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Seminar Papers

NEW ADVANCES IN HERBICIDE USE

Wednesday

9 September 2009

Epping Club, Epping

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Collated / Edited by
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New Advances in Herbicide Use

Date: 9 September 2009
Venue: Epping Club Rawson Street Epping

0800 – 0900	**REGISTRATION & MORNING TEA**	
0900 – 0915	Welcome & Introduction	
0915 – 0945	Henk Smith Syngenta	Turf Herbicides
0945 – 1015	Kym Johnson Biosecurity Queensland	Integrating Herbicide Management for Lantana – A Decision Support Tool for Land Managers
1015 – 1115	David Loschke APVMA **KEYNOTE SPEAKER**	The Importance of Managing Spray Drift
1115 – 1130	**SHORT BREAK**	
1130 – 1200	Adrian Harris CropLife Australia	Herbicide Mode of Action Groups and Resistance Management Strategies
1200 – 1130	David Thompson NSW DECCW	Pesticides Legislation NSW
1230 – 1330	**LUNCH**	
1330 – 1400	Graham Charles NSW DII	Herbicide Use in Genetically Modified (GM) Crops
1400 – 1430	Paul Marynissen Wyong Council	Management Plans for Noxious Weeds
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New Advances in Herbicide Use

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TURF HERBICIDES

Dr Henk Smith,
Technical Manager Lawn & garden,
Syngenta Crop Protection Australia

A common goal shared by most turfgrass managers is to establish and maintain vigorous, high quality, attractive turf. Limiting the deleterious effects of weeds and promoting desirable growth through proper irrigation, fertilisation, mowing and cultural practices are necessary components of a balanced turfgrass management program. Weeds are the major pests on many turfgrass sites. Weeds compete with turfgrasses for growing space, sunlight, soil moisture and plant nutrients. Additionally, weeds detract from the natural beauty of turfgrasses due to differences in colour, size, shape and growth habit. Hence, weed control is necessary on most high quality turf areas.

Weed management almost always come down to a sound program involving;

1. correct weed identification
2. prevention of weed introduction
3. optimal desirable turf management and agronomic practices
4. proper selection and application of a herbicide program

Herbicides for use in turfgrass could be a confusing propositions, as a myriad of brand names have been registered for use in turf (236 from 1 Jan 2003 to date), while all are based on only 24 active ingredients. The choice of herbicide thus becomes important when considering a purchase for a specific weed control outcome.

The most important issue for turf managers when using herbicides is turf safety. Selective herbicides therefore dominate, but care should be taken to understand the impact of using even these selective herbicides in a highly manage turf sward. As an example we can look at sulfonylureas; currently there are four (4) registered for turf use in Australia – trifloxysulfuron (Monument Liquid Turf Herbicide – Syngenta), iodosulfuron (Destiny Selective Turf Herbicide – Bayer), halosulfuron (NutBuster Herbicide – agVantage) and rimsulfuron (Turf Culture Coliseum Herbicide). Although these four all share the same mode of action, the range of weeds they control as well as their relative safety to desired turf species differ vastly (Table 1). Some degree of forethought and consultation is thus needed when planning to include herbicides as part of your complete weed management strategy.

	Broadleaf Weeds	**Sedges**	**Grasses**	**Safe to use**
trifloxysulfuron	Several	Nutgrass Mullumbimby couch	Poa annua, ryegrass & kikuyu	Couch
iodosulfuron	Clover Bindii	No	Ryegrass	Couch, kikuyu & buffalo
halosulfuron	No	Nutgrass Mullumbimby couch	No	Warm & cool season grasses
rimsulfuron	No	No	Poa annua Ryegrass	Couch & Sir Walter Buffalo

INTERGRATING HERBICIDE MANAGEMENT FOR LANTANA – A DECISION SUPPORT TOOL FOR LAND MANAGERS

Kym Johnson
National Lantana Coordinator
Biosecurity Queensland

Summary

The Lantana Weeds of National Significance Program has developed a new best practice Decision Support Tool (DST) to assist land managers in the effective and efficient integration of herbicide management with other control techniques. This electronic resource is built on information gathered from three years of adaptive management trials at 11 sites throughout the east coast distribution of *Lantana camara.* Experimental sites included a range of conservation and primary production areas with differing situational and climatic conditions to gain a broad picture of the response of lantana to management actions. The final resource enables land managers to tailor three to four year integrated management sequences to their properties; and includes interactive calculators to provide realistic predictions of management program cost and expected efficacy.

