HERBICIDES AND THE WATER QUALITY CONUNDRUM

By

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Abstract

HERBICIDAL IMPACT ON the health of the Great Barrier Reef (GBR) lagoon came to the forefront in 2009 with the Queensland Government's Great Barrier Reef Protection Amendment Act 2009 and the concurrent review of diuron by the Australian Pesticides and Veterinary Medicines Authority (APVMA). Subsequently, Federal and Queensland government programs have maintained the spotlight on both freshwater and marine water quality. Ambitious pesticide load reduction targets have been set by the Reef 2050 Plan, as one of the means to improve water quality and the resilience of the GBR ecosystem. Photosystem II (PSII) herbicides in particular are targeted under the plan. Gaining sustained industry practice change is paramount to achieving these targets. Progress is being made, although the challenges remain, both on the practice change level and on the technical knowledge level. Weed management practices with demonstrated environmental benefits include timing spray applications to avoid run-off within the 20–25 days following spraying, incorporation of residual herbicides by non-run-off inducing irrigation or rainfall, switching to strategic and/or banded application of residual herbicides, and avoiding the use of residual herbicides on ratoons where trash blanketing provides sufficient weed suppression. Other farming system improvements such as controlled traffic may reduce the amount of run-off, contributing to reductions in overall herbicide losses. Growers are switching to alternative residual herbicides in response to tighter controls on the PS II herbicides diuron, atrazine, ametryn and hexazinone. Relative risk rankings being developed indicate that alternative herbicides can offer reduced environmental risk.

Introduction

Effective weed management is one of the critical operations that affects sugarcane yields, both through direct competition and the influence on other pests such as rats. Competitive effects on yields have been well reported previously. McMahon *et al.* (1989) considered that effective weed control was critical until at least 10 cm of stalk growth. More recently, Fillols (2011) reported yield losses of up to 30% from nutgrass competition. Similar to other cropping systems, the basic premise of effective weed management in sugarcane is to prevent seed set, thus reducing weed pressure over time.

With the advent of green cane trash blanketing and reduced tillage systems, herbicides have become a major tool for weed management. Productivity-focussed growers treat weed management seriously as it involves considerable investment in both herbicide products and application equipment. Herbicide input costs range from $5/ha to upwards of $180/ha.

Spray rigs can cost from $10 000 for a simple boom to more than $300 000 for self-propelled high-rise spray tractors with dual tanks and spray hoods. Global Positioning Systems (GPS) enabled variable rate systems are beginning to be used in cane.

The need to utilise herbicides to maintain and improve profitability coincides with increasing community expectations of improved environmental stewardship.

Given the proximity of the majority of cane land to waterways and to the Great Barrier Reef lagoon, it is inevitable that some environmental impact occurs. The challenge to growers, advisors and researchers, and the herbicide supply chain is how to meet community expectations of stewardship and reduce off-target impact while retaining herbicides as critical tools for weed management.

The challenge set

Community expectations of environmental stewardship relating to the Great Barrier Reef (GBR) are largely expressed through Reef 2050 Plan, a broad program initiated by the Queensland and Federal governments (Reef 2050 Long-Term Sustainability Plan). Reef 2050 Plan is also Australia's response plan to the United Nations' concern for the health of the GBR (Reef 2050 Long-Term Sustainability Plan).

Within this program, Reef Water Quality Protection Plan has set a target of a 60% reduction in end-of-catchment pesticide loads in priority areas by 2018. Within the context of this plan, and relating to sugarcane, this load reduction relates to the targeted PSII herbicides diuron, hexazinone, ametryn, and atrazine (Reef Water Quality Protection Plan 2013). For sugarcane, a target of 90% of cane land area (Queensland) being managed with best management practices by 2018 has been set to meet this objective.

How are we doing?

