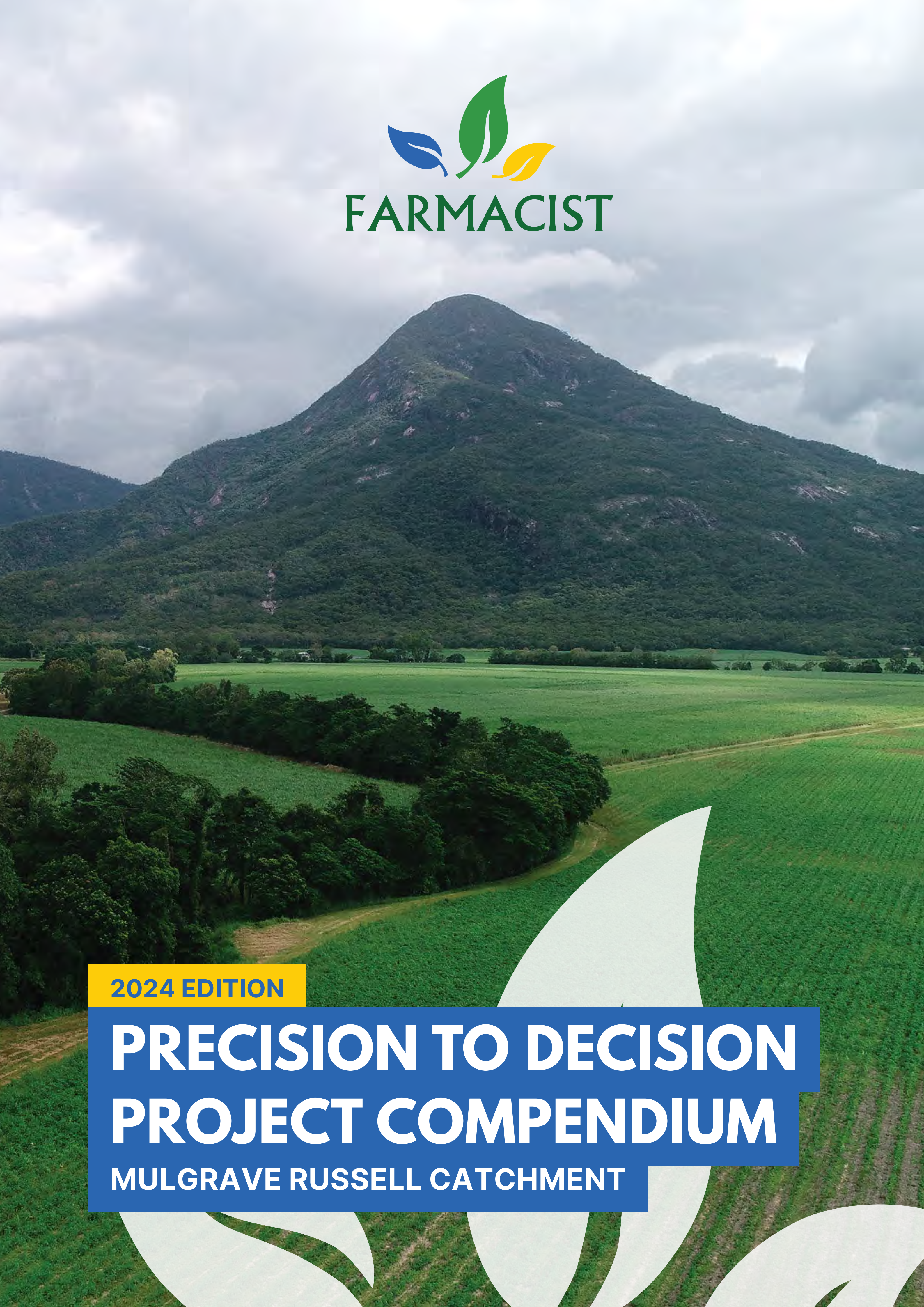

FARMACIST

2024 EDITION

PRECISION TO DECISION PROJECT COMPENDIUM

MULGRAVE RUSSELL CATCHMENT

ACKNOWLEDGEMENTS

THE PRECISION TO DECISION PROJECT TOOK PLACE ON GUBUDA (GORDONVALE) AND BUNNA BINDA (BABINDA). THE FARMACIST FNQ TEAM ACKNOWLEDGE THE YIDINJI PEOPLE AND ORIGINAL CUSTODIANS OF GUBUDA AND BUNNA BINDA AND CELEBRATE THEIR ENDURING CONNECTIONS TO COUNTRY, KNOWLEDGE AND STORIES. WE PAY RESPECT TO ELDERS PAST, PRESENT AND FUTURE.

THIS COMPENDIUM AND THE PRECISION TO DECISION PROJECT WAS MADE POSSIBLE THROUGH THE SUPPORT OF THE MANY SUGARCANE GROWERS OF THE MULGRAVE RUSSELL CATCHMENT. FARMACIST THANK ALL GROWERS WHO HAVE PARTICIPATED IN THE PROJECT, HOSTED TRIALS AND SUPPORTED THE DEVELOPMENT OF OUR FAR NORTH QUEENSLAND TEAM.

FORWARD & ACKNOWLEDGEMENTS

The Precision to Decision Project Compendium brings together a body of work conducted by the Farmacist Far North agronomy team over the three years of the Precision to Decision project. These activities were completed to support the team's work delivering nutrient management plans and agronomy advice to sugarcane growers in the Mulgrave and Russell River catchments and has been informed by the interests and need of the local grower community.

Within this compendium you will find:

- Methodology and results of three nitrogen rate trials
- Data and information from a selection of demonstration activities conducted with growers
- A detailed constraints management section to improve understanding of common constraints to production and remediation methods identified through peer reviewed literature.

We would like to thank the sugarcane growers of the Mulgrave and Russell River catchments who have embraced the Precision to Decision project, welcomed the delivery team onto their farms, provided feedback and advice along the way and made the project a success.

We would also like to thank the Great Barrier Reef Foundation for supporting the program and in doing so investing in our region and backing local ideas and people.

Thanks also go to CANEGROWERS Cairns Region and the Reef and Rainforest Research Centre who have provided ongoing support to the Precision to Decision project and the Farmacist team.

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Citation:

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CONTENTS

INTRODUCTION

Introducing the Mulgrave Russell Water Quality Program

The Mulgrave Russell Water Quality Program was funded by a partnership between the Australian Governments Reef Trust and the Great Barrier Reef Foundation. The Program was coordinated by a collaboration between the Reef and Rainforest Research Centre and CANEGROWERS Cairns Region. The $6 million investment supported Farmacists Precision to Decision project and James Cook University's TropWATER Water Quality Monitoring and Controlled Drainage project. These projects delivered precision agriculture, improved farming practices, water quality monitoring, and controlled drainage, to reduce dissolved inorganic nitrogen (DIN). DIN lost through runoff has reduced resulting in improved catchment water quality, farm productivity and environmental outcomes.

Since 2021, the Mulgrave-Russell Water Quality Program has delivered a robust water quality monitoring program, supported drainage interventions, and provided precision agriculture data and extension support to 80 growers who farm over 11,000 hectares of sugarcane. As a result, approximately 9.32 tonnes of DIN have been prevented from entering the Great Barrier Reef lagoon every year.

Farmacist's Precision to Decision project provided growers with increased access to datasets that are crucial for precision agriculture, including EM soil maps and yield variability maps with supporting soil and tissue samples. These resources enhanced tailored nutrient management plans and one on one agronomy services which were delivered across the Mulgrave Russell catchment. Farmers involved in this project worked with agronomists to develop sophisticated precision nutrient management plans that contributed to reduced costs, increased productivity, and improved the quality of the water running off their farms. Many growers also worked with their agronomist to implement demonstration activities to test different management practices, the results of these activities are shared in this Compendium. Three growers worked with Farmacist to conduct nitrogen rate trials on soils where available data is limited. Trial data and the process of developing the trial design is also included. Farmacist agronomists will continue service these demonstrations and trials with harvests in 2024 and updated results will be shared.

"KEEPING UP WITH MODERN TECHNOLOGY AND FARMING TECHNIQUES IS A PRIORITY FOR ME SO THAT THE FARM IS EFFICIENT AND COST EFFECTIVE, AND A VIABLE BUSINESS TO PASS ON. ITS BASICALLY ECONOMICS SAVING MONEY. WE`RE NOW PUTTING ON LESS FERTILISER BUT STILL PRODUCING THE SAME TONNAGE AND QUALITY OF CANE. PRECISION PLANNING SAVES THE ENVIRONMENT AS WELL. NO ONE WANTS TO DAMAGE THE ENVIRONMENT."

Precision to Decision farmer, 2024

The Program also supported James Cook University's TropWATER Water Quality Monitoring and Controlled Drainage project. This project delivered a dynamic, interactive water quality monitoring and extension program at the paddock and catchment-scale, to improve rapport, research credibility and mutual understanding between scientists, extension practitioners, land managers and farmers, leading to water quality improvement. DIN hot spots were identified and targeted drainage systems were remediated to retain, divert, or treat high nitrate first flushes early in the wet season.

Chapter 1: Research trials rationale

CHAPTER 1-2

Introduction

The Wet Tropics region presents a tropical agricultural landscape characterised by dynamic climatic conditions, including excessive wetness, intense humidity, low solar radiation, and occasional extreme rainfall events (Skocaj & Everingham, 2014). These factors contribute to highly variable landscapes, posing significant challenges for sugarcane growers in the area. The fluctuating weather patterns result in highly variable landscapes which directly impact cane yields and intensify nitrogen losses from the soil, making it exceptionally difficult to optimise nitrogen fertiliser applications that balance profitability and environmental sustainability.

In response to these challenges, our project aimed to assist sugarcane farmers in understanding and effectively managing the complexities of farming in the Wet Tropics. Through a series of research and demonstration trials, we aimed to provide practical insights and solutions to enhance sugarcane nitrogen management in the Wet Tropics.

Objectives of the trials

Our trials focused on three key objectives:

1. Investigating Soil Variability: We aimed to explore the degree of soil variability within sugarcane blocks in the Wet Tropics region. Understanding soil variability is crucial for implementing targeted management practices tailored to specific soil conditions.

2. Assessing Yield Responsiveness: We sought to identify how soil variability influences the responsiveness of sugarcane crops to different nitrogen rates. This information is essential for optimising nitrogen fertiliser applications and maximising crop yields while minimising environmental impact.

Structure of this chapter

This chapter outlines the methodology employed in conducting the trials, including the selection criteria and rationale behind each trial. Furthermore, it presents the results obtained from the trials and discusses their implications for sugarcane nitrogen management in the Wet Tropics region.

Principles of designing a field trial

Designing a field trial involves several key steps to ensure the reliability and relevance of the research findings:

1. Define research objectives: Clearly outline the research objectives and questions you aim to address through the trial. This will guide the entire trial design process.

2. Select experimental variables: Identify the variables you intend to manipulate and measure in the trial. This may include factors like different treatments, soil types, or crop varieties.

3. Choose a suitable location: Select a site that represents the conditions relevant to your research question. Consider factors such as soil type, climate, and previous land use.

4. Randomise and replicate: Randomly allocate treatments to different plots within the trial site to minimise bias and ensure statistical validity. Replicate treatments across multiple plots to increase the reliability of results.

5. Plot layout: Design the layout of plots within the trial area, ensuring adequate spacing between plots and accounting for any potential sources of variability.

6. Control conditions: Implement control plots or treatments to serve as a baseline for comparison. These controls should receive no treatment or a standard treatment to help isolate the effects of the variables being studied.

7. Data collection: Determine the data to be collected during the trial, including measurements, observations, and sampling protocols. Establish a schedule for data collection throughout the trial period.

8. Consider environmental factors: Account for environmental factors that may influence the trial, such as weather conditions, pests, and diseases. Implement measures to mitigate these factors as much as possible.

9. Monitor and maintain: Regularly monitor the trial plots to ensure that experimental conditions are maintained consistently throughout the trial period. Address any issues or deviations promptly.

10. Data analysis: Once the trial is complete, analyse the collected data using appropriate statistical methods to evaluate the effects of the experimental variables and draw meaningful conclusions.

By following these steps and adhering to sound experimental principles, you can design a field trial that yields reliable and informative results relevant to your research objectives.

> "WE'RE CURRENTLY WORKING WITH FARMACIST FOR A MORE PRECISE APPROACH TO OUR PREVIOUS PRACTICES.
>
> **Precision to Decision farmer, 2024**

Trial methodology scheme: This schematic outlines the key activities undertaken to develop the trial guided by the principles. Further explanations about each method are provided in the proceeding section.

1. DEFINE RESEARCH OBJECTIVES	• Consult with Technical Advisory Group (TAG) • Literature review
2. SELECT EXPERIMENTAL VARIABLES	• Nitrogen rates • Soil type
3. CHOOSE A SUITABLE LOCATION	• Site variability assessment • Soil characterisation
4. RANDOMISE AND REPLICATE	• Treatments were randomised • Each trial had 4 replicates
5. PLOT LAYOUT	• Treatment width was matched to fertiliser equipment available, biomass sampling area determined • Review by TAG
6. CONTROL CONDITIONS	• Baseline soil and biomass sample were collected
7. DATA COLLECTION	• TAG informed data collection methods
8. CONSIDER ENVIRONMENTAL FACTORS	• RSD and pachymetra samples were taken
9. MONITOR AND MAINTAIN	• Regular drone flights and site inspections were undertaken
10. DATA ANALYSIS	• Data analysis reviewed by TAG

Methodology

1. Define research objectives

Development of the Technical Advisory Group

Recognising the importance of industry expertise, we formed a Technical Advisory Group (TAG) comprising key stakeholders:

Farmacist

- Will Higham – Project Manager and Chair of P2D TAG
- Shannon Byrnes – Lead for N Rate Trials
- Belinda Billing – Lead for Extension Delivery Platform
- Eduardo de Lima Reis – Coordination support for N Rate Trials
- Hannah van Houweninge – Secretariat

SRA

- Dr. Danielle Skocaj – Principal researcher for N Rate Trials
- Julian Connellan – Guidance and peer review

DS Consulting

- Jordan Villaruz – Coordination support for N Rate Trials and on ground support

TRAP Services

- Dr. Charissa Rixon – Senior spatial agronomist

DAF

- Jack Robertson – Guidance and peer review

DESI

- Dr. Bronwyn Masters – Guidance and peer review
- Nikita Tahir – Guidance and peer review

TROPwater

- Dr. Aaron Davis – Guidance and peer review

Canegrowers Cairns Region

- Joel Tierney – Guidance and peer review

RRRC

- Dr. Rickard Abom – Observer

GBRF

- Carolyn Trewin – Observer

Their role was to offer guidance and peer review throughout the design, implementation, and reporting phases of N rate trials in sugarcane. Specifically, they supported key activities including:

a. Assisting with literature review

b. Identifying knowledge gaps

c. Exploring opportunities for collaboration and co-location of research and monitoring efforts

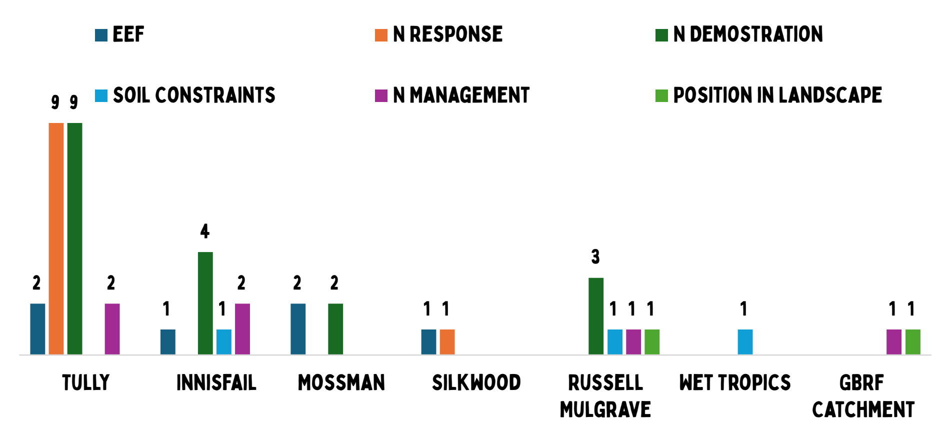
d. Reviewing methods, results, and key findings.

This collaborative approach ensured that our trial design and subsequent activities were informed by industry insights and best practices, enhancing the robustness and relevance of our research endeavours.

Results from literature review

Following guidance from the TAG, we conducted a thorough literature review of studies examining nitrogen management in sugarcane within the Wet Tropics. The review highlighted a significant research gap in nitrogen management within the Russell Mulgrave catchments, see figure below. Surprisingly, there have been no previous studies exploring nitrogen rates in this specific catchment area, highlighting the need for further investigation.

GRAPH DISPLAYS NUMBER OF PEER REVIEWED ARTICLES FOR EACH TOPIC AND DISTRICT



2. Select experimental variables

Nitrogen rate and soil type were chosen as key experimental variables to explore their impact on sugarcane yield within the Russell Mulgrave catchment.

3.Choose a suitable location

When it came to selecting suitable locations for our trial sites, several crucial considerations guided our decision-making process. Firstly, we sought areas where a single variety was consistently planted across the entire block, ensuring uniformity in crop composition. Additionally, we preference sites where the sugarcane crop was relatively young, typically in the early ratoon stage, to minimise variability associated with crop maturity.

Another important factor was the size of the trial site. We needed enough rows to accommodate multiple replicates of each treatment, ensuring robust statistical analysis and reliable results. This necessitated selecting sites with ample space and suitable layout to accommodate our experimental design.

Furthermore, we prioritised locations where there was a distinct change in soil type from one end of the paddock to the other. This allowed us to gain more results from a single trial site.

To assess site variability and confirm the presence of distinct soil types within the selected blocks, we employed a variety of spatial datasets. These included soil maps, drone imagery, electromagnetic (EM) mapping, and satellite images. However, to validate the variability observed in these datasets, ground truthing was essential. This involved collecting soil samples from various points within the trial area and analysing them to confirm differences in soil composition.

An example of the site variability assessment and soil characterisation for the chosen trial site can be seen at the end of this chapter.

Additionally, to ensure the reliability of our findings, the Department of Resources conducted ground truthing investigations to validate the variability assessments. This involved conducting a comprehensive soil characterisation for the selected trial blocks which involved deep soil core samples and exploring factors such as soil texture, soil pH and position in the landscape to produce a new soil map.

Overall, by carefully selecting and assessing trial site locations, we were able to ensure that our field trials were conducted under conditions representative of those encountered by sugarcane growers in the region. This approach enhanced the relevance and reliability of our research findings, ultimately benefiting the agricultural community and contributing to the advancement of sustainable farming practices in the Russell Mulgrave region.

4. Randomise and replicate

All treatments were randomised and each treatments had three or four replicates. Each replicate contained two soil types, one at either end of the block. Using biomassing to assess yields allowed for two datasets to be collected from each replicate.

5. Plot layout and design

Trial site designs were reviewed by the TAG.

6. Control conditions

Prior to the application of any treatments, we conducted a thorough assessment of the trial area by collecting baseline biomass samples and soil samples. These samples were obtained to establish a reference point and gain insights into the initial state of both the crop and the soil.

7. Data collection

The data collection methodology was developed in consultation with the TAG.

Soil samples were also taken from sampling plots at the time of biomass sampling.

8. Consider environmental factors

As part of our assessment, we conducted sampling for RSD and pachymetra to identify any potential factors limiting yield. In addition to these samples, we also closely monitored the presence and activity of pests, weeds, and diseases throughout the trial period. This approach allowed us to gather valuable insight into the factors that could influence the performance of the sugarcane in this trial.

9. Monitor and maintain

Regular drone flight and site inspections were undertaken to monitor any changes in the trial site and to ensure any issues were promptly addressed.

10. Data analysis

In consultation with the TAG appropriate statistical methods were used to evaluate the effects of the experimental variables and draw meaningful conclusions.

CHAPTER 1-2

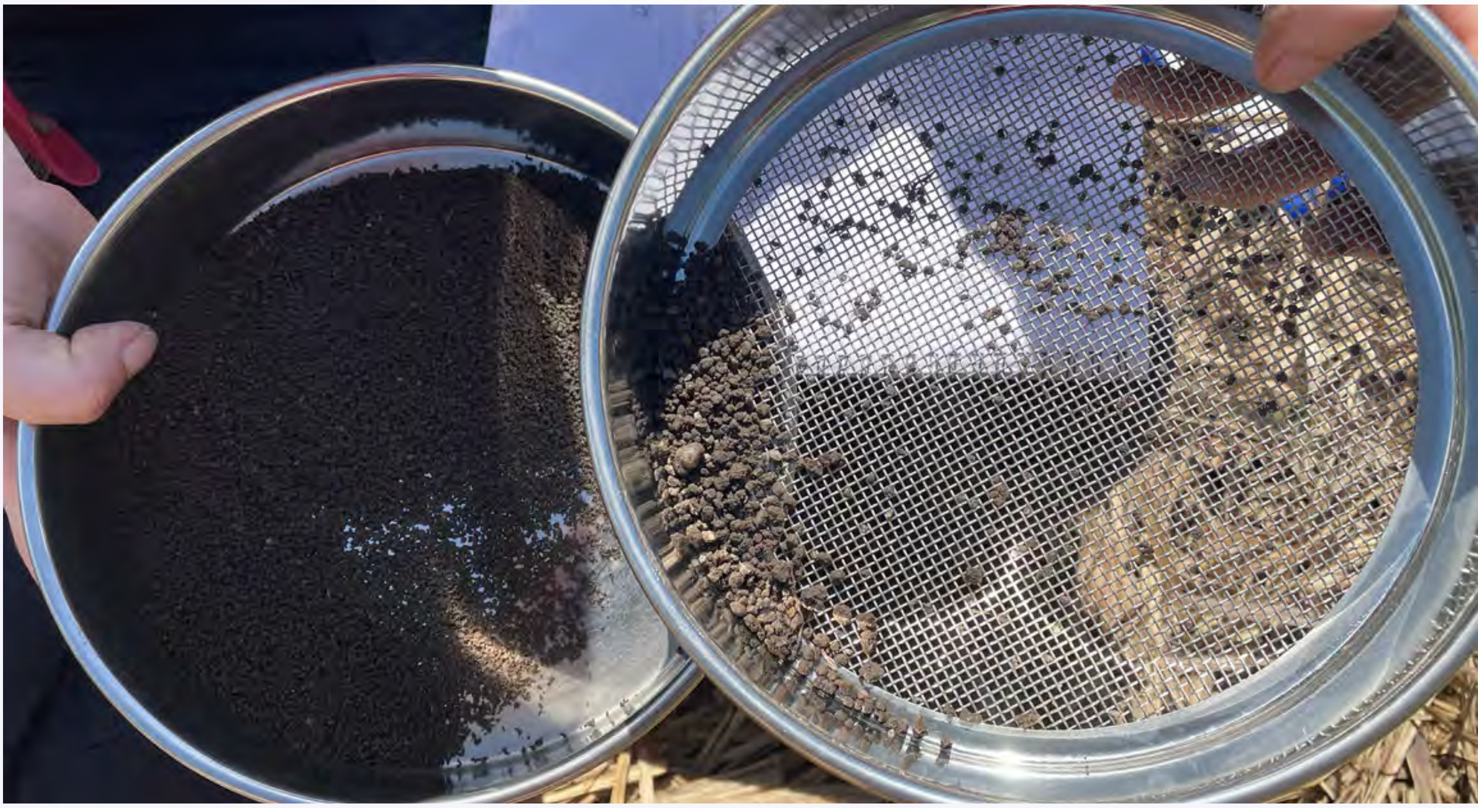
Example: Site variability and soil characterisation – Babinda

Block variability was assessed using multiple spatial datasets, including soil maps, drone imagery, EM mapping, and satellite images (see figure opposite). Confirmation of variation within the block was achieved through ground truthing using soil sampling and Department of Resources soil characterisation. The variability assessment showed similarities in the trends observed in elevation and the EM map. Generally, at lower elevations, higher EC readings were found, corresponding to a higher water table. At these lower elevations and higher water table areas, the soil characterisation revealed a higher peat content.

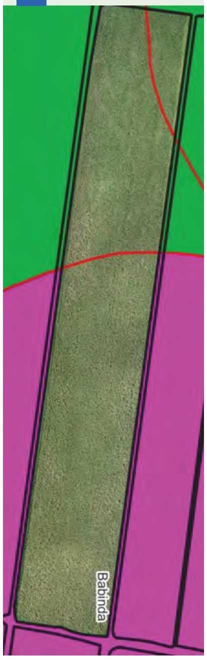
The variability assessment and the soil characterisation identified numerous different soil types present within the block. Specifically, more peaty-based soils, such as Wanjuru and Wyvuri, at the lower elevations of the block. Wanjuru and Wyvuri soils are deep to very deep, poorly to very poorly drained, and are associated with former swamps. Additionally, Niringa soil, a moderately well to poorly drained sandy-textured soil, was found, particularly in depressions and incisions associated with prior streams or paleochannels about the edges of the former swamp.

Bulgun soil, was found at the higher end of the block. Bulgan represents a soil type that is found in depressions and lower lying poorly drained positions on the floodplain and about the swamp margins. It comprises a very dark and thick, organic-rich, clay-textured surface overlying grey, structured, mottled, clay loam to medium clay subsoils. This end of the block also contained, Hewitt soil, a deep to very deep, poorly to very poorly drained, very dark grey to black, organic-rich, peaty soil, that was found around the edges of the former swamps.

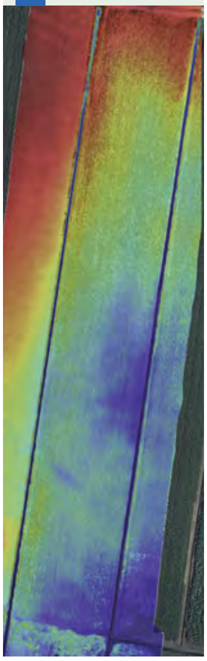
Note: This variability is observed within a block that is 6.7 hectares in size, measuring approximately 100 meters in width and 650 meters in length.



1 SOIL MAP 1:50,000

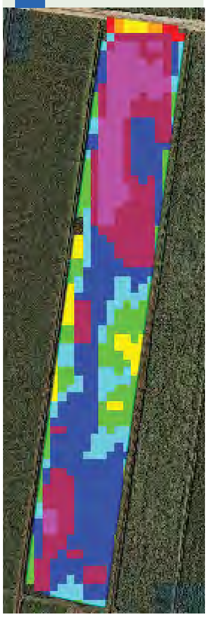


2 ELEVATION MAP

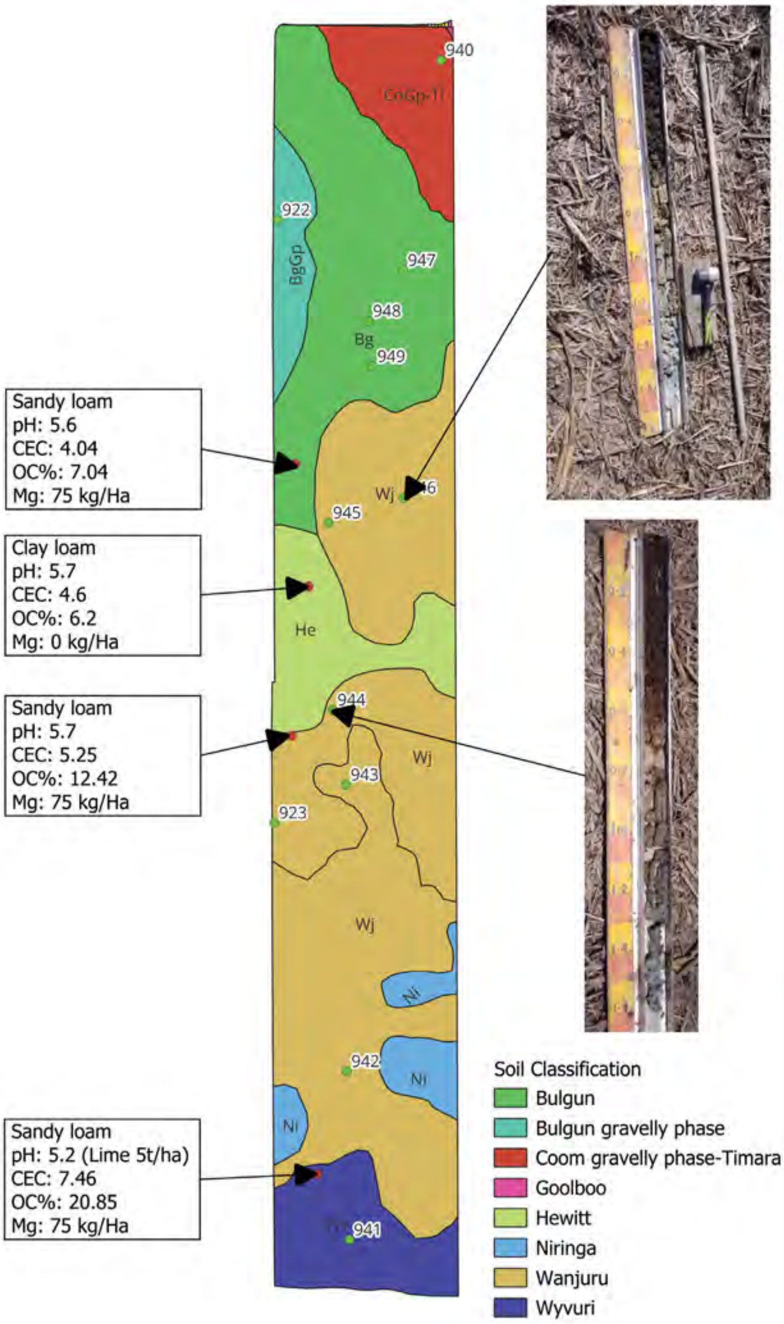


3 EC MAP

4 SATELLITE IMAGERY



5 **REFINED SOIL MAP FROM DEPARTMENT OF RESOURCES** - 1:5,000.
Created following site assessment. Displaying soil sampling locations and soil core profiles displayed.



