N were measured for each crop stage are presented in Table 39.

Table 39: Mean and standard error of oxidised nitrogen as N in irrigation water

Crop Stage	Oxidised nitrogen as N (mg/L)
Plant	1.5 (±0.3)
1st Ratoon	1.1 (±0.2)

Post-harvest soil N

Following the harvest of each crop soil mineral N levels in the top 60cm of the soil profile were calculated in all treatments. Mean nitrate and ammonium levels and total mineral N are presented in Table 40. Following harvest soil N levels remained low in each treatment, there was no evidence of any significantly raised levels of mineral N in the top 60cm of the soil profile. Higher rates of applied N did not result in higher levels of N remaining in the soil profile following harvest indicating that the majority of mineral N not utilised by the crop had either been converted to another form which is no longer immediately available to the crop or had moved out of the profile due to leaching, runoff, denitrification or via a combination of these loss pathways.

Table 40: Mean and coefficient of variation (plant crop only) of soil (0-60cm) nitrate, ammonium and total mineral N in each treatment following the harvest of the plant and ratoon crops

Crop Stage	Treatment (kg N/ha)	NO3 (kg/ha)	NH4 (kg/ha)	Total mineral N (kg/ha)
Plant	130	9	19	28 (13%)
	170	10	22	31 (8%)
	210	7	23	30 (5%)
1st Ratoon	170	7	15	22
	210	7	15	22
	250	7	19	27

Nitrogen exported to the mill

During the harvesting of trial sites stalk samples were taken at random locations from within each strip to estimate the amount of N exported to the mill (Table 41).

In the plant crop, N in stalk exported to the mill increased significantly at the highest N rate (210 kg N/ha) in comparison to the two lower N rates. However, there was also corresponding increase in yield at the highest N rate in comparison to the lowest N rate.

Table 41: Mean of N in stalk exported to the mill (kg/ha) and kg of N in stalk/tonne of stalk for each treatment and crop stage

Crop Stage	N Rate (kg/ha)	Mean Yield (TCH)	N in Stalk Exported to Mill (kg/ha)	Kg of N in Stalk/tonne of Stalk
Plant	130	127 b	63 b	0.50
	170	137 a	67 b	0.49
	210	142 a	81 a	0.57
1st Ratoon	170	106	56 a	0.53
	210	111	-	-
	250	114	71 a	0.62

P<0.05, means followed by a common letter are not significantly different at the 5% level

Partial N budget

The two N budgets show the major inputs and outputs for the SIX EASY STEPS method recommended N application rate when using the DYP of 180 tch and the Grower N application rate for the plant crop.

Budget 1. SIX EASY STEPS (Mean yield: 137 TCH)

Inputs (kg/ha)		Outputs (kg/ha)	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**170**	1. Crop N uptake	**189**
2. Pre plant soil mineral N	**27^**	2. Soil residual mineral N	**31**
3. In season soil N mineralisation estimate	**20**		
4. N in irrigation water	**15**		
Total Inputs	**232**	**Total Outputs**	**220**

Estimate of N in attached dead leaf and below ground biomass used in calculation crop N uptake. Estimate of N in components is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
12

This budget was close to being in balance with little N unaccounted.

Budget 2. Grower N rate (Mean yield: 142 TCH)

Inputs (kg/ha)		Outputs (kg/ha)	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**210**	1. Crop N uptake	**193**
2. Pre plant soil mineral N	**27^**	2. Soil residual mineral N	**30**
3. In season soil N mineralisation estimate	**20**		
4. N in irrigation water	**15**		
Total Inputs	**272**	**Total Outputs**	**223**

Estimate of N in attached dead leaf and below ground biomass used in calculation of crop N uptake. Estimate of N in components is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
49

With the higher N application rate more N was unaccounted. There appears to be no additional N taken up by the crop at the higher N rate.

*Unaccounted for N = Total Inputs – Total Outputs
^Pre plant soil N is nitrate N calculated for the top 20cm of the soil profile and does not include ammonium N.

Site 12 – Javisfield, Delta

Site characteristics

Variety:	Q208⁽ᵇ⁾	Row width:	1.63 m	Water source:	Bore

Soil characteristics (0-20cm)

% Sand (fine):	42	Type:	Dermosol	% Organic carbon:	0.74
% Sand (coarse):	39	Texture:	Loam	Soil pH (1:5 Water):	7.1
% Silt:	12	QDPI:	BGnb	Cation exchange capacity:	8.2
% Clay:	7				

Crop establishment   Harvest dates

Planting date:	8/06/2012	Harvest -Plant:	30/07/2013	3rd Ratoon	15/06/2016
		1st ratoon:	28/09/2014		
		2nd ratoon:	1/09/2015		

Site overview

This trial site suffered from significant weed and irrigation management issues over the duration of the trial. Monitoring of soil moisture was undertaken in the second and third ratoons crops (Figure 29). Weed pressure increased over the duration of the trials, and may have been a significant factor in the decline of the 3rd ratoon crop yield.

Yield and return

There was no yield response with higher rates of applied N in any of the ratoon crops (Table 42). In the 1st ratoon crop there was a significant decline in CCS at higher N rates and a significant decline in net revenue at the Grower and High N rates by over $400/ha.

Table 42: Mean cane and sugar yield, CCS and gross revenue, costs and net revenue

Crop stage	N rate Kg N/ha	Cane yield tch	CCS units	Sugar yield tsh	Net revenue $/ha
Plant*	170 – ~DYP 180	-	-	-	-
	210 – grower	-	-	-	-
	250 – high	-	-	-	-
	p-value	n/a	n/a	n/a	n/a
	95% LSD	n/a	n/a	n/a	n/a
1st ratoon	210 – ~DYP 180	97	16.3 a	15.9	$3,253 a
	250 – grower	95	15.7 b	14.9	$2,839 b
	290 – high	98	15.6 b	15.3	$2,807 b
	p-value	0.434	0.010	0.142	0.012
	95% LSD	10.1	0.5	1.5	$344
2nd ratoon	210 – ~DYP 180	92	15.4	14.1	$2,890
	250 – grower	92	15.4	14.2	$2,815
	290 – high	91	14.9	13.6	$2,539
	p-value	0.945	0.116	0.624	0.185
	95% LSD	13.1	0.8	2.4	$636
3rd ratoon	210 – ~DYP 180	71	11.6	8.2	$1,619
	250 – grower	75	11.3	8.5	$1,609
	290 – high	73	11.3	8.2	$1,472
	p-value	0.673	0.401	0.831	0.516
	95% LSD	17.2	0.9	2	$519

* Plant crop data was lost due to rakes being combined

Figure 28 presents the statistical results for an analysis over the crop cycle (first ratoon through to third ratoon – no data was collected for the plant crop so it could not be included).

The results indicate that there was a statistically significant difference in CCS between the treatments but not in cane yield, sugar yield or net revenue. The SIX EASY STEPS DYP 180 treatment was found to have significantly higher CCS than the grower and high rate treatments.

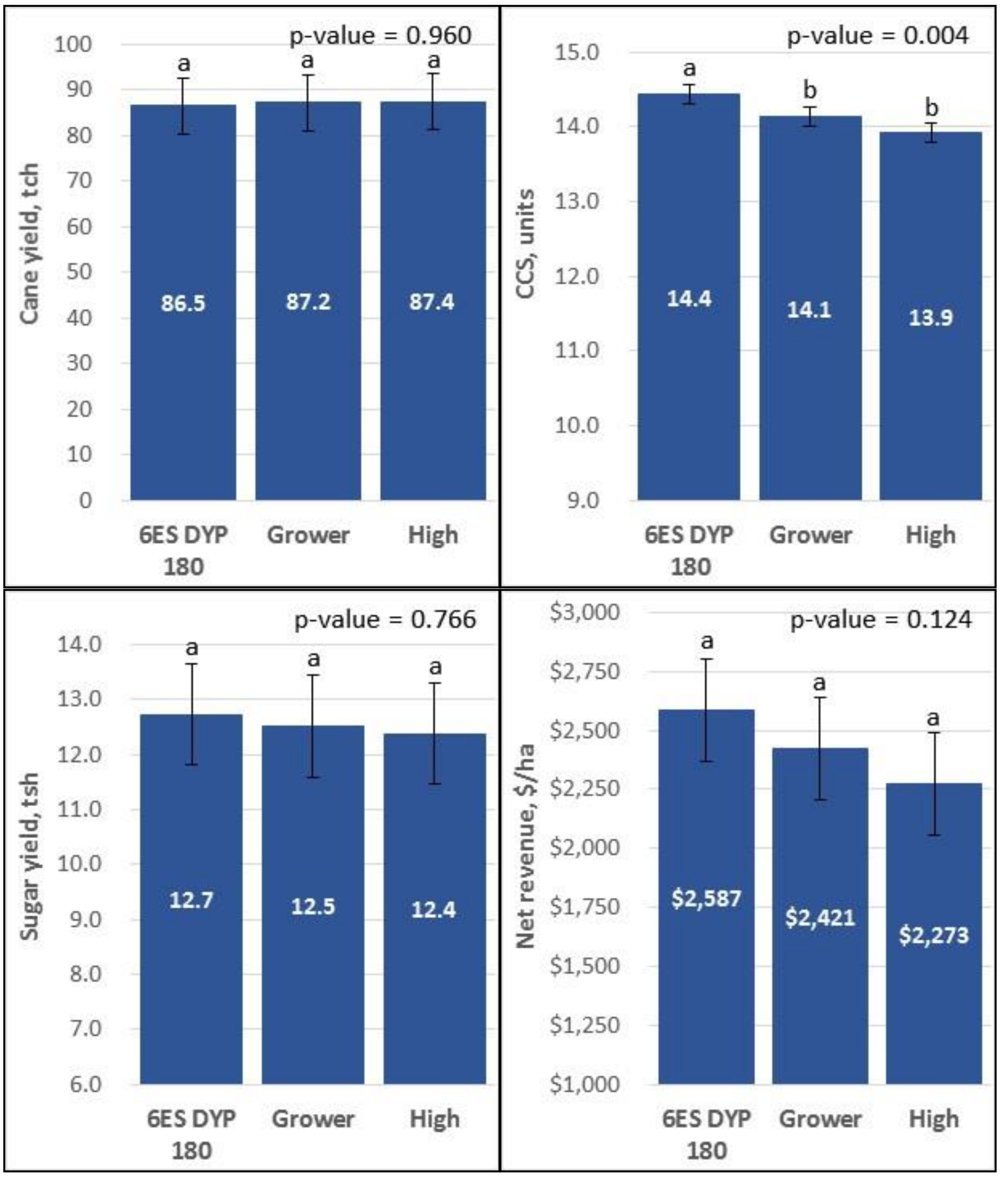

Figure 28: Average over crop cycle – cane yield, CCS, sugar yield and net revenue

Sensitivity analyses reveal that the economic outcome over the crop cycle (first ratoon through to third ratoon) was not sensitive to fluctuations in the sugar price or fertiliser price within the considered ranges.

Pre-plant soil N

Prior to planting on average across the trial site a total of 50(±4) kg/ha of mineral N was found in the top 60cm of the soil profile. This included 29(±3) kg/ha of nitrate nitrogen and 20(±1) kg/ha of ammonium nitrogen.

Nitrate nitrogen levels in irrigation water

Irrigation water applied to this trial site was supplied via a bore. Mean levels of oxidised nitrogen as N were <0.05 mg/L over the duration of the trial.

Post-harvest soil N

Following the harvest of each crop soil mineral N levels in the top 60cm of the soil profile were calculated in all treatments. Nitrate and ammonium levels and total mineral N are presented in Table 43. Following harvest soil N levels remained low in each treatment.

Higher rates of applied N did not result in higher levels of N remaining in the soil profile following harvest indicating that the majority of mineral N not utilised by the crop had either been converted to another form which was no longer immediately available to the crop or had moved out of the profile due to leaching, runoff, denitrification or via a combination of these loss pathways.

Table 43: Soil (0-60cm) nitrate, ammonium and total mineral N in each treatment following harvest of each crop stage

Crop Stage	Treatment (kg/ha)	NO3 (kg/ha)	NH4 (kg/ha)	Total mineral N (kg/ha)
Plant	170	7	10	17
	210	7	15	22
	250	7	10	17
1st Ratoon	210	7	15	22
	250	7	24	31
	290	7	22	29
2nd Ratoon	210	7	7	15
	250	7	12	19
	290	7	7	15
3rd Ratoon	150	12	15	27
	170	7	14	21
	210	10	15	25

Nitrogen exported to the mill

During the harvesting of trial sites stalk samples were taken at random locations from within each strip to estimate the amount of N exported to the mill (Table 44). In the 1st and 2nd ratoon crops there was a trend for increased concentration of N in stalks with higher N application rates.

Table 44: Mean of N in stalk exported to the mill and kg of N in stalk/tonne of stalk for each treatment and crop stage

Crop Stage	N Rate (kg/ha)	Mean Yield (TCH)	N in Stalk Exported to Mill (kg/ha)	Kg of N in Stalk/tonne of Stalk
Plant	170	-	79 a	-
	210	-	-	-
	250	-	98 a	-
1st Ratoon	210	97	74 a	0.76
	250	95	85 a	0.89
	290	98	89 a	0.91
2nd Ratoon	210	92	73 a	0.79
	250	91	86 a	0.95
	290	91	83 a	0.91

$P<0.05$, means followed by a common letter are not significantly different at the 5% level

Irrigation management

Prior the installation of soil moisture monitoring equipment, observations of plant growth along with the excavation of holes using a shovel and auger to assess soil moisture suggested that there were periods of less than optimum soil moisture in the profile during the development of the plant and first ratoon crops. Soil moisture monitoring was conducted at this site in the 2nd and 3rd ratoon crop using a PR2 profile probe and a HH2 hand logging device. The information obtained was provided to the grower on a regular basis to assist the grower with irrigation management decisions. Readings were conducted weekly over the monitoring period. The access tube for the probe was placed in the centre of the bed approximately 50 meters from the top of the block. Data collected from the site for the 3rd ratoon crop is presented in Figure 29. The data indicates that irrigation events were regular and that in some cases were becoming excessive due to movement of soil moisture well below the rootzone.

Although soil moisture levels appeared to be more than adequate at the top of the block visual inspection of the bottom of the block revealed that irrigation water had not reached the end of the block in some furrows for some time resulting in poor crop development in some areas.

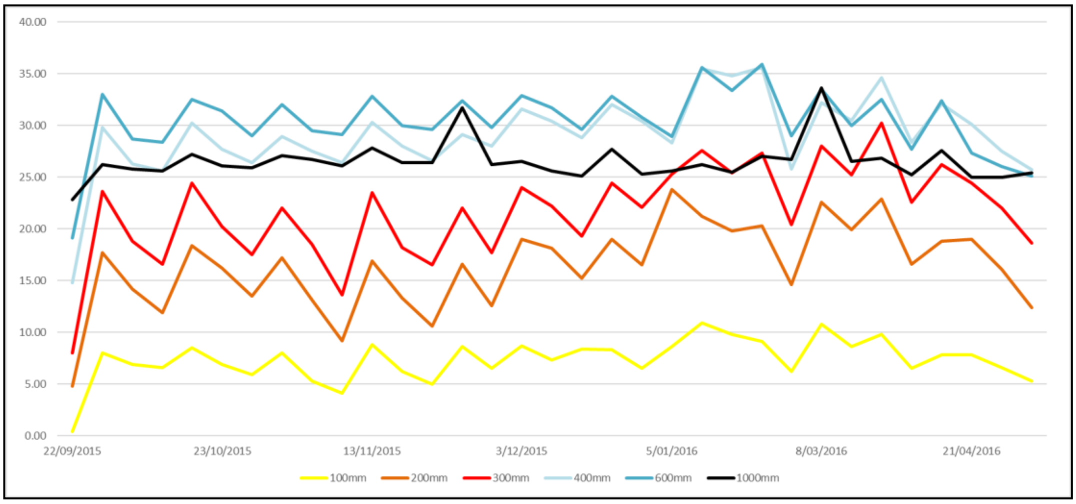

Figure 29: Grower 12 - 3rd ratoon soil moisture data from the top of the block

Weed management

Weed pressure at this site became progressively greater over each crop stage. The grower was unable to gain control of the weeds although herbicides were applied each season. Weed pressure may have reduced yields at this site particularly in the later ratoons.

Although the grower attempted to change in irrigation management at this site assisted by soil moisture data provided on a regular basis, factors such as poor weed control and the incomplete irrigation of rows may have impacted crop yields.

Partial N budget

The two N budgets show the major inputs and outputs for the SIX EASY STEPS method recommended N application rate when using the DYP of 180 tch and the Grower N application rate for the 1st Ratoon crop.

Budget 1. SIX EASY STEPS (Mean yield: 97 tch)

Inputs (kg/ha)		Outputs (kg/ha)	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**210**	1. Crop N uptake	**119**
2. Soil mineral N following plant crop harvest	**17**	2. Soil residual mineral N	**22**
3. In season soil N mineralisation estimate	**10**		
4. N in irrigation water	**0**		
Total Inputs	**237**	**Total Outputs**	**141**

Estimate of N in below ground biomass used in calculation of crop N uptake. Estimate is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
96

This budget indicates that there was a considerable amount of N which was unaccounted.

Budget 2. Grower N rate (Mean yield: 95 tch)

Inputs (kg/ha)		Outputs (kg/ha)	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**250**	1. Crop N uptake	**138**
2. Soil mineral N following plant crop harvest	**22**	2. Soil residual mineral N	**31**
3. In season soil N mineralisation estimate	**10**		
4. N in irrigation water	**0**		
Total Inputs	**282**	**Total Outputs**	**169**

Estimate of N in below ground biomass used in calculation of crop N uptake. Estimate is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
113

With the higher N application rate more N was unaccounted. The crop appears to have accumulated more N, however this has not translated into additional yield.

*Unaccounted for N = Total Inputs – Total Outputs

Site 14 – Brandon, Delta

Site characteristics

Variety:	Q183⁽ᵇ	Row width:	1.52	Water source:	Bore

Soil characteristics (0-20cm)

% Sand (fine):	48	Type:	Dermosol	% Organic carbon:	0.81
% Sand (coarse):	21	Texture:	Loam	Soil pH (1:5 Water):	7.0
% Silt:	14	QDPI:	BUfb	Cation exchange capacity:	9.5
% Clay:	17				

Crop establishment

Planting date:	6/08/2012

Harvest dates

Harvest -Plant:	11/07/2013
1st ratoon:	5/09/2014
2nd ratoon:	7/08/2015
3rd ratoon:	19/09/2016

Site overview

This trial site was managed according to best management principles. The crop was established with few gaps and weed and irrigation management were very good over the four seasons. The plant crop which was a late plant did not perform to the expectations of the grower. During post-harvest soil sampling of the plant crop it was found that there was a compacted zone within the soil profile (30-50cm) across the trial site (Figure 31). It is likely that the compaction limited the yield potential of the plant crop. Following discussion with the grower an implement was used to deep rip each side of the hill. This remedial activity appeared to be effective in alleviating the compaction issue.

Yield and return

Higher rates of applied N did not improve yields in any of the crop stages (Table 45). Following the poor performance of the plant crop the yield of the 1st ratoon and following ratoons was significantly greater. The reason for this may be due to the plant crop being a late plant and the presence of soil compaction across the block which was alleviated prior to the development of the ratoon crop. The N rate for the SIX EASY STEPS treatment at this trial site was established using the DYP of 180 TCH. After consideration of the trial results it was decided that for the 3rd ratoon the high N rate treatment be replaced with a DYP 150 treatment to evaluate whether the lower N rate would have any effect on cane and sugar production.

Table 45: Mean cane and sugar yield, CCS and gross revenue, costs and net revenue

Crop stage	N rate Kg N/ha	Cane yield tch	CCS units	Sugar yield tsh	Net revenue $/ha
Plant	170 – ~DYP 180	108	15.1	16.2	$3,381
	210 – grower	108	14.8	15.9	$3,190
	250 – high	106	14.8	15.6	$3,023
	p-value	0.803	0.192	0.458	0.053
	95% LSD	14.8	0.5	1.8	$389
1st ratoon	210 – ~DYP 180	145	14.7	21.3	$4,298
	250 – grower	148	14.6	21.5	$4,212
	290 – high	149	14.6	21.7	$4,188
	p-value	0.554	0.799	0.456	0.344
	95% LSD	13.7	0.8	1.1	$272
2nd ratoon	210 – ~DYP 180	141	15.0	21.0	$4,504
	250 – grower	137	15.2	20.7	$4,375
	290 – high	137	15.3	20.9	$4,342
	p-value	0.802	0.580	0.859	0.354
	95% LSD	24	1.1	2.3	$410
3rd ratoon	170 – ~DYP 150	146	14.7	21.3	$4,200
	210 – ~DYP 180	145	14.6	21.0	$4,060
	250 – grower	145	14.5	20.9	$3,964
	p-value	0.977	0.816	0.821	0.191
	95% LSD	22.3	0.7	2.1	$623

Figure 30 presents the statistical results for an analysis over the crop cycle (plant cane through to second ratoon – the third ratoon was excluded to enable the mean value for the high rate to be predicted given that it was not included in the third ratoon). The results indicate that there were no statistically significant differences in cane yield, CCS, sugar yield or net revenue[10] between the treatments.

[10] While the unprotected F-test for net revenue had a p-value less than 0.05, protected pairwise comparisons (using the Bonferroni method) did not indicate significant differences between the treatments.

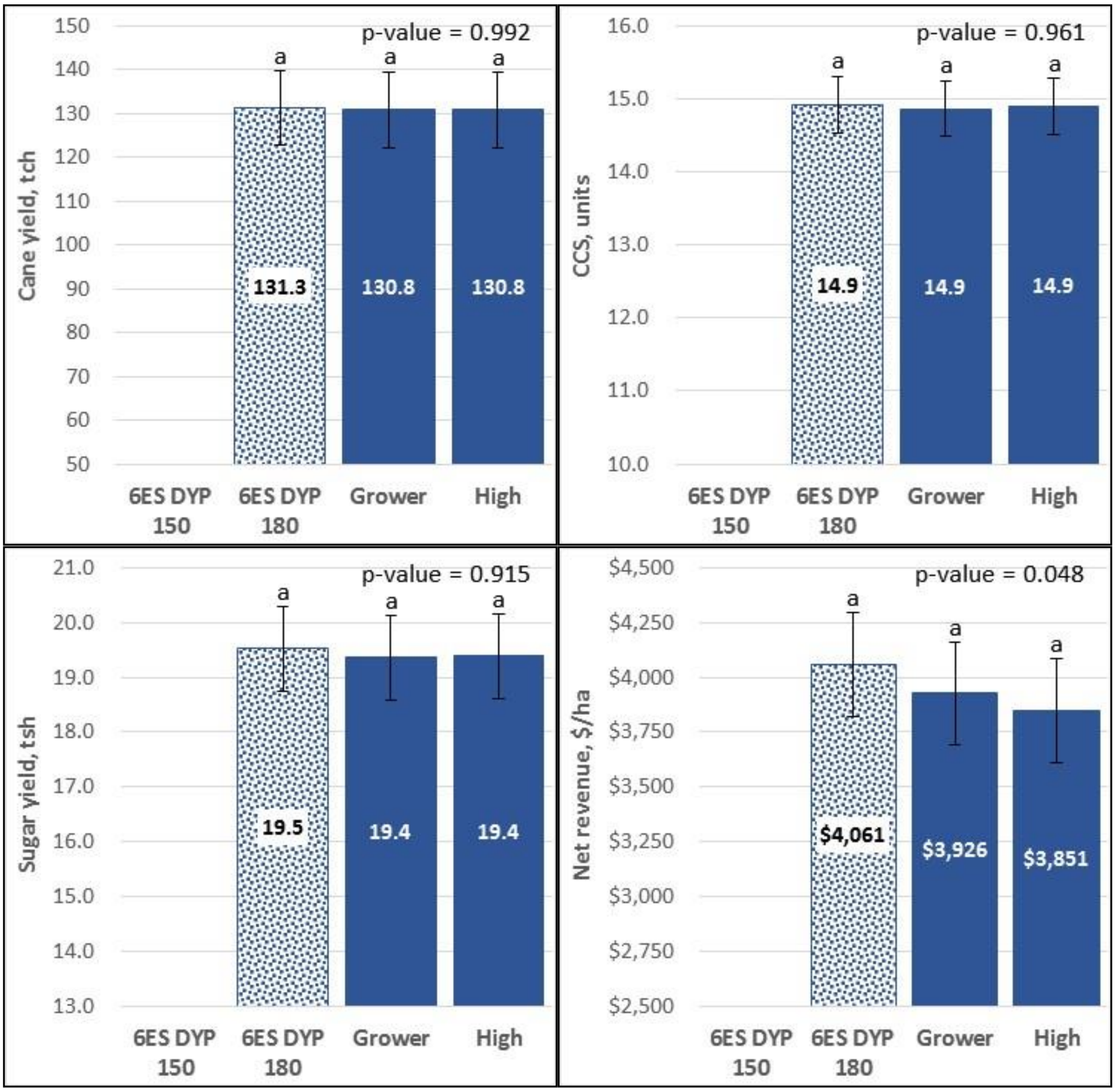

Figure 30: Average over crop cycle – cane yield, CCS, sugar yield and net revenue

Sensitivity analyses reveal that the economic outcome over the crop cycle was not sensitive to fluctuations in the sugar price or fertiliser price within the considered ranges.

Pre-plant soil N

Prior to planting on average across the trial site a total of 16(±6) kg/ha of mineral N was found in the top 60cm of the soil profile. This included 5(±3) kg/ha of nitrate nitrogen and 11(±3.0) kg/ha of ammonium nitrogen.

Nitrate nitrogen levels in irrigation water

Irrigation water applied to this trial site was supplied from a bore. During the crop cycle water samples were taken from the fluming as the trial site was being irrigated. Mean levels of oxidised nitrogen as N were measured for each crop stage are presented in Table 46.

Table 46: Mean and standard error of oxidised nitrogen as N in irrigation water

Crop Stage	Oxidised nitrogen as N (mg/L)
Plant	2.6 (±0.1)
1st Ratoon	2.7 (±0.4)
3rd Ratoon	2.5 (±0.6)

Post-harvest soil N

Following the harvest of each crop soil mineral N levels in the top 60cm of the soil profile were calculated in all treatments. Nitrate and ammonium levels and total mineral N are presented in Table 47. Following harvest soil mineral N levels remained low in each treatment. Higher rates of applied N did not result in higher levels of N remaining in the soil profile following harvest indicating that the majority of mineral N not utilised by the crop had either been converted to another form which was no longer immediately available to the crop or had moved out of the profile due to leaching, runoff, denitrification or via a combination of these loss pathways.

Table 47: Soil (0-60cm) nitrate, ammonium and total mineral N in each treatment following the harvest of each crop stage

Crop Stage	Treatment (kg/ha)	NO3 (kg/ha)	NH4 (kg/ha)	Total mineral N (kg/ha)
Plant	170	7	12	19
	210	10	12	22
	250	10	15	24
1st Ratoon	210	7	7	15
	250	7	7	15
	290	7	7	15
2nd Ratoon	210	7	7	15
	250	7	7	15
	290	7	7	15
3rd Ratoon	170	3	13	15
	210	3	14	16
	250	3	11	13

Nitrogen exported to the mill

During the harvesting of trial sites stalk samples were taken at random locations from within each strip to estimate the amount of N exported to the mill (Table 48). In the plant crop, N in stalk exported to the mill increases significantly at the high N application rate (250 kg N/ha), without any significant change in crop yield indicating some luxury N uptake (approximately 19 kg N/ha) by the crop. In the 1st ratoon crop there was significant increases in the amount of N exported to the mill at both N rates above 170 kg N/ha, however there was no corresponding yield increase.

Table 48: Mean of N in stalk exported to the mill (kg/ha) and kg of N in stalk/tonne of stalk for each treatment and crop stage

Crop Stage	N Rate (kg/ha)	Mean Yield (TCH)	N in Stalk Exported to Mill (kg/ha)	Kg of N in Stalk/tonne of Stalk
Plant	170	108	51 a	0.47
	210	108	-	-
	250	106	70 b	0.66
1st Ratoon	170	145	87 c	0.60
	210	148	111 b	0.75
	250	149	142 a	0.95
2nd Ratoon	170	141	106 a	0.75
	210	137	116 a	0.85
	250	137	106 a	0.77

P<0.05, means followed by a common letter are not significantly different at the 5% level

Compaction

Following harvest of the plant crop a pit (Figure 31) was excavated in the trial site using a shovel. It showed that the majority of the plant crop rootzone was within the top 25cm of the soil profile. Very little root activity was found below 30cm. This observation confirmed that there was compaction present in the trial block area. A pit was excavated on another farm in a similar soil type with no history of compaction, root activity could be clearly seen at a depth of 50cm.

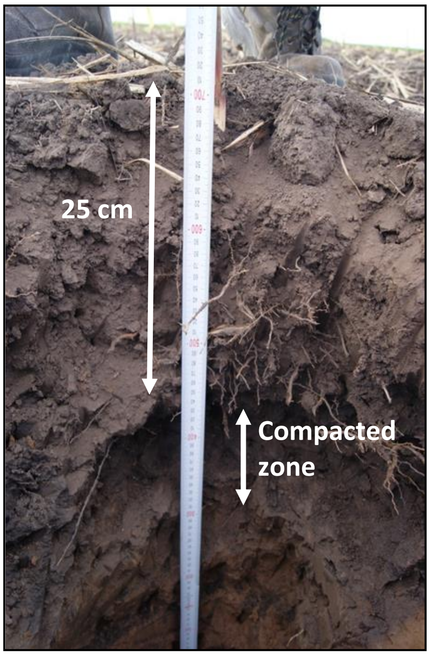

Figure 31: Soil pit showing compacted zone in profile

Partial N budget – Plant Crop

The two N budgets show the major inputs and outputs for the SIX EASY STEPS method recommended N application rate when using the DYP of 180 tch and the growers preferred N application rate for the plant crop.

Budget 1. SIX EASY STEPS (Mean yield: 108 tch)

Inputs (kg/ha)		Outputs (kg/ha)	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	170	1. Crop N uptake	108
2. Pre plant soil mineral N	16	2. Soil residual mineral N	19
3. In season soil N mineralisation estimate	20		
4. N in irrigation water	26		
Total Inputs	**232**	**Total Outputs**	**127**

Estimate of N in below ground biomass used in calculation of crop N uptake. Estimate is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
105

This budget indicates that there was a considerable amount of N which was unaccounted.

Budget 2. Grower N rate (Mean yield: 108 tch)

Inputs (kg/ha)		Outputs (kg/ha)	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**210**	1. Crop N uptake	**115**
2. Pre plant soil mineral N	**16**	2. Soil residual mineral N	**22**
3. In season soil N mineralisation estimate	**20**		
4. N in irrigation water	**26**		
Total Inputs	**272**	**Total Outputs**	**137**

Estimate of N in below ground biomass used in calculation of crop N uptake. Estimate is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
135

With the higher N application rate more N was unaccounted, there appears to be little additional accumulated N with the higher N application rate.

*Unaccounted for N = Total Inputs – Total Outputs

Partial N budget – 3rd Ratoon crop

A partial N budget was developed for the 3rd ratoon crop to investigate the effects of reducing the N application rate by 40 kg N/ha at this site. The two N budgets show the major inputs and outputs for the SIX EASY STEPS method recommended N application rate when using the DYP of 150 tch and the Grower N application rate.

Budget 1. SIX EASY STEPS (Mean yield: 146 tch)

Inputs (kg/ha)		**Outputs (kg/ha)**	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**170**	1. Crop N uptake	**125**
2. Soil residual mineral N following harvest of 2nd ratoon	**15**	2. Soil residual mineral N	**15**
3. In season soil N mineralisation estimate	**20**		
4. N in irrigation water	**27**		
Total Inputs	**232**	**Total Outputs**	**140**

Estimate of N in below ground biomass used in calculation of crop N uptake. Estimate is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
92

Although the N application rate for the 3rd ratoon was reduced by 40 kg N/ha the N budget shows that there is still a considerable amount of N unaccounted.

Budget 2. Grower N rate (Mean yield: 145 tch)

Inputs (kg/ha)		**Outputs (kg/ha)**	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**250**	1. Crop N uptake	**138**
2. Soil residual mineral N following harvest of 2nd ratoon	**15**	2. Soil residual mineral N	**13**
3. In season soil N mineralisation estimate	**20**		
4. N in irrigation water	**27**		
Total Inputs	**312**	**Total Outputs**	**151**

Estimate of N in below ground biomass used in calculation of crop N uptake. Estimate is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
161

With the higher N application rate significantly more N was unaccounted, with little additional N accumulated by the crop.

*Unaccounted for N = Total Inputs – Total Outputs

Site 15 – Brandon, Delta

Site characteristics

Variety:	Q253⁽ᵇ⁾	Row width:	1.52 m	Water source:	Bore

Soil characteristics (0-20cm)

% Sand (fine):	57
% Sand (coarse):	0
% Silt:	17
% Clay:	26

Type:	Vertosol
Texture:	Clay loam
QDPI:	RUgd

% Organic carbon:	1.3
Soil pH (1:5 Water):	6.9
Cation exchange capacity:	20.9

Crop establishment

Planting date:	1/04/2013

Harvest dates

Harvest -Plant:	1/07/2014
1st ratoon:	30/6/2015
2nd ratoon:	29/09/2016

Site overview

This trial site was managed according to best management principles. The crop was established with few gaps and weed management was very good over the three crop stages. Very good farm management practices combined with good soil fertility and very good irrigation management has allowed this grower to achieve consistent high cane and sugar yields over the duration of the trials.

Yield and return

Higher rates of applied N did not improve cane or sugar yield at this site (Table 49). There was a steady decline in yields across all treatments in ratoons which was not related to N rate.

For ratoon crops the grower decided to retain the same N rates which were applied for the plant crop. The lowest N rate in the ratoon crops were equivalent to the N rate which would be recommended by the SIX EASY STEPS method if a DYP of 150 TCH was applied.

Table 49: Mean cane and sugar yield, CCS and gross revenue, costs and net revenue

Crop stage	N rate Kg N/ha	Cane yield tch	CCS units	Sugar yield tsh	Net revenue $/ha
Plant	150 – ~DYP 180	197	13.4	26.2	$5,951
	190 – grower	201	12.8	25.7	$5,624
	230 – high	198	12.9	25.5	$5,550
	p-value	0.384	0.183	0.127	0.055
	95% LSD	10.5	1	0.9	$449
1st ratoon	150 – ~DYP 150	186	12.1	22.5	$5,353
	190 – ~DYP 180	192	12.0	23.1	$5,394
	230 – grower	185	11.9	22.0	$5,012
	p-value	0.184	0.611	0.140	0.073
	95% LSD	11.4	0.6	1.5	$476
2nd ratoon	150 – ~DYP 150	163	13.2	21.6	$4,013
	190 – ~DYP 180	167	13.0	21.7	$3,912
	230 – grower	167	12.6	21.0	$3,572
	p-value	0.546	0.175	0.418	0.093
	95% LSD	11.8	1	1.8	$563

Figure 32 presents the statistical results for an analysis over the crop cycle (plant cane through to second ratoon). Given that the High rate was not trialled in the first and second ratoons and the DYP 150 was not trialled in the plant cane, the statistical analysis was unable to predict mean values for these treatments over all crops harvested from the site. The results indicate that there was a statistically significant difference in sugar yield and net revenue between the DYP 180 and grower treatments but not in cane yield[11] or CCS.

[11] While the unprotected F-test for cane yield had a p-value less than 0.05, protected pairwise comparisons (using the Bonferroni method) did not indicate significant differences between the DYP 180 and grower

The SIX EASY STEPS DYP 180 treatment was found to have significantly higher sugar yield and net revenue (by $350/ha per crop, or $1,050 over all three crops) than the grower N rate treatment.

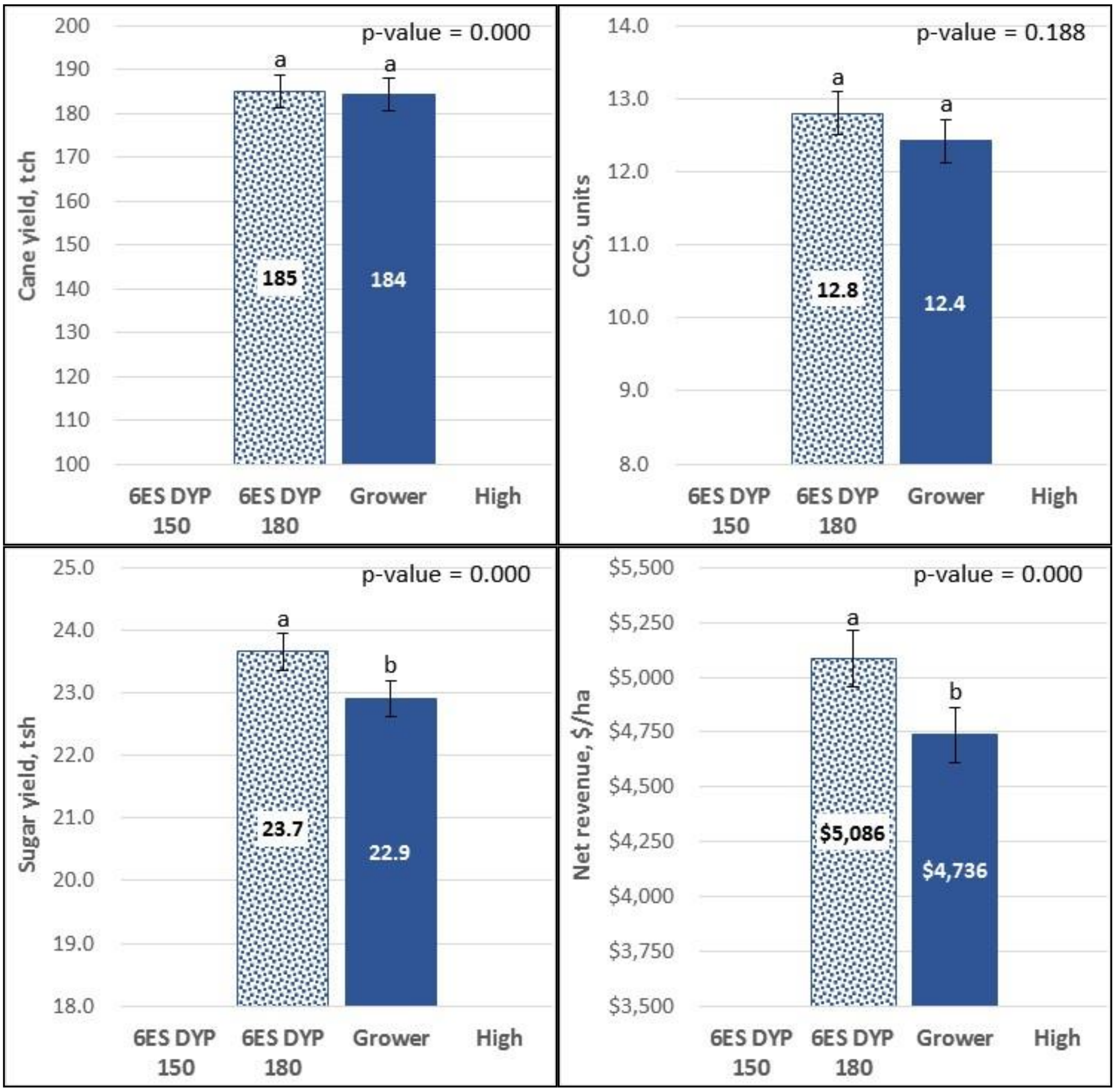

Figure 32: Average over crop cycle – cane yield, CCS, sugar yield and net revenue

Sensitivity analyses reveal that the economic outcome over the crop cycle was not sensitive to fluctuations in the sugar price or fertiliser price within the considered ranges.

Pre-plant soil N

Prior to planting on average across the trial site a total of 27(±4) kg/ha of mineral N was found in the top 60cm of the soil profile. This included 17(±3) kg/ha of nitrate nitrogen and 10(±2) kg/ha of ammonium nitrogen.

Nitrate nitrogen levels in irrigation water

Irrigation water applied to this trial site was supplied from a bore. During the crop cycle water samples were taken from the fluming as the trial site was being irrigated. Mean levels of oxidised nitrogen as N were measured for each crop stage are presented in Table 50.

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treatments. Instead, this result likely occurred due to the results from the DYP 150 or high treatments, whose means over the crop cycle could not be predicted (as mentioned above).

Table 50: Mean and standard error of oxidised nitrogen as N in irrigation water

Crop Stage	Oxidised nitrogen as N (mg/L)
Plant	<0.05#
1st Ratoon	0.26 (±0.02)
2nd Ratoon	0.50*

Result based on four samples
* Result based on one sample

Post-harvest soil N

Following the harvest of each crop stage soil mineral N levels in the top 60cm of the soil profile were calculated in all treatments. Nitrate and ammonium levels and total mineral N are presented in Table 51. Following harvest soil N levels remained low in each treatment. Higher rates of applied N did not result in higher levels of N remaining in the soil profile following harvest indicating that the majority of mineral N not utilised by the crop had had either been converted to another form which was no longer immediately available to the crop or had moved out of the profile due to leaching, runoff, denitrification or via a combination of these loss pathways.