Introduction

Lantana camara, one of Australia's 20 Weeds of National Significance, has a distribution that covers more than four million hectares of Queensland and New South Wales' most productive and environmentally significant regions. Recent impact assessments indicate that it currently costs the Australian grazing sector in excess of $121 million (05/06 values) in lost production and management costs on an annual basis (AEC group, 2007a). This has significant flow on impacts to the Australian economy as well as a suite of social implications for the producers involved. In addition, lantana has serious impacts on a diversity of environmental systems; and 1322 native plant species and 158 animal species have been listed as negatively affected by lantana invasion (National Lantana Management Group, 2009).

Prescribed integrated control strategies are seen as an important component of best practice weed control (Carter *et al.* 2006). However, 2003 and 2006 lantana stakeholder surveys (AEC group, 2007b) indicated that many land managers were unsure of how to integrate the wide array of control options available and management effectiveness was suffering as a consequence. In June 2006, funding was provided through the Federal Government's Defeating the Weed Menace Program for a three year project to develop the DST discussed in this paper.

Methods

Adaptive management trials were conducted at 11 sites in Queensland (Yarraman, Clairview, Ingham, Glen Ruth Station and Atherton) and New South Wales (Grafton, Ballina, Border Rangers NP, Berry, Gloucester and Wollongong) to identify suitable integrated management sequences under a variety of environmental and management situations.

Paired treatment and control plots were established using 10 x 10 m quadrats at each of the management sites. Measurements of lantana density, grass coverage, native plant species numbers and density, bare ground and other weed invasion were taken on a 4-6 monthly basis. Photo monitoring points were also established to provide visual records of the sites and plant condition both before and after treatment rounds.

Decisions on the most appropriate management actions for the trial sites were made through regular expert and stakeholder consultation and on the basis of data collected from the previous management action.

Where possible, local contractors or the land managers themselves were employed to under take management activities. This ensured the standard of management was equivalent to 'real-life' scenarios and provided a realistic representation of expected management costs and outcomes. Records of cost and time invested in control were also taken.

Results and Discussion

A Lantana Best Practice Manual has been developed for use in conjunction with the DST. This resource provides background information on management techniques and environmental variables that impact on control effectiveness. It also includes planning tools to assist in the development of a Property Pest Management Plan (PPMP) which is seen as critical to the establishment of clear and realistic management goals.

Once a PPMP has been developed, the land manager will have identified: (i) the extent and distribution of lantana infestations on their property; (ii) the highest priority management areas; (iii) timeframes for undertaking management activities; and (iv) desired outcomes. This basic information is vital for successful use of the DST.

The effectiveness of the Lantana DST hinges on its ability to represent a complex set of parameters in a manner that is user friendly and provides an accurate management scenario for the end user. From the data collected and extensive consultation via stakeholder workshops, it was determined that three primary variables could be used to determine suitable and cost effective control sequences. These are:

1. *access to the management site* – this influences the type of equipment that can be used and is defined by terrain, vegetation cover, geographical and infrastructure barriers;
2. *density of the infestation* – this influences the type of management technique that is feasible and cost effective; and
3. *size of the management area* – the scale of infestation will determine the suitability of broad scale treatments such as fire, large machinery of aerial spraying. Significant economy of scale savings may be achieved through these techniques and must be factored into the final calculations.

The DST guides the user through a series of questions that lead to a number of comparable (in terms of cost and effectiveness) management sequences. Secondary variables including management technique preference, control calendars and availability of equipment can then be used to determine the most appropriate sequence of control.

Incorporating interactive calculators to assess the cost of control and comparative efficacy of different management scenarios, this tool promises to provide greater surety to land managers struggling with the issue of integrated control.

