FINAL REPORT 2016/002

Protecting our Chemicals for the Future through the Accelerated Adoption of Best Management Practices

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Co-funder(s):	Queensland Government through the Reef Water Quality Program
Date:	27 April 2020
Key Focus Area (KFA):	7. Knowledge and technology transfer and adoption

Sugar Research Australia

Queensland Government

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Please cite as: Billing, BJ (2019) Protecting our Chemicals for the Future Through the Accelerated Adoption of Best Management Practice. Final Report Project 2016/002. Sugar Research Australia Limited, Brisbane.

ABSTRACT

The Protecting our Chemicals for the Future through the Acceleration of Best Management Practices project ran in the Wet Tropics for three years from September 2017. The project set out to improve water quality in Great Barrier Reef catchments through increasing the uptake of management practices to reduce losses of herbicides and pesticides to the environment with sugarcane growers in the Tully, Innisfail/Babinda and Mulgrave milling areas. The project utilised tools such as rainfall simulation, grower group work and field demonstrations to connect sugarcane grower collaborators and sugar industry extension staff with science and solutions to water quality and weed and pest issues facing the farmers.

The project used behaviour change principles to inform project design, messaging and interactions with industry and the grower community and also drew on the learnings of the Cane Changer program run in the Wet Tropics by behavioural science experts Behaviour Innovation.

The project focussed on the promotion of selected principle-based key messages, giving grower collaborators the opportunity to identify their own means of applying these on-farm:

- Less on = Less off
- Timing really matters
- Apply imidacloprid products according to label
- Do I have canegrubs, or is it something else?

Protecting our Chemicals for the Future has resulted in practice change among participating growers and collaborators, the provision of resources and messaging for industry extension staff and resellers, and shifted culture among many involved to be accepting of an ability to influence water quality for the better. Key messages have been shared beyond the immediate project collaborators through regular updates in SRA's Cane Connection magazine, presentations at shed meetings and industry events and provision of information and resources to extension staff outside of the Wet Tropics.

EXECUTIVE SUMMARY

The Protecting our Chemicals for the Future through the Acceleration of Best Management Practices project ran in the Wet Tropics for three years from September 2017. The project's set objectives were to improve water quality in the Great Barrier Reef catchments through increasing the uptake of management practices to reduce losses of herbicides and pesticides to the environment within the community of sugarcane growers in the Tully, Innisfail/Babinda and Mulgrave milling areas.

End of catchment monitoring run by the Queensland Government Department of Environment and Science routinely finds chemicals in exceedance of ecological protection thresholds, however only a small number of chemicals drive these exceedances. The herbicide diuron dominates despite the 2012 Review that mandated lowered rates for the Wet Tropics (and application windows for other regions). Project staff surmised that these exceedances could be reduced through improved herbicide selection and drew heavily on the work of SRA Agronomist Emilie Fillols to inform alternative chemicals highlighted through the project. Focusing on importance of application timing to avoid the wet season and improving understanding of herbicide properties, particularly of varying environmental toxicity thresholds, project staff sought to prevent the diuron problem being replicated by another favoured herbicide. Further to this, the opportunity for an overall reduction in the use of residual herbicides where weed pressure is low was promoted, particularly for application close to or within the wet season.

Imidacloprid, the chemical used to control canegrubs in sugarcane, is the other chemical that routinely shows up in exceedance notices. While there are alternative herbicides and strategies for controlling weeds, imidacloprid is the only readily available product for controlling canegrubs. Many farmers have strong memories of farms decimated by canegrub infestations prior to the registration of imidacloprid, and as the application cost has reduced so have application rates increased. Like diuron, imidacloprid has a very low ecological protection threshold. These products are toxic to the aquatic environment at very low amounts, and to prevent continued exceedances usage patterns must become more strategic.

Tools such as rainfall simulation, grower group work and field demonstrations were used to connect collaborating growers and sugar industry extension staff with science and solutions to water quality and weed and pest issues facing the farmers.

Protecting our Chemicals for the Future activities were designed to highlight chemicals that posed the greatest risk of loss to the environment and paired these results with up to date information on the environmental toxicity and persistence of the chemicals to give growers and advisors a clear understanding of the relative risk related to commonly used and emerging herbicides. Annual rainfall simulation demonstrating the variation in losses to the environment from each chemical formed the foundation of the water quality focussed activities and information provided to growers.

In order to provide a more rounded set of information, efficacy demonstrations were included in the suite of activities, allowing growers to trial new, more environmentally sound practices on farm and share the results with neighbouring growers. Many of these were targeted to managing specific weed issues in a sustainable way and testing new chemicals in real life situations. Some had simple composite sampling equipment installed, and all were able to be related back to the rainfall simulation activities carried out in each district annually. This work also enabled economic outcomes to be added to the information.

Key messages that were developed and promoted focussed on the positive, i.e. what can be achieved, rather than negative warnings.

- Less on = Less off
- Timing really matters

Growers and advisors were encouraged to think about the range of chemicals available and the range of farm issues they deal with and find solutions that work for them and the local environment.

While much of the work focussed on herbicides, the on-going exceedances of imidacloprid thresholds in Wet Tropics rivers led to an additional focus on stewardship of imidacloprid. This was addressed through groups involving growers and local advisors where the life cycle of canegrubs and historic sites of high pressure and known behaviour were discussed in detail to develop ideas for strategic application. In addition, growers were encouraged not to assume that crop symptoms such as stool tipping, sparse growth and drying leaves were canegrubs without first checking for pachymetra. Growers were trained to take soil tests for both pachymetra and nematodes and encouraged to use the SRA laboratory service. This work was strongly supported by Tully Sugar and MSF Sugar.

Working in concert with local extension staff and industry groups was a priority both in terms of efficiently and effectively achieving the project objectives and in ensuring the key messages of the project have legacy.

A formal partnership with Tully Sugarcane Productivity Services Limited (TCPSL) was in place to help service the Tully area. The TCPSL staff assisted in organising grower groups and events and in implementing and monitoring efficacy demonstrations.

Through funding arrangements with the DES, a formal partnership with local QDAF staff was put in place, with Jack Robertson, Allan Blair and Marcus Bulstrode supporting the project support through grower meetings and training, drone mapping, herbicide demonstration and calibration of herbicide rigs.

Other informal partnerships were formed over the life of the project with the following:

Tully

- Tully Sugar (Cofco)
- Tully Canegrowers
- GF Rural

Innisfail/Babinda

- Innisfail Canegrowers
- MSF Sugar (Michael Porta)
- Innisfail Babinda Cane Productivity Services
- GF Rural

Mulgrave

- MSF Sugar
- Cairns Region Canegrowers
- NQ Rural Supplies

Staff from these organisations routinely supported project activities, helped reach out to growers and helped to extend key messages. These organisations continue to use project materials and promote project messages.

Protecting our Chemicals for the Future used basic social sciences to develop project activities and in order to measure the effectiveness of the project.

Management changes made over the three years by growers in a control group who had no Project interaction were compared with growers involved in the Project. In addition to this, the Project drew on planning fundamentals from the Les Robinson's Enabling Change theory. The key principles that were incorporated into the annual running of the project include:

1. Desirability
2. Enabling context
3. Can do
4. Buzz
5. Invitation
6. Trial
7. Satisfaction
8. This should = Sustained adoption of change (as opposed to a one-off trial)

While not every grower involved in Protecting our Chemicals for the Future made change to the way they manage their farm, many did. Growers reported making changes to chemical management over a total of 22,836 hectares of sugarcane growing area. Changes focused on:

- Better selection of residual chemicals
- Reduction in use of residual chemicals
- Improved timing of residual chemical application to avoid the wet season
- Use of zonal application strategies for residual chemicals (banding and targeted application)
- Reduction in use of imidacloprid

It should be noted that many growers who attended meetings and workshops were already making sustainable and thoughtful decisions around chemical management. Some of these growers were able to make further improvements. However for some of these growers the Project provided evidence that they had made good decisions in switching to modern chemicals earlier, and in some cases these growers used this information to bring new growers into the program. For this reason they valued the information and activities and in many cases continued involvement over the three years.

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1. BACKGROUND

1.1. Project overview

In September 2016 Sugar Research Australia (SRA) initiated the Protecting our Chemicals for the Future through the Acceleration of Best Management Practices project in the Wet Tropics. The project set objectives to improve management practices around chemical use in sugarcane in the Tully, Innisfail/Babinda and Mulgrave milling areas by extending research findings through grower group work and field demonstrations. A broad range of research focusing on reducing losses of herbicides at the paddock scale was utilised as a basis for informing practices demonstrated by the project. This included:

- Developing an alternative herbicide management strategy to replace PSII herbicides in the Wet Tropics area: Emilie Fillols
- The Paddock to Reef Integrated Monitoring, Modelling and Reporting Program; Mackay Whitsunday Research Trials: Ken Rohde *et al.*
- Reducing the risk of herbicide runoff in sugarcane farming through controlled traffic and early-banded application; Bronwyn Masters *et al.*
- Precision application (band spray) of herbicides on sugarcane in the Burdekin region; Mark Silburn *et al.*

The combined research highlights a number of practices and decisions sugarcane growers in the Wet Tropics of Queensland can utilise to reduce losses of herbicide from the paddock. The Queensland Government's End of Catchment Loads Monitoring Program annually shows that herbicides continue to be picked up in the rivers of the Wet Tropics sugarcane catchments, with annual exceedances for products such as diuron and atrazine. Protecting our Chemicals for the Future set out to increase the uptake of these identified practices among the Wet Tropics growers, and at the same time to increase awareness of the practices among the sugarcane extension community and local resellers.

One of the primary methods for demonstrating the benefits of these farm management practices was through the use of rainfall simulation. A Technical Oversite Group was coordinated to inform the methods and chemicals for demonstration. This group included:

- Dr Aaron Davis; James Cook University, TropWater
- Emilie Fillols; Sugar Research Australia
- Nicholas Matthews; Nufarm (later replaced by Mark Rantucci)
- Darren Westerhuis; Bayer (later replaced by Tony Fitzgerald)
- Chris Johnson; Department of Environment and Science
- Peter Samson; Sugar Research Australia, Research Funding Unit
- Megan Bickle; Department of Environment and Science (replaced by Kim Kurtz)

This group met at the beginning of the project and set out the standard for the rainfall simulation method, designed the initial demonstrations and then met annually to review findings, project progress and inform the following year of work.

End of Catchment Loads monitoring data also shows an increasing trend for exceedances of the pesticide imidacloprid, used to control the canegrub. The project sought to incorporate strategies for improving stewardship of imidacloprid, a strategy that has gained support locally.

Protecting our Chemicals for the Future also includes an element of social science, acknowledging that bombarding the target audience with more and more information is not necessarily the best conduit to change. A social survey was drawn up for the initial groups of growers engaged as collaborators in the project, with a number of non-engaged growers also identified. This strategy for understanding attitudes, with an emphasis on identifying barriers to change, was based on work by the Canadian-based Doug McKenzie Mohr's Community Based Social Marketing (CBSM). As the project progressed, the project leader also drew on the work of John Pickering, who has been working on the Cane Changer program with CANEGROWERS organisation and Sydney-based behaviour change specialist Les Robinson.

Important messages from the local behaviour change specialists are based around positivity and creating a sense in the sugarcane industry as being powerful environmental stewards. Talking to the collaborating growers themselves, they regularly comment on the importance of telling the good news stories, not to ourselves but to the wider community. All theories promote understanding barriers and/or desirability of the change to the audience targeted at the outset of a program.

2. PROJECT OBJECTIVES

2.1. Project targets

The main objective for Protecting our Chemicals for the Future was to increase the uptake of best management practices. The process of the project enabled the development of key practices and related messages to achieve this. For example, rainfall simulation work highlighted chemicals that posed a far reduced risk of loss to the environment than others, as well as the impact of improved timing of application of chemicals. Better product selection, improved timing and application methods such as banding and zonal/targeted application were the main practices promoted. A target of at least 20% of grower participants taking up practices in year one was set, followed by 40% in subsequent years. The 20 % target was met and exceeded in year one, and subsequent years came very close with at 35% of growers reporting making a change.

Activity targets set for the project are summarised below, activity targets were met for this project:

Table 1: Activity Targets set for Protecting our Chemicals for the Future.

District	Grower group	Demonstrations	Band spray equipment use	Improved imidacloprid management activity
Mulgrave	3 groups of 8 per year	3 + 1 rainfall sim per year	One activity per year	2 activities per year
Innisfail Babinda	3 groups of 8	3 + 1 rainfall sim per year	One activity per year	2 activities per year
Tully	3 groups of 8	3 + 1 rainfall sim per year	One activity per year	2 activities per year

Paddock to Reef practice change data supplied annually.

3. OUTPUTS, OUTCOMES AND IMPLICATIONS

3.1. Outputs

Protecting our Chemicals for the Future has assisted over 97 growers make changes to chemical management over a total of 22,836 hectares of sugarcane growing area in the northern Wet Tropics. These changes reflect an improved understanding by the growers, advisors and resellers of factors that increase risk of chemical runoff from farm and those chemicals that are more likely to result in an exceedance of ecological thresholds. In addition to achieving practice change, Protecting our Chemicals for Future has produced the following outputs:

- Resources to help explain chemical properties and risk
- Rainfall simulation data sets replicated across three districts that support the work of SRA Agronomist Emilie Fillols
- Supported ACS Laboratory to purchase standards and develop testing procedures for metabolites of the chemical flumioxazin (first test in Australia to our knowledge)
- Work with Canegrowers Innisfail to develop a new weed management planning process that has been adopted by Smartcane BMP
- Contributed to the development of the Pesticide Decision Support Tool, completed in 2019 by Dr Michael Warne and due for release by DES in mid-2020
- Developed skills in rainfall simulation, herbicide/weed efficacy demonstration among project staff from SRA and TCPSL
- Developed short field-based workshops to teach growers how to conduct their own pachymetra tests
- Grower based demonstration and testing of new herbicides Amicarbazone and flumioxazin

3.2 Outcomes and implications

The combination of field-based demonstrations with the rainfall simulation activity was effective in highlighting chemical risks, safer chemical options and jointly investigating the effectiveness of new products and practices. The simulation activity generates reliable local data in a short time. The field demonstrations answer grower questions about efficacy, economics and impact on cane yield. Growers who take part in field activities become spokespeople and advocates. The field demonstrations are also a way to help growers address weed issues and form more meaningful relationships than can be achieved via group work.

Knowing that imidacloprid was the second most detected chemical in Wet Tropics waterways, it would have been beneficial to have had a strategy to address this issue early on. The work in this area was begun in response to local requests from both industry and growers concerned about the issue and seeing the opportunity to try and make a difference. The workshops were productive and provided an avenue for continuing discussion around solutions among local industry and key growers, which is a very important place to start. The new work of SRA Adoption and QDAF to run an imidacloprid stewardship project across industry with the support of productivity boards is welcome and required.

The work of Protecting our Chemicals for the Future continues and evolves through the SRA project Cane to Creek 2.0, funded in 2019 by The Great Barrier Reef Foundation. Stream-based wet season monitoring through this project has found continued presence of diuron in all sites. This reflects the data of the ongoing DES GBR End of Catchment Monitoring Program. Discussion with growers has revealed the continuing practice of applying the chemical Barrage (diuron and hexazinone) at a spike rate of 900g/ha late in the season. This practice was targeted by the project and, while many

growers involved have reported ceasing this practice, more is needed to be done. It is hoped that this very local monitoring of streams combined with the data sets produced through Protecting our Chemicals may provide enough evidence required to promote further change. There is more work to be done on understanding the value of spiking, including how effective it really is and whether newer, low rate chemicals may play the same role with a reduced impact. Some of this work is being done through Cane to Creek 2.0, however research into this area would be beneficial.

The value of ongoing interaction with growers cannot be overestimated. At the outset this project intended to work with formal arrangements in place with local productivity services. This was only achieved in Tully, with other organisations unable to make the time commitment. Informal relationships and support continued, however the project may well have achieved greater impact, particularly in terms of practice change, had there been a local contact with a real time commitment in each district. Adequate staffing of projects could allow for greater depth of detail and interaction around local demonstration sites and timely responses to grower questions and needs.

4. INDUSTRY COMMUNICATION AND ENGAGEMENT

4.1. Industry engagement during the project

This project is all about industry engagement, which has been outlined in other sections of the report. Of interest, and importance are the key messages developed and promoted throughout the three years.

Key messages

Over the three years of the project two very simple, but broad messages or principles have been promoted regularly. Grower collaborators are invited to explore how they might apply these across their farm/s and across the year.

Herbicide use

1. Less on = Less off.

We relate this to rate of chemical required based on product selection, application method (banded or zonal application within a block), varying management and application across a farm based on weed pressure.

2. Timing really matters.

We relate this to the 21 days versus 3 days rainfall simulation work and highlight that we can't predict every rainfall event, but we do know that the wet season is most likely to arrive in December.

These two principles combined with some of the chemical properties' datasets provide the basis for discussion within the group with the aim of growers bringing forward their own strategies to share with others. We have stuck with two principles as this is easy to remember, and growers can apply the principles themselves.

These principles are now used by local extension and advisory groups: WTSIP, Smartcane BMP, MSF and Canegrowers organisation. The work was presented to the WTSIP Cane Technical Advisory Group with support for wide-spread use of these as guiding principles. This also resulted in an invitation to share the work in the Tablelands.

Canegrubs / imidacloprid

This area of work has been evolving over the course of the project and has been responsive to what has been learnt from growers and local extension providers about canegrub management. Again, the messaging has been kept simple.

Treat only where you need to.

We accept very few growers are going to check for canegrubs, although we encourage them to look. Growers are encouraged to consider historical grub pressure, where there are known grub-prone areas on their farm. They are advised to refrain from treating elsewhere and encouraged to talk to their neighbours who do not attend meetings for a community treatment approach.

Apply the product according to label.

Work in the Herbert, pre-dating Protecting our Chemicals for the Future, identified poor application of imidacloprid was resulting in poor closure of the application slot. It was thought that this was likely to cause high losses to the environment as rainfall runoff would move through the opening in the soil and taking the product with it. The project leader worked with Nufarm and Bayer during the Smartcane BMP training program, to showcase what is required for correct application, with many growers identifying that their machinery was not set up correctly. This work was not done in the Wet Tropics, and so was incorporated into Protecting our Chemicals for the Future. Machinery was made available at field days to explain how to achieve correct application and Bayer and Nufarm representatives were available to help growers with their machinery. The DAF Stool Zippa was included in later field days as an option for improving closure of the slot. In the final year a demonstration was completed with TSL comparing use of the Stool Zippa to improve closure to standard application. The demonstration resulted in similar losses across treatments with the exception of one replicate (no Zippa) where it was identified that correct depth of application had not been achieved, particularly early in the cane row. Work is continuing with TSL to promote correct application, including depth (10cm) and closure. This work is being done in conjunction with SRA Weeds Agronomist Emilie Fillols who has identified the importance of depth of placement in her recent research. This work has also highlighted the importance of applying to blocks with a history of canegrub pressure, as these blocks typically have lighter soils with lower clay content, making correct application more achievable.

Is it pachymetra or is it canegrubs?

Work by Greg Shannon, agronomist with TSL, highlighted that growers were treating for canegrubs where they actually had high pachymetra spore counts. It was identified that resellers and growers were uninformed about the signs of pachymetra and the subtle differences to look for, compared to canegrubs. Tully Sugar Limited (TSL) and SRA ran a session on identifying pachymetra and how to take soil tests for extension staff and local resellers. Greg undertakes widespread testing for pachymetra in the area, and through the program distribution maps have been shared and awareness of the issue has been raised. In the final years of the project, this message has been spread to the Innisfail/Babinda and the Mulgrave areas. During the 2019 Mulgrave Water Quality Field Day, a small group session on how to take soil samples for pachymetra and nematodes was run for growers and advisors and in the final month of the program, a session attracting around 20 growers and advisors was run in the Innisfail area following a request from growers who were unable to make it to the Water Quality Field Day. During these sessions, growers were taught to take their own soil tests for pachymetra and nematodes and how to look for signs of both canegrubs and pachymetra in their cane. This has resulted in an increase in growers taking samples and sending

them to the SRA laboratory for testing. The solution to pachymetra is to plant a resistant variety. During field days and the Innisfail event growers were provided with a list of varieties with various resistance ratings for each variety (including resistance to pachymetra). If growers can identify the problem and understand the solution, they can reduce the amount of imidacloprid applied for 'suspected grubs.'

4.2. Connecting with other extension providers

Protecting our Chemicals for the Future has worked with other extension providers across the Wet Tropics, in an effort to reach out to more growers and to create a legacy where the messages above are shared more widely and beyond the life of the project. An anonymous survey was sent out to extension providers and resellers in the districts, to see how effective the project has been. This method has its pros and cons – it is easy not to do the survey without an individual contacting you directly, but it was felt those who did do the survey would answer more honestly if they are anonymous. This was important to us as we are hoping to utilise learnings from this survey in on-going work. The survey was not sent to extension providers beyond the area the project was ran, however resources have been made available to Farmacist to help inform the Sandy Creek work and Project Blue Water and also to SRA colleagues running the Myrtle Creek project.

The results were interesting (displayed in Figure 1 through to Figure 8), showing the project has been valued and those attending have been able to make use of the information. It seems that the extension officers valued the information for themselves and for the growers they work with. There was a mix of 'New knowledge for me' and 'Brush up on my skills' responses for the herbicide and canegrub work, reflecting the mix of extension providers working in the districts. It was good to see that all activities resulted in some providers finding 'New ideas for supporting my own work' and 'Access to useful resources.' In regard to this, providers from CANEGROWERS, DAF and WTSIP have all approached SRA for access to information and resources from Protecting our Chemicals for the Future and utilised information in activities such as staff training.

It was interesting to see that the key message 'Timing Really Matters' has resulted in greater uptake from extension officers than 'Less on = Less off'. This seems to be the opposite to growers, who are happy to learn that some chemicals will runoff less than others (a simple change) and view the timing principle as a little more difficult to apply. We will continue to work with extension providers on both principles, as they tend to be self-supporting (if you are planning on using a residual herbicide close to the wet season, choose one that likely to lose less to the environment). However, it is heartening to see that the extension community is taking up the messages and is likely to continue to champion the timing message, even though it is seen as challenging.

A learning from this survey has been the value of attending broader industry events, including extension provider only workshops, to provide project updates. These events allow greater reach and entice people to attend future project focused events.

Results are summarised in the following graphs:

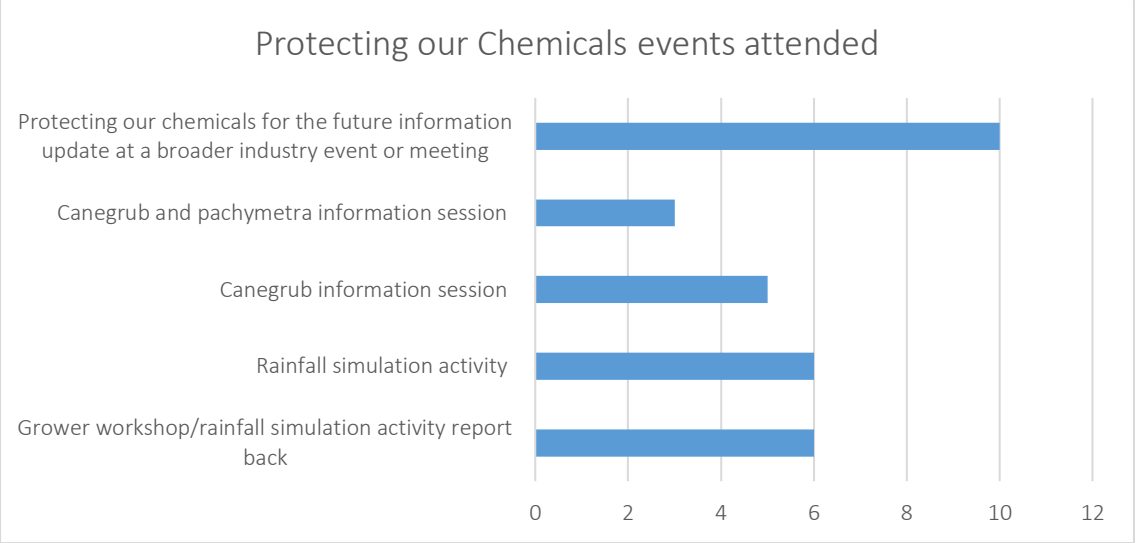


Figure 1: Wet Tropics extension staff attendance at Protecting our Chemicals for the future events

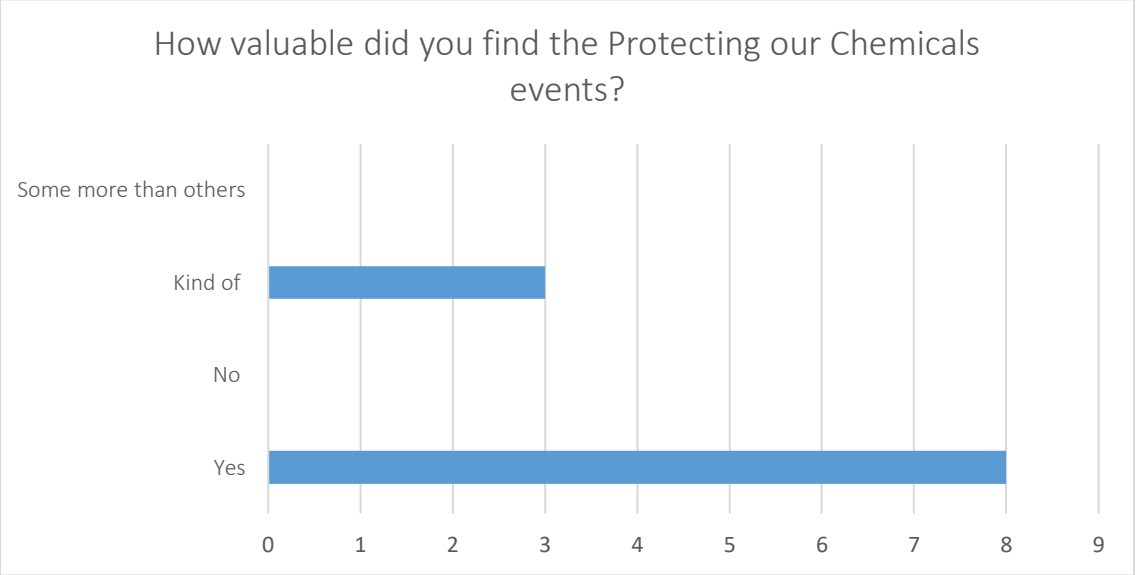


Figure 2: Wet Tropics extension staff rate the value of Protecting our Chemicals for the Future events.