Table 51: Soil (0-60cm) nitrate, ammonium and total mineral N in each treatment following the harvest of each crop stage

Crop Stage	Treatment (kg/ha)	NO3 (kg/ha)	NH4 (kg/ha)	Total mineral N (kg/ha)
Plant	150	7	17	24
	190	7	19	27
	230	7	27	34
1st Ratoon	150	10	17	27
	190	10	17	27
	230	17	24	41
2nd Ratoon	150	10	22	32
	190	11	18	28
	230	10	20	30

Soil mineral N testing nine months after planting

The standard practice according to the protocols (Appendix 1) for this project was to soil sample strips following the harvest of the trial site. Some additional soil sampling was undertaken at this site when the plant crop was approximately nine months of age to determine how much mineral N was remaining in the soil profile (0-60cm) at this time. Fertiliser was applied across the trial site at planting (50kg N/ha) and then again three months after planting (side dressed application) to establish the strips with the various rates of applied N. At nine months after planting soil samples were taken from the centre of the hill with results of the analysis presented in Table 52.

Levels of ammonium in the soil were low in all treatments, however in replicates two and four of the 230 kg N/ha treatment nitrate levels were high in the top 40 cm of the soil profile. The results appear to indicate that at nine months in a plant crop (Table 52) there were still some residual pockets of nitrate remaining in the soil profile at this time, however by harvest soil nitrate levels (kg/ha) were uniformly low.

Table 52: Ammonium and nitrate levels (mg/kg) in the top 60cm of the soil profile for each treatment and replicate nine months after planting

Treatment (Kg N/ha)	Replication	Sampling Depth (0-20cm)	NH4 (mg/kg)	NO3 (mg/kg)
150	Rep 1	0-20	<2	<2
		20-40	<2	<2
		40-60	<2	<2
	Rep 2	0-20	<2	<2
		20-40	<2	2
		40-60	<2	<2
	Rep 3	0-20	2	12
		20-40	<2	2
		40-60	<2	4
	Rep 4	0-20	<2	3
		20-40	<2	3
		40-60	<2	3
190	Rep 1	0-20	<2	<2
		20-40	<2	<2
		40-60	<2	<2
	Rep 2	0-20	<2	<2
		20-40	<2	<2
		40-60	<2	<2
	Rep 3	0-20	2	8
		20-40	<2	3
		40-60	<2	3
	Rep 4	0-20	<2	17
		20-40	<2	6
		40-60	<2	3
230	Rep 1	0-20	2	<2
		20-40	<2	<2
		40-60	<2	<2
	Rep 2	0-20	<2	90
		20-40	<2	33
		40-60	<2	15
	Rep 3	0-20	<2	6
		20-40	<2	<2
		40-60	<2	<2
	Rep 4	0-20	<2	31
		20-40	2	12
		40-60	<2	4

Nitrogen exported to the mill

During the harvesting of trial sites stalk samples were taken at random locations from within each strip to estimate the amount of N exported to the mill (Table 53). In the plant crop, N in stalk exported to the mill increases significantly at the higher N application rates (190 and 230 kg N/ha), without any significant increase in crop yield indicating that some luxury N uptake by the crop had taken place.

Table 53: Mean of N in stalk exported to the mill (kg/ha) and kg of N in stalk/tonne of stalk for each treatment and crop stage.

Crop Stage	N Rate (kg/ha)	Mean Yield (TCH)	N in Stalk Exported to Mill (kg/ha)	Kg of N in Stalk/tonne of Stalk
Plant	150	197	116 b	0.59
	190	201	155 a	0.77
	230	198	138 a	0.70
1st Ratoon	150	186	125 a	0.67
	190	192	127 a	0.66
	230	185	113 a	0.61

P<0.05, means followed by a common letter are not significantly different at the 5% level.

Partial N budget

The two N budgets show the major inputs and outputs for the SIX EASY STEPS method recommended N application rate when using the DYP of 180 tch and the growers preferred N application rate for the plant crop.

Budget 1. SIX EASY STEPS (Mean yield: 197 TCH)

Inputs (kg/ha)		Outputs (kg/ha)	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**150**	1. Crop N uptake	**191**
2. Pre plant soil mineral N	**27**	2. Soil residual mineral N	**24**
3. In season soil N mineralisation estimate	**30**		
4. N in irrigation water	**0**		
Total Inputs	**207**	**Total Outputs**	**215**

Estimate of N in below ground biomass used in calculation of crop N uptake. Estimate is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
-8

This budget shows a negative figure which indicates that more nitrogen was removed from the system than was supplied. It is likely that in season soil N mineralisation accounted for this deficit.

Budget 2. Grower N rate (Mean yield: 201 TCH)

Inputs (kg/ha)		Outputs (kg/ha)	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**190**	1. Crop N uptake	**206**
2. Pre plant soil mineral N	**27**	2. Soil residual mineral N	**27**
3. In season soil N mineralisation estimate	**30**		
4. N in irrigation water	**0**		
Total Inputs	**247**	**Total Outputs**	**233**

Estimate of N in below ground biomass used in calculation of crop N uptake. Estimate is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
14

With the higher N application the budget remained close to being balanced, with some additional N accumulated by the crop.

*Unaccounted for N = Total Inputs – Total Outputs

Site 16 – Home Hill, Delta

Site characteristics

Variety:	Q240⁽ᵈ⁾	Row width:	1.52 m	Water source:	Bore

Soil characteristics (0-20cm)

% Sand (fine):	51	Type:	Dermosol	% Organic carbon:	0.95
% Sand (coarse):	5	Texture:	Loam	Soil pH (1:5 Water):	8.0
% Silt:	23	QDPI:	BUfc	Cation exchange capacity:	16.9
% Clay:	21				

Crop establishment

Planting date:	29/04/2014

Harvest dates

Harvest -Plant:	6/10/2015
1st ratoon:	2/08/2016

Site overview

This trial site was managed according to best management principles. The crop was established with few gaps and weed management was good over the two crop stages of the trial. Good farm management practices combined with good soil fertility and good irrigation management has allowed this grower to achieve good consistent cane and sugar yields at this site.

Yield and return

Higher rates of applied N did not result in higher yields of cane or sugar at this site in the plant or ratoon crop (Table 54). For the ratoon crop the grower decided to retain the same N rates which were applied for the plant crop. The lowest N rate in the ratoon crop was equivalent to the N rate recommended by the SIX EASY STEPS method if a DYP of 150 tch was applied.

Table 54: Mean cane and sugar yield, CCS and gross revenue, costs and net revenue

Crop stage	N rate Kg N/ha	Cane yield tch	CCS units	Sugar yield tsh	Net revenue $/ha
Plant	160 – ~DYP 180	165	14.1	23.2	$4,170
	200 – grower	167	13.7	22.8	$3,910
	240 – high	167	13.7	22.8	$3,823
	p-value	0.572	0.141	0.691	0.133
	95% LSD	6.9	0.6	1.6	$495
1st ratoon	160 – ~DYP 150	147	12.2	17.9	$3,979
	200 – ~DYP 180	148	12.3	18.2	$4,019
	240 – grower	148	12.2	18.0	$3,875
	p-value	0.976	0.819	0.473	0.215
	95% LSD	12.5	0.8	0.6	$254

Figure 30 presents the statistical results for an analysis over both the plant and first ratoon crops. Given that the High rate was not trialled in the first ratoon and the DYP 150 was not trialled in the plant cane, the statistical analysis was unable to predict mean values for these treatments over both crops. The results indicate that there were no statistically significant differences in cane yield, CCS, sugar yield or net revenue between the DYP 180 and Grower treatments. While the unprotected F-test for cane yield, CCS and sugar yield had p-values less than 0.05, protected pairwise comparisons (using the Bonferroni method) did not indicate significant differences between the DYP 180 and Grower treatments in any of the three production measures. Instead, this result likely occurred due to results from the DYP 150 or High treatments, whose means over the crop cycle could not be predicted (as mentioned above).

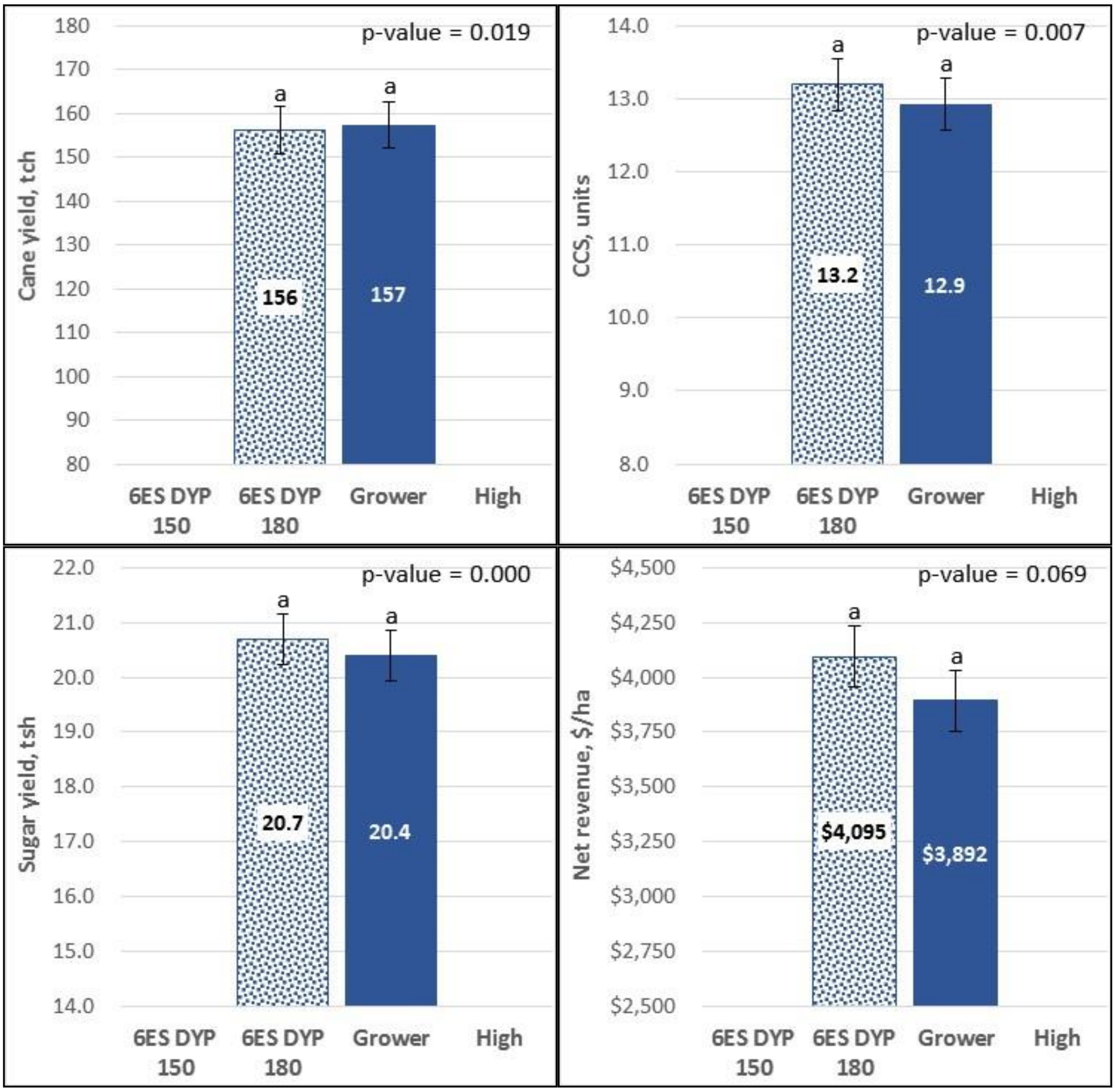

Figure 33: Average over crop cycle – cane yield, CCS, sugar yield and net revenue

Sensitivity analyses reveal that the economic outcome over both the plant and first ratoon crops was not sensitive to fluctuations in the sugar price or fertiliser price within the considered ranges.

Pre-plant soil N

Prior to planting on average across the trial site a total of 26(±3) kg/ha of mineral N was found in the top 60cm of the soil profile. This included 16 (±3) kg/ha of nitrate nitrogen and 10 kg/ha of ammonium nitrogen.

Nitrate nitrogen levels in irrigation water

Irrigation water applied to this trial site was supplied from a bore. During the crop cycle water samples were taken from the fluming as the trial site was being irrigated. Mean levels of oxidised nitrogen as N were measured for each crop stage are presented in Table 55.

Table 55: Mean and standard error of oxidised nitrogen as N in irrigation water

Crop Stage	Oxidised nitrogen as N (mg/L)
Plant	4.1 (±0.2)
1st Ratoon	3.7 (±0.6)

Post-harvest soil N

Following the harvest of each crop soil mineral N levels in the top 60cm of the soil profile were calculated in all treatments. Nitrate and ammonium levels and total mineral N are presented in Table 56. Following harvest of the plant crop soil mineral N levels remained low in each treatment. In the ratoon levels of mineral N were considerably higher, however this did not appear to be related to the N rates. Higher rates of applied N did not result in higher levels of N remaining in the soil profile following harvest indicating that the majority of mineral N not utilised by the crop had either been converted to another form which was no longer immediately available to the crop or had moved out of the profile due to leaching, runoff, denitrification or via a combination of these loss pathways.

Table 56: Soil (0-60cm) nitrate, ammonium and total mineral N in each treatment following the harvest of each crop stage

Crop Stage	Treatment (kg/ha)	NO3 (kg/ha)	NH4 (kg/ha)	Total mineral N (kg/ha)
Plant	160	7	17	24
	200	10	12	22
	240	7	12	19
1st Ratoon	160	29	34	63
	200	11	35	46
	240	14	30	44

Site 17 – Giru, BRIA

Site characteristics

Variety:	Q183⟨D⟩	Row width:	1.60 m	Water source:	Channel

Soil characteristics (0-20cm)

% Sand (fine):	38	Type:	Sodic Duplex	% Organic carbon:	0.91
% Sand (coarse):	13	Texture:	Loam	Soil pH (1:5 Water):	6.9
% Silt:	20	QDPI:	6Drc	Cation exchange capacity:	12.9
% Clay:	29				

Crop establishment

Planting date:	20/04/2014

Harvest dates

Harvest -Plant:	28/06/2015
1st ratoon:	12/06/2016

Site overview

This trial site was managed according to best management principles. The crop was established with few gaps and weed management was good over the two crop stages which were part of the trial. Good farm management practices combined with good soil fertility and in general good irrigation management has allowed this grower to achieve consistent cane and sugar yields over the duration of the trials.

Yield and return

There was no response to higher rates of applied N in the plant crop (Table 57). For the ratoon crop the grower decided to retain similar N rates to those which were applied to the plant crop. The lowest N rate in the ratoon crop was equivalent to the N rate recommended by the SIX EASY STEPS method if a DYP of 150 TCH was applied. For the ratoon crop, the DYP 150 treatment had significantly lower cane yield than the DYP 180 and Grower treatments, but it also had significantly higher CCS than the DYP 180 treatment. In terms of sugar yield, the grower rate had significantly higher sugar yield than both SIX EASY STEPS treatments in the 1st ratoon. No statistically significant differences in net revenue were identified between the treatments in either the plant cane or 1st ratoon crops.

Table 57: Mean cane and sugar yield, CCS and gross revenue, costs and net revenue

Crop stage	N rate Kg N/ha	Cane yield tch	CCS units	Sugar yield tsh	Net revenue $/ha
Plant	150 – ~DYP 180	182	13.3	24.3	$5,989
	190 – grower	181	13.1	23.7	$5,737
	240 – high	183	13.4	24.4	$5,922
	p-value	0.818	0.301	0.295	0.326
	95% LSD	6.6	0.7	1.5	$522
1st ratoon	160 – ~DYP 150	150 b	12.5 a	18.8 b	$4,830
	200 – ~DYP 180	157 a	11.9 b	18.8 b	$4,676
	240 – grower	158 a	12.3 ab	19.4 a	$4,845
	p-value	0.005	0.026	0.019	0.086
	95% LSD	5.5	0.5	0.6	$224

Figure 34 presents the statistical results for an analysis over both the plant and first ratoon crops. Given that the High rate was not investigated in the first ratoon and the DYP 150 was not investigated in the plant cane, the statistical analysis was unable to predict mean values for these treatments over both crops. The results indicate that there were no statistically significant differences in cane yield, CCS, sugar yield or net revenue between the DYP 180 and grower treatments[12].

[12] While the unprotected F-test for cane yield, CCS, sugar yield and net revenue all had p-values less than 0.05, protected pairwise comparisons (using the Bonferroni method) did not indicate significant differences between the DYP 180 and grower treatments in any of the four measures. Instead, this result likely occurred due to results from the DYP 150 or high treatments, whose means over the crop cycle could not be predicted (as mentioned above).

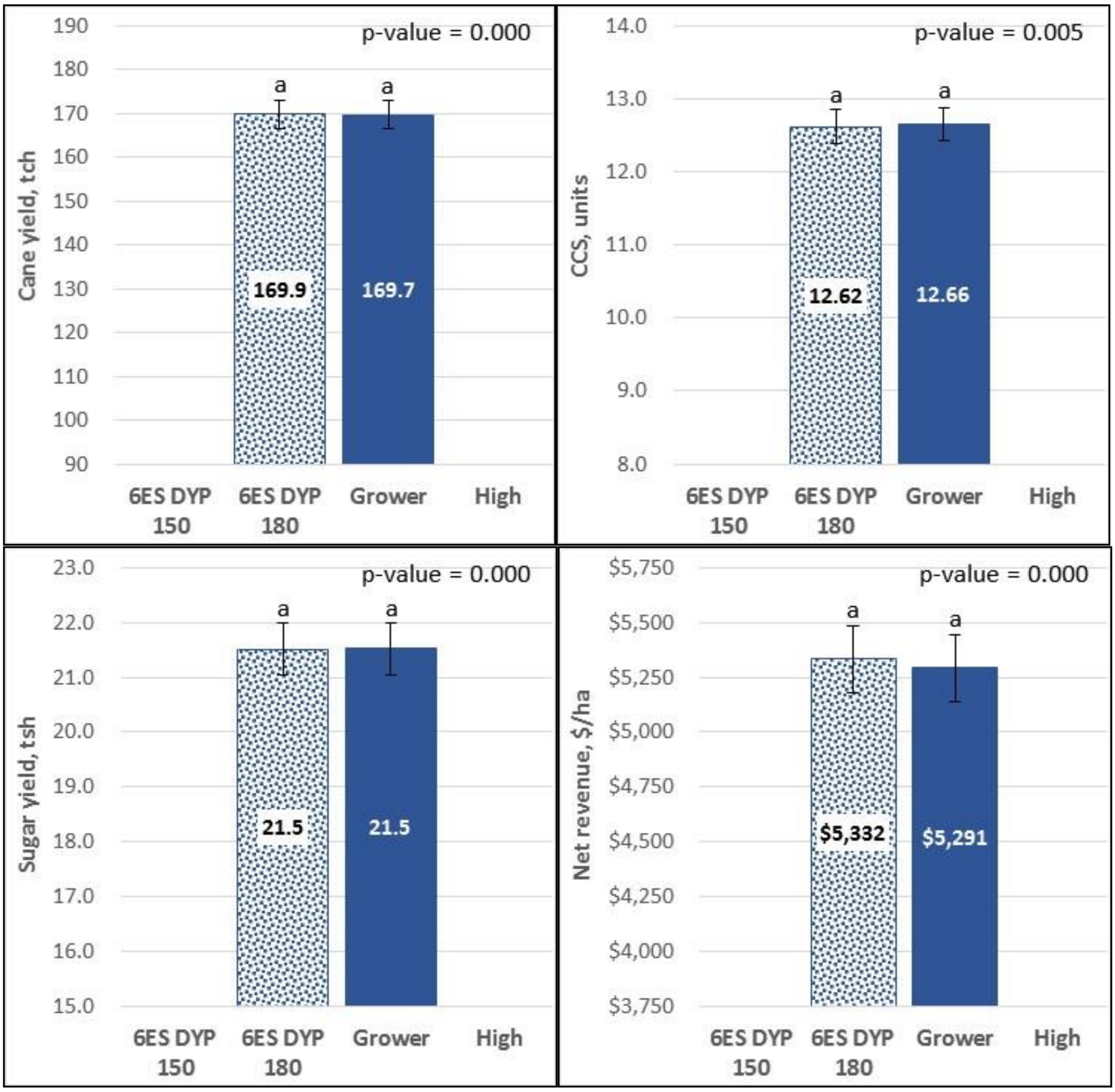

Figure 34: Average over crop cycle – cane yield, CCS, sugar yield and net revenue

Sensitivity analyses reveal that the economic outcome over both the plant and first ratoon crops was not sensitive to fluctuations in the sugar price or fertiliser price within the considered ranges.

Pre-plant soil N

Prior to planting on average across the trial site a total of 39(±2) kg/ha of mineral N was found in the top 60cm of the soil profile. This included 30(±2) kg/ha of nitrate nitrogen and 9(±1) kg/ha of ammonium nitrogen.

Nitrate nitrogen levels in irrigation water

Irrigation water applied to this trial site was supplied via a channel. Mean levels of oxidised nitrogen as N were <0.05 mg/L over the duration of the trials.

Post-harvest soil N

Following the harvest of each crop soil mineral N levels in the top 60cm of the soil profile were calculated in all treatments. Nitrate and ammonium levels and total mineral N are presented in Table 58. Following harvest soil mineral N levels remained low in each treatment. Higher rates of applied N did not result in higher levels of mineral N remaining in the soil profile indicating that the majority of mineral N not utilised by the crop had either been converted to another form which was no longer immediately available to the crop or had moved out of the profile due to leaching, runoff, denitrification or via a combination of these loss pathways.

Table 58: Soil (0-60cm) nitrate, ammonium and total mineral N in each treatment following the harvest of each crop stage

Crop Stage	Treatment (kg/ha)	NO3 (kg/ha)	NH4 (kg/ha)	Total mineral N (kg/ha)
Plant	150	7	17	24
	190	12	15	27
	240	10	17	27
1st Ratoon	160	4	29	33
	200	12	24	36
	240	11	20	31

Nitrogen exported to the mill

During the harvesting of trial sites stalk samples were taken at random locations from within each strip to estimate the amount of N exported to the mill (Table 59).

Table 59: Mean of N in stalk exported to the mill (kg/ha) and kg of N in stalk/tonne of stalk for each treatment and crop stage.

Crop Stage	N Rate (kg/ha)	Mean Yield (TCH)	N in Stalk Exported to Mill (kg/ha)	Kg of N in Stalk/tonne of Stalk
Plant	150	182	153 a	0.84
	190	181	150 a	0.83
	240	183	161 a	0.88

P<0.05, means followed by a common letter are not significantly different at the 5% level

Partial N budget

The two N budgets show the major inputs and outputs for the SIX EASY STEPS method recommended N application rate when using the DYP of 180 tch and the Grower N application rate for the plant crop.

Budget 1. SIX EASY STEPS (Mean yield: 182 TCH)

Inputs (kg/ha)		**Outputs (kg/ha)**	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**150**	1. Crop N uptake	**164**
2. Pre plant soil mineral N	**39**	2. Soil residual mineral N	**24**
3. In season soil N mineralisation estimate	**20**		
4. N in irrigation water	**0**		
Total Inputs	**209**	**Total Outputs**	**188**

Estimate of N in below ground biomass used in calculation of crop N uptake. Estimate is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
21

This budget was close to being in balance with little N unaccounted.

Budget 2. Grower N rate (Mean yield: 181 TCH)

Inputs (kg/ha)		Outputs (kg/ha)	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**190**	1. Crop N uptake	**199**
2. Pre plant soil mineral N	**39**	2. Soil residual mineral N	**27**
3. In season soil N mineralisation estimate	**20**		
4. N in irrigation water	**0**		
Total Inputs	**249**	**Total Outputs**	**226**

Estimate of N in below ground biomass used in calculation of crop N uptake. Estimate is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
23

With the higher N application rate the budget was still close to being in balance, this was mainly due to more N being accumulated by the crop, however this did not translate into additional yield.

*Unaccounted for N = Total Inputs – Total Outputs

Site 18 – Clare, BRIA

Site characteristics

Variety:	Q240⊕	Row width:	1.52 m	Water source:	Channel/Bores

Soil characteristics (0-20cm)

% Sand (fine):	42	Type:	Vertosol	% Organic carbon:	0.80
% Sand (coarse):	2	Texture:	Clay	Soil pH (1:5 Water):	7.7
% Silt:	21	QDPI:	2Ugd	Cation exchange capacity:	20.1
% Clay:	35				

Crop establishment

Planting date:	19/05/2014

Harvest dates

Harvest -Plant:	7/07/2015
1st ratoon:	7/09/2016

Site overview

This trial site was managed according to best management principles. The crop was established with few gaps and weed management was good over the two crop stages which were part of the trials. Good farm management practices combined with fair soil fertility and good irrigation management has allowed this grower to achieve good consistent cane and sugar yields over the duration of the trials.

Yield and return

There was no yield increase (tch or tsh) with higher N rates in the plant crop, however the High rate suffered a significant decline in CCS (Table 60). Moreover, the High treatment had significantly lower mean net revenue than the DYP 180 treatment by over $400/ha.

In the ratoon crop, the grower decided to continue with the same treatments which were applied to the plant crop. The lowest N rate (160 kg N/ha) in the ratoon crop was equivalent to the N rate prescribed by the SIX EASY STEPS method when using the DYP of 150 tch. This N rate produced significantly less cane than the DYP 180 treatment, which is the SIX EASY STEPS prescribed N rate for a ratoon at this site. However, there was no significant difference in sugar yield or net revenue.

Table 60: Mean cane and sugar yield, CCS and gross revenue, costs and net revenue

Crop stage	N rate Kg N/ha	Cane yield tch	CCS units	Sugar yield tsh	Net revenue $/ha
Plant	160 – ~DYP 180	163	13.6 a	22.2	$4,911 a
	200 – grower	163	13.6 a	22.1	$4,766 ab
	240 – high	161	13.4 b	21.5	$4,492 b
	p-value	0.806	0.022	0.358	0.051
	95% LSD	8.1	0.2	1.2	$394
1st ratoon	160 – ~DYP 150	141 b	15.0	21.2	$4,414
	200 – ~DYP 180	149 a	15.1	22.4	$4,653
	240 – grower	150 a	14.7	22.1	$4,451
	p-value	0.005	0.476	0.124	0.402
	95% LSD	6.2	0.9	1.8	$579

Figure 35 presents the statistical results for an analysis over both the plant and first ratoon crops. Given that the High rate was not trialled in the first ratoon and the DYP 150 was not trialled in the plant cane, the statistical analysis was unable to predict mean values for these treatments over both crops. The results indicate that there were no statistically significant differences in cane yield, CCS, sugar yield or net revenue between the DYP 180 and grower treatments[13].

[13] While the unprotected F-test for cane yield and CCS had p-values less than 0.05, protected pairwise comparisons (using the Bonferroni method) did not indicate significant differences between the DYP 180 and grower treatments in either of the measures. Instead, this result likely occurred due to results from the DYP 150 or high treatments, whose means over the crop cycle could not be predicted (as mentioned above).

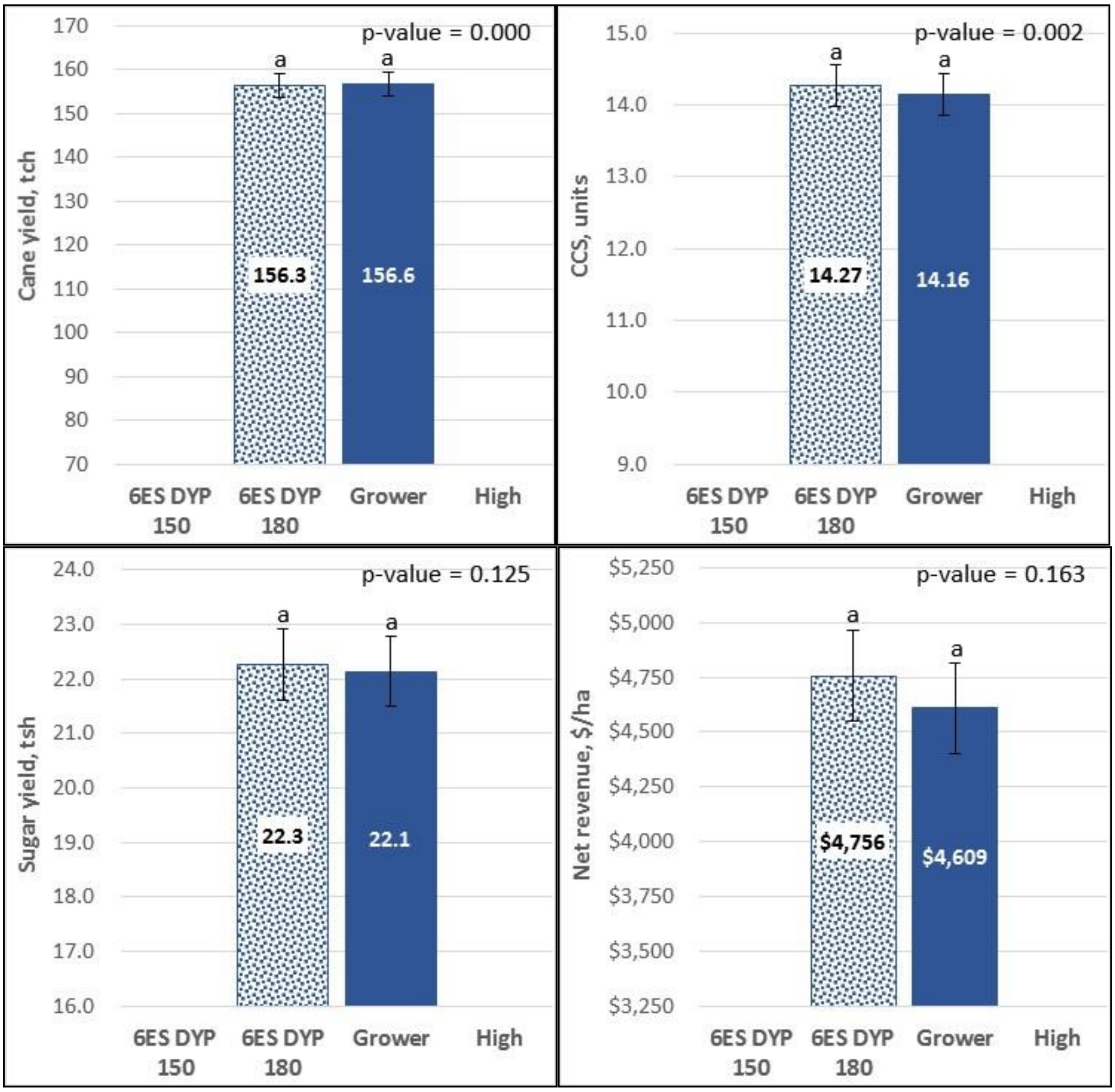

Figure 35: Average over crop cycle – cane yield, CCS, sugar yield and net revenue

Sensitivity analyses reveal that the economic outcome over both the plant and 1st ratoon crops was not sensitive to fluctuations in the sugar price or fertiliser price within the considered ranges.

Pre-plant soil N

Prior to planting on average across the trial site a total of 77(±7) kg/ha of mineral N was found in the top 60cm of the soil profile. This included 65(±6) kg/ha of nitrate nitrogen and 12 (±1) kg/ha of ammonium nitrogen.

Nitrate nitrogen levels in irrigation water

Irrigation water applied to this trial site was supplied from multiple sources which included bores and a channel. During the plant and ratoon crop water samples were taken from the fluming as the trial site was being irrigated. Mean levels of oxidised nitrogen as N were measured for each crop stage are presented in Table 61.

Table 61: Mean and standard error of oxidised nitrogen as N in irrigation water

Crop Stage	Oxidised nitrogen as N (mg/L)
Plant	1.1*
1st Ratoon	3.4(±.04)

* Result based on one sample

Post-harvest soil N

Following the harvest of each crop soil mineral N levels in the top 60cm of the soil profile were calculated in all treatments. Nitrate and ammonium levels and total mineral N are presented in Table 62. Following harvest soil mineral N levels remained low in each treatment. Higher rates of applied N did not result in higher levels of N remaining in the soil profile following harvest indicating that the majority of mineral N not utilised by the crop had either been converted to another form which was no longer immediately available to the crop or had moved out of the profile due to leaching, runoff, denitrification or via a combination of these loss pathways.

Table 62: Soil (0-60cm) nitrate, ammonium and total mineral N in each treatment following the harvest of each crop stage

Crop Stage	Treatment (kg/ha)	NO3 (kg/ha)	NH4 (kg/ha)	Total mineral N (kg/ha)
Plant	160	7	24	31
	200	7	24	31
	240	7	24	31
1st Ratoon	160	6	26	32
	200	9	19	28
	240	9	23	31

Nitrogen exported to the mill

During the harvesting of trial sites stalk samples were taken at random locations from within each strip to estimate the amount of N exported to the mill (Table 63).

In the plant crop N in stalk exported to the mill increased significantly at the Grower and High N application rates, without any significant increase in crop yield indicating that some luxury N uptake by the crop had taken place.

Table 63: Mean of N in stalk exported to the mill (kg/ha) and kg of N in stalk/tonne of stalk for each treatment for the plant crop

Crop Stage	N Rate (kg/ha)	Mean Yield (tch)	N in Stalk Exported to Mill (kg/ha)	Kg of N in Stalk/tonne of Stalk
Plant	160	164	113 b	0.69
	200	163	133 a	0.82
	240	162	136 a	0.84

P<0.05, means followed by a common letter are not significantly different at the 5% level

Partial N budget

The two N budgets show the major inputs and outputs for the SIX EASY STEPS method recommended N application rate when using the DYP of 180 tch and the Grower N application rate for the plant crop.

Budget 1. SIX EASY STEPS (Mean yield: 164 tch)

Inputs (kg/ha)		Outputs (kg/ha)	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**160**	1. Crop N uptake	**183**
2. Pre plant soil mineral N	**77**	2. Soil residual mineral N	**31**
3. In season soil N mineralisation estimate	**10**		
4. N in irrigation water	**11**		
Total Inputs	**258**	**Total Outputs**	**214**

Estimate of N in below ground biomass used in calculation of crop N uptake. Estimate is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
44

Approximately 44 kg N/ha was unaccounted in this budget. This was mainly due to the high levels of mineral N in the soil prior to planting.

Budget 2. Grower N rate (Mean yield: 163 tch)

Inputs (kg/ha)		Outputs (kg/ha)	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**200**	1. Crop N uptake	**172**
2. Pre plant soil mineral N	**77**	2. Soil residual mineral N	**31**
3. In season soil N mineralisation estimate	**10**		
4. N in irrigation water	**11**		
Total Inputs	**298**	**Total Outputs**	**203**

Estimate of N in below ground biomass used in calculation of crop N uptake. Estimate is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
95

With the higher N application rate more N was unaccounted. The crop did not accumulate any additional N.

*Unaccounted for N = Total Inputs – Total Outputs

Site 19 – Brandon, Delta

Site characteristics

Variety:	Q183⁽ᵇ⁾	Row width:	1.52 m	Water source:	Bore/Creek

Soil characteristics (0-20cm)

% Sand (fine):	45	Type:	Vertosol	% Organic carbon:	1.35
% Sand (coarse):	3	Texture:	Clay loam	Soil pH (1:5 Water):	7.7
% Silt:	23	QDPI:	RUgb	Cation exchange capacity:	22.5
% Clay:	29				

Crop establishment Harvest dates

Planting date:	6/05/2014	Harvest -Plant:	11/08/2015
		1st ratoon:	3/11/2016

Site overview

Prior to planting the sugarcane crop the grower at this site grew a large soybean crop, details of the potential N contribution to the cane crop are provided in Table 62.

This trial site was generally managed according to best management principles. The crop was established with few gaps, weed and irrigation management was very good over the two crop stages. Good farm management practices combined with good soil fertility and in general good irrigation management has allowed this grower to achieve consistent cane and sugar yields over the duration of the trials.

Yield and return

There was no response to higher N application rates in either the plant or ratoon crops (Table 64). While no statistically significant differences in net revenue were identified between the treatments, the lowest N application rate attained the highest mean net revenue in the plant cane (50 kg N/ha) and in the first ratoon (DYP 150).

Table 64: Mean cane and sugar yield, CCS and gross revenue, costs and net revenue

Crop stage	N rate Kg N/ha	Cane yield tch	CCS units	Sugar yield tsh	Net revenue $/ha
Plant	50*	200	13.4	26.9	$5,409
	100*	202	13.1	26.3	$5,091
	150*	203	13.4	27.2	$5,317
	p-value	0.695	0.377	0.279	0.284
	95% LSD	9	0.9	1.6	$608
1st ratoon	170 – ~DYP 150	183	13.4	24.4	$4,597
	210 – ~DYP 180	179	13.2	23.5	$4,297
	250 – grower	184	13.1	24.1	$4,350
	p-value	0.345	0.228	0.373	0.200
	95% LSD	12	0.4	2	$511

Given that neither of the SIX EASY STEPS or higher N rate treatments were trialled in the plant crop at this site, this report cannot evaluate the performance of each treatment over multiple crops.

Pre-plant soil N

Prior to planting the sugarcane crop and whilst the soybean crop was still standing, soil samples were taken from across the trial site. Soil mineral N levels were 23(±1) kg/ha in the top 60cm of the soil profile. This included 14 kg of nitrate nitrogen and 9(±1) kg of ammonium nitrogen.

N contribution from legume crop

The soybean crop was allowed to go to seed and then slashed and incorporated prior to planting. Prior to being slashed a total of 48 (1m x 1m) biomass samples were taken from across the trial site to estimate crop size to determine the potential N contribution to the sugarcane crop. Table 65 provides details of the soybean crop and its potential N contribution.

Table 65: Soybean N accumulation and potential N contribution to the sugarcane crop

Legume dry mass (t/ha)	N%	Above ground crop N accumulation (kg/ha)	Above and below ground crop N accumulation (kg/ha)
11.8 (±0.3)	3.1 (±0.03)	365 (±9.1)	475*

* Calculated by using an estimate for the below ground component (30% of the above ground crop N accumulation).

Nitrate nitrogen levels in irrigation water

Irrigation water applied to this trial site was supplied from a bore and a local creek. Mean levels of oxidised nitrogen as N were <0.05 mg/L over the duration of the trial.

Post-harvest soil N

Following the harvest of each crop soil mineral N levels in the top 60cm of the soil profile were calculated in all treatments. Nitrate and ammonium levels and total mineral N are presented in Table 66. Following harvest soil N levels remained low in each treatment. Higher rates of applied N did not result in higher levels of N remaining in the soil profile following harvest indicating that the majority of mineral N not utilised by the crop had either been converted to another form which was no longer immediately available to the crop or had moved out of the profile due to leaching, runoff, denitrification or via a combination of these loss pathways.

Table 66: Soil (0-60cm) nitrate, ammonium and total mineral N in each treatment following the harvest of each crop stage

Crop Stage	Treatment (kg/ha)	NO3 (kg/ha)	NH4 (kg/ha)	Total mineral N (kg/ha)
Plant	50	7	12	19
	100	7	10	17
	150	7	12	19
1st Ratoon	170	9	32	41
	210	5	14	19
	250	12	32	44

Nitrogen exported to the mill

During the harvesting of trial sites stalk samples were taken at random locations from within each strip to estimate the amount of N exported to the mill (Table 67). It was expected that there would be a large amount of N contributed to the cane crop by the breakdown of the legume crop over the growing season. There was a significant ($p<0.05$) increase in the amount of N in the millable stalk at the highest N rate (150kg N/ha), although there was no significant increase in yield. This suggests that there was a considerable amount (23 kg N/ha) of luxury N uptake from the applied nitrogen fertiliser at the highest N rate.

Table 67: Mean of N in stalk exported to the mill (kg/ha) and kg of N in stalk/tonne of stalk for each treatment and crop stage.

Crop Stage	N Rate (kg/ha)	Mean Yield (TCH)	N in Stalk Exported to Mill (kg/ha)	Kg of N in Stalk/tonne of Stalk
Plant	50	200	142 b	0.71
	100	202	146 b	0.72
	150	203	169 a	0.83

P<0.05, means followed by a common letter are not significantly different at the 5% level

Partial N budget

The two N budgets show the major inputs and outputs for the lowest N rate and the Grower N application rate for the plant crop following a soybean crop. According to the SIX EASY STEPS method the recommend N application rate following a large legume crop is zero applied N.

Budget 1. Lowest N application rate (Mean yield: 200 tch)

Inputs (kg/ha)		Outputs (kg/ha)	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**50**	1. Crop N uptake	**180**
2. Pre plant soil mineral N	**23**	2. Soil residual mineral N	**19**
3. In season soil N mineralisation estimate	**30**		
4. N in irrigation water	**0**		
5. Contribution from soybean crop	**475**		
Total Inputs	**578**	**Total Outputs**	**198**

Estimate of N in below ground biomass used in calculation of crop N uptake. Estimate is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
380

The contribution of N from the soybean crop has resulted in a significant amount of N which was unaccounted.