Free copies of the Lantana Best Practice Manual and Decision Support Tool can be ordered from the National Lantana Coordinator at LantanaWoNS@deedi.qld.gov.au.

References

AEC group (2007a). *The economic impact of lantana on the Australian grazing sector,* Qld Dept. Natural Resources and Water, Brisbane.

AEC group (2007b). *Lantana survey analysis (final report),* Qld Dept. Natural Resources and Water, Brisbane.

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National Lantana Management Group (2009). *Draft plan to protect environmental assets from lantana,* Brisbane.

THE IMPORTANCE OF MANAGING SPRAY DRIFT

David Loschke
Australian Pesticides and Veterinary Medicines Authority

Dr David Loschke's academic background is in molecular genetics and biochemistry. David worked in research and teaching for twenty years mainly at the University of Florida and at the Australian National University in Canberra before joining the Australian Pesticides and Veterinary Medicines Authority (APVMA) in 1997. He has dealt with many issues of pesticide regulation at the APVMA and was appointed the APVMA's Principal Scientist for Agricultural Chemicals in 2002.

Concerns among the public about possible risks from pesticide spray drift have increased dramatically over the last few years as more people become aware of the issue from internet and media reports. The Australian Pesticides and Veterinary Medicines Authority (APVMA), the federal agency that regulates pesticides, uses scientific information to determine the risks when using each pesticide and decides whether the risk can be controlled safely. Some level of spray drift happens with almost every outdoor pesticide spray application, and the APVMA is now placing stronger use restrictions on pesticide labels to reduce spray drift.

The risks that arise from off-target spray drift are caused by the exposure of people and other living things to a chemical that has drifted to a place where it should not be. Each active chemical is different and can create different kinds of risks. When the properties of a specific chemical are compared with the living things it might affect and linked to the way spray drift deposits accumulate downwind, the APVMA can estimate how far spray drift risks can reach from the application area.

The APVMA has recently refined its spray drift risk assessment policy and is now applying a broader range of drift-control restrictions on pesticide labels. This more stringent regulation is already being applied to all new products and will be applied to all existing products as the APVMA works through them dealing with the higher risk pesticides first.

Of all the factors contributing to spray drift that the APVMA can control with label restrictions, spray droplet size is the most important. It is easy to understand that very small droplets are more likely to drift, but the risk is even greater than most realise. During the past 20 years, growers have heard again and again that they need to apply pesticides with very small droplets in order to achieve good coverage on their targets and therefore achieve good efficacy. But many growers have taken this message too far and apply pesticides with spray droplets that are finer than needed to achieve efficacy.

In fact, with fine droplets efficacy can actually be reduced by losing part of the pesticide to off-target drift – pesticide that was intended for the crop. More importantly, other people including other farmers may be harmed by the drifted pesticide and will justifiably call for greater restrictions or even bans to pesticide use. The APVMA is dealing with this by requiring many pesticides to be applied with a "COARSE" droplet size. For example, all 2,4-D products must now be applied with Coarse droplets, and by the 2009-2010 season, the other phenoxy herbicides will have the same requirement. The APVMA will ensure that the droplet size required on the label still provides good efficacy for the product.

The new labels will also limit applications to times when the wind speed is between 3 and 20 km/hr and will forbid applications during times of surface temperature inversions. It is likely that applications of 2,4-D through the night during surface temperature inversion conditions have been one of the biggest factors in the serious damage caused to cotton and vineyard crops during the last several years.

One of the most significant changes that growers must comply with will be new mandatory "no-spray zones" on pesticide labels. These protective no-spray zones (often called buffer zones) are different for each pesticide and are determined from scientific studies that examine each pesticide's hazards. The no-spray zones will only exist in the downwind direction at the time of application and only when the kind of risk identified on the label is present in that direction. The label will specify the distance from the identified risk where spraying must stop. That area can be treated later when the wind is blowing in a different direction.

Chemical users can find more information on these changes on the APVMA website at www.apvma.gov.au. Look under the heading "Spray Drift" where a number of downloadable documents can be found including the general policy document – APVMA OPERATING PRINCIPLES IN RELATION TO SPRAY DRIFT RISK.