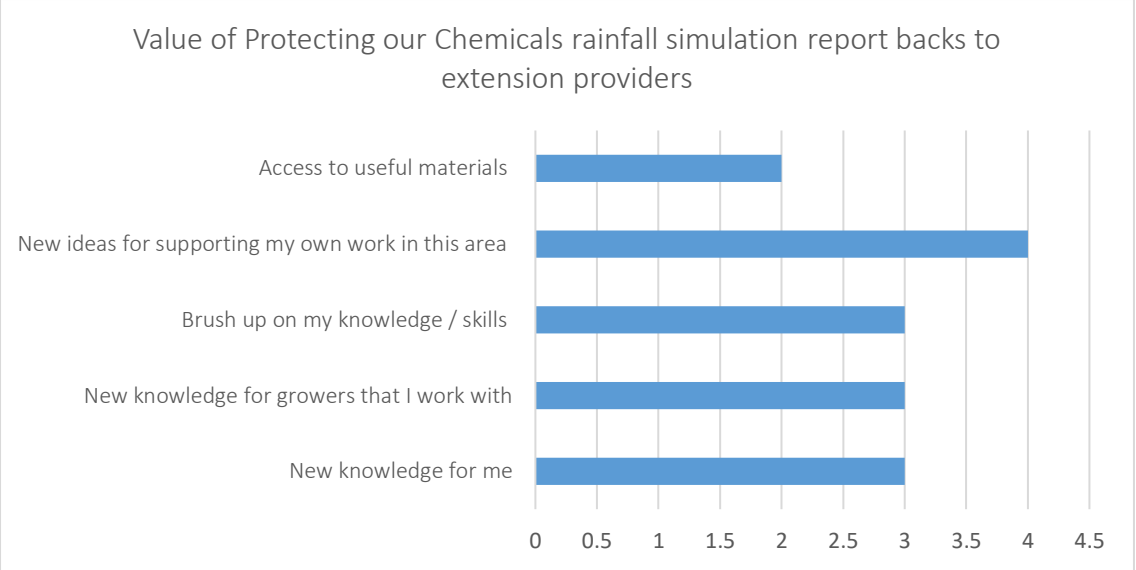


Figure 3 Wet Tropics extension staff describe what value they obtained from rainfall simulation report back events

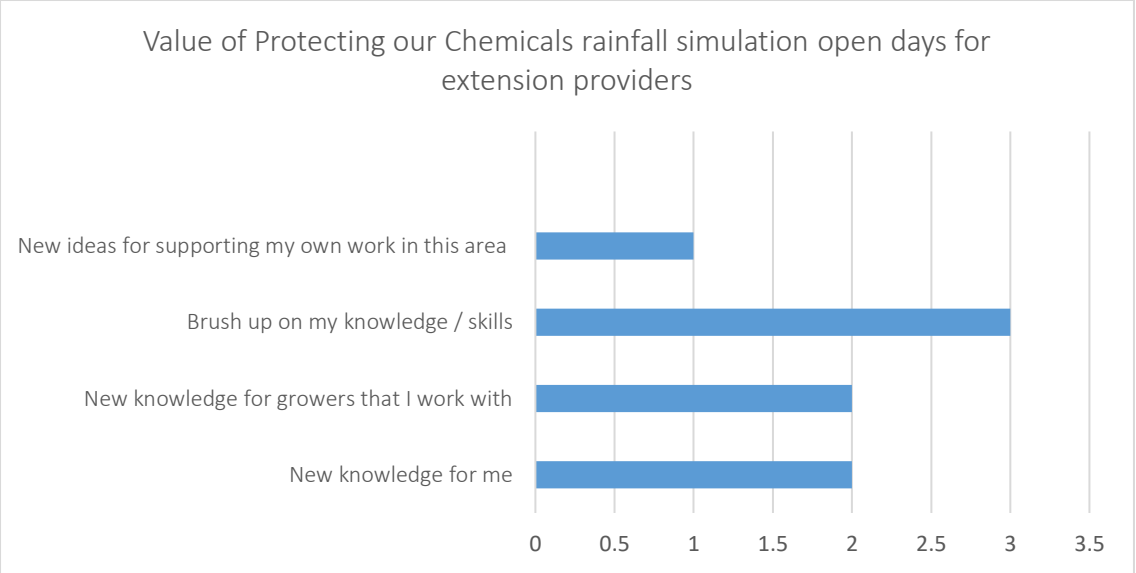


Figure 4: Wet Tropics extension staff describe what value they obtained from rainfall simulation open days

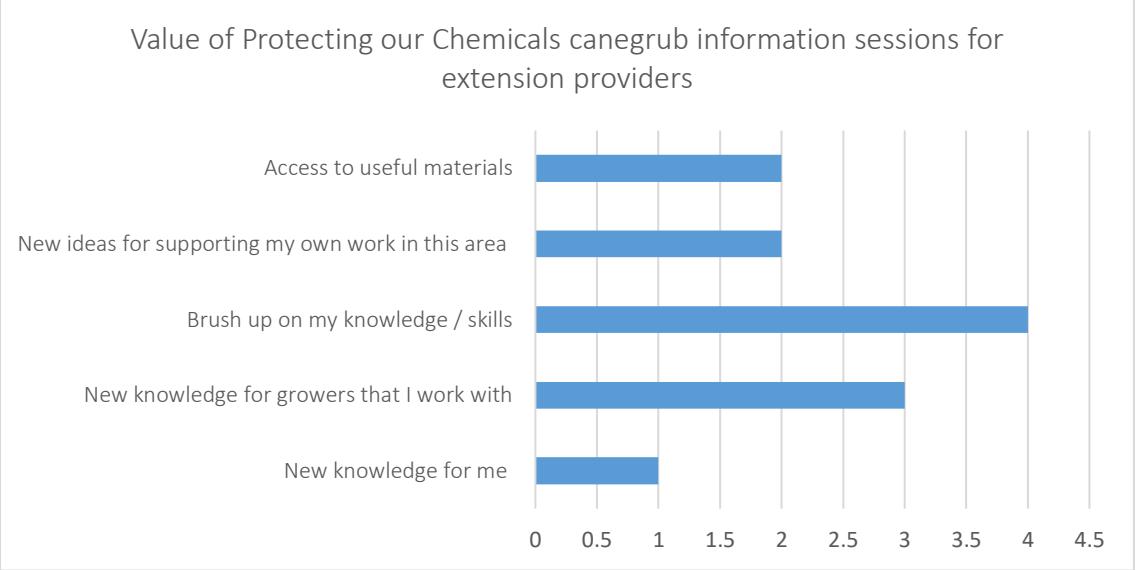


Figure 5: Wet Tropics extension staff describe what value they obtained from canegrub information sessions

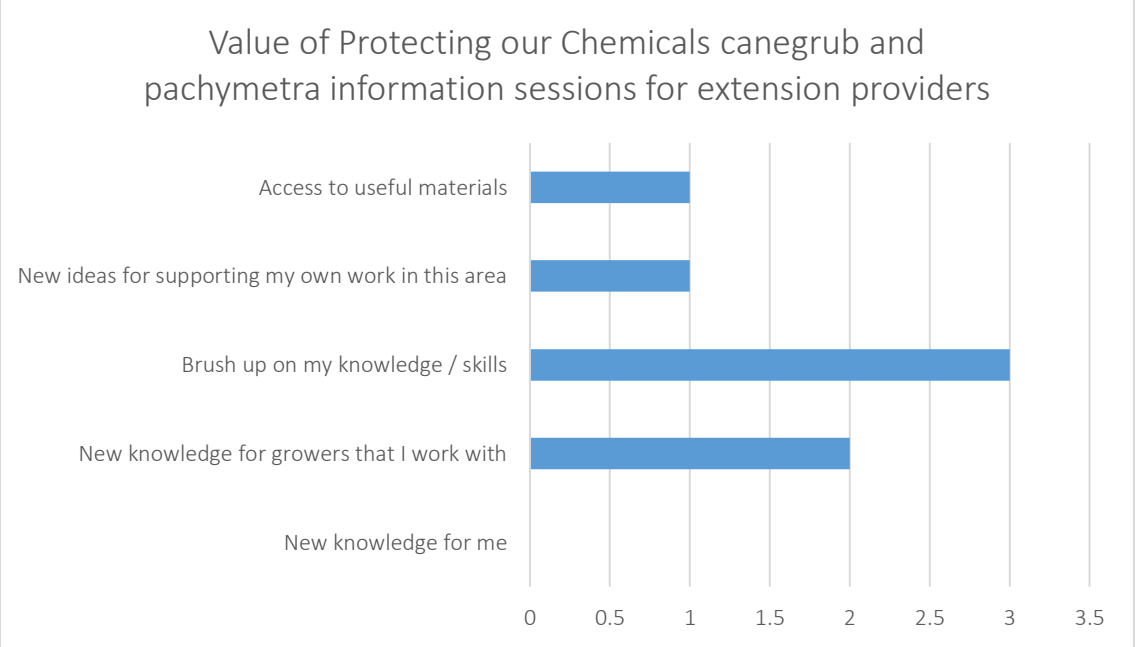


Figure 6: Wet Tropics extension staff describe what value they obtained from canegrub and pachymetra information sessions

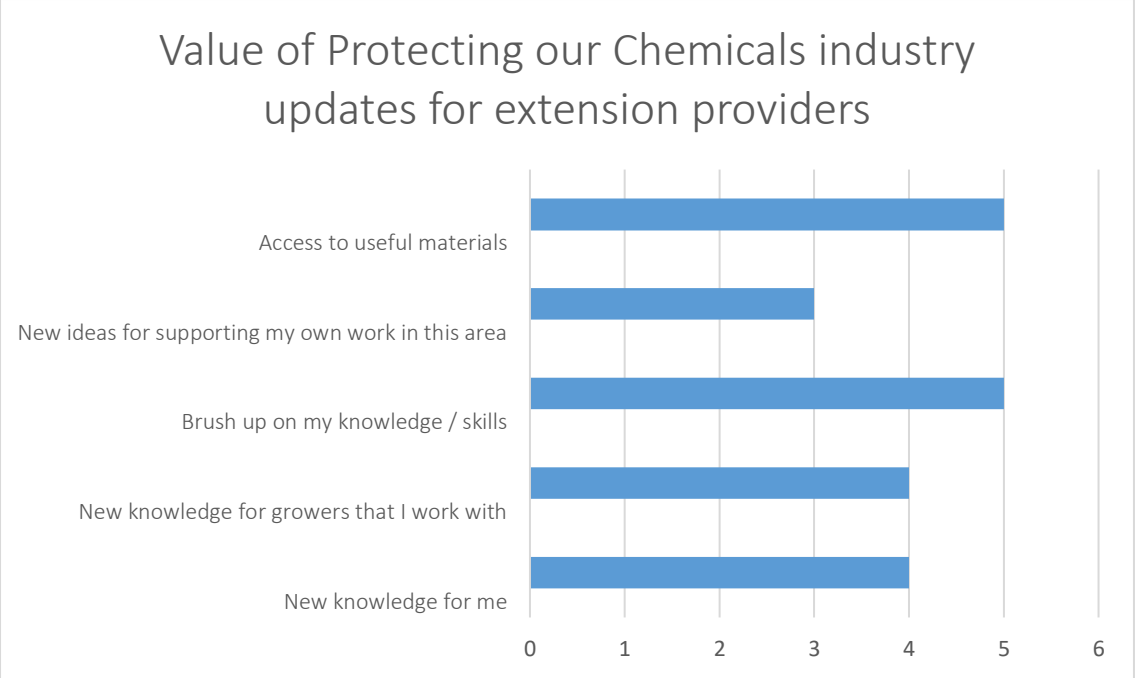


Figure 7: Wet Tropics extension staff describe what value they obtained from project updates at industry events

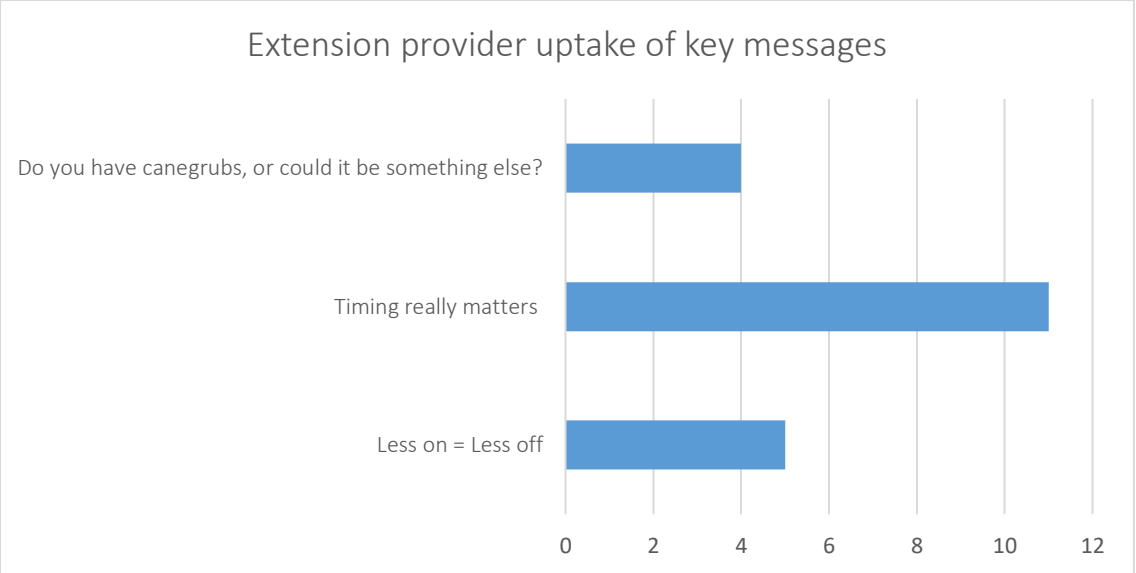


Figure 8: Wet Tropics extension staff indicate which key Protecting our Chemicals for the Future messages they are using themselves

5. METHODOLOGY

5.1. Use of behavioural change theory within project

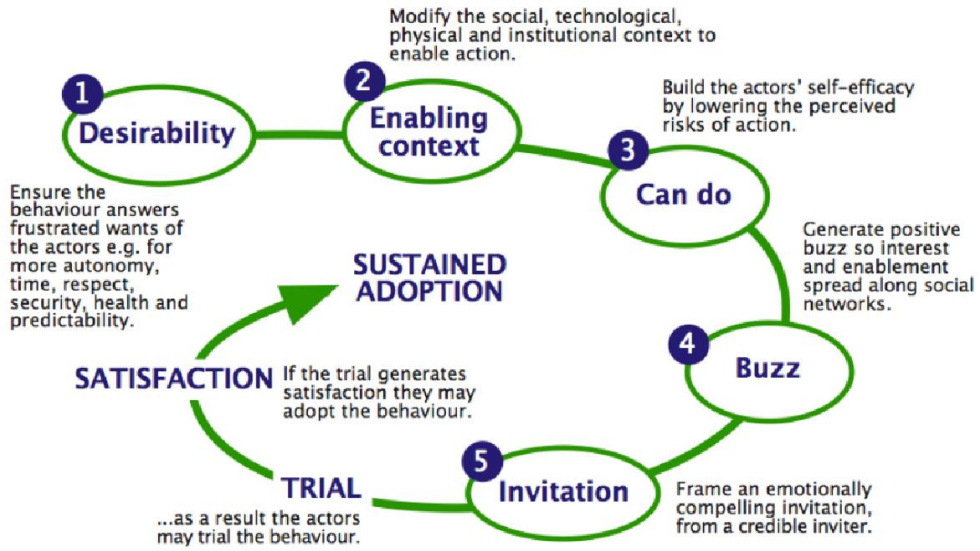


Figure 9: Five Conditions for Change; Les Robinson; Enabling Change

Les Robinson's Enabling Change approach, illustrated above (Figure 9), is used widely within local government and health related programs, particularly those associated with sustainability, health and wellbeing. It draws on a number of theories and provides five conditions required for individuals or communities to make a change. Protecting our Chemicals for the Future has used this as a guide to what might work within the project. Below we detail how these five conditions have been created through Protecting our Chemicals for the Future.

DESIRABILITY

We all want to live happy, healthy lives, to dream and exercise our autonomy, to offer our children a future and to be perceived by others in a positive way. Beyond this… desire is often driven by frustration. – Les Robinson, Changeology, 2013

For some growers, the prospect of leaving their land and water in a better state for their children is in fact the motivating force to get involved with programs like Protecting our Chemicals for the Future. For others, they believe that that being involved in such programs impacts the way others perceive them, in a positive way. These attributes are enough for many to get involved and for some to make a change based on the principles promoted.

Others are drawn to the program due to its name, "Protecting our Chemicals for the Future" – this speaks to the desire to exercise autonomy in decision making. The two simple principles also address adults' desire to make their own decisions, and to be trusted to do that wisely.

There are a number of growers who came to the program through frustration with weed control. Many of the growers, particularly in the Innisfail area, have joined the project because they are having trouble with vine control. The ability to take part in demonstrations on farm or share the results of those demonstrations has been the attraction.

ENABLING CONTEXT

Practice change for water quality improvement is often perceived by growers as being focussed on what you can't do. It is often seen as something that is going to cost money, require new equipment, is complicated and risks productivity. Protecting our Chemicals for the Future seeks to address this by showing growers, on their own farms, how we can measure water quality improvement from simple changes and highlighting that there are a range of things that can be done that can make a big difference for limited effort and cost. By bringing growers together in small groups, there is often someone within the group who has already made a change and can talk to others about how they have gone about it, usually in a positive way. Having local extension staff as well as growers in the room also highlights that there is plenty of support available.

CAN DO

Running on farm demonstrations has had two outcomes that relate to improving 'can do' within the grower population and the local extension group.

1. Growers who have had trouble with weed control or have an issue to solve, are able to work with project staff and gain confidence in new approaches. Almost every demonstration has resulted in a practice change for the grower involved.
2. Where demonstrations are targeted at promoting an identified question or solution raised by the local group, it has been found that growers beyond that group take an interest (it has relevance beyond the group). These demonstrations are also of interest to local advisors and resellers who become additional spokespeople for the work, and supporters for growers looking to make change.
3. Information from the rainfall simulation work is discussed in small groups, ensuring understanding of the information and time to generate ideas from the group around how the learnings can be applied.

BUZZ

Each year in Tully and the Mulgrave area a large Water Quality Field Day event has been run. These events are designed to promote the project to a wider audience and attract additional members. These Field Days are also an opportunity to promote the projects' work and the key messages, and for investors to get value for money. Each event has attracted upwards of 50 attendees and has resulted in attracting grower collaborators for demonstrations and new group members.

Grower collaborators have often mentioned that they would like the good work they do acknowledged within the community. We have made an effort to get some press in attendance at Field Days, resulting in interviews with ABC radio and articles in the Cairns Post. We would have liked to achieve more in this area, as this also addresses the aspect of desiring to be perceived in a positive way – which is expressed clearly by grower collaborators in conversation.

Inviting growers to attend rainfall simulation activities was thought to be a way to do the same, and in Tully the initial event certainly did create a buzz and get growers talking. This work is being done for the interest of growers, and we continue to let growers and extension staff know where we will be and at what time.

INVITATION

In the initial year of the project, with a smaller target number of growers, we called growers and met with growers on farm to explain the project and get them involved. With the chief investigator being

new to the area, it helped to have a local productivity services officer involved in the process. In Tully, early recruitment was particularly effective as it was done with TCPSL who have long term relationships with their growers. At this point the project had no outputs to present to the growers approached, we were able to explain the project's work and talk to these growers about the issues they are facing and ask, 'how can we help with **your** problem?'.

As the project has grown, we have attracted new members through field days, attending local productivity services shed meetings and organised events to share the results of the project with a wider audience. This is an effective method as we are there in person, growers can ask us questions and they are aware of the work we are doing. It is not unusual for growers to come forward and ask to host a demonstration or rainfall simulation after a presentation at one of these events.

TRIAL

While we host demonstrations with a number of growers, as the project has progressed others have begun to trial things on farm. Some will trial aspects of demonstrations we have conducted, while others will take the principles promoted and apply them on farm. This step is important, it doesn't need to be more than one block, but the process gives the grower confidence to take it further.

SATISFACTION

The growers must be satisfied with the results of their own trial of an idea, product or approach before they will take the change further. Keeping the principles simple and transferable provides scope for growers to find changes that are likely to satisfy them in terms of economic cost and equipment requirements. There have been a couple of examples where demonstrations have not gone to plan; for example, an October rainfall event that caused soil erosion in a plant cane demonstrations on a hill slope in / near Innisfail meant that the product promoted (pendimethalin) was washed away with the soil and did not perform as well as hoped. Despite the product not underperforming compared to his typical treatment, there was no benefit that the grower saw with the change.

Learnings from Cane Changer

John Pickering's Cane Changer project has an agreement to share information with SRA's Cane to Creek project and as such is also able to inform Protecting our Chemicals for the Future.

The project has addressed a number of aspects of the Cane Changer findings:

- Promoting a positive message, rather than focusing on the negative
    - We focus on what can be done to make improvements rather labouring on the negative data in our results (i.e. focus on the small amount of loss generated by imazapic and isoxaflutole rather than the high losses from atrazine, and when talking about products with high losses focus on the role of timing).
- Keeping messaging very simple, not confusing with layers of information
    - Two key messages that grower collaborators can adapt.
- Involving family
    - Growers feel that their children and grandchildren are learning at school that farming on the GBR is a crime, so we spoke at a local school about the project and have received interest from other schools.

- Cane Changer has found change is more likely if the partner of the farmer is involved, so we hosted a group of wives of growers at the SRA Meringa station and spoke to them about water quality and organised a tour of the SRA sugarcane breeding program led by Dr Felicity Atkin. The women were offered additional training and support to bring them up to speed in nutrient and herbicide management and as a result a couple attended a short SIX EASY STEPS course through SRA's Cane to Creek program with their partner. Canegrower organisation Chair Steve Calcagno attended the session and highlighted chemical selection as an important and simple way of making a difference to runoff losses. He urged the women to support their partners to make careful decisions and highlight products such as isoxaflutole as better options than the older chemicals. Following this, Stephen assisted in promoting attendance at a Protecting our Chemicals grower report back session held in an area local to many of the women, with many of their partners attending.
- Growers with children bring them out to do weed surveys in efficacy trials and have them help with collection of samples during wet weather.

Promoting a positive image of the local industry:

- As above, we try to get media (non-cane focused) involved and have spoken at the Mulgrave Landcare group to present a different side of water quality and sugarcane. The messages promoted are that cane farmers are interested in learning more about the relationship between their farm and local waterways and we highlight some strategies being taken up to change the situation.

5.2 Activities with project collaborators

Protecting our Chemicals for the Future has a goal of increasing the uptake of best management practices relating to chemical use on Wet Tropics sugarcane farms through engagement of growers in science that helps us understand risk of chemical loss to the waterways. Strategies to achieve this include rainfall simulation activities, grower group meetings to discuss and share information, assistance in the correct set-up of band spray equipment and use of social science to improve understanding of grower attitudes to water quality and management practices.

As the project has progressed, some adjustments were made based on feedback from participating growers, including block scale demonstrations of modern chemicals, improved timing to avoid application close to the wet season and application methods such as zonal management and band spraying as well as group work to encourage better management of imidacloprid.

Work with resellers was also added, partly in response to difficulty in engaging with growers in the Innisfail area and recognising the important role resellers play in the decision-making process.

Full details of project activities are given in Appendix: 11.1 Project Delivery and Methods.

6. RESULTS AND DISCUSSION

6.1. Practice change

Changes made with support of the project are captured in Table 2, Table 3 and Table 4 as number of growers and impacted hectares.

Table 2: Grower Collaborator Practice change numbers 2016-17

District	Change herbicide/ alternative residual	Change herbicide replace residual with knockdown	Change timing	Other practice change *	Combined activities Ha x change	Considering change**	Value information
Mulgrave	3		1	2		2	
hectares	760		118	418	518	288	1304
Innisfail/ Babinda	3		2	1		2	
hectares	1062		377	241		672	1879
Tully	2	2				5	
hectares	1000	397			2945	1521	2945
Total growers	**8**	**2**	**3**	**3**	**16**	**9**	**All growers**
Total ha	**2822**	**397**	**495**	**659**	**4373**	**2481.6**	**6128**

**Other practice change typically refers to improve practices around imidacloprid management, timing of application, product change or reduced residual application through planning and greater use of knockdowns. Also includes reduced overall chemical application through targeting blocks.*

*** Considering change is mainly grower collaborators interested in new chemistry or reducing use of residuals, but believe they need to reduce weed pressure to do so.*

Table 3: Grower Collaborator Practice change numbers 2017-18

District	Change herbicide/ alternative residual	Improve timing	Reduction in overall residuals	Other*	Consider change**	Value info/total hectares
Mulgrave	6 growers	3 growers/	5 growers	6 growers	9 growers	
hectares	1540	840	424	1700	1592	4716
Innisfail/ Babinda	2 growers		1 grower	1 grower	8 growers	
hectares	538		182	353	1899	2596
Tully	3 growers	3 growers	3 growers	5 growers	6 growers	
hectares	1084	700	376	981	2601	9204
Total Growers	**11**	**6**	**9**	**12**	**23**	**All growers**
Total ha	**3162**	**1540**	**982**	**3034**	**6092**	**All growers**

**Other: Majority of other = canegrub/imidacloprid management improvement including starting to monitor for presence, treat one year out of every two and use of soil-specific treatments (suSCon in soils/areas considered high risk and no treatment elsewhere), one banding of residuals and one increased awareness of the importance of avoiding older residual herbicides due to a greater understanding of why this chemistry is causing issues, one reconsidering spike rates in late spray.*

***Considering change is mainly grower collaborators interested in new chemistry, this is a mix of grower collaborators who have not made a shift from the older chemistry and grower collaborators who have made the shift but are now interested in trialling products that have come on the market last year and this year and can see potential value (particular interest in being able to move completely away from atrazine), also site-specific application and use of hooded sprayer set up through project last year.*

Table 4: Growers Collaborator Practice change numbers 2018-19

	Timing	chemical selection	Reduction in chemical use	application method	improve imidacloprid	Considering change 2019*
Mulgrave	2	6	2	3	2	4
hectares	260	655	178	635	195	487
Innisfail/ Babinda	1	5	1	1	1	3
hectares	50	1102	55	60	185	1072
Tully	2	5		1	2	3
hectares	544	953		500	1210	900
Total Growers	5	16	3	5	5	10
Total hectares	854	2710	233	1195	380	2459

**Growers considering change will be engaged through the Cane to Creek 2.0 project or directly by DAF extension officer Jack Robertson. Those considering change in Mulgrave will be engaged through working directly with a spray contractor who has agreed to work with Jack.*

What do these changes mean?

Reductions in active ingredient applied have been modelled for some common scenarios captured in the data sets above and are set out in Table 5 to Table 12. It should be noted that herbicide strategies recommended by this project focus on targeted product selection to address weed pressure and type per block (or even within block), with a preference for modern chemicals and use of knock downs only where weed pressure is low. The scenarios below are plausible generalisations based on the information we have and indicate a potential large decrease in the amount of active ingredient applied due to the effort of Protecting our Chemicals for the Future.

Scenarios depict common changes discussed with growers during annual surveys:

- changing to newer/lower rate chemicals,
- applying residual herbicides early rather than late (late application = close to the wet season),
- utilising modern, photostable chemicals for better control when applying early,
- removing residual herbicides from late application,
- changing from traditional high rate, high loss products such as atrazine for vine control to modern photostable chemicals that result in lower losses.
- Reduction in annual application of imidacloprid modelled as halving of the liquid product applied.

