RESULTS OF ENHANCED EFFICIENCY FERTILISER TRIALS IN THE CATCHMENTS OF THE GREAT BARRIER REEF

INCLUDES CASE STUDIES AND MODELLING OUTCOMES FROM THE WET TROPICS

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QUEENSLAND SUGARCANE INDUSTRY PIONEERS ENHANCED EFFICIENCY FERTILISER (EEF) RESEARCH

Image 1 (page 1): Harvesting a trial site.
Image 2 (above): Harvest in the Burdekin.

INTRODUCTION

The Queensland sugarcane industry is a pioneer in Enhanced Efficiency Fertiliser (EEF) research. With support from project partners over four seasons, Queensland growers tested EEFs on 74 sugarcane farms located between Mossman and Bundaberg.

The project was a collaborative partnership between sugarcane growers, CANEGROWERS, Sugar Research Australia (SRA), regional productivity services, the Australian Department of Agriculture, Water and the Environment (DAWE), and the Queensland governments' Department of Agriculture and Fisheries (DAF) and Environment and Science (DES) and the Great Barrier Reef Foundation.

A technical management group made up of representatives from CANEGROWERS, SRA, DAWE, DAF, DES, University of Queensland (UQ) and CSIRO was responsible for ensuring the research was scientifically robust.

The large number of trials and consistency in trial design enabled the collection and analysis of a wealth of data to determine:

- what types, blends and rates of EEF perform better
- where EEFs get optimal results – soil types, rainfall conditions and regions
- when EEFs work best – application time.

The project evaluated the production and profitability implications for commercial farms from applying EEFs in place of conventional urea fertiliser.

Given EEFs are reported to reduce nitrogen (N) losses (from the crop root zone) by better matching N supply to crop demand over the growing season, the EEFs were tested at N rates 20% below the SIX EASY STEPS (6ES) guidelines (Step 4) over four ratoons.

HOW EEFs CAN HELP

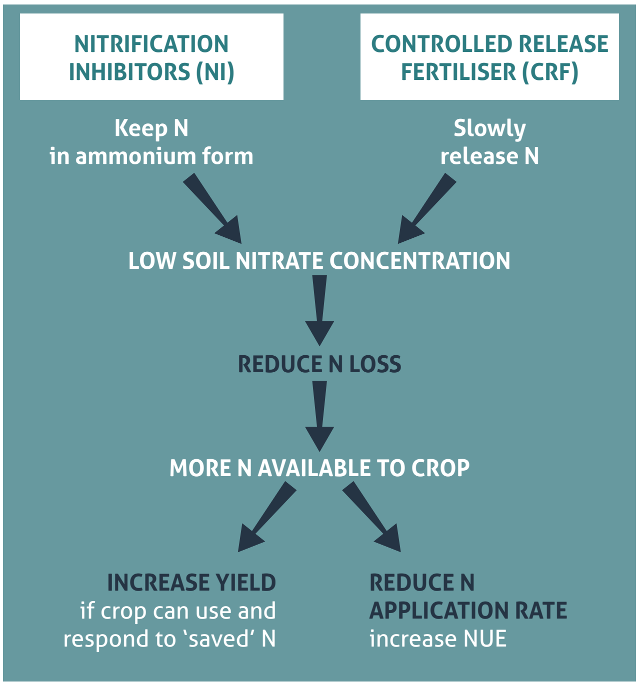


Diagram 1: Benefits of EEFs.

THE TREATMENTS APPLIED TO TRIAL SITES

Two main types of EEFs were tested in the project:

- controlled release fertilisers (CRFs), which release N slowly through a polymer coating
- nitrification inhibitors (NIs) such as 3,4-Dimethylpyrazole (DMPP), which are added to urea to stabilise the N in ammonium form.

Treatments included:

- nitrogen at the 6ES rate applied as urea (Urea 6ES)
- nitrogen at 20% less than the 6ES rate applied as urea (Urea -20%)
- nitrogen at 20% less than the 6ES rate applied as a blended product which consisted of 33% DMPP treated urea and 67% controlled release fertiliser (DMPP/CRF -20%)
- nitrogen at 20% less than the 6ES rate applied as either a CRF blended with urea (at a ratio of 20% CRF and 80% urea), or DMPP treated urea, or other EEF product. **Note:** These treatments were collectively referred to as the 'Wildcard'.

The treatments were replicated (three replicates) and randomised at each site.