It is important that all pesticide users appreciate that the public is now holding them to a higher standard in relation to spray drift than in the past. Signs of this are clearly evident overseas in recent regulatory decisions and court cases. Public sentiment in Australia is also evident in letters to Ministers and regulators and in many recent media reports. Responsible control of spray drift is a very important issue for the farm community in maintaining access to valuable chemical tools into the future.

HERBICIDE MODE OF ACTION GROUPS AND RESISTANCE MANAGEMENT STRATEGIES

Dr Adrian Harris,
Assistant Director – Regulatory and Technical,
CropLife Australia

Importance of herbicide resistance

Australia has the biggest herbicide resistance problem in the world. Repeated use of the same few herbicides for weed control in grain crops, often at low rates, has caused much of the resistance development (Neve and Powles, 2005, Powles 2009).

Herbicide resistance has increased rapidly since it was first reported in annual ryegrass in 1982 and has become a key constraint to crop production in all states with a history of intensive herbicide use. Resistant annual ryegrass is now very widespread across the grain belt of southern and eastern Australia and resistance has been detected to six different herbicide chemical groups to date in this weed alone.

Resistance has now been confirmed in 34 weed species in Australia, and, even more worrying, resistance has developed to 11 different herbicide chemical groups. Cases of multiple resistance are also commonly reported where, for example, annual ryegrass populations are resistant to two or more chemical groups. Selection of resistant weeds can occur in as little as 3-4 years if no attention is paid to resistance management and this significantly reduces herbicide options for the grower. Many important horticultural weed species have been confirmed with resistance to a wide range of herbicides, e.g. barnyard grass, stinging nettle and capeweed.

If the resistance problem is not managed, many herbicides will become ineffective, resistance will develop in new weeds and situations, and weeds may become resistant to new herbicides as they are released. Ultimately, minimum till systems could be threatened because few herbicides will be effective. Farmers should not expect that new herbicides will continue to be developed and released regularly enough to overcome the resistance problem, as the research and development required for each new chemical takes over ten years and $200 million dollars on average.

Managing herbicide resistance

Resistance can be managed by continually following current resistance management strategies, including integrated weed management (IWM), and using the application rate specified on the herbicide product label. The main aims are to avoid repeated use of the same herbicide or chemically related herbicides and not cut rates. IWM combines herbicides with other cultural practices for weed control, maximising the opportunity to prevent seed-set and to reduce the weed seed bank.

Herbicide Mode of Action Groups

In order to manage herbicide resistant weeds, all herbicides sold in Australia are grouped by biochemical mode of action of the active constituent against weeds. The mode of action is indicated by a letter code on the product label such as:

GROUP	**G**	**HERBICIDE**

CropLife Australia developed the world's first herbicide mode of action classification system in the late 1980s, based on the resistance risk of each group of herbicides. Australia was the first country to introduce compulsory mode of action labelling on products, but other countries have since adopted mode of action classification systems.

CropLife Australia completely revised the herbicide mode of action grouping and labelling system in February 2008 to better align it with the international system and to incorporate new information on many herbicides. Six new herbicide mode of action groups were created (Groups H, O, P, Q, R and Z) to more accurately group herbicides, but most herbicides have not changed group. Titles describing some of the existing herbicide groups were also changed to more accurately describe those groups. The old groups E, F and K have the most changes. Most of the other groups remain unchanged, but 24 active constituents were moved to a different group and the new group should be used when referring to the resistance management strategies.

Some affected herbicide product labels may not be updated to show the new mode of action letters until 2011. Meanwhile, farmers should read the active constituent on the product label, then check the current mode of action letter on the CropLife Australia website at www.croplifeaustralia.org.au. The mode of action letter on the website may be more up to date than the letter on the product label. The website also contains a table that shows which active constituents have changed mode of action letter and may therefore require a different resistance management strategy. Where there is a temporary difference in mode of action group on labels, the new mode of action group on the CropLife website should be used.