Chapter 2: Research trial results

Introduction

Despite our extensive planning, field trials don't always proceed as expected. Challenges such as extreme weather and difficulties in applying treatments impacted our trials. Nevertheless, the preparation and sampling, outlined in Chapter 1, allowed us to adapt our trials to still obtain meaningful results. Of the three selected research trial sites, one was significantly affected by weather, and another faced challenges in treatment application. Fortunately, we had established one of our demonstration trials as a backup nitrogen rate trial. For the site where we encountered treatment application issues, we adjusted the trial's objective to examine how each soil type in the block responded to seasonal variations.

Chapter structure

1. Overview of trial sites

• Description of each trial site

• Specific challenges encountered at each site

2. Trial design and methodology

• Trial design and layout

• Outline any adjustments made to methodology due to unforeseen challenges

3. Results

• Presentation of data collected from the trials

• Analysis of nitrogen rate responses in different soil types

• Examination of seasonal variations' impact on different soil types

4. Discussion

• Interpretation of trial results

• Implications for sugarcane nitrogen management in the Wet Tropics

• Recommendations based on findings

5. Conclusion

• Summary of key findings

• Final thoughts on the impact of the trials on future research and practice

This chapter will present the results obtained from the trials and discuss their implications for sugarcane nitrogen management in the Wet Tropics region.

Trial site 1: Deeral

1. Overview of trial site

1.1 Site background

A visual site assessment was conducted during the selection of this trial site. Key observations, soil sample results, and trial activities are summarised below:

- Visual site assessment: Detailed observations made during the site selection process
- Soil sample results: Findings from soil sampling at the trial site
- Trial activities: Summary of the activities carried out during the trial.

SITE OBSERVATIONS

SOIL TYPE	Timara (Timara-Malbon heavy)	Malbon Prior (Malbon heavy, Malbon heavy-Timara)
CLAY %	52	29
SAND %	17	63
SILT %	37	14
WATER TABLE HEIGHT (NOV 2022)	1.4m	1.4 – 1.6m
DRAINAGE	Very poorly drained / Poorly drained Waterlogged in Wet season	Poorly drained
PESTS	Rats ground & climbing Armyworm – October 2022	Rats ground & climbing Armyworm – October 2022
DISEASE	RSD – Negative Pachymetra – Not Detected	RSD – Negative Pachymetra – Not Detected

Armyworm – Treated with Lorsban (Chlorpyrifos) and was no longer an issue after being treated.

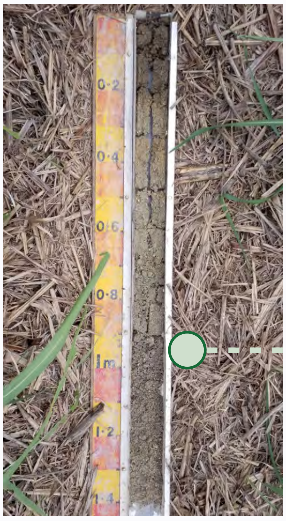
Rat damage.

CHAPTER 1-2

AVERAGE SOIL SAMPLE RESULTS FROM EACH SOIL TYPE FOR 2022 AND 2023

SOIL ANALYTE	UNITS	GUIDELINE VALUE	PRIOR 2022	PRIOR 2023	TIMARA 2022	TIMARA 2023
OC (WB)	%	> 2	0.90	1.27	1.69	1.53
CEC	meq/100g	-	3.68	4.42	4.35	4.97
ZN (HCL)	mg/kg	> 0.6	0.25	0.51	0.72	0.68
CU	mg/kg	> 0.2	0.13	0.46	0.77	0.70
PBI	-	-	88.75	120.42	135	147.69
P BSES	mg/kg	> 50	38.5	55.46	38.25	53.46
MG (AMM. ACET)	meq/100g	> 0.10	0.40	0.47	0.55	0.59
PH	1:5 Water	> 5.5	6.38	6.05	5.90	5.97
AL	%	< 30	4.25	5.75	8.48	6.38
CA (AMM. ACET)	meq/100g	> 0.65	2.98	3.57	3.23	3.90

Note: A guideline value is the threshold below which plant growth and yield may decline, except for aluminum (Al), where exceeding 30% can also lead to reduced yield.



CLIMATE CONDITIONS THROUGHOUT THE TRIAL

RAIN	2021	2022	2023	2024 (TO 31ST JAN)
RAINFALL (MM)	5511	5409	5315	835
DAYS OF RAIN	253	222	254	26

MALBON PRIOR SOIL CORE

TIMARA SOIL CORE
Indications of waterlogging 1.2-1.6m below surface.

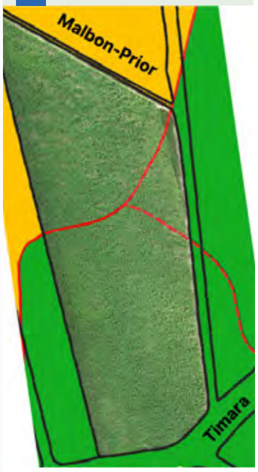
SITE ACTIVITIES & DATES

ACTIVITY	HARVEST OR BIOMASS DATE	VARIETY	RATOON AGE
YEAR 1 (COMMERCIAL HARVEST)	27/07/2021	SRA26	P
YEAR 2 (9-MONTH BIOMASS) NO TREATMENT	15/06/2022		1R
YEAR 3 (9-MONTH BIOMASS) TREATMENT APPLIED	04/04/2023		2R
YEAR 4 (9-MONTH BIOMASS) TREATMENT APPLIED	04/07/2024		3R

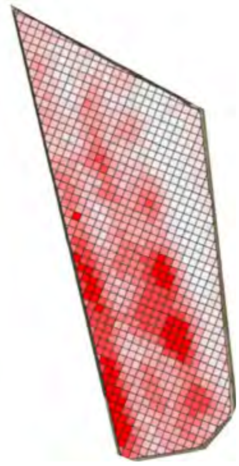
1.2 Site variability

As detailed in Chapter 1, a site variability assessment was conducted to understand the degree of variability within the trial block. The results of this assessment are presented below.

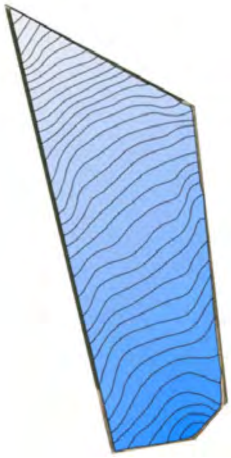
1 SOIL MAP 1:50,000



2 EC MAP

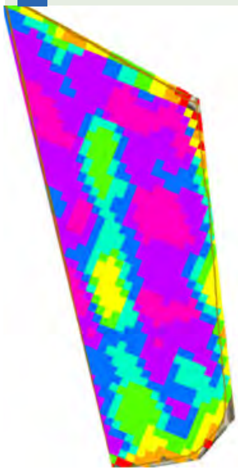


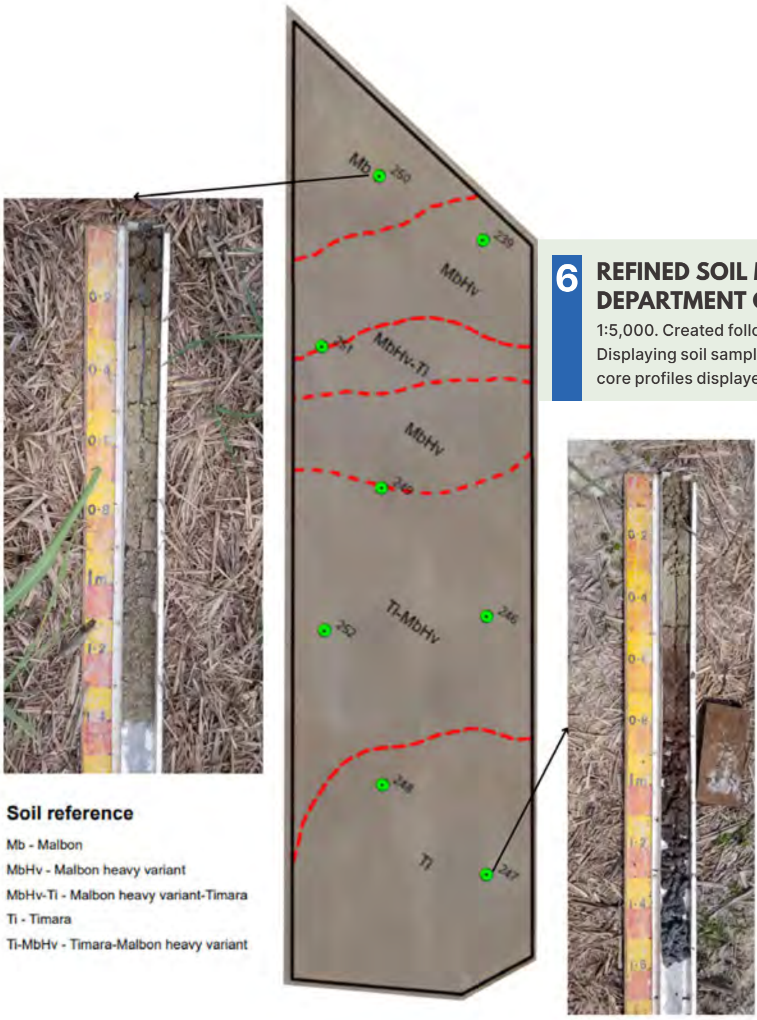
3 ELEVATION MAP



4 DRONE IMAGERY

5 SATELLITE IMAGERY





6 REFINED SOIL MAP FROM DEPARTMENT OF RESOURCES

1:5,000. Created following site assessment. Displaying soil sampling locations and soil core profiles displayed.

2. Trial design and methodology

The methodology for this trial site remained consistent with the approach outlined in Chapter 1, with one exception: the trial site included only three replicates of each treatment. The treatments comprised:

- 50 kg/ha of nitrogen
- 100 kg/ha of nitrogen
- 150 kg/ha of nitrogen
- 200 kg/ha of nitrogen

All other nutrients were applied according to soil analysis requirements to ensure that no other nutrients limited growth.

3. Results

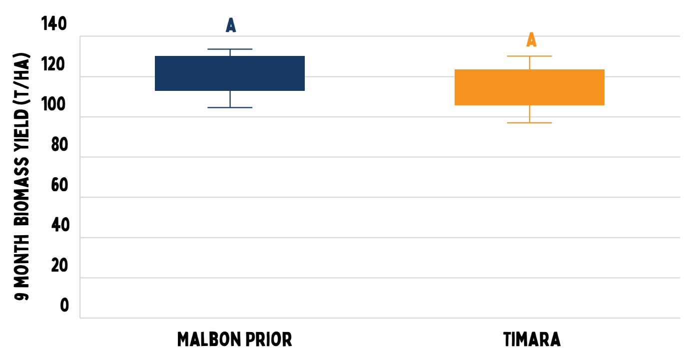
3.1 Baseline results 2022

Before applying the treatments, baseline biomass sampling was conducted to identify existing yield variability between the soil types. N rate was applied based on the growers current practice. The results of these biomass samples are shown opposite. The boxplots display yield (t/ha) and sugar yield (t/ha) for each soil type. The average yield observed at the Malbon Prior end of the trial was 120 t/ha, while the Timara end was 114 t/ha. Similarly, the average sugar yield (t/ha) observed at the Malbon Prior end was 19 t/ha and the Timara end was 18.1 t/ha. No significant differences were observed between the soil types for yield and sugar yield, as indicated by the identical letters above the boxplots, which denote no significant difference.

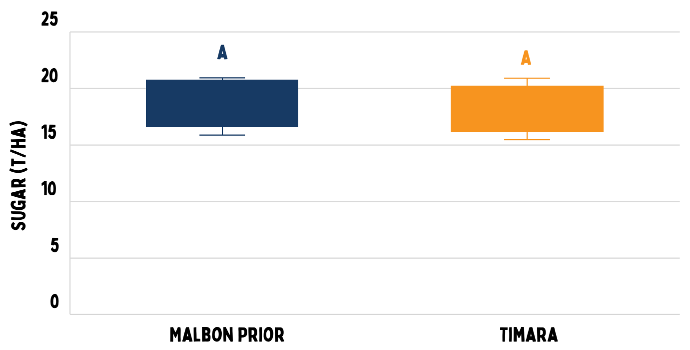
3.2 Year 1 – trial results 2023

The first-year results are shown in the boxplots opposite, illustrating biomass yield and sugar yield for each soil type and nitrogen application rate. There were no significant differences between the nitrogen rates, as indicated by the identical letters above the boxplots. Despite the lack of statistical significance, there was a notable difference in average

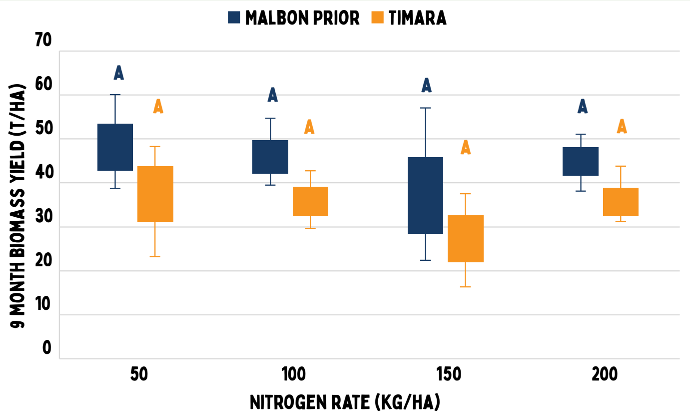
CANE YIELD (T/HA) ACHIEVED ON EACH SOIL TYPE BASED ON BASELINE BIOMASSING RESULTS



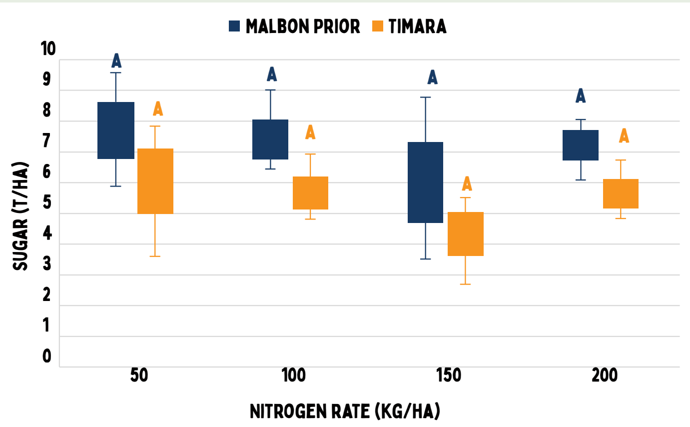
SUGAR YIELD (T/HA) ACHIEVED ON EACH SOIL TYPE BASED ON BASELINE BIOMASSING RESULTS



CANE YIELD (T/HA) ACHIEVED FOR 4 NITROGEN RATES AND 2 SOIL TYPES BASED ON 2023 BIOMASS RESULTS



SUGAR YIELD (T/HA) ACHIEVED FOR 4 NITROGEN RATES AND 2 SOIL TYPES BASED ON 2023 BIOMASS RESULTS



yield between the two ends. The biomass yield at the Malbon Prior end was 10.1 t/ha higher than the Timara end. Similarly, the average sugar yield differed by 1.7 t/ha, with the Malbon Prior end again showing higher yields than the Timara end.

3.2 Year 2 – trial results 2024

The second-year results are shown in the boxplots opposite, illustrating biomass yield and sugar yield for each soil type and nitrogen application rate. There were no significant differences between the nitrogen rates, as indicated by the identical letters above the boxplots. Despite the lack of statistical significance, there was a notable difference in average yield between the two ends. The biomass yield at the Malbon Prior end was 5.2 t/ha higher than the Timara end. Similarly, the average sugar yield differed by 1 t/ha, with the Malbon Prior end again showing higher yields than the Timara end.

4. Key findings

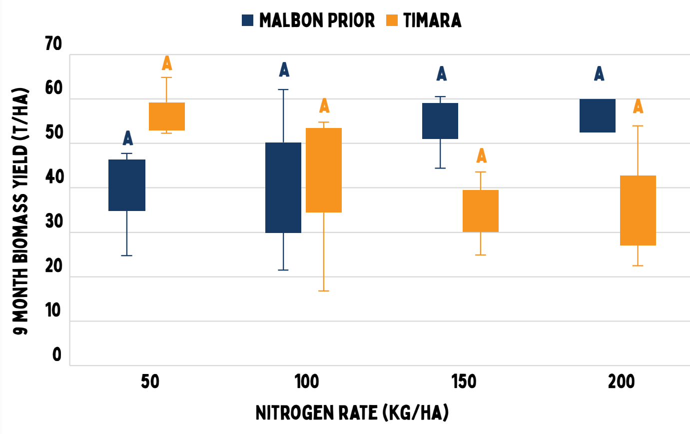
The trial assessed the effects of varying nitrogen application rates on biomass and sugar yield across different soil types over two years. The baseline results in 2022 showed no significant yield differences between soil types, with Malbon Prior and Timara ends averaging 120 t/ha and 114 t/ha in biomass yield, and 19 t/ha and 18.1 t/ha in sugar yield, respectively.

In 2023 and 2024, there were no significant yield differences between the N rates. However, the Malbon Prior end consistently achieved higher yields than the Timara end, with a 10.1 t/ha and 5.2 t/ha higher biomass yield, and a 1.7 t/ha and 1 t/ha higher sugar yield in each year, respectively.

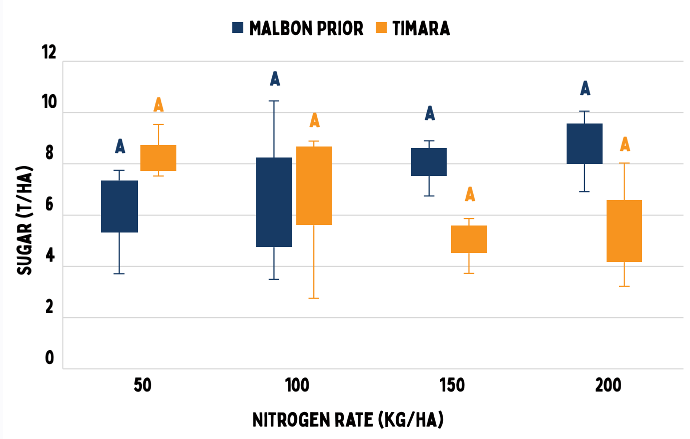
These results suggest that factors other than N rate, such as inherent soil characteristics or micro-environmental conditions, may significantly influence yield performance. Further research into these factors is recommended for optimising yields.

These findings highlight the importance of conducting site-specific soil assessments and implementing tailored nutrient and constraint management strategies to optimise sugarcane production.

CANE YIELD (T/HA) ACHIEVED FOR 4 NITROGEN RATES AND 2 SOIL TYPES BASED ON 2024 BIOMASS RESULTS



SUGAR YIELD (T/HA) ACHIEVED FOR 4 NITROGEN RATES AND 2 SOIL TYPES BASED ON 2024 BIOMASS RESULTS



CHAPTER 1-2

Trial site 2: Babinda

1. Overview of trial site

1.1 Site background

A visual site assessment was conducted during the selection of this trial site. Key observations, soil sample results, and trial activities are summarised below:

- Visual site assessment: Detailed observations made during the site selection process
- Soil sample results: Findings from soil sampling at the trial site
- Trial activities: Summary of the activities carried out during the trial.

SITE OBSERVATIONS		
SOIL TYPE	Wanjuru	Bulgan
CLAY %	28	20
SAND %	42	54
SILT %	30	26
WATER TABLE HEIGHT (NOV 2022)	0.7-1.4m	1.4m
DRAINAGE	Very poorly drained. High water table, waterlogging in wet weather	Poorly drained
PESTS	Rats ground & climbing	Rats ground & climbing
DISEASE	RSD – Negative Pachymetra Spore Count - 1,020,360	RSD – Negative Pachymetra Spore Count - 1,020,360

WANJURU SOIL CORES

Both soil cores taken from Wanjuru soil type, unfortunately no soil cores were taken from the Bulgun soil type. Note the dark organic peat layer to 0.6m and grey clay from 1.3m onward on both samples.
The grey indicates poor aeration.

CHAPTER 1-2

AVERAGE SOIL SAMPLE RESULTS FROM EACH SOIL TYPE FOR 2022 AND 2023

SOIL ANALYTE	UNITS	GUIDELINE VALUE	WANJURU 2022	WANJURU 2023	BULGUN 2022	BULGUN 2023
OC (WB)	%	> 2	14.02	10.01	7.03	3.70
CEC	meq/100g	-	5.44	3.80	4.03	3.22
ZN (HCL)	mg/kg	> 0.6	0.46	NA	0.18	NA
CU	mg/kg	> 0.2	0.55	NA	0.43	NA
PBI	-	-	2100.00	1788.89	1225.00	704.44
P BSES	mg/kg	> 50	152.50	215.00	397.50	442.22
MG (AMM. ACET)	meq/100g	> 0.10	0.22	NA	0.17	NA
PH	1:5 Water	> 5.5	5.45	5.54	5.48	5.62
AL	%	< 30	44.25	37.83	29.00	38.56
CA (AMM. ACET)	meq/100g	> 0.65	2.35	2.06	1.89	1.66

Note: A guideline value is the threshold below which plant growth and yield may decline, except for aluminum (Al), where exceeding 30% can also lead to reduced yield.

CLIMATE CONDITIONS THROUGHOUT THE TRIAL

RAIN	2021	2022	2023
RAINFALL (MM)	4853	4543	5258
DAYS OF RAIN	207	188	199

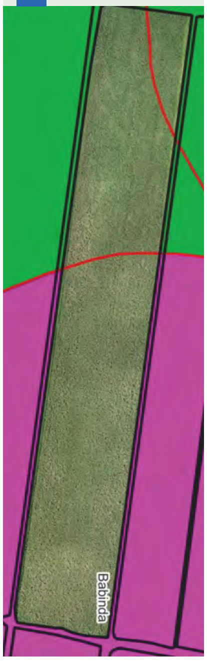
SITE ACTIVITIES & DATES

ACTIVITY	HARVEST OR BIOMASS DATE	VARIETY	RATOON AGE
YEAR 1 (COMMERCIAL HARVEST)	27/07/2021	Q208	2R
YEAR 2 (9-MONTH BIOMASS)	15/06/2022		3R
YEAR 3 (9-MONTH BIOMASS)	04/04/2023		4R

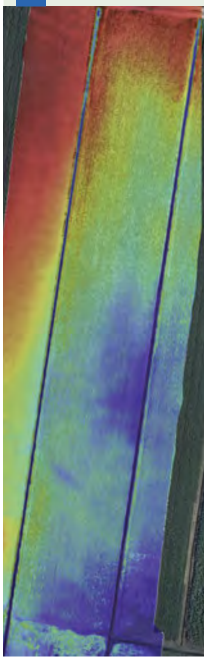
1.2 Site variability

As detailed in Chapter 1, a site variability assessment was conducted to understand the degree of variability within the trial block. The results of this assessment are presented below.

1 SOIL MAP 1:50,000

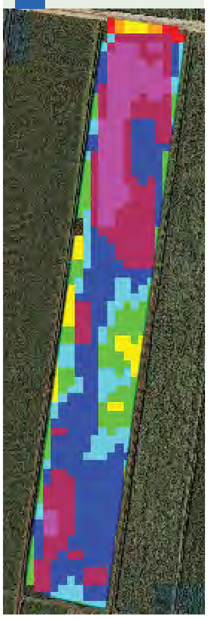


2 ELEVATION MAP

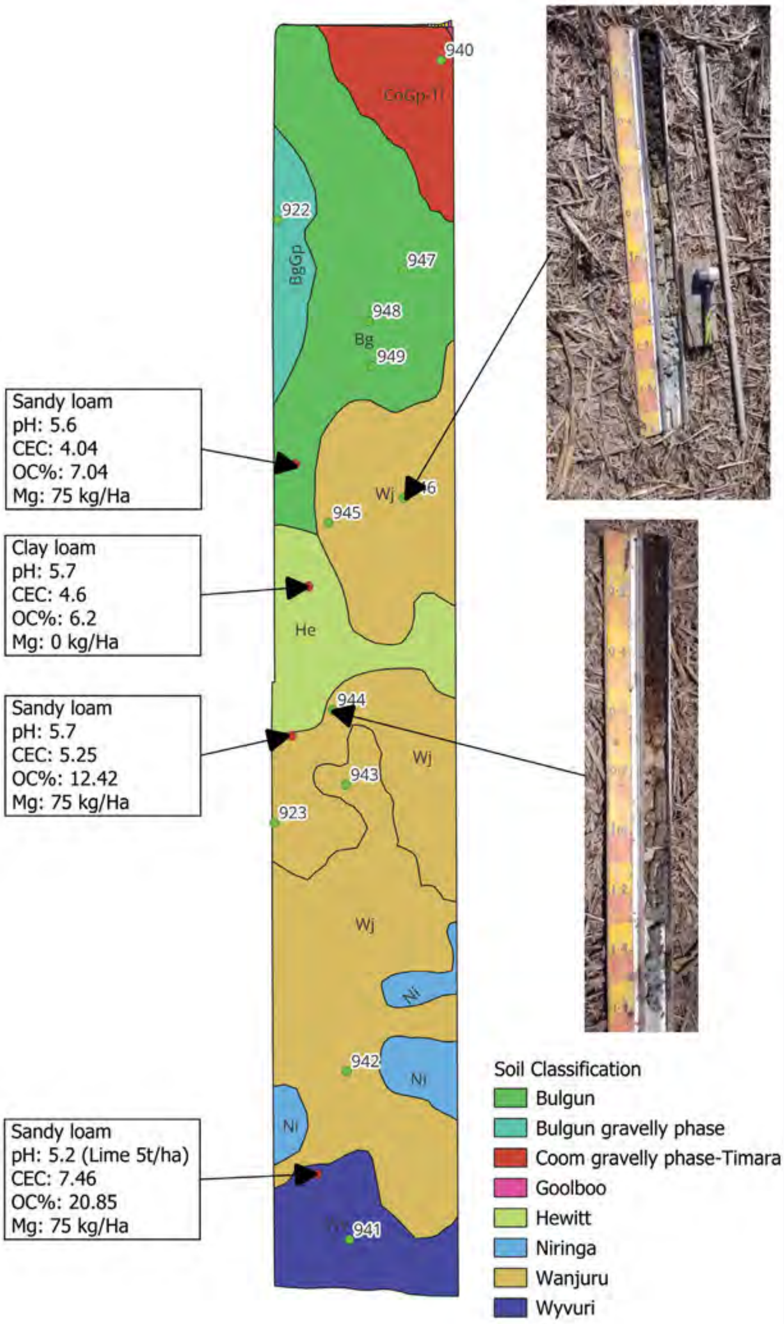


3 EC MAP

4 SATELLITE IMAGERY



5 REFINED SOIL MAP FROM DEPARTMENT OF RESOURCES - 1:5,000. Created following site assessment. Displaying soil sampling locations and soil core profiles displayed.