The Reef Water Quality Protection Plan's 2015 Report Card states that for pesticides, best management practices were being used on 32% of cane land area (Queensland) as at June 2015. This contributed to a 33.7% reduction in end-of-catchment pesticide loads, across the whole Great Barrier Reef catchment, compared with the 2009 benchmark (Great Barrier Reef Report Card 2015).

The 2015 Report Card suggests that pesticide practices as a percentage of total cane land, ranked according to impact on water quality are:

- Low risk: 8%
- Moderate risk: 28%
- Moderate to high risk: 46%
- High risk: 18%

High risk practices relate to timing of herbicide applications and rainfall run-off.

Progress in achieving the 60% reduction target is primarily assessed by modelling conducted by Department of Natural Resources and Mines (DNRM), self-reported grower practice data from Reef Plan and field data from the Paddock to Reef trial sites and The Great Barrier Reef Catchment Load Monitoring Program.

The Great Barrier Reef Catchment Load Monitoring Program monitors actual concentrations of pesticides at 15 sites across 14 catchments. Analysis of water samples screens for 57 pesticide compounds. Pesticide presence is of interest when concentrations exceed trigger values for eco-toxicity. Trigger values are set by the Australian and New Zealand Environment Conservation Council (ANZECC) and the Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) and are published in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality.

Monitoring results indicate that losses in run-off do occur frequently, with highest concentrations during the initial runoff inducing rains of the wet season (Great Barrier Reef Report Card 2015).

Registered herbicides for sugarcane

Registration by the Australian Pesticides and Veterinary Medicines Authority (APVMA) of pesticides implies that environmental risks posed by these products is within scientific and community acceptance levels, when used as per label instructions. There are currently twenty-six herbicide active ingredients registered for use in cane that are commercially available to Australian cane farmers (Table 1). Six of these are Photosystem II (Group C) herbicides.

Table 1—Herbicide active ingredients currently registered for use in-cane, and on the market. Group C are PS II inhibitors.

Chemical group	Active ingredient	Example Trade name(s)
Group B	imazapic	Flame, Spark, Bobcat i-maxx
	halosulfuron - methyl	Sempra
Group C	ametryn	Gesapac Combi, Amtrex, Viking
	atrazine	Atradex, Gesaprim, Gesapax Combi
	terbutryn	Agtryne MA
	hexazinone	Bobcat Combi, Bobcat i-maxx, Barrage,
	metribuzin	Tomahawk, Mentor
	diuron	Diurex, Bobcat Combi, Barrage
Group D	pendimethalin	Stomp Xtra
	trifluralin	Treflan
Group G	flumioxazin	Valor
Group H	isoxaflutole	Balance
Group I	2,4-D	Amicide, Tordon 75D, Trooper
	dicamba	Cadence, Kamba, Dicamba
	fluroxypr	Starane Advanced, Comet
	MCPA	Agritone 750 , MCPA 750
	picloram	Tordon 75D, Trooper
Group J	2,2-DPA	Dalapon
Group K	metolachlor	Dual Gold, Bouncer 960S
	s - metolachlor	Clincher Plus, Bouncer
Group L	diquat	SpraySeed
	paraquat	Gramoxone,SpraySeed, Nuquat, Revolver
Group M	glyphosate	Roundup, Weedmaster
Group N	glufosinate	Basta
Group R	asulam	Asulox
Group Z	MSMA	Daconate, Monopoly

Growers and advisors trust that the approval process for herbicides in Australia provides a suite of products that, when use as per label instructions, have an environmental impact within scientifically accepted standards.

Given the incidences of exceedances, does this mean that the approval process needs revising or does it indicate there is a degree of non-compliance to label instructions?

Research and flow-on practice change

Weed management research for the Australian sugarcane industry has traditionally focussed on herbicide efficacy and has been mainly undertaken by industry and chemical company personnel. Since the initiation of the Reef Water Quality Protection Plan, research has expanded to include environmental aspects of herbicide use and participation by a broader range of researchers and organisations.