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

A total of 54 trial sites had at least one Wildcard treatment with 137 crops harvested during the 2018, 2019, 2020, and 2021 harvest seasons.

Table 1: A breakdown of crops harvested by type of Wildcard and region.

REGION	DMPP UREA	CRF BLENDED WITH UREA	OTHER	TOTAL
Wet Tropics	41	20	5	66
Burdekin	12	21	8	41
Mackay-Whitsundays	12	16	2	30
Total number of harvests	65	57	15	137

Map 1: EEF trial sites within the catchments of the Great Barrier Reef.

DATA COLLECTION

Cane yield and CCS data were supplied by local sugar mills and used to calculate sugar yield and grower profitability.

Results were then analysed to identify differences in cane yield, sugar yield and profitability attributed to EEFs.

NITROGEN USE EFFICIENCY (NUE)

To compare the nitrogen use efficiency of EEFs vs urea, several measures were employed.

These included calculating the total amount of N captured by crops grown with EEFs compared to those grown with urea and the proportion of N supplied by these products.

POST-HARVEST SOIL NITROGEN

Soil mineral nitrogen was assessed within one to two days following harvest to calculate kilograms of nitrogen per hectare (kg N/ha) remaining in the top 20cm of the soil profile and then compared across treatments.

Image 3: Collecting and processing biomass samples.

RESULTS

UREA APPLIED AT N RATES 20% LESS THAN 6ES

Compared to applying urea at the 6ES recommended rate, the lower rate of urea reduced cane yields in medium and high rainfall conditions. However, under low rainfall conditions CCS improved and higher grower profitability was achieved.

Nevertheless, the current accuracy of seasonal climate forecasts makes targeting low rainfall conditions risky – which highlights the opportunity for applying EEFs to protect N from rainfall induced losses.

PERFORMANCE OF DMPP TREATED UREA COMPARED TO UREA APPLIED AT 6ES

The project tested DMPP treated urea in 65 trials on 25 sites over four seasons. Mean sugar yield in tonnes of sugar per hectare (tsh) and net revenue in dollars per hectare ($/ha) results are presented in **Figure 1.**

The sites were located on commercial sugarcane farms and spread across the Wet Tropics (15), Burdekin (6) and Mackay-Whitsundays (4) regions.

The DMPP treated urea was applied at an N rate 20% lower than 6ES guidelines, referred to as 'DMPP urea -20%'.

Compared to urea applied at the 6ES N rate DMPP urea -20% produced:

- Similar fertiliser cost
- Similar cane yield and sugar yield
- Higher CCS (on average by 0.14 units)
- Similar profitability
- Similar crop N content even though DMPP was applied at 20% less N
- No difference in post-harvest soil N (top 20cm of profile)
- More cane per kg of applied N due primarily to lower N rate and a limited yield response when using urea applied at the 6ES rate.