2. Trial design and methodology

The methodology for this trial site remained consistent with the approach outlined in Chapter 1, with one exception: the trial site included only three replicates of each treatment. The treatments comprised:

- 50 kg/ha of nitrogen
- 100 kg/ha of nitrogen
- 150 kg/ha of nitrogen

We also had additional treatments investigating if phosphorus applications had an impact on yield. The additional treatments were:

- 10 kg/ha of phosphorus + 50 kg/ha of nitrogen
- 10 kg/ha of phosphorus + 100 kg/ha of nitrogen

Each of the treatments above had four replicates.

All other nutrients were applied according to soil sample requirements to ensure that no other nutrients limited growth.

2. Results

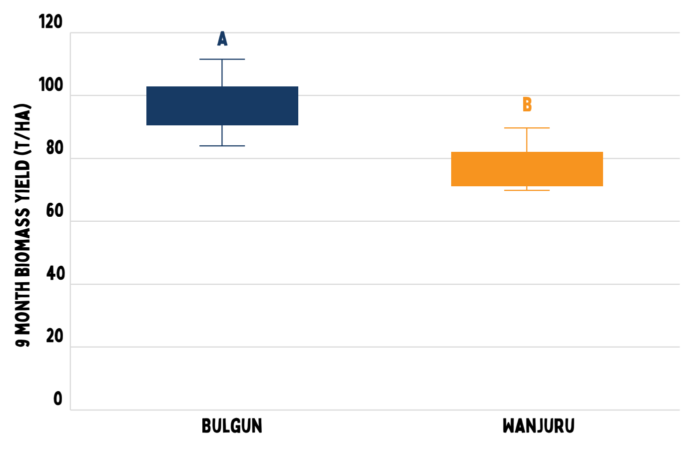
Baseline results 2022

Prior to the treatments, baseline biomass sampling was conducted to assess yield variability between the soil types. Fertiliser was applied as per grower's current practice. The results of these biomass samples are presented below. The boxplots show yield (t/ha) and sugar yield (t/ha) for each soil type. At the Bulgun end of the trial, the average yield was 97 t/ha, whereas at the Wanjuru end, it was 78 t/ha. Similarly, the average sugar yield at the Bulgun end was 11.7 t/ha, compared to 9.5 t/ha at the Wanjuru end. Significant differences in both yield and sugar yield between the soil types are indicated by the different letters above the boxplots, with distinct letters denoting significant differences.

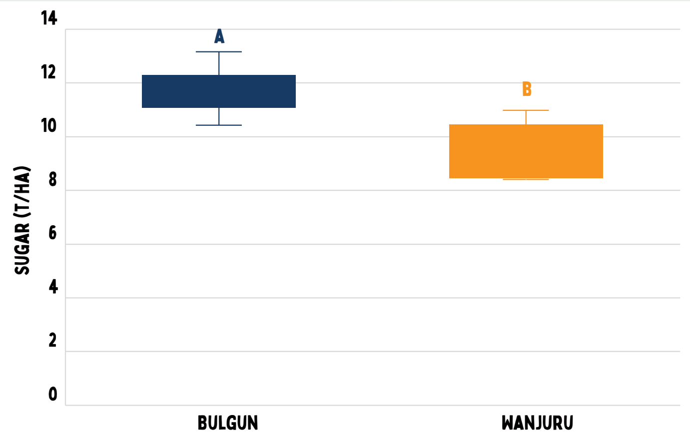
Year 1 – trial results 2023

The first-year results display biomass yield and sugar yield for each soil type and nitrogen application rate, including additional treatments with 10 kg/ha of phosphorus. Significant differences were found between the soil types and some rates, as indicated by the differences in letters above the boxplots. A significant difference of 21.6 t/ha in average yield was observed between the Bulgun end (higher yield) and the Wanjuru end. Similarly, the average sugar yield differed by 3.3 t/ha, with higher yields at the Bulgun end compared to the Wanjuru end. For each soil type, 100 kg/ha of nitrogen tended to yield the highest results. This reflects the 6ES rate for both soil types with all soil organic carbon level being above 2.4%.

CANE YIELD (T/HA) ACHIEVED ON EACH SOIL TYPE BASED ON BASELINE BIOMASSING RESULTS



SUGAR YIELD (T/HA) ACHIEVED ON EACH SOIL TYPE BASED ON BASELINE BIOMASSING RESULTS



Year 2 – trial results 2024

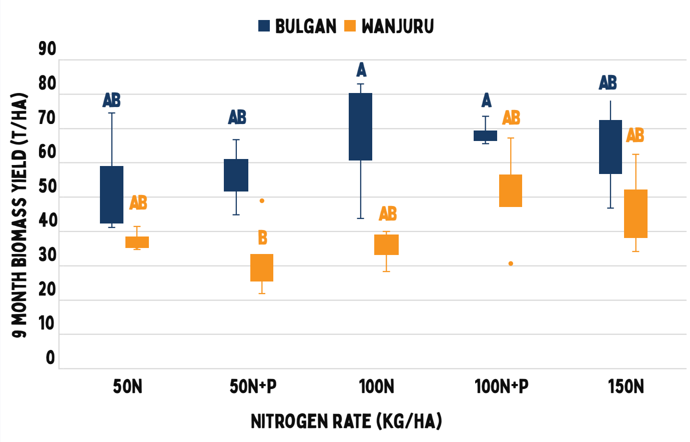
We had intended to collect results for the second year from this trial site however the block was severely affected by Ex Cyclone Jasper, the wettest tropical cyclone on record, and the trial was terminated.

3. Key findings

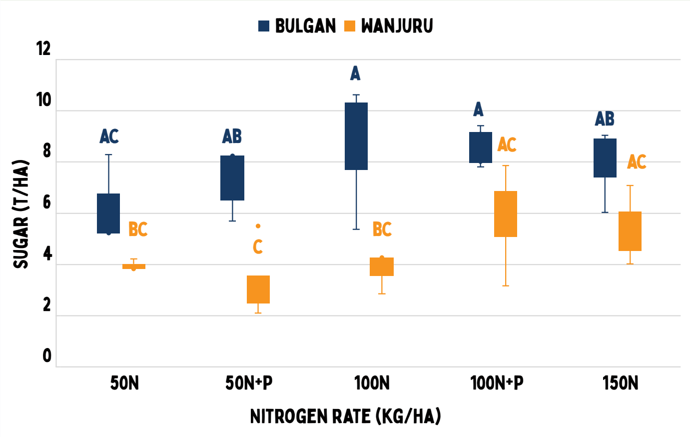
The trial at Babinda provided valuable insights into the impact of soil type and nutrient application on biomass and sugar yields. Significant differences were observed between the Bulgun and Wanjuru soils, with Bulgun consistently yielding higher biomass and sugar content. The Wanjuru soil type had heavy clay below the peat and a higher water table. As a consequence, this area experienced more waterlogging over the wet season than the Bulgan area. The optimal nitrogen application rate for maximising yields tended to be around 100 kg/ha across both soil types. Additionally, treatments incorporating phosphorus did not significantly improve yields for each soil type. Phosphorus is not recommended based on soil test analysis on either soil, however PBI is very high particularly on the Wanjuru soil.

These findings highlight the importance of conducting site-specific soil assessments and implementing tailored nutrient and constraint management strategies to optimise sugarcane production.

CANE YIELD (T/HA) ACHIEVED FOR 4 NITROGEN RATES, WITH 2 NITROGEN RATES WITH 10KG/HA OF PHOSPHORUS AND 2 SOIL TYPES BASED ON 2023 BIOMASS RESULTS



SUGAR YIELD (T/HA) ACHIEVED FOR 4 NITROGEN RATES, WITH 2 NITROGEN RATES WITH 10KG/HA OF PHOSPHORUS AND 2 SOIL TYPES BASED ON 2023 BIOMASS RESULTS



CHAPTER 1-2

Trial site 3: Gordonvale

1. Overview of trial site

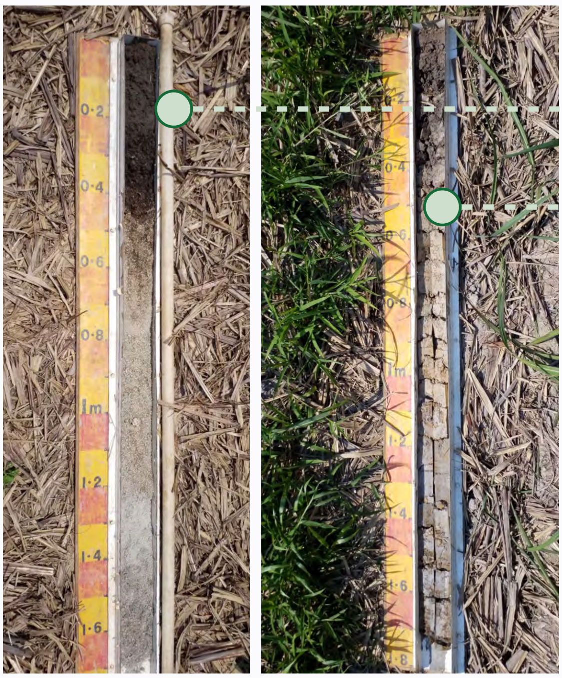
1.1 Site background

A visual site assessment was conducted during the selection of this trial site. Key observations, soil sample results, and trial activities are summarised below:

- Visual site assessment: Detailed observations made during the site selection process
- Soil sample results: Findings from soil sampling at the trial site
- Trial activities: Summary of the activities carried out during the trial.

SITE OBSERVATIONS

SOIL TYPE	Prior (Redefined as Lugger, Lugger - heavy and Niringa)	Jarra (Redefined as Timara & Coom)
CLAY %	12	35
SAND %	73	39
SILT %	15	26
WATER TABLE HEIGHT (NOV 2022)	Below 1.75m	Below 1.75m
DRAINAGE	Imperfectly drained / Poorly drained / Very Poorly drained	Poorly drained
PESTS	Rats ground & climbing	Rats ground & climbing
DISEASE	RSD – Negative Pachymetra – Not detected	RSD – Negative Pachymetra – Not detected



SOIL CORES FROM EACH SOIL TYPE

Prior soil core.

Jarra soil core.

AVERAGE SOIL SAMPLE RESULTS FROM EACH SOIL TYPE FOR 2022, 2023 & 2024

SOIL ANALYTE	UNITS	GUIDELINE VALUE	JARRA 2022	JARRA 2023	JARRA 2024	PRIOR 2022	PRIOR 2023	PRIOR 2024
OC (WB)	%	> 2	1.72	1.42	1.73	1.99	2.13	2.47
CEC	meq/100g	-	3.70	3.54	3.48	2.08	2.14	2.18
ZN (HCL)	mg/kg	> 0.6	1.30	1.54	1.19	1.55	1.28	0.77
CU	mg/kg	> 0.2	0.39	0.52	0.54	0.14	0.13	0.12
PBI	-	-	232.50	282.50	290.00	195.00	292.50	217.50
P BSES	mg/kg	> 50	16.00	22.50	16.50	117.50	88.75	71.50
MG (AMM. ACET)	meq/100g	> 0.10	0.26	0.20	0.22	0.06	0.06	0.06
PH	1:5 Water	> 5.5	5.33	5.18	5.23	5.50	5.28	5.30
AL	%	< 30	67.00	78.00	77.50	74.75	83.25	85.25
CA (AMM. ACET)	meq/100g	> 0.65	0.74	0.43	0.37	0.34	0.22	0.18

Note: A guideline value is the threshold below which plant growth and yield may decline, except for aluminum (Al), where exceeding 30% can also lead to reduced yield.

CLIMATE CONDITIONS THROUGHOUT THE TRIAL

RAIN	2021	2022	2023	2024 (TO 28TH MAY)
RAINFALL (MM)	2425	2306	2895	1772
DAYS OF RAIN	120	121	133	91

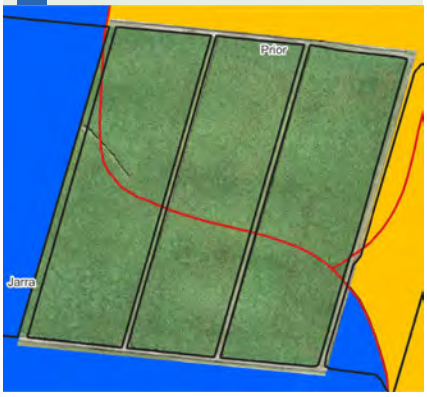
SITE ACTIVITIES & DATES

ACTIVITY	HARVEST OR BIOMASS DATE	VARIETY	RATOON AGE
YEAR 1 (HARVEST)	13/10/2021	Q253	1R
YEAR 2 (BIOMASS)	22/06/2022		2R
YEAR 3 (BIOMASS)	29/06/2023		3R
YEAR 4 (BIOMASS)	23/04/2024		4R

1.2 Site variability

As detailed in Chapter 1, a site variability assessment was conducted to understand the degree of variability within the trial block. The results of this assessment are presented below.

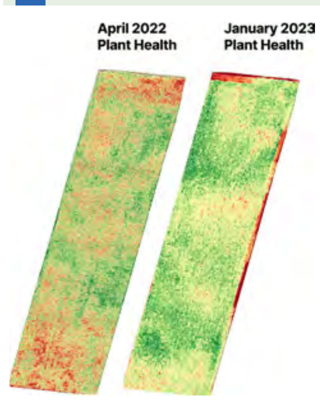
1 SOIL MAP 1:50,000

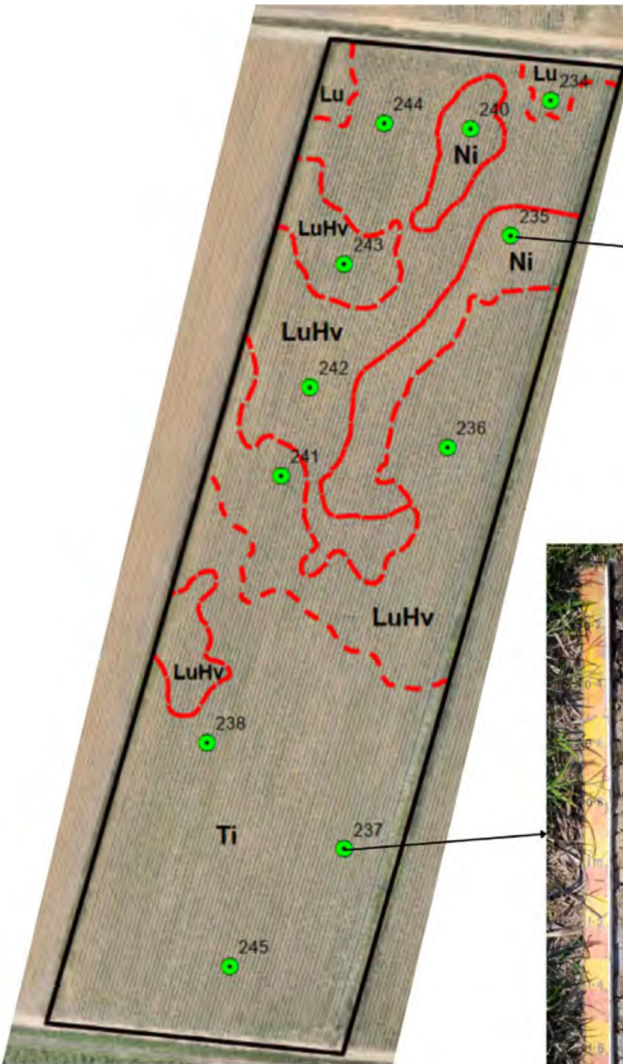


2 EC MAP

3 ELEVATION MAP

4 DRONE IMAGERY





5 REFINED SOIL MAP FROM DEPARTMENT OF RESOURCES

1:5,000. Created following site assessment. Displaying soil sampling locations and soil core profiles displayed.

Soil reference

Lu - Lugger
LuHv - Lugger heavy variant
Ni - Niringa
Ti - Timara

2. Trial design and methodology

The methodology for this trial site followed the approach outlined in Chapter 1, with one exception: nitrogen rate treatments were not included. We faced challenges in treatment application, so this trial focused on how yield varied from year to year, investigating the role of soil type. Fertiliser was applied according to the growers' standard practice.

Each of the treatments above had four replicates.

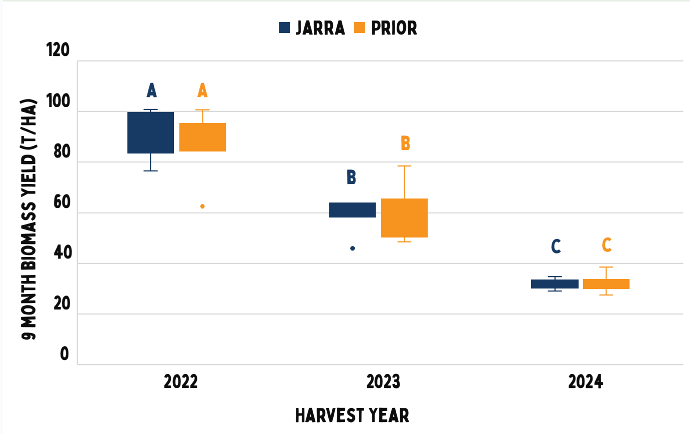
3. Results

The boxplots below display yield (t/ha) and sugar yield (t/ha) for each soil type across three years (2022–2024). The results indicate significant differences in yield and sugar yield between the years, as denoted by different letters above the boxplots. However, there was no significant difference in yield and sugar yield for each soil type. Overall, yield and sugar yield decreased over time.

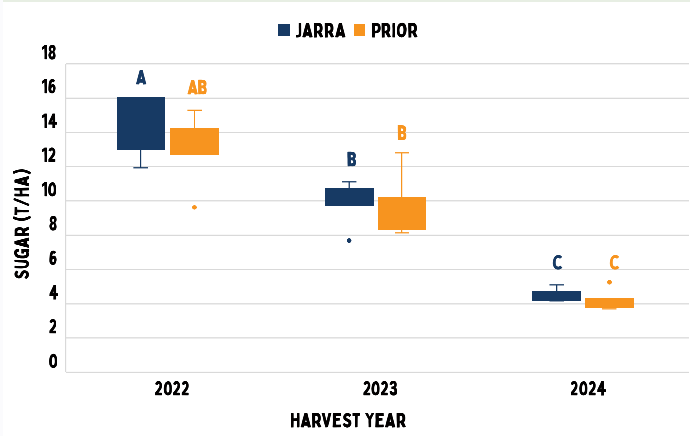
4. Key findings

The trial at Gordonvale provided valuable insights into the effects of soil type on yield and sugar yield over three years (2022–2024). The study demonstrated significant year-to-year differences in both yield and sugar yield. However, no significant differences were observed between the soil types. Notably, both yield and sugar yield exhibited a declining trend over the trial period. At the beginning of the trial, soil tests did show a calcium deficiency in both soil types, with Jarra experiencing a decline over the year and Prior, being significantly deficient, remaining at this very low value. These findings underscore the importance of understanding seasonal variability and crop age and their impact on crop performance, which can inform future agricultural practices and fertiliser applications to optimise yield outcomes.

CANE YIELD (T/HA) ACHIEVED ON EACH SOIL TYPE BASED ON BASELINE BIOMASSING RESULTS FOR 2022-2024



SUGAR YIELD (T/HA) ACHIEVED ON EACH SOIL TYPE BASED ON BASELINE BIOMASSING RESULTS FOR 2022-2024



CHAPTER 1-2

Demonstration trial - Mirriwinni

This demonstration trial aimed to assess crop response to varying nitrogen rates. Given it was a demonstration trial, we did not conduct in-depth variability assessments. Instead, we selected a block with a relatively uniform soil type, Timara Coom, that was planted with a single sugarcane variety, third ratoon SRA6. We collected soil samples, recorded commercial harvest data, and conducted monthly drone flights throughout the trial period. The aim of this trial was to evaluate the crop's response to different nitrogen application rates: 50 kg/ha, 100 kg/ha, 150 kg/ha, and 200 kg/ha of N. By maintaining consistent conditions across the block, we aimed to understand the impact of these nitrogen levels on yield and crop health, providing valuable insights for optimising future fertiliser practices.

AVERAGE SOIL SAMPLE RESULTS FROM EACH SOIL TYPE FOR 2022

SOIL ANALYTE	UNITS	GUIDELINE VALUE	TIMARA-COOM 2022
OC (WB)	%	> 2	1.08
CEC	meq/100g	-	9.92
ZN (HCL)	mg/kg	> 0.6	1.03
CU	mg/kg	> 0.2	0.86
PBI	-	-	140
P BSES	mg/kg	> 50	47.67
MG (AMM. ACET)	meq/100g	> 0.10	1.53
PH	1:5 Water	> 5.5	6.77
AL	%	< 30	4.06
CA (AMM. ACET)	meq/100g	> 0.65	8.00

Note: All nutrients were above guideline values.

CLIMATE CONDITIONS THROUGHOUT THE TRIAL

RAIN	2022	2023	2024 (TO 30TH APRIL)
RAINFALL (MM)	4543	5258	3556
DAYS OF RAIN	188	199	96

The trial was harvested 29th November 2023. We plan to collect commercial harvest data again in 2024. Each treatment was 6 rows and had 4 replicates, as seen in the trial map below. There are additional treatments on the map, 100 P and 150 P, these were testing if the addition of Pasture N had an impact on yield. The results of the Pasture N trials are discussed in Chapter 3.

Results

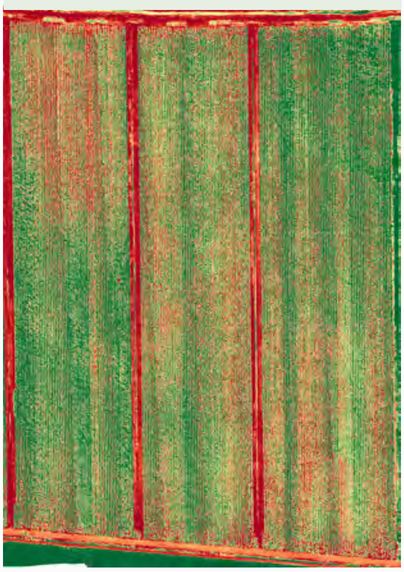
Drone imagery

The monthly drone imagery revealed that visual differences in the treatments were present, especially in the higher nitrogen rate treatments. Examples shown below:

DRONE FLIGHT ON THE 27TH MARCH 2023

TRIAL DESIGN four replicates of four nitrogen rates (50, 100, 150 and 200 kg N/ha)

DRONE FLIGHT ON THE 17TH AUGUST 2023 Drone map with plant indicator (red shows less productive and green shows better productivity)



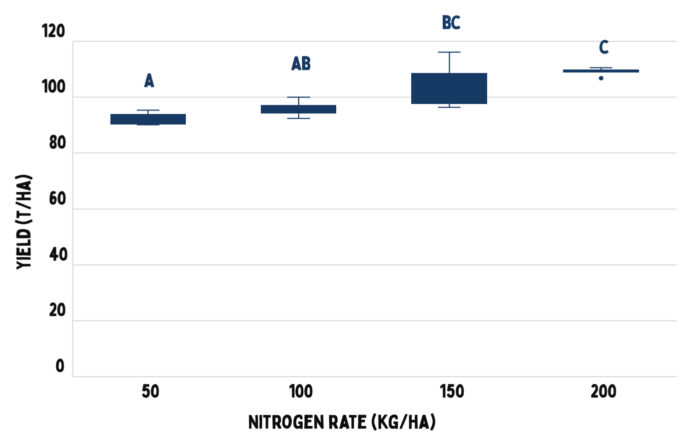
Commercial harvest data

The boxplots opposite display the commercial harvest yield (t/ha) and sugar yield (t/ha) for each nitrogen rate treatment. The results indicate significant differences in both yield and sugar yield between the different nitrogen rate treatments, as denoted by the different letters above the boxplots. There were significant differences in yield and sugar yield between the 50 kg/ha N and 150 kg/ha N treatments, as well as between the 50 kg/ha N and 200 kg/ha N treatments. However, there were no significant differences between the 50 kg/ha N and 100 kg/ha N treatments, the 100 kg/ha N and 150 kg/ha N treatments, or the 150 kg/ha N and 200 kg/ha N treatments. The highest yields and sugar yields were observed in the 150 kg/ha N and 200 kg/ha N treatments.

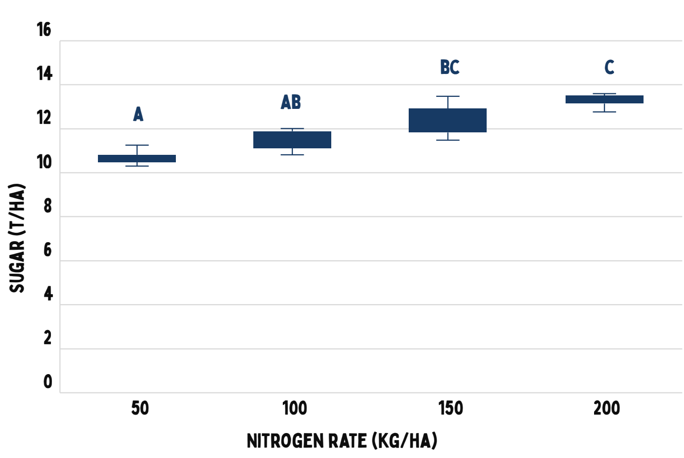
Key findings

This demonstration trial at Mirriwinni effectively assessed crop response to varying nitrogen rates, revealing significant differences in yield and sugar yield between the 50 kg/ha N and higher nitrogen rate treatments (150 kg/ha N and 200 kg/ha N). The highest yields were observed in the 150 kg/ha N and 200 kg/ha N treatments, indicating that these nitrogen levels optimise crop performance. Additionally, the neutral soil pH of 6.77 created optimal conditions for nutrient availability, ensuring that all essential soil nutrients were fully accessible to the plants. This balanced pH level played a crucial role in maximising nutrient uptake, thereby significantly enhancing plant growth and yield. By maintaining this optimal pH, the trial demonstrated how important soil pH management is for achieving high crop productivity. The site was also relatively free from other constraints with no micro-nutrient or trace element deficiencies and no evidence of waterlogging. These findings offer valuable insights for optimising future fertiliser practices and underscore the importance of maintaining suitable soil conditions for optimal crop performance.

CANE YIELD (T/HA) ACHIEVED FOR FOUR NITROGEN RATES (50, 100, 150 AND 200 KG N/HA) BASED ON 2023 COMMERCIAL HARVEST RESULTS



CANE YIELD (T/HA) ACHIEVED FOR FOUR NITROGEN RATES (50, 100, 150 AND 200 KG N/HA) BASED ON 2023 COMMERCIAL HARVEST RESULTS



Summary of Chapter 2: Research trial results

In Chapter 2, the results of the research trials were presented, detailing the performance and outcomes across various sites under different nitrogen application rates. Despite extensive planning, the trials faced significant challenges due to extreme weather and treatment application difficulties. Among the three trial sites, one was severely impacted by weather, and another faced issues with treatment application. However, a demonstration trial focusing on nitrogen rates served as a backup to ensure meaningful data collection.

At the Deeral site, soil type was found to have a more significant impact on sugarcane yield than the varied nitrogen rates, emphasising the importance of site-specific soil assessments for optimising crop performance.

The Babinda site showed significant differences in yield and sugar yield between soil types, with the optimal nitrogen application rate being around 100 kg/ha. Unfortunately, this trial was terminated in its second year due to cyclone damage.

The Gordonvale site focused on yield variations over time, revealing significant year-to-year differences but no substantial differences between soil types. This highlighted the influence of seasonal variability and crop age on performance.

A demonstration trial at Mirriwinni, which evaluated crop response to varying nitrogen rates, showed that higher nitrogen rates (150 kg/ha and 200 kg/ha) significantly increased yield and sugar yield compared to lower rates. Additionally, the trial underscored the importance of maintaining a neutral soil pH of 6.77 for optimal nutrient availability, enhancing plant growth and yield.

Across the trial sites the poor performing soil had more severe waterlogging and drainage limitations. The soil difference in site 1 and 2 coincided with difference in water table heights and presence of water logging in the wet season affecting yield. This was established through site classification with the Queensland Government Department of Resources. These conditions are not unusual in the Wet Tropics sugar industry.

Overall, the trials highlighted the critical role of tailoring nutrient management to soil type and the importance of understanding the variability that exists within your farm to optimise sugarcane production. These findings provide valuable insights for refining fertiliser practices and nitrogen management strategies in the Wet Tropics region.