The Paddock to Reef program (Paddock to Reef Integrated Monitoring, Modelling and Reporting Program 2013–2018) and other research has identified a number of key areas that highlight practice change opportunities:

Timing

Timing from application to first run-off is critical. Rohde K *et al.* (2013) determined that herbicide losses in rainfall run-off could be decreased by half by timing application to avoid rainfall run-off for 20–25 days after application (Figure 1).

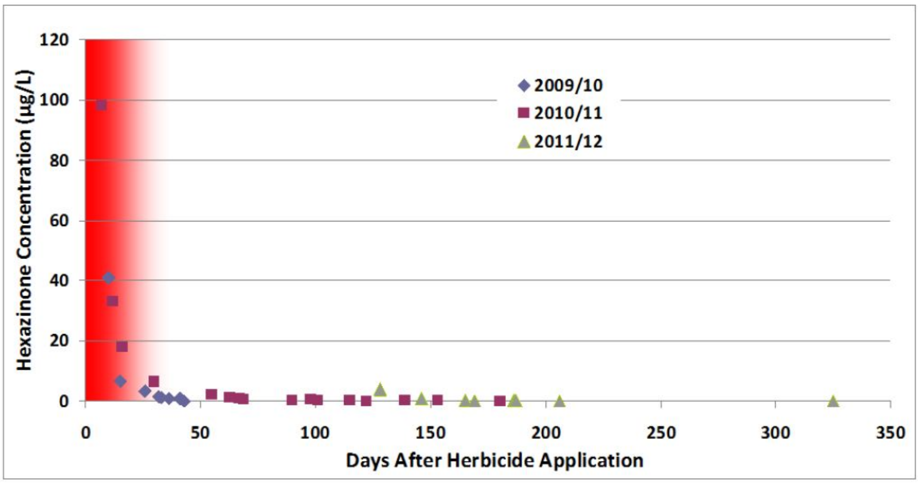

Fig. 1—Losses in run-off are greatest if run-off occurs within the first 25 days after application (Rohde *et al.*).

Despite well intended actions, growers often get 'caught-short' for a number of reasons:

- The imprecise science of weather forecasting may result in actual rainfall events differing in time or intensity to that forecast, especially for localised storm cells.
- In extended dry Springs, growers have to weigh up the risks associated with early applications being rendered less effective by ongoing dry conditions, or delaying application with the prospect of block inaccessibility due to sudden seasonal changes.
- Late harvests through December and even into January may lead to herbicide application during higher risk periods.
- Growers engaged in off-farm employment do not always have the ability to optimise timing of applications.
- Large time-constrained farm operations often prefer to rely on pre-emergent herbicides to keep cane blocks weed free for a longer period of time rather than relying on several post-emergence options.

Incorporating herbicides

Incorporation by irrigation or light rain without causing run-off can effectively reduce losses in subsequent run-off events. Rohde *et al.* (2013) also concluded that herbicide lost to run-off approximately halves with every additional 50 mm of rainfall or irrigation before run-off occurs. Overhead irrigation is widely used in the Atherton Tableland and southern Queensland districts to incorporate herbicides. This practice should result in a lower risk of loss for these districts compared with other areas that either use overhead irrigation less frequently for incorporation or rely on rainfall. Promoting herbicide incorporation with irrigation should be a priority in other districts that have irrigation capacity.

Banded application of residual herbicides

Re-thinking application strategy from blanket application of residual herbicides on ratoons to banded residuals over the drill in combination with knockdown sprays for the inter-row also offers opportunities for reducing the actual volume of residual herbicides used. Silburn *et al.* (2011) showed multiple benefits of banded application of residual herbicides. Banding reduced the residual herbicide load in the block by 50%, with subsequent reductions in rainfall run-off losses of 22 to 50%. In furrow irrigated blocks, banding reduced losses in irrigation run-off by up to 88% (Oliver *et al*, 2014).