Budget 2. Growers preferred N application rate (Mean yield: 203 tch)

Inputs (kg/ha)		Outputs (kg/ha)	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**150**	1. Crop N uptake	**202**
2. Pre plant soil mineral N	**23**	2. Soil residual mineral N	**19**
3. In season soil N mineralisation estimate	**30**		
4. N in irrigation water	**0**		
5. Contribution from soybean crop	**475**		
Total Inputs	**678**	**Total Outputs**	**221**

Estimate of N in below ground biomass used in calculation of crop N uptake. Estimate is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
457

With the higher N application rate more N was unaccounted although the crop appears to have accumulated more N.

*Unaccounted for N = Total Inputs – Total Outputs

Site 20 – Clare, BRIA

Site characteristics

Variety:	Q252⁽ᵇ⁾	Row width:	1.8 m (Dual row)	Water source:	Channel

Soil characteristics (0-20cm)

% Sand (fine):	31	Type:	Sodic Duplex	% Organic carbon:	0.9
% Sand (coarse):	8	Texture:	Clay	Soil pH (1:5 Water):	8.2
% Silt:	23	QDPI:	2Dyb	Cation exchange capacity:	23.1
% Clay:	38				

Crop establishment / Harvest date

Planting date:	6/03/2015	Harvest -Plant:	15/09/2016

Site overview

At this trial site row spacing was 1.8m with a dual row of cane as standard farming practice.
This trial site was managed according to best management principles. The crop was established with few gaps and weed and irrigation management were good. Good farm management practices has enabled this grower to achieve good yields at this site.

Yield and return

There was no response to higher N application rates in the plant crop and little difference in mean net revenue between the treatments (Table 68).

Table 68: Mean cane and sugar yield, CCS and gross revenue, costs and net revenue

Crop stage	N rate Kg N/ha	Cane yield tch	CCS units	Sugar yield tsh	Net revenue $/ha
Plant	160 – ~DYP 180	160	16.2	25.9	$5,374
	200 – grower	164	16.0	26.2	$5,352
	240 – high	167	15.8	26.4	$5,307
	p-value	0.054	0.122	0.540	0.891
	95% LSD	7.6	0.5	1.6	$464

Pre-plant soil N

Prior to planting on average across the trial site a total of 34(±12) kg of mineral N was found in the top 60cm of the soil profile. This included 19(±10) kg of nitrate nitrogen and 15(±3) kg of ammonium nitrogen.

Nitrate nitrogen levels in irrigation water

Irrigation water applied to this trial site was supplied from a channel. During the growth of the plant crop six water samples were taken from the fluming as the trial site was being irrigated. Mean levels of oxidised nitrogen as N were found to be 0.5 (±0.2) mg/L.

Post-harvest soil N

Following the harvest of each crop soil mineral N levels in the top 60cm of the soil profile were calculated in all treatments. Nitrate and ammonium levels and total mineral N are presented in Table 69. Following harvest soil N levels remained low in each treatment. Higher rates of applied N did not result in higher levels of N remaining in the soil profile following harvest indicating that the majority of mineral N not utilised by the crop had either been converted to another form which was no longer immediately available to the crop or had moved out of the profile due to leaching, runoff, denitrification or via a combination of these loss pathways.

Table 69: Soil (0-60cm) nitrate, ammonium and total mineral N in each treatment following the harvest of the plant crop

Crop Stage	Treatment (kg/ha)	NO3 (kg/ha)	NH4 (kg/ha)	Total mineral N (kg/ha)
Plant	160	14	23	36
	200	14	25	39
	240	11	16	27

Site 21 – Brandon, Delta

Site characteristics

Variety:	Q208⑰	Row width:	1.52 m	Water source:	Bore

Soil characteristics (0-20cm)

% Sand (fine):	56	Type:	Dermosol	% Organic carbon:	1.3
% Sand (coarse):	1	Texture:	Loam	Soil pH (1:5 Water):	8.2
% Silt:	25	QDPI:	BUfc	Cation exchange capacity:	21.1
% Clay:	18				

Crop establishment / Harvest dates

Planting date:	6/03/2015	Harvest -Plant:	26/08/2016

Site overview

This trial site was managed according to best management principles. The crop was established with few gaps and weed management was good. Very good farm management practices combined with good soil fertility has allowed this grower to achieve very high cane and sugar yields.

Yield and return

There was no response to higher N application rates in the plant crop (Table 70). While no statistically significant differences in net revenue were identified between the treatments, the SIX EASY STEPS DYP 180 treatment attained mean net revenue that was about $500/ha higher than the other rates. Something to note here is the value of CCS, particularly at high yielding sites. At this site, an improvement of 0.1 CCS provides a financial benefit to the farmer that is equivalent to an extra 3.5 TCH, so the 0.6 CCS difference between the DYP 180 and High treatment is equivalent to an extra 21 TCH.

Table 70: Mean cane and sugar yield, CCS and gross revenue, costs and net revenue

Crop stage	N rate Kg N/ha	Cane yield tch	CCS units	Sugar yield tsh	Net revenue $/ha
Plant	160 – ~DYP 180	258	12.9	33.3	$7,474
	200 – grower	258	12.5	32.2	$6,977
	240 – high	262	12.3	32.3	$6,908
	p-value	0.480	0.222	0.403	0.212
	95% LSD	11.7	1	2.8	$1,009

Pre-plant soil N

Prior to planting on average across the trial site a total of 55(±9) kg of mineral N was found in the top 60cm of the soil profile. This included 40(±9) kg of nitrate nitrogen and 15 kg of ammonium nitrogen.

Nitrate nitrogen levels in irrigation water

Irrigation water applied to this trial site was supplied from a bore. During the growth of the plant crop four water samples were taken from the fluming as the trial site was being irrigated. Mean levels of oxidised nitrogen as N, were found to be 0.2 (±0.1) mg/L.

Post-harvest soil N
Following the harvest of the plant crop soil mineral N levels in the top 60cm of the soil profile were calculated in all treatments. Nitrate and ammonium levels and total mineral N are presented in Table 71. Soil mineral N levels were low in each treatment. Higher rates of applied N did not result in higher levels of N remaining in the soil profile following harvest indicating that the majority of mineral N not utilised by the crop had either been converted to another form which was no longer immediately available to the crop or had moved out of the profile due to leaching, runoff, denitrification or via a combination of these loss pathways.

Table 71: Soil (0-60cm) nitrate, ammonium and total mineral N in each treatment following the harvest of the plant crop

Crop Stage	Treatment (kg/ha)	NO3 (kg/ha)	NH4 (kg/ha)	Total mineral N (kg/ha)
Plant	160	19	16	35
	200	20	20	40
	240	17	22	39

Site 22 – Clare, BRIA

Site characteristics

Variety:	Q253⌽	Row width:	1.6 m	Water source:	Channel

Soil characteristics (0-20cm)

% Sand (fine):	23	Type:	Vertosol	% Organic carbon:	0.85
% Sand (coarse):	3	Texture:	Clay	Soil pH (1:5 Water):	7.0
% Silt:	21	QDPI:	2Ugd	Cation exchange capacity:	23.4
% Clay:	53				

Crop establishment **Harvest dates**

Planting date:	20/03/2015	Harvest -Plant:	17/06/2016

Site overview

This trial site was managed according to best management principles. The crop was established with few gaps and weed management was good. Good farm management practices has allowed this grower to achieve good yields in a soil which is considered to be poor and difficult to manage in the BRIA.

Yield and return

There was no yield response to higher N application rates in the plant crop, there was however a significant decline in CCS (Table 72). The SIX EASY STEPS recommended N application rate had significantly higher CCS than the High N rate treatment. While no statistically significant differences in net revenue were identified between the treatments, the High N rate treatment had much lower mean net revenue than the lower N rate treatments (at least $500/ha lower).

Table 72: Mean cane and sugar yield, CCS and gross revenue, costs and net revenue

Crop stage	N rate Kg N/ha	Cane yield tch	CCS units	Sugar yield tsh	Net revenue $/ha
Plant	170 – ~DYP 180	163	11.9 a	19.4	$4,295
	240 – grower	174	11.5 ab	20.0	$4,241
	290 – high	169	11.1 b	18.7	$3,732
	p-value	0.103	0.043	0.257	0.082
	95% LSD	14.2	0.8	2.3	$729

Pre-plant soil N
Prior to planting on average across the trial site a total of 57(±4) kg of mineral N was found in the top 60cm of the soil profile. This included 27(±3) kg of nitrate nitrogen and 30(±1) kg of ammonium nitrogen.

Nitrate nitrogen levels in irrigation water
Irrigation water applied to this trial site was supplied via a channel. Mean levels of oxidised nitrogen as N were <0.05 mg/L over the duration of the trial.

Post-harvest soil N
Following the harvest of each crop soil mineral N levels in the top 60cm of the soil profile were calculated in all treatments. Nitrate and ammonium levels and total mineral N are presented in Table 73. Soil N levels remained low in each treatment. Higher rates of applied N did not result in higher levels of N remaining in the soil profile following harvest indicating that the majority of mineral N not utilised by the crop had either been converted to another form which was no longer immediately available to the crop or had moved out of the profile due to leaching, runoff, denitrification or via a combination of these loss pathways.

Table 73: Soil (0-60cm) nitrate, ammonium and total mineral N in each treatment following the harvest of a plant crop

Crop Stage	Treatment (kg/ha)	NO3 (kg/ha)	NH4 (kg/ha)	Total mineral N (kg/ha)
Plant	170	11	26	37
	240	15	36	51
	290	12	30	42

Partial N budget

The three N budgets show the major inputs and outputs for the SIX EASY STEPS method recommended N application rate when using the DYP of 180 tch, the Grower and the High N application rates for the plant crop.

Budget 1. SIX EASY STEPS (Mean yield: 163 tch)

Inputs (kg/ha)		Outputs (kg/ha)	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**170**	1. Crop N uptake	**131**
2. Pre plant soil mineral N	**57**	2. Soil residual mineral N	**37**
3. In season soil N mineralisation estimate	**20**		
4. N in irrigation water	**0**		
Total Inputs	**247**	**Total Outputs**	**168**

Estimate of N in below ground biomass used in calculation of crop N uptake. Estimate is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
79

There was a considerable amount of N which was unaccounted.

Budget 2. Grower N rate (Mean yield: 174 tch)

Inputs (kg/ha)		Outputs (kg/ha)	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**240**	1. Crop N uptake	**134**
2. Pre plant soil mineral N	**57**	2. Soil residual mineral N	**51**
3. In season soil N mineralisation estimate	**20**		
4. N in irrigation water	**0**		
Total Inputs	**317**	**Total Outputs**	**185**

Estimate of N in below ground biomass used in calculation of crop N uptake. Estimate is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
132

With the higher N application rate more N was unaccounted, there was little additional N accumulated by the crop.

*Unaccounted for N = Total Inputs – Total Outputs

Budget 3. High N rate (Mean yield: 174 tch)

Inputs (kg/ha)		Outputs (kg/ha)	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**290**	1. Crop N uptake	**139**
2. Pre plant soil mineral N	**57**	2. Soil residual mineral N	**42**
3. In season soil N mineralisation estimate	**20**		
4. N in irrigation water	**0**		
Total Inputs	**367**	**Total Outputs**	**181**

Estimate of N in below ground biomass used in calculation of crop N uptake. Estimate is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
186

With the higher N application rate more N was unaccounted, with little additional N accumulated by the crop.

*Unaccounted for N = Total Inputs – Total Outputs

Site 23 – Jarvisfield, Delta

Site characteristics

Variety:	Q240⁽ᵇ⁾	Row width:	1.52 m	Water source:	Bore

Soil characteristics (0-20cm)

% Sand (fine):	28	Type:	Dermosol	% Organic carbon:	1.6
% Sand (coarse):	2	Texture:	Loam	Soil pH (1:5 Water):	7.0
% Silt:	36	QDPI:	BGnc	Cation exchange capacity:	29.9
% Clay:	34				

Crop establishment / Harvest dates

Planting date:	17/04/2015	Harvest -Plant:	24/09/2016

Site overview

This trial site was managed according to best management principles. The crop was established with few gaps and weed and irrigation management were good. Good farm management practices combined with good soil fertility has allowed this grower to achieve high yields at this site.

Yield and return

At this site higher rates of applied N did not show a statistically significant improvement in yields or net revenue (Table 74).

Table 74: Mean cane and sugar yield, CCS and gross revenue, costs and net revenue

Crop stage	N rate Kg N/ha	Cane yield tch	CCS units	Sugar yield tsh	Net revenue $/ha
Plant	150 – ~DYP 180	193	15.0	28.8	$5,790
	190 – grower	193	14.7	28.4	$5,575
	230 – high	202	15.2	30.6	$6,161
	p-value	0.150	0.350	0.147	0.233
	95% LSD	15	1	3.4	$1,007

Pre-plant soil N

Prior to planting on average across the trial site a total of 114(±30) kg of mineral N was found in the top 60cm of the soil profile. This included 91(±26) kg of nitrate nitrogen and 23 (±4) kg of ammonium nitrogen. Mineral N levels were extremely high at this site, the reason for this is not clear.

Nitrate nitrogen levels in irrigation water

Irrigation water applied to this trial site was supplied from a bore. During the growing of the plant crop four water samples were taken from the fluming as the trial site was being irrigated. Mean levels of oxidised nitrogen as N were 0.8 (±0.1) mg/L.

Post-harvest soil N

Following harvest soil mineral N levels in the top 60cm of the soil profile were calculated in all treatments. Nitrate and ammonium levels and total mineral N are presented in Table 75. Soil N levels were low in each treatment. Higher rates of applied N did not result in higher levels of mineral N remaining in the soil profile indicating that the majority of mineral N not utilised by the crop had either been converted to another form which was no longer immediately available to the crop or had moved out of the profile due to leaching, runoff, denitrification or via a combination of these loss pathways.

Table 75: Soil (0-60cm) nitrate, ammonium and total mineral N in each treatment following the harvest of the plant crop

Crop Stage	Treatment (kg/ha)	NO3 (kg/ha)	NH4 (kg/ha)	Total mineral N (kg/ha)
Plant	150	8	20	28
	190	8	17	25
	230	9	19	28

Partial N budget

The three N budgets show the major inputs and outputs for the SIX EASY STEPS method recommended N application rate when using the DYP of 180 tch, the Grower N application rate and the High N rate. The High N rate was included as this provided the grower with the highest net revenue although this was not significant.

Budget 1. SIX EASY STEPS (Mean yield: 193 tch)

Inputs (kg/ha)		Outputs (kg/ha)	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**150**	1. Crop N uptake	**175**
2. Pre plant soil mineral N	**114**	2. Soil residual mineral N	**28**
3. In season soil N mineralisation estimate	**30**		
4. N in irrigation water	**8**		
Total Inputs	**302**	**Total Outputs**	**203**

Estimate of N in below ground biomass used in calculation of crop N uptake. Estimate is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
99

There was a considerable amount of N which was unaccounted.

Budget 2. Grower N rate (Mean yield: 193 tch)

Inputs (kg/ha)		Outputs (kg/ha)	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**190**	1. Crop N uptake	**184**
2. Pre plant soil mineral N	**114**	2. Soil residual mineral N	**25**
3. In season soil N mineralisation estimate	**30**		
4. N in irrigation water	**8**		
Total Inputs	**342**	**Total Outputs**	**209**

Estimate of N in below ground biomass used in calculation of crop N uptake. Estimate is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
133

With the higher N application rate more N was unaccounted, there was little additional N accumulated by the crop.

Budget 3. High N rate (Mean yield: 202 tch)

Inputs (kg/ha)		Outputs (kg/ha)	
Component	**Result**	**Component**	**Result**
1. N from fertiliser	**230**	1. Crop N uptake	**197**
2. Pre plant soil mineral N	**114**	2. Soil residual mineral N	**28**
3. In season soil N mineralisation estimate	**30**		
4. N in irrigation water	**8**		
Total Inputs	**382**	**Total Outputs**	**225**

Estimate of N in below ground biomass used in calculation of crop N uptake. Estimate is based on data from a paper by Connellan and Deutschenbaur 2016 (included in Appendix 6).

Unaccounted for N* (kg/ha)
157

At the Higher N application rate more N was unaccounted, with little additional N accumulated by the crop.

*Unaccounted for N = Total Inputs – Total Outputs

4.3 Summary of results over the crop cycle

Tables 76 and 77 provide a summary of the production and economic results from the trial sites. More specifically, Table 76 presents the average cane yield and CCS for each nitrogen rate treatment over the crop cycle at each site[14], while Table 77 shows the mean sugar yield and net revenue. For easier inspection, statistically significant p-values are in red.

The summary shows some consistent trends. For example:
Cane yield – sites 3, 6, 8, 10 and 11 all show that the High treatment and/or the Grower treatment has significantly higher mean cane yield than the DYP 150 treatment but not the DYP 180 treatment.
CCS – sites 3, 4, 6, 7, 10 and 12 all show that the DYP 150 treatment and/or the DYP 180 treatment has significantly higher mean CCS than the High treatment and in some cases the Grower treatment.
Sugar yield – no consistent trend, although at Site 15 significantly more sugar was produced at the DYP of 180 in comparison to the higher N application rates.
Net revenue – the DYP 150 or 180 attains the highest average net revenue at every site over the crop cycle, although in most cases this is not statistically significant.

Table 76: Summary of cane yield and CCS results over the crop cycle

Site	Cane yield, TCH					CCS, units				
	DYP 150	DYP 180	Grower	High	*95% LSD*	DYP 150	DYP 180	Grower	High	*95% LSD*
2	112	115	**116**	n/a	*9*	**15.5**	15.5	15.3	n/a	*0.4*
3	154 b	156 ab	163 ab	**165** a	*11*	**13.7** a	13.6 a	13.4 ab	13.2 b	*0.4*
4	130	131	127	**134**	*15*	**15.3** a	15.2 a	15.1 ab	15.0 b	*0.3*
5	n/a	116	**118**	118	*7*	n/a	**15.3**	15.3	15.2	*0.2*
6	101 b	105 ab	107 a	**108** a	*5*	**15.2** a	15.0 a	14.4 b	14.4 b	*0.4*
7	**128**	-	-	127	*10*	**16.1** a	-	-	15.8 b	*0.3*
8	92 b	94 ab	96 ab	**98** a	*5*	**16.9**	16.8	16.7	16.6	*0.5*
9	74	78	78	**78**	*7*	16.4	**16.6**	16.4	16.4	*0.4*
10	112 b	119 ab	121 ab	**125** a	*11*	**15.8** a	15.4 ab	15.3 ab	15.0 b	*0.7*
11	116 b	124 a	**128** a	n/a	*6*	**15.5**	15.0	14.8	n/a	*0.9*
12	n/a	87	87	**87**	*12*	n/a	**14.4** a	14.1 b	13.9 b	*0.3*
14	n/a	**131**	131	131	*17*	n/a	**14.9**	14.9	14.9	*0.8*
15	-	**185** a	184 a	-	*8*	-	**12.8**	12.4	-	*0.6*
16	-	156 a	**157** a	-	*11*	-	**13.2** a	12.9 a	-	*0.7*
17	-	170 a	**170** a	-	*7*	-	12.6 a	**12.7** a	-	*0.5*
18	-	156 a	**157** a	-	*6*	-	**14.3** a	14.2 a	-	*0.6*

[14] Trial sites that have only been harvested once are not included.

Table 77: Summary of sugar yield and economic results over the crop cycle

Site	Sugar yield, tsh					Net revenue, $/ha				
	DYP 150	DYP 180	Grower	High	*95% LSD*	DYP 150	DYP 180	Grower	High	*95% LSD*
2	17.6	17.8	**17.8**	n/a	*2.1*	**$3,575**	$3,532	$3,460	n/a	*$996*
3	20.9	21.1	**21.8**	21.7	*1.4*	**$4,398**	$4,354	$4,377	$4,228	*$395*
4	19.8	19.9	19.1	**20.0**	*2.2*	**$3,971**	$3,924	$3,617	$3,714	*$459*
5	n/a	17.8	**18.0**	17.9	*1.1*	n/a	**$3,522**	$3,483	$3,358	*$192*
6	15.4	**15.8**	15.5	15.7	*0.9*	$3,462 a	**$3,468** a	$3,268 a	$3,255 a	*$262*
7	**20.6** a	-	-	19.9 a	*1.5*	**$4,341** a	-	-	$3,944 b	*$245*
8	15.4 a	15.6 a	15.9 a	**16.1** a	*0.8*	**$3,100**	$3,051	$3,068	$3,011	*$279*
9	12.2	**13.0**	12.8	13.0	*1.3*	$2,347	**$2,477**	$2,347	$2,342	*$311*
10	17.7	18.4	18.5	**18.8**	*1.5*	$3,743	**$3,781**	$3,715	$3,642	*$479*
11	18.1	18.6	**19.0**	n/a	*1.6*	**$4,009**	$4,008	$3,988	n/a	*$520*
12	n/a	**12.7**	12.5	12.4	*1.9*	n/a	**$2,587**	$2,421	$2,273	*$433*
14	n/a	**19.5**	19.4	19.4	*1.6*	n/a	**$4,061** a	$3,926 a	$3,851 a	*$475*
15	-	**23.7** a	22.9 b	-	*0.6*	-	**$5,086** a	$4,736 b	-	*$254*
16	-	**20.7** a	20.4 a	-	*0.9*	-	**$4,095**	$3,892	-	*$275*
17	-	21.5 a	**21.5** a	-	*0.9*	-	**$5,332** a	$5,291 a	-	*$308*
18	-	**22.3** a	22.1 a	-	*1.3*	-	**$4,756** a	$4,609 a	-	*$412*

4.4 Summary of results across all trial sites in the Delta and Burdekin River Irrigation (BRIA) Area

This analysis aims to provide an understanding of how the nitrogen rate treatments have performed across all of the trial sites in each of the major cane grower areas of the Delta and the BRIA. The statistical model that was employed included additional parameters that accounted for the variation attributed by spatial differences between trial sites and interactions between location (or space) and other parameters fitted to the model. The model fits the terms for crop class, treatment, and crop class x treatment as fixed effects as we are interested in examining their influence on production and profitability. All other terms were fitted as random effects. For instance, the terms for trial and replicate are fitted as random effects signifying that they are random samples of all possible trials and replicates in the population. Wald tests were used to test the significance level of the fixed terms and pairwise comparisons were made within each crop class.

Figures 36 & 37 display the results for the overarching treatment effect across trial sites and crop classes in the cane growing areas of the Burdekin Delta and BRIA, respectively. The treatments are ordered (left to right) by the quantity of N applied (lowest to highest), which is also indicated by the shade of colour from light to dark. The graphs show mean cane yield, CCS, sugar yield or the net revenue of any given treatment, while the error bars illustrate the average 95% LSD (as each pairwise comparison has its own 95% LSD). Significance letters have been placed above each 95% LSD bar to indicate statistical significance. Common letters indicate that differences between the corresponding treatments, are not statistically significant.

In the Delta, mean cane yield of the High N rate treatment was 4.4 tch more than the DYP 180 treatment (Figure 36). There was no significant difference in cane yield between the DYP 150 treatment and the Grower treatment. There was no significant difference in CCS between the DYP 150 and DYP 180 treatments, however mean CCS declined significantly by 0.2 units at the Grower N rate treatment in comparison the DYP 180 N rate treatment. The higher cane yield of the High N rate when combined with the loss of CCS resulted in no significant difference in sugar yield between treatments.
The economic results show that the Grower and High N rate treatments had significantly lower mean net revenue than both of the SIX EASY STEPS treatments. These statistically significant differences ranged between $155/ha and $275/ha per crop, or between $620/ha and $1,108/ha over the crop cycle (all four crops - Plant to 3rd ratoon).

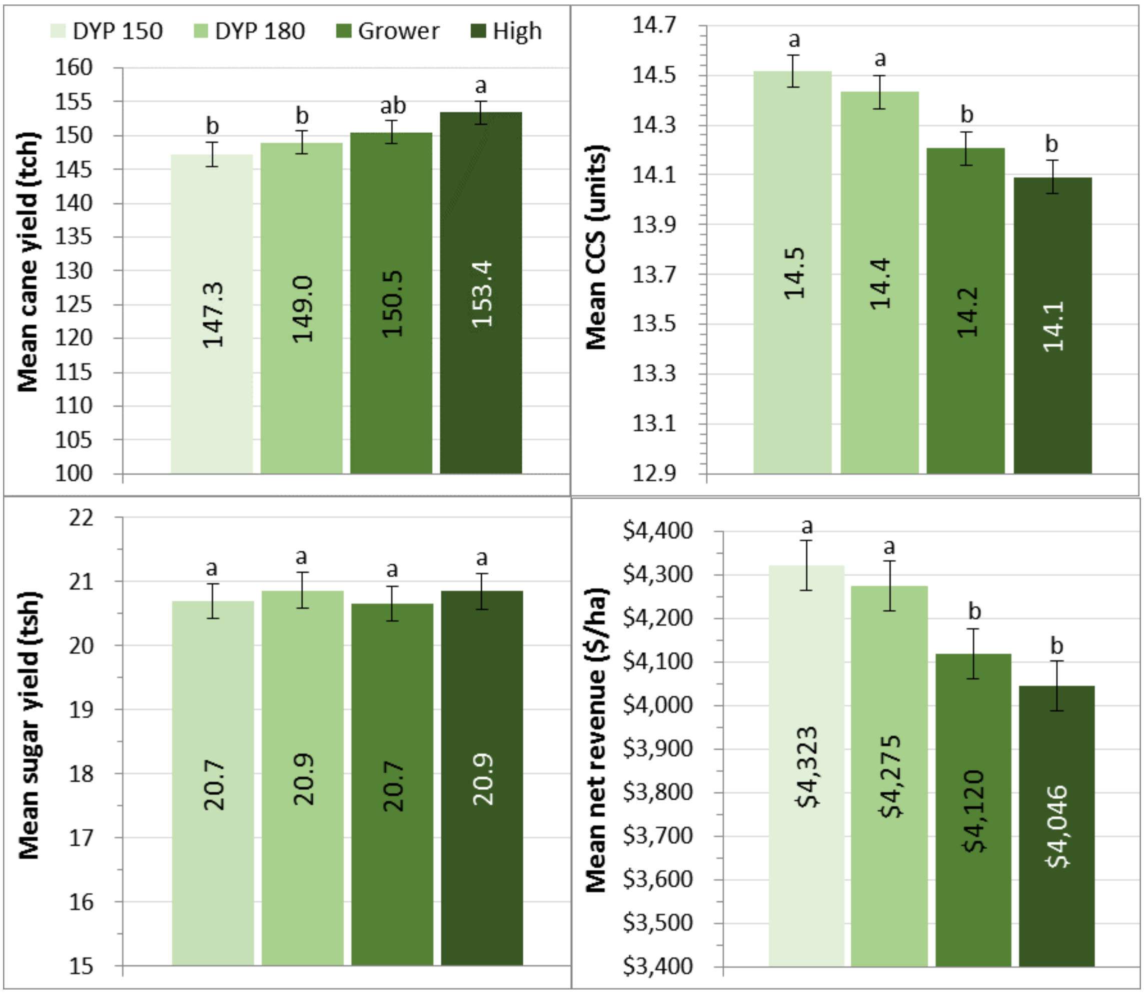

Figure 36: Treatment effects on mean cane yield (tch), mean CCS, mean sugar yield (tsh) and mean net revenue across all Delta trial sites and crop classes.

In the BRIA sugarcane yield at the Grower N rate treatment was 2 tch higher than the DYP 180 treatment (Figure 37). There was also a significant difference in cane yield between the DYP 150 and the DYP 180 treatments (3.3 tch). CCS declined significantly by 0.2 units at the Grower N rate treatment in comparison to the DYP 180 treatment, although there was no significant difference in CCS between the Grower and High treatments. The higher cane yield at the High N rate treatment when combined with the decline in CCS resulted in no significant difference in sugar yield between treatments.

Similarly to the Delta, the economic results show that the Grower and High N rate treatments had lower mean net revenue than both of the SIX EASY STEPS treatments. However, only the difference between the High N rate treatment was statistically significant. By comparison, mean net revenue for the High N rate treatment was around $150/ha less than the SIX EASY STEPS treatments (or $600/ha less over the crop cycle).

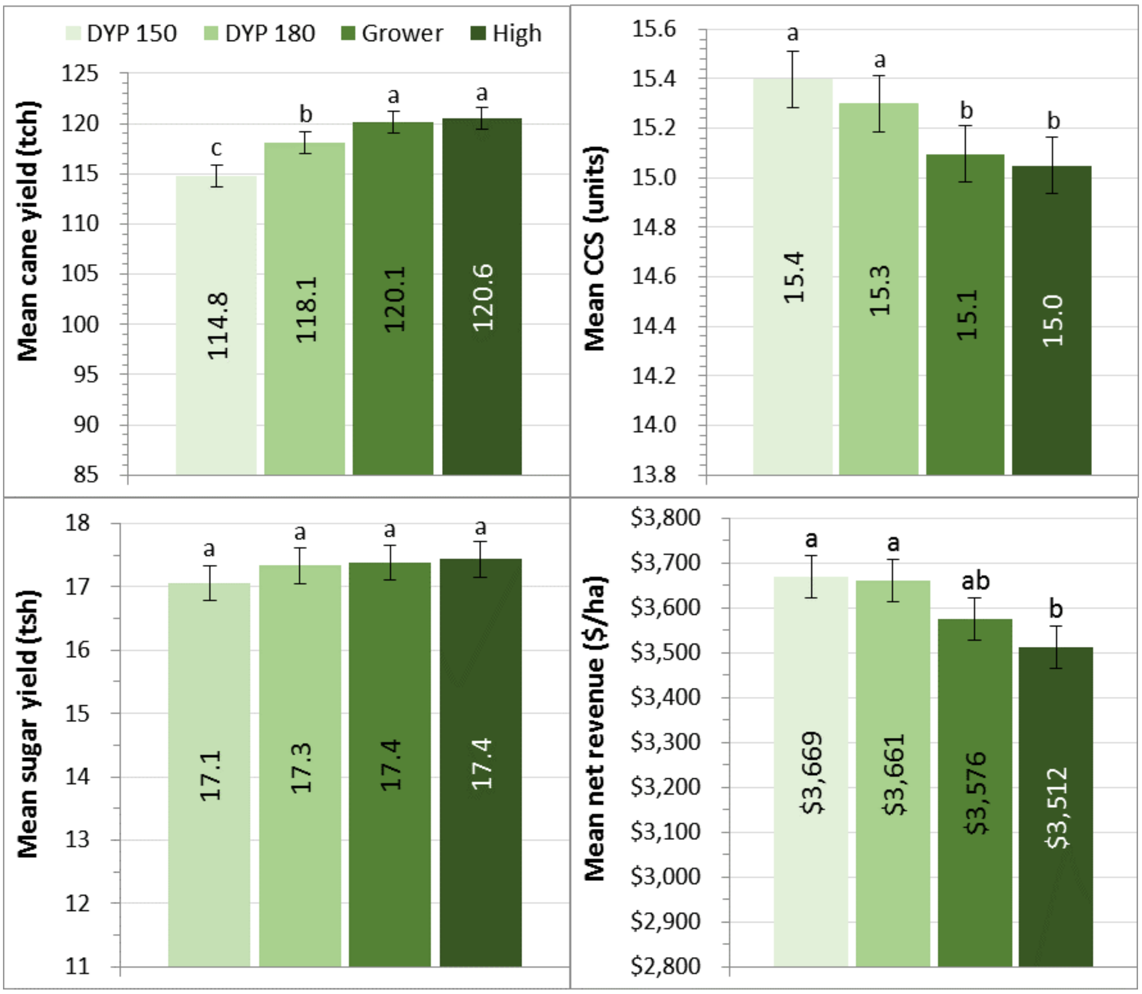

Figure 37: Treatment effects on mean cane yield (tch), mean CCS, mean sugar yield (tsh) and mean net revenue across all BRIA trial sites and crop classes.

4.5 Analysis across all trial sites

This analysis aims to provide an understanding of how the nitrogen rate treatments have performed across all trial sites in both the Delta and the BRIA. This evaluation uses the same statistical model as the two analyses in the preceding section across all sites in the Delta and the BRIA, respectively. Figures 38, 39, 40 and 41 display the results for the overarching treatment effect (in green – all crop classes) and the treatment effect within each crop class (in blue – left to right, plant to third ratoon). The treatments are ordered (left to right) by the quantity of N applied (lowest to highest), which is also indicated by the shade of colour from light to dark. The columns indicate the mean cane yield, CCS, sugar yield or the net revenue of any given treatment, while the error bars illustrate the average 95% LSD.

When comparing the mean cane yield across all sites and crop stages (in green) the Grower N rate treatment produced 1.8 tch more than the DYP 180 treatment and 4.5 tch more that the DYP 150 treatment. The blue columns show mean cane yield within each crop stage for each treatment. In the plant crop the High N rate treatment produced 2.8 tch more than the DYP 180 treatment and 8.3 tch more than the DYP 150 treatment. In the 1st ratoon crop the High N rate treatment produced 3.7 tch more that the DYP 180 treatment and 7.3 tch more that the DYP 150 treatment. In the second ratoon the response to N appeared to decline with the High N rate treatment producing 3.7 tch more than the DYP 180 treatment and only 5 tch more that the DYP 150 treatment. In the 3rd ratoon there were no statistically significant differences in mean cane yield between any of the N rate treatments.

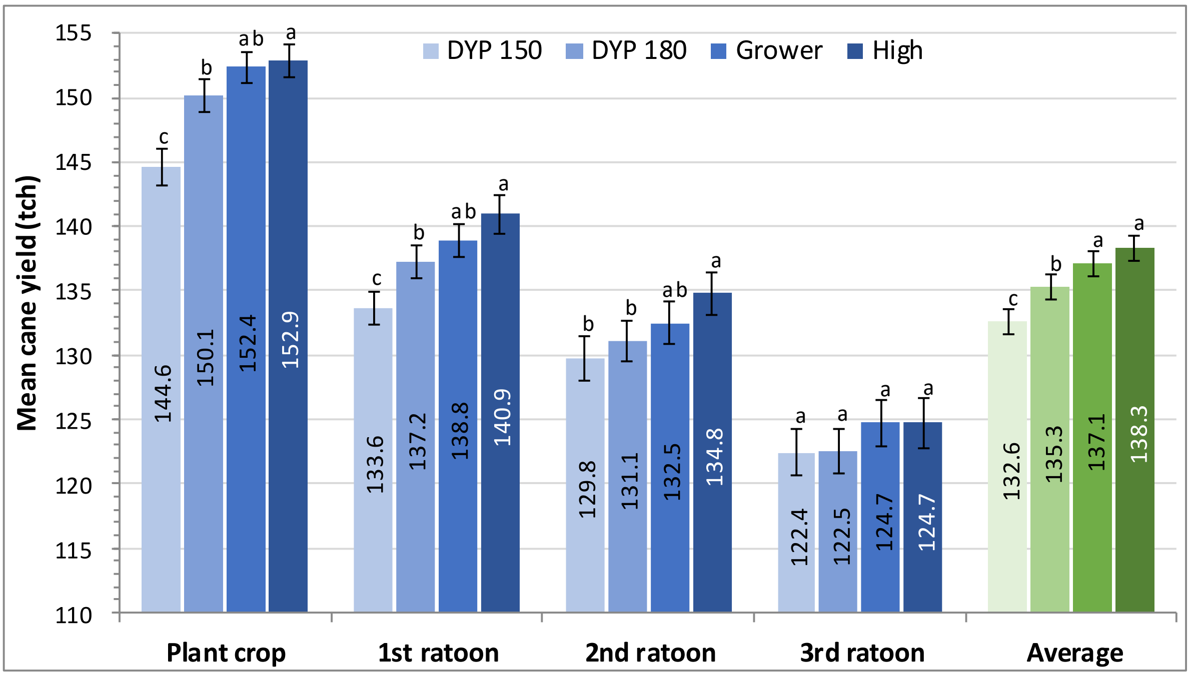

Figure 38: Mean cane yield (tch) summarised across all trial sites and crop stages (in green) and mean cane yield across all sites and at each crop stage (in blue)

Mean CCS (Figure 39) across all sites and crop stages (in green) declined significantly (0.2 units) at the Grower N rate treatment in comparison to the SIX EASY STEPS DYP 180 N rate treatment. There was no significant difference in CCS between the two SIX EASY STEPS treatments and no significant difference between the Grower and High treatments. Mean CCS across all sites with each crop stage analysed separately is highlighted in blue. In the plant crop CCS declined significantly (0.2 units) at the Grower N rate treatment in comparison to the DYP 180 treatment. The same trend was also found in the 1st ratoon. In the 2nd ratoon CCS was considerably higher across all treatments, however CCS declined significantly (0.2 units) at the High N rate treatment in comparison to the DYP 180 treatment. In the 3rd ratoon CCS declined significantly (0.3 units) at the Grower N rate treatment in comparison to the DYP 180 treatment, however there was no significant difference in CCS between the two SIX EASY STEPS treatments or the Grower and High treatments.

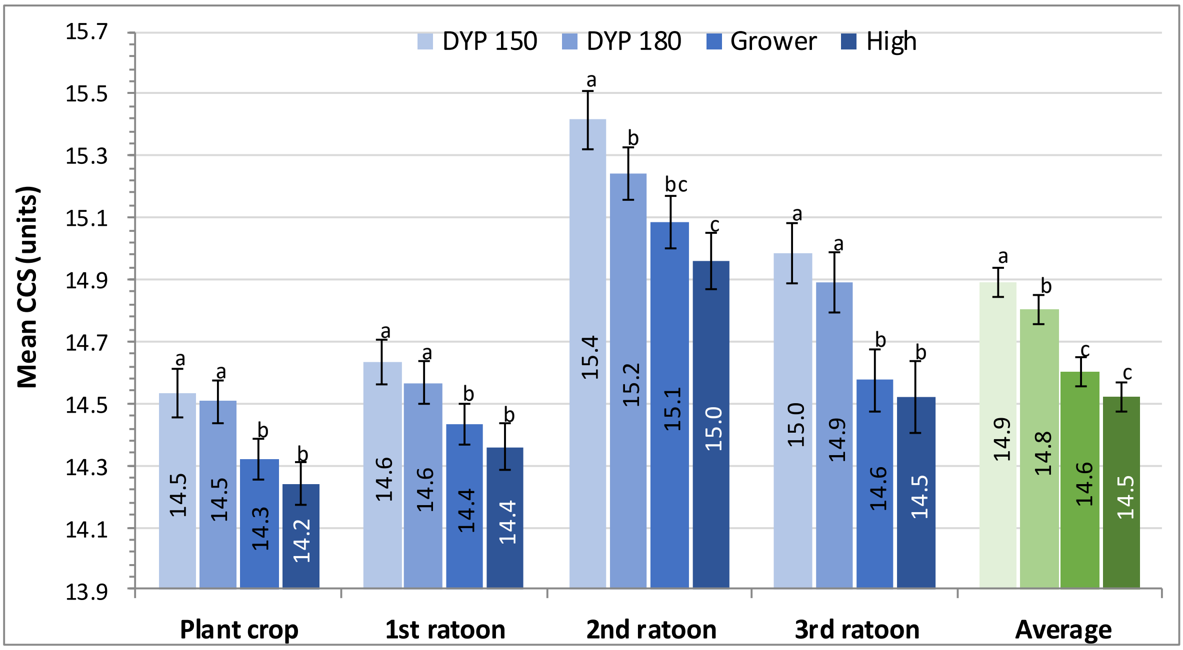

Figure 39: Mean CCS summarised across all trial sites and crop stages (in green) and mean CCS across all sites and at each crop stage (in blue)

Mean sugar yield (Figure 40) across all sites and crop stages (in green) was significantly lower (0.3 tsh) at the DYP 150 N rate treatment in comparison to the DYP 180 treatment. There was no difference in tonnes of sugar produced between the DYP 180 treatment and the Grower and High treatments. Mean tonnes of sugar across all sites with each crop stage analysed separately is highlighted in blue. In the plant crop sugar yield was significantly lower (0.7 tsh) at the DYP 150 N rate treatment in comparison to the DYP 180 treatment and the Grower and High treatments. A similar trend was also found in the 1st ratoon crop with the DYP 150 treatment producing 0.4 tsh less than the Grower and High treatments. In the 2nd and 3rd ratoons there were no significant differences in tonnes of sugar produced between any of the four N rates.