Chapter 3: On farm demonstration activities

Introduction to on farm demonstrations

Many growers have questions about how different management practices will work on their farms. Perhaps they have heard results from trials that were conducted elsewhere, or information has been developed for the practice in different crops, but a key piece of information remains missing. How will this work on my farm? Precision to Decision offered growers the opportunity to run demonstration trials with Farmacist agronomists to answer those questions. Agronomists worked with the grower to understand what they wanted to learn and then designed demonstration activities to generate answers to growers' questions.

Some questions that were asked focused on the impact of cover crops on soil attributes such as phosphorus and soil carbon and how this might benefit subsequent crops, others were around practices to improve farm economics and sustainability through rate changes, use of ameliorants and maximising alternative sources of nitrogen and others tested methods for improving sugar yield.

On farm demonstrations are important because they allow growers to answer these questions under the environmental and management conditions that are specific to their farm. Depending on the activity, the outcomes of the demonstration may give the grower the confidence to go ahead with the practice change across their farm, or in some cases the results may provide reasons for not making a change. Sometimes the demonstration sites reveal more new questions in the process of exploring the original questions.


FARMACIST

Trialling PastureN with different rates of fertiliser

Summary

This study explored how the microbial enhancement fertiliser, PastureN, could impact sugarcane yield under varying fertiliser rates. PastureN, is applied as a liquid containing nitrogen-fixing and bacillus microbes, along with plant-based amino acids. It has been successfully used to boost biomass in pastures with lowered nitrogen fertiliser rates in trials in Australia. These demonstrations assessed the product on sugarcane in the Mulgrave area.

The manufacturer explains that the applied microbes colonise the plant, the root surface and surrounding soil. They fix atmospheric nitrogen, converting it to plant available ammonium nitrogen similar to Rhizobium/legume symbiosis. Bacillus microbes promote a balanced soil microbiome and may inhibit the growth of pathogenic fungi and bacteria. Amino acids enhance the plant uptake of nitrogen fixing microbes and can stimulate crop growth.

PastureN should be applied in at least 100L water/ha in moist conditions on actively growing cane with enough leaf area for microbe colonisation. Not all of the product needs to be taken up by the leaf since the microbiota also colonise the soil and root area. Therefore, application occurs early in the wet season using a high-rise sprayer. Hot, dry and/or windy conditions will damage the microbes and prevent colonisation.

Prior to application, the microbes must be rehydrated and mixed with amino acids in a clean spray tank. Which takes about 30 minutes. Each PastureN pack covers 5ha at a cost of $40/ha at the recommended rate.

Trial 1:

Location: Aloomba, Mulgrave

Soil type: Innisfail

Crop class & variety: SRA 26 1st Ratoon

Year: 2022-2023

Treatments:

T1: 100% Fertiliser / 5 replicates

T2: 100% Fertiliser + PastureN / 5 replicates

T3: 75% Fertiliser / 5 replicates

T4: 75% Fertiliser + PastureN / 5 replicates

Results

There was no significant difference between treatments.

This indicates that in this season, fertiliser could be reduced by 25 percent with no impact on yield at this site. There was no indication that the PastureN increased yield or sugar production.

There was minimal variation between treatments and replicates except for one outlier replicate with lower-than-average tonnes/ha in the 100% fertiliser treatment. The least variation was found in the 75% fertiliser treatment. The highest variation in tonnes cane and CCS was found in the 100% fertiliser treatment, with a reduction in variation occurring where PastureN was applied. Variability was reduced in CCS results for both treatments where PastureN was applied.

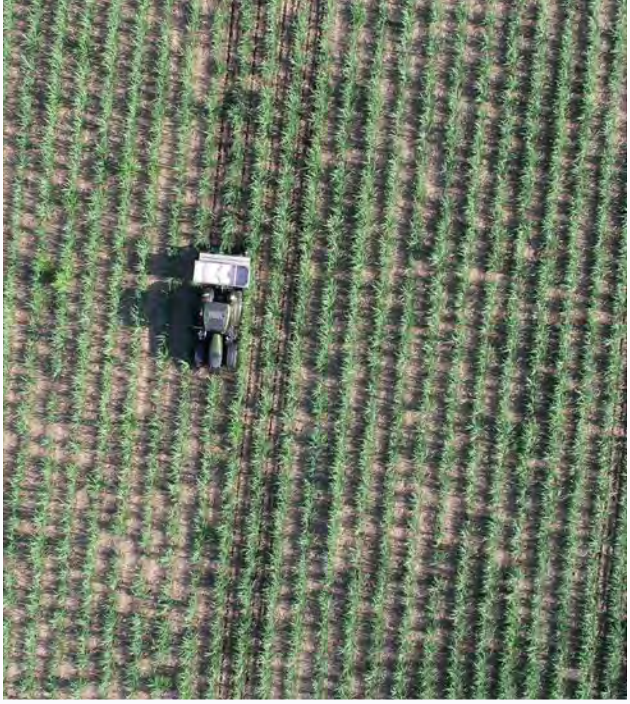


TABLE SHOWING AVERAGE RESULTS FOR EACH DEMONSTRATION TREATMENT

TREATMENT	CANE YIELD (T/HA)	CCS	SUGAR YIELD (T/HA)
120 kgN/ha	117.44	11.40	13.41
120 kgN/ha + PastureN	118.53	11.53	13.66
90 KgN/ha	118.07	11.82	13.95
90 KgN/ha + PastureN	118.78	11.97	14.22

Demonstration design and methods

Fertiliser was applied on November 3, 2022, according to a randomised, replicated trial design. The 100 percent rate reflects the growers' standard practice on this soil type, which is a reduced nitrogen rate compared to the full rate of 140N calculated through SIX EASY STEPS.

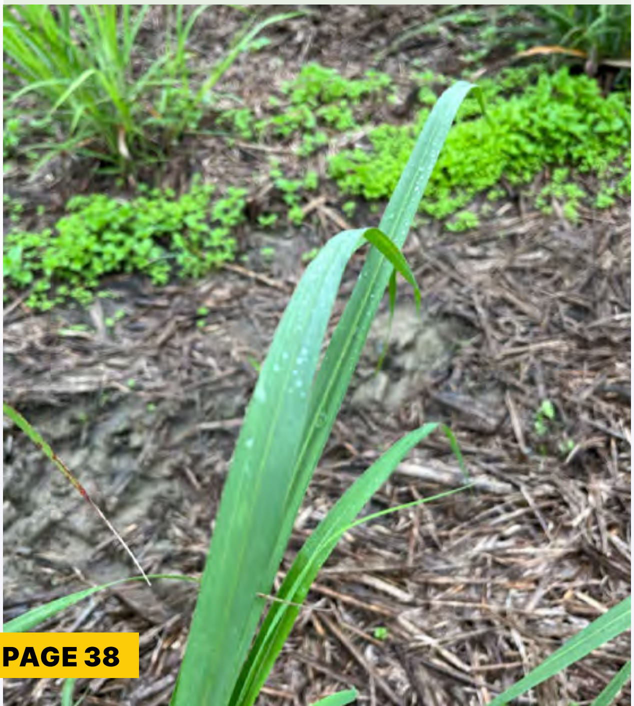
PastureN was applied at out of hand on February 21, 2023, using a high-rise sprayer with a water rate of 300L/ha. Prior to application the freeze-dried nitrogen fixing microbes were mixed with the Bacillus microbes and amino acid formulation. The microbial formulations all require refrigeration before use and must be applied to cane in moist conditions.

The block was commercially harvested over two days from October 31 to November 1st, 2023. Tonnes and CCS were supplied through mill data for each replicate.

Recommendations

This demonstration shows that high cane yields are possible on this soil type with a reduced rate of nitrogen. In this instance reduction of nitrogen fertiliser and application of PastureN appeared to increase CCS and reduce variation in CCS, however there was no yield impact. Continued investigation of the potential of PastureN over multiple years in a range of soils and climate types is recommended.

PastureN droplets on sugacrane.



Trial 2:

Location: Little Mulgrave

Soil type: Clifton

Crop class & variety: 5R Q200

Year/s: 2022-23

Treatments:

T1: Grower standard practice (3 replicates)

T2: Grower standard practice + PastureN (3 replicates)

Results

In this trial PastureN increased average tonnes cane/ha by 6.6 tonne.

The three PastureN replicates had higher tonnes cane with much less variability across the replicates than the treatment without PastureN.

TREATMENT	CANE YIELD (T/HA)
Grower rate with Pasture N	50.36
Grower fertiliser rate	43.71

Demonstration design and methods

Fertiliser was applied at one rate across the block using the growers' standard practice, which is a greatly reduced nitrogen and potassium rate compared to the full rate of 140N and 100K calculated through SIX EASY STEPS.

PastureN was applied at out of hand at end of January 2023, using an inter-row sprayer with a water rate of 300L/ha.

The block was commercially harvested on October 15th, 2023. Tonnes of cane were supplied through mill data for each replicate. A mill issue resulted in the loss of CCS data. Without CCS tonnes/sugar per hectare is also not able to be calculated.

Recommendations

The data from this trial indicates an application of PastureN could increase cane yield with historically low fertiliser rates on an older (fifth) ratoon. While we do not have the data to assess whether the yield increase resulted in an increase in tonnes sugar this result is promising and indicates more trial work is necessary.

Ideal PastureN application conditions (Mulgrave).

Trial 3:

Location: Mirriwinni

Soil type: Timara Coom

Crop class & variety: SRA 6 3rd Ratoon

Year: 2022-2023

Treatments:

T1: 100 kg/ha of Nitrogen

T2: 100 kg/ha of Nitrogen + PastureN

T3: 150 kg/ha of Nitrogen

T4: 150 kg/ha of Nitrogen + PastureN

All treatments had 4 replicates.

These treatments were part of a larger N rate trial outlined in Chapter 2.

Results

There was no significant difference observed between the nitrogen rate and the addition of PastureN. This trial was part of a larger nitrogen rate study, which demonstrated that higher nitrogen rates (150 kg/ha and 200 kg/ha) were optimal for this crop.

Demonstration design and methods

Fertiliser was applied on December 6, 2022, according to a randomised, replicated trial design. The growers' standard practice on this soil type, is close to the SIX EASY STEPS recommended rate of 140 kgN/ha.

PastureN was applied at out of hand on January 10, 2023, using a high-rise sprayer

TREATMENT	CANE YIELD (T/HA)	CCS	SUGAR YIELD (T/HA)
50 kgN/ha	92.34	11.58	10.69
100 kgN/ha	95.87	11.96	11.47
150 kgN/ha	104.18	11.93	12.41
200 kgN/ha	109.12	12.16	13.27

CHAPTER 3

with a water rate of 300L/ha. Prior to application the freeze-dried nitrogen fixing microbes were mixed with the Bacillus microbes and amino acid formulation. The microbial formulations all require refrigeration before use and must be applied to cane in moist conditions.

The block was commercially harvested over two days from November 28th to 29th, 2023. Tonnes and CCS were supplied through mill data for each replicate.

The trial was continued for a second year, with fertiliser being applied on December 21st, 2023, and PastureN applied February 12th, 2024.

Discussion of three PastureN demonstration trials

While all three trials provided insights into the application of PastureN, their outcomes varied. The Aloomba trial showed that the application of PastureN did not significantly increase yield or sugar production, but it did suggest that fertiliser could be reduced by 25% without impacting yield. Additionally, PastureN may have reduced variability in CCS and yield, particularly in the 75% fertiliser treatment, though this effect was not statistically significant.

The Mirriwinni trial demonstrated that higher nitrogen rates (150 kg/ha and 200 kg/ha) were optimal for this crop, and there was no significant difference between nitrogen rates and the addition of PastureN. This highlights the importance of precise nitrogen management to achieve optimal yields and the need to conduct further investigations to improve the understanding of the use of PastureN.

In contrast, the Little Mulgrave trial showed that PastureN increased the average cane yield by 6.6 tonnes per hectare. The three replicates with PastureN had higher and more consistent yields compared to those without PastureN. This suggests that PastureN application may increase yields, particularly where low nitrogen fertiliser rates are used. Without the CCS data from Little Mulgrave, it is not possible to assess the impact on CCS across the trials.

The results from the Aloomba trial indicate that nitrogen rate reductions are possible on the Innisfail soil type without yield loss. All trials were repeated in 2024 and will be harvested later in the year, with updated results to be shared.

These findings indicate that further investigation into PastureN and similar products is warranted to understand their potential role within the Wet Tropics cane industry for sustainable and profitable production. Long-term research is also necessary to determine nitrogen rate requirements on Innisfail soil, as the 2023 results may not be indicative of long-term trends.

Ideal PastureN application conditions (Mirriwinni).

CHAPTER 3

CHAPTER 3

Trialling different nitrogen top-dressing rates after legume crop

Summary

The integration of legume crops into sugarcane cultivation is known to be beneficial to the subsequent sugarcane crop. Legumes, with their nitrogen-fixing abilities, not only contribute to soil fertility but also provide a natural means of replenishing essential nutrients. However, the success of this rotational approach hinges on meticulous management, especially when it comes to fertilisation.

Tailoring fertiliser rates to the specific needs of sugarcane post-legume cultivation is vital to maximising yield, preserving soil health, and ensuring long-term viability of the agroecosystem.

This demonstration investigated the contribution of a legume crop in sugarcane crop rotation, highlighting several key benefits:

- Enhanced soil nitrogen levels
- Reduced nitrogen fertiliser dependency
- Improved crop yields
- Environmental and economic sustainability.

Location: Edmonton, Mulgrave

Soil type: Edmonton

Crop class & variety: Plant Cane Rep 1 – Mixed varieties, Rep 2,3,4 – SRA15

Year: 2022-2023

Treatments:

T1: 0kg of N on Top-dress

T2: 30kg of N on Top-dress

T3: 60kg of N on Top-dress

All treatment received full rate of Potassium (100kg/ha)

Results

There was no statistically significant difference between treatments for CCS, Yield (t/ha) and sugar per hectare. The results were influenced by other variables such as variety and the inherent soil variability rather than the amount of N fertiliser applied.

Inconsistencies between replicates of each treatment and the variability in outcomes makes it challenging to determine the optimal strategy. This highlights the complexity of agricultural practices and emphasizes the importance of considering multiple factors in decision-making.

Incorporating the cost-benefit component reveals that the treatment with 30kg/ha of N demonstrated superior economic performance compared to other treatments. This is particularly pronounced in scenarios where sugar prices are between $400 or $800 per tonne, harvesting cost at $10.00 per tonne, and 1000kg of urea at $1000.

TABLE SHOWING RESULTS FOR EACH TREATMENT WITH TONNES CANE PER HECTARE, TONNES SUGAR PER HECTARE AND CCS

TREATMENT	CANE YIELD (T/HA)	CCS	SUGAR YIELD (T/HA)
60 + 33kgN/ha	111.56	12.45	13.90
30 + 33 kgN/ha	110.64	12.42	13.76
0 + 33 KgN/ha	104.93	12.49	13.09

Demonstration design and methods

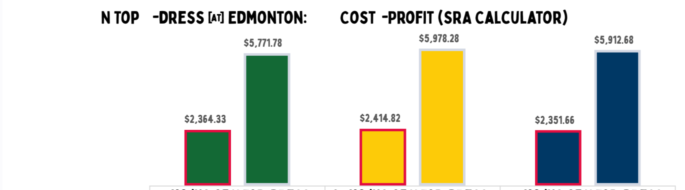
A mix of legumes was grown in the block over fallow before the cane was planted with 33kg/ha of nitrogen fertiliser. Top-dress fertiliser was applied between November 10 and 18, 2022. The treatments were distributed according to a randomised, replicated trial design. The 60kg/ha reflects the growers' standard practice on this soil type for planting.

The block was commercially harvested on September 25th and 26th, 2023. Tonnes and CCS were supplied through mill data for each replicate.

Recommendations

This demonstration shows the benefit of growing legume crops during fallow as part of the sugarcane cycle. Reduced nitrogen fertiliser rates did not reduce sugarcane productivity, or adversely affect the quality of the sugarcane.

COST-PROFIT COMPARISON BETWEEN TREATMENTS WITH TWO POSSIBLE SUGAR PRICES



	0 KG/HA OF N TOP-DRESS	30 KG/HA OF N TOP-DRESS	60 KG/HA OF N TOP-DRESS
SUGAR = $400/T	$2,364.33	$2,414.82	$2,351.66
SUGAR = $800/T	$5,771.78	$5,978.28	$5,912.68

"FNQ FARMERS GENUINELY DO A VERY GOOD JOB. OUR FARMING PRACTICES HAVE IMPROVED OVER THE LAST 10-20 YEARS. WE DON'T WANT ANYTHING TO RUN-OFF INTO WATERWAYS WE WANT TO KEEP IT IN THE PADDOCKS. WE CAN GROW THE SAME AMOUNT OF CANE WITH MORE PRECISE APPLICATION OF FERTILISER AND CHEMICALS. I ALSO KEEP CREEK BANKS VEGETATED AND PLANT LEGUMES IN FALLOW BLOCKS TO HELP REDUCE RUN-OFF."

Doug Hardwick, 2024

Application of top dressing at Aloomba.

CHAPTER 3

Investigating reduced nitrogen rates with application of prilled lime

Summary

Lime is applied to bring soil pH closer to neutral and increase calcium levels. As pH moves closer to seven most nutrients, including nitrogen, become more readily available to the plant. Maintaining a pH between 5.5 to 6 and ensuring sufficient calcium supply throughout the crop cycle are beneficial for promoting crop growth, enhancing resilience to stressors, and optimising the effectiveness of applied fertilisers.

In sugarcane lime is traditionally applied to the entire block at a rate that is expected to provide amelioration benefits for three years. It is not uncommon for lime to only be applied once per 5-6 year crop cycle.

Prilled lime products use ultra fine calcium carbonate particles that are bound into small prills. The fine particles react quickly with the soil to correct pH while adding calcium. Unlike conventional lime these products must be applied annually to provide adequate pH amelioration and calcium. They can be easily applied to the cane bed with a standard granular fertiliser box.

An adequate annual application can address pH issues and calcium deficiency present in the block, preventing run down that can occur over time when lime is applied once per crop cycle.

Anecdotally, growers using prilled lime products in ratoon cane had noted a decrease in CCS and wondered if reducing applied fertiliser to account for the improved availability of nutrients applied could benefit their sugar production.

Location: Highleigh, Mulgrave

Soil type: Virgil (clay)

Crop class & variety: 1R SRA26

Year: 2022-2023

Treatments:

T1: 91N kg/ha

T2: 116 N kg/ha

T3: 136N kg/ha

Prilled lime applied at 150kg/ha across all treatments. Three replicates for each treatment.

Results

There was no significant difference between any treatments for tonnes sugar with variability within the replicates for all treatments. The average tonnes of sugar/ha grown was 18.2-18.3 across the three treatments. This indicates reducing the rate of fertiliser when applying a prilled lime product is unlikely to impact yield.

CCS was highest for the 116N treatment and lowest for the 91N treatment. Tonne's cane/ha was highest for the 91N treatment and

TABLE SHOWING RESULTS FOR EACH TREATMENT WITH TONNES CANE PER HECTARE, TONNES SUGAR PER HECTARE AND CCS

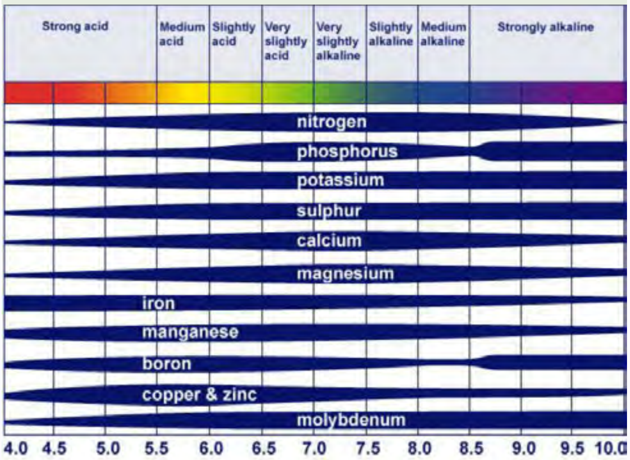
TREATMENT	CANE YIELD (T/HA)	CCS	SUGAR YIELD (T/HA)
91 kgN/ha	138.26	13.20	18.24
116 kgN/ha	136.45	13.36	18.21
136 kgN/ha	135.41	13.42	18.17

lowest for the 136N treatment. However, the difference between these results is not considered significant.

Demonstration design and methods

Prilled lime was applied at 155kg/ha (1.25 bag/acre) to the entire block as a band on the crop row using a three-row spreader. The soil sample for this block indicated a pH of 5.1. This rate of prilled lime has the potential to lift the pH of a clay soil by 0.15 and will supply 55kg/ha of calcium. This will not meet the requirements of the block for pH or calcium, however shifting the pH from 5.1 to 5.25 increases the availability of nitrogen, phosphorus, potassium, sulphur, calcium, magnesium, and molybdenum, as can be seen in the figure below. This includes nutrients that are present in the soil as well nutrients that have been applied as fertiliser.

A diagram showing the availability of nutrients at different pH. Sugarcane farmers target between pH 5.5 and 6.



Three fertiliser treatments were applied as granular fertiliser to a first ratoon block of SRA 26 (91kgN/ha, 116kgN/ha and 136kgN/ha). One blend was used for all three rates, meaning that the amount of potassium and sulphur reduced with the nitrogen rate. The recommended rate using SIX EASY STEPS was 140kgN/ha. There was no phosphorus applied to this block.

The block was well managed for weeds with herbicide applied shortly after harvest and at out of hand. There was no canegrub pressure to impact yield. A fallow crop of soybean was grown in this block over the 2020-2021 wet season prior to planting.

The crop was commercially harvested with tonnes cane and CCS supplied through mill data for each replicate.

Recommendations

The lack of significant difference in yield indicates fertiliser applications can be reduced with an annual application of prilled lime, this is highlighted by the lowest rate of fertiliser growing the most tonnes of cane. As CCS was variable within replicates across all treatments, it is unlikely the reduction in fertiliser applied increased CCS.

It is possible that some nitrogen remained from the fallow crop of soybeans and contributed to the strong yields, however this would likely be a small amount and the lime application may have assisted the crop in utilising this source of nitrogen.

This trial will be continued in 2024 to determine if the results are consistent over time. Additional trials with varied fertiliser rates with and without the prilled lime application would also be informative.

Prilled lime v Ag lime

Prilled lime and ag lime are both used to adjust soil pH levels and increase calcium in soil but they have some key differences:

1. Particle size:

• Prilled lime has much finer particles that are combined into a granule or prill.

• Aglime has larger particles or granules ranging in size from 0.1 to 2 millimetres.

2. Application method:

• Prilled lime can be applied with a conventional granular fertiliser box and is usually applied at lower rates.

• Aglime can be applied either broadcast or banded using a spreader. Any incorporation is done through follow up cultivation.

3. Reaction time:

• Prilled lime reacts more quickly with the soil, helping to raise pH levels faster.

• Aglime begins to react with soil immediately however it can take up to two months to have full effect, including the availability of calcium.

4. Cost and duration of amelioration

• Prilled lime is more expensive due to its processing into pellet form and as a consequence is often applied in sub-optimal amounts. Applications are typically adequate for one year.

• Aglime is usually more cost-effective and readily available since it is commonly produced as a byproduct of quarrying limestone or dolomite. Applications rates are much higher and are usually adequate for three to four years.

Exploring the interaction between sunn hemp *(Crotalaria juncea)* and sugarcane: agricultural, environmental, and economic perspectives

The interaction between sunn hemp *(Crotalaria juncea)* and sugarcane has been researched to accurately assess the agricultural, environmental and economic benefits derived from their combination. Like other Fabaceae plants (legumes, such as soybeans, cowpeas, lablab, peanuts and others), sunn hemp roots have the ability to fix nitrogen from the atmosphere through Rhizobium bacteria. Unlike conventional sugarcane fallow crops, sunn hemp can generate significantly more biomass (and organic matter) through its height (reaching up to 4 metres) and well-developed and extensive root system. (Heuzé V et al., 2018; Lopes, 2000).

In sugarcane systems, sunn hemp has been utilised in crop rotation, as a fallow or cover crop grown over the wet season. Incorporating legumes into crop rotations significantly enhances nitrogen levels in the soil. However, uncertainties remain regarding the best strategies to optimise the capacity of sugarcane to utilise the nitrogen that was fixed in the soil through biological fixation when legumes are involved. Adopting precision fertilisation methods, optimising the use of mill byproducts and incorporating green manure into crop rotations are essential approaches for reducing synthetic nitrogen fertiliser usage and associated N^2O emissions. Research indicates that while legume residues can partly replace basic nitrogen fertilisation, additional nitrogen supplementation is required for sugarcane during later growth stages. The potential reduction in fertiliser application rates due to biological nitrogen fixation ranges from 100% in the first ratoon to gradually decreasing percentages in subsequent ratoons (Peoples, 1995; Hemwong, 2009; Sarah E. Park, 2010; Otto, 2016),

Nematodes are known to constrain yields in sugarcane throughout the Australian industry. Robinson and Reynolds (2022) found that sunn hemp could be used as a strategy to reduce nematode infection in sugarcane soil, specifically *Meloidogyne spp*. (root-knot nematode) and *Rotylenchulus reniformis* (Reniform nematode) due to its characteristics as poor/non-host to these nematode' species.

SUNN HEMP AGRONOMIC CHARACTERISTICS

PHYSICAL TRAITS	PHYSIOLOGICAL TRAITS	ADAPTABILITY
• Height: Tall (up to 2-3m) • Root System: Deep • Stem: Erect • Leaves: Alternate, pinnate • Flowering Period: Summer • Flower Colour: Yellow • Seed Production: High • Growth Rate: Fast	• Photosynthetic Rate: High (C3) • Nitrogen Fixation: High • Drought Tolerance: Moderate • Waterlogging Tolerance: Moderate • Nutrient Requirement: Low for Nitrogen (Nitrogen-fixing legume), will respond to pH correction (5 – 7.5) • Temperature Tolerance: Warm (Adaptable to tropical and subtropical climates) • Response to Day Length: Better results with longer days and short nights (summer)	• Soil Preference: Well-drained • Elevation Range: Sea level to high • Pests: Few • Diseases: Few • Shade Tolerance: Low • Crop Rotation Suitability: Good • Environmental Impact: Positive

Characteristics of sunn hemp

In terms of biomass production, Robinson and Reynolds (2022) noted that sunn hemp ranges from 4 to 7 tonnes per hectare of dry matter assuming it is 25% of green biomass, depending on conditions. The dry matter production in sunn hemp crops sown after rice in Thailand yielded 2 tonnes per hectare. According to Oliveira et al. (2023), sunn hemp achieved dry matter yields ranging from 15 to 20 tonnes per hectare in soils without exchangeable aluminium. However, yield decreased to 5 tonnes per hectare when the crop was grown during periods with longer nights.

Soil health benefits

Beyond the nitrogen fixation other benefits associated with the use of sunn hemp as a fallow crop are under investigation and of interest to sugarcane growers in north Queensland.

One hypothesis suggests incorporation of sunn hemp residues into the soil may increase soil organic carbon levels, with potential for long-term stability. Given its rapid growth and prolific biomass production, if substantiated, this hypothesis suggests significant utility for sunn hemp in carbon sequestration initiatives and sustainable agricultural practices aimed at mitigating environmental impacts.

To test the hypothesis, Precision to Decision Project conducted a study in Aloomba-QLD to measure the Organic Carbon in the soil on a 2nd ratoon sugarcane crop after a sunn hemp fallow crop grown in the summer of 2020.

A soil sample was taken on the block at depth from 0 to 20 cm before planting the sunn hemp on the 27th October 2020, another sample was taken on the 14 of May of 2021, before planting sugarcane. On 11th December 2023, samples were taken at the same block on four georeferenced points at the depths of 0 cm to 20 cm and 20 cm to 40 cm. The determination of soil organic carbon was based on the Walkley-Black chromic acid wet oxidation method.

The results for soil organic carbon levels are as follows:

- Pre sunn hemp (2020): 0.90%
- After sunn hemp – pre-planting sugarcane after incorporation: 1.32%
- 2nd Ratoon Points (00-20 cm): 0.91%, 1.16%, 0.89%, 0.94% (Average: 0.98%)
- 2nd Ratoon Points (20-40 cm): 0.64%, 0.96%, 0.81%, 0.74% (Average: 0.79%).