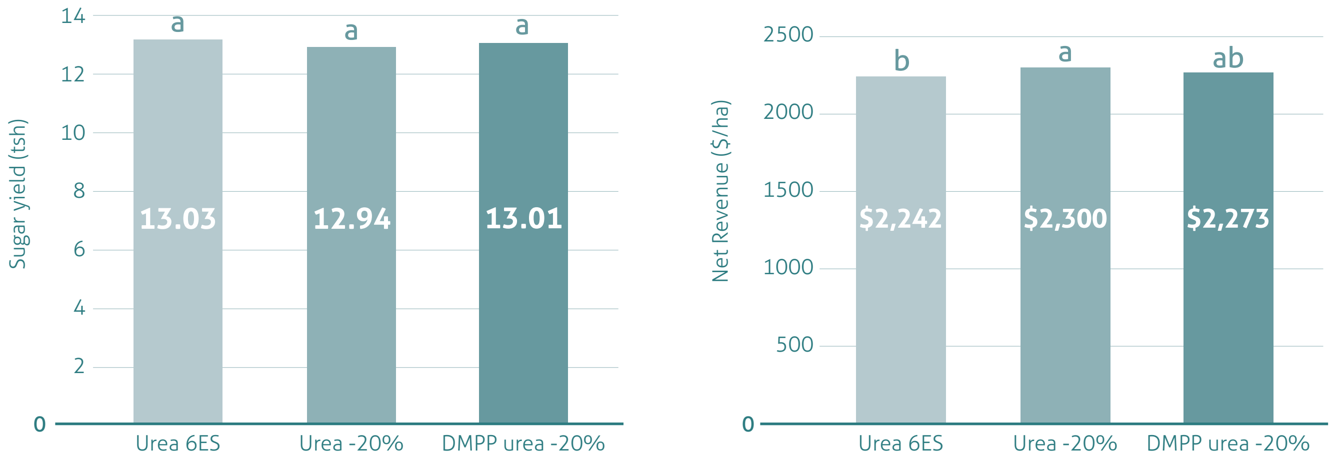


Figure 1: Mean sugar yield (tsh) and net revenue ($/ha) over four ratoons for 65 trials where urea (at 6ES and 20% less) was compared to DMPP treated urea applied at 20% less. P<0.05, means followed by a common letter are not significantly different at the 5% level.

PERFORMANCE OF CRF BLENDED WITH UREA COMPARED TO UREA APPLIED AT 6ES

The project tested a blend of 20% controlled release fertiliser and 80% urea in 57 trials on 25 sites over four seasons.

Mean sugar yield (tsh) and net revenue ($/ha) results are presented in **Figure 2.**

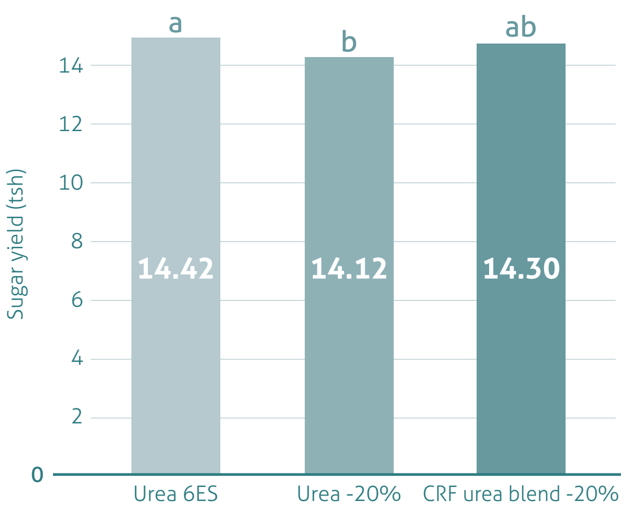
The sites were located on commercial sugarcane farms and spread across the Wet Tropics (8), Burdekin (10) and Mackay-Whitsundays (7) regions.

The blend of 80% urea with 20% controlled release fertiliser was applied at an N rate 20% lower than 6ES guidelines referred to as 'CRF urea blend -20%'.

Compared to urea applied at the 6ES N rate, the CRF urea blend-20% produced:

- Similar fertiliser cost
- Similar cane yield, CCS and sugar yield
- Similar profitability
- Similar crop N content even though the CRF urea blend was applied at 20% less N
- No difference in post-harvest soil N (top 20cm of profile)
- More cane per kg of applied N, due primarily to lower N rate and a limited yield response when using urea applied at the 6ES rate.

Image 4: Post-harvest soil sampling.



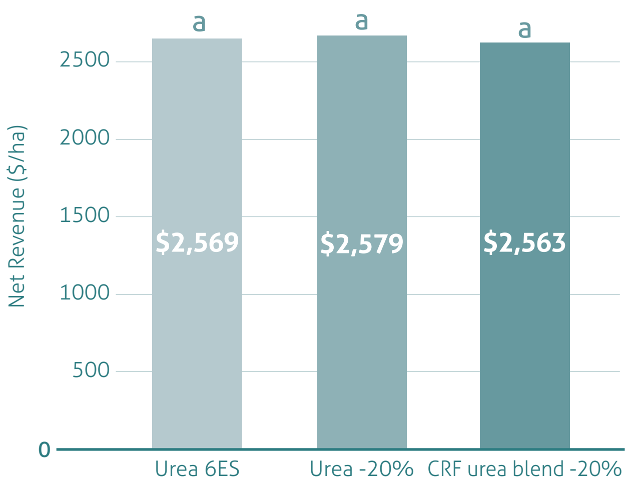


Figure 2: Mean sugar yield (tsh) and net revenue ($/ha) over four ratoons for 57 trials where urea (at 6ES and 20% less) was compared to a blend of CRF and urea applied at 20% less. P<0.05, means followed by a common letter are not significantly different at the 5% level.