Table 5: Reduction in grams active ingredient (gai) applied, achieved by changing to modern chemicals, two examples

8694 ha change from Barrage (diuron and hexazinone) + atrazine mix to imazapic			
Measure: Swap diuron + hexazinone and atrazine residual control for imazapic residual control			
Active	grams active /ha	Ha applied	Total gai applied
Hexazinone	118.8	8694	1032847
Diuron	421.2	8694	3661913
Atrazine	1980	8694	17214120
		Total active applied in KG	**21908.88**
Active	Grams active /ha	Ha applied	Total gai applied
Imazapic	96	8694	834624
		Total active applied in KG	**834.62**
		Total reduction in applied in KG	**21074.25**
8694 ha change from Barrage (diuron and hexazinone) to isoxaflutole			
Measure: Swap Barrage (diuron + hexazinone) control for isoxaflutole residual control			
Active	Grams active /ha	Ha applied	Total gai applied
Hexazinone	118.8	8694	1032847.2
Diuron	421.2	8694	3661912.8
		Total active applied kg/ha	**4694.76**
Active	Grams active /ha	Ha applied	Total gai applied
Isoxaflutole	112.5	8694	978075
		Total active applied in KG	**978.10**
		Total reduction in active applied in KG	**3716.70**

8694ha calculated as hectares reported as changing to modern residuals

Table 6: Reduction in grams active ingredient (gai) applied, achieved by reducing area sprayed with older/high rate vine control products and spiking with old PSIIs.

Remove residual herbicide from out of hand spray on 1612 hectares: Metribuzin applied with common knockdowns			
Measure: Metribuzin applied to 100% of farm at close-in vs knockdown-only applied to 50% of farm			
Active	Grams active /ha	Ha	Total gai applied
Metribuzin	1500	1612	2418000
2,4D	1260	1612	2031120
Fluroxypyr	333	1612	536796
		Total active applied in KG	**4985.916**
Active	Grams active /ha	Ha	Total gai applied
metribuzin	1500	806	1209000
2,4D	1260	1612	2031120
Fluroxypyr	333	1612	536796
		Total active applied in KG	**3776.92**
		Total reduction in active applied in KG	**1209**
Measure: Metribuzin applied to 100% of farm at close-in vs knockdown-only applied to all farm			
Active	Grams active /ha	Ha	Total gai applied
Metribuzin	1500	1612	2418000
2,4D	1260	1612	2031120
Fluroxypyr	333	1612	536796
		Total active applied in KG	**4985.92**
Active	Grams active /ha	Ha	Total gai applied
2,4D	1260	1612	2031120
Fluroxypyr	333	1612	536796
		Total active applied in KG	**3776.92**
		Total reduction in active applied in KG	**24184**

1612ha calculated as hectares reported as reducing overall residual herbicide use

Table 7: Reduction in grams active ingredient (gai) applied, achieved by reducing and ceasing spiking with older residual herbicides

Reduce pre-emergent spikes from out of hand spray on 1612 hectares			
Measure: Barrage and Atrazine spikes applied 50 of farm rather than entire farm with common knockdowns at closein			
Active	Grams active /ha	Ha	Total gai applied
Diuron	421.2	1612	678974.4
Hexazinone	118.8	1612	191505.6
Atrazine	450	1612	725400
2,4-D	1260	1612	2031120
Fluroxypyr	333	1612	536796
		Total active applied in KG	**4163.80**
Active	Grams active /ha	Ha	Total gai applied
Diuron	421.2	806	339487.2
Hexazinone	118.8	806	95752.8
Atrazine	450	806	362700
2,4-D	1260	1612	2031120
Fluroxypyr	333	1612	536796
		Total active applied in KG	**3365.86**
		Total reduction in active applied in KG	**797.94KG**
Remove pre-emergent spikes from out of hand spray on 1612 hectares			
Measure: Cease late season application of Barrage (diuron and hexazinone) and Atrazine spikes and manage with knockdowns only			
Active	Grams active /ha	Ha	Total gai applied
Diuron	421.2	1612	678974.4
Hexazinone	118.8	1612	191505.6
Atrazine	450	1612	725400
2,4-D	1260	1612	2031120
Fluroxypyr	333	1612	536796
		Total active applied in KG	**4163.80**
Active	Grams active /ha	Ha	Total gai applied
2,4-D	1260	1612	2031120
Fluroxypyr	333	1612	536796
		Total active applied in KG	**2567.92**
		Total reduction in active applied in KG	**1595.90KG**

1612ha calculated as hectares reported as reducing overall residual herbicide use

Table 8: Reduction in grams active ingredient (gai) applied, achieved by increasing area under band spray management of residual herbicides

Banded application of residual herbicides over 7639ha			
Measure: Banded application of Barrage (diuron and hexazinone) and Atrazine spikes rather than broadcast application			
Active	grams active /ha	ha	total gai applied
Diuron	421.2	7639	3217547
Hexazinone	118.8	7639	907513.2
Atrazine 1L	900	7639	6875100
		Total active applied in KG	**11000.20**
Barrage and Atrazine spikes applied as band			
Active	grams active /ha	ha	total gai applied
Diuron	210.5	7639	1608010
Hexazinone	59.4	7639	453756.6
Atrazine	450	7639	3437550
		Total active applied in KG	**5499.60**
		Total reduction in active applied in KG	**5500.80KG**
Measure: Banded application of Metribuzin rather than broadcast application			
Active	Grams active /ha	Ha	Total gai applied
Metribuzin	1500	7639	11458500
		Total active applied in KG	**11458.5**
Metribuzin applied as band			
Active	Grams active /ha	Ha	Total gai applied
Metribuzin	750	7639	5729250
		Total active applied in KG	**5729.25**
		Total reduction in active applied in KG	**5729.25**
Measure: Banded application of isoxaflutole rather than broadcast application			
Active	grams active /ha	ha	total gai applied
Isoxaflutole	112.5	7639	859.3875
		Total active applied in KG	**859.3875**
Isoxaflutole applied as band			
Active	grams active /ha	ha	total gai applied
Isoxaflutole	56.25	7639	429693.75
		Total active applied in KG	**429.7**
		Total reduction in active applied in KG	**429.7**

7636ha calculated as one third of changes reported under other in 16/17 and 18/19 + application method numbers for 17/18

Table 9: Change to modern chemicals and improving timing, common scenarios and reduction in losses achieved over 2889 hectares where change of chemical was reported

Improvement from timing				
Measure: average reduction in loss from 3-day to 21-day delay between application and rainfall utilising averaged results from project rainfall simulation data				
Move from late application of two products to early application				
Product	**Early apply losses**	**Late apply losses**	**Reduction in loss of active in simulation**	**Potential reduction in loss over 2889ha**
Imazapic	3.15gai/ha	22.95gai/ha	19.8 gai/ha	**57 kg**
Barrage diuron	13gai/ha	35gai/ha	22 gai/ha	**63.5 kg**
Barrage hexazinone	23 gai/ha	6 gai/ha	17 gai/ha	**49 kg**
			Total reduction in active applied active in KG	**170**
Change to photostable chemicals in order to apply early - two common scenarios				
	Early apply losses	**Late apply losses**	**Reduction in loss of active in simulation**	**Potential reduction in loss over 2889ha**
Metribuzin		185gai/ha		
Isoxaflutole	15.8gai/ha			
			Potential reduction in losses 169.2 gai/ha	**489 kg**
Atrazine		365gai/ha		
Barrage diuron		35gai/ha		
Barrage hexazinone		23gai/ha		
Imazapic	3gai/ha			
			Potential reduction in losses 420 gai/ha	**1213 kg**

2889ha calculated as hectares reported as improving timing of application

Table 10: Reduction in imidacloprid application by half over 2715 ha.

Measure: Reduction by half of imidacloprid application calculated as liquid product			
Liquid imidacloprid formulation applied to 2715ha			
Active	grams active /ha	ha	total gai
Imidacloprid	490	2715	1330350
		Total active applied in KG	**1330.35**
Liquid imidacloprid formulation applied to 1357 ha (half area)			
Active	grams active /ha	ha	total gai
Imidacloprid	490	1357.5	665175
		Total active applied in KG	**665.2**
		Total reduction in active applied in KG	**665.2**

2715ha is calculated from imidacloprid reduction hectares reported in 17/18 plus two thirds of changes categorised as other in 16/17 and 18/19.

Table 11: Improving stewardship targeting high weed pressure blocks/farms, reduction in active ingredient applied over a 150ha farm and as 8694ha

Improved product selection for late applied vine control				
Measure: Changes from mobile, high rate product to less mobile, lower rate photostable*product				
	Grams active in recommended rate	**Total gai applied over 150 ha**	**Potential reduction in applied active moving to flumioxazin over 150ha in KG**	**Potential reduction in applied active moving to amicarbazone over 150ha in KG**
Atrazine	1980	297000	192	147
Metribuzin	1500	225000	120	75
Flumioxazin	700	105000		
Amicarbazone	1000	150000		
Potential KG reduction in active ingredient applied over 8694ha				
Atrazine to Flumioxazin	**11128**			
Atrazine to Amicarbazone	**8520**			
Metribuzin to Flumioxazin	**6955**			
Metribuzin to Amicarbazone	**4347**			

*Photostable products are more suitable for earlier application due slower degradation from UV

8694ha is used for calculations based on total growers reporting a shift to alternative residual chemicals

Table 12: Improving stewardship targeting high weed pressure blocks/farms with new photostable chemicals. Reduction in losses of active ingredient applied based on lower rate products applied three weeks prior to wet season, rather than higher rate products applied during the wet season.

Potential decrease in losses				
Product selection for vine control	**Simulated losses with late application (kg ai)**	**Simulated losses with early application (kg ai)**	**Potential reduction in loss across a 150 ha from *changing to flumioxazin* in KG**	**Potential reduction in loss across a 150ha farm *changing to amicarbazone* in KG**
Atrazine	365		339	347
Flumioxazin		26		
Amicarbazone		18		
Metribuzin	185		159	167
Flumioxazin		26		
Amicarbazone		18		

**Reductions are based on averaged results from project rainfall simulations conducted over three districts X three years using losses of atrazine and metribuzin applied three days prior to rainfall and flumioxazin and amicarbazone applied three weeks prior to rainfall. The loss reduction value is calculated Atrazine / Metribuzin average result at three days x 150ha – flumioxazin/amicarbazone averaged result at three weeks X 150ha.*

The impact of timing

Growers have reported an increase in avoiding application of residual herbicides close to the wet season. Rainfall simulation data routinely shows reduction in losses of more than half for all commonly applied residual herbicides and new products on the market. Simulation results have been averaged across the three years and are presented in Figure 10.

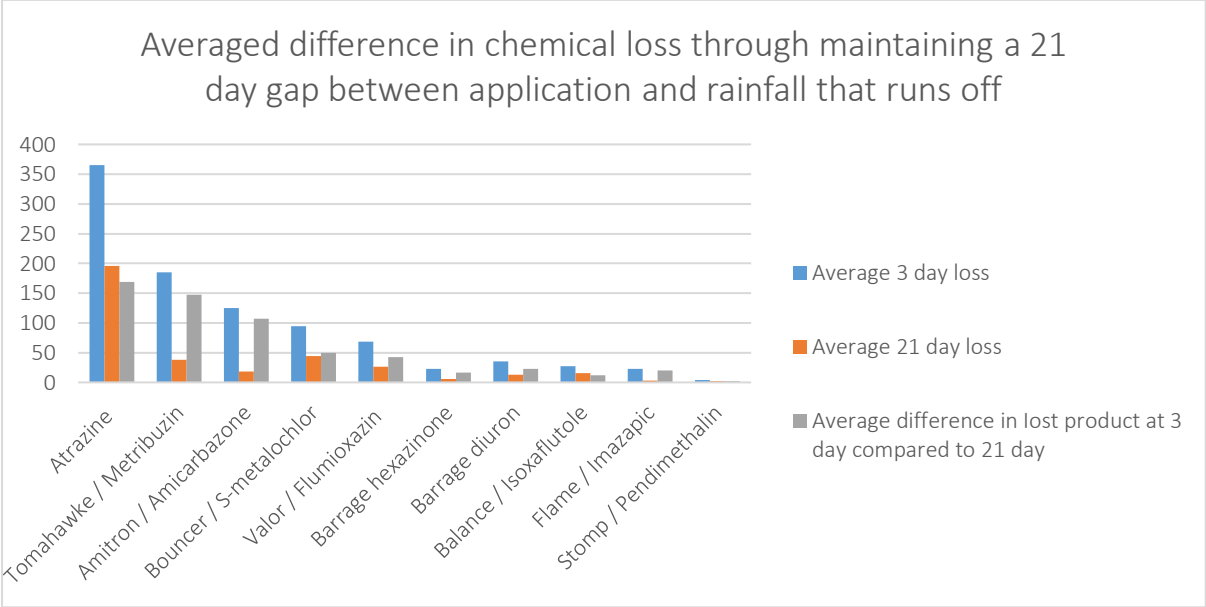


Figure 10: **The average difference between chemical loss achieved by maintaining a 21-day gap between application and rainfall that runs off in grams/L.**

6.2 Culture and attitudes

Protecting our Chemicals for the Future has incorporated social science in the program design and in understanding changes among growers involved. At the outset the objective was to utilise the work of Doug McKenzie Mohr to understand whether the project has had an impact. Surveys were conducted at the beginning of the project with growers involved and a subset who would not be involved.

In addition to the work of McKenzie Mohr the project has worked on incorporating the Five Conditions of Change, from Sydney based social scientist Les Robinson and has been informed by the local work being done by John Pickering and his Cane Changer team.

Did the project make a difference?

Yes, it has made a difference. Table 13 and Table 14 show the differences in adoption of changes in practice and attitude between the initial grower group members and the control group. Early in the project a control group of six growers was set up to compare changes to practice and attitude. These growers were considered to have reasonable productivity and to be open to taking part in such an exercise. They were mainly relatively small growers, and have off farm work, or run farm contracting businesses as well as farming themselves. One grower contacted to be in the control group requested that they be a part of the project. This grower hosted a rainfall simulation in year two and made a change to his chemical selection.

None of the control group have made changes to chemical management over the past three years. However, these growers were not all initially undertaking what could be considered poor practices. Two Mulgrave growers considered locally to be difficult and known to keep to themselves have progressive herbicide strategies, with one describing how he zonally applies his residual (typically Balance) to his ratoons and only applies a residual to the full field during plant. Five of the six mentioned that they had dramatically reduced their diuron use due to regulations, and one cited environmental reasons as a factor in this decision and three of the six had made other changes related to chemical use in the past five years. These changes were driven by the reduction in diuron use, with growers looking for a replacement.

During conversations, many of the growers from the control group discussed their passion for the local environment, particularly nearby creeks and waterfalls. Interestingly, this passion did not always translate into considering the business impact on the environment. Conversely, some of the growers initially surveyed, who joined the project in year one, did not indicate a strong connection to their local environment but were driven by a passion to represent their industry in a positive way. All growers surveyed indicated that changes they had made in the past were, at least in part, influenced by regulatory changes to PSII chemical usage. Changes included reduce use of diuron, reduce use of Velpar (diuron/hexazinone blend), stop using diuron, reduce use of regulated herbicide and, as a result of this reduction, try or adopt new chemicals as part of standard farm management. It also seemed that the regulations raised an awareness of chemicals leaving the farm.

All of the initial group of growers have made some changes, this may be refining use of residuals to reduce overall application, adopting new chemicals or application strategy. All of the first group of grower collaborators had some degree of acceptance that chemicals were leaving the farm in rainfall runoff. Many felt at the beginning of the project that these losses were exaggerated by the media. Three years later they have a greater level of acceptance of the issues and, having made changes that they know are making a real difference, feel a lot more positive. There remains a desire among the grower collaborators to have good news stories told regarding changes in land management rather than what is perceived as focusing on the negative. As news of new regulations emerged in the media towards the end of this project the mood has shifted somewhat, although the group remains confident that they can influence losses in a positive way. Some grower collaborators are now more interested in involvement in projects to prove sugarcane farms are managed to limit losses as opposed to using resources to learn together how to improve management. This is something that needs to be managed through good communication and engagement. Table 13 and Table 14 summarise changes made and attitudes towards environmental considerations in decision-making of the control group and the core groups of growers involved.

Table 13: Attitudes toward water quality issues and practice change control group growers.

Control group	Environment is a factor in decision making	Considers pesticides are entering waterways	Have made changes in last five years	2019 Considering changes	Environment is a factor in decision making 2019	Considers pesticides are entering waterways 2019
1	Not a consideration	No not likely	No	No	No	Maybe something in it, hear about Project 25 from others
2	Yes, but least important	No	No	No	No	No
3	Yes, but least important	No, it's not my job, I assume if it has been approved for use it is ok.	Yes chemical	Yes, watch neighbours	No	No, that is the APVMA's job. We don't use a lot of herbicide
4	Yes, some importance	Yes, but not from my farm	Yes chemical	Consider new chemicals	Yes, still a consideration	Yes, but not from my farm
5	Yes, some importance	Yes, I border the Mulgrave river	Yes, chemical	Consider new chemicals	Yes still a consideration	Yes, good to hear that we have made some good decisions
6	Not a consideration	No	No	No	No	No

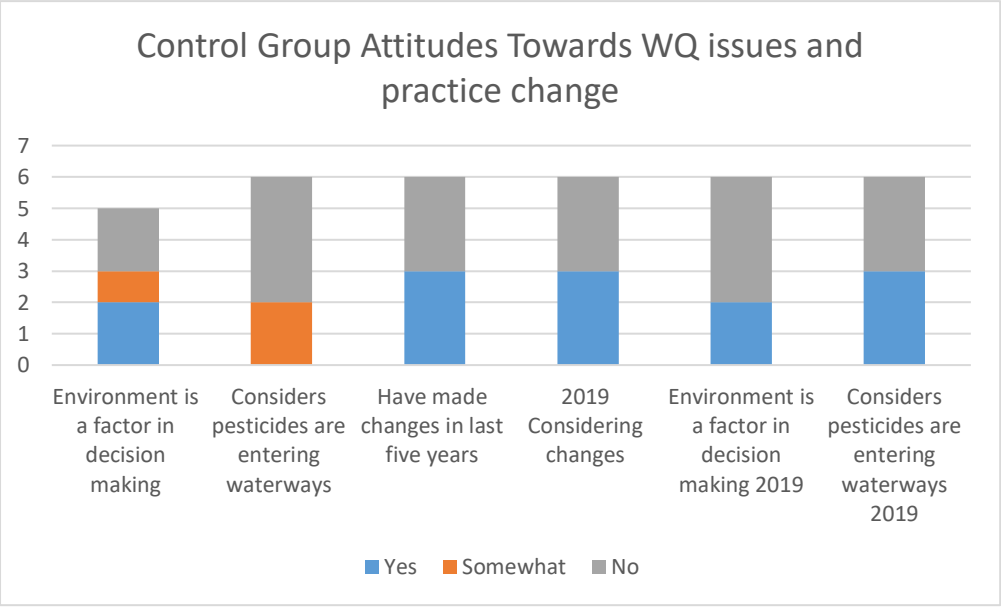


Figure 11: Visual representation of control group attitudes toward water quality issues and practice change control group growers.

Table 14: Attitudes toward water quality issues and practice change, year one grower collaborators

	Environment is a factor in decision making	Considers pesticides are entering waterways	Made change during project	Have made changes in previous five years	Considering changes	Environment is a factor in decision making 2019	Considers pesticides are entering waterways 2019
Mulgrave growers							
1	Yes	Yes, but not from my farm. Timing is challenging in wet tropics but important	Reduced imidacloprid use, now only on plant cane and only where there have been historic grub issues, improved drainage to hopefully reduce chemical use	Reduced use of Velpar due to regulations	Better ways to reduce imidacloprid losses/use	Yes	We all need to do our bit. We need to stop people using chemicals as insurance
2	Yes, absolutely	Very concerned, everything comes back to being sustainable. I want everything to stay in the paddock	Yes, better use of dual spray	Yes, application, timing chemicals	Always	Yes absolutely	Yes, and we need to get better at telling the good stories so that we can share among all grower collaborators and the community
3	A little	Yes some. Timing is challenging in wet tropics but important	Yes, increased density of legume planting to reduce spray in fallow and plant cane	Reduced use of Velpar due to regulations	Always looking	Yes, I saw that with the rainfall simulation	Yes, and we have ideas for how we can improve that
4	Yes, absolutely	Very concerned, we are a big farm right on the river, we can make a difference	Yes, testing for pachymetra to reduce imidacloprid use	Yes, no residual in ratoons	Always	Yes absolutely	Yes, and we want to help get ideas out there about how everyone can help. We want to be part of a progressive industry

	Environment is a factor in decision making	Considers pesticides are entering waterways	Made change during project	Have made changes in previous five years	Considering changes	Environment is a factor in decision making 2019	Considers pesticides are entering waterways 2019
5	Yes, especially with the regs	Yes, I do. But my farm does not have any creeks / river running through	Reduced imidacloprid use, now only on plant cane and only where there have been historic grub issues	Reduced atrazine to plant cane only, Velpar now only as a spike where there is a grass problem and no use after Nov	Have shields but never used, did not have time during this project	Yes, and I can see safe ways of making a difference	My farm isn't on a creek but I still want to do the right thing.
6	Yes, I want my kids to enjoy the creeks like I did	Yes, I do. Timing is challenging in wet tropics but important	Application method, timing and chemicals, reduced overall use of residual	No more barrage and diuron	Always	Yes, I do still think the media exaggerates and doesn't help with the way we report on it. I would like to see more positive stories.	Yes - I can see that.
7	Yes somewhat	Yes, I have changed chemicals and hope that they are better. Timing is challenging in wet tropics but important	Improved timing and overall reduction in chemical use	Try new chemicals in ratoons	Always interested but it must stack up financially	Yes I want a clean healthy creek for my family to play in. I do still think the media exaggerates and doesn't help with the way we report on it. I would like to see more positive stories.	Yes - I was also happy to learn that the earlier decisions I made to change herbicides were good ones, because we didn't really know at the time.
8	Yes somewhat	Yes, I have changed chemicals and hope that they are better	Overall reduction in chemical use, some ratoons knockdown only, some only one pass with residual instead of two	Try new chemicals in ratoons	Always interested, looking at improving fallow	Yes, I do still think the media exaggerates and doesn't help with the way we report on it. I would like to see more positive stories.	Yes - I can see that .

	Environment is a factor in decision making	Considers pesticides are entering waterways	Made change during project	Have made changes in previous five years	Considering changes	Environment is a factor in decision making 2019	Considers pesticides are entering waterways 2019
9	No money is always a factor and have been ill in recent years (cancer) so getting well has been focus.	Not really considered	Demonstration trial with imazapic after harvest and removal of residual spike in second pass taken up across farm	Tried a new chemical (Balance) in 2011 but stopped to costs and illness	Anything recommended will try if in financially able	I guess so. Important thing is I can get good weed control and not cause problems.	Yes I think so

	Environment a factor in decision making	Do you think you can impact on water quality in local creeks	Made change during project	Have made changes in last five years	Considering changes	Environment a factor in decision making 2019	Consider pesticides are entering waterways 2019
Tully growers							
10	Somewhat, not main factor though.	Yes, concerned about WQ and managing impact on farming. Timing is challenging in wet tropics but important	Uses the shields again on certain blocks.	Tried shields and DHS and used on a number of blocks for first time in years. Took up new chemistry, reduced use of residuals, very little diuron or Velpar used on farm. Regulation has been a factor in chemical changes	Always open to trying new things. Nothing in particular at moment though	Yes, I can do things on my farm that will have a better outcome. I can see that.	Yes, we get runoff. It has to go somewhere

	Environment a factor in decision making	Do you think you can impact on water quality in local creeks	Made change during project	Have made changes in last five years	Considering changes	Environment a factor in decision making 2019	Consider pesticides are entering waterways 2019
11	Yes have stopped using PSII in ratoon cane	Yes, timing and in relation to rainfall is the most difficult challenge we face, along with getting all grower collaborator to accept responsibility	Moved to zonal application of targeted residual herbicides, focussed on 20m ends of the block and problem spots within block	Remove PSII herbicides from farm, take up Balance. This approach had resulted in some increase in vine callopo pressure that is addressed through the zonal application of better targeted herbicide	Always looking at new ways of doing things.	Yes, we all need to consider the impact we have on the community.	Yes, and it is good to see that we can make a difference
12	Yes have been creating spray maps to reduce use of Velpar to targeted areas	Yes am aware of and concerned about water quality issues and the pressure this puts on the industry	None	Reduced use of residuals through weed mapping	Open to trying new chemicals not that has better access to information on chemical ecotoxicity etc.	Yes, it is and we need the best information to make good decisions. The risk matrix will be good.	Yes. We need to be able to demonstrate the improved practices we are doing
13	Yes, have been involved in P2R paddock monitoring	Yes we have made changes to reduce PSII and are using new chemicals	Are working on one pass of residuals with project	Yes reduce use of older chemicals.	Yes better understandi ng of drivers of runoff. Interested in new chemicals for single pass managemen t	Yes, it is and we need the best information to make good decisions. The risk matrix will be good.	Yes.