Despite these clear benefits in reducing the overall load of residual herbicides in the system, there has been limited uptake of banded spraying of residuals.

Analysis of grants to growers from 2009 to 2016 under the Reef Rescue program suggests that practices reducing the amount of residual herbicides being used should be in place over approximately 83 000 hectares (Burnett–Mary, Mackay–Whitsunday, Burdekin and wet tropics catchments). Across these catchments, 374 growers received financial assistance for the purchase and/or modification of spray equipment to enable increased use of knockdown herbicides and reduced use of residuals (McCosker, K and Barbi, E pers. comm., 2016).

Band spraying systems vary:

- Band spraying over the cane row just after harvest using a boom with nozzles centred over the row is a very simple, accurate and cheap option to implement; however it works better in GPS guided systems. Some growers report that banding without GPS guidance results in a wavy band along the drill, causing misses. Follow-up spraying of the inter-row using knockdowns is often required.
- Shield/hood sprayers with side nozzles (dual tank) are a more expensive investment for growers. They allow the use of non-selective broad spectrum herbicides (like glyphosate) in the inter-row and can apply a different herbicide, such as a pre-emergent, at the base of the row. These spray rigs vary in design and may be quite heavy; limiting paddock accessibility in wet ground conditions. Some growers who have invested in hooded sprayers have not persisted with their use. Explanations range from being unsure about crop injury, multiple passes required due to different timing for knockdowns versus residual and weed pressure being such that a broadcast residual is the more appropriate strategy.
- Non-shielded dual spray bar systems are a relatively inexpensive alternative to spray shields or hoods. Knockdown herbicides are applied to the inter-row while a different herbicide, such as a pre-emergent, can be applied at the base of the cane row. This system must be correctly set-up to avoid crop injury from non-selective herbicides used for the inter-row. It is estimated that non-shielded dual sprayers are used over approximately 11 000 hectares (Blair, A pers. comm.).

Controlled traffic systems

Silburn *et al.* (2011) also reported that moving to a controlled traffic system, whereby row spacings are matched to machinery wheel spacings, reduced rainfall losses of herbicides by 50 to 58%. This reduction in rainfall run-off from controlled traffic systems is also supported by Rohde *et al.* (2013) who measured a 14% reduction in rainfall run-off from a 1.8 metre controlled traffic system compared with a 1.5 metre row spacing.

Garside and Bell (2006), in their final report for The Sugar Cane Yield Decline Joint Venture and subsequent extension projects, highlighted many agronomic benefits of moving to controlled traffic systems. The SRA Grower Survey 2015 indicated that adoption of controlled traffic (1.8 metre or greater row spacing) ranged from 3 to 30% of growers, depending on region.

The lowest adoption of controlled traffic systems was in the Burdekin and far north (Tully north). Clearly there is an ongoing opportunity to encourage increased adoption of controlled traffic systems, which in turn will assist in addressing water quality issues.

Contrarily, some growers have returned to narrower row spacings, citing weed management as one of the reasons. Especially with open canopy cane varieties, wider row spacings may encourage higher weed pressure over a longer time period before canopy closure. Dual row controlled traffic systems may help to alleviate this as the dual row system tends to achieve canopy closure earlier. However, dual row systems may not be suited to all situations.

Trash blanketing may negate need for residuals

Fillols and Callow (2010) showed that in many cases in trash blanketed ratoons in the Central and Southern regions, trash blanketing provided sufficient weed suppression, as an alternative to applying residual herbicides.

Application of knockdowns towards or after the out-of-hand growth stage was all that was required, to control late season vine and weed growth. This has potential to significantly reduce the total volume of residual herbicides applied. Where residuals were warranted, early application soon after harvesting was generally more effective than late application; also resulting in reduced risk of losses in wet season run-off.

Feedback on practice change from the Reef Plan program suggest that an increasing number of growers now access ratoon blocks individually and make decisions whether to use a residual herbicide based on weed history, anticipated weed pressure and trash levels.