Herbicide Resistance Management Strategies

By using the mode of action letter for each herbicide, farmers can choose an appropriate resistance management strategy to minimise the risk of resistance developing to that herbicide. Always follow the product label for application rates and specific use instructions.

Herbicides in Group A (mostly targeted at annual ryegrass and wild oats) and Group B (broadleaf and grass weeds) are high risk herbicides and specific guidelines are written for use of these products in winter cropping systems. Not all mode of action groups carry the same risk for resistance development, therefore specific guidelines for Groups E, G, H, K, N, O, P and R have not been developed to date because there are no recorded cases of weeds resistant to members of these groups in Australia.

CropLife regularly updates and publishes the current modes of action and resistance management strategies on its website. Further information on the modes of action for all herbicide active constituents, herbicides that have changed mode of action groups, current resistance management strategies and the causes of herbicide resistance are available from the CropLife Australia website at www.croplifeaustralia.org.au under "Resistance Management" or from local advisers and agronomists.

References

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Powles, S. (2009). Sub-label rates boost herbicide resistance. *Rural business* **19** (3), 30-31. (March 2009).

PESTICIDES LEGISLATION NSW

David Thompson
Pesticides Inspector, Metro Region
NSW Dept Environment & Climate Change

Brief overview

***Pesticides Act 1999* obliges user to:**

- gain registered products only, or those made available by Permit
- read label or Permit prior to each use
- follow all relevant label instructions, with particular attention to:
  - DO and DO NOT statements above Table of Use
  - ensuring target pest and use in NSW is identified on label
  - mixing rates and rates of application
  - Withholding or Re-Entry periods; compatibility; water quality
  - Safety Instructions for other people
  - oncoming weather conditions
  - nearby sensitivities: drift (also Threatened Species)

The "Due diligence" defence

Establish (to the Court):
(a) that the commission of the offence was due to causes over which the person had no control, and
(b) that the person took all reasonable precautions and exercised all due diligence to prevent the commission of the offence.

- Identify the risks:
  - adverse weather
  - equipment failure, spillage at mixing, vehicle instability
  - overspray waterways
  - threatened species impacted
  - off-target drift
  - bystander effects
  - incorrect mixing/application/location

- Address the risks
  - gain forecast – document it, save it
  - maintenance program – planned, documented & signed
  - check product appropriateness – alternatives?
  - gain professional advice – document surveys
  - right equipment, right weather
  - notify neighbours
  - check label thoroughly
  - operator trained
  - complete records kept
  - product & equipment updates – documented
  - works manual
  - safety equipment maintenance & replacement – documented
  - occasional unannounced work inspections/audits

Shared liability S 112

A corporation contravenes whether by act or omission

- each director taken also to have contravened, UNLESS
  - court satisfied that:
    - the person not in a position to influence, OR
    - used all due diligence to prevent the contravention
  - Directors to keep detailed records, use only trained workers, ensure a 'diligent' degree of oversight,

Pesticides Regulation includes

- Notification by Public Authorities of pesticide applications to come (e.g. from a Pesticide Notification Plan as found on Councils'/Public Authorities' websites.
- Training for commercial pesticide users
- Record keeping for each application

Licensing

- Under POEO Act, use of herbicides in water
- Whether the DECC Region recommends it
- Metro Region considers not necessary in most cases
- Public Register http://www.environment.nsw.gov.au/prpoeoapp/searchregister.aspx

Threatened Species

Pesticides Act S 9/11 Harm to animals or plants

- Strict liability Threatened Species – i.e. if it occurs, deemed to be offence.
- Due diligence defence – for Court to decide
- No on-farm defence

NP&W Act S 118A Harm/pick threatened/endangered/vulnerable species

HERBICIDE USE IN GENETICALLY MODIFIED (GM) CROPS

Graham Charles
Research Agronomist (Weeds)
NSW Department of Industry & Investment
Cotton Catchment Communities CRC

The Australian cotton industry has been growing genetically modified, herbicide tolerant cotton varieties for the past 10 seasons. Over 85% of the cotton planted in the 2009/10 season will include the glyphosate tolerance, Roundup Ready Flex® gene. Almost all of this cotton will also include two insecticidal genes, toxic to the helicoverpa caterpillar, previously the most damaging pest of cotton production in Australia.