	Environment a factor in decision making	Do you think you can impact on water quality in local creeks	Made change during project	Have made changes in last five years	Considering changes	Environment a factor in decision making 2019	Consider pesticides are entering waterways 2019
14	Yes, trying to reduce use of Velpar, and all residuals for environmental reasons. Regulations have also played a role in this. We also need to manage our weeds - need a balance	Yes, have reduced use of residual chemicals because of this and regulations.	Tried using dual spray rig for second pass but decided weeds were not so bad to warrant any residual in second pass.	Reduction in PSII chemicals and use of new (Balance after harvest).	Would like to get more use out of variable rate spray rig.	Yes, it is and we need the best information to make good decisions. The risk matrix will be good.	Yes.
15	Yes, but has reduced all chemical use due to concerns for human health	Yes	Review of canegrub control and application of suSCon granules	Move away from regulated herbicides, and herbicides overall. Very proud of riparian revegetation undertaken with Cassowary Coast Council	Always looking to reduce use of chemicals but must balance with weed control	Yes and human health.	Yes
16	Some consideration	Yes some	Trial new herbicide after harvest	Reduction in Diuron use	Open to new ideas	Yes, it is important	Yes
17	Some consideration	Yes some	Trialled use of drone to map grass stools, liked but needs automation	Change of chemical	Would like to find a way to automate drone mapping of weeds for zonal application	Yes, and we have learned some really important things to help us make good decisions. We still have challenges with the weather and mills, but good to know we can make better decisions late in the year.	Yes.
Innisfail growers							

	Environment a factor in decision making	Do you think you can impact on water quality in local creeks	Made change during project	Have made changes in last five years	Considering changes	Environment a factor in decision making 2019	Consider pesticides are entering waterways 2019
18	Yes	Yes	New chemical with strong binding to replace late PSII for vine control	Revised chemicals	Yes, is moving to CTF and will do banding	Yes, and it is good to learn the new herbicides offer some better options, with good weed control.	Yes we are learning more about that
19	Yes	Yes	Reduce residuals/spikes in vine control	Revised chemicals reduce diuron use	Would like to do more work on best stewardship outcome on vine control	Yes, it is a consideration. We need to show leadership.	Yes we are learning more about that
20	Yes	Yes	No	Revised chemicals, less diuron	May review spikes	Yes, and managing my time.	Yes
21	Yes	Yes	Reduce chemicals in fallow with better equipment set up	Band spraying and new chemistry	Always looking at what is new	Yes it still is a big part of my decision making	Yes
22	A little	Maybe, unsure	No	Reduced diuron use	May look at newer chemicals	Yes, I try, but it is difficult with the climate we farm in.	There seems to be evidence. I do think there is exaggeration in the media
23	Yes	Yes	No	Got RR funding for shields which used on low lying farms, no longer use as switched to new chemicals and believe that they have less runoff	Will do demonstration in C2C 2 for vine management	Yes, is involved in WTMIP and new Cane to Creek (C2C) work	Yes there is and we need to get more uptake. We also need to use the information to get the best weed control with minimum impact

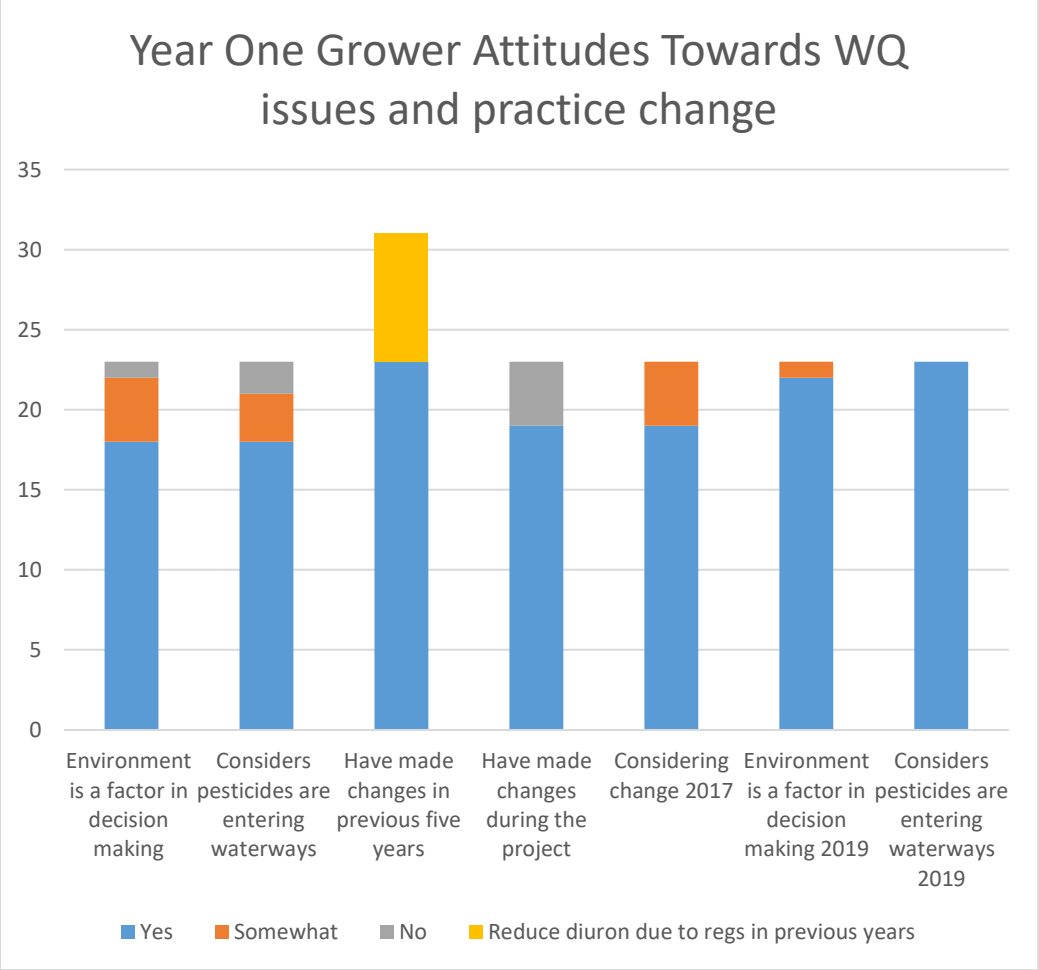


Figure 12: Attitudes toward water quality issues and practice change, year one grower collaborators

Each year between 27% and 35% of growers participating in the project have made changes, with many making multiple changes. Many who have not made changes began the project with progressive herbicide strategies. Every grower participating in Protecting our Chemicals reported that they found the program valuable, either for providing information to support change or providing information that supports changes made in the past and all commented that the project provided positive messages and could help them and others make future decisions. The attitude-based survey shows that the group involved earliest and for the longest time all made changes and there was an increased acceptance of the risk of chemicals impacting the aquatic environment. This is summarised visually in Figure 12, while Figure 11 shows that there was no real shift in attitudes towards the environmental risk of farm chemicals within the control group.

Growers and industry have also taken ownership of the annual water quality field days, with the event in Tully for 2019 being led by local Canegrower organisation, WTMIP and WTSIP staff along with SRA. The 2017 and 2018 events were both co-funded by Canegrower organisations and WTMIP, with strong industry support from day one. In the Mulgrave area the event will continue with support from the Cairns Regional Canegrowers.

Importantly, attitudes of growers involved in the project towards action to reduce losses have shifted.

The most obvious shifts are:

- Acceptance of risk associated with timing of application of herbicides in the Mulgrave area, where the idea of applying chemical well before the wet season was initially seen as impossible. This message was accepted more readily in Tully and there is still work to be done in Innisfail.
- Acceptance of industry/individual responsibility for imidacloprid issues and issues with blanket application.
- Openness to discussing water quality.
- Ownership of the program.

Timing

When working with growers in Innisfail and Mulgrave in year one, the majority of growers were adamant that they needed to apply residual late in the season for vine control because "there is a chance that we won't get into the paddock again after December." In year three the same group accepted the importance of timing as a way to avoid high losses during the wet season without question. Many have begun to apply the chemical risk properties to decision-making on problem blocks and when new products are discussed. A number of growers contacted the project to let them know they were trialling amicarbazone as an atrazine replacement as it is photo-stable which meant they could put it out early.

Imidacloprid and responsibility

Initial conversations around canegrub control resulted in descriptions of how bad canegrubs have been in the Wet Tropics, with growers often distressed at the memories of their crops being destroyed by heavy infestation. The most common phrase, particularly in the Mulgrave area, was "we need this product", however it was rarely used in conjunction with any role that the grower might play in improving stewardship of the product. By the second year, growers had seen presentations on local water quality monitoring programs undertaken by the Department of Environment and Science (DES), and many in the Mulgrave had taken part in a canegrub workshop with SRA's Phil Ross via the Protecting our Chemicals program. During the second round of workshops these growers were proud to speak out themselves about the importance of only using imidacloprid products where they are needed. This was a big shift for a number of the growers.

Openness to water quality issue

Growers involved in the project clearly had some interest in understanding losses from farm and the greater water quality issues from the outset. However, the growers with the greatest existing interest in this area were often already managing their farm with limited residual and imidacloprid use. These growers attend larger events and some of the small group work to show their support for the work. Those that got the greatest value from the program and attended the majority of the events were interested in the water quality story, but reported that they felt there was an exaggeration by media and researchers in this regard. They reported feeling unfairly targeted by media. They typically joined the program due to an interest in learning more about herbicides and to support SRA. These are the grower collaborators who have made the most change in terms of practice and, while most still feel the Reef agenda is exaggerated, they report feeling that they are doing 'the right thing' by making changes to timing and adopting newer chemicals. This has

translated across the TF11.9 Cane to Creek project with grower collaborators comfortable to discuss reductions in nitrogen use in relation to field demonstrations, even at the height of the Reef Regulation debate.

Ownership of the program

Grower collaborators from year one, and many from year two of the program, have taken ownership and many have supported new project work in their areas. Most telling, and rewarding, has been the number of grower collaborators hosting shed meetings who have taken it upon themselves to call their neighbours to help promote the meetings. In year three all grower collaborators hosting shed meetings had made the effort to set up tables and chairs, arrange coffee and tea and made calls to neighbouring farms. The Tully Upper Murray grower has offered his shed as a community base for any new project work. This level of ownership and responsibility was not expected in such a short time. In addition to this, by year two of the project the project leader began to receive phone calls from a small number of growers who had been advised by others within the project to change their chemical program.

The key message of Less on = Less off has been taken up by some growers who, in discussion, will use this as reasoning for a decision they have made or are considering, including in reference to nitrogen use.

6.3 Successes and challenges

Successes

Generating data for growers: This is the most powerful component of the project. The data is only produced to be shared with the grower collaborators to help them. The data is shared in a timely way, in their own district. Meetings are un-hurried and all questions are welcome.

Project name: The project name resonates with grower collaborators and industry. We regularly receive positive feedback on this, and from the outset, it puts grower collaborators at ease.

Growing the project with grower collaborators and industry: Making the time for grower and industry input into the project has been a great success. Taking questions early in the year and seeking to answer them has been a positive process and helped in building a relationship with the project participants.

Each year we meet with growers to get ideas for the coming months. We ask them what they found interesting and what questions they would like answered. This has informed future rainfall simulations and efficacy demonstrations.

Industry concern about imidacloprid runoff led us to increase that component of the project and, with less interest in band spraying than we anticipated, we have been able reduce the focus on that component.

From the outset grower collaborators had questions about the eco-toxicity of different chemicals and this, combined with a need to provide context to rainfall simulation results, led us to pull together data on chemical properties. Growers are annually provided with an updated A3 sheet which includes 95% eco-system protection values, half-life, adsorption and solubility for common and new sugarcane herbicide and pesticides. This has also provided a conduit for information back to DES staff on how this information can be used, with regard to the proposed Chemical Risk Matrix.

Meeting locally: Meeting at growers' sheds or places they feel comfortable has been a successful approach. It has meant we are able to combine demonstration work with rainfall simulation feedback meetings where dates have aligned, and over time has led the grower collaborators to build ownership of the project.

Involving resellers: A handful of resellers voluntarily attend shed meetings and events, but many are unable to make the time. Allan Blair and Belinda Billing ran three evening workshops for resellers that were well received. Store managers reported that the stewardship information could help them encourage their staff to start recommending newer products, admitting that their older staff, often with a large client base, were much more likely to recommend old products that they were familiar with.

In Tully the project has worked with TSL to help build reseller understanding of pachymetra and raise reseller awareness of the water quality issue that the overuse of imidacloprid is causing. This was well received by the group. Resellers are now part of the Tully Extension Group, an informal arrangement between all extension staff working in Tully who have begun meeting semi-regularly, with leadership provided by Fiona George and Alex Lyndsay. The group was initiated in 2018 and has gained momentum, with attendees valuing the opportunity to share information and discuss issues, research and findings to create a united message to take to growers. Protecting our Chemicals was one of the first topics for the group, with the key messages of the project being adopted by the group.

Working with extension providers: local extension providers are always invited to grower group meetings and field days. This means that they are able to hear the information with the growers and continue to spread and reinforce the message. This has led to presentations to the WTSIP Cane Technical Advisory Group and working with local Smartcane BMP staff on stewardship messaging for weed management plans.

Challenges

Banded sprayers: the challenge in getting data on growers who received Australian Government funding for the purchase of shielded/hooded spray rigs was demoralising and took up a lot of time. While a number of growers were assisted and in response did use their spray rig, this was a disappointment. Direct contact with the project would likely have resulted in much greater uptake of support than the indirect method applied.

Canegrubs: This was a challenge and success. A success because we did see shifts in attitudes around use of imidacloprid products, but also a challenge in that we wanted to provide useful and timely information and support to grower collaborators to bring about more strategic use of the products. Particularly early on, grower collaborators wanted to know which product they should use to get the better environmental outcome. This was a distraction from the main message, only use it where you need it. It also became evident very early that most grower collaborators did not know how to check for canegrubs and were unlikely to do so without assistance. This is a cultural issue that needs greater attention. SRA is working on redeveloping the industry canegrub management program GrubPlan and running a new industry-wide program to focus on better canegrub management with an emphasis on reducing over-use of imidacloprid. In conjunction with this, SRA entomologist Dr Kevin Powell is looking into methods for ultra-sensitive imaging to detect early canegrub damage in blocks that, in future, may provide more information on where to look for canegrubs and apply appropriate chemical. Current work with DAF's Marcus Bulstrode showed that reasonably advanced damage (stool tipping and drying) is possible to spot with a standard camera, but this can easily be

confused with other concerns. This method provides grower collaborators with the ability to target a site within a block to look for canegrubs; however, the popularity for this method varied, with grower collaborators consulted often suggesting productivity boards or SRA could fly drones across the district and then go and check the damage sites – this would obviously need to be funded somehow!

Paddock to Reef Reporting: This takes up a lot of time, and often the grower collaborators have provided the information to other extension officers very recently. In the final year of the project we were able to achieve a data-sharing agreement across all three regions. This is better for grower collaborators and better for extension providers. We still contact all grower collaborators directly to discuss changes related to the project.

Innisfail: Challenges in Innisfail began with the unexpected withdrawal of support from Innisfail/Babinda Cane Productivity Services early in the project. This occurred due to a lack of time available to staff to commit to supporting the project as was required. Informal support was offered through DAF and Grow Force (resellers) and eventually through Innisfail Canegrowers. IBCPSL offered support where possible, through sharing information and hosting Protecting Our Chemicals at their trade show in year two of the project. The combination enabled connection with a range of growers to share the key messages and findings, resulting in practice change and the foundation for a good connection with one of Innisfail and Tully's most popular resellers, Grow Force. This connection has been profitable for both parties, with the store manager commenting that the information provided through the project helps the staff to promote newer chemicals rather than relying on the old and trusted brews and provides an edge to the advice they can provide to customers. For Protecting our Chemicals this is an outcome (though difficult to track penetration), as is the willingness of the staff to promote the project, events and the possibility of making an impact on reseller culture.

Conclusion

Protecting our Chemicals for the Future has been a successful project for both practice change outcomes and for promoting SRA as a key player in water quality extension in the Wet Tropics. The project has achieved its milestones and influenced key messaging on herbicide use across multiple programs within the Wet Tropics. Interest in the project findings has extended outside of the project area, resulting in opportunities for expansion of the work in future years.

Using basic knowledge of social science to inform the project processes has prompted the project leaders to think carefully about activities, messaging and to take more time to talk with and listen to grower collaborators and industry staff.

One of the most powerful aspects of the project has been to work locally and to return with results within a six-month period. Having some results to share from year one provided motivation and impetus for the project to move forward and gather support as it continued. We did not expect so many new faces in the final year, however this was the case. It is heartening to have accessed additional funding through the Reef Trust program to continue this work, marrying it with nitrogen management. It is hoped these growers continue to partner with SRA and, with momentum in place, many more new faces will join us leading to continued improvement in farm management and stewardship.

7. RECOMMENDATIONS FOR FURTHER RESEARCH DEVELOPMENT & ADOPTION

It is recommended that further work is undertaken in the following areas:

- Improve understanding of environmental impact of new herbicides flumioxazin (including metabolites) and amicarbazone, including establishment of ecotoxicity thresholds and losses of the flumioxazin metabolites.
- Continue work on the herbicide risk matrix, with inclusion of research standard rainfall simulation loss data.
    - Work with extension staff to establish best format and extension methods for the herbicide risk matrix.
- Continue work to build relationships with resellers of agrichemicals and provide for a dedicated program of work establishing a stewardship framework for responsible sale of herbicides and pesticides in the GBR.
- Increased research and development in drone-enabled mapping of canegrub pressure, including work on technologies for early detection.
- Increased effort or formal program to enable farm scale planning focusing on stewardship of all chemicals, priority must be imidacloprid
- Increased extension effort around effective stewardship of chemicals, utilising the risk matrix.
- Continuation of effort in bringing growers and extension providers together with water quality science, inclusive of improving understanding of the issues and working together on solutions.
- More extension and research around vine control options for late in the season (wet season).
- Development and extension for weed mapping (tractor, drone, farmer knowledge) for zonal herbicide application.

8. PUBLICATIONS

Cane Connection articles and online clips can be viewed here:

https://sugarresearch.com.au/caneclip/protecting-our-chemicals-for-the-future/

https://sugarresearch.com.au/water-quality-science-display-field-day/

https://sugarresearch.com.au/wp-content/uploads/2018/06/CaneConnection-Winter-2018-F-Web.pdf (p6)

https://sugarresearch.com.au/wp-content/uploads/2017/11/CaneConnection-Summer-17-F-LowRes.pdf (p12)

https://sugarresearch.com.au/wp-content/uploads/2019/09/CaneConnection-Spring-2019_Web.pdf (p10)

A presentation on Protecting our Chemicals was made at both the APEN and ASSCT conferences in 2018.

9. ACKNOWLEDGEMENTS

We would like to acknowledge our funding partners:

Sugar Research Australia, Queensland Department of Environment and Science, Bayer Crop Science and Nufarm for making this work possible.

We would like to acknowledge the following individuals for their outstanding support during the course of this project:

- Jack Robertson and Marcus Bulstrode (Department of Agriculture and Fisheries)
- Aaron Davis (James Cook University, TropWater)
- Jordan Villaruz and Noel Lingard (Tully Cane Productivity Services Limited)
- Greg Shannon (Tully Sugar Limited)
- Tony Fitzgerald (Bayer)
- Nick Matthews and Mark Rantucci (Nufarm)
- Andrew Franklin (Sumitomo)
- Emilie Fillols (Sugar Research Australia)
- Deb Telford: Innisfail Canegrowers
- Bianca Spannagle: Innisfail Babinda Cane Productivity Service

10. REFERENCES

Robinson, Les, 2013 Changeology How to enable groups, communities and societies to do things they've never done before; Green Books Ltd, Dartington Space, Dartington Hall, Totnes, Devon

11. APPENDIX

11.1. Project Delivery and Methods

Year 1: Project Delivery and Methods

Rainfall simulation activities

The year one strategy was entirely devised by the technical oversite group set up to oversee the project in conjunction with the project leader. Treatments applied are outlined in the tables below.

Rainfall simulation treatments year one

Table 15: Timing and product selection; Residual chemicals applied on trash at 21 and 3 days before rainfall simulation applied. All applied at maximum label rates

Active ingredient	Product name	Rate (all top label rate)
Atrazine	Atradex	3.3kg/ha
Pendimethalin	Romper	2.25L/ha
Metribuzin	Mentor	2kg/ha
S-Metolachlor	Bouncer	1.8L/ha
Diuron + Hexazinone	Barrage	900g/ha
Imazapic	Flame	400ml/ha
Isoxaflutole	Balance	200g/ha

Table 16: Timing and product selection; Knockdown chemicals applied on trash at 21 and 3 days before rainfall simulation applied. All applied at maximum label rates

Active ingredient	Product name	Rate
2,4-D	Amine 625	3.5L/ha
Fluroxypyr	Comet 400	1.5L/ha
Paraquat	Nuquat 250	1.6L/ha
MCPA	Agritone 750	930ml/ha
Dicamba	Kamba 500	560ml/ha

Table 17: Application method; Banded application of diuron and hexazinone (Barrage) with glyphosate applied to the inter-row compared to a broadcast application of diuron and hexazinone (Barrage). All products applied at maximum label rates.

Active ingredient	Product name	Rate
Diuron and hexazinone	Barrage	900g/ha
Glyphosate	Weedmaster Argo	5L/ha

Growers were invited to attend the rainfall simulation events in each district, to ensure they understood where and how the data was generated. Good attendance was recorded in Tully and the Mulgrave area. Innisfail's event was held the week before Christmas and attendance was poor.

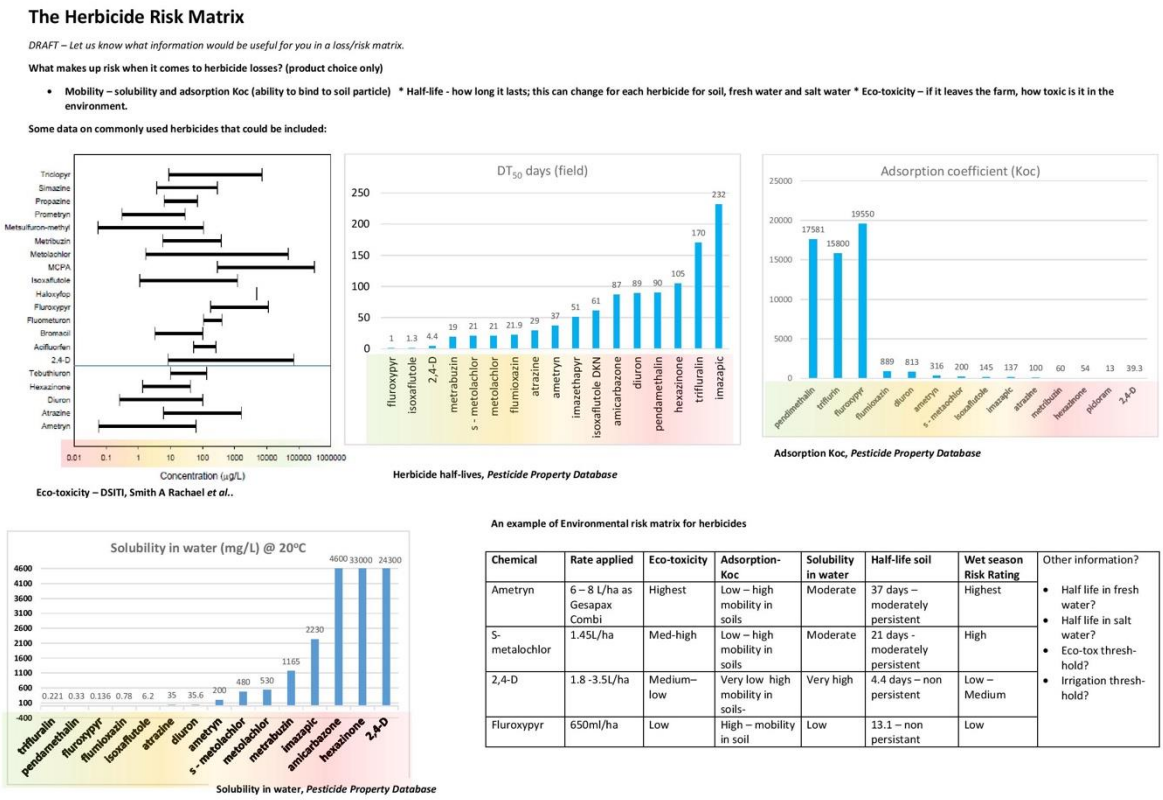
The Tully event was well attended with around 40 growers and advisors attending following project delivery partners, Tully Cane Productivity Services Limited (TCPSL), promoting the event to all members. Growers were interested in the demonstration and results, noting that there was a history in the area of water quality monitoring being undertaken but no results shared locally. These growers also noted that leaching was a big issue for them, perhaps more so than surface runoff.

Due to the starting time of the project, the rainfall simulations occurred late in November and December 2016. The Tully simulation was undertaken on a common alluvial soil type following a harvest of 95 tonne to the hectare. The large quantity of trash and dry soil meant that runoff was difficult to achieve. A method for sampling to 70cm depth using a hand auger was devised and plots were sampled at depths of 10cm intervals down to 70cm. This method proved successful in showing that the herbicide was leaching down the profile, with the values largely reflecting the products found in surface runoff at other sites.

The Mulgrave simulation attracted the majority of the group approached to participate in the project, and the grower hosts were very supportive arranging a barbecue for the group and talking about their own move to knockdown strategies to manage weeds in all their ratoon blocks.

Work in Innisfail had a difficult start with Innisfail Babinda Cane Productivity Services (IBCPS) deciding that they did not have the capacity to support the project as was originally planned. Staff offered what support they could, bringing a small group of growers together to discuss the project early on with many of these growers along with IBCPS and Maryborough Sugar Factory (MSF) staff attending the simulation event.

Analysis of the rainfall simulation runoff data showed that sharing the chemical runoff data on its own would not be adequate for promoting best practice management for herbicide use. Some of the knockdown products commonly used in cane are applied at high rates and are highly mobile. Without data to show why these are considered less of a risk to the environment than residual herbicides that have lower runoff rates the message would be very confusing. To help with this, handouts on the various risk factors relating to commonly used herbicides were produced (Figure 13) to provide greater context to the runoff data incorporating eco-toxicity, half-life, adsorption coefficients and solubility data for commonly used herbicides and pesticides. This document was updated annually as new data became available.



Chemical	Rate applied	Eco-toxicity	Adsorption-Koc	Solubility in water	Half-life soil	Wet season Risk Rating	Other information?
Ametryn	6 – 8 L/ha as Gesapax Combi	Highest	Low – high mobility in soils	Moderate	37 days – moderately persistent	Highest	• Half life in fresh water? • Half life in salt water? • Eco-tox thresh-hold? • Irrigation thresh-hold?
S-metalochlor	1.45L/ha	Med-high	Low – high mobility in soils	Moderate	21 days - moderately persistent	High	
2,4-D	1.8 -3.5L/ha	Medium–low	Very low high mobility in soils-	Very high	4.4 days – non persistent	Low – Medium	
Fluroxypyr	650ml/ha	Low	High – mobility in soil	Low	13.1 – non persistant	Low	

Figure 13: The first herbicide risk matrix hand out provided to growers to provide context for rainfall simulation data during grower meetings in year one

The grower meetings were run by project leader Belinda Billing with support from technical advisors and project partners Aaron Davis from James Cook University (JCU) and Jack Robertson from Queensland Department of Agriculture and Fisheries (DAF).

Grower group meetings were held early in the new year (2017) to share results. The agenda included:

- Share latest published information on chemicals detected in local Great Barrier Reef Catchment Loads Monitoring Program explanation of rainfall simulation and the demonstration design used
- Results from the rainfall simulation demonstrations
- Explanation of various chemical risk factors (eco-toxicity, persistence, adsorption and solubility)

- Explanation of banded spraying and a demonstration from DAF project partner using a mobile display
- Discussion on how this information can be used to improve water quality in the district.

The grower meetings were structured to support small group work with time for questions and informal discussion with the project staff. This was particularly useful for the session with the chemical risk factors where having three staff present allowed participating growers to ask questions in small groups and work through the material. Table 18 shows attendance at both the rainfall simulation demonstration and the grower feedback sessions.

Table 18: Event attendance rainfall simulation demonstration and grower feedback meetings

Event	Mulgrave group	Innisfail/Babinda Group	Tully Group
Demonstration	12	4	40
Discussion	10	8	24

Figure 14: Tully Rainfall Simulation Grower Field Day, December 2016

During grower Rainfall simulation report-back meetings much of the discussion around how to use the information revolved around timing of application. The simulation data shows a big difference in losses where the products are applied 21 days prior to rainfall when compared to 3 days. The immediate response from participating growers in year one was that this was not going to be possible as a common strategy as rainfall is difficult to predict. This was particularly true in the Mulgrave area, where the common practice is to spray residual later in the year to control vine and as growers believe that, once it starts raining, they may never get back in the paddock. This is typically done around November/December. Growers response to the timing data showed that they

understood the rainfall simulation was showing that this is a risky practice. In the first meeting, participating growers were also interested to see that some residual herbicides were producing far less runoff than others (isoxaflutole and imazapic in particular). Several growers attending use these products and they commented that they are very effective, particularly for grass control. Growers commented that since using isoxaflutole as an early/after harvest spray application they have greatly reduced their guinea grass problems. Both imazapic and isoxaflutole are now affordable products. Some growers note that imazapic is now very cheap and they wondered if it would lead to it being over-used.