PERFORMANCE OF WILDCARDS AT 20% LESS COMPARED TO UREA APPLIED AT 6ES

The Wildcards were tested in 137 trials on 54 sites over four seasons.

Wildcard EEFs consisted mostly of DMPP treated urea or CRF blended with urea (at a ratio of 20% CRF and 80% urea), while the few others were either Nitrapyrin (a nitrification inhibitor) or pure CRF.

All Wildcard EEFs were applied at N rates 20% less than the 6ES recommendation.

Findings identified that EEF performance was influenced by soil type, rainfall and fertiliser application time. Mean sugar yield (tsh) and net revenue ($/ha) results are presented in **Figure 3.**

Compared to urea applied at the 6ES N rate, the Wildcard EEFs (-20% N) produced:

- Similar cane yield to Urea 6ES in nearly all situations
- Higher CCS in low and medium rainfall conditions
- Similar profitability to Urea 6ES across all soil, rainfall and application time combinations
- Appeared more profitable in sandy soils with high rainfall after late fertiliser application, which was consistent with previous research.

These findings indicate that the benefits of EEFs are more evident in high rainfall conditions when the likelihood of N losses are greatest.

OTHER EEF STRATEGIES

The project also examined other EEF strategies involving blends of EEFs and different N rates.

The most tested of these was a blend of 67% controlled release fertiliser and 33% DMPP treated urea applied at 20% less N. This product appeared to perform as well as DMPP treated urea and the CRF urea blend in terms of cane and sugar yield and nitrogen use efficiency. However, the product is not currently commercially available, and due to its high cost (50-60% higher than Urea 6ES), was significantly less profitable to apply except for a few situations (e.g. sandy soils with high rainfall after late fertiliser application).

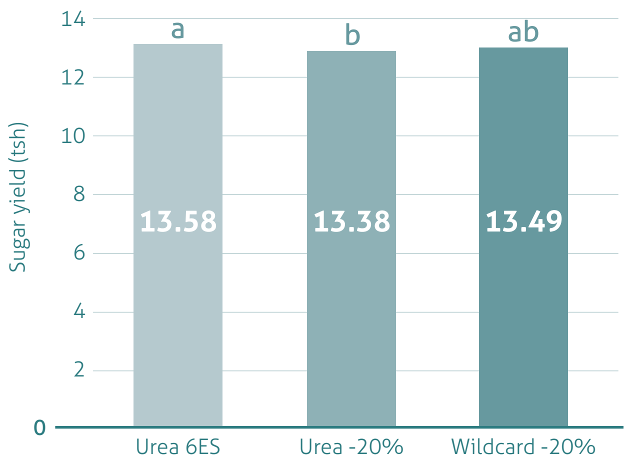
Another EEF strategy tested in six trials was the same EEF blend (67% CRF and 33% DMPP) but applied at the 6ES recommended N rate.

It did not increase yield relative to the same EEF blend at the lower rate, which made it even less profitable due to the additional fertiliser costs.

Also, this option did not result in any additional N being captured by the crop and consequently had lower NUE.

MEASUREMENT OF N LOSSES VIA LEACHING

At four sites in the Wet Tropics and two in the Burdekin the movement of dissolved inorganic N (DIN) through the soil profile in leachate was monitored by ceramic pore water samplers.



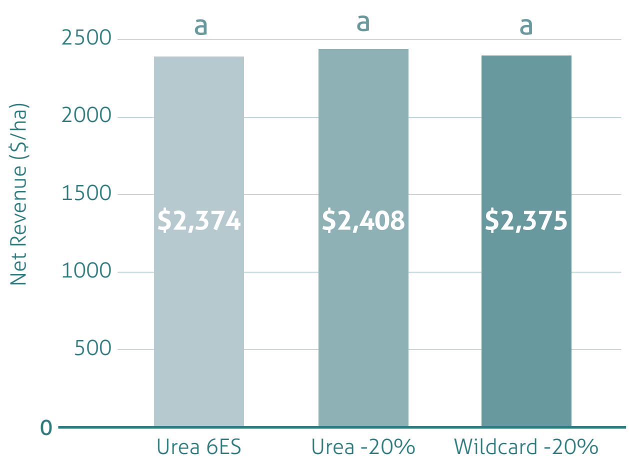


Figure 3: Mean sugar yield (tsh) and net revenue ($/ha) over four ratoons for 137 trials where urea (at 6ES and 20% less) was compared to all Wildcards applied at 20% less. P<0.05, means followed by a common letter are not significantly different at the 5% level.