The use of the Roundup Ready Flex gene has contributed to improvements in in-crop weed control, with broadcast in-crop applications of glyphosate replacing many pre-planting and in-crop residual herbicide applications, hand-hoeing and some in-crop cultivation passes. Applications of glyphosate have many advantages over these older technologies. Glyphosate requires fewer man hours to apply, is less damaging to the crop than were the residual herbicides and early-season cultivation, the timing of its applications are more flexible (only being applied after weeds have emerged), generally glyphosate has a broader spectrum of control (readily controlling many of the weeds which were not well controlled by the residual herbicides), and it has a reduced environmental footprint, with fewer environmental and off-target issues.

Consequently, the introduction of herbicide tolerant GM cotton to Australia has been beneficial to the cotton grower and the environment, with improved weed control, better crop yields, and subsequent reductions in the use of cultivation and residual herbicides and associated environmental problems. The introduction of this technology has also enhanced the ability of cotton growers to develop more flexible farming systems for cotton. These include the adoption of permanent beds and permanent wheel tracks with much reduced levels of cultivation, the opportunity to plant into and retain standing stubble from previous crops, and the flexibility to adopt different planting configurations, including ultra-narrow row cotton. Comparisons of typical weed management inputs to conventional (non-GM) and Roundup Ready Flex cotton systems are shown in Table 1. Both traditional conventional systems (the standard system of the 1980s and 1990s) and a modified conventional system are shown. The modified conventional system has developed over the last decade and is now the more widely used conventional system.

Table 1. A comparison of typical inputs in conventional and GM cotton systems.

Inputs	Traditional conventional	Modified conventional system now used	Roundup Ready Flex® cotton
Pre-planting	Heavy cultivation x 2 Hilling up Nitrogen Trifluralin & diuron incorporated	Glyphosate & 2,4-D x 2 Nitrogen & reshape beds	Glyphosate & 2,4-D x 2 Nitrogen & reshape beds
At planting	Pendimethalin & fluometuron banded	Pendimethalin & fluometuron banded	
In-crop	Inter-row cultivation Inter-row cultivation Hand-hoeing Inter-row cultivation & directed prometryn	Inter-row cultivation Inter-row cultivation Shielded glyphosate Inter-row cultivation & directed prometryn	Glyphosate Inter-row cultivation Glyphosate Glyphosate

However, increasing reliance on glyphosate in the farming system has led to other problems, including species shift to weeds which are more tolerant of glyphosate and may be difficult to control with other herbicides, and the emergence of glyphosate resistant weed species. These problems have not been caused by the adoption of a GM crop, but by over-reliance on glyphosate in the whole farming system. A robust crop management plan for resistance management in Roundup Ready cotton was developed for this product and implementation of this plan ensures that weeds are well managed in-crop. The results of this management are monitored and reviewed annually to ensure the system is stable and effective.

Species shift and the emergence of glyphosate resistant weeds are relatively minor issues for cotton production but much larger issues for the farming system and the environment. In practical terms, they can be treated as a single issue, as the causes of their development and the strategies required to manage these issues are the same. In simple terms, resistance and species shift result from over-reliance on a single weed management tool and corresponding under-use of alternative management tools. In this case, the problems are caused by the substitution of glyphosate for cultivation, hand-hoeing and other herbicides.

To date, glyphosate resistant individuals of three weed species (rye grass, awnless barnyard grass and liverseed grass) have emerged in the farming system, with a fourth species, flaxleaf fleabane showing high levels of tolerance to glyphosate. Problems have also emerged from a range of other glyphosate tolerant species, including pig weed and the bindweed complex.

The problems of glyphosate resistant grasses could be readily addressed in cotton, with minimal impact on the system, by reintroducing a residual grass herbicide. This could be applied pre-or post-crop emergence, but mechanical incorporation is problematic in standing stubble and post-emergence in the ultra-narrow row configuration. Control of these weeds is more problematic in fallow and likely to require regular use of a double-knock approach, following glyphosate with either an alternative herbicide, such as paraquat, or a cultivation pass, increasing the number of inputs and the cost of the system. Glyphosate tolerant perennial weeds, such as bindweed, are very difficult to control with a herbicide once established. Their management will probably require the use of strategic heavy cultivation.