These slight variations in organic carbon levels align with the recommendations of The Australian sugarcane nutrition manual (2018), which notes that soil organic carbon increments from legume fallow crops often result in immediate, though modest, improvements. The findings suggest that significant long-term stabilisation and gradual increase in organic carbon levels are more realistic goals than expecting substantial short-term gains.

Incorporating sunn hemp residues can potentially enhance soil organic carbon levels, particularly when combined with other sustainable practices. For the specific sugarcane crop block studied, the increase in soil organic carbon was not sufficient to permanently change the soil Nitrogen Mineralisation Index. After the sunn hemp it improved from Medium-Low (0.81% – 1.20%) index to Medium (1.21% – 1.60%), returning to the Medium-Low range after 2 sugarcane harvests (2022 and 2023). However, on average, the soil organic carbon content was 7% higher than it was prior to the sunn hemp fallow crop.

To gain a more comprehensive understanding of sunn hemp's long-term impact on soil health, additional testing at regular intervals is essential. Future research should involve more frequent soil sampling and analysis over multiple growing seasons. This will help to better capture the variations and trends in soil organic carbon levels, providing a clearer picture of sunn hemp's sustainability benefits.

Calculating nitrogen contribution following a legume fallow

The Australian sugarcane nutrition manual (2018) highlights the significant contribution of nitrogen to the sugarcane crop following a legume fallow. However, the recommendations are based on soybeans, cowpeas, lablab and peanuts only. During the Precision to Decision project, numerous biomass samples were collected to support nitrogen recommendations for sugarcane planting. However, some areas featured sunn hemp as the fallow crop. Employing methods similar to those outlined in the SRA CALCULATION OF NITROGEN CONTRIBUTION FROM A FALLOW LEGUME, a subset of sunn hemp samples underwent analysis to determine nitrogen content (%). With the equation below, it is possible to calculate nitrogen present in the crop and a potential reduction in the amount of synthetic nitrogen to be applied as fertiliser.

Total N contribution kg.ha^{-1} = Total N % (lab analysis)x dry matter per ha (t.ha^{-1})x1.30

This formula assumes that the root system contributes an additional 30% to the total biomass measured above ground.

A total of four samples were taken in different soil and crop conditions, in the Gordonvale, Aloomba and Babinda regions. The nitrogen content reported were (Total nitrogen - Combustion); 0.85%, 1.40%, 1.50%, 2.00%.

Previous analysis from the Tully region averaged: 1.75%.

Using the previous and current information, Total N% of 1.50% was adopted to suggest Nitrogen rates (kg.ha-1) after sunn hemp fallow crop.

The table below showcases the anticipated nitrogen contribution from sunn hemp across varying yields.

Aloomba grower, Neil Maitland, in a young crop of sunn hemp on his farm.

Farmacist graduate agronomist Daniel Knowles in a sunn hemp crop in the Mulgrave mill area.

LEGUME CROP	DRY MATTER (T.HA^{-1})	N % OF DRY MASS	N CONTENT ABOVE GROUND (KG.HA^{-1})	N CONTENT BELOW GROUND (KG.HA^{-1})	TOTAL N CONTRIBUTION (KG.HA^{-1})
Sunn hemp	4	1.50	60	18	78
	6		90	27	117
	8		120	36	156
	10		150	45	195
	12		180	54	234
	20		300	90	390

CHAPTER 3

The impact of soil parameters on a sunflower fallow crop

Trial summary

Precision agriculture is a highly effective approach for identifying paddock variability and understanding its underlying causes, enabling producers to make informed management decisions that enhance output and profitability. One of the best methods for determining soil variation across paddocks is through electromagnetic (EM) soil surveys. During the P2D project, Farmacist conducted numerous EM surveys using the Topsoil Mapper (TSM).

The TSM employs magnetic induction to measure the electrical conductivity (EC) of soils, which varies with changes in soil type, moisture content, and dissolved salts. This data can be instrumental for targeted ameliorant and fertiliser applications. Additionally, EM surveys can help identify opportunities to improve the productivity of fallow crops.

Sunflowers are a viable option for a winter/spring cover crop in the Wet Tropics agricultural districts. A well-managed sunflower crop can decrease weed pressure, alleviate soil compaction, improve water infiltration, and reduce erosion (Reef Catchments, 2015). This demonstration aimed to investigate how spatial datasets could be used to enhance the productivity of a sunflower fallow crop.

Mid-aged sunflower crop with a variable yields (visible depression in centre of image).

Location: Goldsborough, Mulgrave

Soil type: Liverpool

Crop class & variety: Fallow, Common Black Sunflower

Year: Late Winter Crop 2023

Sunflower rate: 16kg/ha (5kg/ha recommended rate) - unfertilised

Three soil sampling sites were selected based on differentiating soil EC and a bare fallow control. Depths of 0-20cm and 40-60cm were sampled.

Methodology

EM and elevation survey

Conducted an EM and elevation survey before planting sunflowers.

According to Queensland soils mapping, the entire block is classified as Liverpool soil type (uniform fine sandy loam or loam soils on low alluvial flood plains and levees) at a 1:50,000 ratio (Queensland Globe).

The block had a 0.1% grade in elevation.

Soil sampling and ground truthing

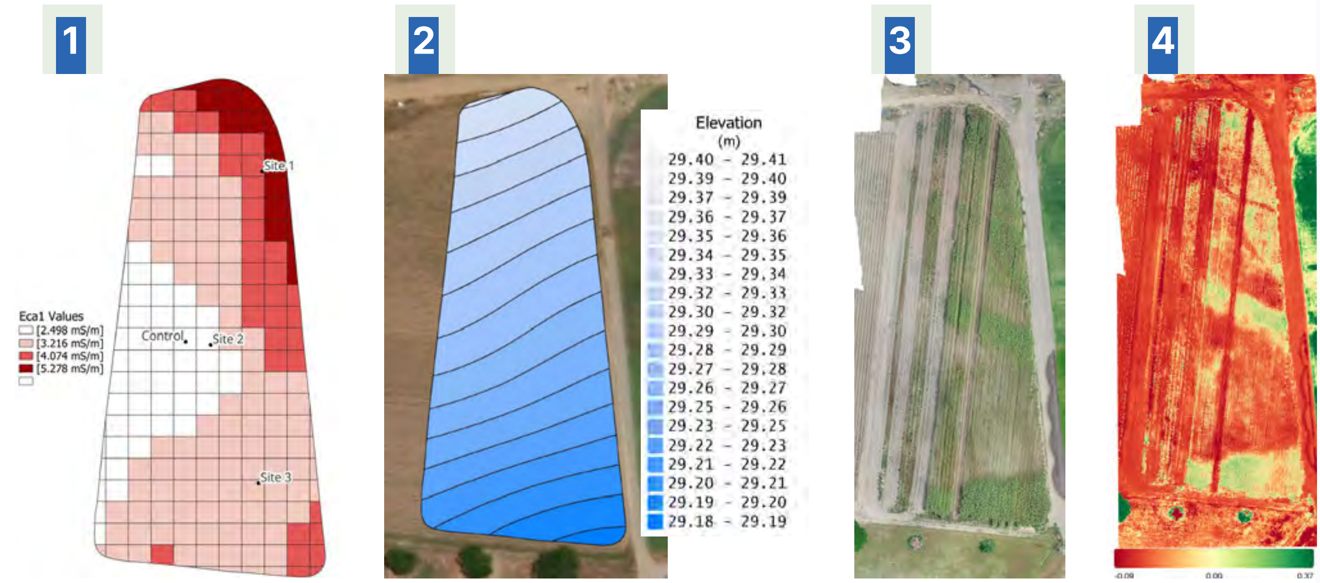
Determined ground truthing soil sampling locations using EC mapping to differentiate between soil types.

Monitoring

Conducted regular drone flights throughout the trial to monitor variability in sunflower yields.

These methods allowed for precise assessment and management of the sunflower fallow crop, leveraging spatial datasets to optimise crop productivity.

Spatial datasets collected from the trial site, including (1) EM survey measuring soil electrical conductivity to identify variations in soil type, moisture content, and dissolved salts, (2) Elevation map documenting the land's topography for understanding water drainage, erosion, and soil distribution, (3) Drone imagery capturing high-resolution images of the sunflower crop throughout its growth cycle to highlight growth patterns and identify areas of poor performance, and (4) Drone imagery with plant health filter to assess plant health and detect early signs of stress, disease, or nutrient deficiencies.



Results

The figures above highlight significant variability in soil EC values and sunflower yield, with yields tending to correlate with patterns observed in the EM survey. The results suggest that soil variability had a substantial influence on sunflower growth, with plant yield differing markedly across the block, as depicted in Image 3 and Image 4 (previous page).

Site specific observations

Site 1

Soil composition: The soil was a clay loam, transitioning to medium clay with depth and heavier compared to other sites.

Nutrient levels: Site 1 had higher levels of micronutrients (Zinc, Copper, Iron, Manganese), greater phosphorus availability, and the highest pH at 6.5.

Performance: Sunflowers at Site 1 exhibited robust growth throughout all stages. The higher clay content supported better moisture and nutrient retention, benefiting crop growth during dry periods.

Site 2 (control)

Soil composition: Both sites had similar soil properties, nutrient levels, and pH (5.5 to 5.8). Soils were clay loams with a wetter A horizon that became drier with depth, lighter in texture than Site 1.

Performance: Growth was stunted with thinner stalks at both sites. The similarities in soil composition, nutrients, moisture, and location suggest that sunflower presence did not significantly influence nutrient levels. The primary limiting factor for yield was likely moisture availability during critical growth periods.

Site 3

Soil composition: The soil had higher silt content in the A horizon, transitioning to clay loam with depth, with a colour change at 30-40 cm (grey-brown to red-brown).

Nutrient levels: This site had lower electrical conductivity (EC), Phosphorus Buffering Index (PBI), and phosphorus levels throughout the crop cycle.

Performance: Growth was poor, likely due to lower moisture availability throughout the soil profile, which was the main factor limiting crop development.

In conclusion, the variability in sunflower growth across the trial site was primarily influenced by soil texture and moisture retention capabilities. Heavier clay soils with better moisture retention supported better crop growth, whereas lighter soils with lower moisture availability limited crop performance. These findings suggest that soil management practices aimed at improving moisture retention could enhance sunflower yields in similar environments. Potential options to remediate poor water-holding capacity include the strategic application of mill mud. This practice can increase the organic matter content in the soil, thereby enhancing its ability to retain water.

This trial underscored the importance of EM survey data in identifying soil variability. The EM survey in conjunction with the drone imagery and soil samples provided valuable insights into soil texture, moisture content, and nutrient distribution. This information allowed for precise identification of areas with poor water-holding capacity and nutrient deficiencies. The observed correlation between EM survey data and yield variability highlights the importance of utilising geospatial datasets to optimise crop management practices and enhance overall productivity.

Recommendations

Wet Tropics soils are highly variable in composition and chemistry. Key recommendations from this demonstration are to always soil sample your fallow blocks, and if possible, take multiple point source samples as nutrients and soil vary, within blocks. Follow the recommended nutrient application rate, placement, and timing from your soil sample and take note of agronomist recommendations to effectively address soil nutrient deficiencies and optimise crop growth in accordance with specific soil conditions and constraints.

Recommendations for growers trialling sunflowers as a break crop

1. Plant into a soil profile of full subsoil moisture (GRDC, 2016). Water availability is important, especially in the early to flowering growth stages.

2. Sunflowers' tolerance to different soil constraints allows them to be cultivated in various soil types, but they thrive best in friable soil (GRDC, 2016).

3. Effective weed management throughout the initial 7 weeks of crop establishment is critical as sunflowers do not shade out weeds (GRDC, 2017).

4. Trial sunflowers in a mixed species fallow with legumes to supress weeds, encourage soil biological diversity, and reduce lesion nematode populations, fix nitrogen, and improve soil structure.

5. Be aware of past residual herbicides applied to the block as sunflowers can be susceptible to sulfonylurea (Group B) herbicides (GRDC, 2017). Sunflowers are sensitive to Sempra (Halosulfuron-methyl), Picloram, Atrazine, Imazapic and Imazethapyr and Metsulfuron-methyl. Always check plant back periods on chemical labels.

6. There is benefit in establishing arbuscular mycorrhizal fungi levels when planting sunflowers as it is the plants symbiotic relationship with these fungi that supports extraction of both phosphorus and zinc from soils. The fungi colonise the sunflowers root system, effectively expanding the structure to allow absorption of phosphorus from a greater area. This can be done through a Predicta B test from the South Australian Research and Development Institute laboratory.

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Grains Research and Development Corporation, Grownotes Sunflower, February 2017.

Sugar Research Australia, Nematode in Sugarcane, 2022.

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Chapter 4: Farm constraint management

Why focus on managing yield constraints?

A focus on managing yield constraints can provide economic, social, and environmental benefits for the farmer and the wider community.

At its core, a focus on managing yield constraints should support financial decision making around actions to improve yield or increase input efficiency while maintaining yield. For example, addressing yield constraints to improve Nitrogen Use Efficiency (NUE) at property scale for Great Barrier Reef water quality outcomes.

There are a wide range of yield constraints that affect sugarcane production. This document focusses on sugarcane yield constraints that are common in the Wet Tropics region of Queensland. Summary information including advice for remediation of the relevant yield constraints are presented in the following pages.

Every farm and farmer is different. A one-size-fits-all approach won't work for managing yield constraints. Identifying, describing and mapping yield constraints within the property provides the farmers and their trusted agronomists with a framework for discussion and decision making (including prioritising and action planning). Farmacist has developed a constraints management planning process as a guidance tool (Page 100).

When a landholder and their trusted agronomists are working through the constraints management planning process it is critical to work within the current capacity of the farm business (personal and business goals, yield records and land, labour, machinery, and financial resources). The potential for yield improvement will be relative to the type and severity of the constraints present within the property and the farm business capacity to implement the recommended actions. For example, waterlogging in low lying properties may be a significant yield constraint, however the financial capacity to implement recommended actions may be limited in the short term (a medium term business plan may be required to support action).

FARMACIST

CHAPTER 4

Wet tropics sugarcane yield constraints

Guide to using the constraints chapter

Soil chemistry

Soil acidity

Constraints explained

Soils of the Wet Tropics are naturally acidic. Soil acidity is caused by presence of excessive hydrogen and aluminium ions on the cation exchange sites (CEC). Soil acidification is accelerated through the addition of nitrogen-based fertilisers and removal of cane to the mill.

A decline in soil pH is also accompanied by a reduction in CEC and lower availability of some essential plant nutrients. Aluminium also becomes more soluble in acidic soils and is toxic to many plants, especially legumes.

A decline in soil pH is often associated with low calcium. Soil calcium should be maintained above the critical value to avoid yield loss due to both calcium deficiency and acid pH (0.65 me%) (Hurney 1971, Ridge et al 1980, Haysom et al 1986).

Implementation timeline & complexity

Management is highly complex given the Wet Tropics SIX EASY STEPS guidelines do not incorporate guidance for increasing soil pH [1:5 water] above 5.5.

Management will require multiple operations and specific knowledge (for example, liming estimates from soil test reports to identify suitable liming application rates to increase soil pH [1:5 water] above 5.5).

Management actions will be required at the commencement of the fallow and possibly after harvesting the third or fourth ratoon crop depending on the length of the cropping cycle.

It is expected that when soil pH (1:5 water) is maintained above 5.5 it will also address the impact of soil acidity and aluminium toxicity on the performance of sugarcane and rotational cover crops. It will also contribute to achieving balanced nutrition.

Solutions

Confirm with a soil test measuring soil pH (1:5 water).

Focus on topsoil amelioration.

Unlike other sugarcane growing regions, the Wet Tropics SIX EASY STEPS guidelines do not incorporate guidance for increasing soil pH [1:5 water] above 5.5. Follow the lime requirements as determined from soil calcium levels.

Broadcast or banded application of calcium based (lime) products to maintain soil exchangeable calcium above the critical value.

Application should coincide with the commencement of the fallow period (as a minimum) to allow adequate time for the amelioration of pH.

Reapplication may be required if extending crop cycles beyond 4th ratoon. This is best confirmed through a soil test.

Agronomist, Shannon Byrnes, pH testing a soil sample.

Calcium deficiency

Constraints explained

Usually occurs in acidic soils and high rainfall areas. Can severely limit productivity.

A cane yield response to calcium is almost certain when the soil test critical value is below 0.65 me%.

When soil test values are between 0.65 and 2.0 me% calcium applications are still recommended to ensure cane yield is not limited.

Calcium is also required for nodulation and nitrogen fixation in legume break crops.

Implementation timeline & complexity

Management is less complex with remediation strategies well understood and required knowledge well known.

Management actions will be required at the commencement of the fallow and possibly after harvesting the third or fourth ratoon crop depending on the length of the cropping cycle.

It is expected that soil exchangeable calcium will be maintained at least above the critical value. This will help ensure the supply of this essential plant macronutrient is adequate for achieving balanced nutrition and does not constrain productivity. It will also help alleviate soil acidity and reduce aluminium saturation.

Solutions

Confirm with a soil test measuring exchangeable calcium (amm-acet.).

Rates should be determined using the Wet Tropics SIX EASY STEPS nutrient management guidelines for calcium.

Broadcast, banded or variable rate application of calcium-based products to maintain soil exchangeable calcium above the marginal value.

As a minimum, application should coincide with the commencement of the fallow period (3-6 months prior to planting) for the amendment to become effective.

Products should ideally be incorporated into the soil.

Reapplication may be required if extending crop cycles beyond 4th ratoon. This is best confirmed through a soil test.

Mill by-products are also a significant source of calcium. They can be applied during the fallow or onto ratoon crops. When applied to the last ratoon or fallow, adjustments can be made to the rate of other calcium-based products (e.g., lime). Refer to the SIX EASY STEPS Toolbox guidance to account for nutrients contained in mill by-products.

Use leaf analysis to confirm the adequacy of calcium uptake and identify hidden hunger.

Soil sampling is important to understand soil chemical constraints that will impact crop productivity.

Magnesium deficiency

Constraints explained

Magnesium deficiency usually occurs in acidic soils and high rainfall areas.

A cane yield response to magnesium is almost certain when the soil test critical value is below 0.10 me%.

When soil test values are between 0.10 and 0.25 me% calcium applications are still recommended to ensure cane yield is not limited.

Implementation timeline & complexity

Management is less complex with remediation strategies well understood and required knowledge well known.

Management actions will be required at the commencement of the fallow and possibly after harvesting the third or fourth ratoon crop depending on the length of the cropping cycle.

It is expected that soil exchangeable magnesium will be maintained at least above the critical value. This will help ensure the supply of this essential plant macronutrient is adequate for achieving balanced nutrition and does not constrain productivity.

Solutions

Confirm with a soil test measuring exchangeable magnesium (amm-acet.).

Rates should be determined using the Wet Tropics SIX EASY STEPS nutrient management guidelines for magnesium.

Broadcast, banded or variable rate application of magnesium-based or blended products to maintain soil exchangeable magnesium above the marginal value.

As a minimum, application should coincide with the commencement of the fallow period.

Products should ideally be incorporated into the soil.

Reapplication may be required if extending crop cycles beyond 4th ratoon. This is best confirmed through a soil test.

Mill by-products are also a significant source of magnesium. They can be applied during the fallow or onto ratoon crops. When applied to the last ratoon or fallow, adjustments can be made to the application rate of other magnesium-based products. Refer to the SIX EASY STEPS Toolbox guidance to account for nutrients contained in mill by-products.

Use leaf analysis to confirm the adequacy of magnesium uptake and identify hidden hunger.

Calcium: Magnesium ratio

Constraints explained

Refers to the proportion of available calcium and magnesium in the soil. Unfortunately, as it does not reference the actual levels of these elements in the soil, it can be difficult to interpret.

A low Ca:Mg ratio can indicate 1) low calcium and normal magnesium or 2) normal calcium and high magnesium.

A high Ca:Mg ratio can indicate 1) too little magnesium relative to calcium or 2) excessive calcium relative to magnesium.

Soils with excessive calcium levels are uncommon in the Wet Tropics but can result in increased soil pH to levels that can restrict nutrient uptake and cause deficiencies of other nutrients such as magnesium, zinc and copper.

Magnesium deficiency in a soybean grown as a fallow crop.

Soils with excessive magnesium levels are likely to be difficult to cultivate (hard) and poorly structured (crusty with reduced water infiltration and drainage). May also impact the uptake of potassium and calcium.

Implementation timeline & complexity

Management is complex, requiring multiple operations and specific knowledge to correctly ammend both exchangeable soil calcium and magnesium levels.

Management actions will be required at the commencement of the fallow and possibly after harvesting the third or fourth ratoon crop depending on the length of the cropping cycle.

It is expected that soil exchangeable calcium and magnesium will be maintained at least above the critical values. This will help ensure adequate supply of both calcium and magnesium which are essential plant nutrients. It will also help minimise undesirable effects on soil structure.

Solutions

Need to review soil exchangeable calcium and magnesium levels in combination with the Ca:Mg ratio.

The Ca:Mg ratio is not useful for identifying calcium and magnesium deficiencies.

As calcium and magnesium deficiencies often occur together, it is important that both are addressed to achieve balanced nutrition.

Select the most appropriate soil ameliorant or blended product to maintain soil calcium and magnesium levels above marginal values. Do not over- nor under-apply either of these elements.

Silicon deficiency

Constraints explained

Usually occurs in light-textured soils. Significant increases in cane yields (ranging from 16 to 45%) have been obtained from addressing sub-optimal levels of plant available silicon.

Banded application of lime to ameliorate calcium deficiency, aluminium toxicity and correct pH.

A cane yield response to silicon is almost certain when soil test values are below 10 mg/kg (Silicon $CaCl_2$) AND 70 mg/kg (Silicon BSES).

When soil test values are 10-20 mg/kg (Silicon $CaCl_2$) AND above 70 mg/kg (Silicon BSES) a cane yield response is possible.

Cane yield responses are unlikely when soil test results are above 20 mg/kg (Silicon $CaCl_2$) and 70 mg/kg (Silicon BSES).

Implementation timeline & complexity

Management is complex. Previous research has identified management operations and contributed to improved knowledge. However, additional research is required to better manage silicon in the sugarcane production system. Until then, the management guidance currently contained within SIX EASY STEPS should be followed.

Management actions will be required at the commencement of the fallow and possibly throughout the ratoons depending on the length of the cropping cycle, in-field observations, and results of soil and leaf sampling.

This will help reduce the likelihood of encountering sub-optimal levels of plant available silicon and optimum crop growth is maintained.

Solutions

Confirm with soil tests. Two soil assays (silicon BSES H_2SO_4 and silicon $CaCl_2$) are required to determine silicon requirements.

Recognise silicon as an integral part of sugarcane nutrient management.

Broadcast, banded or variable rate application of silicate-based products to maintain soil levels above the marginal value.

Mill ash and mud/ash mixes (at 100-150 wet tonnes/ha) are also a significant source of silicon. They can be applied during the fallow or onto ratoon crops. Refer to the SIX EASY STEPS Toolbox guidance to account for nutrients contained in mill by-products.

Leaf sampling over multiple seasons is useful for monitoring silicon uptake and confirming deficiency symptoms.

Zinc deficiency

Constraints explained

Usually occurs in sandier soils including beach ridges, soils formed from metamorphic or granite rock and sandy, dark alluvial sols near granitic hills. Zinc deficiency may also be encountered following excessive application of lime, high phosphorus applications and extensive earthworks.

Treating zinc deficiency increases root mass, cane yield and CCS.

Implementation timeline & complexity

Management is less complex with remediation strategies well understood and required knowledge well known.

Management actions will be required at the commencement of the fallow, after identifying zinc deficiency or possibly after harvesting the third or fourth ratoon crop depending on the length of the cropping cycle.

This will help ensure the supply of this essential plant micronutrient is adequate for achieving balanced nutrition and does not constrain productivity.

Solutions

When interpreting soil test values use the zinc (HCl) SIX EASY STEPS guideline where soil pH (1:5 water) is less than 6.5. If the soil pH (1:5 water) is above 6.5, use the zinc (DTPA) SIX EASY STEPS guideline.

Application of zinc-based products (44 kg/ha of zinc sulfate heptahydrate or a zinc-fortified planting mixture) to supply adequate zinc for one crop cycle (plant and up to four ratoons) in deficient soils.

Products should ideally be incorporated into the soil close to the developing root system as zinc is relatively immobile.

Zinc sulfate heptahydrate is not compatible with DAP or MAP as zinc will bind to the phosphorus forming a zinc phosphorus complex.

Application to the soil is preferred to a foliar spray. Zinc chelate is a better option for foliar application it has a lower risk of leaf burn.

Monitor the crop for zinc deficiency symptoms. The most distinguishing symptom being initially evident on the third and older leaves in the form of yellowish striping (veinal chloroses) along the whole leaf with the midrib and leaf margins remaining green.

Use leaf analysis to confirm the adequacy of zinc uptake, diagnose deficiency and identify hidden hunger.

Zinc deficiency in young sugarcane.

Copper deficiency

Constraints explained

Usually occurs in organic soils such as peats and sandy, highly leached soils low in organic matter. Soil pH also influences copper availability as copper becomes less available for plant growth in alkaline (high pH) soils).

A cane yield response to copper is almost certain when the “droopy top” deficiency symptom is present.

Implementation timeline & complexity

Management is less complex with remediation strategies well understood and required knowledge well known.

Management actions will be required at the commencement of the fallow, after identifying copper deficiency or possibly after harvesting the third or fourth ratoon crop depending on the length of the cropping cycle.

This will help ensure the supply of this essential plant micronutrient is adequate for achieving balanced nutrition and does not constrain productivity.

Solutions

Best confirmed by symptoms of copper deficiency as the soil test (Copper DTPA) is not reliable. The soil test will highlight a potential copper deficiency.

Plant tissue testing provides a more reliable indication of copper nutrition. Use leaf analysis to confirm the adequacy of copper uptake, diagnose deficiency and identify hidden hunger.

Application of copper-based products (40 kg/ha of copper sulfate pentahydrate, 29 kg/ha of copper sulfate monohydrate or a copper-fortified planting mixture) to supply adequate copper for at least one crop cycle (plant and up to four ratoons) in deficient soils.

Products should ideally be incorporated into the soil close to the developing root system as copper is relatively immobile.

If using a copper sulfate product as a foliar spray do not apply concentrations above 1% to avoid leaf burn of necrotic spots.

Monitor the crop for copper deficiency symptoms. The most distinguishing symptoms being drooping leaves which are characteristic of the “droopy top” symptom, rubbery and flexible stalks, small, dark green patches on leaves as inter-veinal chlorosis.

Sodic soils

Constraints explained

Sodic soils have an exchangeable sodium percentage (ESP) greater than 6%. In these soils, sodium replaces a large proportion of other cations (calcium, magnesium and potassium). This causes the breakdown of soil structure which affects water holding capacity, water infiltration, drainage, cultivation, and machinery access to paddocks. Nutrient uptake is also restricted

Implementation timeline & complexity

Management is complex, requiring multiple operations and specific knowledge.

Management actions largely need to be undertaken at the commencement of the fallow especially where drainage requires improvement and soil ameliorants need to be incorporated into the soil.

Sodium levels in the soil and ESP values should reduce below 6%. This will improve soil structure and crop performance resulting in increased productivity.

Solutions

Confirm with a soil test measuring exchangeable sodium percentage (ESP). An EM survey can assist with identifying sodic areas and soil sampling locations. Also take soil sample to check ESP of the subsoil (40-60 cm).

Incorporate calcium (typically in the form of gypsum) or mill by-products into the surface soil. Lime is also a source of calcium but given its low solubility, should only be used in acid soils (where the soil pH [1:5 water] is less than 5.5). A combination of lime and gypsum may be needed in acid sodic soils.

Application rates should be determined by consulting the SIX EASY STEPS nutrient management guidelines for sodic soils and the gypsum rate calculator for sugarcane (Gypsy).

Improve surface and subsurface drainage.

Check sodium and/or bicarbonate levels in irrigation water (if applicable).

Salinity

Constraints explained

Salinity is caused by an excess of soluble salts (most commonly sodium chloride) in the soil making it difficult for plants to extract water from the soil. This induces water stress (premature wilting and scorching of the leaves), reduces crop growth and even plant death in severe cases.

Usually associated with inundation by sea water in low-lying coastal areas or a rise in the water table resulting in an accumulation of salt at the soil surface.