These were positioned directly below the crop row at a depth of 1 metre and monitored over the wet season for three years to provide an understanding of how EEFs applied at N rates 20% less than 6ES performed relative to urea applied at 6ES recommended rates.

At two Burdekin sites the CRF urea blend was compared to urea **Figure 4.** DIN concentrations in leachate from crops grown with urea were three times higher than those grown with the EEF.

At four sites across the Wet Tropics applications of DMPP-treated urea was compared to urea. DIN concentrations in leachate from crops grown with urea were 1.5 times higher than those grown with the EEF.

Image 5: Collecting water samples from leaching events.

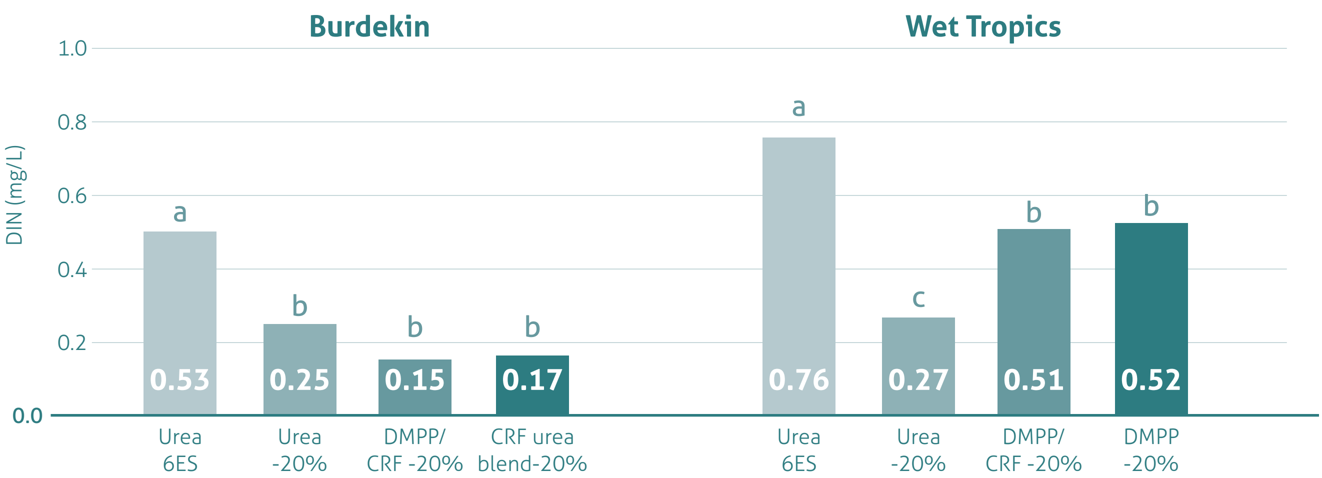


Figure 4: Mean DIN (mg/L) in soil water measured 1 meter below the crop row in each region over three ratoons. P<0.05, means followed by a common letter are not significantly different at the 5% level.

KEY MESSAGES

- Applying urea at -20% results in lost cane yield
- Applying DMPP treated urea at -20 % maintains yield and profitability but also improves NUE
- Applying a CRF urea blend (20% CRF & 80% urea) at -20% maintains yield and profitability but also improves NUE
- EEF blends with high proportions of CRF cost more, which made them less profitable to apply
- Evidence suggests that EEFs were more effective when high loss conditions were experienced (sandy soil, high rainfall, late in season)
- Trying these products when high losses are likely is a good starting point.

WET TROPICS CASE STUDIES

Over the course of the EEF60 project (4 years), the average price of urea was $643 per tonne (ex. GST). In comparison, DMPP treated urea was on average $136 more expensive than urea per tonne, while pure CRF was $855 more expensive per tonne.

Table 2 compares the fertiliser costs for urea applied at SIX EASY STEPS (6ES) recommended N application rate, with DMPP treated urea and 20% CRF blended with 80% urea applied at 20% less N. Given the recent surge in the price of urea, the table also compares the costs at higher urea prices assuming the additional cost of DMPP (+$136) and pure CRF (+$855) remain the same.

Table 2: Nitrogen fertiliser costs ($/ha) at different urea prices.