Nevertheless, evidence from the southern farming system suggests that glyphosate resistance can be avoided if weeds are controlled using just one additional effective alternative weed management tool each year. An additional tool needs to be used each year, regardless of whether a GM crop is planted, and over the whole farm area, including irrigation structures and fence lines, where glyphosate may be the only weed management tool currently used.

The introduction of an alternative GM technology, glufosinate tolerant, Liberty Link® cotton, and possibly other genes in the future, creates other viable options for managing species shift and herbicide resistance in cotton, but does little to assist with managing these weeds in fallows, as glufosinate is not a cost-effective herbicide for fallow use. The introduction of alternative genes also adds to the complexity of the farming system, increasing the likelihood of accidental herbicide damage from drift, contamination and applications to the wrong fields. Nevertheless, these genes offer cotton growers continuing access to the benefits of GM technology, while expanding the range of weed management tools and increasing the stability and sustainability of the system. This is especially true with Liberty Link cotton, where a residual grass herbicide will necessarily be part of the system on most fields.

The use of these GM technologies in canola in Australia is still in its infancy, but problems with species shift and glyphosate resistant weeds are also inevitable in canola, with glyphosate resistant rye grass already present through much of the canola growing area.

Acknowledgements
I acknowledge the support of the NSW Department of Industry & Investment, the Cotton Research & Development Corporation, and the Cotton Catchment Communities CRC.

MANAGEMENT PLANS FOR NOXIOUS WEEDS

Paul Marynissen
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THE '*REST*' OF THE STORY – *RES*TORATION AND *RES*ILIENCE IN WEED-INVADED ECOSYSTEMS

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University of Wollongong, Wollongong

The Weeds of National Significance (WONS) program focuses on 20 widespread weeds that impact on Australia's environmental, social and economic assets. Thirteen of these weeds are prone to occur in NSW and are the targets of strategic management efforts encompassing control, containment, eradication and asset protection. While containment and eradication programs concentrate primarily on the target weed (e.g. containment lines preventing further spread), asset protection programs strive to integrate control of the target weed into larger, holistic programs that achieve an asset protection outcome (e.g. an increase in biodiversity).

With regard to control, WONS programs support ongoing research into control methodologies and have produced best practice guidelines that provide the most updated control methods available to weed managers. Most WONS, and indeed many weeds, have effective and available control methods and land managers across Australia are making good progress in reducing the density and/or distributions of WONS and other weeds. We know how to kill most weeds and are doing it well. However, if the goal of your program is asset protection – specifically, protection of *natural* assets - there is more to the story than just controlling the weeds.

Management of weeds is a vital aspect of protecting native biodiversity and normal ecosystem processes (Byers *et al*. 2002) and the ultimate goal for many land managers is to restore native ecosystems, that is, return the ecosystems to an earlier and better condition. Where weed invasion is the primary impact, weed control is a critical step in this process. But unless the weed invasion is at very early stage, weed control alone may not be enough to return the ecosystem to a healthy, pre-invasion condition: Further restoration activities may be necessary to eliminate the long-term effects that weed invasion has caused. In addition, if ecosystem processes or structure are significantly altered by environmental weeds, weed management alone will not necessarily restore the native ecosystem (Hobbs and Humphries 1995).

This paper uses examples from two WONS, bitou bush (*Chrysanthemoides monilifera* (L.) Norl. subsp. *monilifera* (DC.)) and bridal creeper (*Asparagus asparagoides*, (L.) Druce), to illustrate the need for increased awareness of restoration and to call for an increase in restoration effort following weed management. These two weeds are used as examples because a large amount of information exists about the impacts of these weeds on native ecosystems, as well as on the *response* of ecosystems to the control of these weeds. This information is critical to adequately designing restoration activities. Unfortunately, little work has been conducted on the impacts of invasive plants. This lack of knowledge hampers restoration efforts because if we do not know what the impacts of the weeds are, we cannot know what is required to adequately restore weed-invaded ecosystems. Based on the information we have for bitou bush and bridal creeper, it is becoming apparent that weed removal alone may not be enough.