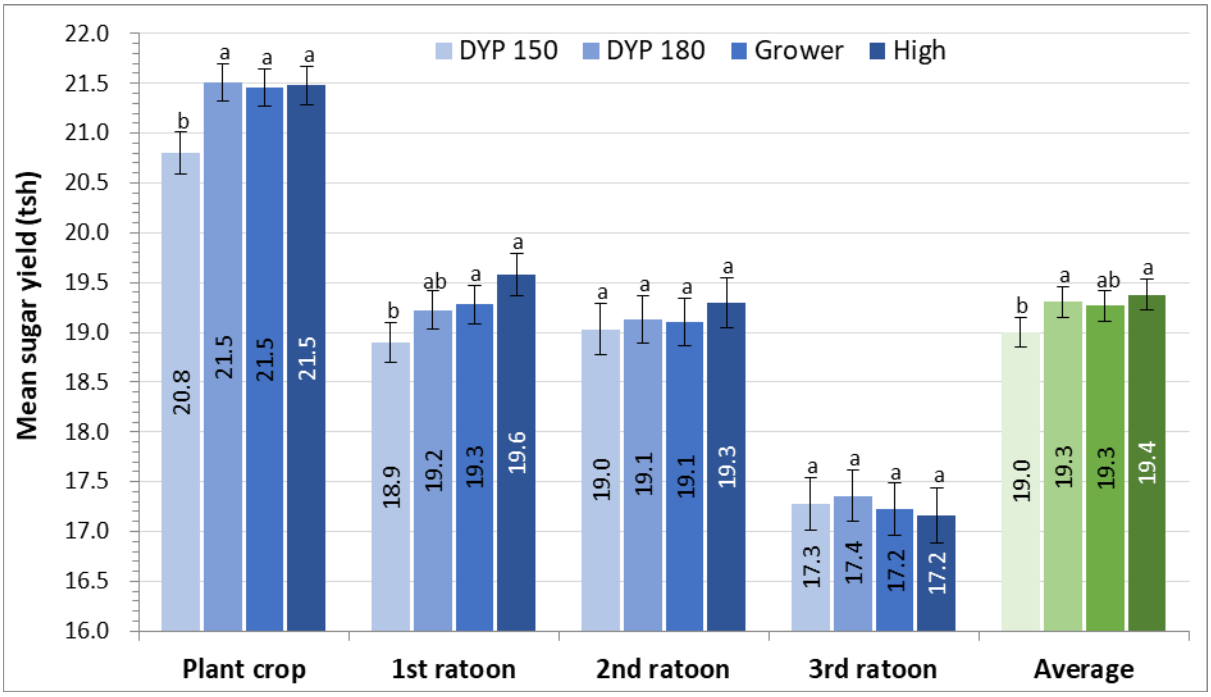

Figure 40: Mean sugar yield (tsh) summarised **across all trial sites and crop stages (in green) and mean sugar yield across all sites and at each crop stage (in blue)**

For net revenue (Figure 41), the results from the Wald test found that the differences between the means of the treatments for the overarching treatment effect were statistically significant (P< 0.000). Comparing the different N rate treatments shows that both of the SIX EASY STEPS treatments attained significantly higher mean net revenue than the Grower and High N rate treatments by between $115/ha per crop and $210/ha per crop, or between $460/ha and $840/ha over the crop cycle (all four crops – plant to 3rd ratoon).

Moreover, the interaction variable, crop class x treatment, was also found to be statistically significant (P<0.002) indicating that treatment performance is influenced by crop class (time effects). In this case, emphasis on treatment effect should be redirected from the overarching effect (in green) to the crop classes (in blue).

A comparison of the treatments for the plant crop shows that the SIX EASY STEPS DYP 180 rate produced the highest mean net revenue compared to the SIX EASY STEPS DYP 150 rate (by $70/ha), grower rate (by $113/ha) and high rate (by $186/ha). In this case, the mean net revenue of the SIX EASY STEPS DYP 180 rate was found to be significantly higher than the mean net revenues of the Grower rate and High rate. While the Grower and High N rate treatments had lower mean net revenue than the DYP 150 and 180 treatments in the first ratoon, none of these differences were statistically significant. In the second ratoon, the SIX EASY STEPS DYP 150 treatment had significantly higher mean net revenue than the Grower (by $192/ha) and High (by $261/ha) N rate treatments, while both the DYP 150 and the 180 were significantly higher than the same treatments in the third ratoon (by between $153 and $347/ha). Notably, the high N rate treatment had the lowest mean net revenue in every crop stage, followed by the Grower N rate treatment.

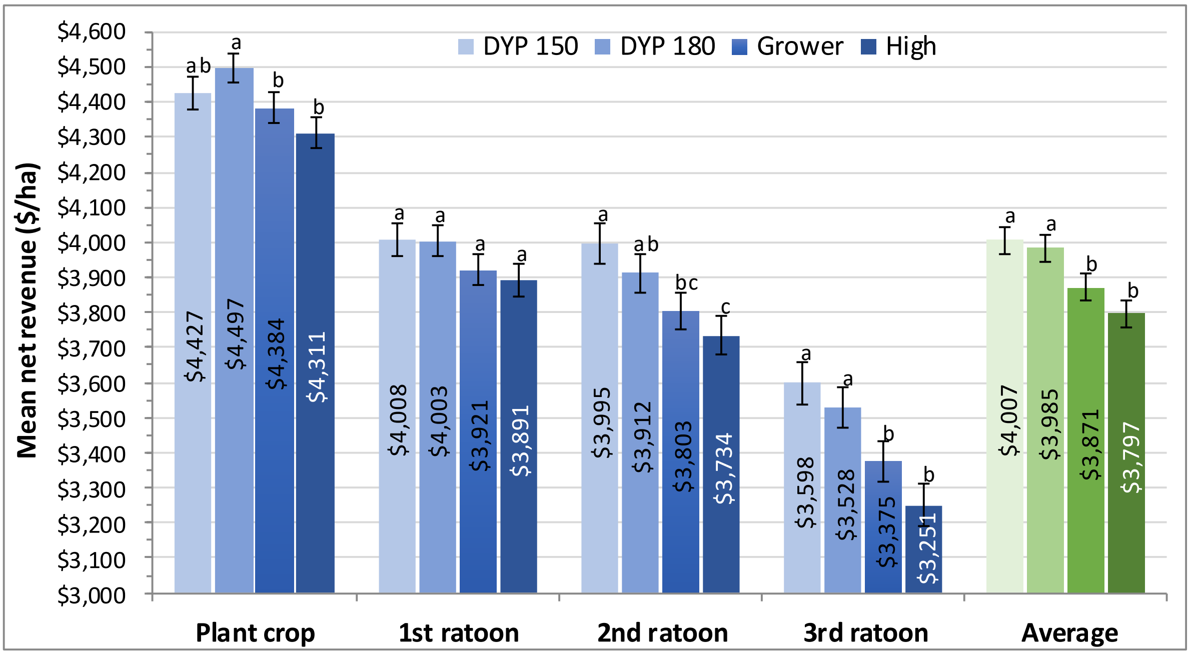

Figure 41: A comparison of mean net revenue for each nitrogen rate treatment across all trial sites and crop stages (in green) and for all trial sites at each crop stage (in blue)

5 Discussion

Yields for the ten sites established in 2011, four sites established in 2012 and one site established in 2013 have ranged from approximately 60 to 200 tonnes of cane per hectare. The differences in yields across sites can be related to soil types and farm management. The responses to applied N has varied from site to site and year to year. Some responses to higher nitrogen application rates were observed in cane yield, however this response was not evident in sugar yield at most sites. At one site a 4th ratoon crop (Grower 3) did respond to higher N rates, above those recommended by the SIX EASY STEPS method. A simple partial N budget for this ratoon crop indicated that the N inputs at the DYP 180 should have provided enough N to meet crop requirements. However this budget did not take into account losses due to factors such as leaching and runoff. At the Grower N rate the budget showed that there was an increase in the amount of N which was unaccounted although the crop did appear to utilise approximately half of the additional applied N. The reason for the response to the N rates above the DYP 180 N rate treatment is not known and further investigation may be warranted.

Examining the production results at each trial site over the crop cycle identified a few consistent trends. For example, five sites showed that the High and/or Grower N rate treatments had significantly higher cane yield than the DYP 150 treatment, but not the DYP 180 treatment. Also, six sites showed that the DYP 150 and/or DYP 180 treatments had significantly higher CCS than the high treatment, and in some cases the grower treatment. Nevertheless, no consistent trends were found with sugar yield.

Given the trade-off between CCS and cane yield that was identified at some of the trial sites, decision makers need to be aware of the value of CCS, particularly at high yielding sites. At Site 21, which produced mean cane yields of around 260 tch, an improvement of 0.1 CCS provided a financial benefit to the farmer that was equivalent to an extra 3.5 tch (or ~$100/ha). Compared to the High N rate treatment, the SIX EASY STEPS treatment attained mean CCS that was 0.6 units higher, which was equivalent to an extra 21 tch (or ~$600/ha).

The economic results for each individual crop indicate that there is a lot of year-to-year variation. Investigating the N rate treatment that performed the best at each trial site shows that a SIX EASY STEPS treatment (either the DYP 150 or 180) achieved the highest mean net revenue in 86% of the harvested crops (48 out of 56 crops). However, when examining all crops harvested from each site, one of the SIX EASY STEPS treatments (either the DYP 150 or 180) achieved the highest profitability (mean net revenue) at every trial site that had more than one crop harvested (16 sites). Although, results from only two of these trial sites indicated that the differences were statistically significant.
The separate statistical analysis of the data from each of the major cane growing areas of the Burdekin (Delta and BRIA) showed that there was little difference in yield response to the various N rate treatments. In the Delta when compared to the BRIA there was a greater response in cane yield at N application rates above the DYP 180 treatment. In the Delta an additional 4.4 tch was produced at the High treatment in comparison to the DYP 180 treatment. In the BRIA only an additional 2 tch was produced at the Grower N rate treatment in comparison to the DYP 180 treatment. In both areas CCS declined significantly by 0.2 units at the Grower treatment in comparison to the DYP 180 treatment. Although there was an increase in tonnes of cane produced sugar yields were not influenced by treatments due the decline in CCS.

Analysis of data from all sites across all crop stages showed very similar trends to those observed when the data was analysed for each of the major growing areas of the Burdekin (Delta and BRIA). There was a significant increase in tonnes of cane produced (1.8 tch) at treatments above the DYP 180 N rate. However there was also a significant decline in CCS which resulted in no significant difference in sugar yield at the DYP 180 N rate and above. In regards to net revenue the DYP 150 and the DYP 180 treatments attained significantly higher net revenue than the Grower and High N rate treatments. These results also found that the relative performance of each N rate treatment

changed between crop classes. Results also showed that the high N rate treatment had the lowest mean net revenue during every crop class.
The statistical analysis across all trial sites showed that both of the SIX EASY STEPS treatments attained significantly higher profitability (mean net revenue) than the Grower and High N rate treatments by at least \$115/ha per crop, or \$460/ha over the crop cycle (all four crops - plant to 3rd ratoon). These results also found that the relative performance of each N rate treatment changed between crop classes. For instance, the profitability of the DYP 150 treatment was found to perform relatively better (although not significantly) than the DYP 180 in later ratoons (2nd and 3rd ratoon), which may provide an incentive for growers to review the suitability of the District Yield Potential that is used as the crop cycle progresses. Results also showed that the High N rate treatment had the lowest mean net revenue during every crop class followed by the Grower treatment, which suggests a negative relationship between profitability and the amount of N applied above the SIX EASY STEPS guidelines.

As part of this project sampling of crop biomass was conducted when crops were approximately nine months of age, just prior to harvest and during the harvesting process (see Appendix 1). Sampling of biomass just prior to harvest was found to be problematic in the Burdekin due to lodging which generally started to occur when crops were nine months of age. Lodging tended to be related to the size of the crop with larger crops tending to fall earlier than smaller crops. At harvest it was very difficult to enter blocks which had lodged. Data from biomass sampling (leaf, cabbage, millable stalk and attached dead leaf) at harvest was found to be highly variable due to the limited access and inability to sample crops accurately. Sampling at this time was discontinued due to this reason. Sampling crops at approximately nine months of age was found to be useful in capturing the maximum amount of N accumulated by the crop whilst still being practical.

Understanding crop N accumulation in sugarcane biomass and the rate at which it accumulates provided insights into plant N requirements. Typically assessing crop N accumulation in the past has been limited to small plot trials, however in this project the practice was employed in strip trials to better understand how much N was accumulated and how much N was unaccounted. By understanding how much N was accumulated by the crop simple partial N budgets could be developed. These demonstrated that some sites were more efficient users of nitrogen than others. For instance at Site 14 the plant crop yielded 108 tch, the partial N budget indicated that this site was inefficient with a considerable amount (105 kg N/ha) of N that was available for the development of the crop being unaccounted following harvest. In contrast the plant crop of Site 15 yielded 197 tch, the partial N budget demonstrated that the site was highly efficient, the budget indicated that a considerable amount of N required to grow this crop was provided by in season soil N mineralisation.

Sampling millable stalk on the face of the harvest during the harvesting process was used to estimate the amount of N removed from the block and shipped to the mill. Sampling millable stalk at this time provided evidence of luxury crop N uptake at a number of sites. Additional N was accumulated by crops at N rates above the DYP 180 treatment, however it did not generally translate in additional yield. For instance at Site 4 in the plant crop at the DYP 180 N rate, 89 kg N/ha was exported to the mill whilst at the High N rate 117 kg N/ha was exported to the mill. There was no significant difference in yield between the two treatments. In this case the grower shipped an additional 28 kg N/ha to the mill with no yield benefit whilst incurring the cost of additional fertiliser and its application.

At some sites inadequate irrigation may have limited crop yields. The addition of soil moisture monitoring equipment at all sites in 2015 provided an understanding of irrigation management practices employed by growers who participated in the trials. At Site 8 soil moisture data indicated that the irrigation program was not matching crop water requirements during a critical phase of crop development and may have had a significant impact on final yield. Focusing on irrigation management using soil moisture monitoring technology has the potential to improve productivity and profitability of many growers in the Burdekin. Improving productivity by improving irrigation management practices will also result in improved nitrogen use efficiency.

6 Conclusion

After concern was raised from Burdekin growers about the effectiveness of SIX EASY STEPS method for determining appropriate N application rates in their region, a large number of replicated strip trials were established on a range of major soil types to examine their N requirements. For each trial, up to four different nitrogen rate treatments were investigated to measure their relative performance. The purpose of the report was to identify the N rate treatment that maximises performance by examining all variables that influence the performance of each treatment. In addition, the report aimed to demonstrate how N accumulates within sugarcane grown in the Burdekin to develop a better understand of nitrogen use efficiency.

Examining the production results at each trial site over all crop classes identified a few consistent trends. For example, five sites showed that the High and/or Grower N rate treatments had significantly higher cane yield than the DYP 150 treatment, but not the DYP 180 treatment. Also, six sites showed that the DYP 150 and/or DYP 180 treatments had significantly higher CCS than the High treatment, and in some cases the Grower treatment. Nevertheless, no consistent trends were found with sugar yield.

Analyses of data from all sites and crop stages showed that above the SIX EASY STEPS N rate treatment slightly higher cane yields were achieved, however this was offset by a decline in CCS which resulted in no significant difference in sugar yields at the DYP 180 treatment and above. However, the SIX EASY STEPS DYP 150 N rate treatment sugar yield was significantly less than the three higher N rate treatments.

Examining the economic results for each individual trial site over all crop classes showed that a SIX EASY STEPS treatment (either DYP 150 or 180) attained the highest profitability (mean net revenue) at every trial site that had more than one crop harvested (16 sites). Moreover, results from the statistical analysis across all trial sites found that both of the SIX EASY STEPS treatments (DYP 150 and 180) attained significantly higher profitability than both the Grower and High N rate treatments. Importantly though, the relative performance of each N rate treatment changed between crop classes. For instance, the SIX EASY STEPS treatments appeared to performed better in later ratoon crops on average. Consequently, these results find little evidence of a positive relationship between profitability and the amount of N applied above the SIX EASY STEPS guidelines.

The incorporation of biomass sampling of strip trials at nine months provided insights into the accumulation of N in the above and below ground biomass of sugarcane grown in the Burdekin. Using this information, partial N budgets were developed for most sites and have supported the findings of the replicated strip trials.

Monitoring soil moisture levels using capacitance based probes in the later stages of the project demonstrated that there are opportunities for growers in the Burdekin to improve productivity by utilising soil moisture monitoring technology to improve irrigation management practices.

At the outset of this project the majority of growers who participated in the trials believed that the principle driver of productivity on their farms was nitrogen. At the completion of the project the same growers now understand that productivity on their farms was driven by good farm management practices. By identifying constraints such as sodicity, weeds and compaction and focusing on good irrigation management practices along with utilising the SIX EASY STEPS method to determine appropriate N application rates, these growers now consider all aspects of their farm management practices and their impacts on productivity and profitability. This project has clearly demonstrated to growers in the Lower Burdekin that by following the SIX EASY STEPS method for determining appropriate N application rates they can maintain productivity and maximise profitability.

7 References

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8 Appendix 1.

Project Protocol – Strip trials

Updated: 3/12/2013

Partial nitrogen budgets for replicated plot trials

Components of the budget

Nitrogen inputs, outputs and status components of a budget are indicated in Fig. 1.

Direct measurements of components A, B, C and D allow a 'partial' budget to be calculated as:

Partial budget = Inputs – Outputs
= (D-A) + B –C

Unless the input processes (mineralisation) and loss processes (denitrification, runoff, sediments, leaching) are measured directly, their cumulative result is reflected in the (D-A) term of the partial budget.

A net positive partial budget indicates accumulation in the soil if D>A or unmeasured net losses are occurring and are not reflected in the soil pools measured at times A and D. A net negative partial budget indicates a reduction in soil nutrient reserves which should be reflected by D<A. If D is not less than A then the soil pools measured at times A and D are not the ones providing available nutrients to the crop.

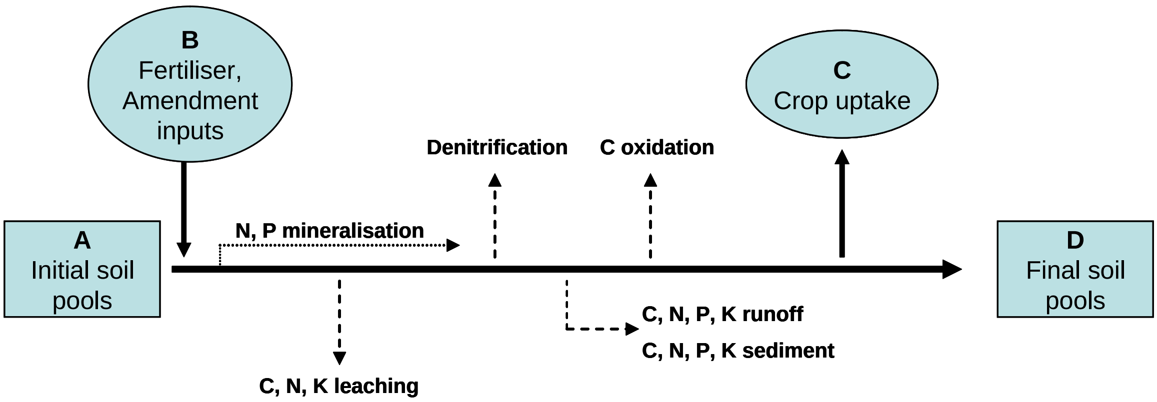


Figure 1. Nutrient input, output and status components of a nitrogen budget. The partial budget is calculated from measurements of A, B, C and D.

Methods for measuring components of a partial N budget

Components A and D
Total N, mineral N (ammonium-N + nitrate-N), potentially mineralisable N @ 7d, 14d of 0-20 cm, 20-40 cm, 40-60cm, 60-80cm, and 80-100cm layers calculated as kg/ha using soil bulk density.

Component B
Inorganic N applied (kg/ha) as fertiliser, and nitrate-N applied in irrigation water.

Component C
Total N calculated as kg/ha using yield and %N content of above ground biomass and its moisture content.

Time of sampling components

Component A
Immediately prior to planting or immediately prior to application of fertiliser/amendment to ratoon. Any trash is removed from the soil surface before sampling.

Component C
Above-ground biomass samples will be taken at 6 months (stalk elongation) from a designated length of row for each rep, and weight of millable stalk and green leaf plus cabbage determined, with subsamples taken for total N and P analysis as detailed in 'Section 2.Protocols for establishing replicated strip trials.'

Immediately prior to harvest, another set of above-ground biomass samples will be taken as described in 'Section 2. Protocols for establishing replicated strip trials,' weighed fresh, and a subsample taken, dried at 60C, re-weighed, ground and sub-sampled for analysis.

Component D
Immediately after harvest, collect separate composite top 0-20 cm, 20-40 cm,
40-60cm, 60-80cm and 80-100cm layers calculated as kg/ha using soil bulk density from row area where biomass samples were taken. Remove any trash from soil surface before sampling.

Protocols for establishing replicated strip trials

A series of replicated demonstration strip trial sites were established in the Burdekin by SRA with a total of 15 sites established. Eight sites are located in the Delta and seven are located in the Burdekin River Irrigation Area (BRIA). The aim of the trial is to compare a range of nitrogen (N) application rates to a nitrogen rate determined using the method regulated under the *Reef Protection Act 2010*.

The following steps were followed to ensure there is adequate consultation with industry and to ensure all relevant data required for this project is obtained:

1. Identify potential trial sites using a consultative process.

2. Assess each site in terms of suitability (size and shape of the block, uniformity of soil type, uniformity of standing crop for ratoon site/s, pest and disease status, uniformity of irrigation system, etc.) Plots will vary from 6 to 16 rows wide. The length of these rows will vary according to block size and shape.

3. Map the potential block using Veris 3100/EM33 to allow stratification of the block into similar units for replication and to identify soil sampling positions.

4. Identify the major soil type(s) in each potential trial block.

5. Collect composite soil samples for each potential trial site:

- Sites to be broken up into 2-3 sample zones according to the protocol shown in Fig 2. Adjustments to zone positions and boundaries will be done to reflect the nature of the block, the occurrence of soil types and Veris/EM maps.
- 8 - 10 subsamples for each depth (see bullet points below) are to be taken in each zone and combined to make one composite sample per zone.
- Where practical take a composite 0-10cm sample in each sampling zone. This sample is to be air dried (see below) and sent to Bundaberg BSES with the profile samples for forwarding on to DERM for pH, EC, exch K, Colwell-P, BSES-P, total org C, total N, W-B org C analysis.
- Take composite 0-20cm, 20-40cm, 40-60cm, 60-80cm & 80-100cm samples in each sampling zone.
- Once collected samples are to be dried by oven at 30°C.

A total of 2.0kg of soil is required for each composite sample.
- 500g for Incitec Pivot lab
- 1.5kg to be sent to Bundaberg SRA

Samples sent to Incitec Pivot are to undergo the following analysis:
- 0-20 cm Custom test 2004-003 plus sand, silt and clay.
- 20-40 cm Custom test 2002-200 plus sand, silt and clay
- 40-60 cm Custom test 2003-153 plus cations, plus sand, silt and clay.
- 60-80 cm Custom test 2003-153 plus cations, plus sand, silt and clay
- 80-100 cm Custom test 2002-200 plus sand, silt and clay

Of the 1.5kg sample sent to Bundaberg 1kg will be placed in storage and the remainder sent to DSITIA for the following analysis:
- Analysis by ERS, DSITIA, Dutton Park includes:
  - Total N, total org C
  - mineral N
  - potentially mineralisable N (PMN) (0-20 cm only)

6. Use the method regulated under the Act and the SRA SIX EASY STEPS to determine inputs from soil test values.

7. Determine the N treatments rates in consultation with the Industry Reference Group (IRG), Technical Management Group (TMG) and each co-operator to establish appropriate rates for each trial site.
   - N treatments will comprise 3-4 rates (depending on block size):
     - A rate determined by the method regulated under the *Environmental Protection Act 1994*.
     - A rate significantly lower than the rate determined by the method regulated under the Act (applied only to the 10 sites established in 2011)
     - A rate growers can associate with i.e. a rate they typically use
     - A high rate which is significantly higher than the industry standard.
8. Rates will be decided after consideration of site/soil specific details and will be equally spaced to allow a yield response curve to be established for the block.

9. Establish each trial using the identified treatments within randomised and replicated layouts.

10. Where possible, capacitance probes, e.g. Enviroscan, or similar equipment will be installed in the block to monitor soil water. As a minimum, rainfall should be regularly recorded using a rainfall gauge at each site.

11. At an irrigation event, where possible a sample will be taken of the irrigation water in a B-bottle supplied on request by DSITIA Dutton Park. Water samples will be frozen and dispatched for nitrate, EC and pH analyses.

12. Strips to be mapped to determine the area within using GPS. For each strip map only the area to be harvested as part of the trial.

15. Collect third-leaf samples during the leaf-sampling season (mid-November – April) from the treatment areas in each strip-trial according to existing SRA protocol. Dried samples will be sent to an accredited laboratory for nutrient analysis. Results will be distributed to co-operators.

16. Collect sugarcane biomass samples (when crop approaches 9 months of age) according to the following procedure:

   - Select 2 lengths of 5 m of crop row that, are not adjacent to each other in each plot. Crop density in the selected areas should be indicative of the plot and not have gaps. Move into the crop so that the sampling is occurring at least 50 meters from the edge.
   - A stalk count from each length of 5m of crop row will be undertaken (use to calculate stalks/m^2).
   - Randomly select 12 stalks from each length of 5m of crop row. Partition the stalks into millable stalk (MS) and green leaf and cabbage (LC) and trash (T). Weigh each component. Use to calculate % millable stalk. Calculate Millable yield (t/ha) = Biomass (t/ha) x % MS/100. Can also be used to determine individual stalk weights, individual millable stalk weight, etc.
   - Select a further sub-sample from the MS and LC and shred each component using a mobile garden mulcher (or similar machine). Collect a subsample of the freshly mulched material and weigh. Dry at 60^{o}C and re-weigh to determine moisture content. Use moisture content to determine total dry biomass. Send about 100g each of MS and LC subsamples to the lab for analysis of total N and P.

20. Immediately prior to burning and harvest, select 12 consecutive (or more depending upon resources) living stalks from the top and bottom of the block from each plot, separate into plant components, weigh, chop, dry at 60C and re-weigh to determine moisture content. Mulch and send about 100g subsamples to the lab for analysis of total N and P.

21. During the harvest, on the face of the crop in 1 or more of the middle rows of each plot select 12 stalks (from two to three locations along the length of the plot), remove and discard the top, weigh the millable stalk, chop, dry at 60C and re-weigh to determine moisture content. Mulch and send about 100g subsamples to the lab for analysis of total N and P.

22. During the harvest, on the face of the crop in 1 or more of the middle rows of each plot conduct stalk counts. Two to three 5 meter lengths of stalks to be counted in each plot (point 21 and 22 are conducted at the same time).

23. Ensure the size of the replicated strips enables yield (tonnes cane/ha) and CCS data to be collected at the mill after harvest.

24. Immediately following harvest, collect separate composite 0-20cm, 20-40 cm, 40-60cm, 60-80cm & 80-100cm samples from row area where biomass samples were taken. Air dry and dispatch to ERS, DERM, Dutton Park, for the following analyses:
    i. Total N, total org C
    ii. mineral N
    iii. potentially mineralisable N (PMN)

25. Consult with Mark Poggio and Mathew Thompson (Department of Agriculture and Fisheries, Ingham and Townsville) to discuss economic issues relating to the trials. Calculate the partial net grower return per hectare using a standardised 'cane payment formula' to determine the partial net return per hectare to the grower:
    b. Grower partial net return = ((price of sugar x (0.009 x (ccs-4)+0.6)) x cane yield) - (cane yield x estimated harvesting costs plus levies) - (fertiliser cost) (kg/ha) – (cane yield x estimated harvesting costs plus levies)

26. Provide summaries of results to the co-operating growers and industry groups.

27. Continue the trials for at least 3 crop cycles.

9 Appendix 2.

Project protocol - Small plot trial

November 2014

Partial nitrogen budgets for replicated plot trials

Components of the budget

Nitrogen inputs, outputs and status components of a budget are indicated in Fig. 1.

Direct measurements of components A, B, C, D and E allow a 'partial' budget to be calculated as:

Partial budget = Inputs – Outputs
= A+B-C-D-E

Unless the input processes (mineralisation) and loss processes (denitrification, runoff, sediments, leaching) are measured directly, their cumulative result is reflected in the (E-A) term of the partial budget.

A net positive partial budget indicates accumulation in the soil if E>A, or unmeasured net losses are occurring and are not reflected in the soil pools measured at times A and E. A net negative partial budget indicates a reduction in soil nutrient reserves which should be reflected by E<A.

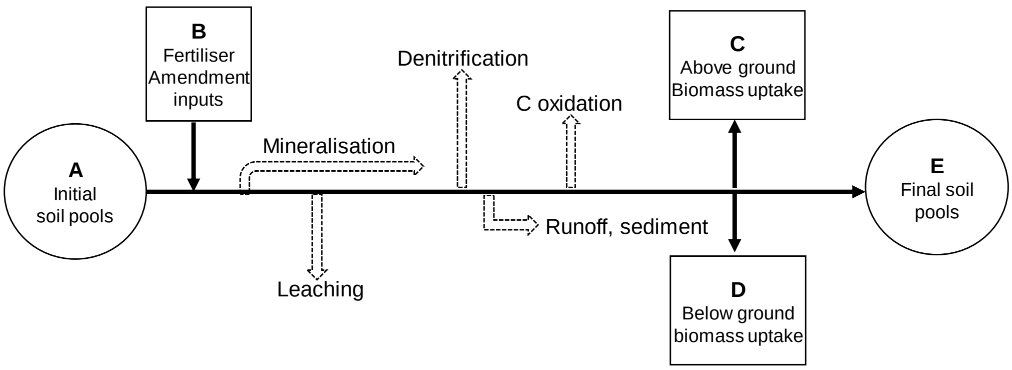


Figure 1. Nutrient input, output and status components of a nitrogen budget.

Methods for measuring components of a partial N budget

Components A and E
Total N, mineral N (ammonium-N + nitrate-N), potentially mineralisable N @ 7d, 14d of 0-20 cm, 20-40 cm, 40-60cm, 60-80cm, and 80-100cm layers calculated as kg/ha using soil bulk density.

Component B
Inorganic N applied (kg/ha) as fertiliser, and nitrate-N applied in irrigation water.

Component C
Total N in above ground biomass calculated as kg/ha using estimated yield and %N content of above ground biomass and its moisture content.

Component D
Total N in below ground biomass calculated as kg/ha using estimated total below ground plant biomass, the %N content and its moisture content.

Time of sampling components

Component A
Immediately prior to planting or immediately prior to application of fertiliser/amendment to ratoon. Any trash is removed from the soil surface before sampling.

Component C
Above-ground biomass samples will be taken at 3, 6, 9 and 12 months from a designated length of row for each rep and weight of tillers or millable stalk, green leaf cabbage and attached trash (if any) determined, with subsamples taken for total N analysis.

Component D
Below ground biomass samples will be taken at 6,and 12 months from a designated length of row for each rep. The total below ground biomass will be determined, with a subsample taken for total N analysis.

Component E
Immediately after harvest, collect separate composite top 0-20 cm, 20-40 cm,
40-60cm, 60-80cm and 80-100cm layers calculated as kg/ha using soil bulk density from row area where biomass samples were taken. Remove any trash from soil surface before sampling.

Protocols for replicated zero N plot trials

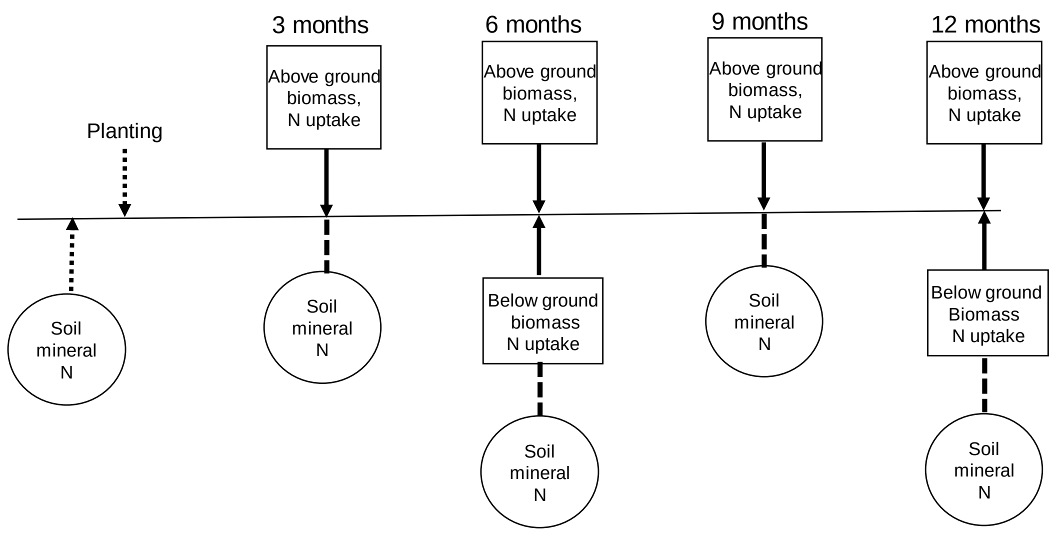


Figure 2. Schematic of sampling procedure for plots which have zero nitrogen fertiliser applied.

Plot size: 0.11 ha

Varieties included in zero N plots: KQ228, Q208 & Q253

1. Prior to planting collect composite soil samples for each rep:

- 6 subsamples for each depth (see bullet points below) are to be taken in each rep and combined to make one composite sample per rep per depth.
- Take composite 0-20cm, 20-40cm, 40-60cm, 60-80cm & 80-100cm samples in each rep.
- Once collected samples are oven dried at 35°C.
- Total no. of samples = 3 var x 5 depths x 4 reps= 60

A total of 1.0kg of soil is required for each composite sample.
- 500g for Incitec Pivot lab
- 500g for storage
- 200g for DSITIA

Samples sent to Incitec Pivot are to undergo the following analysis:
- 0-20 cm Custom test 2004-003 plus sand, silt and clay
- 20-40 cm Custom test 2002-200 plus sand, silt and clay
- 40-60 cm Custom test 2003-153 plus cations, plus sand, silt and clay
- 60-80 cm Custom test 2003-153 plus cations, plus sand, silt and clay
- 80-100 cm Custom test 2002-200 plus sand, silt and clay

200g of sample to be sent to DSITIA for the following analysis:
  - Total N, total org C (5 depths x (zero N/+ N) locations =10 samples)
  - mineral N (3 var x 5 depths x 4 reps = 60 samples)
  - potentially mineralisable N (PMN) (0-20 cm only) (Zero N trial only: 3 var x 4 reps = 12 samples)
  - denitrification potential and capacity (DPC) (0-20 cm only) (Zero N trial only: 3 var x 4 reps = 12 samples)
  - $^{15}N/^{14}N$ (0-20 cm only) (Zero N trial only: 3 var x 4 reps = 12 samples)

2. Use the method regulated under the Act and the BSES SIX EASY STEPS to determine inputs from soil test values.

3. Where possible, capacitance probes, e.g. Enviroscan, or similar equipment will be installed in the block to monitor soil water.

4. At irrigation events, a sample will be taken of the irrigation water in a B-bottle supplied by DSITIA. Water samples will be frozen and dispatched to DSITIA waters lab for nitrate analyses.

5. Collect sugarcane above ground biomass samples at 3, 6, 9 and 12 months according to the following procedure:
   - From the sampling rows (not guard rows) select a 3m length of row from each rep. Crop density in the selected areas should be indicative of the plot and not have gaps.
   - A tiller/stalk count from a 3m length in each rep to be undertaken (use to calculate population (tillers/m^2 or stalks/m^2).
   - In the 3m length cut all plants at ground level and weigh fresh biomass (use this to calculate biomass t/ha). This will give total FW.
   - Collect any surface trash from the 3m length and weigh for total fresh weigh and then subsample. Obtain subsample fresh weight and place sample in oven and after 7 days re weigh for dry weight.
   - Back at processing point undertake partitioning (for 6, 9 and 12 month samples) of material into:
     - Green leaf
     - Cabbage (leaf sheath and immature stalk)
     - Attached dead leaf
     - Millable stalk

- It may be necessary to subsample the material harvested in the field depending upon the amount harvested. If subsampling is necessary then this subsample becomes the Subsample FW.
- Once partitioning of the sample (or subsample) is complete, mulch (or cut up using secateurs) the green leaf, the cabbage and the attached trash samples and place into bags. Weigh to determine the FW of samples in bag.
- Place bags in oven at 60°C to get a dry weight, drying may take up to 7 days.
- Grind samples and send to DSITIA lab for analysis of total N, $^{15}N/^{14}N$.

6. Immediately following biomass sampling at 3,6,9 and 12 months collect composite (2 cores) 0-20cm, 20-40 cm, 40-60cm, 60-80cm & 80-100cm samples from row area where biomass samples were taken. Oven dry at 35°C and dispatch to DSITIA for the following analysis:
    - Total N, total org C (5 depths =5 samples)
    - mineral N (3 var x 5 depths x 4 reps = 60 samples)
    - potentially mineralisable N (PMN) (0-20 cm only) (Zero N trial only: 3 var x 4 reps = 12 samples)
    - denitrification potential and capacity (DPC) (0-20 cm only) (Zero N trial only: 3 var x 4 reps = 12 samples)
    - $^{15}N/^{14}N$ (0-20 cm only) (Zero N trial only: 3 var x 4 reps = 12 samples)

7. Collect sugarcane below ground biomass samples at 6 and 12 months according to the following procedure:

- From within the 3m length of sampled row (for above ground biomass) measure 1m length of row. Use shovel to extract the below ground biomass in the 1 meter length of crop row.
- Bag the below ground biomass sample and wash all soil from the roots and stool. Allow water to drain before weighing sample for fresh weight (FW).
- Subsample the roots and stool, weigh the subsample for fresh weight and then place in oven at 60^0C for 7 days and then reweigh for dry weight.
- Grind samples and send to DSITIA lab for analysis of total N, $^{15}N/^{14}N$ (3 var x 4 reps = 12 samples).

8. Regularly assess the trials for visual differences in plant growth and pest or disease symptoms.

9. Record rainfall, irrigation details (date, time on-time off, volume), fertiliser management (rate, form, placement, date), field operations.

10 Appendix 3.

Leaf samples (third leaf) were taken according to SRA leaf sampling guidelines over the duration of the project. Samples were taken from all sites and each treatment and analysed for total N using the Kjeldahl method.