Cane yield loss can be greater than 20% in severe situations but is varietal dependent.

Implementation timeline & complexity

Management is less complex with Management is complex, requiring multiple operations and specific knowledge.

Management actions largely need to be undertaken at the commencement of the fallow especially where drainage requires improvement and soil ameliorants need to be incorporated into the soil.

This will improve water uptake thereby reducing water stress and alleviating the impact of salinity on crop growth. Soil structure will also improve.

Solutions

Confirm with a soil test measuring electrical conductivity. An EM survey can assist with identifying saline areas and soil sampling locations.

Improve surface and subsurface drainage.

Prevent inundation of saline water.

Apply gypsum and organic matter and incorporate into the surface soil to improve soil structure and hydraulic conductivity.

Check salinity of irrigation water (if applicable).

Phosphorus sorption

Constraints explained

Phosphorus is unavailable for immediate plant uptake where it is bound onto the surface of soil particles or becomes chemically inactivate when it forms insoluble compounds.

The ability of soils to “sorb” or “fix” phosphorus is assessed in the laboratory and reported as the Phosphorus Buffer Index (PBI). Values for sugarcane growing soils range from very low (PBI less than 70) to very high (PBI greater than 420). The higher the PBI value the less amount of phosphorus available for plant uptake.

In soils with very high PBI values and low plant available phosphorus, tillering, final stalk populations, cane and sugar yields are reduced.

Implementation timeline & complexity

Management is complex, requiring multiple operations and specific knowledge

Further research is required to improve the understanding of phosphorus sorption in some soils.

Management actions are likely to be required for plant and ratoon crops.

This will help ensure the supply of this essential plant macronutrient is adequate for achieving balanced nutrition and does not constrain crop performance or productivity.

Solutions

Confirm with a soil test measuring plant available phosphorus (PBSES) and PBI.

Collect separate soil samples from each block.

Follow the SIX EASY STEPS phosphorus management guidelines.

Apply the full plant cane phosphorus requirement at planting.

An annual application of the identified phosphorus requirement is better than applying the full crop cycle requirement at planting.

Phosphorus does not move easily in the soil and should be applied in the root zone.

If possible, apply mill mud or mud/ash mixes and incorporate into the surface soil on very high PBI soils with low plant available phosphorus.

Leaf sampling over multiple seasons is useful for checking on the adequacy of phosphorus inputs and identifying hidden hunger.

Leaf tissue can be sampled and analysed to identify crops that are limited in crucial nutrients.

Fertiliser is applied to address soil chemical constraints identified through soil and leaf analysis.

CHAPTER 4

Research summary

Opportunities to improve calcium management and soil acidity

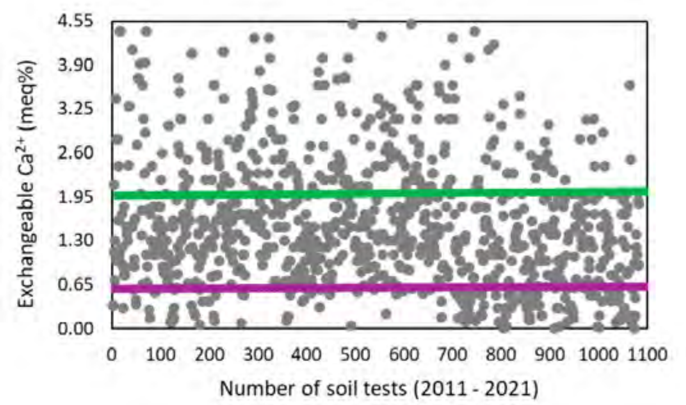
This study analysed the results of soil samples collected from sugarcane fields in the Tully, South Johnstone and Mulgrave mill areas assayed by commercial soil-testing laboratories. For each mill area, the range, mean and median soil test values were calculated. The proportion of samples below critical and marginal values for calcium and magnesium and with a soil pH less than 5.5 was also determined.

Critical values of 0.65 meq% for exchangeable soil calcium and 0.10 meq% for exchangeable soil magnesium were established to identify situations where calcium and magnesium deficiency would likely reduce sugarcane yields and a response to nutrient inputs is almost certain. In comparison, the marginal value (2.00 meq% for calcium and 0.25 meq% for magnesium) is used to identify situations where yields are unlikely to be limited. Between the critical and marginal values, a maintenance nutrient application is warranted to ensure sugarcane yields are not being limited.

Key findings

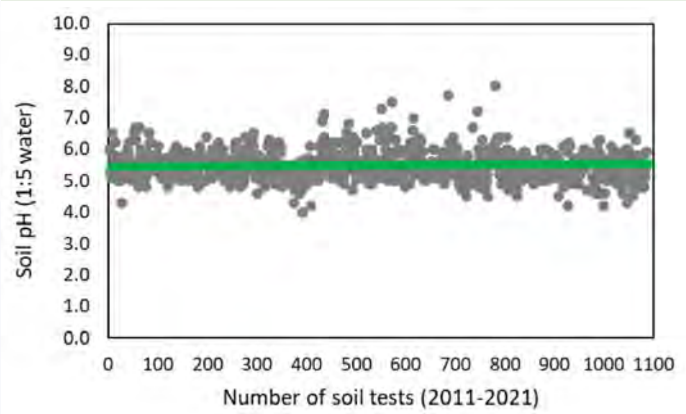
The results of individual soil-test results for exchangeable calcium for the Mulgrave mill area is shown below. Almost 20% of records were below the soil test critical value (as indicated by purple line) and 54% were between the critical and marginal soil values (as indicated by the green line). Previous research has shown the yield of sugarcane crops growing in soils with calcium levels below the critical value is greatly reduced.

Results of individual soil-test results for exchangeable calcium (meq%) for the Mulgrave mill areas. The soil test critical value (0.65 meq%) is represented by the purple line and the marginal value (2.00 meq%) is represented by the green line. Source: Skocaj 2023



The results of individual soil-test results for soil pH (1:5 water) for the Mulgrave mill area is shown below. Around 60% of records had a soil pH below 5.50 (as indicated by green line). This is not surprising given the high proportion of low exchangeable soil Ca values.

Results of individual soil-test results for exchangeable magnesium (meq%) for the Mulgrave mill areas. The soil test critical value (0.10 meq%) is represented by the purple line and the marginal value (0.25 meq%) is represented by the green line. Source: Skocaj 2023



This review has identified opportunities to improve productivity and profitability

• Calcium is an essential nutrient for sustainable sugarcane production to achieve balanced nutrition

• Calcium-based soil amendments need to be applied prior to the wet season to allow a longer reaction time before planting

• Applications of agricultural lime 0-6 weeks prior to planting are insufficient to be fully effective in the plant crop

• Application rates should be based on soil test results. This will ensure crop nutrient requirements are sufficient and the potential for poor calcium nutrition to limit productivity

• If extending crop cycles beyond fourth ratoon it may also be necessary to reapply calcium-based soil amendments

• Soil testing older ratoons will better inform application rates rather than applying general or 'rule of thumb' maintenance rates

• Consider more frequent applications of calcium-based soil amendments at lower rates rather than one single application per crop cycle.

• Monitoring soil acidity and aiming to maintain soil pH above 5.5 will support improved nutrient uptake, reduce aluminium toxicity and improve the performance of legume cover crops.

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Soil health

Soil isn't just dirt—it's a bustling ecosystem full of life that supports everything we grow. It's packed with billions of tiny creatures like bacteria and fungi that make up its living foundation. This living soil is essential for keeping plants, animals, and people thriving. In this section we explore the benefits of improving soil health through exploring case studies relevant to sugarcane cropping systems

Key principles to improve soil health

Maximise presence of living roots: Ensure that there are living roots in the ground year-round to promote soil structure and microbial activity.

Minimise disturbance: Less is often more when it comes to soil management. Avoid unnecessary tillage or compaction that can disrupt soil structure and harm beneficial organisms.

Maximise soil cover: Keep your soil covered to protect it from erosion, conserve moisture, and provide habitat for beneficial organisms. This can be achieved through cover cropping, mulching, or maintaining crop residues.

Maximise biodiversity: Embrace diversity in your fields. Rotating crops, integrating cover crops, and promoting diverse plant species can enhance soil health by fostering a rich and varied ecosystem underground.

Benefits of increasing soil health

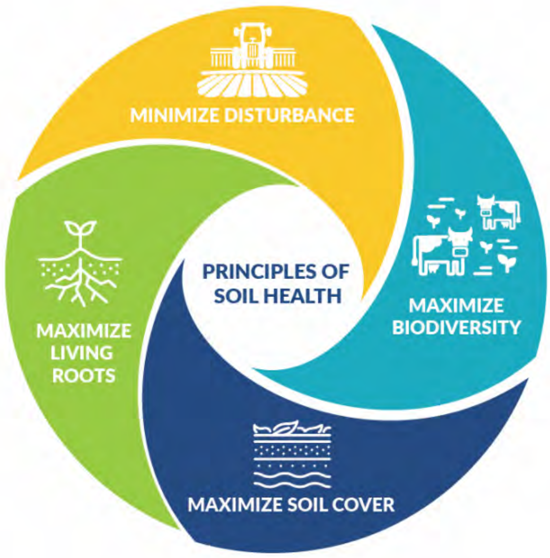
Increased resilience: Healthy soil can better withstand environmental stresses such as drought or heavy rainfall, reducing the risk of crop loss.

Improved yield: Healthy soil provides plants with the nutrients they need for optimal growth, leading to increased crop productivity.

Enhanced sustainability: Practices like minimum tillage and cover cropping help conserve water, reduce erosion, and minimise the need for synthetic inputs, promoting long-term sustainability.

Cost savings: By improving soil health, farmers can reduce their reliance on fertilisers, pesticides, and other costly inputs, ultimately boosting their bottom line.

The Principles of Soil Health. Source: https://www.nrcs.usda.gov/conservation-basics/natural-resource-concerns/soils/soil-health



Cover crops over the fallow improve soil health via multiple pathways. A healthy legume crop also fixes nitrogen, reducing fertiliser costs in plant cane.

Case study 1: Addressing compaction through controlled traffic systems (CTS)

Objective: The objective was to mitigate soil compaction and enhance crop yields through the adoption of controlled traffic systems (CTS).

Reported yield improvement: Research conducted by Braunack (1998) indicated that transitioning from 1.5 m rows to 1.8 m rows (30 cm duals) resulted in notable yield increases of up to 25%.

Study findings: Controlled traffic systems align machinery track width with crop row spacing, thereby reducing soil compaction. Studies by Braunack & McGarry (2006) revealed that crop yields tended to be greater under controlled traffic conditions compared to uncontrolled traffic conditions. Additionally, soil properties such as reduced bulk density and increased hydraulic conductivity were observed under controlled traffic rows as opposed to random traffic rows.

Implementation: The implementation of controlled traffic involves matching machinery track width to crop row spacing. This alignment helps in improving soil properties within the crop row. Recommendations from Garside, Bell, & Robotham (2009) suggest that continued use of controlled traffic systems over time can further enhance both yield and soil properties.

FACT: Did you know that the bulk density of soil can vary greatly depending on factors like soil type, organic matter content, and compaction? For example, sandy soils typically have lower bulk density due to larger particle sizes and less compaction, while clay soils tend to have higher bulk density because of their smaller particle sizes and higher compaction. This variation in bulk density can significantly influence soil properties such as water retention, root penetration, and nutrient availability, making it an important consideration in soil management and agriculture.

Application of compost or mill mud in ratoon cane adds nutrients and organic matter to the soil.

Case study 2: Addressing compaction with mill-mud application

Objective: The aim was to alleviate soil compaction and enhance soil organic carbon through the application of mill-mud.

Reported yield improvement: Studies conducted by Xiangyu et al. (2022) demonstrated that mill-mud application led to significant yield improvements. Plant cane yield increased by 7% following a shallow furrow application of mill-mud and up to 14% with deep trench application of mill-mud compared to control (no mill mud applied).

Study findings: Mill-mud application significantly reduced soil bulk density, indicating effective compaction removal. Moreover, it enhanced soil organic carbon content, contributing to improved soil health and sugarcane productivity. Deep trench application of mill-mud was particularly effective in supplying nutrients to the soil microbial community, thereby enhancing nutrient cycling processes.

Implementation: To implement this approach, farmers apply mill-mud to blocks, especially in areas prone to soil compaction. Deep trenching mill-mud applications is recommended for optimal results, as it addresses compaction stress while promoting soil health and crop productivity.

Application of compost or mill mill can improve soil health by adding soil organic carbon and organic matter.

Case study 3: Assessment of fallow mill by-product application impact of sugarcane productivity

Objective: The objective was to improve soil fertility and crop yields following fallow applications on mill by-products.

Reported yield improvement: Research conducted by Larsen et al. (2023) revealed that application of mud, Mud/Ash, and Ash during fallow periods increased total tonnes of sugar compared to standard practices. However, excessive application led to decreased CCS and grower net revenue.

Study findings: While mill by-products effectively increased cane and sugar yields, excessive application resulted in adverse effects on CCS and grower revenue due to nitrogen applied in the mill mud and increased mineralisation following the addition of organic matter also found within the mill mud. Appropriate application rates are crucial to ensuring soil fertility enhancement without compromising sugar quality and grower profitability.

Implementation: Farmers can implement this approach by banding mill by-products at optimal rates during fallow periods. By following recommended application guidelines, growers can enhance soil fertility, maximise crop yields, and maintain profitability over the long term.

For more information about accounting for nutrients contained in mill by-products see: https://sugarresearch.com.au/growers-and-millers/nutrient-management/six-easy-steps-toolbox/refining-nutrients-for-specific-circumstances/accounting-for-mill-by-product-applications/

"MAKING CHANGES ARE DEFINITELY PROMPTED BY ECONOMIC REASONS. EVERYTHING IS DRIVEN BY ECONOMICS. POSITIVE ENVIRONMENTAL OUTCOMES ARE A WELCOME ADDITIONAL BENEFIT."

Bert Maitland, 2024

Case study 4: Legume fallow management

Objective: The objective was to improve soil fertility and crop yields through legume fallow rotations.

Reported yield improvement: Legume fallow rotations, as studied by Garside & Bell (2011), led to significant crop yield increases ranging from 20% to 34% compared to standard practices.

Study findings: Various legume fallow rotations, including soybean and maize, were found to effectively enhance soil fertility and crop yields. These rotations contributed to improved soil structure, fixed nitrogen, and enhanced nutrient availability for subsequent crops.

Implementation: Farmers can incorporate legume fallow rotations into their cropping systems to improve soil health and break monoculture cycles. By diversifying crop rotations with legume fallow periods, growers can enhance soil fertility, reduce reliance on external inputs, and achieve sustainable increases in crop yields over time.

These case studies underscore the importance of targeted interventions in improving soil health and enhancing crop yields. By addressing soil compaction through controlled traffic systems, applying organic amendments like mill-mud, and implementing effective fallow management practices such as legume rotations, farmers can achieve sustainable agricultural outcomes while ensuring environmental stewardship and economic viability.

Nodules on a soybean crop.

For more information about fallow cropping see: https://sugarresearch.com.au/sugar_files/2022/10/Tully-Fallow-Crops-2022.pdf

For adjusting N rates post legume fallow see: https://sugarresearch.com.au/growers-and-millers/nutrient-management/six-easy-steps-toolbox/refining-nutrients-for-specific-circumstances/accounting-for-legume-fallow-crops/

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Weed management

Nut grass

Constraints explained

While nutgrass may be shaded out when the cane crop is tall, it competes with cane during the important establishment phase in plant cane and when the crop is ratooning. During establishment the cane has reduced ability to compete for moisture and nutrients.

Accessing nitrogen: A moderate to heavy infestations can take up 25-45kg nitrogen / ha.

Accessing potassium: A moderate to heavy nut grass infestations can take up 45-50kg potassium/ha.

Accessing moisture: A heavy nut grass infestation can utilise 11 to 12mm of rainfall (or irrigation) from the top 15-20cm of soil in four to eight days.

Nutgrass roots release allelopathic compounds which may impact cane growth and vigour.

Implementation timeline & complexity

Management through chemical application

Management is less complex so long as the correct chemical is used and applied correctly.

Management action can occur in fallow, plant cane or ratoons. However it is important to apply herbicide at correct growth stage based on label recommendations.

Correct application of systemic herbicides can greatly reduce nutgrass pressure within one growing year. However, it is recommended to monitor for recurring pressure and retreat where necessary as there is evidence that 'nuts' can survive in soil for up to 10 years.

Solutions

Nut grass can be controlled with systemic knock down herbicides Contact herbicides will damage the grass but will not kill the plant. Systemic herbicides should be applied using a coarse or very coarse droplet size and a low water rate (80L/ha). A wetter should be added as per label recommendations.

Plant and Ratoons

- Broadcast halosulfuron-methyl (Sempra) a systemic knock down herbicide that will not damage cane. Double 'knock' application may be required.

- Glyphosate, (a non-selective systemic knock down herbicide) applied with shielded or directed application. Double 'knock' application may be required.

Fallow

- Halosulfuron-methyl (Sempra) can be applied to soybean varieties New Bunya HB1A, Mossman HB1A and Kuranda HB1A.

- Multiple applications of a non-selective knock down (glyphosate) herbicide in an unworked fallow with no cover or rotational crop, or prior to planting cover crop.

- Tillage is NOT an effective method for nutgrass control as the 'nut' must be killed. Disturbing the top (grass) and surface roots will not kill the nut, which will reshoot.

Nut grass can be controlled in sugarcane and legume crops with selective herbicides. Nutgrass competes for nutrients and moisture and reduces yields in both situations.

Non-specific weeds

Constraints explained

Grass and broadleaf weeds compete with the crop for moisture and nutrients, particularly during establishment.

Vines may pull the standing crop down making harvest difficult, which can lead to the loss of the cane stool.

Sub-optimal weed management in sugarcane was estimated to cost an average of $338/ha in 2008, which is estimated to be worth $495 today using the RBA Inflation calculator.

Implementation timeline & complexity

Management through chemical application

Management is complex as it is required multiple times within the cropping year.

Management actions can occur in fallow, plant cane or ratoons. However, it is important to apply herbicide while weeds are small and prior to setting seed.

Correct and timely application of pre-emergent and knock down herbicides can greatly reduce weed pressure within one growing year. However, it is recommended to monitor for recurring pressure and re-treat as necessary. Weeds produce thousands of seeds and many can survive long periods in soil. For example, a thick stand of sickle pod can leave up to 2000 seeds/m^2 with seed remaining viable for up to 10 years.

Solutions

Weeds should be controlled at the earliest stage possible. This will optimise herbicide rates required, reduce the impact of the weeds on the crop (competition) and limit opportunities for weeds to set seed. Prioritise weed control during the fallow to limit weeds in crop.

Always match the chemical being used to the weed/s present and ensure spray equipment is set up correctly for the chemical and target. Pre-emergent chemical should be applied so that it penetrates the soil surface to create a barrier for emerging weeds. This means the herbicide needs to pass through the trash blanket in ratoons, so water rates should be high (300 – 400L/ha). Knock down herbicides should land on the target weed and systemic herbicides will need to translocate within the plant. As high water rates will run off the target weed, low water rates applied as a coarse droplet are required for successful control when using systemic herbicides.

Selecting the best product for weeds targeted, regular calibration of spray equipment and applying products at the right rate with the optimum spray nozzle is important for maintaining good weed control.

In fallow

• Control weeds prior to planting a fallow crop with non-selective systemic herbicide (glyphosate) application and tillage if no nutgrass is present.

• Control grasses with selective knockdown herbicides (haloxyfop) applied during growth of fallow crop.

• Apply non-selective systemic herbicide (glyphosate) at spray out of fallow crop to control all weeds. Monitor weed regrowth and spray again as needed.

• Apply multiple applications of non-selective systemic herbicide to unworked fallow to control all weeds if no fallow crop is to be grown.

• If nut grass is not a problem, tillage, may be used after the wet season.

Plant

Managing for grass weeds in plant cane is essential and can be done with an effective pre-emergent herbicide such as pendimethalin applied prior to cane emergence. Select a product that is suited to soil type and will not cause damage to cane. A knock down herbicide can be added to the mix to control any weeds present at the time of application.

Light tillage can be used to aid early weed control.

Broadleaf and vine herbicides can be controlled with knock-down and/or pre-emergent herbicides. Herbicides should be selected for the weed profile present in each block. Always check the product label to ensure you have selected the correct product for the target weed and application window.

Timing is important and crops should continually be monitored for weed pressure.

Expect applications at:

• Prior to cane emergence/spike – boom spray targeting grass/broadleaf

• 'Out of hand' (after hilling up) - directed spray targeting grass/broadleaf

• After 'out of hand' – high-rise or aerial targeting vines.

Ratoon

Grasses can be controlled with early applications of selected pre-emergent herbicides applied with a knock-down herbicide to control any weeds present.

Broadleaf and vine herbicides can be controlled with knock-down and/or pre-emergent herbicides. Herbicides should be selected for the weed profile present in each block. Always check the product label to ensure you have selected the correct product for the target weed and application window.

Timing is important and crops should continually be monitored for weed pressure.

Expect applications at:

• Prior to cane emergence/spike – boom spray targeting grass/broadleaf

• 'Out of hand' (after hilling up) - directed spray targeting grass/broadleaf

• After 'out of hand' – high-rise or aerial targeting vines.

Spray drones can be used to apply herbicide as spot spray, reducing the need to blanket apply chemical and are useful for spraying vines when the crop can be too tall or conditions to wet for conventional spraying.

Consider the prevailing weather at the time of spraying, dry conditions can limit the effectiveness of many herbicides. Ensure weather conditions are optimal for spraying to avoid drift:

• Wind should be between 3 & 15km/h and steady rather than gusty

• Do not spray if inversion is present

• Temperatures above 30°C and low humidity will reduce droplet size increasing risk of drift.

Always follow label directions when using herbicides. This will impact effectiveness of control and limit damage to cane. Ensure herbicides applied are capable of controlling weeds present.

Guinea and hamil grass (*Panicum maximum* and *Panicum maximum var. maximum* 'Hamil')

Constraints explained

Guinea and hamil grass compete with the cane crop for nutrients and can grow to a significant size in gaps or between cane stools within the row making control with herbicides challenging without damaging the remaining cane.

Roadsides, riparian zones, train lines and grazing paddocks commonly host guinea grass infestations with seed spread through flood waters and on animal fur. Seeds are also carried on machinery, particularly when grass stools are allowed to set seed in the cane crop.

Implementation timeline & complexity

Management with herbicide and manual control

Management is less complex with monitoring and possible treatment required at all crop stages as well as in non-cropping areas. Where a guinea and/or hamil grass infestation is established within a cane crop management becomes complex with additional spot spraying required.

Correct and timely application of pre-emergent and knock down herbicides can greatly reduce weed pressure within one growing year. However, it is recommended to monitor for recurring pressure and retreat as necessary. An established guinea grass stool produces tens of thousands of seeds that are easily spread.

Management actions can occur in fallow, plant cane or ratoons. However, it is important to apply herbicide while weeds are small and prior to setting seed.

Solutions

Fallow

Use of non-selective knock down herbicides (glyphosate) prior to planting a cover or rotation crop, and selective knock down herbicides after a cover or rotation crop is planted. Crops to be commercially harvested may benefit from use of a pre-emergent herbicide.

Plant Cane

Prevention is the priority. Control grasses with knock-down herbicide prior to planting. Apply a pre-emergent such as pendimethalin prior to cane emergence.

Stools of guinea and/or hamil grass can be manually removed using a chipping hoe without damaging plant cane.

Ratoon

Control grass with shielded or directed sprayer using systemic knock-down herbicides (glyphosate).

Fallow crops can help reduce weed pressure in a cane crop, to achieve this fallow crops must be well-grown and should be kept free of grass weeds.

Use pre-emergent herbicide to target grasses (e.g., isoxaflutole, imazapic) with the addition of paraquat immediately after harvest.

Spot spray guinea and/or hamil grass stools in cane with an appropriate herbicide. Ensure good coverage of foliage but avoid contact with sugarcane.

Stools of guinea and/or hamil grass can be manually removed with a chipping hoe without damaging cane.

Manual removal and spot spraying must be done prior to setting seed.

Headlands and water courses

Slash headlands and control weeds on riparian zones prior to seed set.

Maintain vegetation on riparian zones to shade out grasses, and revegetate where needed.

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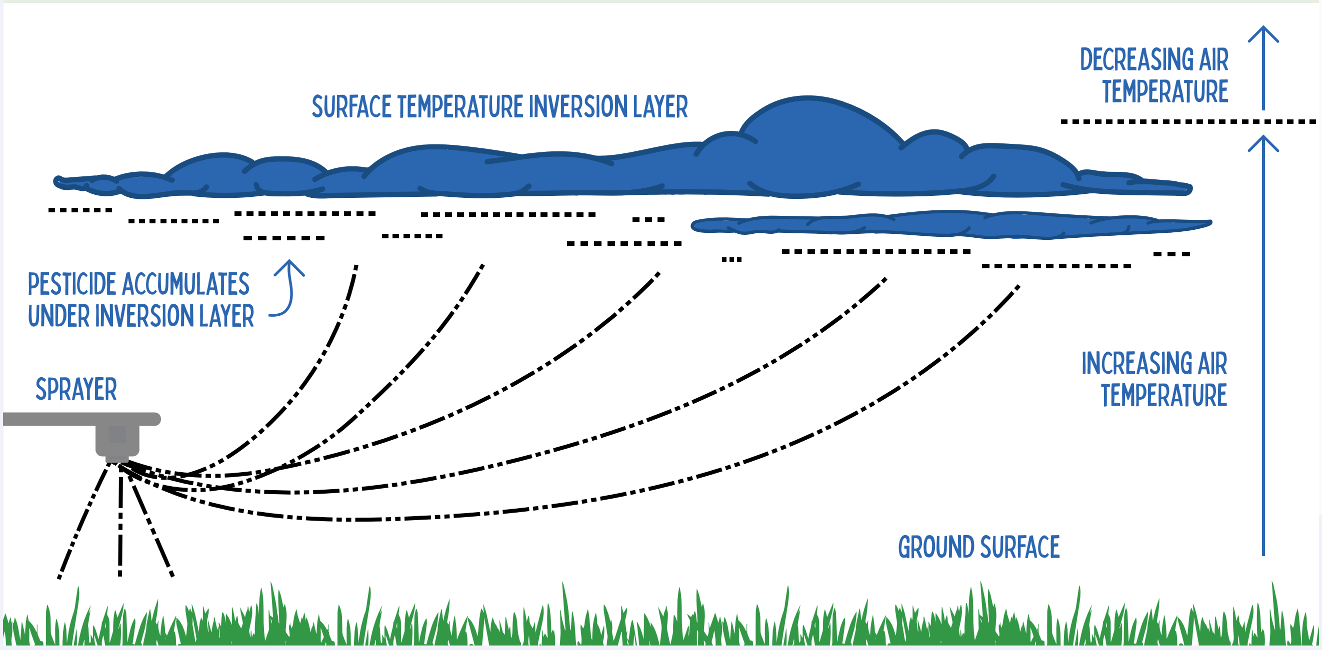
SURFACE TEMPERATURE INVERSION LAYER & ITS EFFECT ON PESTICIDE MOVEMENT



Research summary

Nut grass control in NSW

An SRDC Grower Group Research Project run in northern NSW in the early 2000s found sugarcane yield losses of around 30% in both plant and ratoon cane where nutgrass was not controlled.

Importantly the group also found yield impacts when nutgrass was left uncontrolled for between four and eight weeks after planting or ratooning.

Trials were able to quantify nutrient and moisture lost to competing nutgrass, with potassium uptake equivalent to some full plant cane applications.

The grower group used replicated plot trials in heavily infested plant and ratoon cane blocks to evaluate the effect of delayed control and no control on yield. The results of the trials at two plant cane sites are included below.

The grower group used replicated plot trials in plant and ratoon cane to evaluate several nutgrass specific herbicides on effective removal of the nutgrass tubers, which is the key to elimination of nutgrass. A summary of results is included below.