There was also a lot of discussion around the eco-toxicity information. Growers were interested in this data and commented that, while they want good weed control, they would rather achieve this with the least toxic product applied to their farm. The risk information triggered a range of conversations highlighting concerns the participating growers have around herbicides. They began discussing concerns they have, not just with water quality but also considering the impact on their soil, opportunity for subsequent crops and risk to themselves during handling.

Growers attending were not convinced that the knockdown information was entirely relevant, as the method for applying product to conduct a rainfall simulation does not reflect the method that would be used when applying knockdowns in a typical farming situation.

The method used was applied as directed by the technical oversite group and was also checked with Mark Silburn of the Department of Natural Resources, Mines and Energy (DNRME). Products were applied to bare trash with no, or very limited, weeds present. Growers explained that they would only apply product to actively growing weeds with an adjuvant included to help the product stick to the weeds and therefore thought the losses would be far less than generated by the simulator. Protecting our Chemicals for the Future demonstrations are undertaken with the sole intent of developing useful information that resonates with growers. While the losses from knockdown chemicals data did not achieve this, the information on residual herbicides was appreciated and, given the project leader was new to the region, it was appreciated that they felt able to communicate their concerns openly. Following this, growers and local extension staff were invited to have a say on future simulation activities and the focus of field demonstrations, with feedback incorporated into the next years' work program.

In Tully, the growers had noted early in the project that they felt leaching was a major problem that should be looked at. They responded positively to the leaching data provided and independently raised concerns for the ability of products to break down once they had moved so far through the profile, or into the water table. The group appreciated the effort taken to gather local data, indicating the data was relevant, showing them what could likely happen to their chemical if it was applied in December as was the case with the demonstration site. Conversation around the leaching stood out across the project. The charts below show examples of results provided to growers (one chart from each treatment). These results reflected the results of previous research work used to inform the project.

Year 1 rainfall simulation results

Examples of charts provided to growers for discussion are included below. The key messages from these simulations were that:

- Products applied at a higher rate result in larger amounts of product lost in runoff or leaching (e.g. compare atrazine and metribuzin to isoxaflutole and imazapic).
- Applying herbicides at least 21 days prior to rainfall that runs off reduces losses.
- Applying residual herbicides as a band can halve losses to the environment.

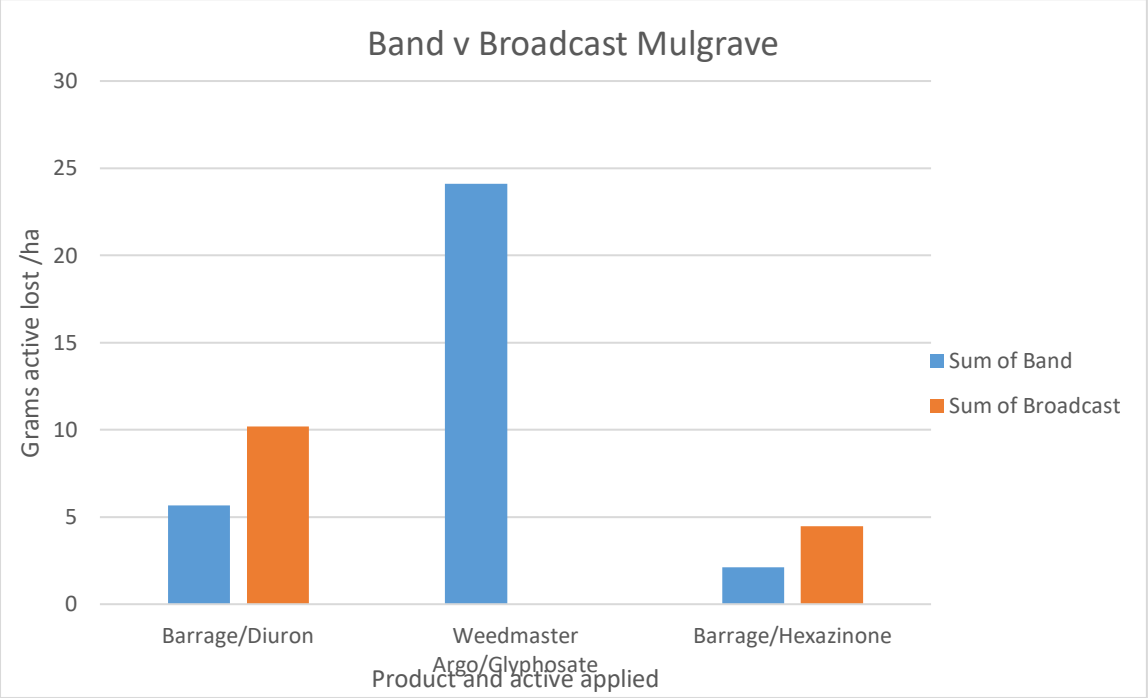


Figure 15: Rainfall simulation results year 1; Banded application using a dual herbicide spray bar. Rainfall applied at 3 days after application.

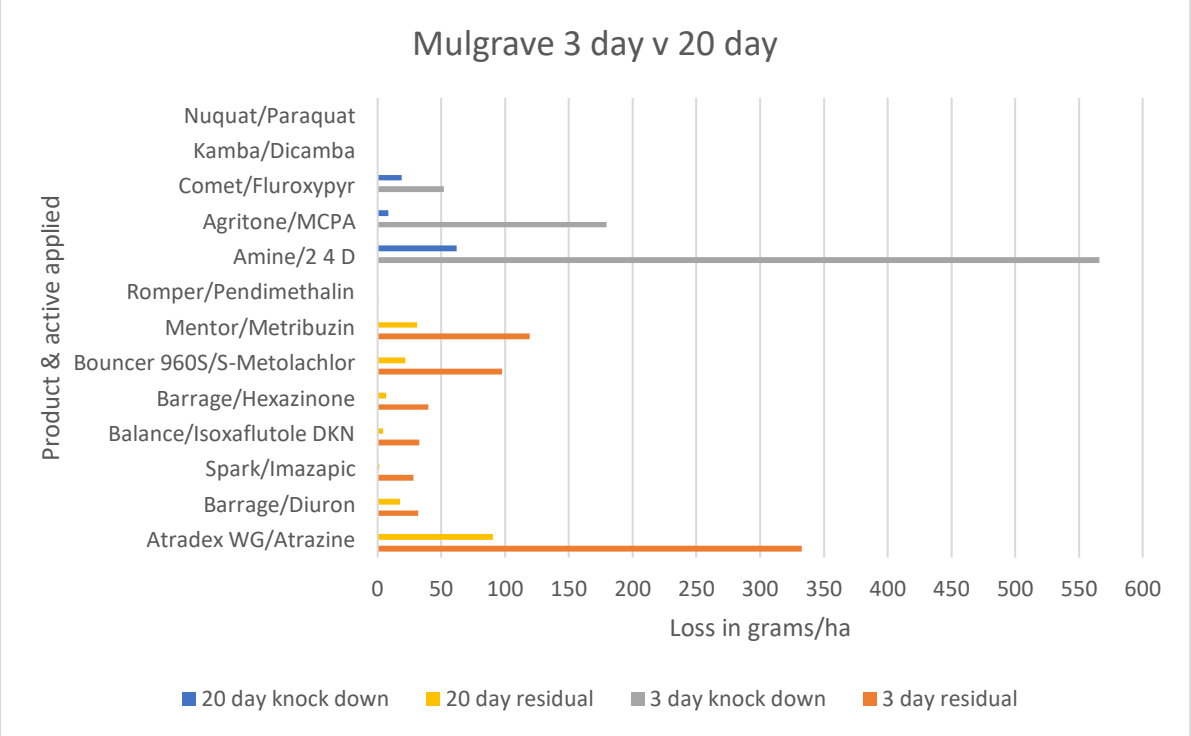


Figure 16: **Rainfall simulation results year 1; The importance of timing and product selection. Rainfall applied at both 3 and 21 days after application**

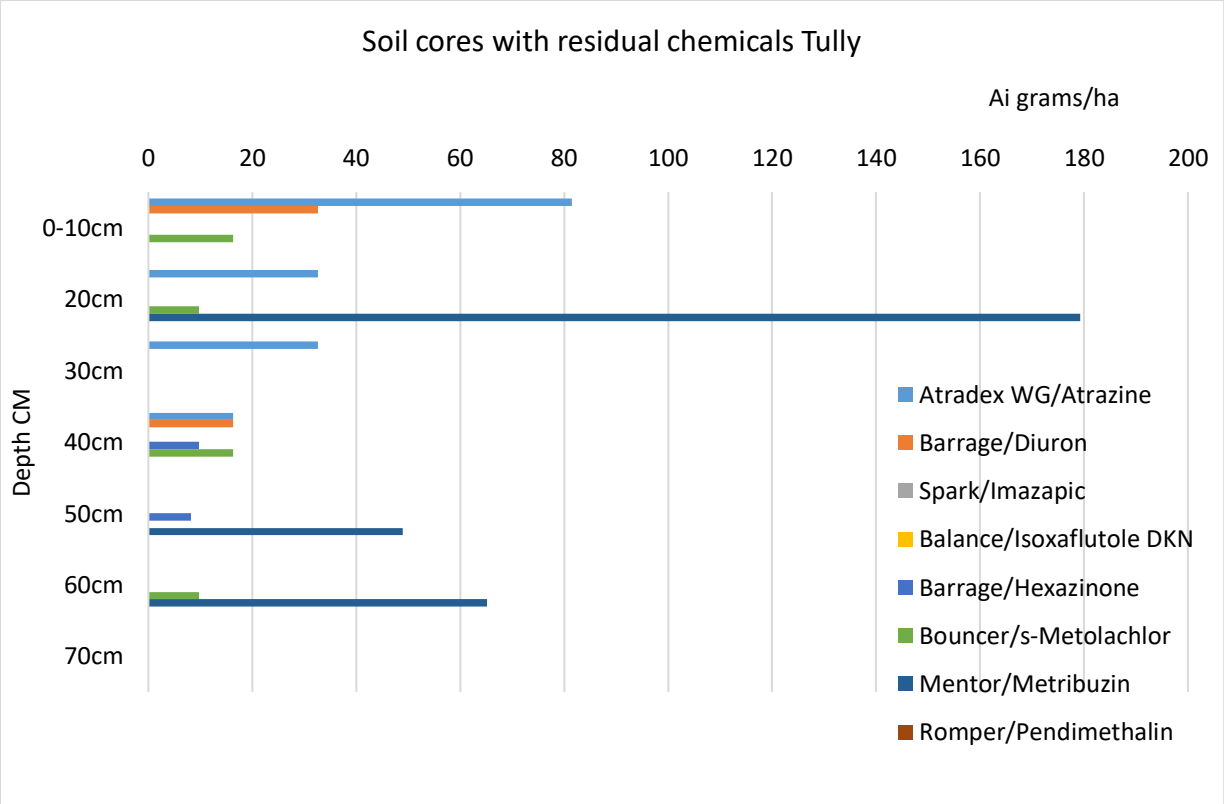


Figure 17: **Rainfall simulation results year 1; The importance of product selection for leaching. Rainfall applied at 3 days after application of residual herbicides, soil cores taken at 10cm intervals down to 70cm depth 4 hours after rainfall was applied.**

Field demonstrations

In year one of the project it was decided that field demonstrations of chemicals and application methods would be useful to support the runoff data generated through the rainfall simulation.

This was piloted through collaboration with Jack Robertson of DAF with two demonstrations of the DAF Dual Herbicide Spray bars, one in the Mulgrave area and one in the Tully area. Information on subsequent weed management as well as chemical runoff concentration data gathered using KP Samplers was presented to growers at subsequent events and directly to the growers participating in the project.

The Tully grower had very few weeds, but considered the block to be a 'dirty block' and was interested to see whether using the dual herbicide spray bars late in the season would give better vine control than the knockdown spray he was using in that situation. With such low weed pressure to begin with there was no difference in weed control between the control with no herbicides applied, broadcast residual application and the banded spray applied using the Dual Herbicide Spray bars. The outcome was the grower will continue his practice of knockdown only, and is interested in working with Marcus Bulstrode of DAF to map vine pressure across his farm using drone imagery to reduce all late season sprays, having improved confidence in his current weed control and realising there is potential to reduce herbicide application further.

The second demonstration in the Mulgrave area was to use of the Dual Herbicide Spray rig on a late-harvested block with medium weed pressure, including heavy patches of nutgrass (difficult to kill). Treatments applied included broadcast residual, banded residual with glyphosate in the inter-row and banded residual glufosinate ammonia in inter-row as well as control sections with no herbicide applied. There was little difference between the treatments other than zero-applied strips, and the Dual Herbicide Spray rig proved effective in controlling the nutgrass and all other weeds present with both glyphosate and glufosinate applied in the inter-row. Glyphosate is a much cheaper and just as effective option for controlling nutgrass as Sempra (halosulfuron) and the choice of pre-emergent (Bobcat I-MAXX: imazapic and hexazinone) provided residual control in the row for the nutgrass and difficult to kill weeds. The conditions were very good for maximising the effectiveness of the knockdowns used, with a shower of rain following application. The Dual Herbicide Spray did a good job of keeping glyphosate and glufosinate off the cane leaves, which was a good test as the block is on a hill with uneven rows. The grower purchased a set of Dual Herbicide Spray bars in year two and trialled them with a quad bike and then in year three purchased a Dual Herbicide Spray rig and worked with the project to use them on farm.

These two demonstrations provided a foundation for building this component of the project.

Increase adoption of shielded sprayers

The strategy

Protecting our Chemicals for the Future began with the goal of improving use of shielded sprayers. Project leaders had consistently heard anecdotal reports of shielded sprayers being under-used, and often un-used. The strategy was to work with growers to improve setup of the equipment and boost confidence in the practice of banding residual, thereby increasing the use of the Reef Rescue funded equipment and reducing the use of high-risk chemicals.

To achieve this:

- Terrain Natural Resource Management (NRM) database manager was contacted and a request was made to work with Terrain to contact potential grower collaborators who received funding for hooded or shielded sprayers and Dual Herbicide Spray bars
- The Wet Tropics Sugar Industry Partnership (WTSIP) leadership team was contacted for support in making contact with growers, at the request of the Terrain NRM database manager
- Tully Productivity Board contacted growers they were aware of who had received funding for purchase of banding equipment
- Local Canegrower organisation collaborators and productivity board staff were contacted to place a notice in newsletters with the offer of assistance with equipment setup and use, appropriate chemistry, and the provision of the most appropriate spray nozzles, if necessary, given many had nozzle types not suited to the shield.

The goal of being able to contact these growers and make a personal offer of assistance was not possible due to the inability to muster the required cooperation.

The project review group requested a survey be undertaken to get a better understanding of banded spray equipment use in the area. The project leader was unofficially provided a list of names, comprising a sub-set of those that received funding for spray equipment that was used for this survey. For the purpose of the survey and subsequent report, only those who received funding for band spray equipment were contacted. The report is included in the appendix. The two main findings of the survey were:

1) we use the banded spray equipment more in wet years when grass is a problem on certain blocks, and
2) we have moved away from using the spray equipment as we have adopted new chemicals (imazapic and isoxaflutole). We believe these chemicals pose less risk than the older chemicals and we are able to spray faster using broadcast equipment.

In addition to this, band spraying demonstrations were incorporated into water quality field days in both Tully and Mulgrave, in partnership with DAF (run by Jack Robertson), and the band spraying results were presented in conjunction with a demonstration of the DAF Dual Herbicide Spray rig at all grower group meetings. During these events, growers were offered support to set up their band spraying equipment. As a result, a number of growers requested support which was provided (see Table 19). All those supported to set up equipment had blocks in mind where they intended to use the equipment, and all except one grower did use the equipment that year. It should be noted that only one of the participating growers intended on using the equipment across their entire farm, the others were looking at targeting blocks where grass issues are a problem.

Table 19: Grower collaborator uptake of shielded and hooded sprayer support work

Mulgrave	Innisfail/Babinda	Tully
4	0	5

Figure 18: **Spraying with the DAF dual herbicide spray bars at Glen Anderson's farm, 2016.**

Best management use of imidacloprid

When reporting on the Great Barrier Reef Catchment Loads Monitoring Program, it was noted that the main chemicals present in Wet Tropics waterways are diuron and imidacloprid. Grower and industry organisations approached the project leader to run workshops on canegrub monitoring and best practice use of imidacloprid. This was piloted in the Mulgrave area with support from Phil Ross, SRA Pest and Weeds Adoption Officer. Four workshops open to no more than 10 growers each were run. Attendees completed application plans based on past canegrub pressure, landscape features and soil type. The focus was on improving understanding of the importance of applying chemical at the right time for effective control and encouraging growers to check fields for canegrub damage rather than simply applying the product. Water quality data showing imidacloprid trends over time was also shared with the growers. In many of the workshops there was discussion about the need to treat for canegrubs with attendees sharing their memories of devastated cane farms due to canegrub outbreaks prior to imidacloprid being available to treat for canegrubs. Feedback from the event was positive and, despite the conversation at the time, many growers who have attended these sessions have shown they are comfortable to speak up in a group situation regarding the importance of stewardship of imidacloprid.

Figure 19: Growers meet for the Mulgrave canegrub management workshop

Year 2: Project Delivery and Methods

Incorporation of grower feedback

Growers who had attended the year one events were invited to provide feedback and information on what they would like to see in a rainfall simulation event for 2017. The main feedback focused on the use of knockdowns in the after-harvest situation. Enquiries were made about methods that could include spraying on weeds, however the advice was that this was too variable. Keeping in mind that knockdown chemicals are rarely an issue in the catchment monitoring program, it was decided to focus on the residual chemicals used in cane, which would allow a better focus for messaging.

Participating growers responded well to the timing work and the information on chemical risk. There was support for the idea of a chart combining the risk factors, or a risk matrix to help with decision making in line with an understanding of the importance of timing. The majority of growers involved in the project were more in favour of a simple poster and handbook and suggested the poster could be designed for the chemical store where it would be a regular and timely reminder to them. This feedback was shared with others working in this area.

Grower collaborators in the Tully area were interested in the difference between plant cane and ratoon chemicals and conditions. In response to this query an attempt was made to investigate plant cane.

Participating growers in all areas were interested to learn how newer chemicals would behave in the banding demonstration. Through talking with growers about what chemicals they are using, it became evident that Bobcat I-MAXX (imazapic and hexazinone) is growing in popularity, has a high price point and with the hexazinone component was considered to be a potential environmental risk. In 2017 this was the chemical used for the banding demonstration, rather than Barrage (diuron/hexazinone) which has a regulated application rate of 900g/ha in the Wet Tropics and has been demonstrated regularly.

These inputs were incorporated into the treatments applied. Table 20, Table 21 and Table 22, outline the chemicals and rates applied and the circumstances.

Treatments applied

Table 20: Timing and product selection; Residual chemicals applied to ratoon cane on trash blanket at 21 and 3 days before rainfall simulation applied. All applied at maximum label rates

Active	Product (example trade name & active)	Application Rate (L or Kg/ha)
Atrazine	Atradex WG	3.3kg/ha
Isoxaflutole	Balance 750 WG	200g
Metribuzin	Mentor WG	2kg
Diuron & Hexazinone	Barrage	900g
Imazapic	Flame	400ml
Flumioxazin	Valor 500 WG	700g

Table 21: Timing and product selection; Residual chemicals applied to bare soil, preferably worked for planting at 21 and 3 days before rainfall simulation applied. All applied at maximum label rates.

Active	Product (trade name & active)	Application Rate (L or Kg/ha)
Atrazine	Atradex WG	3.3kg/ha
S-metolachlor	Bouncer/Dual Gold	1.8L
Pendimethalin	Romper/Stomp	2.25L
Diuron & Hexazinone	Barrage	900g
Imazapic	Flame/Spark	400ml
Flumioxazin	Valor 500 WG	560g

Table 22: Application method; Banded application of imazapic and hexazinone (Bobcat i-Maxx) compared to a broadcast application of diuron and hexazinone (Barrage). All products applied at maximum label rates.

Active	Product (trade name & active)	Application Rate (L or Kg/ha)
Hexazinone and imazapic	Bobcat I-MAXX	3.8L/ha

Rainfall simulation and grower report-backs

Grower collaborators were identified to host rainfall simulation events during feedback sessions and when presenting at shed meetings run by productivity boards. These growers showed great interest in the events, and in Tully and Babinda the hosts helped coordinate afternoon/evening events for growers in the district to learn about the project and rainfall simulation activity. These events were well-attended and provided an opportunity to promote other aspects of the project, such as support for using band spraying. The Babinda group were also interested in learning about steam weeding and we arranged for Bluehand Steam to come and present on the technology they are using with Cassowary Coast Council.

The rainfall simulation activities ran reasonably smoothly with the best outcomes resulting from Tully. In Tully, the participating growers made both a worked plant cane block and a neighbouring ratoon block available, both on the same soil type. In Mulgrave and Innisfail/Babinda we were able to access ratoon blocks only and cleared the trash in order to create a bare soil environment. The results from Tully were shared in all districts along with the local bare soil simulations, where compaction influenced results. We did not look at leaching in the plant cane, which could have provided some interesting results.

Figure 20: Sharing rainfall simulation results at Barry Stubbs' shed, Mirriwinni (near Babinda) 2017.

Once again, the grower meetings were run by project leader Belinda Billing with support from technical advisors and project partners Aaron Davis from JCU and Jack Robertson from DAF. Support in coordinating the meetings was provided by TCPSL in the Tully area and growers Barry Stubbs (Babinda, meeting shown in Figure 20) and Ray Zamora and Dick Camilleri (Tully) also helped bring together growers.

Grower group meetings were held late in the season to share results. The agenda included:

- Explanation of rainfall simulation and the treatments applied
- Results from the rainfall simulation demonstrations (example of results Figure 21, Figure 22 and Figure 23)
- Explanation of various chemical risk factors (eco-toxicity, persistence, adsorption and solubility) with an updated chemical risk matrix hand out (updated using data from the Draft Consensus Statement)

- Explanation of banded spraying and a demonstration from project partner DAF using a mobile display
- Discussion on how this information can be used to improve water quality in the district
- Field walks in grower demonstration sites and results from weed monitoring and economics

Once again, the grower meetings were structured to support small group work with time for questions and informal discussion with the project staff. The field walk component proved popular with growers and enabled them to see some of the strategies discussed in action. Table 23 shows the attendance at both the rainfall simulation demonstration and the grower feedback sessions. Two of these sessions included resellers and were run with Allan Blair (DAF) who provided additional chemical behaviour information and demonstrations.

Table 23: Grower collaborator attendance at rainfall simulations and feedback sessions

Mulgrave groups	**Innisfail/Babinda Group**	**Tully Group**	**Additional**
10 growers SRA Meringa station	10 growers Babinda	24 growers Euramo	Mossman Agricultural Services Board and staff
12 growers Fishery Falls	5 growers South Johnstone	15 Tully Rec Hall	BPS / SRA bus tour from Burdekin
10 growers Barron Delta	5 staff Innisfail GrowForce	12 growers El Arish	Cane Changer/Cane to Creek ladies tour of SRA
Simulation: 4	Simulation: 8	5 growers Syndicate	
		Kennedy; 5 growers	
		5 staff Tully GrowForce	
		Simulation: 12	

Rainfall Simulation Results 2017

As with the 2016 rainfall simulation results (shown in Figure 21, Figure 22 and Figure 23), rate was the main driver of quantity lost to the environment for the majority of the products demonstrated. In the plant cane demonstration, pendimethalin and flumioxazin contradicted the simple message of Less on = Less off, due to the very high adsorption co-efficient of the products and the tendency of flumioxazin to split into three metabolites once in solution.

This provided useful material for discussion with growers, utilising an updated version of the risk matrix, to provide context to how the different factors can influence losses to the environment. Herbicide eco-toxicity data was updated using the 95% protection values published in the draft Reef Plan Scientific Consensus Statement. Growers were relieved to learn that newer products, imazapic and isoxaflutole, were less toxic than diuron and resulted in less loss to the environment even when compared to diuron applied at the regulated rate for the Wet Tropics.

The timing demonstration (chemical applied 3 days and 21 days prior to rainfall simulation) was very effective particularly in Tully where 100mm of rain that did not runoff fell over the three weeks between application of herbicide and the rainfall simulation.

The banding demonstration again showed that residual losses could be halved using this technique. Bobcat I-MAXX was used, as it is a popular and reasonably costly product where economic benefits could be derived from banding.

In 2017 key messages Less on = Less off and Timing Really Matters were developed using the simulation material.

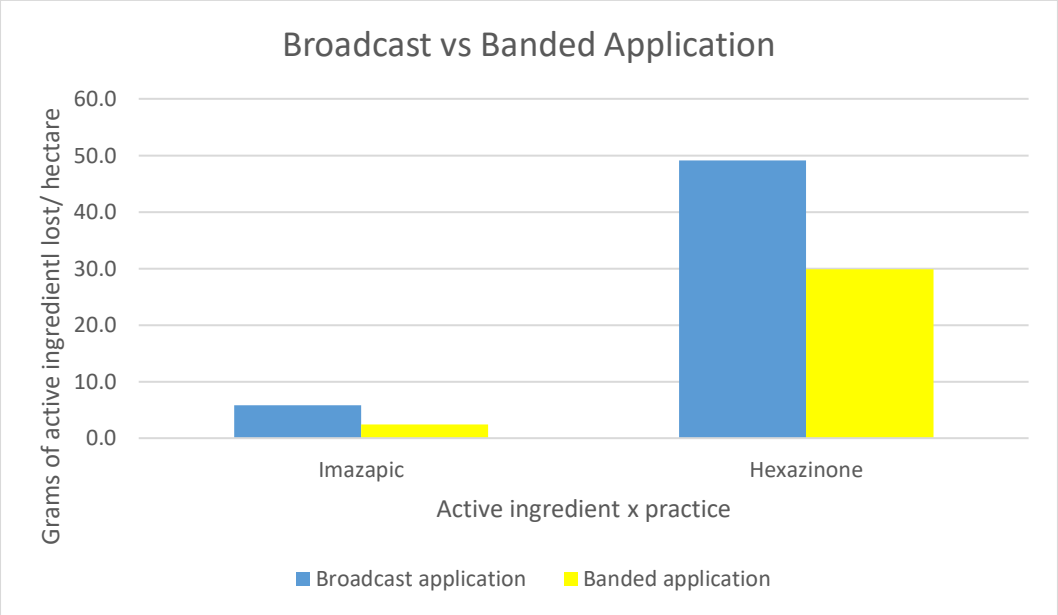


Figure 21: Rainfall simulation results 2017; Broadcast vs banded application results from Mulgrave rainfall simulation 2017; Bobcat i-MAXX (diuron and hexazinone) applied to ratoon cane with trash blanket 3 days prior to rainfall simulation.