Plant crop leaf analysis results

Site ID	Treatment kg N/ha	Rep	Plant Crop %N
Site 1	130	1	1.5
	130	3	1.6
	170	2	1.8
	170	3	1.6
	210	1	1.8
	210	3	1.7
	250	1	1.7
	250	2	1.8
Site 2	130	3	2.5
	130	3	2.3
	170	1	2.5
	170	3	2.4
	170	1	2.4
	170	3	2.4
	210	1	2.6
	210	1	2.3
Site 3	130	1	2.4
	130	3	2.5
	170	1	2.4
	170	3	2.5
	210	2	2.6
	210	3	2.6
	250	1	2.4
	250	3	2.7
Site 4	120	1	2.0
	120	3	1.9
	160	1	2.1
	160	2	2.1
	220	1	2.2
	220	3	2.2
	280	2	2.2
	280	3	2.2

Site ID	Treatment kg N/ha	Rep	Plant Crop %N
Site 5	170	1	2.3
	170	2	2.4
	170	3	2.1
	210	1	2.3
	210	2	2.4
	210	3	2.4
	250	1	2.3
	250	2	2.4
	250	3	2.4
Site 6	130	1	1.6
	130	3	1.6
	170	1	1.7
	170	2	1.7
	210	1	1.6
	210	3	1.7
	250	1	1.7
	250	3	1.8
Site 7	130	1	2.5
	130	3	2.5
	170	1	2.5
	170	2	2.5
	170	3	2.6
	210	3	2.6
	250	1	2.5
	250	3	2.6

Site ID	Treatment kg N/ha	Rep	Plant Crop %N
Site 8	130	1	2.6
	130	2	2.2
	170	1	2.2
	170	3	2.2
	210	1	2.3
	210	3	2.4
	250	1	2.0
	250	2	2.2
Site 9	130	1	2.2
	130	3	2.0
	170	2	2.2
	170	3	2.2
	210	1	2.4
	210	2	2.2
	250	1	2.4
	250	3	2.3
Site 10	130	1	2.0
	130	3	2.0
	170	2	2.1
	170	3	2.0
	210	1	2.0
	210	3	2.1
	250	1	2.1
	250	2	2.2
Site 11	130	1	1.6
	130	2	1.7
	130	3	1.8
	170	1	1.7
	170	2	1.8
	170	3	2.0
	210	1	1.8
	210	2	1.9
	210	3	2.1
Site 12	170	1	2.2
	170	2	2.2
	170	3	2.3
	210	1	2.3
	210	2	2.3
	210	3	2.3
	250	1	2.3
	250	2	2.3
	250	3	2.3

Site ID	Treatment kg N/ha	Rep	Plant Crop %N
Site 14	170	1	2.1
	170	2	2.1
	170	3	2.2
	210	1	2.2
	210	2	2.2
	210	3	2.1
	250	1	2.2
	250	2	2.2
	250	3	2.2
Site 15	150	1	2.1
	150	2	2
	150	3	2.2
	150	4	2.2
	190	1	2.1
	190	2	2.1
	190	3	2.2
	190	4	2.3
	230	1	2.2
	230	2	2.1
	230	3	2.3
	230	4	2.4
Site 16	160	1	2.1
	160	3	2.1
	160	4	2
	200	1	2.3
	200	3	2
	200	4	2
	240	1	2.2
	240	3	2.1
	240	4	2.1
Site 17	150	1	1.8
	150	3	1.8
	150	4	1.8
	190	1	2
	190	3	1.9
	190	4	2
	240	1	1.9
	240	3	1.9
	240	4	1.9

Site ID	Treatment kg N/ha	Rep	Plant Crop %N
Site 18	160	1	1.9
	160	3	1.9
	160	4	2
	200	1	1.9
	200	3	2.1
	200	4	2.1
	240	1	1.9
	240	3	2.2
Site 19	50	1	2
	50	3	1.9
	50	4	1.8
	100	1	2
	100	3	1.9
	100	4	1.9
	150	1	2.1
	150	3	2.1
	150	4	1.9
Site 20	160	1	2.1
	160	2	2.1
	160	3	2.2
	200	1	2.2
	200	2	2.2
	200	3	2.2
	240	1	2.3
	240	2	2.3
	240	3	2.4

Site ID	Treatment kg N/ha	Rep	Plant Crop %N
Site 21	160	1	2.3
	160	2	2.2
	160	3	2
	200	1	2.3
	200	2	2.3
	200	3	2.4
	240	1	2.3
	240	2	2.2
	240	3	2.3
Site 22	170	1	1.9
	170	2	1.9
	170	3	1.9
	170	4	2
	240	1	2
	240	2	2.1
	240	3	2
	240	4	2.1
	290	1	2.1
	290	2	2.2
	290	3	2.4
	290	4	2.5
Site 23	150	2	2.3
	150	3	2.6
	150	4	2.5
	190	2	2.8
	190	3	2.7
	190	4	2.8
	230	2	2.7
	230	3	2.6
	230	4	3.1

Ratoon crop leaf analysis results

Site ID	Treatment kg N/ha	Rep	%N 1st Ratoon	2nd Ratoon	3rd Ratoon	4th Ratoon
Site 2	170	1	1.9	1.8	2.1	
	170	3	1.9	1.7	2.1	
	210	1	2	1.8	2	
	210	3	2.1	1.9	2.1	
	250	1	2	1.9	2.1	
	250	2	2	1.9	2.2	
Site 3	170	1	2.3	2.2	2.4	2.4
	170	3	2.1	2.4	2.5	2.5
	210	1	2.3	2.6	2.5	2.4
	210	3	2.3	2.6	2.5	2.5
	250	2	2.4	2.6	2.5	2.6
	250	3	2.2	2.6	2.6	2.6
	290	1	2.4	2.6	2.6	2.7
	290	3	2.4	2.6	2.6	2.6
Site 4	160	1	2			
	160	3	1.9			
	200	1	2			
	200	2	2			
	260	1	2.2			
	260	3	2			
	300	2	2			
	300	3	2.1			
Site 5	210	1	1.8	2.2		
	210	2	2	2.2		
	210	3	2.1	2.1		
	250	1	2	2.2		
	250	2	2.1	2.2		
	250	3	2.1	2.3		
	290	1	1.9	2.3		
	290	2	2.3	2.2		
	290	3	2.4	2.2		
Site 6	170	1	1.8	1.7	1.9	
	170	3	1.7	1.7	1.9	
	210	1	1.9	1.7	2.1	
	210	2	1.7	1.7	1.9	
	250	1	2	1.8	1.9	
	250	3	1.8	1.9	1.9	
	290	1	1.9	1.9	2	
	290	3	1.8	1.7	2.1	

Site ID	Treatment kg N/ha	Rep	%N		
			1st Ratoon	2nd Ratoon	3rd Ratoon
Site 7	170	1	2.3	2.3	2.4
	170	3	2.2	2.3	2.3
	210	1	2.5	2.5	2.3
	210	2	-	2.4	2.3
	250	1	-	2.5	2.5
	250	3	2.4	2.4	2.4
	290	1	2.4	2.5	2.2
	290	3	2.3	2.5	2.5
Site 8	170	1	2	2	2.3
	170	2	1.7	1.7	2.2
	210	1	2	2	2.4
	210	3	2	1.8	2.5
	250	1	2.1	2.2	2.5
	250	3	2.1	2	2.7
	290	1	2.2	2.2	2.8
	290	2	2.1	1.8	2.5
Site 9	170	1	2.2		
	170	3	1.9		
	210	2	2.2		
	210	3	2.1		
	250	1	2.2		
	250	2	2.3		
	290	1	2.2		
	290	3	2.3		
Site 10	170	1	1.8	2	2
	170	3	1.8	1.8	2
	210	2	1.8	1.9	2.1
	210	3	1.9	1.8	2.1
	250	1	1.9	2.2	2.3
	250	3	1.9	1.9	2.1
	290	1	2	2.3	2.3
	290	2	2	2	2.2
Site 11	170	1	1.6	1.6	
	170	2	1.7	1.7	
	170	3	1.9	1.8	
	210	1	1.6	1.7	
	210	2	1.7	1.9	
	210	3	2	1.8	
	250	1	1.7	1.7	
	250	2	1.6	1.8	
	250	3	2.1	2	

Site ID	Treatment kg N/ha	Rep	%N 1st Ratoon	2nd Ratoon	3rd Ratoon
Site 12	210	1	2.1	2.5	2
	210	2	2.2	2.3	2
	210	3	2.3	2.2	1.9
	250	1	2.2	2.5	2
	250	2	2.3	2.5	1.9
	250	3	2.2	2.3	1.8
	290	1	2.3	2.5	2.1
	290	2	2.4	2.6	2.1
	290	3	2.5	2.5	2
Site 14	210	1	1.8	2	1.8
	210	2	1.8	2	1.8
	210	3	1.8	2.1	1.8
	250	1	1.9	2	1.8
	250	2	1.8	2	1.8
	250	3	1.9	2.1	1.8
	290	1	1.8	2	-
	290	2	1.9	2.3	-
	290	3	1.8	2.1	-
Site 15	150	1	1.9	2.3	
	150	2	1.9	2.1	
	150	4	2.1	2.4	
	190	1	2.1	2.5	
	190	2	2.1	2.3	
	190	4	2.2	2.5	
	230	1	2.1	2.7	
	230	2	2.1	2.6	
	230	4	2.3	2.6	
Site 16	160	1	2.3		
	160	3	2.2		
	160	4	2.2		
	200	1	2.5		
	200	3	2.4		
	200	4	2.5		
	240	1	2.7		
	240	3	2.5		
	240	4	2.5		

Site ID	Treatment kg N/ha	Rep	%N 1st Ratoon
Site 17	160	1	1.6
	160	3	1.9
	160	4	1.8
	200	1	2
	200	3	1.9
	200	4	2
	240	1	1.9
	240	3	1.9
	240	4	1.9
Site 18	160	1	2
	160	3	2
	160	4	1.9
	200	1	2
	200	3	2
	200	4	1.9
	240	1	2
	240	3	2
	240	4	2
Site 19	170	1	2
	170	3	1.9
	170	4	1.9
	210	1	2.1
	210	3	2
	210	4	2
	250	1	2.1
	250	3	2.2
	250	4	2.2

11 Appendix 4.

SRA Industry Update May 26 2015 – Handout

Nitrogen fertiliser requirement for a Sodic Duplex soil in the Burdekin

Sugar Research Australia

Introduction

The SIX EASY STEPS (6ES) guidelines aim to achieve both productive and profitable outcomes, while reducing nutrient losses from farms. The effectiveness of 6ES for Burdekin sugarcane production systems has been tested in an extensive number of replicated strip trials on a range of soil types to examine their nitrogen (N) requirements.

This project compares the efficacy of several N application rates to determine the optimum rate to maintain productivity and profitability. This particular case study examines a Sodic Duplex soil on a commercial farm within the Burdekin River Irrigation Area (BRIA).

Trial site description

Sugar Research Australia (SRA) established the trial in May 2011. Site selection was based on traits such as block size and shape, soil uniformity, pest control measures and yield history as well as the characteristics presented in Table 1.

Table 1: Characteristics of trial site.

Element	Description
Soil type	Sodic Duplex (Clay), QDPI: 2Dyb
Location	Clare, BRIA
Water supply	Channel
Variety	Q183
Row spacing	1.52 m

The site was mapped using electrical conductivity resistivity measurements, which were used to develop a soil sampling strategy. Organic carbon levels across the trial site were on average 0.77%. Irrigation water was tested for nitrates. Levels were less than 2 mg N/L.

Methodology

Pre-plant soil analyses were used to calculate the 6ES N rate. An N rate lower than the 6ES (Low), an N rate equivalent to the farmer's normal practice (Grower) and a high N rate (G+) were also included at this trial site. Table 2 displays the N rates for each treatment.

Table 2: Applied nitrogen rates for each treatment.

	Nitrogen rates (kg N/ha)			
	Low	6ES	Grower	G+
Plant	130	170	210	250
Ratoons	170	210	250	290

Harvest data were collected during each crop stage to ascertain cane and sugar yield for each N rate treatment. An examination of these results identified whether any differences in production could be attributed to nitrogen application rates.

Trial data were collected up to the second ratoon, which was harvested in 2014. Table 3 presents the harvest dates and growing periods for each crop stage. The crop was planted on the 16th May, 2011.

Table 3: Harvest dates and crop age.

	Harvest date	Growing period approximately
Plant crop	20th Jun 2012	13 months
1st ratoon	26th Jun 2013	12 months
2nd ratoon	3rd Nov 2014	16 months

Results

While a general positive relationship appears to exist between N rate and average cane yield (Table 4), yield differences between the 6ES rate and the grower or above-grower rates were not statistically significant at the 5% level. Conversely, yield in the low N rate was significantly lower than all higher rates in the ratoons, except the 6ES rate in the second ratoon.

Table 4: Average cane yield (tc/ha) for each treatment.

	Low	6ES	Grower	G+
Plant	105.9[a]	111.4[a]	113.2[a]	113.2[a]
1st ratoon	112.5[b]	122.1[a]	125.5[a]	123.9[a]
2nd ratoon	107.7[b]	111.4[ab]	115.7[a]	117.2[a]

Averages followed by a common letter are not significantly different at the 5% level.

In contrast to average cane yield, a negative relationship appears to exist between N rate and average Commercial Cane Sugar (CCS) (Table 5)[1]. Statistical analyses show that the low and 6ES rates have significantly higher CCS than the grower and above-grower rates in the ratoons.

Table 5: Average CCS for each treatment.

	Low	6ES	Grower	G+
Plant	13.7	13.3	12.8	12.9
1st ratoon	15.0[a]	14.8[a]	14.2[b]	14.3[b]
2nd ratoon	17.4[a]	17.3[a]	16.5[b]	16.6[b]

Averages followed by a common letter are not significantly different at the 5% level.

Compared to average cane yield and average CCS, the relationship between N rate and sugar yield is much less evident (Table 6). While the low rate appears to result in lower average sugar yields than the other treatments, the statistical tests found no significant difference between any of the treatments.

Table 6: Average sugar yield for each treatment (ts/ha).

	Low	6ES	Grower	G+
Plant	14.4[a]	14.8[a]	14.5[a]	14.8[a]
1st ratoon	16.8[a]	18.1[a]	17.8[a]	17.8[a]
2nd ratoon	18.8[a]	19.2[a]	19.1[a]	19.4[a]

Averages followed by a common letter are not significantly different at the 5% level.

Financial-economic analysis

To quantify the economic return to the grower, the 'net revenue' is calculated for each replicate, which is gross revenue[2] net of fertiliser costs, harvesting costs and levies. These costs are influenced by each treatment's particular combination of cane yield and CCS.

A benefit of growing cane with comparatively higher CCS is that harvesting costs and levies do not increase proportionately, which is in contrast to growing cane with comparatively higher yields. This interaction affects the relative cost and profitability of each treatment to the grower. Environmental costs and benefits, such as the reduction in nutrient runoff, have not been economically quantified in this case study.

The four graphs in Figure 1 compare the net revenue results for each crop class[3] as well as an average over the crop cycle thus far. The economic analysis has concentrated on the average net revenue for each treatment, however the minimum and maximum values are provided to illustrate the range.

They show that the low rate realised the highest net revenue in the plant crop by $22 per hectare. However, the 6ES rate produced higher net revenue in the first and second ratoon (by $223 and $37 per hectare), which boosted its relative performance on average over the crop cycle thus far.

Consequently, over the crop cycle to date, the 6ES rate has achieved the highest average net revenue followed by the low rate (-$89 per hectare), and then the grower rate (-$217 per hectare).

[1] Unfortunately, the CCS was not obtained for the second replicate of the high rate treatment in the plant crop. Accordingly, a statistical analysis was not completed. However, for demonstration purposes it has been substituted with the average CCS of replicates one and three in Table 7.

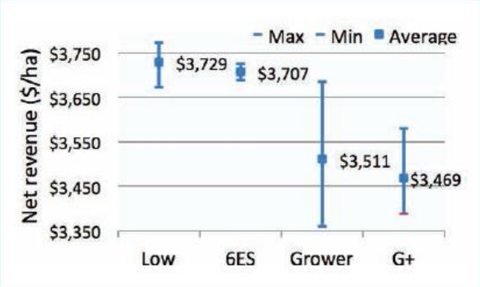
[2] Gross revenue is calculated from cane yield and relative CCS using the cane payment formula.

[3] The CCS value that was not obtained during the plant crop is highlighted red in Figure 1.

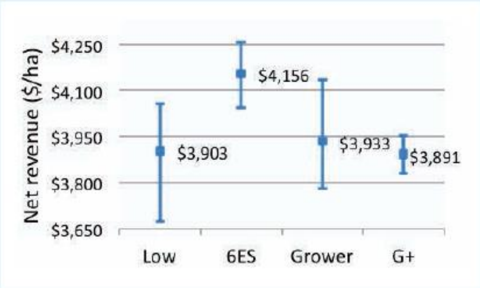
Financial-economic analysis *(continued)*

Figure 1: Net revenue of each treatment.

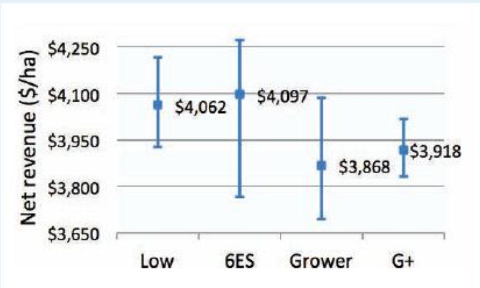
Plant crop



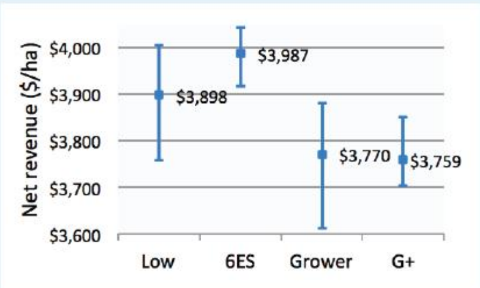
1st ratoon



2nd ratoon



Average over crop cycle thus far



Conclusion

This report examined the productivity and profitability of several N rates on a Sodic Duplex soil. While the higher than 6ES nitrogen rates appeared to achieve higher average yields than the 6ES treatment, average sugar yield was not higher during most crop stages.

Instead, the nitrogen application rate determined by the 6ES guidelines was adequate to maintain production and to optimise profitability.

Furthermore, there was no evidence of a positive relationship between profitability and the amount of N applied above the 6ES guidelines. However, the evaluation is preliminary and requires the integration of additional ratoon data.

Acknowledgements

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Queensland Government

12 Appendix 5.

CaneConnection Spring 2015 – Article

10

RESEARCH

Nitrogen – one piece of the puzzle

The Burdekin is well-known for its cane fields, mango trees and idyllic fishing spots. It is also home to RP20, a collaborative research project funded by the Department of Environment and Heritage Protection.
By Andrea Evers

Project details

Key Focus Area: 2
Soil health and nutrient management

Project name
Nitrogen fertiliser requirements for representative soils of the Lower Burdekin cane growing district

Project number
RP20/14C

Funding body
Department of Environment and Heritage Protection

Project leader
Julian Connellan

Project end date
June 2017

Julian Connellan, SRA researcher and project leader, has been active across the 23 trial sites in the Burdekin, which have been part of the project over the last 4 years.

The collaborators allow Julian to set up strip trials on their farms, while maintaining their usual farm management practices.

A low, medium and high nitrogen rate is applied to the strip trials on each of the collaborators' farms. These rates are calculated according to the SIX EASY STEPS™ guidelines and may therefore vary from one farm to another.

Trials are currently being harvested with Julian and/or Johan Deutschenbaur (SRA technician) attending each harvest to make sure the work is conducted in a way that ensures data integrity.

This often means being in the paddock on weekends to oversee the harvest, for which they have gained respect from the farmers involved in the trials.

Apart from capturing yield and CCS data at harvest, another important area of investigation is to gain a better understanding of how much nitrogen is being captured and used by sugarcane crops. To do this, small sections of selected blocks are harvested at key times during the season to determine how much nitrogen has been taken up by the crop and by their root systems. Soil sampling is also used throughout the various stages of crop development to monitor soil nitrogen levels along with regular testing of irrigation water for nitrates to determine how much nitrogen, if any, is being added with each irrigation event.

By gaining a better understanding of the amount of nitrogen going into the farming system and determining the amount of nitrogen utilised by the crop, growers can develop a simple budget. This information, along with the results obtained from the strip trials, can be used to provide a more informed understanding of crop nitrogen requirements in the Burdekin.

CaneConnection / Spring 2015



A fertiliser box has been specifically developed for this project. It includes load cells that allow Julian to monitor the amount of fertiliser which has been applied to each strip. This piece of machinery is a stool splitter and side dresser. It is not common place to use a commercial size piece of equipment to undertake research. This is yet another factor that makes this project unique.

General farm management practices such as crop establishment, weed control and irrigation management are also monitored at all trial sites to gain an understanding of their potential impacts on final yields.

While there is still another season of trials and data to collect before the project is finalised in 2017, indications so far are that the SIX EASY STEPS™ recommendations provide enough nitrogen fertiliser to allow crops in the Burdekin to reach maximum yield. The preliminary results appear to indicate that the highest net revenue outcomes were achieved with the nitrogen application rate determined by using the SIX EASY STEPS™ method.


To gain a better understanding of irrigation management practices employed by farmers, soil moisture monitoring devices have been placed in all existing trial sites. These devices monitor soil moisture at various depths throughout the soil profile. The probes take regular readings, which are then downloaded and analysed. This information is invaluable in gaining a better understanding of the irrigation management practices employed by farmers involved in the trials and the impact this may have on final yields at each farm.

The RP20 project is being described as a success story for a number of reasons, perhaps most importantly because of the collaborative approach used to develop and implement the project. Scott Robinson, Director of Reef Water Quality within the Department of Environment and Heritage Protection, attributes the success of this project to a number of factors.

'For me, the success of this program can be attributed to two factors. Firstly, growers that were involved in the trial got to experience first-hand the potential benefits of modifying age-old practices—from both productivity and profitability perspectives. Secondly, successful collaboration between growers, industry and government who have collectively improved their understanding of nitrogen use efficiency and their willingness to maintain open minds. As we moved through the project and negotiated the challenges that arose, the growers' willingness to move forward has been reassuring and encouraging.'

David Defranciscis, a third generation Burdekin grower, whose passion for his industry drove him to find a definitive answer to the question 'how much fertiliser do we actually need to grow a profitable crop of cane', has taken on a pivotal role in the project as Industry Liaison Representative. 'It's David's passion and commitment to the project that has made the difference', explains Dominic Henderson, principal Project Officer of EHP. Evan Shannon was also instrumental in setting up the trials. Evan worked with David to help secure funding and provided assistance in the early stages of the project to identify suitable trial sites using his extensive knowledge of the Burdekin.

David is convinced that the collaborative approach between EHP, SRA and the participating growers means that the final results of this trial will lead to positive, on-farm changes that will allow his industry to remain productive and enjoy a profitable future.

'SRA was the perfect fit as far as the science goes. I trusted that SRA would act impartially and knew their scientific methods would stand up anywhere in the world. Nitrogen is an important issue for farmers. We need to care for our environment but at the same time be given the opportunity to run profitable businesses.'

David also believes that the farmers who are participating in the trials (collaborators) are benefiting and experiencing a shift in thinking around nitrogen application, as he did. 'I wouldn't have believed the results unless I saw them on my own land. The trials are being conducted over a full crop cycle on all the major soil types in the Burdekin. To date we have established and harvested 23 trial sites, however I still think everyone needs to test the SIX EASY STEPS™ recommendations on their own farm.'

The trials have highlighted to David the importance of farming practices.

'Historically we've always thought that nitrogen is the answer. However, the trials have shown that good farming practices are essential for maximising crop potential. Regardless of how much nitrogen you apply, if your crop establishment, pest control or irrigation management are lacking you cannot achieve maximum productivity. Good practices along with adequate fertiliser will give farmers the best opportunity to maximise their yields.'

David's sentiments are echoed by a number of other collaborators.

Ryan Matthews, SISL – Selkirk

Ryan Matthews, farm manager at SISL, has been involved in the project for the past 18 months and says the trials are set up in a way that have minimal impact or disruption. The initial angst that he felt about being involved quickly dissipated. 'The trials are a breeze', he said. 'They are harvester and farmer friendly.'

The first harvest of the trial site occurred earlier this year, the results of which were made available to Ryan, as they are to all collaborators involved in the project. Ryan says that these results gave him the confidence to know that he was on the right track and to reduce his nitrogen application on other blocks. 'The information Julian provided has allowed me to build a knowledge base that I will continue to work with each block across the farm.'

Something else that is clear to Ryan is that nitrogen is only one part of the picture. He believes all practices need to be carried out effectively. There is no need to compensate with a high nitrogen rate when other practices on farm, such as irrigation, weed management and crop establishment, are carried out effectively.

Malcolm and Aaron Kelly – BRIA

This is the second year that Malcolm and Aaron Kelly are collaborators in the project. They initially became involved because they wanted to gain a better understanding of nitrogen rates and other factors that may influence yield. They had also just planted a new variety and wanted to see how it would perform using the SIX EASY STEPS™ rate.

The results from their trials so far have seen a slight shift in their views around nitrogen application. 'We now understand that more is not always best and nitrogen wasn't necessarily driving yield, but is one piece of the puzzle', says Aaron.

Both Malcolm and Aaron believe that the results that they get from their second trial block next year will give them information that they think will be suitable for 50-75 percent of their farm.

Being involved in the trial has meant an investment of some extra time but Malcolm and Aaron have been happy to be involved given the outcomes. Aaron explains, 'the bit of extra time that we've invested in the trials has been worthwhile for us. After all, saving on fertiliser means saving money.'

Eric Barbagallo – Home Hill

Eric is one of the original collaborators in the project, beginning in 2011.

Eric says that his involvement in the project has been really good for him.

'We got into bad habits with the belief that if you put enough water and fertiliser on the crop, it'll grow. Before the trials, I was applying around 290 kg per hectare of nitrogen because I used to think the more nitrogen I applied, the bigger the crop would grow.'

Eric is yet another collaborator who, through participation in the project, has experienced a shift in thinking.

He now also believes that nitrogen is only one piece of the whole farm management system.

'I'm now convinced that with a well-managed crop, the SIX EASY STEPS™ rate is ample to grow a profitable crop. There is no doubt in my mind.'

Eric has been impressed with how meticulously the trials have been monitored, which is why he believes that there's no arguing with the results.

13 Appendix 6.

NITROGEN ACCUMULATION IN BIOMASS AND ITS PARTITIONING IN SUGARCANE GROWN IN THE BURDEKIN

By

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KEYWORDS: Nitrogen Accumulation, Biomass, Nitrogen Utilisation Efficiency.

Abstract

THE COMMERCIAL SUGARCANE varieties Q253[ⓓ], Q208ⓓ and KQ228ⓓ, which are grown in the Lower Burdekin, were sampled several times throughout the growing season to study the seasonal changes in nitrogen (N) content in the above- and below-ground biomass. In sugarcane approximately 130 days after planting (DAP), above-ground biomass contained up to 36% of the final above-ground biomass N content. By 200 DAP up to 84% of the total N content of the above-ground biomass had accumulated. From 200 to 270 DAP the rate of N accumulation slowed, and by 365 DAP the above-ground N content had plateaued in Q208ⓓ and KQ228ⓓ and decreased slightly in Q253ⓓ. Of the three varieties, Q253ⓓ appeared to accumulate N more rapidly than the other two varieties during the peak period of N accumulation. Nitrogen utilisation efficiency (kg of dry matter/kg crop N) of each of the three varieties was compared. KQ228ⓓ appeared to be more efficient than Q253ⓓ and Q208ⓓ. Below-ground biomass, which included roots and stool, of the variety Q208ⓓ was sampled at 200 and 365 DAP. At 200 DAP below-ground biomass N was 11% of the above-ground biomass N and by 365 DAP it was 15% of above-ground biomass N. The data presented in this paper provide an insight into the key periods of N uptake and its partitioning during sugarcane development under irrigation in the Lower Burdekin.

Introduction

Nitrogen is a key component of metabolic processes in plants and due to its mobile nature in soils is often a limiting factor in achieving maximum yield in commercial sugarcane crops grown in Australia. Demand for N depends upon a crop's yield potential which is determined by climate, crop age and class and management practices (Muchow and Robertson, 1994).

Determining the correct amount of nitrogen required to achieve maximum cane yield while minimising losses to the environment is a difficult task; however developing a basic understanding of nitrogen accumulation in biomass and the rate at which it accumulates will provide useful insights for agronomists, industry advisors and farmers.

There have been few studies into the accumulation of nitrogen in the above-ground biomass of sugarcane in Australia. Wood *et al.* (1996) investigated the accumulation of N in the above ground biomass of two cultivars (Q117, Q138) and confirmed earlier findings from work in South Africa conducted by Thompson (1988), that most of the N was taken up in the first six months following planting/ratooning. In a recent review, Bell *et al.* (2014) reported that greater than 90% of the total above-ground N uptake occurs in the 200 day period after planting/ratooning.

Few studies have been conducted into the accumulation of nitrogen in below ground biomass (roots and stool) of sugarcane in Australia. Bell *et al*. (2014), summarised the limited data collected to date and suggested that N in stool and root accumulates at about 20 kg N/ha/year while a further 10 kg N/ha/year accumulates in root material down to 60 cm.

The objective of this study was to gain an insight into nitrogen accumulation in the above and below ground biomass of sugarcane and its partitioning in crops grown under irrigation in the Lower Burdekin region of Australia.

Materials and methods

Location and cultural details

The study was conducted on a Sugar Research Australia farm located in the Lower Burdekin region of Queensland (19°30'S, 147°17'E). Three cultivars, Q208⁽ᴾ⁾, Q253⁽ᴾ⁾ and KQ228⁽ᴾ⁾, were grown as plant crops over the 2014–2015 season. The area used for the investigation has a history of being cropped with sugarcane. A bare fallow period of six months occurred prior to planting which took place in August 2014. A split plot design was established with six rows by 10 m in each replicate. Four subsamples (time) were taken randomly from the four middle rows: subplot size was therefore 10 m by 1.52 m.

Altogether there were 48 plots in this trial. On 28 October 2014, sulfate of potash was used to apply 88 and 39 kg/ha of K and S respectively to all blocks as a side dressing banded into the soil. Irrigation water was applied to all blocks via furrows with water supplied from bores. No nitrogen fertiliser was applied to the three main plots (variety) so that the effects of suboptimal N rates on three commercially grown sugarcane varieties could be investigated over a growing season.

Soil sampling and analysis

Prior to planting, a total of 12 soil samples were taken from the three main plots (variety) to a depth of 100 cm. Six cores were taken in each replicate with samples composited for each depth (0–20 cm, 20–40 cm, 40–60 cm, 60–80 cm and 80–100 cm) and analysed for nitrate nitrogen and ammonium nitrogen.

The quantity of mineral nitrogen (sum of nitrate and ammonium) in the top 60 cm of the soil profile (kg N/ha) was calculated for each replicate assuming a bulk density of 1.21 g/cm^3. At 200, 270 and 365 days after planting (DAP) two soil cores were taken from subplots to a depth of 100 cm within the area where above and below-ground biomass samples were taken. Composite samples for 0–20 cm, 20–40 cm, 40–60 cm, 60–80 cm, 80–100 cm were then analysed for nitrate nitrogen and ammonium nitrogen. This information was used to calculate the mineral nitrogen (kg/ha) in the top 60 cm of the soil profile at each biomass sampling.

Above ground biomass

At the end of the tillering stage (approximately 130 DAP) a 3 m length of a randomly selected 10 m row from each main-plot and replicate was harvested and tillers were counted and weighed (sample time 1). A sub-sample was dried at 60°C to determine dry matter accumulation (t/ha). Subsamples were then ground and analysed using Kjeldahl digestion to determine total nitrogen concentration. Nitrogen accumulation (kg/ha) was determined by multiplying the N concentration of the tillers by the estimated biomass dry weight per hectare.

At 200, 270 and 365 DAP, the sampling was repeated (sample times 2, 3 and 4) as described above. Twelve stalks were then randomly selected from each replicate and partitioned into stalk, green leaf, cabbage (which is the immature top of the stalk plus the green leaf sheaths) and attached dead leaf. At 365 DAP surface trash from the sampling area was also collected. Fresh weight of each component was determined and a subsample was then dried and analysed for total nitrogen as described above. The nitrogen accumulation on an area basis in stalk, leaf, cabbage, attached dead leaf and surface trash was determined by multiplying the N concentration of each component by the biomass of the respective component. Net above-ground N accumulation was calculated as the sum of the N accumulation in the individual components.

Below ground biomass

Below ground biomass sampling took place at 200 and 365 DAP in the plot of Q208⁽ᴾ⁾. Sampling was undertaken in the areas where above-ground biomass was harvested during the same period. A 1 m^2 area was randomly selected within the 3 m length of crop row. Roots and stool were excavated using a shovel down to 0.5 m. All soil was washed from roots and stool which were then weighed to determine the fresh biomass weight. A subsample was taken and dried and analysed for total N as described above. Nitrogen accumulation (kg N/ha) was determined by multiplying the N concentration by the below-ground biomass.

Water sampling and irrigation applications

Irrigation water was sourced from bores and supplied to the crop via fluming which delivered water to each of the furrows. Irrigation water was analysed for nitrate nitrogen. The number of irrigation applications applied to the site and the duration of the irrigations were recorded to calculate volume (ML) of irrigation water applied per hectare over 2014–2015. This information along with the concentration of nitrates in the bore water was then used to determine the nitrogen inputs from irrigation water over the duration of the crop development using the equation: N input (kg N/ha) = mg N/L × ML.

Results

Soil nitrogen

Soil mineral nitrogen levels in the three main plots prior to planting were high in the top 60 cm of the soil profile and relatively uniform across the trial. By 200 DAP soil nitrogen levels had declined and by 270 DAP, levels were very low (Table 1).

Table 1—Mineral nitrogen (kg N/ha) in the top 60 cm of the soil profile.

Days after planting	Variety			
	Q253⟨b⟩ Mean*	Q208⟨b⟩ Mean*	KQ228⟨b⟩ Mean*	P Value
0	102.4	84.6	96.8	0.15
200	46	36.9	31.5	0.32
270	16.3	15.7	15.7	0.88
365	17.8	21.2	15.3	0.12

* Mean of four replications

Soil mineral N levels for the three post-planting samplings were not influenced by variety, however N levels declined over the first 270 DAP in each of the three main plots.

Nitrogen applied via irrigation water

Each of the irrigation events applied approximately 1.55 ML/ha. Water samples taken from the fluming during irrigation events were analysed and found to contain 2.91 ± 0.04 mg/L of oxidised nitrogen as N. The total amount of nitrogen applied to each of the three blocks over the growing season was 68 kg N/ha.

Yield measurement

At 365 DAP, mean and standard error for cane yield (tc/ha) was calculated for each variety. Q253⟨b⟩ produced 132 ± 5 tc/ha while Q208⟨b⟩ and KQ228⟨b⟩ produced 106 ± 10 tc/ha and 97 ± 8 tc/ha respectively. Average plant crop yields across the Burdekin in 2014 for the three varieties, grown in a range of soil types and under a variety of farm management practices, were 160 tc/ha for Q253⟨b⟩ and 145 tc/ha and 144 tc/ha for Q208⟨b⟩ and KQ228⟨b⟩ respectively (Sugar Research Australia, 2015). The relative cane yields of the plots therefore comprise 83% (Q253), 73% (Q208) and 67% (KQ228) of the relevant district average yields.

Crop N accumulation

Above-ground biomass (dry matter) accumulation is shown in Figure 1. The variety Q253⟨b⟩ accumulated significantly more biomass from 200 days onwards in comparison to Q208⟨b⟩ and KQ228⟨b⟩. From 270–365 DAP, above-ground biomass did not change significantly in the three varieties.

The accumulation of nitrogen for the three varieties followed that of above-ground biomass and can be described by a typical non-linear model for the period of the trial (Figure 2). N accumulation appeared to increase from 130 DAP until 270 days after which N accumulation plateaued for Q208⟨b⟩ and KQ228⟨b⟩, and declined slightly in Q253⟨b⟩.

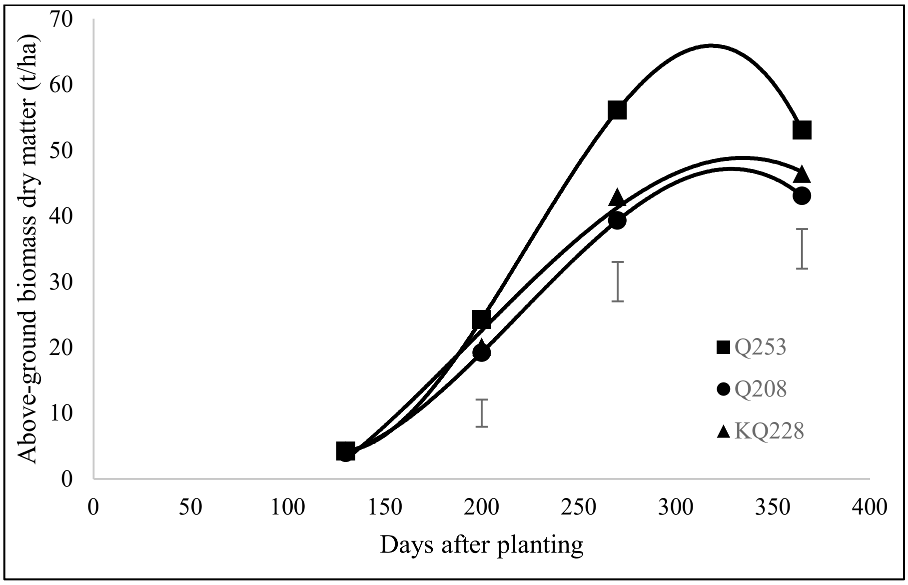

Fig. 1—Crop above-ground biomass accumulation in relation to DAP for three varieties. Vertical bars show the least significant differences of means (P=0.05) of the three varieties. Polynomial functions for three varieties are Q253$^{\Phi}$ (R^2 = 0.99) $y = -2E{-}05x^3 + 0.0118x^2 - 2.1419x + 122.2$, Q208$^{\Phi}$ (R^2 = 0.99) $y = -3E{-}08x^4 + 1E{-}05x^3 - 0.0018x^2 + 0.07x$, KQ228$^{\Phi}$ (R^2 = 0.99) $y = -8E{-}06x^3 + 0.0056x^2 - 0.9227x + 48.11$.

Of the three varieties Q253$^{\Phi}$ accumulated significantly more nitrogen from 200 days onwards in comparison to Q208$^{\Phi}$ and KQ228$^{\Phi}$. There appeared to be no difference in N accumulation between Q208$^{\Phi}$ and KQ228$^{\Phi}$. In the first 130 DAP between 24–35% of the total above-ground N accumulated by the crops was captured. By 200 DAP between 65–84% of the total above-ground N accumulated by the crops was captured, and at around 270 days, N accumulation peaked.

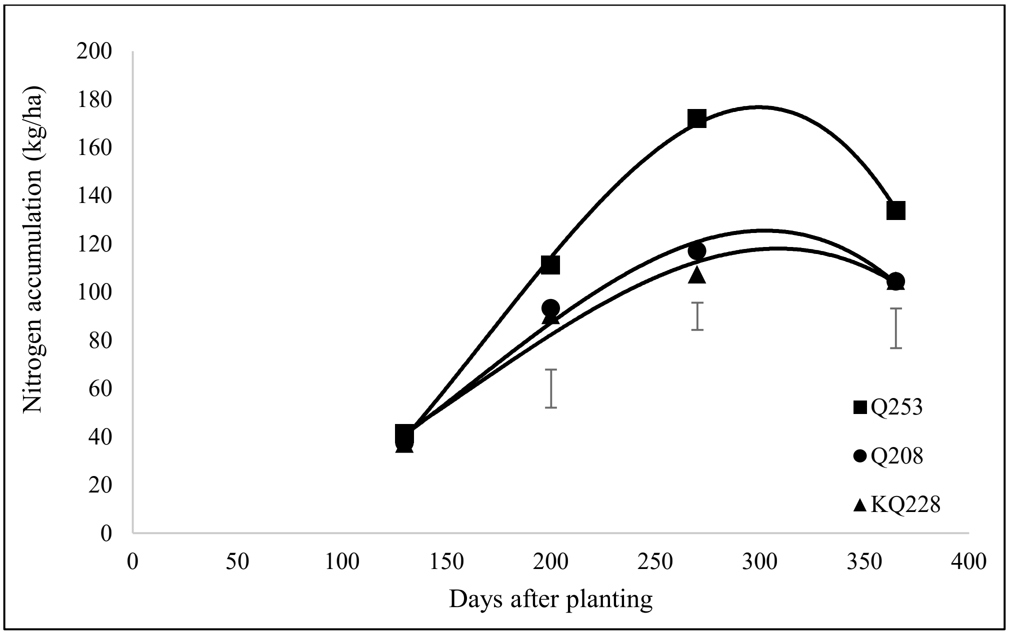

Fig. 2—Crop nitrogen accumulation in relation to DAP for three varieties. Vertical bars show the least significant differences of means (P=0.05) of the three varieties. Polynomial functions for three varieties are Q253$^{\Phi}$ (R^2 = 0.998) $y = -2E{-}05x^3 + 0.011x^2 - 0.7578x$, Q208$^{\Phi}$ (R^2 = 0.9831) $y = -1E{-}05x^3 + 0.0055x^2 - 0.2116x$, KQ228$^{\Phi}$ (R^2 = 0.9645) $y = -9E{-}06x^3 + 0.0042x^2 - 0.818x$.

The production of above-ground biomass per kg of accumulated N (N utilisation efficiency) (Bell *et al.,* 2014) showed little variation between varieties (Table 2), however at 270 DAP, KQ228⁽ᴾ⁾ produced significantly more biomass per kg of crop N than Q253⁽ᴾ⁾ and Q208⁽ᴾ⁾ . However, before and after this time there there was no significant (P>0.05) difference between the three varieties.

Table 2—Mean and standard error for nitrogen utilisation efficiency (kg of dry matter/kg crop N) for three varieties.

DAP	Variety			lsd (P=0.05)
	Q253⁽ᴾ⁾	Q208⁽ᴾ⁾	KQ228⁽ᴾ⁾	
130	103.5 ± 5.5	106.5 ± 4.0	116.5 ± 2.8	ns
200	218.1 ± 6.1	206.4 ± 5.2	223.3 ± 10.5	ns
270	326.0 ± 7.2	336.2 ± 3.5	400.7 ± 9.4	27.2
365	396.1 ± 4.4	414.1 ± 17.0	443.6 ± 21.0	ns

N and biomass accumulation in plant components

Nitrogen accumulation in stalk and dead leaf almost follow the trend in biomass accumulation (Figures 3 and 4). However in green leaves there was a decline in accumulated N from 200 DAP for Q208⁽ᴾ⁾ and KQ228⁽ᴾ⁾ while Q253⁽ᴾ⁾ displayed a significant decline in accumulated leaf N at 365 DAP. Leaf N concentration declined significantly from 200 to 365 DAP for the three varieties (Figure 5).

At 200 DAP the highest proportion of above-ground N was accumulated in the leaf, comprising of approximately 50% of the accumulated N (Table 3). Stalks contained approximately 30%, and cabbage and attached dead leaf each contained approximately 10% of the accumulated N. By 365 DAP, the three varieties underwent a significant shift in the proportion of N accumulated in plant components.