The SRA Grower Survey 2015 supports this, showing that the percentage of ratoons not receiving residual herbicides average 38% across the industry; ranging from 33% in NSW to 68% in the Herbert region (Grower Survey 2015 Report for Sugar Research Australia).

There is scope to increase the area of ratoons not treated with residuals by reductions in weed pressure through encouragement of improved weed management in fallow and plant cane.

Switching to alternative herbicides

Research and grower experience shows that there are effective alternatives to diuron. The current SRA project *Developing an alternative herbicide management strategy to replace PSII herbicides in the Wet Tropics area*, demonstrates there are a number of options for growers apart from diuron.

Options, depending on specific site conditions, include imazapic, isoxaflutole, flumioxazin and mixtures with reduced rates of diuron. Other herbicides with new active ingredients for sugarcane are also within the APVMA registration process.

Yet to be published trial results in ratoons in the wet tropics show that:

- Bobcat® i-maxx (imazapic + hexazinone) is a very efficient herbicide across all trial sites, regardless of the soil type. It has a particularly long period of efficacy, regardless of the soil type and the rainfall amount when compared with imazapic and isoxaflutole. The addition of hexazinone to imazapic is an effective complement to control a wider weed spectrum and extend its period of activity. However it is not very effective in controlling legume vines like calopo.
- Imazapic performance varies in relation to the weed species and the soil type. It is particularly effective against grasses but its efficacy against broadleaves is only short-living and it does not control legume vines such as calopo.
- Isoxaflutole performance varies in relation to the weed species present. It is more effective against grasses than the broadleaves and ipomoea vines. It is particularly effective against legume vines like calopo. Its main limitation is a shorter period of efficacy. Specific soil restrictions apply with this active ingredient.
- Diuron at 500 g ai/ha is more effective at controlling broadleaves than grasses or vines; however, its period of efficacy is very short.

Evidence that growers are using alternative residual herbicides is found in results from the Great Barrier Reef Catchment Load Monitoring Program, with detections of all alternative registered herbicides (Great Barrier Reef Report Card 2015 Results).

The move to alternative residual herbicides to diuron raises the question of whether this is appropriate in terms of environmental stewardship. Are the alternatives more appropriate environmentally? The SRA project *Developing an alternative herbicide management strategy to replace PSII herbicides in the Wet Tropics area* approached this from two viewpoints:

- Rainfall simulations have provided insight into the propensity of different herbicides to be lost in rain-fall run-off.
- Eco-toxicity screening compared the relative toxicity of herbicides to aquatic organisms.

Comparing the relative risks of different herbicides

Data from rainfall simulations and from toxicity studies are combined to develop a relative risk ranking for herbicides used in sugarcane. Using diuron as the reference, herbicides are given a ranking relative to diuron. The relative risk ranking is different from a toxicity ranking, as it also allows for differences in likelihood of losses in run-off and also differences in applied quantities.

For example, data from three runoff simulations done under variable scenarios (plant cane, ratoon on trash blanket) show that all applied herbicides have a much lower offsite risk relative to the high rate application of diuron (1 872 g/ha a.i.; equivalent to 4 kg/ha Bobcat® combi). Generally, all herbicides have a lower relative risk than the diuron high rate under these scenarios; most by at least ten-fold. Ametryn and metolachlor generally had relative risks of 1.5 times and 3 times less than diuron at the high rate.

When the relative risks of the herbicides are compared with the lower application rate of diuron (421.2 g/ha; equivalent to 900 g/ha Bobcat® combi), ametryn (~3 fold higher) and metolachlor (~1.5 fold higher) become higher offsite risks, while hexazinone, metribuzin, isoxaflutole and imazapic pose approximately half the risk of diuron at this lower rate. Overall the data generally show that the possible alternatives to diuron (and other herbicides in common use analysed in this study) pose less of a risk than diuron applied at standard rates (unpublished).