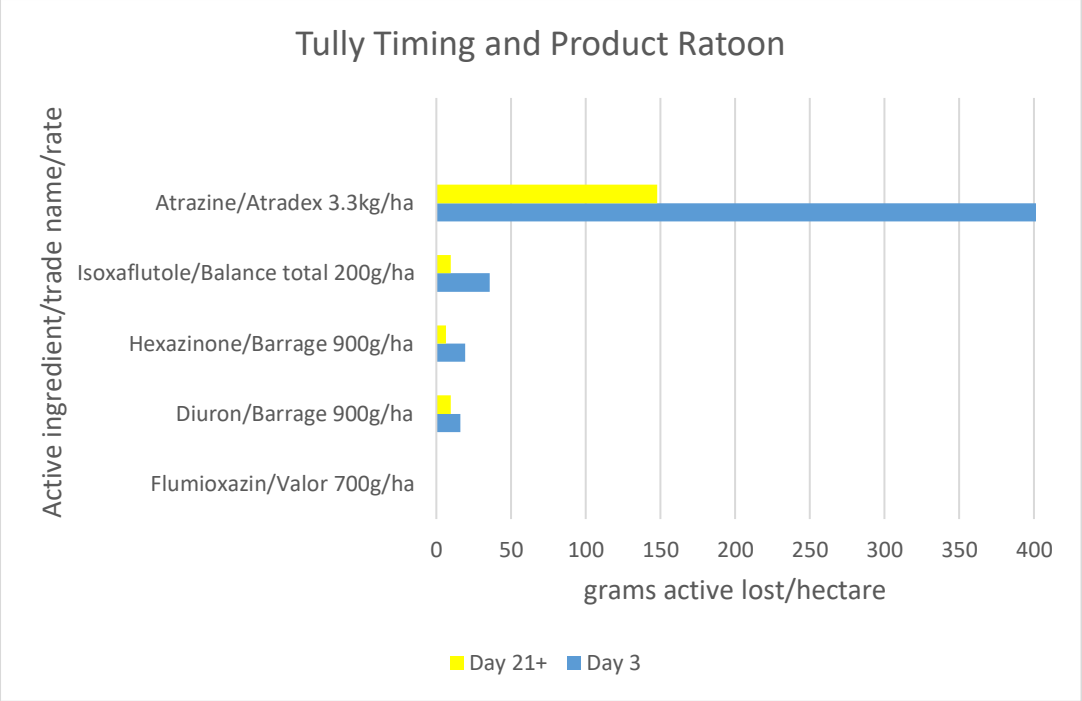


Figure 22: Rainfall simulation results 2017; Timing and product selection Residual chemicals applied to ratoon cane with trash 21 and 3 days before rainfall simulation applied. All applied at maximum label rates.

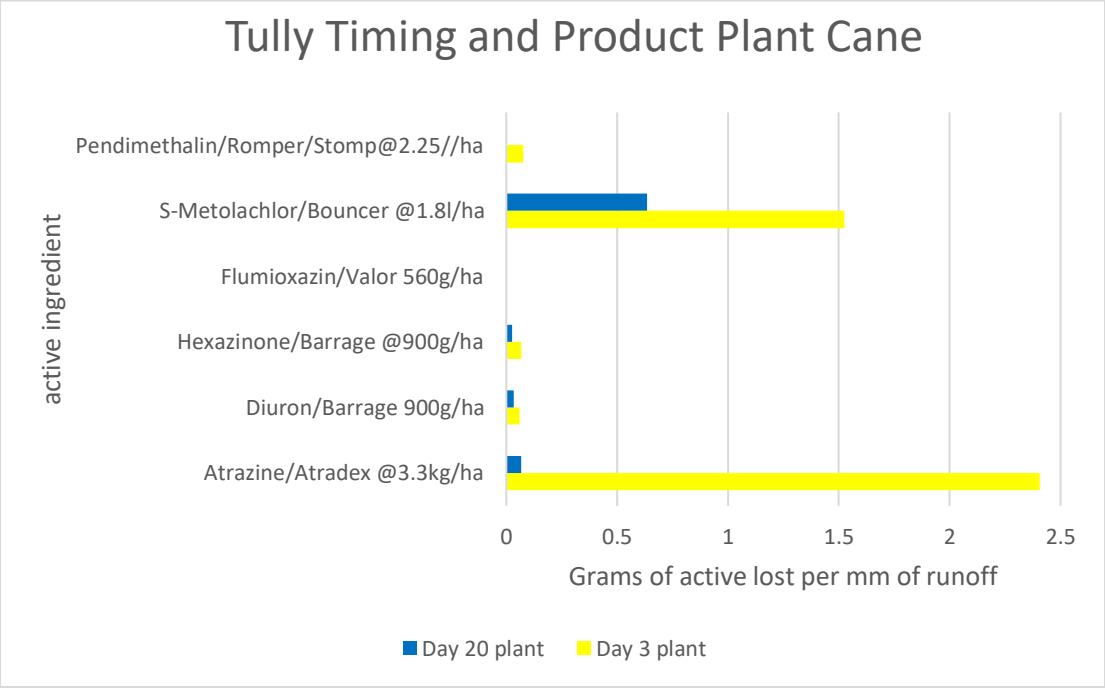


Figure 23: Timing and product selection; Residual chemicals applied to bare soil worked for plant cane 21 and 3 days before rainfall simulation applied. All applied at maximum label rates. Tully simulation.

Field demonstrations

During the first year project review meeting it was decided to run one rainfall simulation in each district per year and to support the simulation with field demonstrations that address questions raised by growers relating to the principles promoted through the rainfall simulation activity. Where suitable, this was supported with KP Samplers to capture initial runoff and analyse for chemical loss at the field scale.

These demonstrations were monitored for efficacy and reports were given to grower groups on cost, efficacy and water quality impact. Grower group meetings were held on site in Innisfail and Tully with site inspections. Growers in the Barron area were able to inspect the banding site.

Growers involved in demonstrations continued to investigate the practice alone or were satisfied with the result and made a change. Some field fact sheets were developed from the most successful demonstrations and some were included in SRA's Cane Connection magazine. The fact sheets are included as Year 2 Field Fact Sheets. The list of demonstrations completed are in Table 24. Examples of case studies completed based on these field demonstrations are included in Appendix 1.

Table 24: Year 2 grower collaborator demonstrations by district

District	**Specific Practices**			
Mulgrave	band spray vs broadcast	trialling modern herbicide, grower practice comparison	trialling modern herbicide, grower practice comparison	
Innisfail/Babinda	comparing modern residual herbicides in ratoon cane	comparing modern residual herbicides in plant cane, grower practice comparison		
Tully	zonal application of residuals to target problem areas.	comparing new residual herbicides	single pass spray program	Knockdown only compared to common Tully residual use (2 passes) in ratoon cane

Canegrub strategies

Grower shed meetings were held in Tully and in the Mulgrave area to discuss historic grub infestation patterns in the areas and current use of imidacloprid products Table 25 shows meetings and attendance). During these meetings, growers were shown large format images of drone photographs taken of nearby blocks where growers suspected that canegrubs were present. It was hoped that growers would come and look at sites identified by the group as potential canegrub damage, however this was taken up by very few growers. Drone footage was taken by Marcus Bulstrode of DAF and at one site did reveal grub damage. In another site it revealed pig damage, the other sites helped identify where to look and showed stool tipping in one case and lodging in another, but no canegrubs.

SRA's new entomologist Dr Kevin Powell spoke to the growers about canegrubs and how they currently manage them. He presented past work he has done in vineyards using hyperspectral imaging from drones to detect early damage from soil-borne pests and discussed the potential of such technology in sugarcane.

Growers were also introduced to the concept of the DAF StoolZippa with footage played and a display of the StoolZippa at Tully.

Growers attending were asked if they have made changes to the way they manage imidacloprid and if so, what changes had they made. In Tully, growers reported moving to treating every second year and returning to treating only areas that had historic damage. Tully Sugar Limited (TSL) agronomist Greg Shannon reported that growers were being encouraged to check for pachymetra if they see symptoms such as stool tipping and drying cane, rather than assuming they have canegrubs and treating. In the Mulgrave area growers reported they were now only treating plant cane. Some had changed to suSCon maxi Intel while others were treating their plant cane with liquid imidacloprid. Some growers were reducing the treatment area to that area that has had historic canegrub pressure. The Nufarm staff have been promoting suSCon maxi Intel as being less available for runoff due it its slow release formulation. SRA's research agronomist Emilie Fillols is currently undertaking independent research into the differences between the two products. Many grower collaborators with farms, or sections of farm that has a long history of high canegrub activity, have made the decision to use this product, which does come with a higher price tag. Protecting our Chemicals staff have not taken strong public position on this as the research is still underway, with the exception that, if growers were previously applying liquid imidacloprid to these blocks annually, there is an overall reduction in active ingredient applied over four years if covered by the slow release product.

Encouragingly, in every meeting, a grower spoke up about the need to show greater stewardship of the chemical. This was a shift from the previous years' Mulgrave workshops where conversation tended to focus on memories of historic canegrub outbreaks in the local area and the need to prevent a re-occurrence. In 2018 no water quality data was presented, however growers made comments about the need to not use imidacloprid as an insurance policy. They shared strategies they were adopting, such as focussing on plant cane and pointed out that heavy soils rarely saw infestations. In both years growers commented that they did not think canegrub pressure was high and that water quality issues related to imidacloprid are an issue that threatens the industry. The grower collaborators in 2018 appeared more confident of being able to apply strategies to reduce usage while not encouraging an outbreak. This included Mulgrave growers, and included those growers that had led the previous years' more negative commentary. This indicates that these growers are spending time thinking about these issues outside of the workshops. It may also be related to the combination of information; many of the growers had attended the Water Quality

Field Days where Ryan Turner had highlighted imidacloprid as an issue in Wet Tropics waterways, and had shown a degree of improvement in the Tully River, which resulted in a positive 'can do' attitude from many.

In the Innisfail/Babinda districts we attended the Innisfail/Babinda Cane Productivity Services Limited (IBCPSL) Trade Night to promote the project and talk to growers about canegrub control and imidacloprid stewardship. This was a good way to meet growers from the area and to raise the issue of imidacloprid stewardship. Growers spoke openly about their use of the product and showed an interest in comparisons between the liquid and granular products. Many of these growers are farming on red soil hills which are attractive to cane beetles (adult form of canegrub). It was interesting to learn that many of the growers would consider using the granular product if they could be sure that it was a better environmental option to the liquid. As with Mulgrave growers, a number have already made this change believing it to be the case. While there is a time saving benefit to using the granular suSCon product, it is more expensive than the liquid form.

During this event growers moved from stall to stall in small groups, enabling focused discussion and time for questions. Information on imidacloprid stewardship was also provided to growers and extension providers attending the Meringa Water Quality Field Day, with presentation by Jack Robertson (DAF) with support from Mark Rantucci (Nufarm) and Tony Fitzgerald (Bayer). This included a display and information on the StoolZippa and correct placement of liquid and granular imidacloprid formulations.

In addition SRA collaborated with TSL to host a resellers' information evening with information shared on imidacloprid stewardship along with a variety update, which fitted in with the push to get growers and advisors to investigate the source of cane stool damage rather than assume that they need to treat for canegrubs. This event was run at the request of Landmark, local resellers who had questions about the imidacloprid issue and pachymetra.

Additional promotion of the concept of responsible use of/stewardship of imidacloprid was provided by Tony Fitzgerald of Bayer (project partner) who presented at all Tully Productivity Services Shed meetings. Tony spoke about the concept of using drones to identify damage, understanding historic areas of high-pressure damage and showed the StoolZippa. Tony's messages was clear to all, use this product wisely.

Table 25: **Year 2; Canegrub and imidacloprid management effort**

District	No. meeting	No. attending
Mulgrave	2	20
Tully	2	16
Innisfail	1	20
Meringa Water Quality Field Day	1	40

Banded sprayer adoption

Figure 24: **Jack Robertson (DAF) assists grower collaborator Doug Hardwick with his hooded sprayer.**

In 2018 there was a greater focus on canegrub/imidacloprid strategies than work to support banding of residual herbicides. The growers the project worked with were all intending to use the banding equipment that year. The project worked with the group of growers in the Barron Delta who had indicated an interest in banding technology. Growers within the group have hooded sprayers and a dual herbicide sprayer (DHS); however, they are not currently using them. Growers requested a demonstration of the effectiveness of band spraying, which was implemented with a key local grower, who uses his farm as a focal point for the Barron grower community. Efficacy results from this work have been shared with the growers along with water quality data to remind them of the reduction in losses. Jack Robertson (DAF) worked with SRA to demonstrate correct set up of the DHS for the demonstration and showed the impact of correct nozzle selection in the hooded sprayer. As a result of this work a local grower who contract sprays for many of the growers in the area will be band applying any residual herbicide used late in the year (this will be targeted at blocks with vine issues – knockdown only strategies will be used where weed/vine pressure is low).

SRA and DAF project staff have worked with a Mulgrave grower who trialled the DAF DHS through the project in 2016/17. He has since purchased a set of DHS spray legs and is receiving assistance in using the equipment. By 2019 the grower reported he was using the DHS across his farm.

An Innisfail grower who received assistance has been using his hooded sprayer intermittently since purchase and has requested assistance to use the equipment more effectively. SRA and DAF staff worked with the grower to replace nozzles and set up the sprayer correctly. It was used in a field-based demonstration for Protecting our Chemicals and he will now use the hoods strategically on his farm. Monitoring of the demonstration showed this grower needs additional support to manage his weeds effectively.

Table 26: Year 2 assistance with hooded and shielded sprayers.

Mulgrave	1
Innisfail/Babinda	1
Tully	1

Year 3: Project Delivery and Methods

Incorporation of grower feedback

Grower/industry feedback meetings were held in Tully and Gordonvale and project lead Belinda Billing attended Innisfail BMP meetings to talk to growers to gain insight into local interests in the final rainfall simulation and field activities for the project in its' final year.

Growers indicated they were satisfied with the results of the plant cane rainfall simulation, which compared products and timing. The plant cane results clearly showed that the pendimethlin was a standout performer and highlighted that there was an opportunity to replace the atrazine that is commonly used in conjunction with the pendimethalin.

Questions raised in these discussion groups were:

- A desire to learn more about the fate of flumioxazin (which is rarely picked up in runoff, but we have learned metabolises quickly in solution)
- A desire for more efficacy work on new chemicals that can help with vine issues (flumioxazin and amicarbazone)
- Request for simulation work on amicarbazone, a new herbicide being heavily promoted in 2018. Emilie Fillols (SRA) has done initial simulation work on this product and growers have requested additional work to be done through Protecting our Chemicals for the Future so that it can be discussed in an extension context.
- Growers pointed out that the maximum label rates used in rainfall simulation work does not represent the rates they use of some products and requested that the common rates they use be compared to the maximum rates.
- Growers in Tully asked to see if we could conduct a simulation to look at losses after herbicide is applied to very wet to saturated soil, as if herbicide is applied during the wet season.
- A request was made to look at newer products applied as a band compared to broadcast.

All of these requests were taken on board and worked into the program for 2018/19. Treatments applied are shown in Table 27, Table 28, Table 29, Table 30 and Table 31.

Since inception the project has worked with ACS laboratory in Melbourne for analysis of chemicals in water, trash and soil samples. The project funded the laboratory to purchase standards and develop a method for testing for two of the metabolites of flumioxazin in order to get a better idea of what is leaving the field in rainfall simulation. The laboratory was not able to source the third known metabolite. Aiming for consistency, flumioxazin was applied at one rate across all treatments.

Table 27: Timing and product selection Residual chemicals applied to ratoon cane on trash blanket at 21 and three days before rainfall simulation applied. All applied at maximum label rates

Trade name	Active ingredient	Rate/ha
Atradex WG	atrazine	3.3kg
Balance 750 WG	isoxaflutole	200g
Bouncer 960 S/Dual Gold	s-metolachlor	1.8L
Barrage	diuron/hexazinone	900g
Flame/Spark	imazapic	400mL
Tomahawk/Mentor WG	metribuzin	2kg
Amitron	amicarbazone	800g
Valor	flumioxazin	700g

Table 28: Timing and product selection; Residual chemicals applied to ratoon cane on trash blanket at 21 and 3 days before rainfall simulation applied. Applied at commonly used grower rates.

Trade name	Active ingredient	rate /ha
Atradex WG	atrazine	2.2kg
Balance 750 WG	isoxaflutole	150g
Bouncer	s-metolachlor	1.8L
Barrage	diuron/hexazinone	900g
Flame	imazapic	300ml
Mentor WG	metribuzin	1.5kg
Amitron	amicarbazone	800g
Valor	flumioxazin	700g

Table 29: Product selection in a worst case scenario; Residual chemicals applied to saturated ratoon cane on trash blanket at 1 day prior to rainfall simulation. All applied at maximum label rates

Trade name	Active ingredient	rate /ha
Atradex WG	atrazine	3.3kg
Balance 750 WG	isoxaflutole	200g
Bouncer	s-metolachlor	1.8L
Barrage	diuron/hexazinone	900g
Flame	imazapic	400mL
Mentor WG	metribuzin	2kg
Amitron	amicarbazone	1kg
Valor	flumioxazin	700g

Table 30: Product selection in a worst case scenario; Residual chemicals applied to saturated ratoon cane on trash blanket at 1 day prior to rainfall simulation. Applied at commonly used grower rates.

Trade name	Active ingredient	rate /ha
Atradex WG	atrazine	2.2kg
Balance 750 WG	isoxaflutole	150g
Bouncer	s-metolachlor	1.8L
Barrage	diuron/hexazinone	900g
Flame	imazapic	300ml
Mentor WG	metribuzin	1.5kg
Amitron	amicarbazone	1000g
Valor	flumioxazin	700g

Table 31: Application method; Banded application compared to a broadcast application using high and low rate chemicals. All products applied at maximum label rates.

Trade name	Active ingredient	rate /ha
Atradex	atrazine	3.3
Barrage	diuron/hexazinone	900
Balance	isoxaflutole	150
Amitron	amicarbazone	1000

Rainfall simulation and grower feedback sessions

As with previous years, growers and extension staff were invited to attend the rainfall simulation events, with an invitation to call in any time. This provided an opportunity for staff from the Wet Tropics Major Integrated Project (WTMIP) and DNRM staff to have a look at a tool they have been considering using in their own work. Grower collaborators in the Mulgrave and Tully areas took the opportunity to participate in conducting the rainfall simulation under the direction of project staff. This resulted in a greater understanding of the work involved in conducting a rainfall simulation. Members of the SRA and Cairns Region Cane Growers boards attended the Mulgrave event. Grower collaborators agreed to be there for a presentation to the boards to help demonstrate how the rainfall simulation activity works.

Group meetings were held in early 2019 rather than November 2018 as had been planned. The delay was due to additional time taken at the laboratory to develop the method for analysing for flumioxazin metabolites (482-HA and APF). The timing worked out well with attendance high (see Table 32 and Table 33) at all locations and many growers preparing to spray for vine. This is a high-risk application with wet soils and runoff highly likely. This provided an opportunity to highlight the risks involved with application of residual herbicides close to, or within, the wet season.

Figure 25: **SRA technician Chris Sterling runs the rainfall simulator in Bartle Frere.**

Engagement in the Innisfail/Babinda area was more successful in the 2018-19 year following on from effort made to meet and talk to growers through the Smartcane Best Management Practice (BMP) Program and the Cane Changer project grower meetings along with attendance at the IBCPSL Trade Night the previous year. Growers and local extension staff attended the rainfall simulation event and two very successful grower meetings were held. There was also an increased interest in field demonstrations in the area in the final year. Events and attendance information is shown in Table 32 and Table 33.

In addition to sharing the rainfall simulation activity results, grower demonstration activities were also shared with growers. This enabled conversation to cover both risk and efficacy of products and application methods promoted through the rainfall simulation data.

An updated version of the handout detailing chemical risk factors was also used to provide context such as eco-toxicity values of chemicals discussed, adsorption, solubility and persistence. The hand-out from the previous year was updated to include new trigger values for Atrazine and 2,4-D (freshwater), and information was checked by Great Barrier Reef Marine Park Authority (GBRMPA) staff (Figure 30). In the 2019 grower group meetings it was good to see growers using the information to talk to each other about what products would work in the dry conditions experienced during that season while limiting risk. Long-term project participants were followed up with phone calls to discuss changes they were considering making, informed by the combined chemical risk factors and rainfall simulation information. This has been the goal of the project; not to provide a list of chemicals to use and chemicals to avoid, but simple principles connected to detailed information that allow growers to make varied decisions across the season, their farm and the year in question.

The group meetings also provided an opportunity to update growers and to answer any questions on the new 2,4-D legislation, with Jack Robertson (DAF) attending most meetings to provide the update and Belinda Billing providing details where this was not possible. Adherence to the new 2,4-D labels

has not been included in the practice change data set, however grower collaborators have taken the advice on board and many have independently reported changing nozzles and those that have utilised aerial application have changed from 2,4-D to MCPA in order to remain within the guidelines.

Rainfall simulation results 2018/2019

Grower feedback was incorporated into the rainfall simulation activities for 2018/19 and allowed for the development of an interesting snapshot that highlighted the key messages of less on = less off and timing really matters quite dramatically (Figure 26). Data from the grower requests for more commonly used rates and the Tully query regarding application to wet soils was put together in a single graph that included products of varied required rates (from effective at high rates to effective at low rates), banding and the timing demonstration work. This Snapshot graph summarises the work and key messages very effectively and provided a great starting point for group discussions. This graph was used for discussion following along with those presented in Figure 27, Figure 28 and Figure 29.

- Grower rates did result in lower losses, however products that provide effective residual control at 400g/ha or less were highlighted as having less risk that products that work at 2 or 3 kg/ha.
- Application to wet soil added to the message of timing really matters and allowed for emphasis on the risks involved with applying residual herbicides in the wet season.
- Analysing for the metabolites of flumioxazin showed that the product does move, although analysis typically only found one of the two breakdown products and occasionally some of the parent material. This lines up with the adsorption coefficient and solubility data that is included in the risk matrix information sheet that shows flumioxazin is more mobile than pendimethalin, but less mobile than products such as diuron, metolachlor and certainly far less mobile than atrazine and hexazinone.
- Banding of low rate products such as isoxaflutole showed that losses are halved when compared to broadcast application regardless of the rate of product applied and that banding of such products has the potential to greatly limit losses of residual herbicides applied close to the wet season.
- A double sided A3 handout combining key messages for reducing losses overall and the risk matrix information was provided to all growers, eco-toxicity data was updated with help from the Office of the Great Barrier Reef (Figure 30).

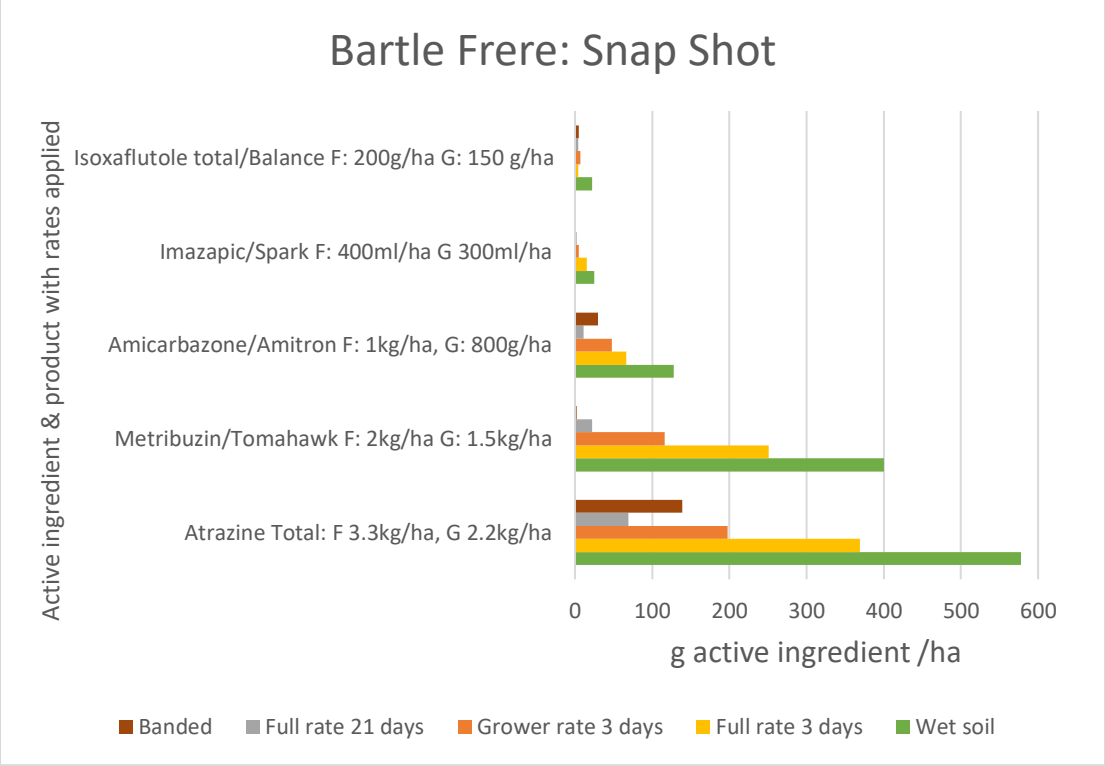


Figure 26: **Rainfall simulation results 2018/19; Babinda/Innisfail rainfall Simulation results snapshot, timing, application method and product selection make a difference.**

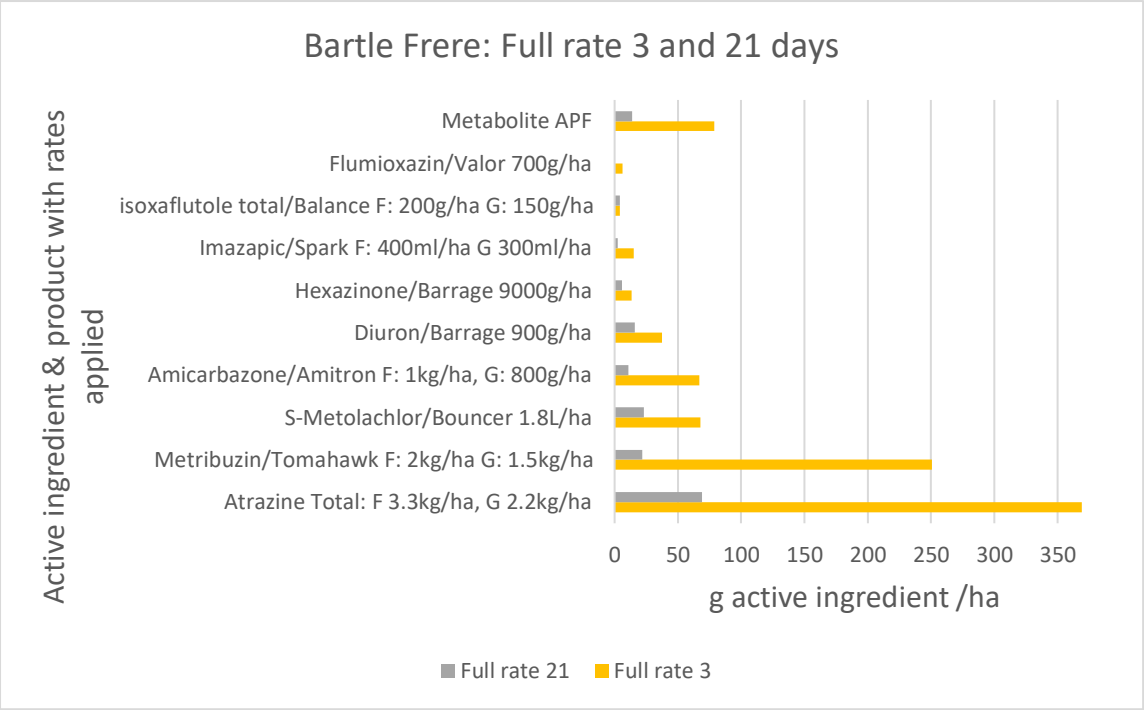


Figure 27: **Rainfall simulation results 2018/19; Timing and product selection Residual chemicals applied to ratoon cane on trash blanket at 21 and 3 days before rainfall simulation applied. Applied at maximum label rates.**