N FERTILISER TYPE	N RATE	UREA PRICE PER TONNE		
		$643	$1,200	$1,700
Urea	6ES*	$196	$365	$517
DMPP	20% below 6ES	$190	$325	$447
20% CRF blended with 80% urea	20% below 6ES	$198	$334	$456

* Assuming the SIX EASY STEPS recommendation is 140 kg N/ha.

Image 6: Calibrating a fertiliser box.

Table 3 provides results from eleven sites located in the Wet Tropics. It also outlines information including location, soil type and texture, variety and the percentage of soil organic carbon. Results include cane yield (tch), CCS, sugar yield (tsh), and net revenue ($/ha). These results show site specific outcomes that are consistent with findings shown in the results section.

Table 3: Trial site descriptions and mean yield, CCS and net revenue results for EEF's -20% compared to Urea 6ES across four ratoons.

LOCATION: GORDONVALE

EEF TYPE APPLIED AT 20% LESS	VARIETY	SOIL TEXTURE (0-20cm)	ORGANIC CARBON (%)	FERTILISER APPLICATION TIMING (EARLY/MID/ LATE)*	CANE YIELD (tch)		CCS		SUGAR YIELD (tsh)		NET REVENUE ($/ha)	
					UREA 6ES	EEF -20%	UREA 6ES	EEF -20%	UREA 6ES	EEF -20%	UREA 6ES	EEF -20%
DMPP treated urea	Q208	Silty Loam	0.8	Mid and Late	107	104	12.80	13.00	13.9	13.7	$2,200	$2,200
DMPP treated urea	Q231	Loam	0.8	Mid and Late	77	78	14.28	14.31	11.2	11.3	$1,895	$1,955
20% CRF blended with 80% urea^	Q208	Loam	1.1	Mid and Late	97	94	14.92	15.11	14.4	14.2	$2,561	$2,549

LOCATION: INNISFAIL

EEF TYPE APPLIED AT 20% LESS	VARIETY	SOIL TEXTURE (0-20cm)	ORGANIC CARBON (%)	FERTILISER APPLICATION TIMING (EARLY/MID/ LATE)*	CANE YIELD (tch)		CCS		SUGAR YIELD (tsh)		NET REVENUE ($/ha)	
					UREA 6ES	EEF -20%	UREA 6ES	EEF -20%	UREA 6ES	EEF -20%	UREA 6ES	EEF -20%
DMPP treated urea	Q231	Loamy Sand	1.6	Mid and Late	66	64	13.17	13.18	8.9	8.6	$952	$964
DMPP treated urea	Q208	Silty Clay Loam	1.3	Mid and Late	80	79	13.75	13.87	11.1	10.9	$1,806	$1,800

LOCATION: TULLY

EEF TYPE APPLIED AT 20% LESS	VARIETY	SOIL TEXTURE (0-20cm)	ORGANIC CARBON (%)	FERTILISER APPLICATION TIMING (EARLY/MID/ LATE)*	CANE YIELD (tch)		CCS		SUGAR YIELD (tsh)		NET REVENUE ($/ha)	
					UREA 6ES	EEF -20%	UREA 6ES	EEF -20%	UREA 6ES	EEF -20%	UREA 6ES	EEF -20%
20% CRF blended with 80% urea	Q208	Loam	2.3	Mid	79	77	13.43	13.42	10.7	10.4	$1,913	$1,852
20% CRF blended with 80% urea	Q208	Clay Loam	2.0	Mid and Late	102	102	13.98	14.02	14.3	14.5	$2,406	$2,386
DMPP treated urea^	Q250	Clay Loam	1.9	Mid	79	79	12.46	12.59	9.9	10.0	$1,966	2,003

LOCATION: HERBERT

EEF TYPE APPLIED AT 20% LESS	VARIETY	SOIL TEXTURE (0-20cm)	ORGANIC CARBON (%)	FERTILISER APPLICATION TIMING (EARLY/MID/ LATE)*	CANE YIELD (tch)		CCS		SUGAR YIELD (tsh)		NET REVENUE ($/ha)	
					UREA 6ES	EEF -20%	UREA 6ES	EEF -20%	UREA 6ES	EEF -20%	UREA 6ES	EEF -20%
20% CRF blended with 80% urea	Q208	Loam	1.1	Mid and Late	70	69	15.15	15.23	10.7	10.6	$1,900	$1,890
DMPP treated urea	Q208	Loam	2.4	Mid	57	58	14.09	14.33	8.0	8.4	$1,576	$1,620
DMPP treated urea	Q231	Loam	1.1	Mid and Late	68	67	12.82	13.02	8.7	8.7	$1,014	$1,043

* Early application - June and July, mid application - August and September, and late application - October, November, and December.
^ Three ratoons only.