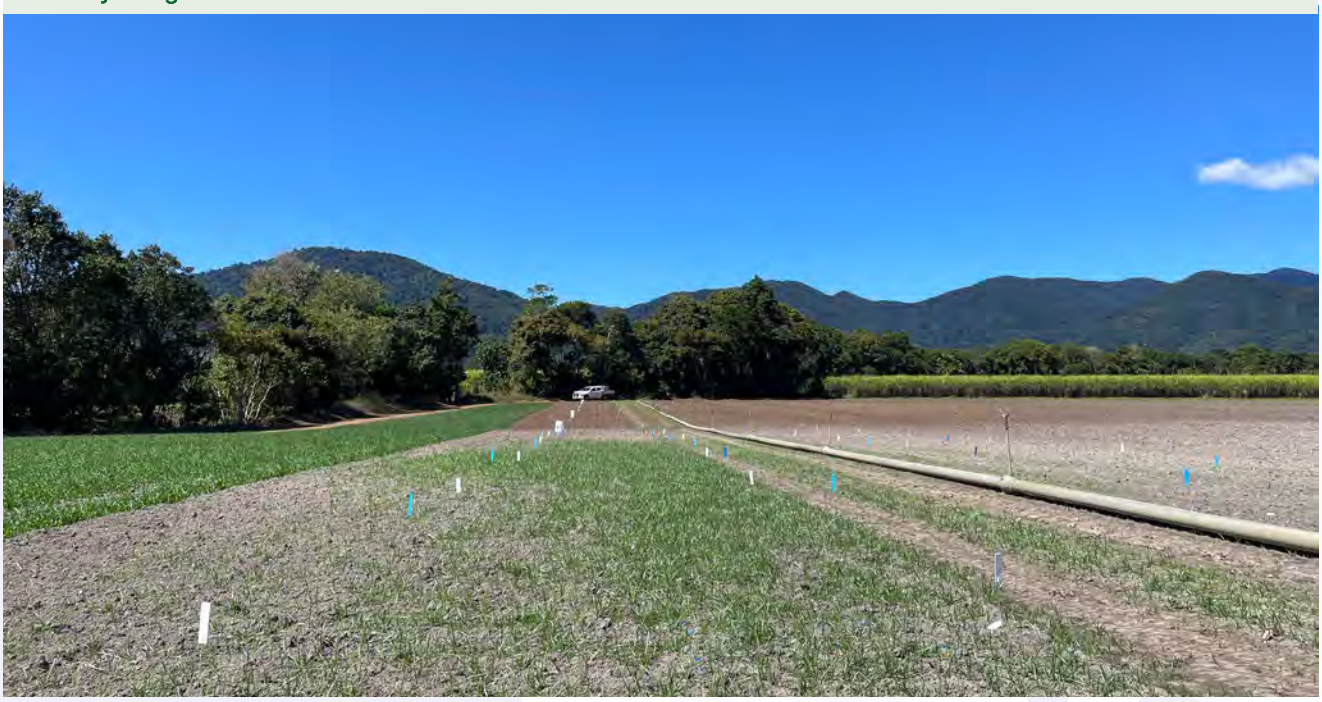
A key message from the group is that nutgrass control requires a long-term integrated approach focussed on reducing the number of viable tubers across fallow, plant and ratoon.

Aitken, R.L, Munro, A.J, and McGuire, P.J. (2011) final report – SRDC Project NFS002 an Integrated Approach to Nutgrass Control. BSES

SUGARCANE YIELD REDUCTION ASSOCIATED WITH TIMING OF NUT GRASS CONTROL

TREATMENTS	MORORO SITE (YIELD T/HA)	WOODFORD ISLAND SITE (YIELD T/HA)
No nut grass (controlled prior to planting)	96.7	103.9
Controlled after 4 weeks.	85.6	103
Controlled after 8 weeks	79.2	94.7
Controlled after 12 weeks.	72.1	84.2
No control	70.6	75.7

A heavy nut grass infestation.



CHAPTER 4

Variety and harvest management

Poor productivity, stool loss & poor CCS

Constraints explained

Variety selection is a critical part of maximising crop yields and CCS. This requires selecting a variety that is suited to the soil type, known disease pressure, intended time of harvest and environmental conditions.

Each variety can be classified as being early, mid or late maturing, depending on when the CCS curve is highest during the season. This information is available in the SRA variety guide. Scheduling the harvest timing of blocks according to the variety present in the block will improve crop CCS. Stool loss due to planting unsuitable varieties can result in gaps, increased weed pressure and reduced productivity.

Implementation timeline & complexity

This is a very complex process. It requires the implementation of clean seed plots to ensure sufficient quantities of suitable planting material and on-farm observations to allow varietal evaluation on the major soil types for the farm and under the individual growers' crop management.

This is an ongoing process and will take a minimum of 3 to 4 years to implement to a level where crop improvements will be gained consistently.

High levels of stool loss/very gappy cane can only be resolved through planting a block with a more suitable variety following a fallow with excellent control of volunteer cane plants and weeds.

Solutions

Implement variety observation plots on each of the major soil types on the farm to allow the evaluation of new and existing varieties, and the subsequent selection of the best performing variety/ies. Once a variety is proven, bulk up planting material in clean seed plots.

When choosing a variety for a particular block, if the maturity window doesn't ideally align with the anticipated harvest time but it's the top-performing option for that soil type, crop ripeners might offer a solution to manage CCS levels.

Identify areas of the farm that need to be harvested within a specific window, e.g. Low-lying blocks that are prone to flooding should be harvested early in the season to allow maximum growth before the next potential flooding event. Certain blocks for Workplace Health and Safety may need to be harvested early to improve visibility around the farm to reduce farm accidents between machinery, and/or locos.

Establishing a structured harvest plan each season can ensure that each variety is harvested within its optimal window to maximise CCS levels. Additionally, it ensures that blocks are harvested around the same time as the previous season to maintain the block's age close to 12 months, thereby maximising both crop yield and maturity.

The use of a brix meter or a small mill to test CCS of blocks prior to harvest will also assist with harvest scheduling to maximise crop CCS.

Be sure to have a fallow and apply excellent weed control before planting with a more suitable variety where a ratoon has become gappy.

Cane varieties can perform differently across the many varied geographic and climatic zones within the Wet Tropics, testing new varieties on farm and having dedicated seed plots is recommended maintain access to suitable, good quality seed cane.

CHAPTER 4

Pathogen build up

Yield reductions may result from plant diseases, such as RSD and soil pathogens especially Pachymetra root rot.

Blocks yielding lower than expected without apparent reasons (such as a soil chemistry constraint), that are planted with sugarcane varieties classified as having susceptible or intermediate tolerance to Pachymetra in the SRA Variety guide, should be assayed for pachymetra.

See disease section for more information.

Poor sugar yield and stool loss

Constraints explained

Reducing extraneous matter by following harvesting best management practices, can result in an improvement of 5 to 15% in sugar yield[1].

Current practice compared to harvest best management results in a 0.7 t/ha sugar loss.[2]

Extraneous matter in the bin at the mill will reduce CCS. Extraneous matter can be the result of harvesting the crop too low which adds dirt to the sample, insufficient cleaning of the cane through the harvester and/or inappropriate topping of the crop.

Harvesting the crop too low can also result in stool loss, resulting in gappy cane, reduced yield, poor input use efficiency and weed infestation in subsequent years.

Implementation timeline & complexity

Management of extraneous matter is relatively simple when you are the harvester owner and operator but can be complex for many growers who work with contractors. An agreement between a harvesting contractor and a grower can be difficult to negotiate. Harvester operators may also require support to get machine settings correct.

Harvesting monitors can be installed and tested within a season and although simple to implement must be valued by the harvesting contractor and the growers that they contract for.

Training of current and future harvester operators will be an ongoing requirement within the industry.

Where stool loss has occurred blocks may need to be fallowed and replanted to return to productive levels. This is not complex but is time consuming and costly.

Solutions

Lifting the base cutter to reduce the amount of soil going into the bins and ensuring that base cutter blades are sufficiently maintained will reduce extraneous matter and stool loss.

Reducing pour rate will allow the extractors to better clean the cane prior to it going into the bin and is the most effective method for reducing extraneous matter. Increasing the speed of the extractor fan has minimal effect on improving the cleaning of the cane but can cause additional yield losses by throwing out cane billets.

Matching the harvester speed to the chopper speed to optimise pour rate is important.

Training of harvester operators, and the inclusion of monitoring systems within the cane harvester is necessary to optimise harvester settings to reduce extraneous matter to optimise CCS.

Harvesting practices can impact CCS and profitability and have a long term impact on the crop.

Research Summary

Investigating losses from green and burnt cane harvesting conditions

Patane et al (2020) found that implementing harvesting best practice could result in significant increases in sugar yields, with current general practice resulting in losses of sugar through high levels of extraneous matter being sent to the mill and cane lost during the harvesting process.

In general, sugarcane harvesters tend to operate at higher ground speeds and fan speeds than those recommended for harvest best practice. The increased ground speed overwhelms the cleaning capacity of the machine, delivering an average of 21 t/h more cane than advised as well as additional extraneous matter. Fan speeds are increased to address the high levels of extraneous matter, inadvertently removing additional cane. Much of the cane removed through the fans disintegrates, making this loss less visible. Trials showed that this increased sugar loss during extraction by 0.15 t/ha compared to standard settings with less cane per hectare delivered to the mill. Analyses revealed that recommended practices yielded higher cane and sugar yields by 4.9 t/ha and 0.7 t/ha respectively compared to standard practices. There were no notable differences in CCS or fibre levels.

References

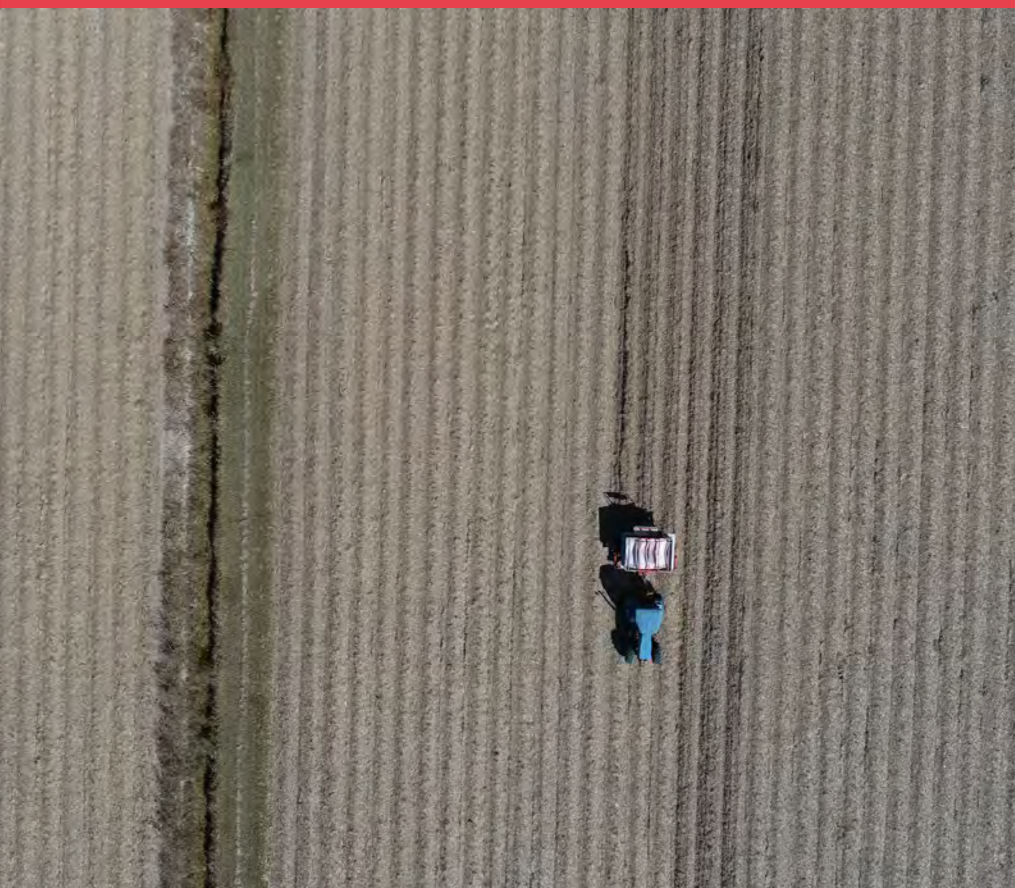
Sugar Research Australia Limited (2014) Harvesting Best Practice Manual. Technical publication MN14001. Sugar Research Australia, Brisbane

Sugar Research Australia Limited (2021) Ratoon Stunting Disease Information Sheet. Sugar Research Australia, Brisbane

Sugar Research Australia Limited (2013) Pachymetra Root Rot Information Sheet IS13005. Sugar Research Australia, Brisbane

Patane, P, Landers, G, Nothard, B, Thompson, M., Norris, CA & Olayemi, M 2020 Investigating losses from green and burnt cane harvesting conditions Proceedings of the Australian Sugar Cane Technologists, Vol 42, pp 343 – 351

A drone image showing different sugarcane varieties growing in the Mulgrave valley.



Disease management

Ratoon stunting disease (RSD)

Constraints explained

Ratoon stunting disease (RSD) is globally recognised as an economically significant constraint to cane productivity. It is caused by the bacterium *Leifsonia xyli*, which primarily infects the xylem vessels but can also be found in leaves and leaf sheaths. RSD impairs water transportation within the plant, causes hormonal imbalances and reduces photosynthesis, resulting in decreased tillering and culm biomass.

Disease transmission occurs through infected planting material and contaminated cutting equipment. Visible symptoms are difficult to identify. In the field the crop may appear stunted with an up and down appearance as different stools may be more or less stunted.

RSD affects all sugarcane varieties to some extent, leading to productivity and profitability losses. Croft et al. (2004) reported yield losses ranging from 5% to 60%, with the greatest impacts noted during times of moisture stress.

Implementation timeline & complexity

RSD Management

Management is complex as it requires vigilance across multiple areas of the farming system (machinery hygiene, fallowing, controlling volunteer cane plants, planting material, planting and harvesting), coordination and communication with other parties (e.g., productivity boards to perform plant source inspections and access approved clean seed, planting and harvesting contractors) and forward planning. Planning is required two to three years prior to planting to ensure access to sufficient quantities of disease free planting material.

Management actions are required throughout the crop cycle. Blocks of RSD infected crops should be fallowed and planted with RSD free material the following year rather than replanting.

Solutions

RSD management, like all farm hygiene, requires a multifaceted approach.

Testing

If a block exhibits poor ratooning and reduced height, testing for RSD is recommended. Where there has been little historical focus on RSD, a whole farm survey would be beneficial. All planting material needs to be inspected and tested for RSD prior to being used.

Fallow management

Fallow blocks for at least 6 months and ensure there is no volunteer cane which may be infected with RSD to reduce the threat of infecting the next plant cane crop.

Use disease free planting material.

Access plant source material from approved seed plots operated by the local productivity board, tissue culture or hot water treated cane that is no older than first ratoon.

Prior to planting contact a productivity officer for a plant source inspection, including an RSD assay.

In general planting material should be no older than first ratoon, disease free, free from pest damage, with intact eyes, uncracked and should not be taken from a lodged crop. It is best if planting material is less than 12 months old.

No varieties are resistant to RSD however some varieties are more sensitive and carry higher levels of the bacteria.

Machinery hygiene

RSD is spread easily by any piece of machinery that cuts an infected cane plant. Cane knives, harvesters, plant cutters, planters (both whole stick and billet) and stool splitters must undergo sterilisation before transitioning between clean cane blocks or moving from one farm to another, particularly when coming from an infected block. There is evidence that RSD can be spread by billet planters with fungicide dip tanks (rather than spray-to-waste) and it is imperative to sterilise planters and change the fungicide solution after every block is planted.

A fallow block with abundant sugarcane volunteers. Fallows are important for breaking the disease cycle, however to be effective sugarcane needs to be completely destroyed, volunteers host commercially significant diseases such as RSD and pachymetra.

Smut

Constraints explained

Sugarcane smut is a fungal disease caused by the pathogen *Ustilago scitaminea*. It is characterised by the formation of large, black, sooty masses of fungal spores on various parts of the plant, including the leaves, stems, and inflorescences.

The disease is spread through infected planting material and windborne spores. Once established, sugarcane smut can lead to reduced yields, stunted growth, and ultimately crop failure. It is estimated that yield loss is equivalent to 0.6% for each 1% increase in the quantity of infected plants. Infected plants may exhibit symptoms such as distorted leaves, swollen and twisted stems, and abnormal growth of flowers and seed heads. Spores survive for 2-3 months in moist soil and longer periods in dry environments.

Implementation timeline & complexity

Management is less complex as the varieties that dominate the Wet Tropics industry are either resistant or intermediate to smut and pose little risk. Smut outbreaks can be found in drier areas particularly following dry conditions.

Management actions in these situations require fallowing and planting with a resistant variety. Smut cannot be effectively managed within the crop cycle.

Solutions

Control measures for sugarcane smut include the use of resistant varieties, crop rotation, application of a suitable fungicide at planting and sanitation practices to prevent the spread of the disease.

In the Wet Tropics resistant and intermediate varieties can safely be grown, however in dry conditions intermediate varieties may become infected.

Hot water treatment can provide 98% control of smut in infected planting material. Both short (52°C for 30 minutes) and longer hot water treatment (50°C for 3 hours) are effective. A fungicide application can reduce infection of disease-free planting material from contaminated soil.

Smut whip on sugarcane.

Pachymetra

Constraints explained

Pachymetra root rot *(Pachymetra chaunorhiza)* is a sugarcane disease found only in Australian cane fields, caused by a fungus-like organism. It significantly reduces root growth and subsequently sugarcane yields in susceptible varieties. Symptoms include soft, flaccid rot of larger roots, leading to smaller and poorly developed root systems, potentially causing stool tipping. Root reddening may occur during the early stages of infection. The damaged roots have a reduced capacity for nutrient and water uptake and plant anchorage. Impacted crops may appear drought stressed or show signs of lacking nutrition prior to any visible stool tipping.

Pachymetra spore counts increase rapidly where susceptible varieties are planted and intermediate varieties have also been found to increase spore loads, particularly in favourable environmental conditions. For example, trials in Bundaberg found yield losses of 17% associated with continual cropping of the intermediate variety Q208A. Higher rainfall has been found to increase spore loads, with higher rainfall areas typically having higher disease levels.

Yield losses of up to 40% and consistently over 10% have been measured in research trials.

Implementation timeline & complexity

Management through variety selection

Management is complex as assessment through soil sampling should be conducted early enough to source and propagate the required planting material.

In practice this means pachymetra sampling and management actions are required at least two years prior to removing the crop impacted by pachymetra. Pachymetra cannot be treated and impacted blocks must be fallowed and planted with a resistant variety.

Where a medium or high spore count is reported a resistant variety should be grown. When selecting the most appropriate resistant variety, considerations include suitability to local soil and moisture conditions, anticipated harvest date (early, mid or late sugar), resistance to other diseases of significance in the area and to ensure a mix of varieties is grown to avoid overreliance on one or two varieties.

Solutions

Pachymetra levels can be assessed through a soil sample, preferably taken in the centre of the cane row prior to any tillage. Samples are assayed by SRA and an estimate of disease severity provided.

Probable disease severity associated with spore counts in a standing crop are as follows:

Low: 0-50,000 spores/kg

Medium: 50,000 – 100,000 spores/kg

High: >100,000 spores/kg

Where spore counts exceed 50,000 spores/kg it is recommended to grow a resistant variety.

It is recommended that pachymetra assessment is done at least two years before fallowing a block, to provide enough time for the most suitable variety to be sourced and propagated to ensure sufficient planting material is available.

It is recommended to only grow resistant varieties in areas with routinely high spore counts.

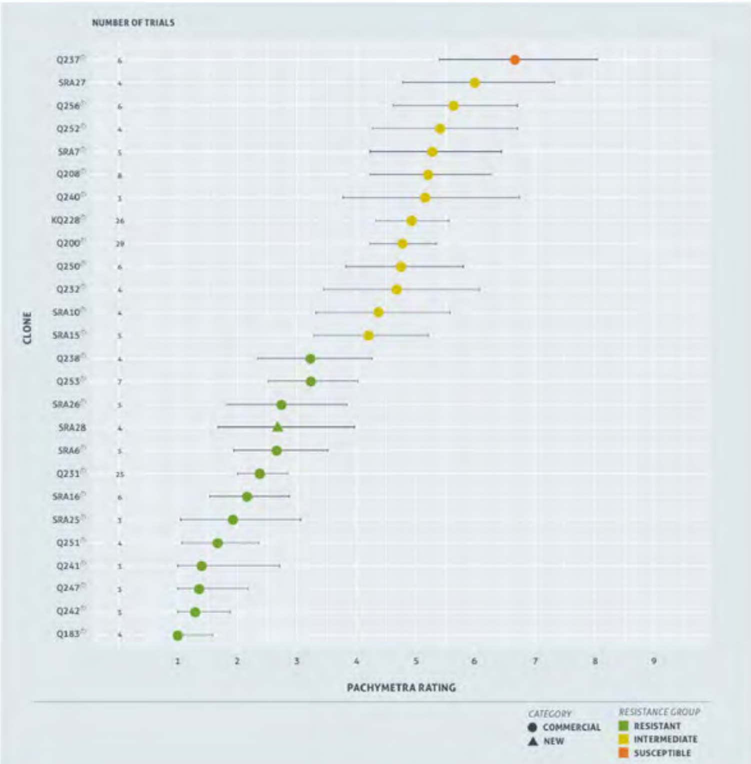
Where pachymetra spore counts are extremely high, test again towards the end of the upcoming crop cycle as a resistant variety is likely necessary for multiple crop cycles to reduce spore numbers in the soil.

There is no evidence that pachymetra becomes more aggressive to an intermediate variety if it is consecutively cropped. Crops will simply suffer yield reduction from the continued build up of pachymetra spores.

Tillage may initially dilute spore numbers, however numbers will increase where susceptible and intermediate varieties are planted.

Pachymetra symptoms may appear similar to other issues such as moisture stress or canegrubs. It is important to conduct an assessment to identify and address the specific constraint.

Pachymetra resistance rating for sugarcane varieties grown in the Wet Tropics. Source Sugar Research Australia.



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Pachymetra levels can be assessed by through sampling soil in the cane stool with analysis conducted at Sugar Research Australia laboratory in Tully.

CHAPTER 4

Research summary

Does rotating cultivars with intermediate resistance influence pachymetra root rot of sugarcane?

This study investigated the effects of rotating sugarcane cultivars with intermediate resistance to pachymetra root rot on pachymetra oospore levels and crop yield. The research addressed industry concerns that repeated cropping of particular intermediate varieties could cause higher than expected yield losses due to pachymetra. These concerns were significant as intermediate cultivars represented more than 70% of the sugarcane grown in Australia at the time of the research (published 2019).

The research project consisted of three field trials, located in the Herbert, Central and Southern growing regions. Initially pachymetra spores counts and cane yields were assessed in ratoon crops of replicated cultivar-assessment trials. This was followed by measurement of pachymetra oospore levels and yield in subsequent crops of Q208 planted on the sites of previous cultivar trials. The relationships between pachymetra oospore levels and cane yield in the plant and first ratoon Q208 crops were then compared.

Key findings - spores

• In the Southern trial pachymetra levels increased under the Q208 plant crop in plots where resistant cultivars were grown previously but were significantly lower than where intermediate or susceptible cultivars had been grown.

• In the Wet Tropics trial pachymetra levels increased under the Q208 plant crop in plots where resistant and some intermediate (Q200) cultivars were grown previously, but were significantly lower than where susceptible cultivars and most intermediate cultivars were grown.

• In the Q208 plant crop pachymetra levels generally decreased or showed little change where intermediate or susceptible cultivars were grown previously, however populations increased by approximately 50% by the end of the first ratoon compared to levels measured at the end of the plant crop in all cultivars.

• Oospore levels in plots planted to Q208 following Q208 were not significantly higher than predicted.

• At the end of first ratoon crops oospore populations were significantly lower where resistant cultivars were grown previously compared to plots where susceptible or intermediate varieties were grown (such as Q232 with162,900 spores/kg soil).

Key findings - yield

• Moderate to high yield losses were incurred with an estimated yield loss of 12% in the Q208 plant crop (with mean of 71,000 spores/kg soil) and 18% yield loss in Q208 first ratoon (mean of 105,000 spores/kg soil).

• Cane yield in plots planted to Q208 following Q208 was not significantly lower than predicted, based on a linear regression between cane yield of Q208 and pre-plant spores/kg soil, compared to other cultivar treatments (i.e., Q208 planted after a different variety).

• The increase in oospore levels under the plant and first-ratoon crops of Q208 and subsequent yield losses demonstrate that improved management of pachymetra root rot could have considerable productivity gains.

These findings suggest that significant yield losses in Q208 were linked to high pachymetra oospore levels under previously grown intermediate and susceptible cultivars. However, there was no evidence supporting the hypothesis that repeatedly planting the same intermediate cultivar could induce host-cultivar-specific virulence in pachymetra.

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SUGAR RESEARCH AUSTRALIA PROBABLE PACHYMETRA SEVERITY GUIDE

PROBABLE DISEASE SEVERITY	FALLOW FIELD	STANDING CROP INTERMEDIATE
Low	0 - 30,000 spores/kg	0 - 40,000 spores/kg
Medium	30 - 50,000 spores/kg	40 - 70,000 spores/kg
High	50 - 120,000 spores/kg	70 - 200,000 spores/kg
Very High	> 120,000 spores/kg	> 200,000 spores/kg

CHAPTER 4

Pest management

Greyback canegrub

Constraints explained

Cane beetles lay eggs in the soil after the first summer storms. Research shows beetles typically fly to the tallest or highest blocks of cane to lay their eggs.

Eggs that are laid in blocks located in low lying areas or with poorly drained soils will often not survive the wet season.

Canegrub larvae feed off sugarcane roots, reducing the ability of the plant to take up nutrients, water and oxygen. Chewing of the roots also makes the plant susceptible to stool tipping and can result in gaps in the cane crop. Weeds such as guinea grass can colonise the gaps further competing with the cane crop for nutrients and moisture. Research shows that blocks infested with canegrubs are more likely to re-infested the following year.

Implementation timeline & complexity

Management through chemical treatment

Management is complex as it should be based off monitoring for canegrub pressure with application of a chemical treatment after pressure is ascertained.

Management actions can occur in ratoons or plant cane. Once canegrub pressure is identified action cannot be taken until the subsequent ratoon or plant crop. Monitoring should be done from March to April in the Wet Tropics.

Treatment cannot occur until the following ratoon or planting. Registered liquid products containing imidacloprid or clothiandin can be applied in ratoons. Liquid products last one year and must be reapplied the following year if canegrub pressure remains.

Slow-release granular products containing imidacloprid are applied at planting and provide longer control.

Chemicals registered to treat canegrubs are only effective when applied correctly. One year treatments may require reapplication when pressure is high across the district.

Solutions

Annual monitoring for presence and pressure. Unlike many pests treatment for canegrubs is applied prior to the pest presence and treatment decisions are based on a risk assessment. Assessment can be based on crop damage the previous year, however, it should be confirmed that damage is not caused by a different issue, such as pachymetra which can also cause stool tipping. Canegrub presence and pressure can be monitored through digging up cane stools around March (Wet Tropics) and checking for grub presence and root pruning. Select blocks for monitoring based on the likelihood of infestation; prioritising higher elevation blocks, larger cane (early plant), lighter soils and sites of infestation the previous year.

Trap cropping (e.g., sorghum) can be used to attract beetles away from the cane crop and to aid monitoring efforts.

Sharing of monitoring information among neighbours can aid community understanding of canegrub pressure.

Where canegrubs are present, treat with registered chemicals applied as per label requirements. Use a plan based on crop age and landscape position, prioritising plant cane, early ratoons, high elevation blocks and lighter soils.

It is important that products are correctly applied to ensure effective control and to minimise off-site movement. Liquid products must be applied 10cm below the soil surface, with complete closure of the slot in ratoons. Applications should occur between October and December. Earlier applications may result in poor control due to loss of product through decomposition. Liquid products can be used on plant and ratoon cane.