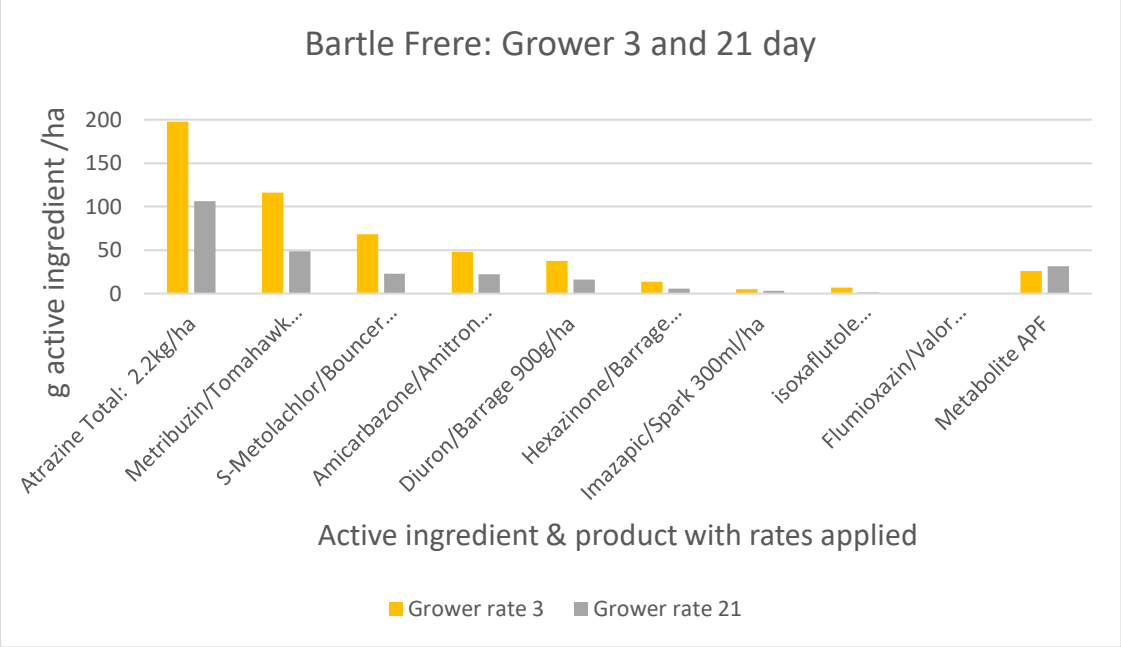


Figure 28: **Rainfall simulation results 2018/19; Timing and product selection Residual chemicals applied to ratoon cane on trash blanket at 21 and 3 days before rainfall simulation applied.**

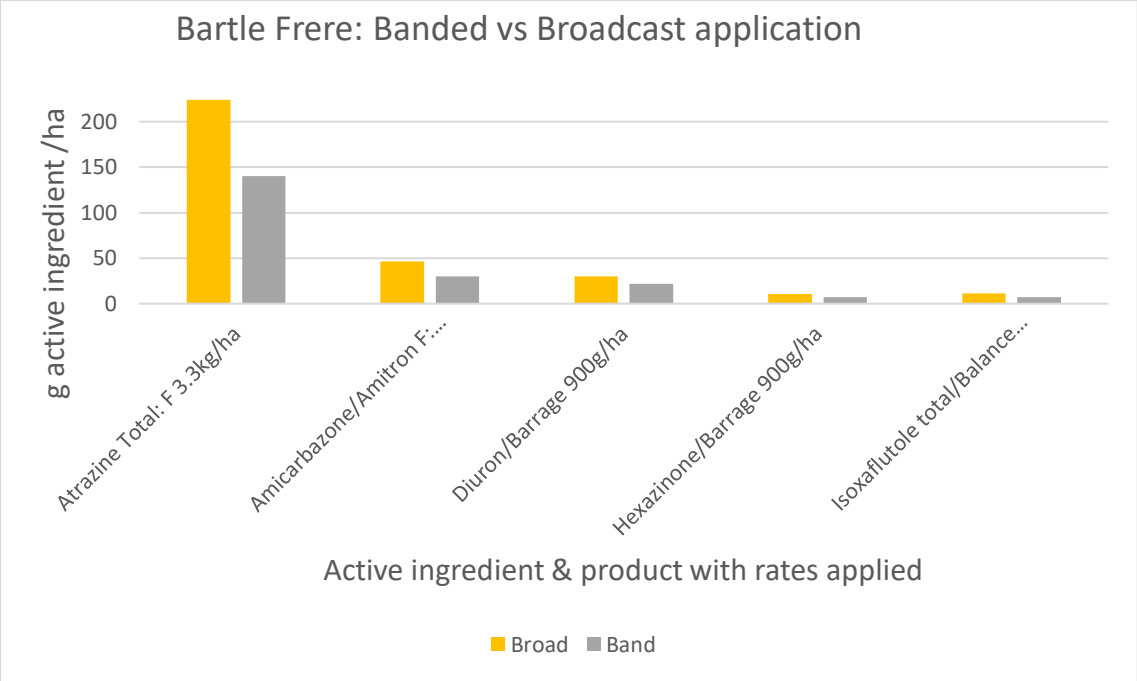


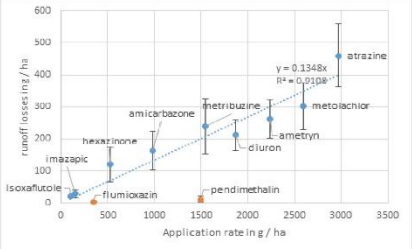
Figure 29: **Rainfall simulation results 2018/19; Broadcast vs banded application results, products applied to ratoon cane with trash blanket 3 days prior to rainfall simulation. Products with a lower application rate reduces losses further with banding.**

Managing environmental risk: **Environmental risk can be managed with careful decision-making based on the following principles.**

#1 Less on = Less off

Reduce the amount applied through

- Banded application: use shielded or hooded sprayers or a dual spray bar.
- Strategic application: create zones across the farm, or within block where residuals herbicides are only applied as required.
- Lower rates: choose products that are effective at a lower rate and where possible choose the lowest effective rate or all chemicals.



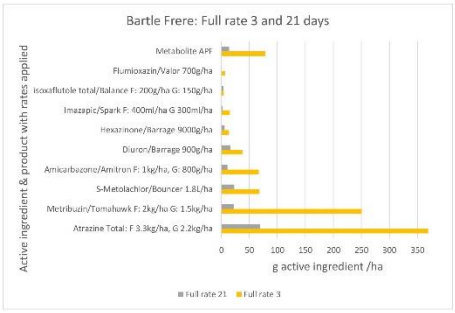
Runoff Loads Compared to Application Rate. Fillols, E 2018.

This chart shows a strong correlation between rate applied and runoff losses (R2 = 0.91). This shows that for all the herbicides on this line, you could expect to lose on average 13% of applied herbicide if run-off occurs after 48 hours or so. This suggests that APPLICATION RATE is the major influence on losses, e.g. Barrage at 4 kg vs Balance at 150 g – both have potential to lose 13% but in absolute volumes losses from Balance are smaller. Pendimethalin and flumioxazin do not fit this correlation, and have minor run-off losses.

#2 Pay attention to timing

The risk of losses of chemical (or any other ag input) to the environment through runoff or leaching is greatly reduced where there is adequate time between application and rainfall that runs off.

Any rain (or irrigation) that falls between application and a runoff will further decrease losses. The risk of loss to the environment is low early in the season and increases closer to and within the wet season.



The importance of timing in reducing runoff, Billing, B 2018

This chart shows runoff from residual chemical applied at 21 days and 3 days before rainfall simulation run to the point of runoff. 100mm of infiltrating rainfall fell between application at 21 days and rainfall simulation. Note greater losses from products applied at higher rates.

#3 The right product. At the right rate. In the right place. At the right time.

- Where the risk of loss is high choose the most suitable products with the lowest eco-toxicity and, or rate for the job.
- The lowest risk will likely come from knock down chemicals that often have lower eco-toxicity and a short half-life.
- Consider strategic application of more risky chemicals, e.g. earlier in the season or only apply where they have the greatest use.

2

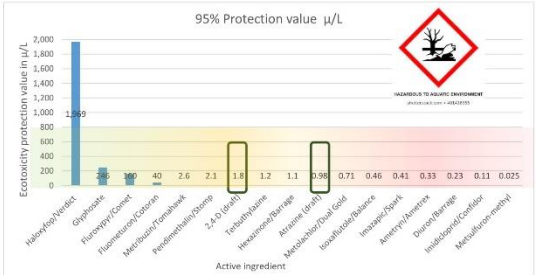
The Herbicide Risk Matrix

Risk Factors

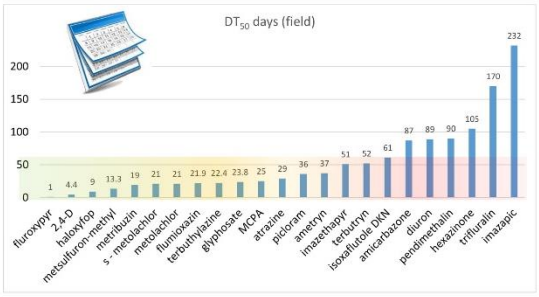
Chemical environmental risk is composed of four factors:

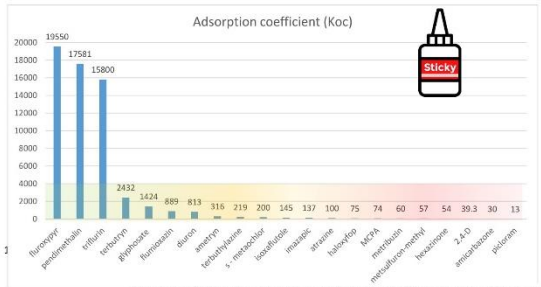
- Chemical environmental toxicity
- Chemical application rate
- Chemical half life (persistence)
- Chemical mobility (solubility + KoC)*

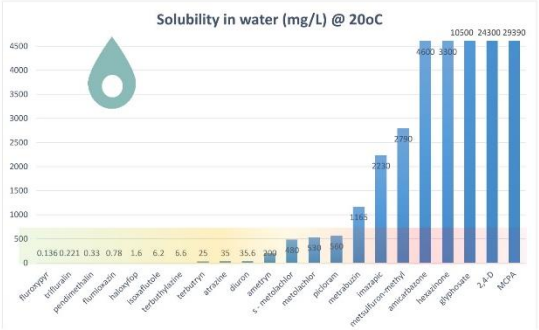
The most influential factors are rate and environmental toxicity followed by half-life, particularly where the half-life is very low. **Mobility can overcome the effect of rate where the KoC is very high for example pendimethalin.*



95 Percent species protection values for herbicides – the smaller the number the more toxic the chemical (to a range of fresh water species). *Source: Waterhouse et al, 2017 Scientific Consensus Statement 2017: A synthesis of the science of land-based water quality impacts on the Great Barrier Reef, Chapter 3. Atrazine and 2,4-D values are draft values provided by DES*







Data sources, Pesticide Properties Database, University of Hertfordshire https://sitem.herts.ac.uk & Kegley, S.E., Hill, B.R., Orme S., Choi A.H., PAN Pesticide Database, Pesticide Action Network, North America http://www.pesticideinfo.org/

Figure 30: **Understanding the herbicide risk matrix hand out, updated for final reporting to growers 2019.**

Table 32: **Year three Rainfall simulation attendance**

Mulgrave	Innisfail/Babinda	Tully
15 grower collaborators+ SRA board visit and presentation	Babinda/Mirriwinni 10	Murray Upper 5

Table 33: **Year three grower group work attendance**

Mulgrave group	Innisfail/Babinda Groups	Tully Groups	Additional updates
15 SRA	Babinda/Mirriwinni 10	Murray Upper 20	Mossman AGM + Water Quality Information Day
10 Fishery Falls	Innisfail 15	Euramo 14	Tully extension and resellers group
Barron 8	GF Rural 6	El Arish 4	Pachymetra and canegrub information sessions with TSL for Tully resellers
		GF Rural 4	WTSIP Cane Technical Advisory Group (CTAG)
			Tablelands Awards night – guest presenter

Canegrub and imidacloprid management

In the final year of the project a multi-faceted approach was taken to the improving of imidacloprid management:

1. Discussing canegrub-prone areas and known canegrub pressure with grower groups (8 groups), with a focus on querying use of imidacloprid on low lying heavy soils. Growers did not believe pressure was high, although some canegrubs were found in the Barron delta, where growers have not been applying imidacloprid due to known low pressure, growers in the Tully Murray reported some pressure in areas known to have regular canegrub pressure.

2. Working with DAF to showcase the Stool Zippa, which has provided a foundation for discussion around placement of chemical. Focal points for discussion are ensuring depth of application and highlight that the slot that may remain open after application is most likely to occur on heavy clay soils, where imidacloprid is unlikely to be required. A demonstration using the Stool Zippa was undertaken with TSL, comparing application of imidacloprid with and without the Stool Zippa. Water quality testing of paddock-scale runoff showed one replicate without Stool Zippa had elevated losses. It is thought that this was likely due to not

attaining correct depth of application (10cm) rather than not achieving closure of the application slot (all treatments were checked and appeared to have good closure). SRA will work with TSL in 2019/2020 to run a similar demonstration comparing conventional commercial application with the Stool Zippa and conventional application with close attention to meeting label application guidelines. Discussion and demonstration on application, product stewardship and the potential of the Stool Zippa was a part of both the Tully and Mulgrave Water Quality Field Days. This was led by project sponsors Nufarm and Bayer, with DAF contributing to the Bayer presentation with the Stool Zippa on display at both events.

3. Is it pachymetra or is it grubs? SRA collaborated with TSL and the TPSL to host extension providers and resellers in the Tully area at an evening workshop to understand the difference between pachymetra and canegrubs. TSL has again undertaken broadscale pachymetra sampling and created district maps detailing pachymetra pressure which has been presented at all productivity services updates. Grower collaborators in the Mulgrave area were taught how to sample for pachymetra and nematodes, with information provided on pachymetra resistant varieties and reminded not to assume that canegrubs are causing stool tipping, dry cane tops etc during the water quality field day. New SRA staff member Will Higham ran this session and included information on how to tell the difference between canegrub damage and pachymetra damage to cane roots. Following this event, the project leader sent a number of soil samples to the SRA Tully laboratory for testing (from attending growers). Productivity services staff and MSF staff are also behind the message which addresses two issues that are of concern for them – lack of variety rotation and a reliance of varieties that are not resistant to Pachymetra, and regular exceedances of imidacloprid detected in GBR Catchment Loads Monitoring Program. Productivity service officers have been assisting growers with soil sampling.

The Tully mill area was very pleased to hear that they have managed to reduce losses of imidacloprid. This good news story has provided much needed positive feedback to the grower group who are determined to keep up with work through Cane to Creek 2.0.

Following a phone call from grower collaborators from the Innisfail area, a canegrub and pachymetra shed meeting style workshop was held in South Johnstone with 24 growers and advisors attending. The event was supported by the local productivity services and Canegrower organisation who had staff attend to both learn (new staff) and reinforce the messaging (more experienced staff).

Water Quality Field Days and additional events and getting the message out

Water Quality Field Days were held in Tully (December 11) and SRA Meringa (May 8) as an opportunity to engage a wider group of growers and extension providers and to share the local work that is being done to support improvements in water quality. These events have provided an opportunity to attract new grower collaborators to the program, and from the outset have offered that opportunity to all local industry providers.

The December 11 event had excellent collaboration from the Tully sugarcane industry, and it is clear the event has been taken on as an annual event for all. Costs for the event were shared between the WTMIP, Canegrower organisation and SRA. The Field Day presentations and group work included:

- John Armour presented early results from the Tully WTMIP monitoring program and GBR Catchment Monitoring data on behalf of Ryan Turner who was unable to attend.

- Jack Robertson (DAF) spoke about band spraying and 2,4-D label updates
- Greg Shannon (TSL) and Tony Fitzgerald (Bayer) spoke about the DAF Stool Zippa (the TSL fertiliser box with Stool Zippa attached was on display).
- Greg Shannon (TSL) discussed legume fallows and accounting for legume N.
- Peter Becke (WTSIP) discussed the WTSIP innovation projects.
- Fiona George (MIP) took growers on a bus tour of some of the WTMIP monitoring and wetland sites.
- Local grower Ray Zamora closed the event with a talk on the changes he has made on his farm and what being a sustainable grower means to him.

Figure 31: Tully Water Quality Field Day, Stool Zippa display

Figure 32: **Tully Water Quality Field Day, Ray Zamora presents on his farming strategies to help improve soil health and water quality.**

The SRA Meringa Field Day was coordinated in house, with close collaboration with Cairns Regional Canegrowers. The day began with large group presentations in the SRA harvester shed with attendees breaking into small groups to visit stalls for the second part of the day, enabling more discussion and getting people into the field. This is also an event that provides project investors Nufarm and Bayer an opportunity to talk with growers within the context of the project messages.

Presentations and group activities included:

- Rohan Wallace presented results from the GBR Catchment Monitoring program.
- Jack Robertson and Daniel Gonzales (DAF) spoke about the DAF Stool Zippa and the importance of correct application, and the SRA farm manager installed a Stool Zippa on the SRA Confidor applicator and put out some demonstration strips with and without. The DAF staff were supported by Tony Fitzgerald (Bayer).
- Mark Rantucci (Nufarm) presented on application technique and stewardship of the suSCon Maxi Intel product.
- Gavin Rodman (SRA) shared field demonstration and sub-catchment monitoring information from the Cane to Creek project.
- Belinda Billing discussed Protecting our Chemicals key messages and potential strategies that take these into account.
- Marcus Bulstrode (DAF) hosted a display of the work he is doing using drones for variable rate mapping of nutrients and herbicides.

- Will Higham (SRA) took grower collaborators into the cane to demonstrate and discuss pachymetra and nematode sampling, digging for canegrubs and how to differentiate between these issues.
- Paul Groves (GBRMPA) presented to the group on the interaction between the land, water and reef, with a focus on connectivity, estuaries and freshwater systems.

The project's key messages and findings have been delivered in person through sessions with extension providers and local project leaders (WTSIP technical working group, Tully extension providers group meeting) and as a guest presenter at the Canegrower Organisation Tablelands Awards night and the Mossman Water Quality Information Day.

Resources and messages have also been shared with project leaders for the Sandy Creek project in the Mackay area and Project Blue Water which is just starting in the Burdekin in order to grow the project footprint and support industry colleagues.

11.2. Year 2 Field Fact Sheets

Sugar Research Australia

COMPARING TWO LOW-RISK RESIDUALS AT AFTER HARVEST AND PSII SPIKES AT WET SEASON ONSET

Grower: **Dick Camilleri**

Location: El Arish, Tully
Ratoon: 3rd Variety: Q250(b
Harvested: 18 July 2017
Row spacing: 1.8m

Known issues: Light to medium weed pressure

Image source: Terrain

Treatments applied after harvest 20 July 2017

T1: IMAZAPIC	T2: FLUMIOXAZIN	CONTROL
Imazapic @ 400g/L (Flame, Spark etc.) Paraquat @ 1.2L/ha **COST: $15/ha**	Flumioxazin @700g/L (Valor) Paraquat @1.2L/ha **Cost: $145/ha**	No treatment applied/unsprayed until second pass
Second pass ***Applied December 18*** Whole block 2,4-D, Tordon (picloram + 2,4-D), Atrazine @ 500g/ha and Barrage @ 500g/ha **COST: $40/ha**		

Efficacy for after harvest: Monthly monitoring conducted from post spray through to October.
Both products controlled most weeds well; imazapic showed greater control of nutgrass.

T1: IMAZAPIC	T2: FLUMIOXAZIN	CONTROL
Best overall control of weed species ***Broadleaf:*** none present in monitoring ***Grass:*** none present ***Nutgrass:*** Some present – best control **January 2018 - some nutgrass present**	Good control of most weed species compared to control. ***Broadleaf:*** none present until October, very low numbers ***Grass:*** none present ***Nutgrass:*** present **January 2018 – nutgrass present (limited control)**	Dominated by nutgrass Limited broadleaf weeds present from September **January 2018 – nutgrass present (no control)**

Nutgrass: T1 August 2017

Nutgrass: T2 August 2017

Control August 2017

Nutgrass: T1 January 2018

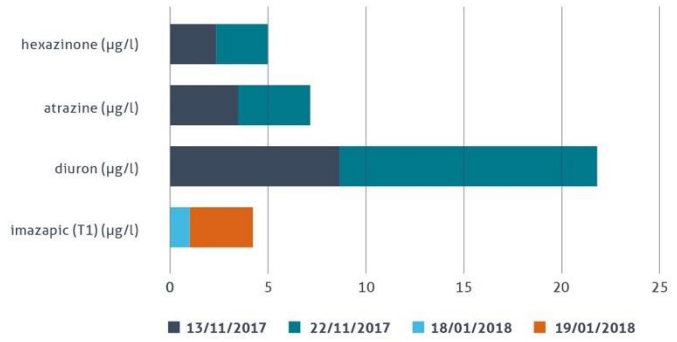
Nutgrass: T2 January 2018

Control January 20

What about water quality?

This graph combines the analysis of first two runoff events after post-harvest application of residual herbicides (approx. 4 months after application) and the first two runoff events after out of hand spray of knock downs with spike rates of diuron, hexazinone and atrazine. Note that no imazapic was detected in samples collected on November 13. No flumioxazin was detected.

Chemical detected in runoff from four rainfall events



Rainfall: 13 November - 30mm, 22 November - 65mm, 18 January - 91mm, 19 January - 72mm.
Note: known degredates for flumioxazin are currently unable to be analysed for, samples were analysed for the active flumioxazin with no detection for either event.

Proposed freshwater eco-toxicity thresh-holds

ACTIVE	TRADE NAME	99% PROTECTION IN µg/l	95% PROTECTION IN µg/l
Diuron	Diurex, Barrage, Bobcat Combi	0.08	0.23
Hexazinone	Barrage, Bobcat Imaxx	0.31	1.1
Imazapic	Flame, Spark	0.036	0.41

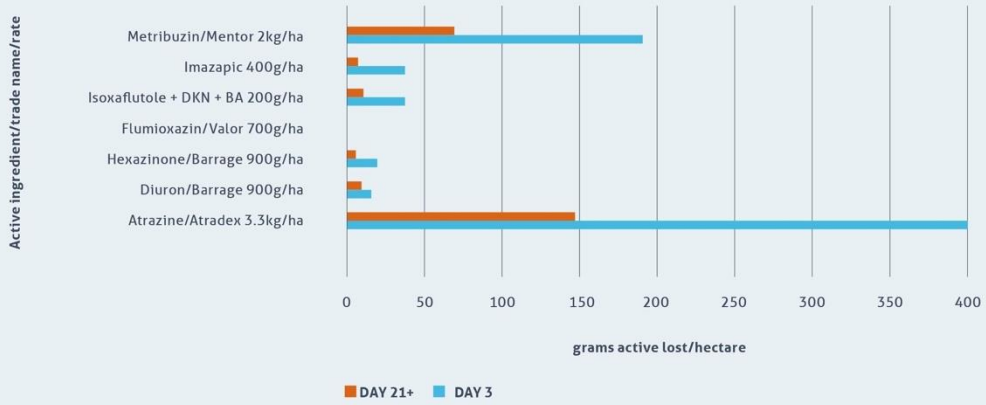
Waterhouse et al, 2017 Scientific Consensus Statement 2017: A synthesis of the science of land-based water quality impacts on the Great Barrier Reef, Proposed ecotoxicity thresh-holds King, O et al. 2017

Key messages:

Timing is key:
More time between application of herbicide and rainfall that runs off the paddock results in less product lost to runoff.

Compare these results with Tully Protecting our Chemicals for the Future Rainfall simulation – the same result happens for all chemicals.

Tully Timing and Product Ratoon



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COMPARING LATE APPLICATION OF RESIDUAL VS ZONAL APPLICATION OF TARGETED RESIDUAL

Sugar Research Australia

Grower: Frank Hughes

Location: Bilyana area, Tully
Ratoon: 5 Variety: Q208(ɒ)
Harvested: 5 June 2017
Row spacing: 1.65m

Known issues: Older ratoon, increasingly high Calopo pressure at end of row, beginning to creep into block. Treatment 2 is designed to control the Calopo, using a minimum amount of hexazinone, a PSII herbicide that Frank has been avoiding due to environmental concerns. This approach puts the hexazinone in the area of highest pressure only. The block also has medium pressure grasses, sickle pod and various broadleaf weeds. Frank rotates chemicals over the crop cycle to avoid resistance while also paying attention to weed pressure.

Treatments applied

T1: GROWERS CURRENT PRACTICE	T2: PROPOSED ZONAL CONTOL	CONTROL
1 September 2017 2,4-D @ 1 L/ha Picloram & 2,4-D /Tordon @0.5L/ha – applied with boom **COST: $15/ha**	1 September 2017 2,4-D @ 1 L/ha Picloram & 2,4-D /Tordon @0.5L/ha – applied to whole row with boom Imazapic & hexazinone (Bobcat Imaxx) Paraquat 20m application on end of both rows with octopus legs **Cost: $35/ha**	No treatment applied
14 February 2018 Imazapic @ 400g/L (Flame, Spark etc.) Paraquat @1.2L/ha applied through octpus legs 2,4-D @ 1.5L/ha Picloram/2,4-D (Tordon, Trooper) applied with boom **COST: $25/ha**	14 February 2018 2,4-D @ 1 L/ha Picloram & 2,4-D /Tordon @0.5L/ha – applied to whole row with boom Imazapic & hexazinone (Bobcat Imaxx) 20m application on end of both rows with octopus legs **COST: $35/ha**	No treatment applied
Spot spray glyphosate @ $10/ha **Total cost: $50/ha**	Spot spray glyphosate @ $10/ha **Total cost: $80/ha**	

Two applications in one pass.

Franks' spray rig has two tanks connected to a flat boom and octopus legs allowing two treatments to be applied at one time, controlled by a GPS variable rate controller.

TREATMENT 1	TREATMENT 2
All of treatment treated same Pass 1: 2,4-D/Tordon boom only Pass 2: 2,4-D/Tordon through boom and imazapic & paraquat through octopus legs	20m end imazapic & hexazinone + paraquat with octopus legs
	Entire treatment 2,4-D/Tordon with boom
	20m end imazapic & hexazinone + paraquat with octopus legs (repeat for pass 2)

Efficacy for after harvest: Monthly monitoring conducted from post spray through to November. Both treatments were effective, a third knock down pass was not required.