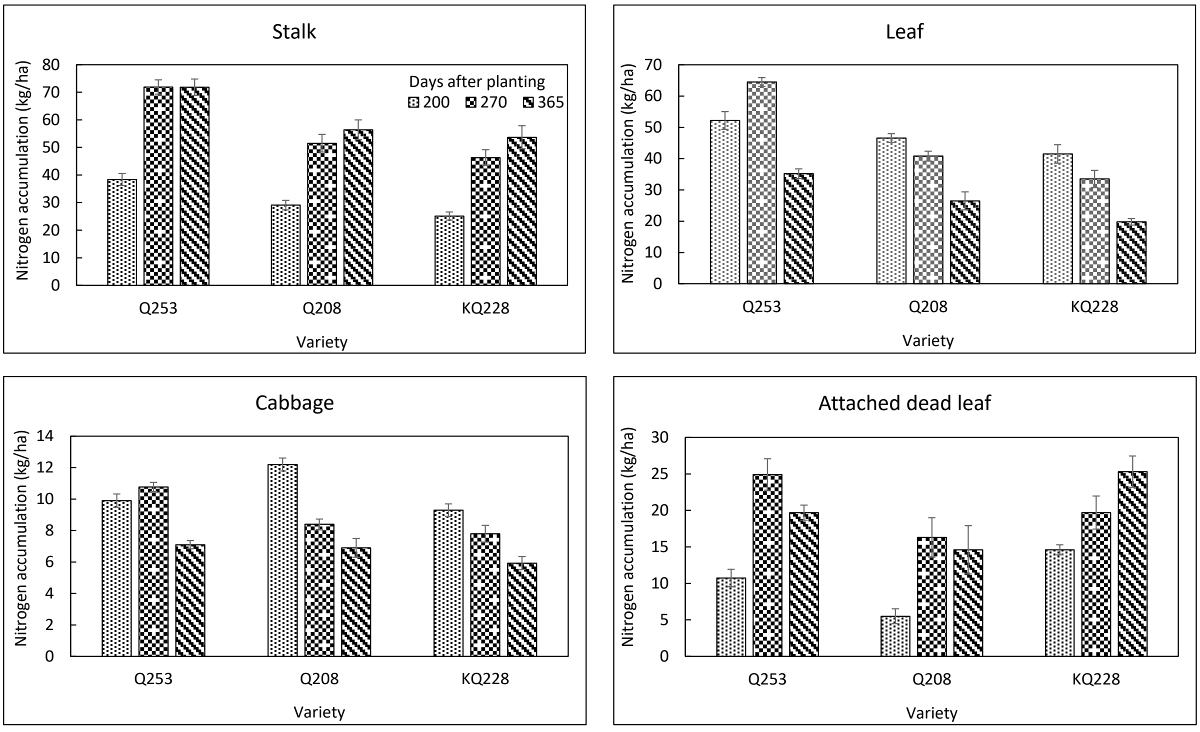

Fig. 3—Mean nitrogen accumulation in crop components in relation to DAP for three commercial varieties Q208⁽ᴾ⁾, Q253⁽ᴾ⁾ and KQ228⁽ᴾ⁾ (vertical line indicates standard error).

At this time, more than 50% of the accumulated above-ground N was located in the stalk while N in leaves declined to less than 30% of the total accumulated N. Accumulated N in cabbage also declined following the general decline in cabbage biomass. Attached dead leaf accumulated N increased significantly mirroring the increase in attached dead leaf biomass (Table 4).

Table 3—Proportion of N accumulated in plant components at 200, 270 and 365 DAP.

Cultivar	Days after planting	Proportion of N accumulation in plant component			
		Stalk	Leaf	Cabbage	Attached dead leaf
Q253$^{\Phi}$	200	0.35	0.47	0.09	0.09
	270	0.42	0.38	0.06	0.14
	365	0.54	0.26	0.05	0.15
Q208$^{\Phi}$	200	0.31	0.5	0.13	0.06
	270	0.44	0.35	0.07	0.14
	365	0.54	0.25	0.07	0.14
KQ228$^{\Phi}$	200	0.28	0.46	0.10	0.16
	270	0.43	0.31	0.08	0.18
	365	0.51	0.19	0.06	0.24

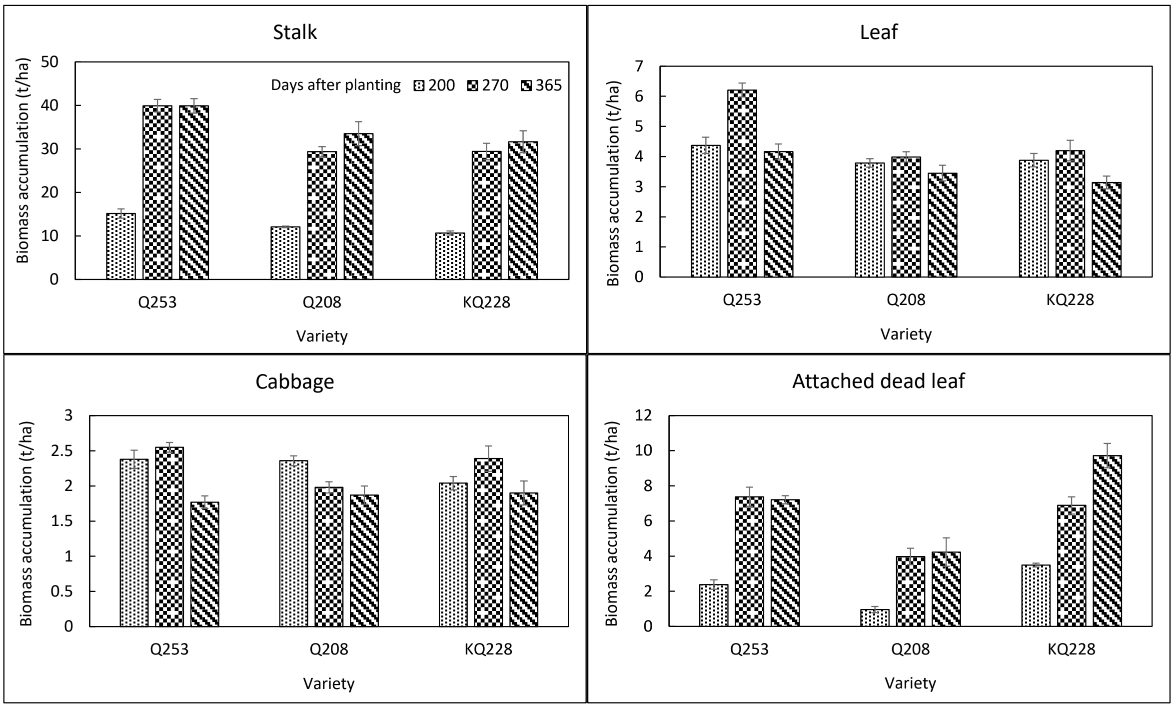

Fig. 4—Mean biomass dry matter accumulation in crop components in relation to DAP for three commercial varieties Q253$^{\Phi}$, Q208$^{\Phi}$ and KQ228$^{\Phi}$ (vertical line indicates standard error).

Table 4—Proportion of biomass accumulated in plant components at 200, 270 and 365 DAP.

Cultivar	Days after planting	Proportion of biomass accumulation in plant component			
		Stalk	Leaf	Cabbage	Attached dead leaf
Q253$^{\Phi}$	200	0.62	0.18	0.10	0.10
	270	0.71	0.11	0.05	0.13
	365	0.75	0.08	0.03	0.14
Q208$^{\Phi}$	200	0.63	0.20	0.12	0.05
	270	0.75	0.10	0.05	0.10
	365	0.78	0.08	0.04	0.10
KQ228$^{\Phi}$	200	0.54	0.19	0.10	0.17
	270	0.69	0.10	0.05	0.16
	365	0.68	0.07	0.04	0.21

During the period when N concentrations in plant components were monitored, leaf N concentration was found to be the highest followed by cabbage, attached dead leaf and then stalk. In general concentrations of N in all components declined to some degree over time, however the greatest decline was observed in leaf N concentration (Figure 5).

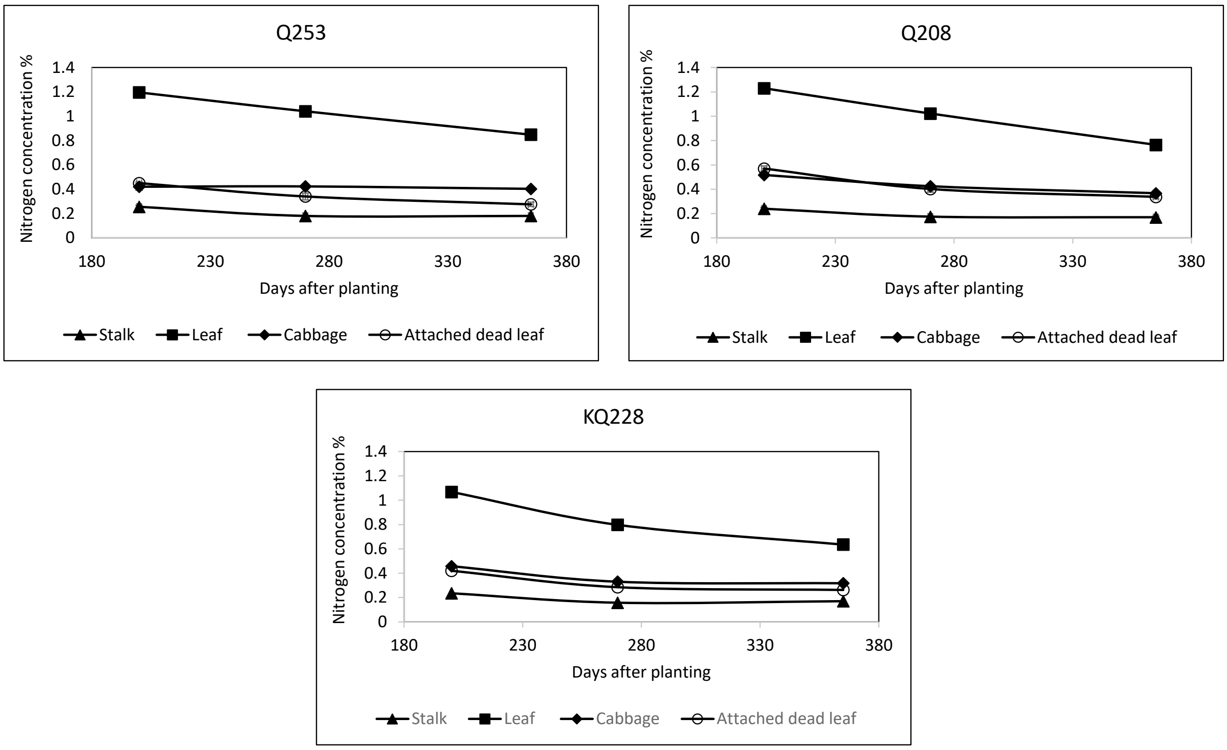

Fig. 5—Mean nitrogen concentration in crop components in relation to DAP for Q253[Φ], Q208[Φ] and KQ228[Φ].

Surface trash

Surface trash biomass collected at 365 DAP varied between varieties. Q208[Φ] had considerably more surface trash biomass, resulting in more accumulated N than the other two varieties. This was also reflected in the estimated kg N/ha calculated for each variety (Table 5).

Table 5—Mean and standard error of surface trash biomass and N accumulation in three varieties sampled 365 DAP.

Variety	Surface trash dry weight (t/ha)	Nitrogen (%)	Nitrogen (kg N/ha)
Q253[Φ]	0.96 ± 0.08	0.52 ± 0.02	4.9 ± 0.2
Q208[Φ]	2.36 ± 0.26	0.45 ± 0.03	10.8 ± 1.5
KQ228[Φ]	1.39 ± 0.08	0.51 ± 0.04	7.1 ± 0.9

The concentration of N in surface trash was found to be considerably higher than the concentration of N found in attached dead leaf (Figure 6).

Below-ground biomass N accumulation

Below-ground biomass samples were taken from the block containing the variety Q208[Φ] at 200 and 365 DAP. Below-ground biomass N at 200 DAP was 11% of the above ground biomass N (Table 6). At 365 DAP, below ground-biomass N increased up to 15% of the above ground biomass N in Q208[Φ].

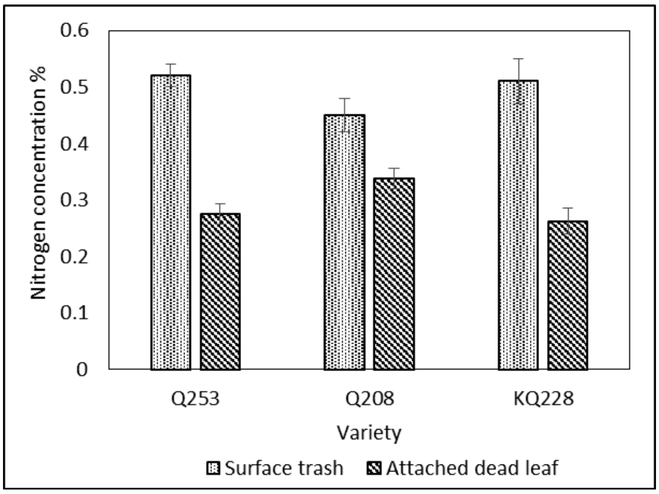

Fig. 6—Mean nitrogen concentration in surface trash and attached dead leaf 365 DAP (vertical line indicates standard error).

Table 6—Mean and standard error of below-ground (roots and stool) biomass and nitrogen accumulation in Q208[⏀].

Days after planting	Biomass dry weight (t/ha)	Nitrogen (%)	Nitrogen (kg N/ha)	kg biomass/kg of N
200	3.6 ± 0.33	0.29 ± 0.01	10.3 ± 1.1	350
365	4.3 ± 0.07	0.36 ± 0.04	15.2 ± 2.0	283

Discussion

Nitrogen accumulation in the three varieties peaked around 270 DAP with the majority of N accumulated within the first 200 DAP. A similar pattern of N accumulation in sugarcane was reported by Thompson (1988) in South Africa and Wood *et al.* (1996) in Australia. The variety Q253[⏀] accumulated significantly more biomass and N than Q208[⏀] and KQ228[⏀] throughout most of the growth period.

Each variety was grown in blocks with uniform soil N which suggests that Q253[⏀] may be more efficient at extracting available N from soil than Q208[⏀] and KQ228[⏀]. Soil N supply was depleted by 270 DAP, which coincided with the cessation of N accumulation in the three varieties. Q253[⏀] lost accumulated N during the final 95 days however Q208[⏀] and KQ228[⏀] showed no changes in accumulated N over this period. Q253[⏀] appears to have lost accumulated N from leaf and cabbage due to a loss of biomass and a significant decline in leaf N concentration.

Attached dead leaf accumulated N remained the same over this period. Taking into account the accumulated N in surface trash, the loss of N observed in Q253[⏀] remains unexplained. Part of the accumulated N loss observed in Q253[⏀] could possibly be due to the cycling of N into the below-ground biomass. However there is not enough data in this study to confirm this.

In general, the four plant components displayed a decline in N concentration from 200 DAP until the final assessment at 365 DAP, the most noticeable of which was leaf nitrogen concentration.

This trend was also observed by Wood *et al.* (1996). The concentration of N in surface trash from each variety was found to be generally higher than that of attached dead leaf. This result was unexpected however it may be due to a lower C/N ratio of the trash as a result of microbial breakdown and CO_2 evolution or possibly the trash absorbing nitrates from the irrigation water. Although the N concentration of surface trash was considerably higher than attached dead leaf, the surface trash biomass and accumulated N in this component was minor in comparison to the sum of the four plant components.

The nitrogen utilisation efficiency (kg dry weight of the above-ground biomass produced per kg of accumulated above ground N) of the three varieties was compared. It was found that KQ228⁽ᶲ⁾ produced significantly more biomass per kg of accumulated N than Q253⁽ᶲ⁾ and Q208⁽ᶲ⁾ at 270 DAP, however given that this occurred only at 270 DAP, further more extensive studies may be required to determine if KQ228⁽ᶲ⁾ is actually a more efficient utiliser of accumulated N than the other two varieties.

There has been very little work investigating the accumulation of below-ground biomass and N in Australia. Bell *et al.* (2014) reported a range of values from ratoon crops sampled at 9 months and at harvest. The below-ground biomass produced per kg of accumulated N was calculated using the reported data, and ranged from 104–274 kg which is lower than the observations from Q208⁽ᶲ⁾ in this study.

Conclusion

This study confirms the findings of a review by Bell *et al.* (2014) that the majority of N uptake occurs in the 200 day period after planting. It has demonstrated that there are differences in the ability of varieties to obtain N from soil and there are some indications that KQ228⁽ᶲ⁾ may be better able to utilise the accumulated N within the plant to produce more biomass per kg of accumulated N in comparison to Q208⁽ᶲ⁾ and Q253⁽ᶲ⁾.

Partitioning of N in plant components above and below ground varies during the season and has highlighted a need for more work to understand how below-ground biomass accumulates N and its cycling within the plant. The effects of late planting or late harvest on the pattern of N accumulation by the crop also requires investigation.

Acknowledgements

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14 Appendix 7.

Queensland Government

Sugar Research Australia

RP20 Burdekin Nitrogen Trials

Case Studies and Trial Results

2011–2016

RP20 Burdekin Nitrogen Trials

The nitrogen equation: how less is giving growers more

The Burdekin Nitrogen Trials (RP20) were established to determine whether the SIX EASY STEPS method provided adequate nitrogen application rates following the introduction of regulations for nitrogen (N) and phosphorous (P) inputs in sugarcane production.

This project has shown that the SIX EASY STEPS guidelines for applying nitrogen maintain productivity and maximise profitability in all cases where the trial covered more than one year.

The variation in yields observed between farms in the Burdekin has been found to be primarily due to soil types and farm management. **Good farm management is the key component for achieving high yields.** This project continues to demonstrate that high nitrogen application rates do not compensate for poor farm management practices.

Funded by the Department of Environment and Heritage Protection, RP20 has been a successful collaboration between cane farmers in the Burdekin, Sugar Research Australia and the Queensland Government.

RP20 was established in 2011 to determine the adequacy of the regulated N for sugarcane production

The project is funded by the Department of Environment and Heritage Protection (EHP)

Sugar Research Australia (SRA) established replicated and randomised large-scale strip trials on the major soil types found in the Burdekin region

A number of factors were considered when establishing the trial sites:

* Block size
* Block shape
* Soil uniformity
* Irrigation systems employed
* Pest control measures
* Yield history

Trial sites are equally distributed between the Delta and BRIA

A technical management group, involving **SRA** and **DSITI**, is responsible for ensuring that the work was scientifically sound

23 grower collaborators have participated in this project:

* 2012 – 10 trial sites
* 2013 – 11 trial sites
* 2014 – 10 trial sites
* 2015 – 13 trial sites
* 2016 – 13 trial sites

= 57 trial sites in total

Data collected from the trial sites include:

* General plant growth and pest pressure
* Plant nutrient status via leaf analyses
* Sugarcane biomass accumulation
* Irrigation water quality
* Soil mineral nitrogen pre planting and post-harvest
* Sugarcane yield, commercial cane sugar (CCS) content and calculated sugar yield

RP20 has covered 12,000 hectares of Burdekin cane land. The total nitrogen saving from this project is 499 tonnes, without compromising sugar yield and profitability.

What the grower collaborators have learned from the trials

1) The SIX EASY STEPS method for calculating fertiliser requirements provides adequate nitrogen to grow cane to its maximum potential.

2) The trial data shows that where a trial site has run for more than one year, the SIX EASY STEPS method is shown to be more profitable to the farmer 100% of the time.

3) The trials have shown that farm management practices play an important role in growing cane.

4) Soil samples are crucial in determining the correct fertiliser to apply for your own soil types.

5) Identifying possible loss pathways, fertiliser placement and timing, irrigation scheduling, compaction and weed control are all important considerations.

6) Different varieties of cane may require different management strategies.

7) Too much nitrogen can have a negative effect on CCS and sugar yield.

8) It is important to get your fertiliser box calibrated to make sure you are putting on the correct amount.

"I found it really interesting with my experiment, on my block, on my soil, with my crop that it didn't matter what rate of nitrogen we put on, the results were very similar. That showed me that the more nitrogen I put on I wasn't actually getting any benefit from."

Ross Gambino

"In all of the five crops it showed up that with the extra nitrogen my sugar was lower but the tonnes were no different. That was a real eye opener to me."

Jim Richardson

"If you put on more than recommended, it's just wasting money."

Allan Richardson

"As far as losses go, we've learned a lot about that and have modified our farming operation to control those and get the best benefit from the nitrogen we do put on. It's keeping the farm well managed with the use of SIX EASY STEPS that shows us the benefit of financial returns".

Steve Pilla

"We were steadfast in that belief that we needed 290 units of nitrogen to grow good crops of cane, which we don't. It's proven now."

Eric Barbagallo

"We're all about being cost effective and this project has highlighted that the most."

Warren Caspanello

"Going forward, I know there's more to be done. This project has inspired me to continue challenging the norms and strive for continuous improvement, which is exciting. I know I can add to what I got out of this."

Frank Catalano

"We are here with lower fertiliser rates and growing more cane than we used to by looking at the whole farm management plan and fertiliser is one part of it."

Ryan Matthews

"The way Julian (SRA Agronomist) conducted all the trials was really professional and exact so you get the true results."

Frank Gorizia

Weather conditions

Weather conditions play a large role in crop performance. As many of these variables cannot be controlled, they are noted below to add further context to the trial outcomes.

Over the five year period in which the trials were conducted (2011-2016), extremes in weather conditions were encountered.

2011

- No cultivation until April due to effects of 2010 season
- Ground was compromised which compromised on ground preparation
- Couldn't laser due to wet
- Planted in May (late plant)

2012

- Harvest results of plant cane were poor due to inadequate ground preparation in 2011
- High June/July rainfall compromised harvest and meant a late crush and reduced yield
- CCS was fairly flat
- Did not get the negative impact of higher nitrogen on CCS

2013-15

- Ideal growing years

2016

- Late harvest due to rain
- Tonnes up but CCS down

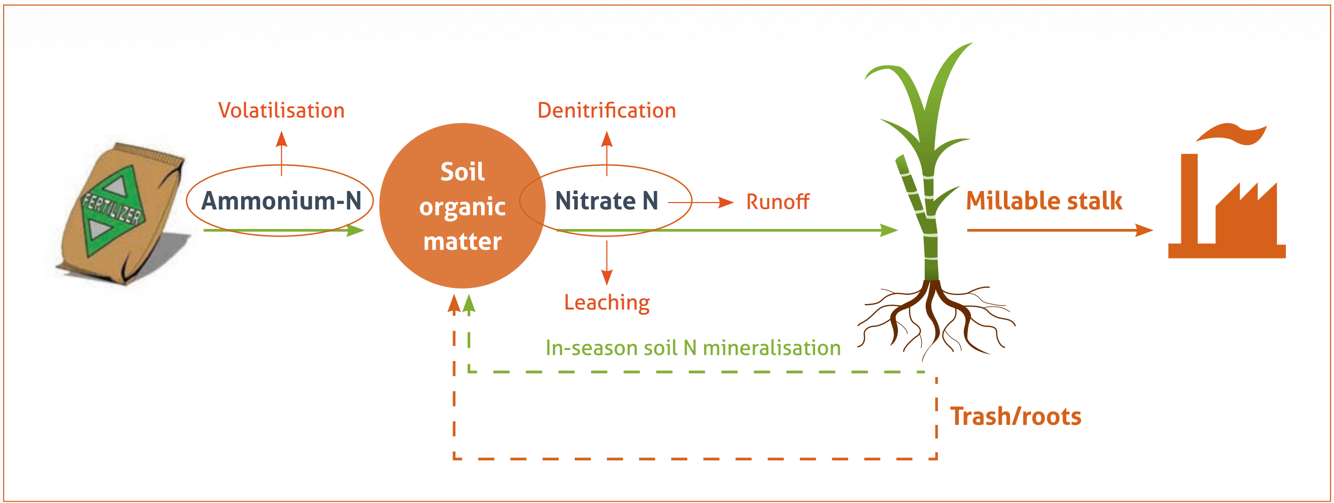
Taking the variable weather conditions into account, the trial results confirm that the SIX EASY STEPS guidelines provide the best method for calculating fertiliser requirements to maximise profitability and sustainability.

NUE and the nitrogen budget

Apart from verifying the effectiveness of the SIX EASY STEPS method for calculating nitrogen fertiliser requirements in the Burdekin, the data collected through this project has enabled researchers to gain further insight into when the crop takes up nitrogen and the complex interactions between soil nitrogen, seasonal conditions and crop recovery of applied nitrogen fertiliser.

The project found that cane crops in the Burdekin required about 1.2 kilograms of nitrogen in the tops plus roots and stool to produce 1 tonne millable stalk; consequently high yielding crops needed to uptake more nitrogen per hectare to meet their demands than lower yielding crops.

As shown in the diagram, the crop obtains most of its nitrogen requirements from applied fertiliser and in-season nitrogen mineralisation from soil organic matter. The challenge for the grower is to get as much of the applied fertiliser nitrogen into the crop as possible. There are many nitrogen loss pathways such as leaching, runoff and denitrification, and the magnitude of these losses in a cropping season will depend on volume applied, soil type, seasonal conditions and its position in the landscape and soil profile.



Trying to mitigate nitrogen losses with appropriate management practices will increase the crop's ability to take up applied fertiliser, and thereby maximise the grower's return on the fertiliser investment as well as reducing any possible environmental impacts.

A useful indicator of nitrogen use efficiency is 'kilograms of applied nitrogen required per tonne of cane produced'. For example, blocks that have a history of requiring large amounts of applied nitrogen to produce a tonne of cane may have an underlying soil or site constraint that, if mitigated, could increase productivity. Growers can monitor nitrogen use efficiency to identify sections of the farm where there are soil or site constraints limiting crop uptake of applied nitrogen, or where there might be large losses of nitrogen occurring.

RP20 Burdekin Nitrogen Trials - project partners

The RP20 project has been an exciting collaboration between cane farmers, industry and the Queensland Government. Each of the partners played a crucial role in the project's success.

Burdekin cane farmers worked with the project team to adjust fertiliser rates in line with the industry standard, freely giving their time and putting their farms into the hands of the project team. At the same time their dedication and open-mindedness has shaped the way trials were conducted, allowing them to learn from the scientists involved to fine tune their farming practices.

Sugar Research Australia (SRA) provided an agronomist who worked directly with cane farmers to undertake rigorous trials on their farms and data analysis to support industry standards reinforced by science. As a body independent from government, SRA provided reassurance to cane farmers seeking comfort in the validity of science and the trials. In addition, SRA has been a marketing lead on this project promoting project results via industry run forums, to encourage greater uptake of the industry standard, SIX EASY STEPS.

Department of Science, Information Technology and Innovation (DSITI) team has led trial design to achieve scientifically robust results and provided data analysis that investigated nitrogen uptake by the plant and its efficiency, also undertaking specialised soil and plant analyses which supported agronomic measurements.

Department of Agriculture and Fisheries (DAF) team played an important role in the project by undertaking economic evaluations to compare the profitability of the different nitrogen rates, and communicated the findings to farmers involved in the project and industry.

Department of Environment and Heritage Protection (EHP) team funded this project with over $2.5 million, pulling together scientists, industry and growers to address a specific and crucial need, negotiating contract terms and issues across project partnerships, project managing and enabling the project to continue despite a variety of challenges it faced over the past six years.

RP20 has achieved its main objective with SRA determining the optimum amount of nutrients required on Lower Burdekin representative soils for plant and ratoon cane crops. Furthermore, the project has revealed that nitrogen management is only one element of the cane farming system to consider for optimising productivity and profitability. Once other farming practices are improved, nitrogen is used more efficiently by the crop, maximising sugarcane production and reducing nitrogen loss to local waterways.

This case study booklet provides a summary of each trial's yield, CSS and economic outcome along with details about each farming situation. Further detail and a full statistical analysis can be found in the project's final report, available at: www.qld.gov.au/FarminginReefCatchments

Case Studies

BRIA

The benefits and results that each grower has taken from the trial vary, however there is one factor that is consistent – the SIX EASY STEPS method is shown to produce the best financial outcome.

The following case studies compare the amount of nitrogen that the grower used before being involved in the trial with the SIX EASY STEPS rate, calculated using a district yield potential (DYP) of 180 tc/ha.

The following parameters have been used to calculate costs and revenue in the trial case studies:

Key parameters	
Sugar price	$424/tonne, (5-year average, 2011-15)
Relative CCS	Actual ccs – daily pool ccs + seasonal pool ccs
Cane payment formula (cane price)	$424 x 0.009 x (CCS-4) + 0.662
Gross revenue	Cane price x tonnes cane per hectare
Harvesting cost + levies	$8.11/tonne, ex GST
Fertiliser prices	Sourced from local supplier, ex GST

Site 2 (BRIA)

Changed approach to farming

BRIA farm

Location
Millaroo

Variety
KQ228$^{\Phi}$

Soil type
Non Sodic Duplex

Soil texture
Sand

QDPI Soil type
6Dbg

Organic carbon
0.35%

Total area of trial block
5.4 ha

The motivation to become involved in the Burdekin Nitrogen Trials was clear for John – to prove that in the Burdekin growers needed to be putting on the amount of nitrogen that they always had been in order to remain productive. Like many, John felt that more nitrogen would produce higher yielding cane. "When the cane was looking less than ideal I would apply more nitrogen as I genuinely thought that this is what the cane needed."

After being presented with the first year of data for this trial site, John was very surprised. He did not expect to see little difference in tonnes across the various treatments in his plant cane. The results of the first ratoon showed the same result, at which point he was convinced that higher nitrogen rates did not improve his crop and that the SIX EASY STEPS method for calculating fertiliser requirements was the way to go.

By the third year of the trials, this grower was so convinced by what he had seen from the first two years that he began changing his farming practices. It wasn't only that he was now using the SIX EASY STEPS method to calculate his fertiliser requirements across his whole farm, he now operated in an entirely different way.

"I changed the way that I farmed altogether. I've gone from focusing on nitrogen to looking at all areas of farm management, in particular irrigation management and weed control. Having changed my view about nitrogen, RP20 has led me to look at other elements, which is why I have now become involved in a further program looking at my farm's nutrient management plans."

"I have discovered that my soil is low in other nutrients, which I didn't realise before. I'm also gaining a better understanding of irrigation management and using tools to measure soil moisture. I'm now basing decisions on the information I get through these monitoring tools rather than just from looking at the cane."

Differences in profitability over full crop cycle

Fertiliser cost savings over trial block when comparing SIX EASY STEPS with high rate (over full crop cycle)	
Fertiliser cost high rate ($/ha)	$2,331
Fertiliser cost SIX EASY STEPS rate ($/ha)	$2,085
Fertiliser cost saving ($/ha)	$246
Fertiliser cost saving over trial block ($)	**$1,329**

Potential improvement in earnings over trial block when comparing SIX EASY STEPS with high rate (over full crop cycle)	
Revenue less HC&L* high rate ($/ha)	$16,172**
Revenue less HC&L* SIX EASY STEPS rate ($/ha)	$16,211
Potential increase in earnings ($/ha)	$39
Potential increase in earnings over trial block ($)	**$210**

Increase in block profitability: $1,540

Potential increase in profitability over 100 hectares: $28,510

** Revenue less HC&L refers to revenue less harvesting costs and levies. Potential savings and increase in return will be dependent on environmental and seasonal factors such as soil variation across the farm, rainfall, management methods, harvest conditions. All prices are excluding GST.* ***This case study compares the amount of nitrogen that the grower used before being involved in the trial with the SIX EASY STEPS rate calculated using DYP 180.***

*** Predicted value from statistical analysis*

Site 2 (BRIA)

Queensland Government | Sugar Research Australia

		Treatment kg N/ha	Cane yield TCH	CCS units	Sugar yield TSH	Relative CCS units	Gross revenue $/ha	Fertiliser costs $/ha	Harvesting costs + levies $/ha	Net revenue $/ha
Plant crop *Date planted: 01/05/2011 Date harvested: 10/09/2012*	**SIX EASY STEPS rate DYP 150***	130	135	15.2	20.6	15.0	$5,774	$392	$1,099	$4,284
	SIX EASY STEPS rate DYP 180	**170**	**141**	**15.1**	**21.3**	**14.9**	**$5,956**	**$447**	**$1,140**	**$4,368**
	Grower rate	210	144	15.0	21.6	14.8	$6,021	$503	$1,165	$4,353
1st Ratoon *Date harvested: 31/07/2013*	**SIX EASY STEPS rate DYP 150***	170	107	15.3	16.5	15.2	$4,696	$507	$871	$3,318**
	SIX EASY STEPS rate DYP 180	**210**	**113**	**15.3**	**17.3**	**15.2**	**$4,919**	**$570**	**$916**	**$3,433**
	Grower rate	250	114	15.0	17.2	15.0	$4,860	$634	$923	$3,303**
2nd Ratoon *Date harvested: 12/08/2014*	**SIX EASY STEPS rate DYP 150***	170	108	15.2	16.3	15.0	$4,568	$503	$872	$3,193
	SIX EASY STEPS rate DYP 180	**210**	**106**	**15.1**	**16.0**	**14.9**	**$4,465**	**$567**	**$858**	**$3,040**
	Grower rate	250	106	15.0	15.9	14.8	$4,438	$630	$862	$2,946
3rd Ratoon *Date harvested: 09/09/2015*	**SIX EASY STEPS rate DYP 150***	170	99	16.5	16.4	15.9	$4,577	$437	$804	$3,336
	SIX EASY STEPS rate DYP 180	**210**	**102**	**16.4**	**16.6**	**15.7**	**$4,608**	**$500**	**$823**	**$3,285**
	Grower rate	250	101	16.0	16.2	15.3	$4,456	$563	$822	$3,070

* *The N rate is 20 kg below the SIX EASY STEPS rate calculated using DYP 150*
DYP 150 – District yield potential of 150 tc/ha
DYP 180 – District yield potential of 180 tc/ha
** *Predicted value from statistical anaylsis*

Comparison of trial site and Productivity Group	
Productivity Group average 2012-2015 (TCH)	107.14
Trial block average SIX EASY STEPS rate (TCH)	115.23

Site 5 (BRIA)

Suiting management style to conditions for maximum result

BRIA farm

Location
Giru

Variety
Q200[⊕]

Soil type
Sodic Duplex

Soil texture
Loam

QDPI Soil type
6Drc

Organic carbon
0.87%

Total area of trial block
20 ha

Going into the trial believing that nitrogen was making the difference, Steve was worried about the effect that the lower nitrogen rates would have on his crop. He was convinced that he would see a difference between the various treatments. The data from the first year of the trial showed very little difference in tonnage between treatments, at which he was surprised and thought that there must be something wrong. When the data from the second year was presented and again showed no noticeable difference between the trialled nitrogen rates, he realised that things other than nitrogen were driving tonnes.

In 2013 weed management was identified as a problem. The crop was gappy in places causing weed issues in the second year, which were then addressed. Steve also began to focus on improving irrigation, having encountered channel supply problems in 2014. He ensured that the crop received water when needed and found he got a better yield with his first ratoon than in his plant cane due to better irrigation scheduling and weed management. "While I was disappointed that tonnage wasn't there during the first year of the trial, I realised nitrogen was not the reason. Throughout the trial I began to focus on other areas such as weed control and irrigation, from which I had good results."

After seeing the results from the first three years of the trial, this grower decided to reduce the rates on his trial blocks, including a low rate of ENTEC.

"This trial taught me that if the crop is well managed, nitrogen will not make the difference. I now assess what the conditions are that I cannot control and suit the management style to achieve the best possible result."

Differences in profitability over full crop cycle – plant cane to 2nd ratoon

Fertiliser cost savings over trial block when comparing SIX EASY STEPS with high rate (plant cane to 2nd ratoon)	
Fertiliser cost high rate ($/ha)	$1,548
Fertiliser cost SIX EASY STEPS rate ($/ha)	$1,117
Fertiliser cost saving ($/ha)	$431
Fertiliser cost saving over trial block ($)	**$8,617**

Potential improvement in earnings over trial block when comparing SIX EASY STEPS with high rate (plant cane to 2nd ratoon)	
Revenue less HC&L* high rate ($/ha)	$11,621
Revenue less HC&L* SIX EASY STEPS rate ($/ha)	$11,685
Potential increase in earnings ($/ha)	$64
Potential increase in earnings over trial block ($)	**$1,280**

Increase in block profitability: $9,897

Potential increase in profitability over 100 hectares: $49,486

* *Revenue less HC&L refers to revenue less harvesting costs and levies. Potential savings and increase in return will be dependent on environmental and seasonal factors such as soil variation across the farm, rainfall, management methods, harvest conditions. All prices are excluding GST.* ***This case study compares the amount of nitrogen that the grower used before being involved in the trial with the SIX EASY STEPS rate calculated using DYP 180.***

Site 5 (BRIA)

		Treatment *kg N/ha*	Cane yield *TCH*	CCS *units*	Sugar yield *TSH*	Relative CCS *units*	Gross revenue *$/ha*	Fertiliser costs *$/ha*	Harvesting costs + levies *$/ha*	Net revenue *$/ha*
Plant crop *Date planted: 10/09/2012* *Date harvested: 02/10/2013*	**SIX EASY STEPS rate DYP 180**	**170**	**94**	**15.4**	**14.5**	**14.6**	**$3,861**	**$280**	**$764**	**$2,817**
	Grower rate	210	95	15.4	14.7	14.6	$3,918	$336	$771	$2,811
	High rate	250	96	15.2	14.7	14.4	$3,885	$392	$782	$2,711
1st Ratoon *Date harvested: 07/10/2014*	**SIX EASY STEPS rate DYP 180**	**210**	**132**	**14.8**	**19.5**	**14.2**	**$5,234**	**$408**	**$1,071**	**$3,755**
	Grower rate	250	135	14.6	19.7	14.1	$5,275	$486	$1,093	$3,696
	High rate	290	135	14.8	20.0	14.2	$5,356	$563	$1,096	$3,696
2nd Ratoon *Date harvested: 19/10/2015*	**SIX EASY STEPS rate DYP 180**	**210**	**123**	**15.9**	**19.5**	**15.4**	**$5,421**	**$429**	**$997**	**$3,995**
	Grower rate	250	125	15.8	19.7	15.3	$5,464	$511	$1,011	$3,943
	High rate	290	121	15.7	19.0	15.2	$5,241	$593	$983	$3,666
3rd Ratoon *Date harvested: 20/11/2016*	**ENTEC, very low**	150	95	15.2	14.4	14.1	$3,725	$422	$769	$2,535
	SIX EASY STEPS rate DYP 150	170	95	15.0	14.3	14.0	$3,678	$399	$770	$2,509
	SIX EASY STEPS rate DYP 180	**210**	**90**	**14.9**	**13.5**	**13.9**	**$3,463**	**$455**	**$733**	**$2,275**

DYP 150 – District yield potential of 150 tc/ha
DYP 180 – District yield potential of 180 tc/ha

Comparison of trial site and Productivity Group	
Productivity Group average 2013-2016 (TCH)	113.8
Trial block average SIX EASY STEPS rate (TCH)	109.9

Site 17 (BRIA)

SIX EASY STEPS sufficient to grow a profitable crop

BRIA farm

Location
Giru

Variety
Q183

Soil type
Sodic Duplex

Soil texture
Loam

QDPI Soil type
6Drc

Organic carbon
0.91%

Total area of trial block
45 ha

With good farm management practices and understanding of the SIX EASY STEPS method of calculating nutrient requirements, the trials confirmed for Ryan what he had suspected.

"The trial cemented my thinking that there is no need to apply higher levels of nitrogen to accommodate for environmental conditions. The SIX EASY STEPS has enough buffer in it as shown by the results from low nitrogen rate application."

Differences in profitability over plant cane and 1st ratoon crops

Fertiliser cost savings over trial block when comparing SIX EASY STEPS with grower rate (plant crop and 1st ratoon)	
Fertiliser cost grower rate ($/ha)	$732
Fertiliser cost SIX EASY STEPS rate ($/ha)	$620
Fertiliser cost saving ($/ha)	$112
Fertiliser cost saving over trial block ($)	**$5,029**

Potential improvement in earnings (revenue less harvest costs and levies) over trial block when comparing SIX EASY STEPS with grower rate (plant crop and 1st ratoon)	
Revenue less HC&L* grower rate ($/ha)	$11,314
Revenue less HC&L* SIX EASY STEPS rate ($/ha)	$11,285
Potential increase in earnings ($/ha)	-$29
Potential increase in earnings over trial block ($)	**-$1,298**

Increase in block profitability: $3,732

Potential increase in profitability over 100 hectares: $8,293

** Revenue less HC&L refers to revenue less harvesting costs and levies. Potential savings and increase in return will be dependent on environmental and seasonal factors such as soil variation across the farm, rainfall, management methods, harvest conditions. All prices are excluding GST.* ***This case study compares the amount of nitrogen that the grower used before being involved in the trial with the SIX EASY STEPS rate calculated using DYP 180.***

Site 17 (BRIA)

Queensland Government

Sugar Research Australia

		Treatment *kg N/ha*	Cane yield *TCH*	CCS *units*	Sugar yield *TSH*	Relative CCS *units*	Gross revenue *$/ha*	Fertiliser costs *$/ha*	Harvesting costs + levies *$/ha*	Net revenue *$/ha*
Plant crop *Date planted: 20/04/2014* *Date harvested: 28/06/2015*	**SIX EASY STEPS rate DYP 180 (approx.)**	**150***	**182**	**13.3**	**24.3**	**15.1**	**$7,809**	**$341**	**$1,479**	**$5,989**
	Grower rate minus 10 kg of N	190	181	13.1	23.7	14.8	$7,604	$397	$1,471	$5,737
	High rate	240	183	13.4	24.4	15.1	$7,869	$467	$1,481	$5,922
1st Ratoon *Date harvested: 12/06/2016*	**SIX EASY STEPS rate DYP 150**	160	150	12.5	18.8	14.8	$6,269	$224	$1,215	$4,830
	SIX EASY STEPS rate DYP 180	**200**	**157**	**11.9**	**18.8**	**14.2**	**$6,232**	**$279**	**$1,277**	**$4,676**
	Grower rate	240	158	12.3	19.4	14.5	$6,462	$335	$1,281	$4,845

** This is 10kg N/ha below the SIX EASY STEPS rate calculated using the DYP180*
DYP 150 – District yield potential of 150 tc/ha
DYP 180 – District yield potential of 180 tc/ha

Comparison of trial site and Productivity Group	
Productivity Group average (TCH)	117.16
Trial block average SIX EASY STEPS rate (TCH)	169.85

Trial Results

BRIA

The following trial results include all trials for the duration of the project.