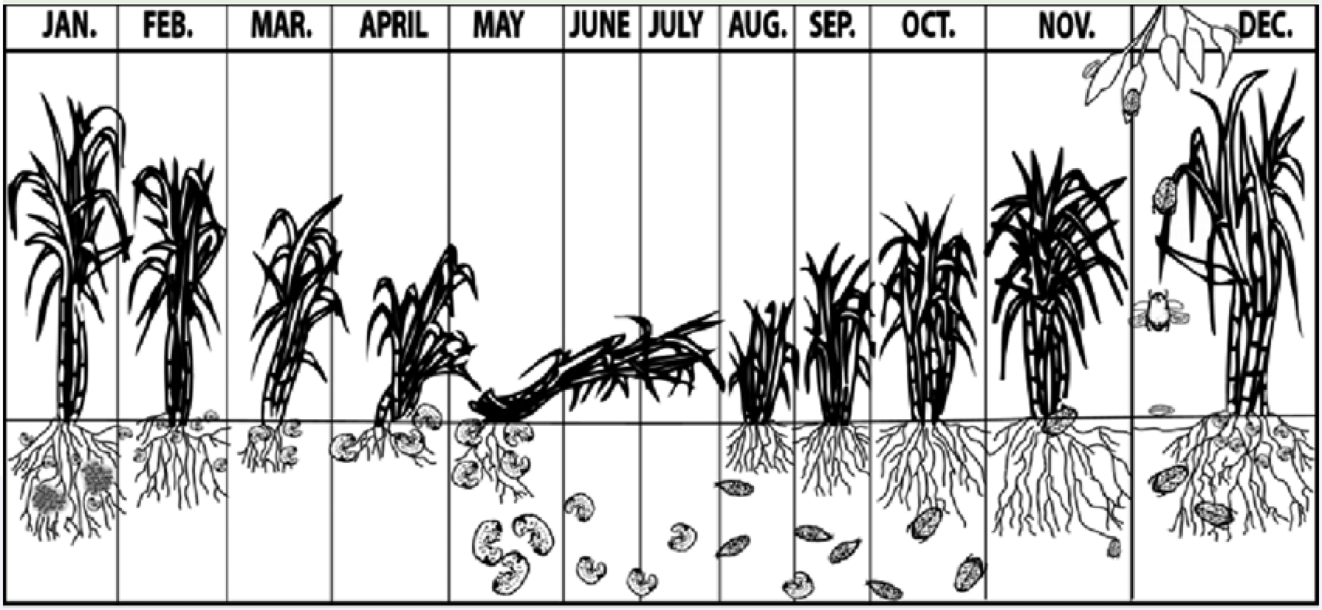
The granular product (Suscon Maxi) can be applied to plant cane and can be applied to the soil surrounding the set at planting, 2-5cm above the set at first working or 5-15cm above the set when applied at cutaway or fill in. The cutaway or fill in method is recommended where there will be more than 20cm of soil above the set in the finished row. Regardless of timing of application granules should be covered with at least 10cm of soil after application and 15-20 cm of compacted soil once the row is finished and hilled up. Do not disturb granules or remove soil with cultivations after application.

Currently only two chemicals (imidacloprid and clothianidin) are registered to treat cane grubs and both are Neonicotinoids. All neonicotinoids are currently under review by the APVMA and research into alternatives is ongoing.

Reducing compaction, minimising tillage and increasing soil organic matter can increase naturally occurring canegrub pathogens such as *Adelina sp, Metarhizium* and *Paenibacillus popilliae*.

Note tillage will NOT eliminate or prevent canegrub infestations.

Lifecycle of the greyback canegrub. Beetles lay eggs with the first summer storms typically from November to December with eggs hatching after two weeks. Grubs encounter soil applied pesticide from February to April. (Image Goebel, François-Régis & Sallam, Nader & Samson, P.R. & Chandler, K. (2010). Quantifying spatial movement of the greyback cane beetle in the sugarcane landscape: Data available and research needs. 32nd Annual Conference of the Australian Society of Sugar Cane Technologists 2010, ASSCT 2010. 71-83.)



Ground rat *(Rattus sordidus)* also known as the dusky field rat and canefield rat

Constraints explained

Ground rats cause significant economic losses to North Queensland cane crops through crop loss and costs associated with baiting. Crop losses are associated with chewing cane stalks and secondary colonisation of chewed stalks by bacteria, fungi and/or insects. This can lead to productivity losses of 10-30% as a result of reduced yield and CCS.

Rats live in burrows within cane fields, with as many as 23 rats per nest.

Breeding occurs between January and July, coinciding with summer grass abundance as grass seeds are the dominant food source of the ground rat. The high protein content of grass and weed seeds stimulate female rats to ovulate and increase sperm production in males. As seed supply declines rats begin to eat sugarcane. After harvest rats will return to non-crop harbourage areas (e.g., drains and creek banks, riparian zones and revegetated areas) and recolonise the cane crop from November onwards.

Implementation timeline & complexity

Management through baiting and food source reduction

Management is complex as it requires management of grass weeds and harbourage areas and possibly baiting. Successful management requires a neighbourhood approach.

Management action begins with monitoring for rat chewing in young ratoons and control of grass and weeds prior to setting seed. Monitoring and grass/weed control (both in-crop and surrounds) is required every year to prevent increases in numbers (particularly ground rats). When numbers escalate it is difficult to bring them under control until after harvest when rats return to harbourage areas in search of alternative food sources.

Solutions

The first line of defence against ground rats is grass and weed management. Research shows a relationship between breeding and availability of non-cane food sources (e.g. grass seed). Therefore, reducing grass and weed seed availability will limit breeding. This includes good grass and weed management in crop and harbourage areas. Harbourages can include any grassy or weedy areas. Grass/weeds should be managed to prevent seeding which can be achieved through maintaining heavy trash blankets, use of targeted herbicides in crop and slashing in non-crop areas (e.g. headlands, spoon drains).

Maintaining and/restoring vegetation along riparian areas will limit grass and weed growth through shading, limiting the need for additional management.

Baiting should only be carried out in conjunction with monitoring and should occur at the earliest signs of rat damage (chewed stalks in newly ratooning blocks). Aim to reduce rat populations before the population increases. To achieve this baiting should be carried out as rats return to blocks after harvesting or planting, from October onwards. As ground rats are native, baiting must be done according to the conditions of industry wide permits.

Biological control can be enriched by attracting owls, natural predators of rats. Owls typically inhabit tree hollows, and providing nesting boxes can expand their roosting options. Owls and other birds of prey are unable to hunt rats in standing cane or tall thickets of grass and predation will be enhanced by reducing grass weeds on headlands and riparian zones.

Climbing rat *(Melomys burtoni)*

Constraints explained

The climbing rat is smaller than the ground rat and causes more localised damage as infestations tend to occur immediately adjacent to harbourage areas, extending around 15m into the cane block. Damage is caused by chewing through stalks at around 1.5m height with yield and CCS reductions caused by the chewing along with secondary colonisation of bacteria, fungi and/or insects.

Climbing rats build grass nests in the cane canopy and while they can breed year-round, peak in-crop breeding occurs at canopy closure. Breeding rates are much lower than ground rats, however, climbing rats may migrate to cane crops from harbourage areas throughout the year. They will completely exit the crop at harvesting and return at canopy closure, usually from February onwards.

Implementation timeline & complexity

Management through baiting and food source reduction

Management is complex as it requires management of grass weeds and harbourage areas and possibly baiting. Successful management requires a neighbourhood approach.

Management action begins with monitoring for rat chewing in young ratoons and control of grass and weeds prior to setting seed. Monitoring and grass/weed control (both in-crop and surrounds) is required every year to prevent increases in numbers (particularly ground rats). When numbers escalate it is difficult to bring them under control until after harvest when rats return to harbourage areas in search of alternative food sources.

Solutions

Control measures are the same as for ground rats, however baiting programs should begin in February for optimum control.

Always follow label instructions when using regulated chemicals and poisons.

Climbing rat nest in sugarcane at Bartle Frere.

CHAPTER 4

Nematode

Constraints explained

Plant parasitic nematodes attack the roots of sugarcane crops reducing root growth, nutrient and moisture uptake, yield and crop resilience to other stressors. Nematodes are estimated to account for yield losses of 10% in plant cane and 7% in ratoons across the sugarcane industry.

Root lesion nematodes *(Pratylenchus spp.)* cause necrotic lesions on roots, reducing their ability to take up water and nutrients resulting in stunted growth, poor vigour, and decreased yields. Nematode surveys of North Queensland sugarcane soils found that root lesion nematodes occurred in most fields and was commonly present in high population densities.

Root knot nematodes *(Meloidogyne spp.)*, form galls or knots on the roots, which disrupt the plant's vascular system, leading to similar symptoms of reduced root growth and yield. Surveys in North Queensland found root knot nematode was dominant in sandy soils and caused the most severe damage to sugarcane, consistent with moisture and nutrient limitations often present in lighter soils.

There are many other species of nematodes documented in Australian cane fields and it has been found that productivity losses are caused by the entire community of parasitic nematodes present. It is believed that most cane blocks will have at least five species of PPN present.

Free living nematodes are considered beneficial, feeding on bacteria, fungi, parasitic nematodes and other soil organisms. Free living nematodes play a beneficial role in soil, making nutrients available to the crop and helping to maintain a population of natural predators of plant parasitic nematodes. North QLD surveys found that bacterial-feeding nematodes were more common than fungal-feeding, omnivorous and predatory free-living nematodes.

Nematode life cycles are as short as four to five weeks with females laying several hundred eggs allowing numbers to rapidly increase. Adults are attracted to the secretions of host plants.

Implementation timeline & complexity

Management through fallow cropping

Management is complex to highly complex requiring the best choice of fallow crop based on the nematode species present and in lower lying/wet areas effective water management is required to enable the growth of a fallow crop.

Management actions can only be taken in the fallow. Soil testing to establish nematode species and pressure should be done prior to ploughing out the previous crop.

It is expected that important pest nematode populations will be reduced and free-living nematode numbers may increase following a fallow crop. This will benefit the subsequent sugarcane crop, however, nematode management in mono-cropping systems is of ongoing concern.

Management through application of organic amendments

Management is less complex requiring the application of mill mud, mud ash, mud/ash mixes or compost to an impacted block.

Higher rates of mill mud/ash and compost can be applied prior to plant, or lower rates can be banded onto ratoons (but there is no data available on the impact of applications in ratoons on nematode numbers).

It is expected that pest nematode populations will be reduced and free-living nematode numbers may increase benefiting the subsequent sugarcane crop, however, nematode management in mono-cropping is ongoing and will be required at least every crop cycle.

Solutions

Crops can be monitored for nematode pressure through soil testing with assays performed by SRA. Samples should be collected from the centre of the sugarcane row prior to plough out.

Avoid plough out replant, as sugarcane is a host plant for plant parasitic nematodes.

Include a legume rotation during the fallow. Where possible harvest blocks to be fallowed early to provide a longer break from sugarcane and control volunteer cane plants. Peanut, velvet bean and soybean crops (A6785 and Stuart) can reduce plant parasitic nematodes numbers by 80-90%. These options will suppress root knot and root lesion nematode, however, research shows peanuts provide greater suppression of root knot nematode than soybean.

Cowpea, other soybean varieties and lab lab are resistant to root lesion nematode only.

Sunn hemp, mustard and marigold are also known to reduce root knot nematodes. French marigolds *(Tagetes patula)* are thought to suppress a wider range of nematode species than African marigold *(Tagetes erecta)*.

Once a host plant is replanted (such as sugarcane) plant parasitic nematodes numbers will once again increase.

Using minimum tillage and preserving the trash blanket between sugarcane crops supports beneficial nematodes which help to balance the plant parasitic nematodes population.

Applications of compost, mill mud/ash helps build organic matter to support free living nematode populations and has been found to reduce parasitic nematodes. Similar to growing resistant cover crops, plant parasitic nematodes numbers will increase over the crop cycle where mill mud/ash or compost is applied prior to planting.

The nematicide Nimitz is registered for sugarcane, however, nematicides are costly and will also kill beneficial soil biology.

There are currently no varieties of sugarcane that are resistant to nematodes in Australia.

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Fallow crops are an important tool for reducing nematode pressure, with each crop providing varying levels of resistance to commercially significant nematodes and a range of other benefits such as nitrogen fixation, bio-fumigation and biomass. Pictured here, sunflowers, sunn hemp growing in the Mulgrave Russell catchment of the Wet Tropics.

Research Summary

Root Knot Nematode response to legume crops

A study by Stirling et al. (2006) compared the response of three varieties of soybean, mung bean, peanut, lablab, cowpea and velvet bean to two species of root-knot nematode *(Meloidogyne javanica* and *M. incognita)* using three varieties of soybean. The study compared the amount of galling on the legume crop roots at seven weeks after planting and measured the nematode populations at 14 weeks after planting. Crops were planted four and 12 weeks after the sugarcane harvest to assess the impact of bare fallow time.

The impact of additional fallow time

The roots of mung bean, lablab and all soybean cultivars except cv. Stuart were severely galled by root-knot nematode at both planting times; however, because root-knot nematode populations declined rapidly in the bare fallow that followed the sugarcane harvest, galling was less severe in the second planting compared with the first planting.

The impact of choice of fallow/cover crop

Peanut, velvet bean and cowpea cv. Meringa showed little or no nematode damage at either planting time, indicating strong resistance to both species of root knot nematode.

Final nematode counts were high in mungbean, lablab and all soybean except Stuart. Populations were much lower after peanut, velvet bean and soybean cv. Stuart. Glass house studies showed the impact of root knot nematode on Leichardt soybean depended on the species of nematode. The authors warned that local populations of root knot nematode may damage certain soybean varieties on sandy soils and could increase in number, impacting the subsequent sugarcane crop. Resistant varieties such as Stuart are the best selection for lighter soils.

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TABLE SHOWING RESISTANCE RATINGS OF VARIOUS COVER CROPS TO ROOT KNOT NEMATODE (RKN) AND ROOT LESION NEMATODE (RLN), TWO NEMATODE SPECIES OF MOST CONCERN IN SUGARCANE PRODUCTION

SPECIES	ROOT KNOT NEMATODE	ROOT LESION NEMATODE
Soybean Stuart	R	R
Soybean Leichardt	HS	R
Soybean A6785	R	R
Soybean (most cultivars)	HS	R
Cowpea Meringa	MS	R
Cowpea (most cultivars)	HS	R
Lab Lab (all)	HS	R
Sunflower	HS	R
Sunn hemp	R	MS*
Velvet Bean	R	R
Peanut (all)	HR	R
Mustard	HR	HS
French Marigold	HR	R

HS: Highly susceptible, high levels of nematode multiplication. **MS:** Moderately susceptible, ready multiplication of nematodes. **R:** Resistant: Limited multiplication of nematodes. **HR:** Highly resistant, No reproduction of nematodes.


FARMACIST

Water management

Irrigation management

Constraints explained

Inefficient irrigation practices can cause poor water use efficiency, and issues such as excessive runoff, waterlogging and reduced soil aeration, which causes harm to root health.

Under-irrigation stresses sugarcane plants, affecting growth rates, yields and nutrient use efficiency.

In some situations, poor quality irrigation water can cause salt accumulation.

Variable application of water through poorly maintained irrigation equipment can lead to uneven crop growth and reduced yield and input use efficiency.

Implementation timeline & complexity

Management is highly complex requiring understanding of different soil types, crop stage and climate with management adjusted to meet requirements of each parameter. This involves understanding soil Readily Available Water and adjusting irrigation application over time to account for changing water requirements for different crop stages and weather patterns. In addition, many technologies require upskilling for effective use.

Management actions to improve accuracy of irrigation are required throughout the crop cycle.

Solutions

Level fields to improve water distribution and implement advanced irrigation technologies to optimise water use as such precision irrigation scheduling and employing soil moisture sensors to maximise crop growth and to reduce nutrient leaching.

Waterlogging

Constraints explained

Waterlogging reduces oxygen levels in the soil restricting root respiration and nutrient uptake.

Salter et al. (2018) highlighted that when sugarcane is subjected to 35 days of waterlogged conditions, where the water table is within 50 cm of the soil surface, the yield decreases by 0.5 tons per hectare for each day of waterlogging.

Other issues to be aware of include:

- Nitrogen losses due to denitrification in waterlogged soils
- Increased pest and disease pressure in moist conditions.

Implementation timeline & complexity

Management is complex requiring knowledge of the most suitable drainage system for each situation and methods for installation. Detailed knowledge of current gradient (slope) and levels (elevation) throughout the block are required along with specialist equipment and technology.

Management actions for improved drainage are most effective when completed during the fallow.

Solutions

Implement interception drains, sub-surface pipes, and mole drains for effective drainage.

Use field leveling to enhance runoff and install surface drains with grass cover to filter sediments.

Where there are limitations to reducing waterlogging select varieties with greater tolerance.

Mound planting/pre-formed beds, where the sett is planting into a raised mound around 30-45cm high helps to keep the sugarcane roots above waterlogged soil aiding aeration. This system is also beneficial for growing cover crops in very wet blocks.

When flood water sits in a block it saturates the soil creating an anaerobic environment. In this situation flooding occurred soon after harvest killing much of the ratooning cane leaving open space for weeds to thrive.

Surface water management

Constraints explained

Inadequate surface water drainage can result in surface water pooling and, if elevation is too steep, can increase the risk of erosion. Erosive water flows from poorly designed drainage systems and inadequate surface drainage and elevation can damage drainage networks and increase sediment and nutrient losses.

Implementation timeline & complexity

Management is complex requiring knowledge of the most suitable drainage system for each situation and methods for installation. Detailed knowledge of current gradient (slope) and levels (elevation) throughout the block are required along with specialist equipment and technology.

Solutions

Employ laser leveling to create a uniform field surface. Reduce slope where feasible to manage water flow and minimise erosion. Install surface drains with appropriate gradients. Use grass-covered drains to filter sediments and nutrients. Restructure fields with raised beds or mounds to improve water management and select tolerant crop varieties.

References

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Holden , J., & McGuire, P. (2014). Irrigation of Sugarcane Manual. Sugar Research Australia Ltd.

Reghenzani, J. R., & Roth, C. H. (2006). Best-practice surface drainage for low-lying sugarcane lands. BSES Limited.

Salter, B., Park, G., & Kok, E. (2018). A field experiment to evaluate the response of sugarcane varieties to waterlogging. Sugar Research Australia.

Low lying areas often have high water tables, as indicated by the grey clay shown here. Grey soils indicate a very low oxygen environment which will certainly impact on productivity.

Case Study

Impact of waterlogging on sugarcane varieties

Background

Salter et al. (2018) explored the effects of early and late waterlogging on the development and yield of eight sugarcane varieties: KQ228A, Q200A, Q183A, Q208A, Q247A, Q219A, Q232A, and MQ239A. The investigation included stalk population development, crop traits at harvest, nitrogen uptake, and yield, comparing control, early waterlogging, and late waterlogging conditions.

Results and discussion

Crop traits at harvest

Stalk numbers: At final harvest, waterlogging did not significantly affect stalk numbers in the plant crop. Q247A, Q208A, and Q200A had higher stalk populations overall. In late waterlogging, Q183A, Q200A, and Q208A showed lower stalk populations compared to controls.

Stalk weight: Early waterlogging led to smaller stalk weights than control and late treatments. Q232A and MQ230A had the heaviest stalks.

Millable stalk percentage: Higher in control and late treatments, with Q208A and Q219A having high percentages, indicating maturity despite possible distortion by side shooting post-flowering.

Dry matter: Higher in late treatment compared to control, with Q200A showing the highest dry matter content.

First ratoon crop

Stalk count: Waterlogging treatments had no significant effect on stalk population. Q247A and Q200A had higher stalk numbers; Q183A had the lowest.

Stalk weight: Reduced by early waterlogging; no difference between control and late treatments. Low stalk weights were noted for Q200A and Q247A.

Millable stalk percentage and dry matter: Not significantly affected by waterlogging. Q208A and MQ239A had high millable stalk percentages; MQ239A and Q232A had higher dry matter percentages.

Nitrogen Uptake and NUE

Total crop N content: Varied significantly among varieties, with Q232A, Q219A, KQ228A, and MQ239A accumulating the most. Early waterlogging reduced total crop N in MQ239A and Q200A.

Nitrogen utilisation efficiency (NUE): No significant treatment or variety interactions.

Yield

Biomass yield and sugar yield: Early waterlogging significantly reduced biomass and sugar yields compared to late waterlogging. Early waterlogging resulted in a 37% loss (35.9 tc/ha), while late waterlogging resulted in a 16.3% loss (15.8 tc/ha).

CCS and TSH: CCS was not significantly affected by treatments, though variety effects were evident. TSH was significantly lower in early waterlogged conditions.

Conclusions

Early waterlogging severely impacts young sugarcane plants, reducing yield more significantly than late waterlogging. Varietal differences are crucial in response to waterlogging, with some varieties like Q200A and Q247A showing resilience. Optimal planting strategies and selecting varieties based on waterlogging tolerance could mitigate these effects and enhance yield stability.

References

Salter, B., Park, G., & Kok, E. (2018). A field experiment to evaluate the response of sugarcane varieties to waterlogging. Sugar Research Australia.

CHAPTER 4

Water can sit in low lying areas within a block creating localised water logging.

Wet blocks tend to host high levels of grass weeds which can be difficult to control and compete with sugarcane for nutrients, moisture and light.

Constraint management planning

Strategising for success: Maximising potential in challenging situations

What is a constraint management plan?

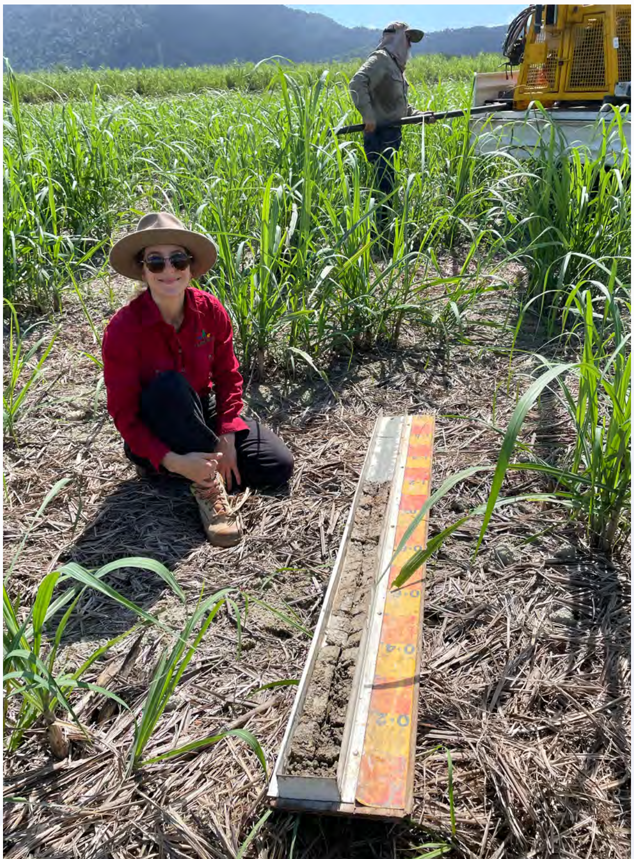
A constraint management plan (CMP) documents areas within a farm that are limited by constraints, identifies what the constraints are and outlines long and short-term strategies for addressing the constraints. Constraints that are challenging to rectify are also identified along with strategies for how to best manage them.

Inputs to support a constraints management plan

A constraint management plan should be built from a range of data inputs, agronomist ground truthing and observations, land manager observations and capacity. A recommended list is provided below. The list is not exhaustive as new datasets will become available over time. Where all elements are not available it should not be considered a limitation to completing a constraint management plan, every land manager will have some datasets available and most importantly, will have knowledge of their land. The process of bringing information together to map known constraints and identifying actions to address them is useful regardless.

Inputs for farm constraints mapping:

- Current farm maps
- Grower observations of constraints marked on farm map
- Soil maps at finest scale available
- Electro Magnetic (EM) maps with interpretation
- Elevation maps
- Soil sample analysis for past five years
- Soil sample locations mapped on soil and/or EM maps
- Satellite yield maps (ideally more than one year)
- Drone imagery of farms
- Mapping of regular flooding identifying moving water/short term flooding and standing water
- Weed source identification
- Drainage map including subsurface drainage
- High water table mapping



Proposed process for farm constraint mapping

The most important aspect of the process of creating a constraint management plan is to engage the land manager, ensuring crop issues they experience are identified and addressed. The land manager will provide important information to assist in interpreting other data layers which should enrich and inform the land managers own observations.

Step 1. Collate all available datasets (e.g., farm maps, soil maps, EM maps, soil sample analysis). Review dataset for expected constraints. This may relate to soil analysis, visible yield differences in satellite mapping or concerns relating to elevation. Document these concerns as questions to ask the grower. It may be useful to print and bind a copy to take to the land manager.

Step 2. Work with land manager to map constraints according to their own observations.

Step 3. Review collated dataset with land manager, explaining each dataset and discussing potential constraints identified in desk top analysis. Add any additional constraints to map and identify any issues that require further investigation.

Step 3. Discuss constraints identified and land managers capacity to address them. Develop a timeline and document constraints that will require additional support to undertake management (e.g. funding, training, new machinery or agronomy investigation and advice).

Step 4. Conduct investigation into any constraints identified that required further information.

Step 5. Agronomist to clearly document constraints identified with proposed management actions, timeline for action and support requirements. Identify any support that can be provided by agronomist and include it in timeline.

Step 6. Group constraints into four categories and map according to constraint type: Farm management constraints, Soil physical constraints, Soil chemical constraints and Landscape position. Documents from step 5 and step 6 along with supporting data sets comprise a constraint management plan.

Step 7. Land manager to review plan, allowing for changes. constraint management plan should be reviewed annually.

Example constraint management plan

Farm number: MUL-XXXX **Farm manager:** Jimmy J Example

Farm location:

FARM CONSTRAINT MANAGEMENT				
CONSTRAINT	BLOCK/S IMPACTED	ACTION	TIMELINE	SUPPORT REQUIRED
High grass pressure	11A-11C and 6A to 6D	1. Develop and follow weed management plan with agronomist 2. Replace spray nozzle 3. Manage grass on headlands and riparian zones 4. Revegetate riparian zones	1. Immediate and ongoing 2. By June 2024 3. Immediate and ongoing 4. Long term	Action 4 requires funding or support from Landcare
RSD	6A-6D, 12A-C	1. Access clean seed source and propagate planting material 2. Fallow and manage volunteers 3. Plant with clean seed source 4. RSD testing on more blocks	1. Immediate and ongoing 2. Fallow half blocks next year and other half following year 3. 2025 and 2026 4. Immediate and ongoing	Action 4 requires support from productivity board or agronomists to access testing
Pachymetra	11A-11C	1. Access clean seed source and propagate planting material 2. Fallow and manage volunteers 3. Plant with clean seed source 4. Pachymetra testing on any additional blocks with intermediate varieties	1. Immediate and ongoing 2. Fallow blocks 2024 3. 2025 4. Immediate and ongoing	Action 4 requires support from agronomists

SOIL PHYSICAL CONSTRAINTS				
CONSTRAINT	BLOCK/S IMPACTED	ACTION	TIMELINE	SUPPORT REQUIRED
Waterlogging	11A-11C	1. Laser Level 2. Clean adjacent drain	1. At fallow in 2026 2. Immediate	Laser level contractor
Water holding capacity	1B, 1D	1. Grow multi-species fallow 2. Apply mill mud	1. At fallow 2024 2. At plant 2025	No support required

SOIL CHEMICAL CONSTRAINTS

CONSTRAINT	BLOCK/S IMPACTED	ACTION	TIMELINE	SUPPORT REQUIRED
Low calcium, low pH, high aluminium	All blocks at planting	1. Assess at third ratoon 2. Apply ameliorant according to soil requirements	1. Immediately after harvest on third ratoon blocks 2. Immediately after harvest on all third ratoon blocks	Agronomist support for soil sampling and interpretation
Low phosphorus	1A-1D	1. Band mill mud 2. Apply mill mud at planting	1. Immediately after harvest 2. At planting as per soil analysis	Agronomist support soil sampling and interpretation

LANDSCAPE POSITION CONSTRAINTS

CONSTRAINT	BLOCK/S IMPACTED	ACTION	TIMELINE	SUPPORT REQUIRED
High water table due to low lying swamp	34-36	Consider alternative uses for area	Long term	Agronomist support for soil sampling and interpretation
Low CCS	All	1. Crop ripening program 2. Review variety selection and harvest schedule	1. Program design begins immediately 2. Review varieties and harvest schedule prior to harvest commencing	Agronomist to conduct review with land manager, design ripening program, trial treatments and asses brix for ripener program and harvest scheduling

Farm Constraints Map

Farm MUL-XXXX

CONCEPTUAL DIAGRAM OF POTENTIAL YIELD CONSTRAINTS

MAP KEY

LOW WATER HOLDING CAPACITY	GRASS WEEDS	WATER LOGGING
HIGH PACHYMETRA SPORE COUNT	RSD	LOW CALCIUM
LOW PHOSPHORUS	POOR PH	WEED SOURCE

CHAPTER 4

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