T1:	T2:	CONTROL
Med-high weed pressure early, majority blue top Weed pressure increased significantly with onset of wet season Weed pressure reduced by both sprays, long-term reduction in weed pressure achieved with final residual spray. Limited weed pressure in mid section of cane throughout where shading occurs.	Med high weed pressure early, majority blue top. Improved control on ends evident as weed pressure increased with onset of wet season. Final spray successful in reducing pressure on ends and mid section, with shading reducing weed pressure where knock down chemicals only applied.	Higher weed pressure than both treatments throughout. (knock down chemical applied in

2017/ 18 Frank Hughes Weed Observations

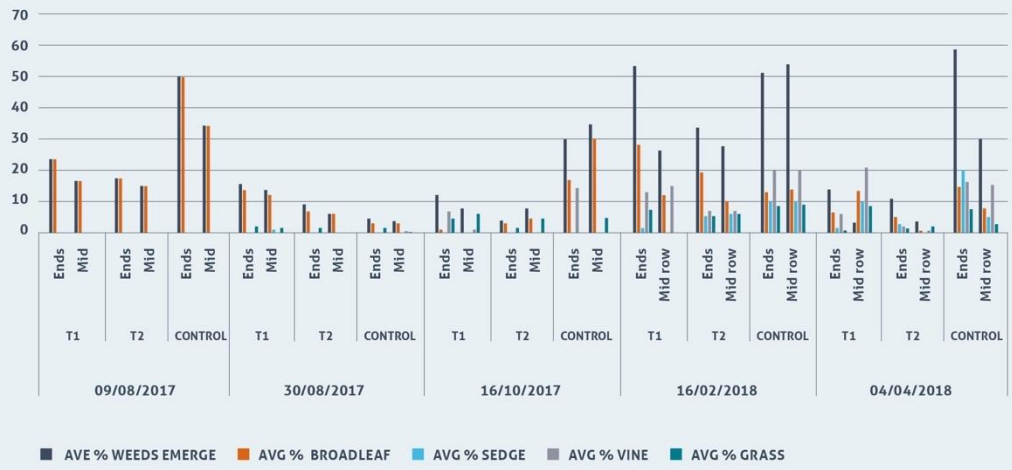


Chart shows percent coverage of monitoring plots of grass, broadleaf, vine and total weeds

Treatment one at 14 February 2018

Treatment two at 14 February 2018

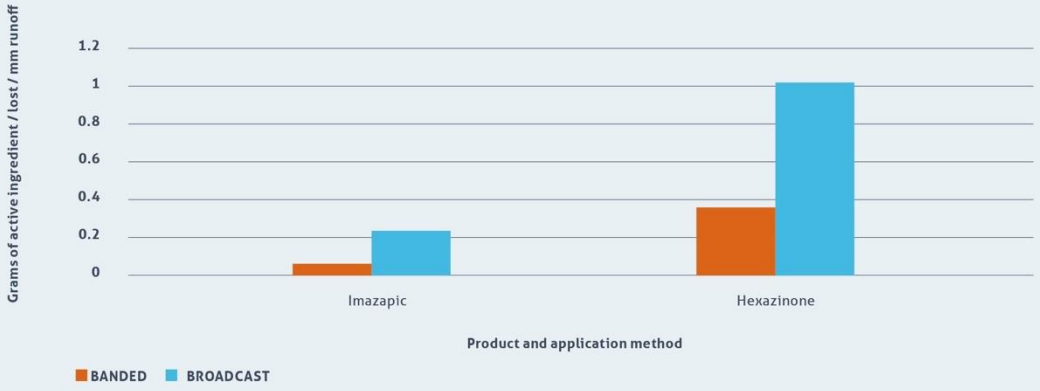
Control at 14 Febraury 2018

Key messages:

Less product on =
less product off, zonal application of herbicides with high environmental risk puts the product only where it is most needed, meaning there is less to lose overall.

Compare these results with Tully Protecting our Chemicals for the Future Rainfall simulation, where the DAF dual herbicide spray bar was used to band Bobcat Imaxx, resulting in half of the plot being sprayed compared to a broadcast application of the same product. Note the higher amounts of hexazinone are due to the higher rate, Bobcat Imaxx is Imazapic 95g/ha, hexazinone 475g/ha.

Banding vs Broadcast study, Tully 2017



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COMPARISON OF BROADCAST VS BANDED USE OF RESIDUALS IN SUGARCANE

Sugar Research Australia

Grower: Mark Savina

Location: Barron Delta, Cairns
Ratoon: 1 Variety: Q242(b)
Harvested: 2 August 2017
Row spacing: 1.8m

Mark is interested in reducing his use of residual herbicides for environmental and economic reasons. He is interested in band spraying as he has found the weed pressure in his wheel tracks is greatly reduced through his controlled traffic farming system (the wheel track is compacted, reducing weed growth). This block had high vine pressure the previous year and was expected to have the some issue in 2017/18.

Treatments applied

T1: BROADCASTS PSII RESIDUAL	T2: BANDED PSII RESIDUAL	CONTROL
07 December 2017 Atrazine (Atradex) 2.2 kg/ha Diuron + Hexazinone (Barrage) 900g Paraquat @ 1L/ha **Cost: $45/ha**	07 December 2017 Atrazine (Atradex) 2.2 kg/ha Diuron + Hexazinone (Barrage) 900g glyphosate @ 1.2L/ha **Cost: $25/ha**	No treatment
05 January 2018 high rise spray broadcast Fluroxypyr (Comet, Starane) 800ml/ha Picloram, 2,4-D (Tordon) 700ml/ha 2,4-D 800ml/ha **Cost: $35**	05 January 2018 high rise spray broadcast Fluroxypyr (Comet, Starane) 800ml/ha Picloram, 2,4-D (Tordon) 700ml/ha 2,4-D 800ml/ha **Cost: $35**	05 January 2018 high rise spray broadcast Fluroxypyr (Comet, Starane) 800ml/ha Picloram, 2,4-D (Tordon) 700ml/ha 2,4-D 800ml/ha **Cost: $35**

Efficacy for after harvest: Monitoring for treatment efficacy was undertaken post treatment

T1: BROADCASTS	T2: BANDED	CONTROL
Early weed pressure dominated by grasses. Grasses controlled well by December spray and shade from cane. Vine present with rain in January, appears well controlled by final spray. Block survey shows higher pressure on ends of rows with some concentrated areas of high pressure.	Early weed pressure dominated by grasses. Grasses controlled well by December spray and shade from cane. Vine present with rain in January, appears well controlled by final spray. Block survey shows higher pressure on ends of rows and some concentrated areas of high pressure. Slightly higher vine pressure in T2.	Early weed pressure dominated by grasses. Grass pressure reduced by shade from cane. Heavy vine present with rain in January, well controlled by high rise spray. Block survey shows higher pressure on ends of rows and some concentrated areas of high pressure.

Weed pressure under banded vs broadcast residual chemicals + knock down application with highrise to all

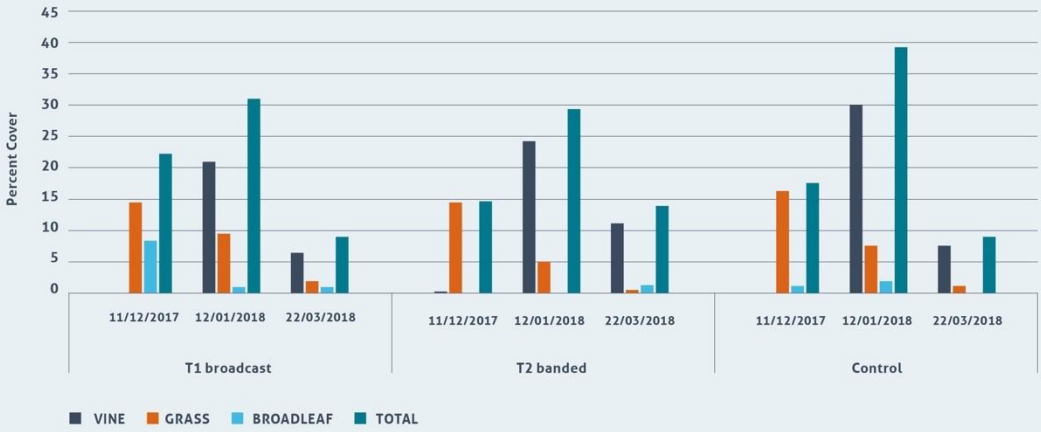


Chart shows percent coverage of monitoring plots of grass, broadleaf, vine and total weeds.

T1 broadcast + high rise spray March 2018

T2 band + high rise spray March 2018

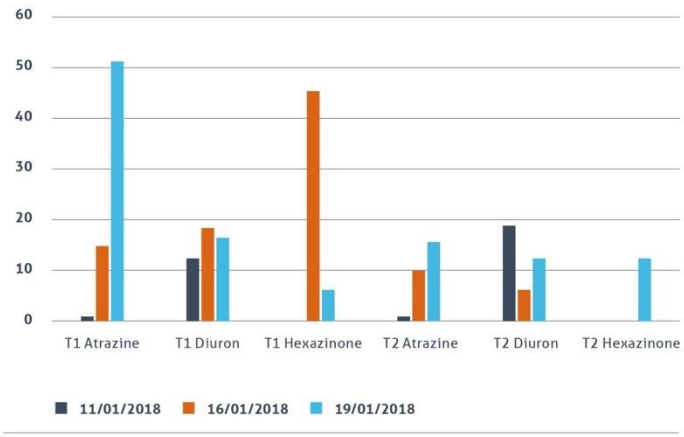
Control –broadcast only March 2018

***(Left)** Dual herbicide spray set up to allow banding of residual chemical.*

What about water quality?

The graph to the right shows losses in micrograms per litre for three rainfall events subsequent to chemical application. As this is a well drained site chemical was analysed from water that collected from fullstops buried around 1m below ground in both the inter-row and row. This allows us to look at chemical leaching to the ground water.

Banded vs Broadcast PSII



Rainfall: 06 January 2018, 10 January 2018, 04 February 2018 and 05 February 2018

Proposed freshwater eco-toxicity thresholds - the lower the value, the greater the toxicity.

ACTIVE	TRADE NAME	99% PROTECTION IN µg/l	95% PROTECTION IN µg/l
Atrazine	Atradex	0.17	0.989
Hexazinone	Barrage	0.31	1.1
Diuron	Barrage, Diurex	0.08	0.23
2,4-D	Amine 2,4-D (marine values only available)	1,040	2,516

Proposed freshwater eco-toxicity thresh-holds - the lower the value the greater the toxicity.
Note; Atrazine values are draft and have not been approved – for mark only
Waterhouse et al, 2017 Scientific Consensus Statement 2017: A synthesis of the science of land-based water quality impacts on the Great Barrier Reef, Proposed ecotoxicity thresh-holds King, O et al. 2017

Key messages:

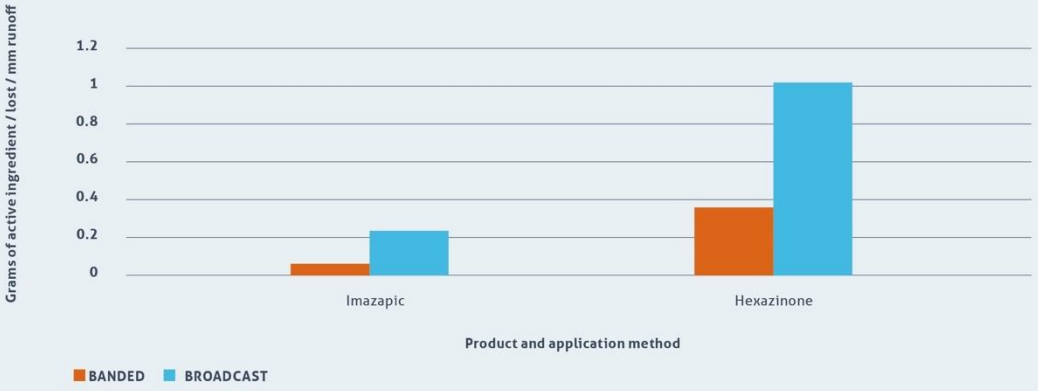
Less on = Less off – Less product applied results in less product leaving the farm. This principle can be applied to banding, zonal application within a block or zonal application across a farm with the focus on using the most effective chemical where it is most needed. Lower rates of herbicide usually result in lower rates of run off. Exceptions to this rule are pendimethalin and paraquat which bind very tightly to soil particles.

Key messages:

Less product on =
less product off, zonal application of herbicides with high environmental risk puts the product only where it is most needed, meaning there is less to lose overall.

Compare these results with Tully Protecting our Chemicals for the Future Rainfall simulation, where the DAF dual herbicide spray bar was used to band Bobcat Imaxx, resulting in half of the plot being sprayed compared to a broadcast application of the same product. Note the higher amounts of hexazinone are due to the higher rate, Bobcat Imaxx is Imazapic 95g/ha, hexazinone 475g/ha.

Banding vs Broadcast study, Tully 2017



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AFTER HARVEST NON-PSII STRATEGY VS GROWER PRACTICE

Sugar Research Australia

Grower: Anonymous

Location: Mulgrave, Gordonvale
Ratoon: 3 Variety: Q208ϕ
Harvested: 5 September 2017
Row spacing: 1.5m

Medium weed pressure, with historic para-grass, sicklepod and vine.

This demonstration showed the benefits of after harvest application of a non-PSII residual herbicide (imazapic) which proved effective in terms of cost, efficacy and dollars. The demonstration also showed the benefit of targeting sicklepod with 2,4-D + picloram.

Treatments applied

T1: GROWER PRACTICE	T2: AFTER HARVEST NON PSII	CONTROL
After harvest broadcast: 12/09/2017 Atrazine @ 500g/ha MSMA (Daconate) @ 1l/ha, & Paraquat @1.2l/ha **Cost: $33/ha**	**After harvest broadcast: 14/09/2017** Imazapic (Spark) @ 400ml/ha & Paraquat @ 1.2l/ha **Cost: $17/ha**	No spray
DATE 21/11/2017 Fluroxypyr (Comet 400) @1.5L/ha 2,4-D & Picloram / Enforcer 75D 75/D @700ml/ha **Cost: $61/ha**	**DATE 03/10/2017** 2,4-D @ 625 L/ha Picloram & 2,4-D /Enforcer 75D @700ml/ha DATE 20/11/2017 2,4-D @ 625ml/ha Picloram & 2,4-D / Enforcer 75D @700ml/ha **COST: $30/ha ($15/ha per spray)**	
Spot spray Diuron 1kg, MSMA (Daconate) 700ml, paraquat 1L /300L = $40/300L **Total cost: $94 + spot spray**	**Spot spray** Diuron 1kg, MSMA (Daconate) 700ml, paraquat 1L /300L = $40/300L **Total cost: $47/ha + spot spray**	**Spot spray** Diuron 1kg, MSMA (Daconate) 700ml, paraquat 1L /300L = $40/300L

Efficacy for after harvest: Monthly monitoring conducted from post spray through to October.

T1: GROWER PRACTICE	T2: PROPOSED PRACTICE	CONTROL
Dry weather early on, very limited pressure. First rain high numbers of sickle pod and grass patches emerged.	Dry weather early on, very limited pressure. First rain high numbers of sickle pod and grass patches emerged. Better control of grass and sickle pod using targeted products.	Dry weather early on, very limited pressure. First rain high numbers of sickle pod and grass patches emerged.

Weed pressure under banded vs broadcast residual chemicals + knock down application with highrise to all

Chart shows average percent weed coverage of monitoring plots (16 plots / treatment)

T1: 26/09/2018

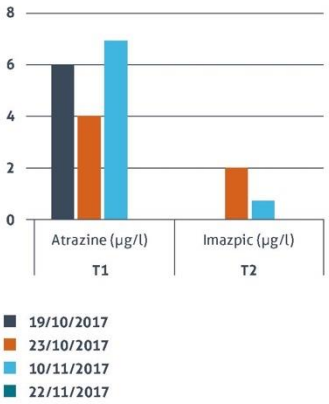
T2: 26/09/2018

Control: 26/09/2018

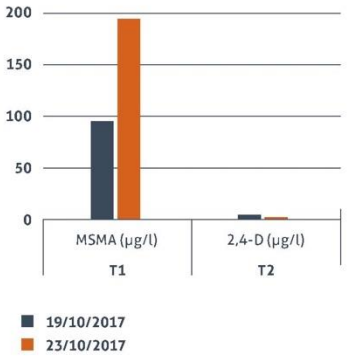
What about water quality?

This site has springs close to the surface and as such reaches runoff point quickly. Monitoring of four events in the months after chemical application showed a higher amount of atrazine in runoff than imazapic. Knock down chemicals were analysed for in the initial two rainfall events only and showed high amounts of the persistent and moderately toxic MSMA in runoff water, very little 2,4-D and no picloram. By November 22 no chemical was detected. No further monitoring was undertaken.

Gordonvale runoff: **residual chemicals**



Gordonvale runoff: **knock down chemicals**



Rainfall: *19 October 2017 166mm, 23 October 2017 44mm, 10 November 2017 31, 22 November 2017 22mm.*

Proposed freshwater eco-toxicity thresholds - the lower the value, the greater the toxicity.

ACTIVE	TRADE NAME	99% PROTECTION IN µg/l	95% PROTECTION IN µg/l
Imazapic*	Flame, Spark	0.036	0.41
2,4-D*	Amine 2,4-D (marine values only available)	1,040	2,516
Fluroxypyr	Starane, Comet	87	200

Note; no values available for atrazine, MSMA, picloram and paraquat.
**Waterhouse et al, 2017 Scientific Consensus Statement 2017: A synthesis of the science of land-based water quality impacts on the Great Barrier Reef, Proposed ecotoxicity thresh-holds King, O et al. 2017*

Key messages:

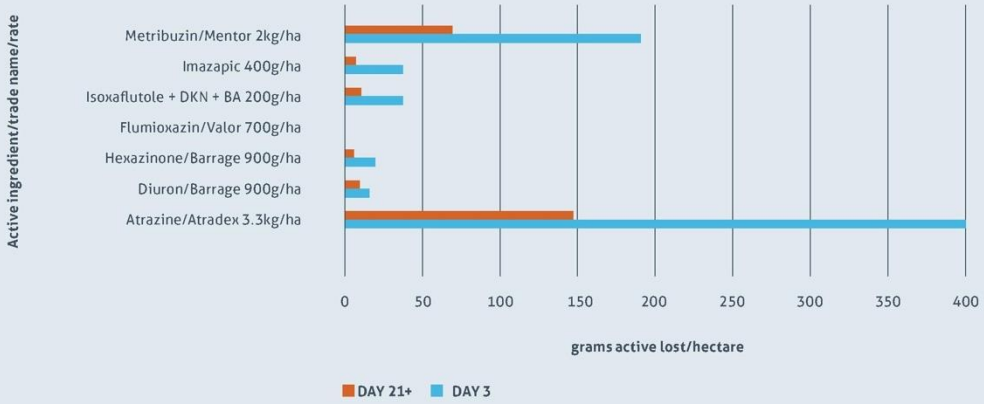
Timing is key: More time between application of herbicide and rainfall that runs off the paddock results in less product lost to runoff. Application of herbicides one month before rainfall that ran off resulted in low levels of residual chemicals lost to runoff.

Product selection: MSMA is an arsenic based chemical and therefore is stable in the environment. It will persist for a long time and can build up in soils. The shorter half-life of other knock down chemicals, such as 2,4-D and picloram resulted in little or no chemical being detected in analysis of runoff. Imazapic requires a lower rate for effective control than atrazine, therefore losses of imazapic were lower than atrazine.

Compare these results with Tully Protecting our Chemicals for the Future Rainfall simulation – losses for most herbicides will reduce with more time between application and run off. In most cases where a herbicide is applied at a high rate the losses will be greater. A small number of herbicides have a very high KoC (ability to bind to soil particles) and therefore have low losses regardless of rate, an example is pendimethalin, and perhaps flumioxazin.

Timing study – 3 day vs 21 day

Tully Timing and Product Ratoon



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Sugar Research Australia

COMPARING KNOCK DOWN HERBICIDE STRATEGY WITH RESIDUAL HERBICIDE STRATEGY IN RATOON CANE

Grower: **Ray Zamora**

Location: Riversdale area, Tully
Ratoon: 3rd Variety: Q208
Harvested: 6 July 2017
Row spacing: 1.8m

Known issues: Light to medium weed pressure, block fallowed with two crops of soybean prior to planting to reduce weed pressure and improve soil condition, allowing minimum herbicide use throughout ratoons.

Treatments applied after harvest

T1: RESIDUAL CONTROL	T2: KNOCK DOWN CONTROL	T3: CONTROL
11 July 2017 Imazapic @ 400g/L (Flame, Spark etc.) Paraquat @1.2L/ha **Cost: $15/ha**	1 September 2017 2,4-D @ 1 L/ha Picloram & 2,4-D /Tordon @0.5L/ha **Cost: $15/ha**	No treatment applied
27 October 2017 Metribuzin (Mentor, Tomahawk) @ 1.5L/ha 2,4-D @ 1.5L/ha Paraquat 1L/ha **Cost: $75/ha**	3 November 2017 Paraquat 1.2L/ha **Cost: $5/ha**	Spray out with paraquat December.
Spot spray glyphosate @ $10/ha **Total cost: $90/ha**	Spot spray glyphosate @ $10/ha **Total cost: $30/ha**	

Efficacy for after harvest: Monthly monitoring conducted from post spray through to February. Both treatments were effective, and a third knock down pass was not required.

Knock down vs residual control average % weed cover

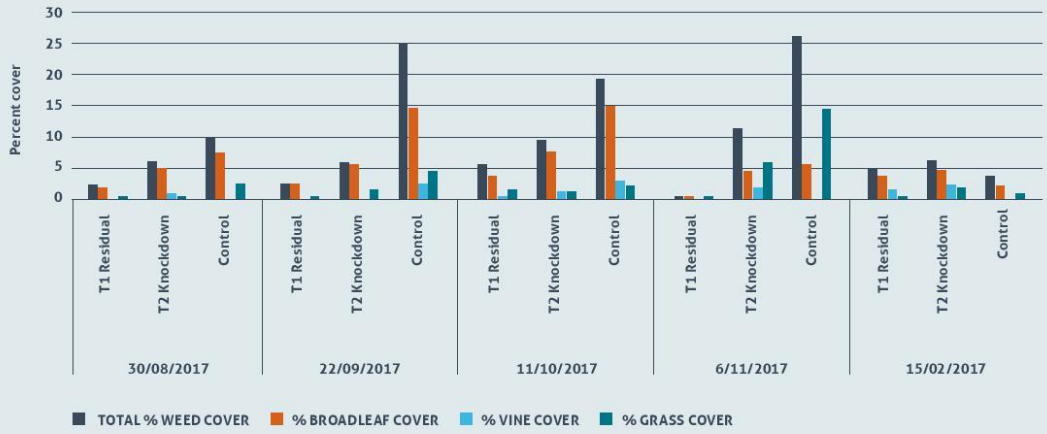


Chart shows average percent weed coverage of monitoring plots (16 plots / treatment)

T1: Residual control, September 2017

T2: Knock down control, September 2017

Control: No spray, September 2017

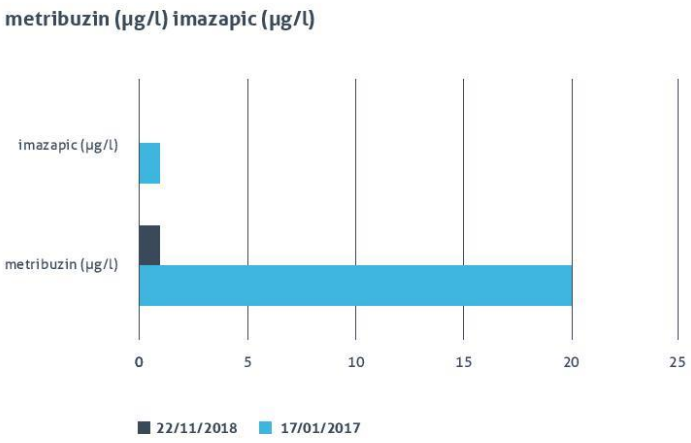
T1: Residual control, February 2018

T2: Knock down control, February 2018

Control: No spray, February 2018

What about water quality?

The graphs show analysis of two runoff events. The time between herbicide application and runoff events has led to much greater losses of metribuzin, applied much closer to the wet season than the Imazapic, which had four months between application and a runoff event. (Note: no residual herbicides were applied to Treatment 2. Due to the lower eco-toxicity and short half-life of knock down chemicals no analysis was completed for any of the products applied.)



Rainfall: 60mm on 22 November 2017 and 100mm on 17 January 2018.
Imazapic was not detected on the January event.

Proposed freshwater eco-toxicity thresholds - the lower the value, the greater the toxicity.

ACTIVE	TRADE NAME	99% PROTECTION IN µg/l	95% PROTECTION IN µg/l
Imazapic	Flame, Spark	0.036	0.41
Metribuzin	Mentor, Tomahawk	2	2.6
2,4-D	Amine 2,4-D (marine values only available)	1,040	2,516

Note: no values available for picloram and paraquat.
Waterhouse et al, 2017 Scientific Consensus Statement 2017: A synthesis of the science of land-based water quality impacts on the Great Barrier Reef, Proposed ecotoxicity thresh-holds King, O et al. 2017

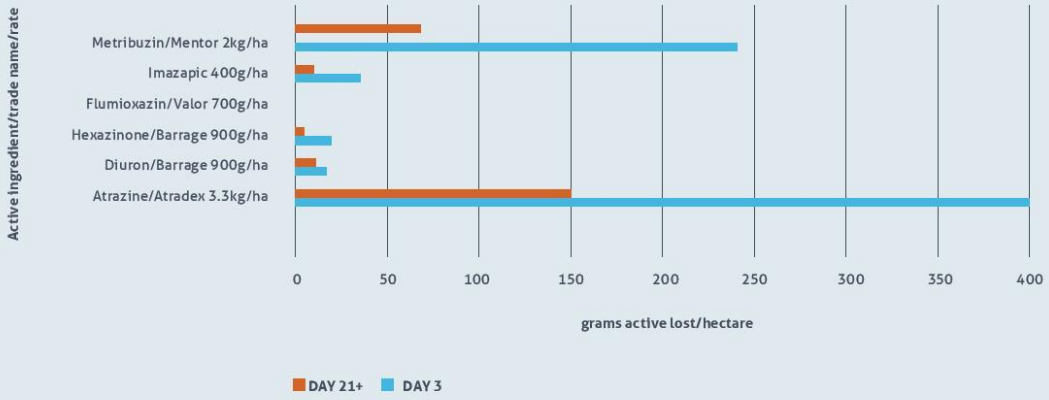
Key messages:

Less product on, less product off:
A ratoon block with low weed pressure can effectively be managed with low risk knock down chemicals.

Timing is key:
More time between application of herbicide and rainfall that runs off the paddock results in less product lost to runoff.

Timing study –
3 day vs 21 day

Banded vs broadcast application of residual herbicide Mulgrave study



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