These results cover all major soil types to ensure that findings of this project are applicable to all sugarcane growers in the Burdekin region.

The graphs contained in the following trial results use Relative CCS to calculate revenue.

Trial results – Site 2

Queensland Government

Sugar Research Australia

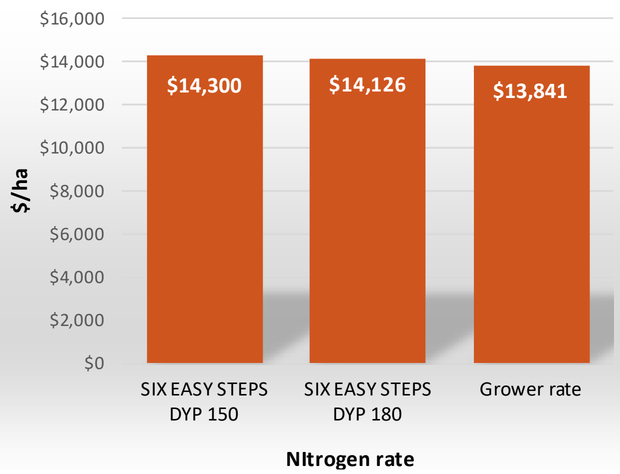
BRIA farm

Soil type	QDPI soil type	Organic carbon
Non Sodic Duplex	6Dbg	0.35%
Soil texture	**Crop variety**	
Sand	KQ228^(PBR)	

Mean results for tonnes of cane, sugar and CCS for each nitrogen treatment					
		Treatment kg N/ha	Cane yield TCH	CCS units	Sugar yield TSH
Plant crop *Date planted: 01/05/2011* *Date harvested: 10/09/2012*	**SIX EASY STEPS rate – DYP 150**	130*	135	15.2	20.6
	SIX EASY STEPS rate – DYP 180	**170**	**141**	**15.1**	**21.3**
	Grower rate	210	144	15.0	21.6
1st Ratoon *Date harvested: 31/07/2013*	**SIX EASY STEPS rate – DYP 150**	170*	107	15.3	16.5
	SIX EASY STEPS rate – DYP 180	**210**	**113**	**15.3**	**17.3**
	Grower rate	250	114	15.0	17.2
2nd Ratoon *Date harvested: 12/08/2014*	**SIX EASY STEPS rate – DYP 150**	170*	108	15.2	16.3
	SIX EASY STEPS rate – DYP 180	**210**	**106**	**15.1**	**16.0**
	Grower rate	250	106	15.0	15.9
3rd Ratoon *Date harvested: 09/09/2015*	**SIX EASY STEPS rate – DYP 150**	170*	99	16.5	16.4
	SIX EASY STEPS rate – DYP 180	**210**	**102**	**16.4**	**16.6**
	Grower rate	250	101	16.0	16.2

** This rate is 20 kg N/ha below Six Easy Steps DYP 150*

Revenue less fertiliser, harvesting costs and levies over full crop cycle



This trial site was generally well managed over the duration of the crop cycle. The crop was established with few gaps. The incidence of weeds was low to moderate.

The difficulty for the grower at this site is its very sandy, low organic carbon soil, which is prone to leaching, has poor water holding capacity and a very low cation exchange capacity, which limits the ability of the soil to hold on to essential nutrients such as potassium, calcium and magnesium.

Due to the remote location of this site there are limited options for importing organic material such as mill mud to improve organic carbon levels.

Trial results – Site 5

Queensland Government

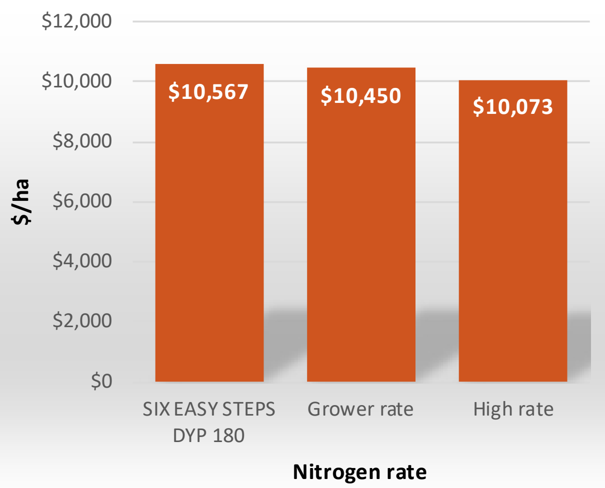
Sugar Research Australia

BRIA farm

Soil type	QDPI soil type	Organic carbon
Sodic Duplex	6Drc	0.87%
Soil texture	**Crop variety**	
Loam	Q200⁽ᴰ⁾	

Mean results for tonnes of cane, sugar and CCS for each nitrogen treatment					
		Treatment kg N/ha	Cane yield TCH	CCS units	Sugar yield TSH
Plant crop *Date planted: 10/09/2012* *Date harvested: 02/10/2013*	**SIX EASY STEPS rate – DYP 180**	**170**	**94**	**15.4**	**14.5**
	Grower rate	210	95	15.4	14.7
	High rate	250	96	15.2	14.7
1st Ratoon *Date harvested: 07/10/2014*	**SIX EASY STEPS rate – DYP 180**	**210**	**132**	**14.8**	**19.5**
	Grower rate	250	135	14.6	19.7
	High rate	290	135	14.8	20.0
2nd Ratoon *Date harvested: 19/10/2015*	**SIX EASY STEPS rate – DYP 180**	**210**	**123**	**15.9**	**19.5**
	Grower rate	250	125	15.8	19.7
	High rate	290	121	15.7	19.0
3rd Ratoon *Date harvested: 20/11/2016*	**ENTEC (very low)**	150	95	15.2	14.4
	SIX EASY STEPS rate – DYP 150	170	95	15.0	14.3
	SIX EASY STEPS rate – DYP 180	**210**	**90**	**14.9**	**13.5**

Revenue less fertiliser, harvesting costs and levies from plant to 2nd ratoon*



** 3rd ratoon excluded from this graph as different treatments were used*

The crop was established with some gaps throughout the trial site and the gaps were large enough to have negatively impacted yields to some degree. The incidence of gaps was randomly distributed across the block.

Weed management was reasonable however the incidence of weeds did increase in later ratoons. Irrigation management was fair however there were periods where irrigation frequency was less than optimum to achieve maximum cane yield at this site.

Higher rates of N had a negative impact on CCS in the plant crop.

Trial results – Site 6

Queensland Government

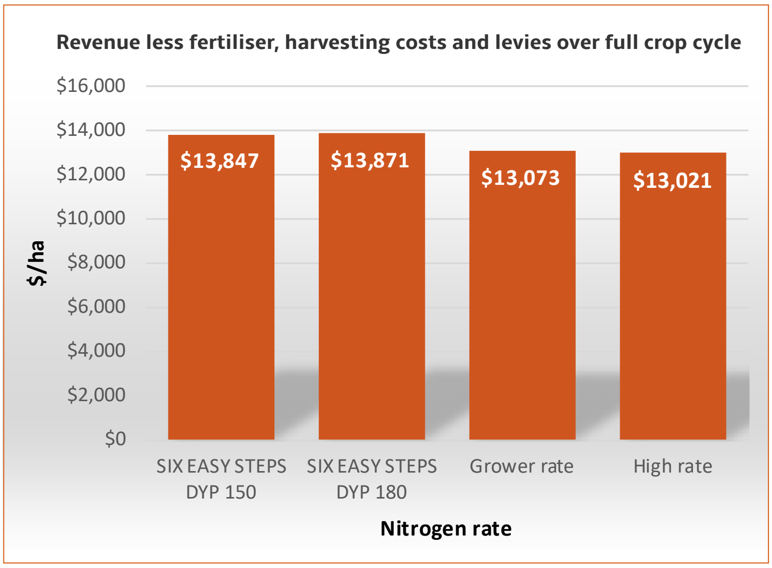
Sugar Research Australia

BRIA farm

Soil type	QDPI soil type	Organic carbon
Sodic Duplex	2Dyb	0.77%
Soil texture	**Crop variety**	
Clay	Q183⁽ᵈ⁾	

Mean results for tonnes of cane, sugar and CCS for each nitrogen treatment

		Treatment kg N/ha	Cane yield TCH	CCS units	Sugar yield TSH
Plant crop *Date planted: 16/05/2011* *Date harvested: 20/06/2012*	SIX EASY STEPS rate – DYP 150	130	106	13.7	14.4
	SIX EASY STEPS rate – DYP 180	**170**	**111**	**13.3**	**14.8**
	Grower rate	210	113	12.8	14.5
	High rate	250	113	12.8	14.9
1st Ratoon *Date harvested: 26/06/2013*	SIX EASY STEPS rate – DYP 150	170	112	15.0	16.8
	SIX EASY STEPS rate – DYP 180	**210**	**122**	**14.8**	**18.1**
	Grower rate	250	126	14.2	17.8
	High rate	290	124	14.3	17.8
2nd Ratoon *Date harvested: 03/11/2014*	SIX EASY STEPS rate – DYP 150	170	108	17.4	18.8
	SIX EASY STEPS rate – DYP 180	**210**	**111**	**17.3**	**19.2**
	Grower rate	250	116	16.5	19.1
	High rate	290	117	16.6	19.4
3rd Ratoon *Date harvested: 07/07/2015*	SIX EASY STEPS rate – DYP 150	170	80	14.7	11.7
	SIX EASY STEPS rate – DYP 180	**210**	**75**	**14.7**	**11.0**
	Grower rate	250	76	14.3	10.8
	High rate	290	76	14.0	10.7



This trial site was generally well managed. The crop was established with few gaps and weed management was good over the four seasons. Irrigation management appeared to be generally adequate.

Higher N rates had a negative impact on CCS in the 1st and 2nd ratoon crops.

Trial results – Site 8

Queensland Government

Sugar Research Australia

BRIA farm

Soil type
Sodic Duplex

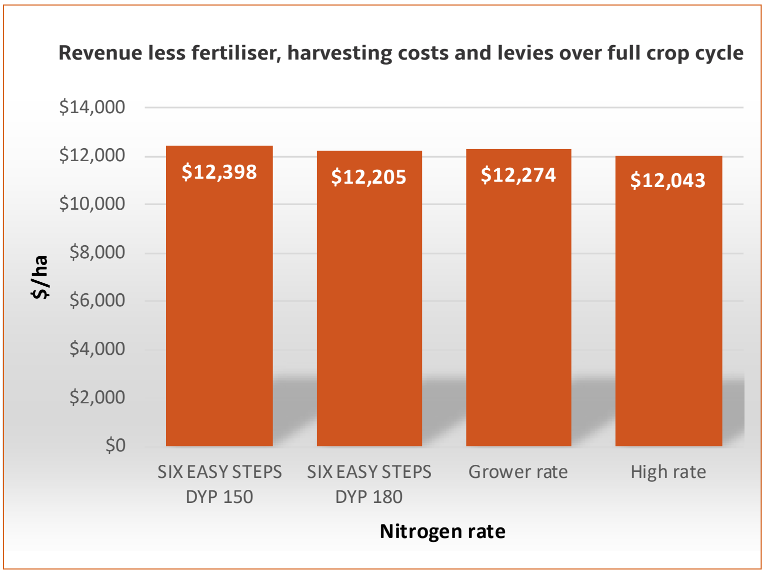
Soil texture
Clay loam

QDPI soil type
2Dyb

Crop variety
Q208⯑

Organic carbon
0.6%

Mean results for tonnes of cane, sugar and CCS for each nitrogen treatment					
		Treatment kg N/ha	Cane yield TCH	CCS units	Sugar yield TSH
Plant crop *Date planted: 16/05/2011* *Date harvested: 08/09/2012*	**SIX EASY STEPS rate – DYP 150**	130	126	15.9	20.0
	SIX EASY STEPS rate – DYP 180	**170**	**131**	**15.5**	**20.3**
	Grower rate	210	134	15.6	20.9
	High rate	250	136	15.6	21.2
1st Ratoon *Date harvested: 06/09/2013*	**SIX EASY STEPS rate – DYP 150**	170	79	16.2	12.8
	SIX EASY STEPS rate – DYP 180	**210**	**82**	**16.2**	**13.3**
	Grower rate	250	84	16.2	13.6
	High rate	290	85	16.0	13.6
2nd Ratoon *Date harvested: 16/10/2014*	**SIX EASY STEPS rate – DYP 150**	170	79	17.3	13.7
	SIX EASY STEPS rate – DYP 180	**210**	**82**	**17.1**	**14.0**
	Grower rate	250	81	17.2	14.0
	High rate	290	86	16.9	14.4
3rd Ratoon *Date harvested: 05/10/2015*	**SIX EASY STEPS rate – DYP 150**	170	84	18.1	15.1
	SIX EASY STEPS rate – DYP 180	**210**	**81**	**18.2**	**14.7**
	Grower rate	250	85	18.0	15.4
	High rate	290	85	17.9	15.3



The plant crop was established with few gaps and weed management was good over the four crop stages.

Prior to planting, gypsum was applied to this block at a rate of 5 tonnes/ha.

Soil moisture monitoring data collected during the development of the 3rd ratoon crop along with general observations over the duration of the trail indicated that irrigation management practices could be adjusted to improve productivity at this site.

Trial results – Site 9

Queensland Government

Sugar Research Australia

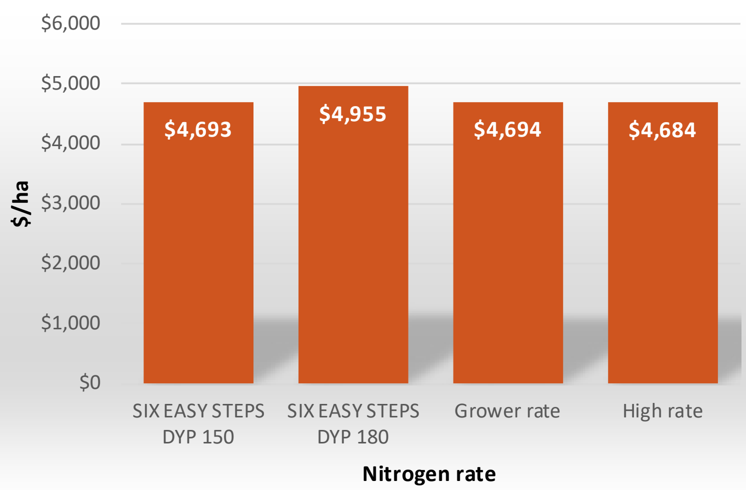
BRIA farm

Soil type	QDPI soil type	Organic carbon
Vertosol	2Ugd	0.59%
Soil texture	**Crop variety**	
Clay	KQ228$^{\Phi}$	

Mean results for tonnes of cane, sugar and CCS for each nitrogen treatment

		Treatment *kg N/ha*	Cane yield *TCH*	CCS *units*	Sugar yield *TSH*
Plant crop *Date planted: 23/05/2011* *Date harvested: 23/10/2012*	**SIX EASY STEPS rate – DYP 150**	130	90	16.7	15.0
	SIX EASY STEPS rate – DYP 180	**170**	**96**	**17.0**	**16.3**
	Grower rate	210	95	16.7	15.9
	High rate	250	96	16.8	16.1
1st Ratoon *Date harvested: 10/09/2013*	**SIX EASY STEPS rate – DYP 150**	170	59	16.2	9.5
	SIX EASY STEPS rate – DYP 180	**210**	**60**	**16.2**	**9.6**
	Grower rate	250	60	16.0	9.7
	High rate	290	61	16.1	9.8

Revenue less fertiliser, harvesting costs and levies for plant and 1st ratoon



The crop was established with a considerable number of gaps randomly distributed throughout the block. Weed management was fair over the duration of the trial at this site.

Prior to planting gypsum was applied to this block at a rate of 5 tonnes/ha.

Trial results – Site 11

Queensland Government

Sugar Research Australia

BRIA farm

Soil type
Sodic Duplex

Soil texture
Loam

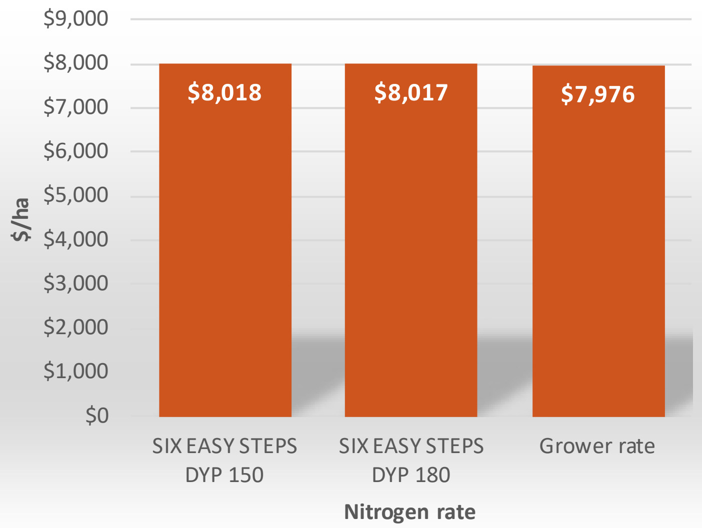
QDPI soil type
6Drc

Crop variety
KQ228⁽ᴾ⁾

Organic carbon
0.9%

Mean results for tonnes of cane, sugar and CCS for each nitrogen treatment					
		Treatment *kg N/ha*	Cane yield *TCH*	CCS *units*	Sugar yield *TSH*
Plant crop *Date planted: 05/05/2011* *Date harvested: 19/08/2012*	**SIX EASY STEPS rate – DYP 150**	130	127	15.6	19.8
	SIX EASY STEPS rate – DYP 180	**170**	**137**	**15.1**	**20.6**
	Grower rate	210	142	14.8	21.1
1st Ratoon *Date harvested: 13/07/2013*	**SIX EASY STEPS rate – DYP 150**	170	106	15.4	16.3
	SIX EASY STEPS rate – DYP 180	**210**	**111**	**15.0**	**16.7**
	Grower rate	250	114	14.8	16.8

Revenue less fertiliser, harvesting costs and levies for plant and 1st ratoon



At this trial site row spacing was 1.5m with a controlled traffic system in place as standard farming practice.

The crop was established with few gaps and weed management was good over the duration of the trial.

The plant crop yielded considerably better than the first ratoon crop. The change in productivity is likely due to a change in irrigation management at this site.

Trial results – Site 17

Queensland Government

Sugar Research Australia

BRIA farm

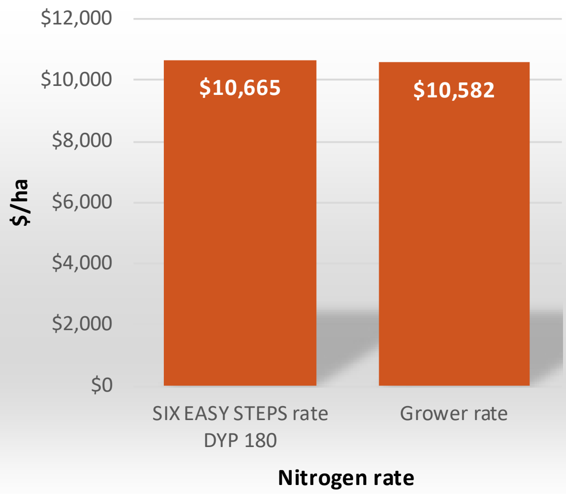
Soil type	QDPI soil type	Organic carbon
Sodic Duplex	6Drc	0.91%
Soil texture	**Crop variety**	
Loam	Q183	

Mean results for tonnes of cane, sugar and CCS for each nitrogen treatment

		Treatment kg N/ha	Cane yield TCH	CCS units	Sugar yield TSH
Plant crop *Date planted:20/04/2014* *Date harvested: 28/06/2015*	**SIX EASY STEPS rate – DYP 180**	**150***	**182**	**13.3**	**24.3**
	Grower rate	190	181	13.1	23.7
	High rate	240	183	13.4	24.4
1st Ratoon *Date harvested: 12/06/2016*	**SIX EASY STEPS rate – DYP 150**	160	150	12.5	18.8
	SIX EASY STEPS rate – DYP 180	**200**	**157**	**11.9**	**18.8**
	Grower rate	240	158	12.3	19.4

** This is 10 kg N/ha below SIX EASY STEPS rate DYP 180*

Revenue less fertiliser, harvesting costs and levies for plant and 1st ratoon



This graph compares only two rates as the grower requested low rate be examined in the 1st ratoon crop.

This trial site was managed according to best management principles. The crop was established with few gaps, and weed and irrigation management was good over the two crop stages that were part of the trial.

Good farm management practices combined with good soil fertility has allowed this grower to achieve consistent cane and sugar yields at this site.

Trial results – Site 18

Queensland Government

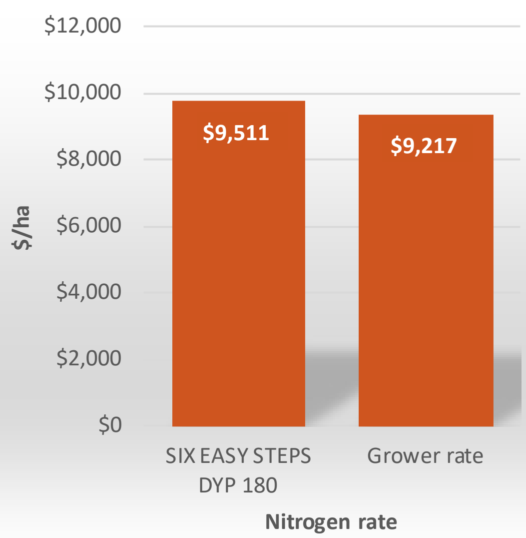
Sugar Research Australia

BRIA farm

Soil type	QDPI soil type	Organic carbon
Vertosol	2Ugd	0.8%
Soil texture	**Crop variety**	
Clay	Q240	

Mean results for tonnes of cane, sugar and CCS for each nitrogen treatment					
		Treatment *kg N/ha*	**Cane yield** *TCH*	**CCS** *units*	**Sugar yield** *TSH*
Plant crop *Date planted: 19/05/2014* *Date harvested: 07/07/2015*	**SIX EASY STEPS rate – DYP 180**	**160**	**163**	13.6	**22.2**
	Grower rate	200	163	13.6	22.1
	High rate	240	161	13.4	21.5
1st Ratoon *Date harvested: 07/09/2016*	**SIX EASY STEPS rate – DYP 150**	160	141	15.0	21.2
	SIX EASY STEPS rate – DYP 180	**200**	**149**	**15.1**	**22.4**
	Grower rate	240	150	14.7	22.1

Revenue less fertiliser, harvesting costs and levies for plant and 1st ratoon



** This graph compares only two rates as the high rate treatment was not continued in the 1st ratoon crop.*

This trial site was managed according to best management principles. The crop was established with few gaps, weed and irrigation management was good over the two crop stages which were part of the trial.

Good farm management practices combined with fair soil fertility has allowed this grower to achieve good consistent cane and sugar yields over the duration of the trial.

Trial results – Site 20

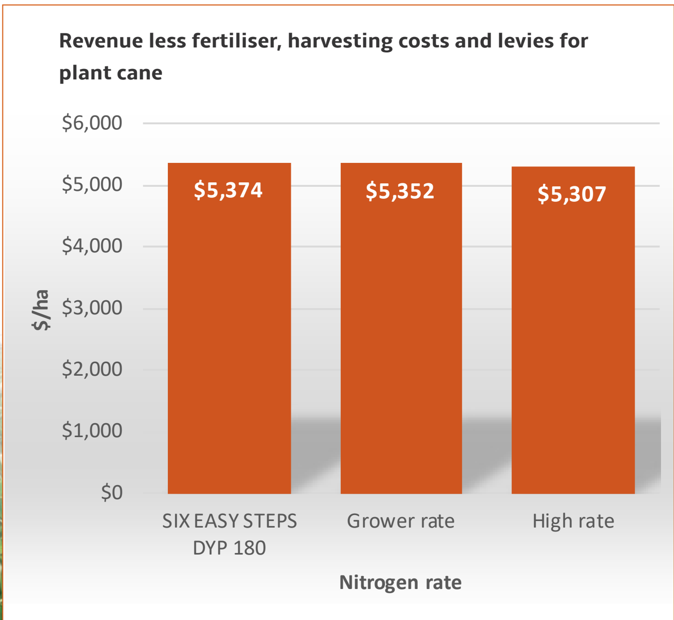
Queensland Government

Sugar Research Australia

BRIA farm

Soil type	QDPI soil type	Organic carbon
Sodic Duplex	2Dyb	0.9%
Soil texture	**Crop variety**	
Clay	Q252	

Mean results for tonnes of cane, sugar and CCS for each nitrogen treatment					
		Treatment *kg N/ha*	**Cane yield** *TCH*	**CCS** *units*	**Sugar yield** *TSH*
Plant crop *Date planted: 06/03/2015* *Date harvested: 15/09/2016*	**SIX EASY STEPS rate – DYP 180**	**160**	**160**	**16.2**	**25.9**
	Grower rate	200	164	16.0	26.2
	High rate	240	167	15.8	26.4



At this trial site, row spacing was 1.8m with a dual row of cane as standard farming practice.

This trial site was managed according to best management principles. The crop was established with few gaps, and effective weed and irrigation management.

Good farm management practices have enabled this grower to achieve good yields.

Trial results – Site 22

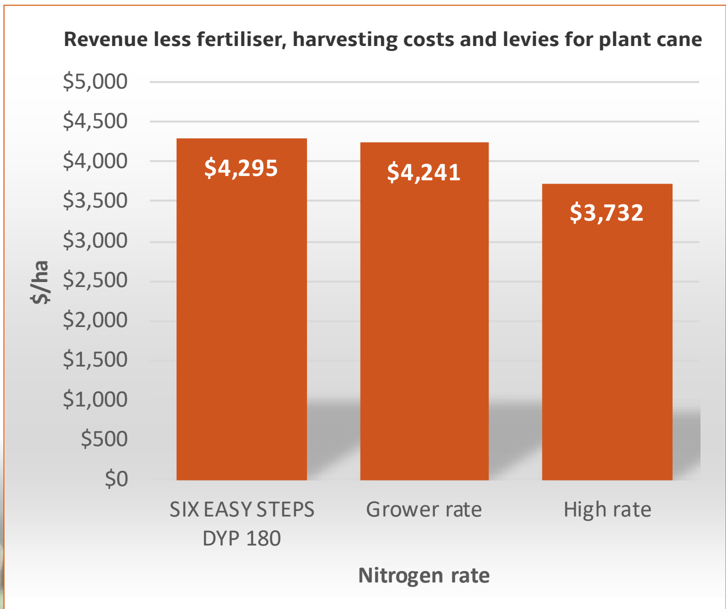
BRIA farm

Soil type	QDPI soil type	Organic carbon
Vertosol	2Ugd	0.85%
Soil texture	**Crop variety**	
Clay	Q253⫯	

Mean results for tonnes of cane, sugar and CCS for each nitrogen treatment

		Treatment *kg N/ha*	Cane yield *TCH*	CCS *units*	Sugar yield *TSH*
Plant crop *Date planted: 20/03/2015* *Date harvested: 17/06/2016*	**SIX EASY STEPS rate – DYP 180**	**170***	**163**	**11.9**	**19.4**
	Grower rate	240	174	11.5	20.0
	High rate	290	169	11.1	18.7

** This is 10 kg N/ha above 6ES*

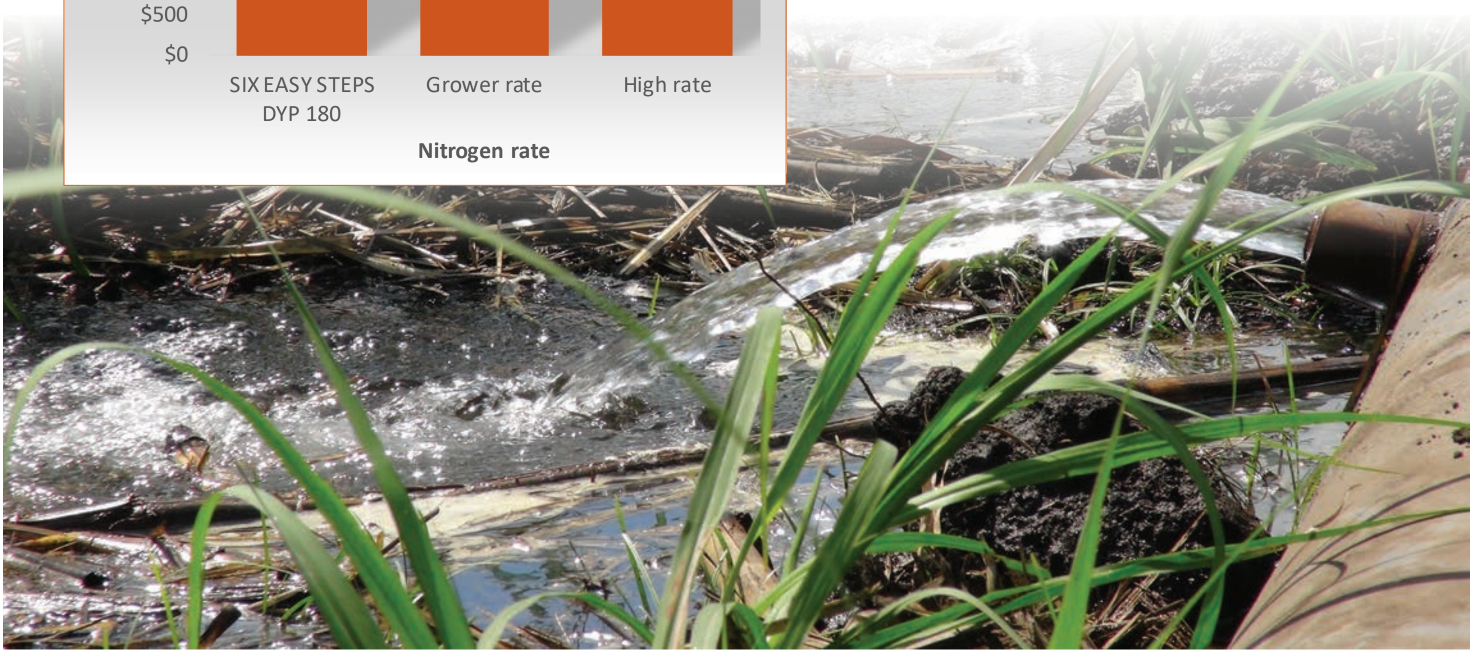


This trial site was managed according to best management principles.

The crop was established with few gaps, and good weed and irrigation management.

Good farm management practices have allowed this grower to achieve good yields in a soil which is considered to be difficult to manage in the BRIA.

There was a significant decline in CCS with higher N application rates.



Case Studies

DELTA

The benefits and results that each grower has taken from the trial vary, however there is one factor that is consistent – the SIX EASY STEPS method is shown to produce the best financial outcome.

The following case studies compare the amount of nitrogen that the grower used before being involved in the trial with the SIX EASY STEPS rate, calculated using a district yield potential (DYP) of 180 tc/ha.

These parameters have been used to calculate costs and revenue in the following case studies:

Key parameters	
Sugar price	$424/tonne, (5-year average, 2011-15)
Relative CCS	Actual ccs – daily pool ccs + seasonal pool ccs
Cane payment formula (cane price)	$424 x 0.009 x (CCS-4) + 0.662
Gross revenue	Cane price x tonnes cane per hectare
Harvesting cost + levies	$8.11/tonne, ex GST
Fertiliser prices	Sourced from local supplier, ex GST

Site 3 (Delta)

Increasing profitability through changed management practices

Delta farm

Location
Airville

Variety
KQ228$^{\phi}$

Soil group
BUfc

Soil type
Dermosol

Soil texture
Loam

Organic carbon
0.9%

Total area of trial block
5.1 hectares

Jim had been concerned for some time that his sugar levels had been supressed, which is something that had also concerned his father before him. When he heard about the RP20 project he was keen to become involved to see if these trials could give him some answers.

Before the trials, he had been getting regular soil tests carried out but admits that the amount of nitrogen he was applying was based more on history rather than the results of the soil tests, with maximum rates traditionally close to the high rate applied during the trials.

There are two distinct zones in this block which have different soil chemical and physical properties. Crop vigour appeared to vary according to these zones.

Jim felt that there was a benefit in applying lime as he believed that he got better water penetration. Lime was applied to the 3rd and 4th ratoons and the watering regime was increased. He believes that this made a significant difference to the 4th ratoon results. For this block, the key was to improve water penetration so that the fertiliser that was being applied could work effectively.

In the past, this grower had applied lime but decided to cut it out when the financial situation didn't allow it. He now realises that perhaps he should have cut down on the fertiliser rather than the lime.

"For a long time we only put nitrogen on. We now realise that we should have been focusing on other things as well, like potassium and lime. These trials have proved to me that it's a combination of everything that makes the difference, not just nitrogen."

Differences in profitability over crop cycle – excluding 3rd ratoon

Fertiliser cost savings over trial block when comparing SIX EASY STEPS with high rate (over full crop cycle excl. 3rd ratoon*)	
Fertiliser cost high rate ($/ha)	$2,232
Fertiliser cost SIX EASY STEPS rate ($/ha)	$1,682
Fertiliser cost saving ($/ha)	$550
Fertiliser cost saving over trial block ($)	**$2,806**

Potential improvement in earnings over trial block when comparing SIX EASY STEPS with high rate (over full crop cycle excl. 3rd ratoon*)	
Revenue less HC&L* high rate ($/ha)	$19,143
Revenue less HC&L* SIX EASY STEPS rate ($/ha)	$19,096
Potential increase in earnings ($/ha)	-$47
Potential increase in earnings over trial block ($)	**-$238**

** 3rd ratoon excluded as data from one strip only presented for each treatment due to loss of rake data*

Increase in block profitability: $2,568

Potential increase in profitability over 100 hectares: $50,356

** Revenue less HC&L refers to revenue less harvesting costs and levies. Potential savings and increase in return will be dependent on environmental and seasonal factors such as soil variation across the farm, rainfall, management methods, harvest conditions. All prices are excluding GST.* ***This case study compares the amount of nitrogen that the grower used before being involved in the trial with the SIX EASY STEPS rate calculated using DYP 180.***

Site 3 (Delta)

Queensland Government

Sugar Research Australia

		Treatment *kg N/ha*	Cane yield *TCH*	CCS *units*	Sugar yield *TSH*	Relative CCS *units*	Gross revenue *$/ha*	Fertiliser costs *$/ha*	Harvesting costs + levies *$/ha*	Net revenue *$/ha*
Plant crop *Date planted: 06/05/2011* *Date harvested: 24/08/2012*	SIX EASY STEPS rate DYP 150	130	153	13.5	20.7	14.1	$5,983	$315	$1,241	$4,427
	SIX EASY STEPS rate DYP 180	170	157	13.2	20.8	13.8	$5,963	$371	$1,275	$4,318
	Grower rate	210	163	12.8	21.0	13.4	$5,953	$426	$1,325	$4,201
	High rate	250	163	12.6	20.6	13.1	$5,798	$482	$1,325	$3,991
1st Ratoon *Date harvested: 17/07/2013*	SIX EASY STEPS rate DYP 150	170	151	14.3	21.5	14.4	$6,068	$347	$1,221	$4,500
	SIX EASY STEPS rate DYP 180	210	153	14.2	21.8	14.3	$6,119	$429	$1,243	$4,446
	Grower rate	250	159	13.9	22.1	14.0	$6,182	$511	$1,289	$4,382
	High rate	290	163	13.5	21.9	13.6	$6,048	$593	$1,318	$4,137
2nd Ratoon *Date harvested: 04/08/2014*	SIX EASY STEPS rate DYP 150	170	143	15.2	21.9	14.9	$6,084	$347	$1,163	$4,573
	SIX EASY STEPS rate DYP 180	210	146	15.2	22.1	14.9	$6,154	$429	$1,180	$4,545
	Grower rate	250	151	15.1	22.7	14.8	$6,296	$511	$1,221	$4,564
	High rate	290	154	14.9	22.9	13.2	$6,328	$593	$1,250	$4,485
3rd Ratoon * *Date harvested: 02/07/2015*	SIX EASY STEPS rate DYP 150	170	156	12.8	19.9	14.1	$6,098	$347	$1,262	$4,489
	SIX EASY STEPS rate DYP 180	210	146	12.7	18.5	14.0	$5,652	$429	$1,181	$4,042
	Grower rate	250	143	12.6	18.0	13.9	$5,492	$511	$1,159	$3,821
	High rate	290	143	12.3	17.5	13.5	$5,289	$593	$1,156	$3,540
4th Ratoon *Date harvested: 07/07/2016*	SIX EASY STEPS rate DYP 150	170	167	11.7	19.6	13.0	$5,847	$397	$1,357	$4,093
	SIX EASY STEPS rate DYP 180	210	167	11.8	19.8	13.1	$5,915	$453	$1,357	$4,106
	Grower rate	250	180	11.8	21.2	13.0	$6,331	$509	$1,462	$4,360
	High rate	290	181	11.7	21.2	13.0	$6,332	$564	$1,469	$4,298

** Data presented is from one strip only for each treatment due to loss of rake data*
DYP 150 – District yield potential of 150 tc/ha
DYP 180 – District yield potential of 180 tc/ha

Comparison of trial site and Productivity Group	
Productivity Group average 2012-2016 (TCH)	122.6
Trial block average SIX EASY STEPS rate (TCH)	153.8

Site 14 (Delta)

Continuous improvement through getting the right balance between tonnes and CCS

Delta farm

Location
Brandon

Variety
Q183⊕

Soil type
Dermosol

Soil texture
Loam

QDPI Soil type
BUfb

Organic carbon
0.81%

Total area of trial block
4.85 ha

As someone who had sought agronomic advice in the past to plan for particular farm management practices, Frank went into the trials with an open mind, to see for himself which nitrogen rate would give him the best value for money on his farm. He wasn't sure what to expect but was willing to accept the results.

After having conducted the trials on his farm for a full crop cycle (from plant cane to 3rd ratoon), the outcome was better than Frank expected. Not only did the trials allow this grower to determine which nitrogen rate would provide him with the best outcome, he was encouraged to look at his other farming practices and determine how these were affecting his crop.

During the first year of the trial, compaction was identified as a limiting factor on his farm, due to the weather conditions experienced in previous years. He was advised to work the ground after the first ratoon was harvested, which he believes led to an increase of at least 25% in crop yield.

This farm had moisture probes in two locations during the trial, which gave the grower valuable data and a good indication of how his irrigation management system was working.

"Throughout the trial, Julian (SRA Agronomist) discussed all trial data with me and we spoke about matching the fertiliser with crop requirements. This led me to improve some of my management practices, such as the timing of fertiliser application."