The development of a relative risk ranking for herbicides will provide two clear benefits:

- It provides us with confidence that encouraging the use of alternative herbicides to PSII's, specifically diuron, is in fact environmentally beneficial.
- As farm management decision-making systems become more sophisticated, growers and advisors can tailor herbicide options according to the environmental sensitivity applying to specific cane blocks.

Future research and development needs

When the relative risk ranking for herbicides used in sugarcane is finalised, smart tools to assist growers in their decision-making can be developed. Tools could take into account herbicide efficacy, relative ecological risk, weed targets, cane stage and soil type.

Apart from strategies reducing the amount of herbicides used or the use of alternative herbicide chemistry, research efforts could focus on 'filtering' runoff water before it enters watercourses or 'locking' herbicides to soil so they are less prone to runoff transport.

Meeting the water quality challenge involves the industry community, including growers, advisors, researchers and agribusiness. Scientific evidence will provide answers to many questions but ultimately growers make practice change decisions.

Many growers are already committed to industry stewardship. Programs like SmartCane BMP, and Bonsucro encourage grower participation in appropriate weed management programs. Growers are increasingly recognising the value of learning from each other in both formal and informal learning groups.

We see increasing grower engagement through projects such as Project Catalyst, the recently funded wet tropics project *Protecting our chemicals for the future through accelerated adoption of best management practice* (co-funded by SRA, EHP, Bayer and CropCare) and the continued support for the Sandy Creek growers water quality monitoring group supported through EHP funding.

For sugarcane, the current collaboration among a range of organisations; from our own industry organisations and growers, to universities to government research, extension and regulators; is probably unprecedented.

REFERENCES

Anon (2016) Great Barrier Reef Report Card 2015 Results. State of Queensland.

Anon (2015) Reef 2050 Long-Term Sustainability Plan, Commonwealth of Australia 2015.

Anon (2013) Reef Water Quality Protection Plan 2013, State of Queensland.

Anon (2013) Paddock to Reef Integrated Monitoring, Modelling and Reporting Program, Reef Water Quality Protection Plan 2013–2018. State of Queensland.

Fillols EF (2011) Impact of nutgrass on sugarcane yield. *11th Queensland Weed Symposium Proceedings* 2011, 51–54.

Fillols FJ, Callow BG (2010) Efficacy of pre-emergent herbicides on fresh trash blankets – results on late harvested ratoons. *Proceedings of the Australian Society of Sugar Cane Technologists* **32**, 460–473

Garside AL, Bell MJ. (2006) Final Report – SRDC Project YDV002. Sugar Cane Yield Decline Joint Venture Phase 2 (July 1999–June 2006). BSES Limited.

McMahon GG, Williams RC, McGuire PJ (1989) The effects of weed competition on ratoon sugarcane yield. *Proceedings of the Australian Society of Sugar Cane Technologists* **11**, 88–92.

Oliver P, Anderson JS, Davis A, Lewis S, Brodie J, Kookana, R (2014) Banded applications are highly effective in minimising herbicide migration from furrow-irrigated sugar cane. *Science of the Total Environment.* Vol 466–467, January 2014, 841–848.

Rohde K, McDuffie S, Agnew J, (2013) Paddock to Sub-catchment Scale Water Quality Monitoring of Sugarcane Management Practices. Final Report 2009/10 to 2011/12 Wet Seasons, Mackay Whitsunday Region. Department of Natural Resources and Mines, Queensland Government for Reef Catchments (Mackay Whitsunday Isaac) Limited Australia.

Silburn. DM, Foley. JL, deVoil. RC. (2011) Managing runoff of herbicides under rainfall and furrow irrigation with wheel traffic and banded spraying. *Agriculture, Ecosystems and Environment*. **180,** 40–53.

Watson P, Watson. D. (2015) Grower Survey 2015 Report for Sugar Research Australia. Down to Earth Research.