SUMMARY OF MODELLING OUTPUTS

- IDENTIFYING WHEN AND WHERE EEFs PROVIDE WATER QUALITY BENEFITS

Nitrogen (N) losses are challenging to measure experimentally at a broad range of locations, so a project was developed with CSIRO utilising modelling to evaluate the effect of EEF on N losses across the Wet Tropics.

The investigation looked at climate x soil x crop start interactions to identify when and where EEF use could reduce nitrogen (N) losses to the environment compared to current industry recommended N rates of urea for ratoon sugarcane crops in the Wet Tropics.

Modelling was verified with experiments where yield and surface water N losses were measured across several years (Image 7).

The evaluation of total N loss covered a wide range of climate locations, soils, time of harvest and seasonal conditions (10 climate regions x 5 soil types x 3 ratoon crop start times x 70 seasons).

Image 7: Measuring surface water N losses in sugarcane.

HOW EEFS CAN DELIVER BENEFIT TO SUGARCANE GROWERS

EEFs can help reduce the amount of soil nitrate in the soil, reduce the risk of N loss and make more N available to the crop. (Diagram 1) To generate benefits from EEF, three prerequisite conditions need to be met (Diagram 2).

P **Protection period**

P **Possibility of N loss events**

P **Potential for crop to use saved N**

Diagram 2: Three prerequisite conditions for **obtaining benefit** from EEF

1. EEF usually provide protection for 2 – 12 weeks, depending on product. **This protection period** results in less N being available for loss
2. The **possibility of N loss events** increases as fertilising is closer to the Wet Season. EEFs reduce N loss when the protection period overlaps N loss events
3. Cane yield benefits from EEF are obtained when there is **potential for the crop to use the 'saved N'.** This explains why yield benefits are more frequently obtained for later crops and in wet climates

WHERE AND WHEN DO EEFs PROVIDE LOSS REDUCTION BENEFITS?

Reducing N rates leads to reduced N loss. The use of EEF will enhance this benefit, especially for late crops (Figure 5). In drier climates of the Wet Tropics (less than 2050 mm) N loss reductions from using EEF are largely limited to late starting crops as the larger 'N loss events' are generally limited to the wet season. In wet climates (greater than 2600 mm) N loss reductions from using EEF are realised through the year as there can be 'N loss events' through the year in these wetter climates.

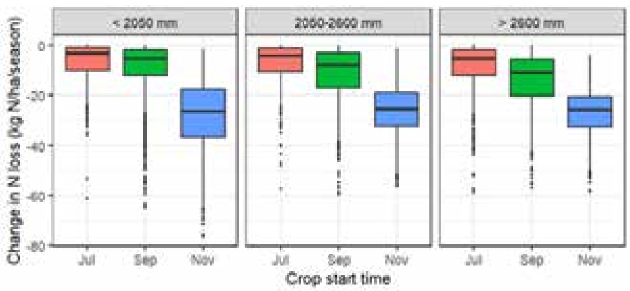


Figure 5: N loss reductions from using EEF in place of urea at 3 crop start times (July, Sept, Nov) for dry to wet climate regions of the Wet Tropics.

For further information:
Tony Webster (tony.webster@csiro.au)
Research Agronomist
0407 295 638

Image 8: Calibrating a fertiliser box.

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FOR MORE INFORMATION

The EEF60 final report document can be downloaded from the SRA website or via the QR code on the right.

EEF60 Final Report

Visit the EEF60 project page on the SRA website by scanning the QR code.

EEF60 Project page

Julian Connellan
Project Agronomist

Sugar Research Australia Limited
ABN 16 163 670 068

Meringa Office
A PO Box 122, Gordonvale Qld 4865
M 042 335 8845
E jconnellan@sra.com.au
sugarresearch.com.au

Queensland Government

Matt Thompson
Agricultural Economist

Department of Agriculture and Fisheries
Queensland Government

Townsville Office
A 9-15 Langton St, Garbutt Qld 4814
M 0428 147 447
E matthew.thompson@daf.qld.gov.au
daf.qld.gov.au