In 2015, this grower fine tuned his fertiliser application through later application of fertiliser so that the nitrogen was accessible to the crop at the right time. *"I was willing to take the extra cost I would incur by applying the fertiliser later and I was happy with the result. I feel I now have the balance right between tonnes and CCS and have grown record tonnes that I believe are a result of focusing on my management practices. I have a benchmark now of what I'm capable of producing on my farm. I know that I can improve on what I've gained from being part of these trials and am excited about striving for continuous improvement."*

Differences in profitability over full crop cycle – plant cane to 2nd ratoon

Fertiliser cost savings over trial block when comparing SIX EASY STEPS with high rate (plant to 2nd ratoon)	
Fertiliser cost high rate ($/ha)	$1,999
Fertiliser cost SIX EASY STEPS rate ($/ha)	$1,495
Fertiliser cost saving ($/ha)	$504
Fertiliser cost saving over trial block ($)	**$2,446**

Potential improvement in earnings over trial block when comparing SIX EASY STEPS with high rate (plant to 2nd ratoon)	
Revenue less HC&L* high rate ($/ha)	$13,552
Revenue less HC&L* SIX EASY STEPS rate ($/ha)	$13,677
Potential increase in earnings ($/ha)	$126
Potential increase in earnings over trial block ($)	**$609**

Increase in block profitability: $3,055

Potential increase in profitability over 100 hectares: $62,994

** Revenue less HC&L refers to revenue less harvesting costs and levies. Potential savings and increase in return will be dependent on environmental and seasonal factors such as soil variation across the farm, rainfall, management methods, harvest conditions. All prices are excluding GST.* ***This case study compares the amount of nitrogen that the grower used before being involved in the trial with the SIX EASY STEPS rate calculated using DYP 180.***

Site 14 (Delta)

Queensland Government

Sugar Research Australia

		Treatment kg N/ha	Cane yield TCH	CCS units	Sugar yield TSH	Relative CCS units	Gross revenue $/ha	Fertiliser costs $/ha	Harvesting costs + levies $/ha	Net revenue $/ha
Plant crop *Date planted: 06/08/2012* *Date harvested: 11/07/2013*	**SIX EASY STEPS rate DYP 180**	**170**	**108**	**15.1**	**16.2**	**15.7**	**$4,866**	**$608**	**$876**	**$3,381**
	Grower rate	210	108	14.8	15.9	15.4	$4,759	$692	$877	$3,190
	High rate	250	106	14.8	15.6	15.4	$4,656	$775	$859	$3,023
1st Ratoon *Date harvested: 05/09/2014*	**SIX EASY STEPS rate DYP 180**	**210**	**145**	**14.7**	**21.3**	**14.5**	**$5,908**	**$432**	**$1,178**	**$4,298**
	Grower rate	250	148	14.6	21.5	14.4	$5,925	$515	$1,197	$4,212
	High rate	290	149	14.6	21.7	14.4	$5,995	$597	$1,210	$4,188
2nd Ratoon *Date harvested: 07/08/2015*	**SIX EASY STEPS rate DYP 180**	**210**	**141**	**15.0**	**21.0**	**15.3**	**$6,097**	**$454**	**$1,140**	**$4,504**
	Grower rate	250	137	15.2	20.7	15.5	$6,024	$541	$1,109	$4,375
	High rate	290	137	15.3	20.9	15.6	$6,082	$627	$1,113	$4,342
3rd Ratoon *Date harvested: 19/09/2016*	**SIX EASY STEPS rate DYP 150**	170	146	14.7	21.3	13.7	$5,826	$369	$1,257	$4,200
	SIX EASY STEPS rate DYP 180	**210**	**145**	**14.6**	**21.0**	**13.6**	**$5,730**	**$424**	**$1,246**	**$4,060**
	Grower rate	250	145	14.5	20.9	13.6	$5,692	$480	$1,247	$3,964

DYP 150 – District yield potential of 150 tc/ha
DYP 180 – District yield potential of 180 tc/ha

Comparison of trial site and Productivity Group	
Productivity Group average 2013-2016 (TCH)	129.66
Trial block average SIX EASY STEPS rate (TCH)	136.85

Site 21 (Delta)

Fertiliser management on large crops

Delta farm

Location
Brandon

Variety
Q208⁽ᴰ⁾

Soil type
Dermosol

Soil texture
Loam

QDPI Soil type
BUfc

Organic carbon
1.3%

Total area of trial block
8 ha

Located on some of the most fertile soil in the Burdekin, this farm has historically produced high tonnes with reasonable CCS. A self-proclaimed high nitrogen user before joining the trials, this grower was concerned that he would no longer be as productive if he was to reduce the amount of nitrogen that he applied to his crop. He believed that a large crop required a large amount of nitrogen.

With an ideal growing year in 2015, the plant crop was harvested in 2016 with exceptional results. The tonnes across the various treatments showed little difference, with the tonnes of sugar improving from the lower nitrogen rate treatments.

The trials showed that past practices may not always have achieved the best result. In some cases, the grower believes the large quantities of nitrogen being applied were likely to suppress sugar as the crop was not given the opportunity to mature towards the end of the growing cycle. Instead, the large amounts of nitrogen were encouraging the crop to grow more biomass at this time.

"I now believe that I have the right balance to maximise profitability on my farm. Being involved in this trial has shown me that nitrogen is not driving my crop. It's about getting all of the various farm management practices in balance based on the crop and my soil type."

After fine tuning other management practices such as timing of fertiliser application, irrigation management and weed control, this grower says his focus has shifted.

"I'm seeing the whole picture now as being crucial to growing the best crop I can. Using the SIX EASY STEPS along with good farm management practices will ensure that I have a profitable business into the future."

Differences in profitability in the plant crop

Fertiliser cost savings over trial block when comparing SIX EASY STEPS with high rate (plant crop)	
Fertiliser cost high rate ($/ha)	$501
Fertiliser cost SIX EASY STEPS rate ($/ha)	$389
Fertiliser cost saving ($/ha)	$112
Fertiliser cost saving over trial block ($)	**$894**

Potential improvement in earnings over trial block when comparing SIX EASY STEPS with high rate (plant crop)	
Revenue less HC&L* high rate ($/ha)	$7,409
Revenue less HC&L* SIX EASY STEPS rate ($/ha)	$7,863
Potential increase in earnings ($/ha)	$454
Potential increase in earnings over trial block ($)	**$3,635**

Increase in block profitability: $4,529

Potential increase in profitability over 100 hectares: $56,611

** Revenue less HC&L refers to revenue less harvesting costs and levies. Potential savings and increase in return will be dependent on environmental and seasonal factors such as soil variation across the farm, rainfall, management methods, harvest conditions. All prices are excluding GST.* ***This case study compares the amount of nitrogen that the grower used before being involved in the trial with the SIX EASY STEPS rate calculated using DYP 180.***

Site 21 (Delta)

Queensland Government

Sugar Research Australia

		Treatment kg N/ha	Cane yield TCH	CCS units	Sugar yield TSH	Relative CCS units	Gross revenue $/ha	Fertiliser costs $/ha	Harvesting costs + levies $/ha	Net revenue $/ha
Plant crop *Date planted:* *06/03/2015* *Date harvested:* *26/08/2016*	**SIX EASY STEPS rate DYP 180**	**160**	**258**	12.9	**33.3**	**14.0**	**$9,959**	**$389**	**$2,096**	**$7,474**
	Grower rate	200	258	12.5	32.2	13.5	$9,518	$445	$2,096	$6,977
	High rate	240	262	12.3	32.3	13.4	$9,537	$501	$2,128	$6,908

DYP 150 – District yield potential of 150 tc/ha
DYP 180 – District yield potential of 180 tc/ha

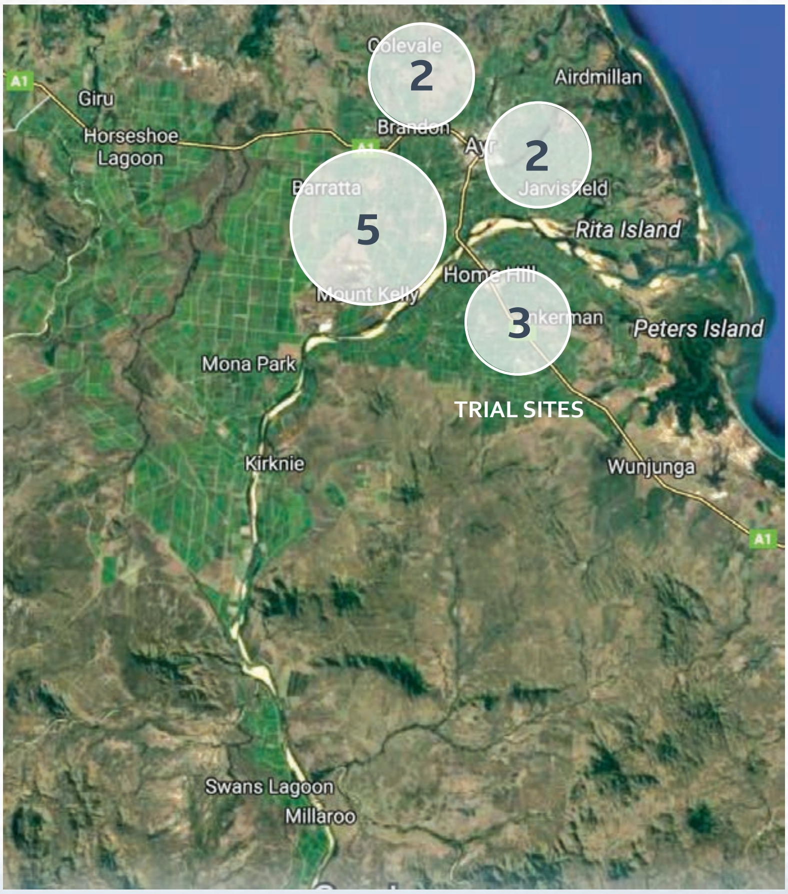
Comparison of trial site and Productivity Group	
Productivity Group average 2016 (TCH)	138.76
Trial block plant cane SIX EASY STEPS rate (TCH)	258.00

Trial Results

Delta

The following trial results include all trials for the duration of the project.

The trials cover all major soil types to ensure that findings of this project are applicable to all sugarcane growers in the Burdekin region.



The graphs contained in the following trial results use Relative CCS to calculate revenue.

Trial results – Site 1

Queensland Government

Sugar Research Australia

Delta farm

Soil type
Dermosol

Soil texture
Loam

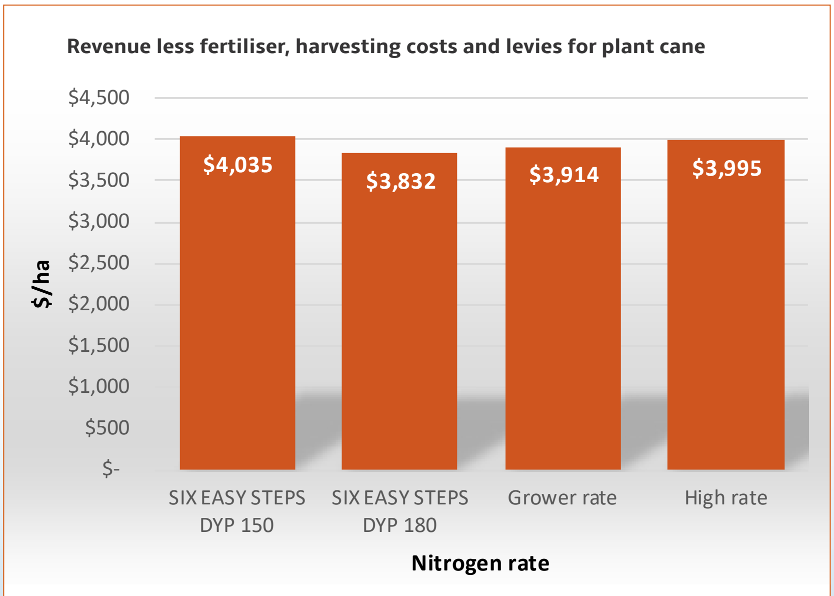
QDPI soil type
BUfb

Crop variety
Q208

Organic carbon
0.89%

Mean results for tonnes of cane, sugar and CCS for each nitrogen treatment

		Treatment *kg N/ha*	Cane yield *TCH*	CCS *units*	Sugar yield *TSH*
Plant crop *Date planted: 03/05/2011* *Date harvested: 20/09/2012*	**SIX EASY STEPS rate – DYP 150**	130	125	15.4	19.2
	SIX EASY STEPS rate – DYP 180	**170**	**118**	**15.6**	**18.5**
	Grower rate	210	128	15.2	19.5
	High rate	250	132	15.2	20.2



This trial site was generally well managed.

The crop was established with few gaps and weed management was good over the development of the plant crop.

In general irrigation management appeared to be adequate however crop vigour appeared to vary considerably throughout the block.

Trial results – Site 3

Queensland Government

Sugar Research Australia

Delta farm

Soil type
Dermosol

Soil texture
Loam

QDPI soil type
BUfc

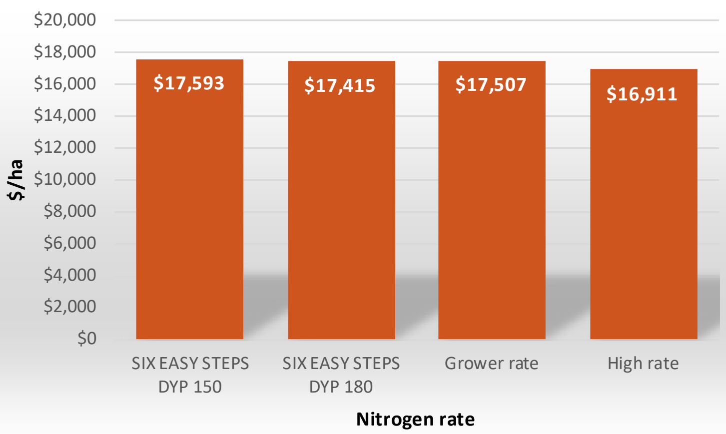
Crop variety
KQ228⌽

Organic carbon
0.9%

Mean results for tonnes of cane, sugar and CCS for each nitrogen treatment					
		Treatment *kg N/ha*	**Cane yield** *TCH*	**CCS** *units*	**Sugar yield** *TSH*
Plant crop *Date planted: 06/05/2011* *Date harvested: 24/08/2012*	SIX EASY STEPS rate – DYP 150	130	153	13.5	20.7
	SIX EASY STEPS rate – DYP 180	**170**	**157**	**13.2**	**20.8**
	Grower rate	210	163	12.8	21.0
	High rate	250	163	12.6	20.6
1st Ratoon *Date harvested: 17/07/2013*	SIX EASY STEPS rate – DYP 150	170	151	14.3	21.5
	SIX EASY STEPS rate – DYP 180	**210**	**153**	**14.2**	**21.8**
	Grower rate	250	159	13.9	22.1
	High rate	290	163	13.5	21.9
2nd Ratoon *Date harvested: 04/08/2014*	SIX EASY STEPS rate – DYP 150	170	143	15.2	21.9
	SIX EASY STEPS rate – DYP 180	**210**	**146**	**15.2**	**22.1**
	Grower rate	250	151	15.1	22.7
	High rate	290	154	14.9	22.9
3rd Ratoon *Date harvested: 02/07/2015*	SIX EASY STEPS rate – DYP 150	170	156	12.8*	19.9
	SIX EASY STEPS rate – DYP 180	**210**	**146**	**12.7***	**18.5**
	Grower rate	250	143	12.6*	18.0
	High rate	290	143	12.3*	17.5
4th Ratoon *Date harvested: 07/07/2016*	SIX EASY STEPS rate – DYP 150	170	167	11.7	19.6
	SIX EASY STEPS rate – DYP 180	**210**	**167**	**11.8**	**19.8**
	Grower rate	250	180	11.8	21.2
	High rate	290	181	11.7	21.2

** Data from one strip only presented for each treatment due loss of rake data*

Revenue less fertiliser, harvesting costs and levies over full crop cycle excluding 3rd ratoon



This trial site was generally managed according to best management principles.

The crop was established with few gaps and weed management was good over the five seasons.

Good farm management practices combined with good soil fertility and in general good irrigation management have allowed this grower to achieve consistent cane and sugar yields over the duration of the trials.

Trial results – Site 4

Queensland Government

Sugar Research Australia

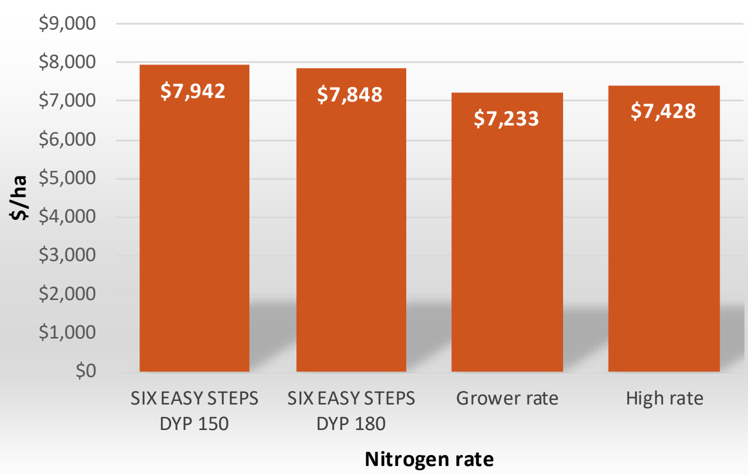
Delta farm

Soil type	**QDPI soil type**	**Organic carbon**
Dermosol	BUmd	0.99%
Soil texture	**Crop variety**	
Loam	Q200	

Mean results for tonnes of cane, sugar and CCS for each nitrogen treatment

		Treatment kg N/ha	Cane yield TCH	CCS units	Sugar yield TSH
Plant crop *Date planted: 04/05/2011* *Date harvested: 14/09/2012*	SIX EASY STEPS rate – DYP 150	120	143	14.9	21.2
	SIX EASY STEPS rate – DYP 180	**160**	**145**	**15.0**	**21.7**
	Grower rate	220	139	14.8	20.6
	High rate	280	144	14.8	21.2
1st Ratoon *Date harvested: 22/08/2013*	SIX EASY STEPS rate – DYP 150	160	118	15.6	18.4
	SIX EASY STEPS rate – DYP 180	**200**	**118**	**15.4**	**18.1**
	Grower rate	260	114	15.4	17.6
	High rate	300	125	15.2	18.9

Revenue less fertiliser, harvesting costs and levies for plant and 1st ratoon



The plant crop at this trial site was managed according to best management principles.

The crop was established with few gaps, weed and irrigation management were also good, however there was change in the ownership of this trial site following the harvest of the plant crop which resulted in a change in management practices employed for the ratoon crop.

Observation during the development of the ratoon crop revealed that the crop was not watered with the same frequency as previously and weed management was generally considerably poorer.

Trial results – Site 7

Queensland Government

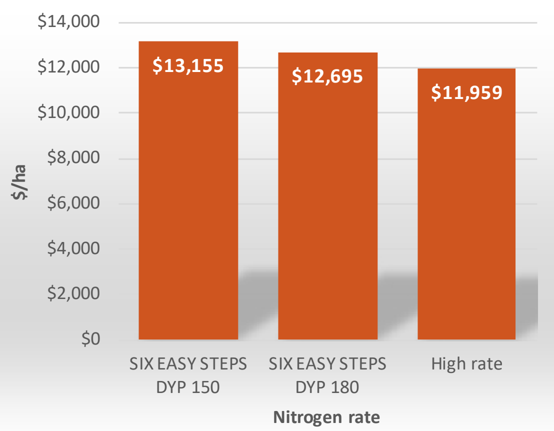
Sugar Research Australia

Delta farm

Soil type	QDPI soil type	Organic carbon
Dermosol	CUfc	058%
Soil texture	**Crop variety**	
Loam	Q208	

Mean results for tonnes of cane, sugar and CCS for each nitrogen treatment

		Treatment kg N/ha	Cane yield TCH	CCS units	Sugar yield TSH
Plant crop *Date planted: 19/05/2011* *Date harvested: 26/10/2012*	**SIX EASY STEPS rate – DYP 150**	130	150	15.6	23.5
	SIX EASY STEPS rate – DYP 180	**170**	**152**	**15.5**	**23.5**
	Grower rate	210	No data due to mechanical error when applying fertiliser		
	High rate	250	151	15.2	23.0
1st Ratoon *Date harvested: 13/09/2013*	**SIX EASY STEPS rate – DYP 150**	170	124	16.1	19.9
	SIX EASY STEPS rate – DYP 180	**210**	No data due to mechanical error when applying fertiliser		
	Grower rate	250			
	High rate	290	120	15.9	19.1
2nd Ratoon *Date harvested: 14/10/2014*	**SIX EASY STEPS rate – DYP 150**	170	128	15.6	20.0
	SIX EASY STEPS rate – DYP 180	**210**	**125**	**15.6**	**19.4**
	Grower rate	250	125	15.4	19.2
	High rate	290	125	15.3	19.2
3rd Ratoon *Date harvested: 08/11/2015*	**SIX EASY STEPS rate – DYP 150**	170	111	17.2	19.1
	SIX EASY STEPS rate – DYP 180	**210**	**111**	**17.0**	**18.9**
	Grower rate	250	112	16.7	18.7
	High rate	290	111	16.6	18.4



Revenue less fertiliser, harvesting costs and levies for plant cane, 2nd and 3rd ratoon

This trial site was generally managed according to best management principles. The crop was established with few gaps and weed management was good over the four seasons.

Good farm management practices combined with good soil fertility have allowed this grower to achieve consistent cane and sugar yields over the duration of the trials.

Trial results – Site 10

Queensland Government

Sugar Research Australia

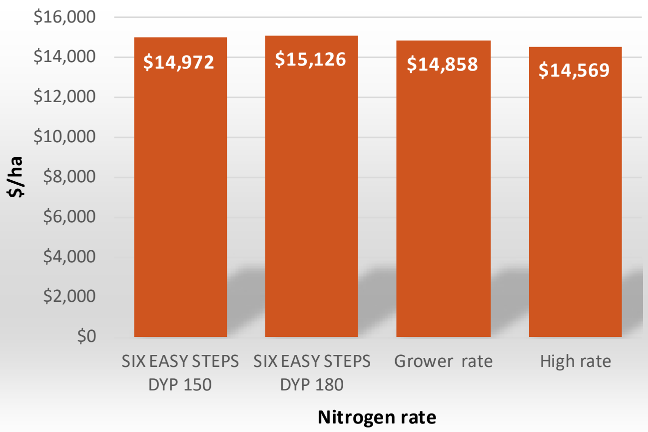
Delta farm

Soil type	QDPI soil type	Organic carbon
Vertosol	RUgb	0.84%
Soil texture	**Crop variety**	
Clay loam	Q208⦶	

Mean results for tonnes of cane, sugar and CCS for each nitrogen treatment

		Treatment kg N/ha	Cane yield TCH	CCS units	Sugar yield TSH
Plant crop *Date planted: 03/08/2011* *Date harvested: 13/09/2012*	SIX EASY STEPS rate – DYP 150	130	122	15.5	18.9
	SIX EASY STEPS rate – DYP 180	**170**	**129**	**15.2**	**19.7**
	Grower rate	210	130	15.3	20.0
	High rate	250	133	15.1	20.1
1st Ratoon *Date harvested: 02/08/2013*	SIX EASY STEPS rate – DYP 150	170	117	15.4	18.0
	SIX EASY STEPS rate – DYP 180	**210**	**125**	**15.0**	**18.7**
	Grower rate	250	127	15.0	19.1
	High rate	290	133	14.8	19.6
2nd Ratoon *Date harvested: 12/07/2014*	SIX EASY STEPS rate – DYP 150	170	99	14.7	14.5
	SIX EASY STEPS rate – DYP 180	**210**	**102**	**14.3**	**14.7**
	Grower rate	250	106	14.0	14.9
	High rate	290	113	13.5	15.3
3rd Ratoon *Date harvested: 16/10/2015*	SIX EASY STEPS rate – DYP 150	170	111	17.4	19.3
	SIX EASY STEPS rate – DYP 180	**210**	**120**	**17.2**	**20.6**
	Grower rate	250	120	16.8	20.2
	High rate	290	122	16.5	20.1

Revenue less fertiliser, harvesting costs and levies over full crop cycle



This trial site was generally managed according to best management principles.

The crop was established with few gaps and weed management was good over the four seasons.

Good farm management practices combined with reasonable soil fertility have allowed this grower to achieve reasonable cane and sugar yields over the duration of the trials.

Trial results – Site 12

Queensland Government

Sugar Research Australia

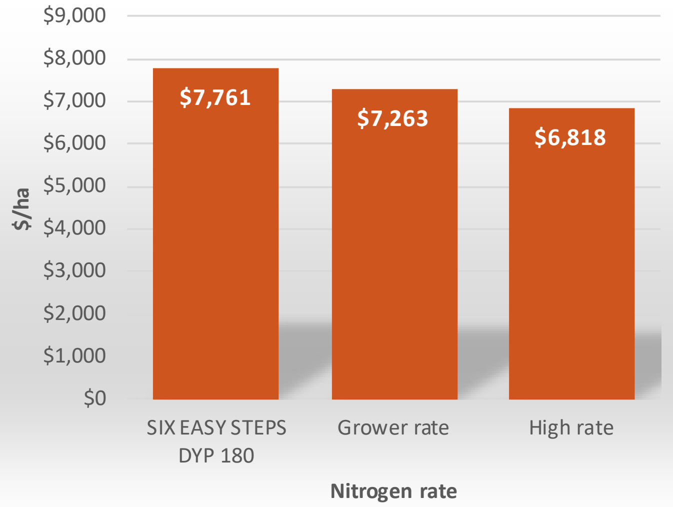
Delta farm

Soil type	QDPI soil type	Organic carbon
Dermosol	BGnb	0.74%
Soil texture	**Crop variety**	
Loam	Q208[Ⓟ]	

Mean results for tonnes of cane, sugar and CCS for each nitrogen treatment

		Treatment *kg N/ha*	Cane yield *TCH*	CCS *units*	Sugar yield *TSH*
Plant crop *Date planted: 08/06/2012* *Date harvested: 30/07/2013*	**SIX EASY STEPS rate – DYP 180**	**170**	Mill data not available		
	Grower rate	210			
	High rate	250			
1st Ratoon *Date harvested: 28/09/2014*	**SIX EASY STEPS rate – DYP 180**	**210**	**97**	**16.3**	**15.9**
	Grower rate	250	95	15.7	14.9
	High rate	290	98	15.6	15.3
2nd Ratoon *Date harvested: 01/09/2015*	**SIX EASY STEPS rate – DYP 180**	**210**	**92**	**15.4**	**14.1**
	Grower rate	250	92	15.4	14.2
	High rate	290	91	14.9	13.6
3rd Ratoon *Date harvested: 15/06/2016*	**SIX EASY STEPS rate – DYP 180**	**210**	**71**	**11.6**	**8.2**
	Grower rate	250	75	11.3	8.5
	High rate	290	73	11.3	8.2

Revenue less fertiliser, harvesting costs and levies for 1st, 2nd and 3rd ratoon*



** Plant crop not included*

This trial site suffered from significant weed and irrigation management issues over the duration of the trial.

Monitoring of soil moisture levels was undertaken in the second and third ratoons crops.

Weed pressure increased over the duration of the trials, and caused significant issues for the harvester in the 3rd ratoon crop. Weed pressure may have been a significant factor in the decline of the 3rd ratoon crop yield.

Trial results – Site 14

Queensland Government

Sugar Research Australia

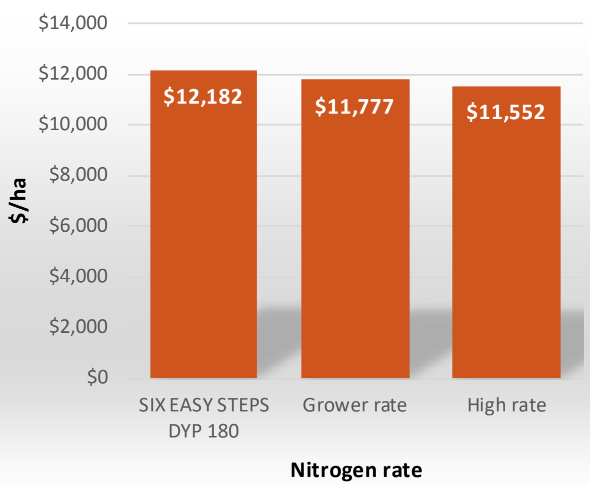
Delta farm

Soil type	QDPI soil type	Organic carbon
Dermosol	BUfb	0.81%
Soil texture	**Crop variety**	
Loam	Q183⁽ᵖ⁾	

Mean results for tonnes of cane, sugar and CCS for each nitrogen treatment

		Treatment kg N/ha	Cane yield TCH	CCS units	Sugar yield TSH
Plant crop *Date planted: 06/08/2012* *Date harvested: 11/07/2013*	**SIX EASY STEPS rate – DYP 180**	**170**	**108**	**15.1**	**16.2**
	Grower rate	210	108	14.8	15.9
	High rate	250	106	14.8	15.6
1st Ratoon *Date harvested: 05/09/2014*	**SIX EASY STEPS rate – DYP 180**	**210**	**145**	**14.7**	**21.3**
	Grower rate	250	148	14.6	21.5
	High rate	290	149	14.6	21.7
2nd Ratoon *Date harvested: 07/08/2015*	**SIX EASY STEPS rate – DYP 180**	**210**	**141**	**15.0**	**21.0**
	Grower rate	250	137	15.2	20.7
	High rate	290	137	15.3	20.9
3rd Ratoon *Date harvested: 19/09/2016*	**SIX EASY STEPS rate – DYP 150**	170	146	14.7	21.8
	SIX EASY STEPS rate – DYP 180	**210**	**145**	**14.6**	**21.5**
	Grower rate	250	145	14.5	21.4

Revenue less fertiliser, harvesting costs and levies for plant to 2nd ratoon



This trial site was managed according to best management principles.

The crop was established with few gaps and weed and irrigation management were very good over the four seasons. The plant crop which was a late plant did not perform to the expectations of the grower.

During the post-harvest soil sampling of the plant crop it was found that there was a compaction zone within the soil profile (30-50cm) across the trial site. It is likely that compaction limited the yield potential of the plant crop. Following discussion with the grower an implement was used to deep rip each side of the hill, which appeared to be effective in alleviating the compaction.

Trial results – Site 15

Queensland Government

Sugar Research Australia

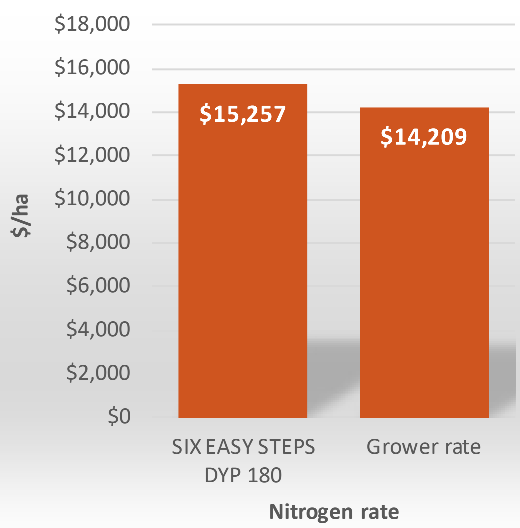
Delta farm

Soil type	QDPI soil type	Organic carbon
Vertosol	RUgd	1.3%
Soil texture	**Crop variety**	
Clay loam	Q253	

Mean results for tonnes of cane, sugar and CCS for each nitrogen treatment

		Treatment kg N/ha	Cane yield TCH	CCS units	Sugar yield TSH
Plant crop *Date planted: 01/04/2013* *Date harvested: 01/07/2014*	**SIX EASY STEPS rate – DYP 180**	**150**	**197**	**13.4**	**26.2**
	Grower rate	190	201	12.8	25.7
	High rate	230	198	12.9	25.5
1st Ratoon *Date harvested: 30/06/2015*	**SIX EASY STEPS rate – DYP 150**	150	186	12.1	22.5
	SIX EASY STEPS rate – DYP 180	**190**	**192**	**12.0**	**23.1**
	Grower rate	230	185	11.9	22.0
2nd Ratoon *Date harvested: 29/09/2016*	**SIX EASY STEPS rate – DYP 150**	150	163	13.2	21.6
	SIX EASY STEPS rate – DYP 180	**190**	**167**	**13.0**	**21.7**
	Grower rate	230	167	12.6	21.0

Revenue less fertiliser, harvesting costs and levies from plant cane to 2nd ratoon



** This graph compares only two rates as a high rate treatment was not applied at this trial site for the 1st or 2nd ratoons.*

This trial site was managed according to best management principles.

The crop was established with few gaps and weed management was very good over the three crop stages.

Very good farm management practices combined with good soil fertility has allowed this grower to achieve consistent high cane and sugar yields over the duration of the trials.

Moddus® was applied to the plant, 1st ratoon and 2nd ratoon crops.

Trial results – Site 16

Queensland Government

Sugar Research Australia

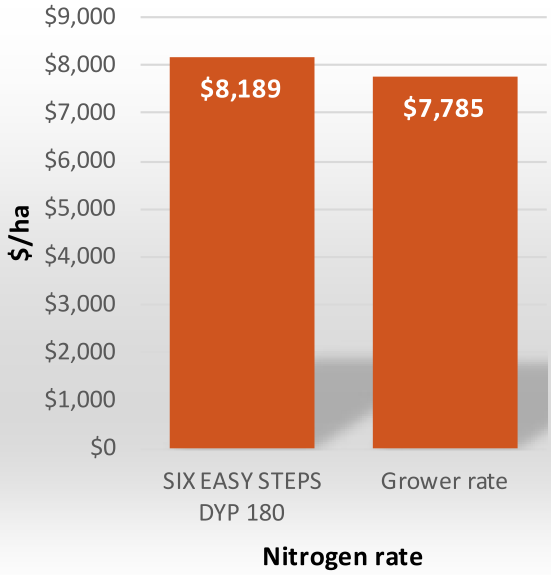
Delta farm

Soil type	QDPI soil type	Organic carbon
Dermosol	BUfc	0.95%
Soil texture	**Crop variety**	
Loam	Q240⑴	

Mean results for tonnes of cane, sugar and CCS for each nitrogen treatment

		Treatment *kg N/ha*	Cane yield *TCH*	CCS *units*	Sugar yield *TSH*
Plant crop *Date planted: 29/04/2014* *Date harvested: 06/10/2015*	**SIX EASY STEPS rate – DYP 180**	**160**	**165**	**14.1**	**23.2**
	Grower rate	200	167	13.7	22.8
	High rate	240	167	13.7	22.8
1st Ratoon *Date harvested: 02/08/2016*	**SIX EASY STEPS rate – DYP 150**	160	147	12.2	17.9
	SIX EASY STEPS rate – DYP 180	**200**	**148**	**12.3**	**18.2**
	Grower rate	240	148	12.2	18.0

Revenue less fertiliser, harvesting costs and levies for plant and 1st ratoon



** This graph compares only two rates as the high rate treatment was not retained for the 1st ratoon.*

This trial site was managed according to best management principles. The crop was established with few gaps, weed and irrigation management was good over the two crop stages which were part of the trial.

Good farm management practices combined with good soil fertility has allowed this grower to achieve good consistent cane and sugar yields at this site.

Trial results – Site 19

Queensland Government

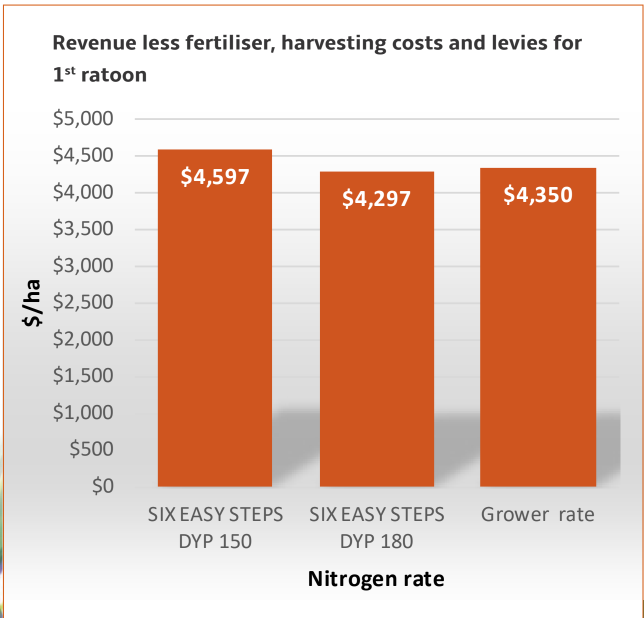
Sugar Research Australia

Delta farm

Soil type	QDPI soil type	Organic carbon
Vertosol	RUgb	1.35%
Soil texture	**Crop variety**	
Clay loam	Q183⟮	

Mean results for tonnes of cane, sugar and CCS for each nitrogen treatment

		Treatment kg N/ha	Cane yield TCH	CCS units	Sugar yield TSH
Plant crop *Date planted: 06/05/2014* *Date harvested: 11/08/2015*	**Following large legume crop**	50	200	13.4	26.9
	Following large legume crop	100	202	13.1	26.3
	Following large legume crop	150	203	13.4	27.2
1st Ratoon *Date harvested: 03/11/2016*	**SIX EASY STEPS rate – DYP 150**	170	183	13.4	24.4
	SIX EASY STEPS rate – DYP 180	**210**	**179**	**13.2**	**23.5**
	Grower rate	250	184	13.1	24.1



Prior to planting the sugarcane crop the grower at this site grew a large soybean crop.

This trial site was managed according to best management principles.

The crop was established with few gaps, and weed and irrigation management were very good over the two crop stages.

Very good farm management practices combined with good soil fertility have enabled this grower to achieve consistently high cane and sugar yields over the duration of the trials.

Trial results – Site 21

Queensland Government

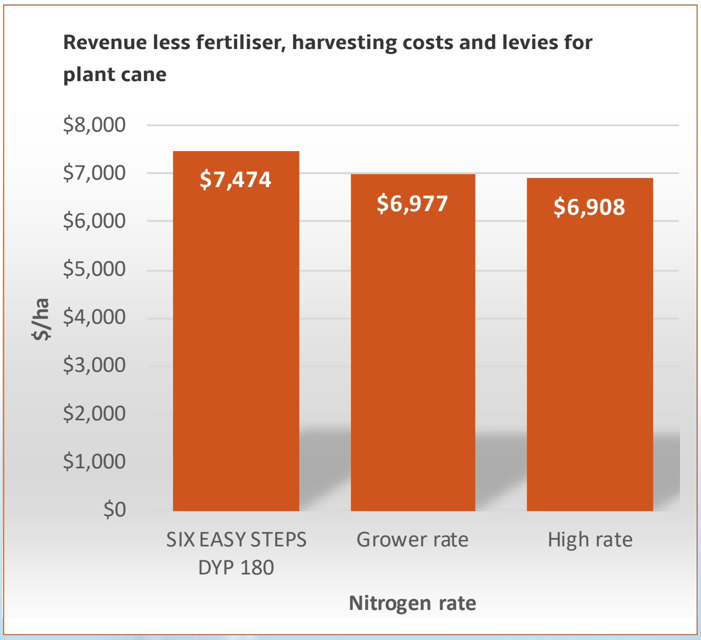
Sugar Research Australia

Delta farm

Soil type	QDPI soil type	Organic carbon
Dermosol	BUfc	1.3%
Soil texture	**Crop variety**	
Loam	Q208(Ф)	

Mean results for tonnes of cane, sugar and CCS for each nitrogen treatment

		Treatment kg N/ha	Cane yield TCH	CCS units	Sugar yield TSH
Plant crop *Date planted: 06/03/2015* *Date harvested: 26/08/2016*	**SIX EASY STEPS rate – DYP 180**	**160**	**258**	**12.9**	**33.3**
	Grower rate	200	258	12.5	32.2
	High rate	240	262	12.3	32.3



This trial site was managed according to best management principles.

The crop was established with few gaps, weed and irrigation management were good.

Very good farm management practices combined with good soil fertility have allowed this grower to achieve very high cane and sugar yields.

Trial results – Site 23

Queensland Government

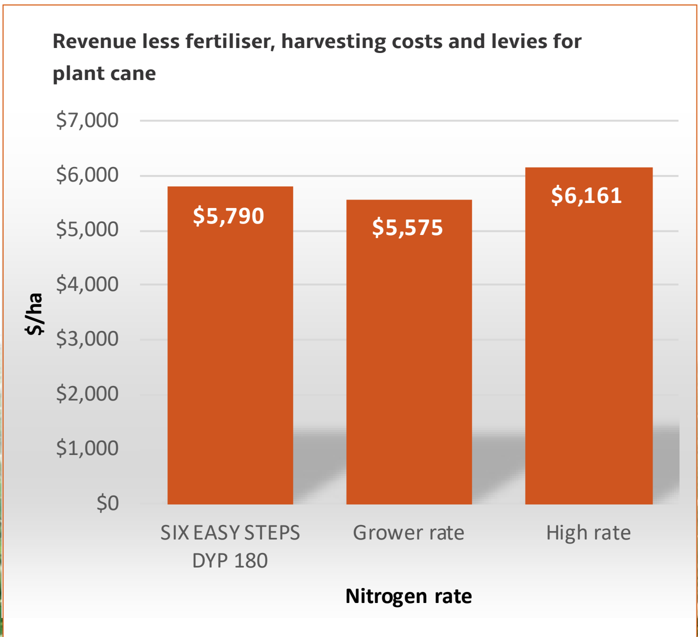
Sugar Research Australia

Delta farm

Soil type	QDPI soil type	Organic carbon
Dermosol	BGnc	1.6%
Soil texture	**Crop variety**	
Loam	Q240	

Mean results for tonnes of cane, sugar and CCS for each nitrogen treatment

		Treatment *kg N/ha*	Cane yield *TCH*	CCS *units*	Sugar yield *TSH*
Plant crop *Date planted: 17/04/2015* *Date harvested: 24/09/2015*	**SIX EASY STEPS rate – DYP 180**	**150**	**193**	**15.0**	**28.8**
	Grower rate	190	193	14.7	28.4
	High rate	230	202	15.2	30.6



This trial site was managed according to best management principles.

The crop was established with few gaps and weed and irrigation management were good.

Good farm management, combined with good soil fertility have allowed this grower to achieve high yields at this site.