Restoring resilience

Resilience is the capacity of an ecosystem to tolerate disturbance or to recover from damage, such as a storm event or disease. Resilience in native ecosystems is increased by having many different species in each different ecosystem layer (e.g. multiple shrub species, multiple grass species, etc) and also by having high numbers of each of those different species – so high species diversity and abundance lead to resilient ecosystems. If the goal of a weed management program is protecting natural ecosystems, then an outcome of the program must be to ensure that the ecosystems are as resilient as possible after weed control and restoration. Recent evidence from studies of bitou bush and bridal creeper-invaded ecosystems indicates that current weed management and restoration techniques may not be returning ecosystems to previous resilient levels.

Bitou bush

Bitou bush invasion reduces native plant species abundance (Mason and French 2007, French *et al.* 2008) and alters the diversity of native seeds and seedlings (Mason *et al*. 2007). In bitou bush invaded ecosystems, native species from all layers (grasses, herbs, shrubs, trees and vines) were less abundant and occurred more infrequently (Mason and French 2007). In addition, management actions (i.e. controlling bitou bush) can also reduce abundance and alter native species diversity (Mason and French 2007). Off-target herbicide damage during bitou bush control can cause lower native plant species abundance in sprayed areas and intensive bitou bush management (e.g. bush regeneration), while reducing the threat of bitou bush, has been associated with an increase in other weeds, which may cause secondary weed invasion after bitou bush is removed (Mason and French 2007, French *et al*. 2008).

Thus, bitou bush invasion and its subsequent management can lead to a reduction in resilience in coastal ecosystems. If the goal is to return that resilience, there must be increases in native species abundance and diversity following bitou bush control. This can be achieved however it will require modification of our current techniques. Bitou bush control *can and does* lead to an increase in native species abundance (Mason and French 2007) – so species that are already there may become more plentiful – but control measures must strive to prevent off-target damage and introduction of other weeds. Hygiene procedures should be put in place for bush regenerators and contractors and these should be combined with follow-up removal of secondary weeds, which are also likely to be present in the seedbank. Greater efforts should also be taken to protect native species prior to herbicide applications.

While native plant abundance can increase following bitou bush control, managed sites may not get a consequent increase in native plant diversity as a result of control. The species that are *supposed* to be at the site (the ones that were there previously) may not always be present in the seedbank, and they may not be able to re-establish through natural dispersal. Studies in bitou bush-invaded habitats show that the seed of many native species is not present in below or above-ground seedbanks (Mason *et al*. 2007). In addition, recent work indicates that the majority of native species that are assumed to "disperse in" naturally are not doing so, likely as a result of multiple factors: 1) the nature of their seed dispersal mechanisms, e.g. many are ant dispersed and only move 9 m or so, while many others have no dispersal mechanism at all and simply fall beneath the parent plant, 2) lack of connectivity, e.g. seed sources for wind or vertebrate dispersed species may be too far away for effective dispersal, or 3) lack of propagule pressure, e.g. desired species may only exist low numbers, thus producing very limited seed and reduced likelihood of dispersal (French *et al.* in review). Many of these conditions are true for coastal communities in NSW, thus the presumption that "nature will take its course" and species will re-establish or disperse into a site following weed control is not necessarily valid.

Bridal creeper

Bridal creeper reduces native plant diversity and abundance (Turner and Virtue 2006, Turner *et al*. 2008a). The main impact is expressed through a change in the structure of the native community, with understorey shrubs and trees that bridal creeper uses as supports being most heavily impacted (Turner and Virtue 2006, Turner *et al*. 2008a). In addition, bridal creeper produces a large tuberous mat that occupies extensive space in the top-soil, which excludes other plants (Turner 2008). Thus, bridal creeper invasion can also lead to a reduction in resilience in native ecosystems.

If the goal is to return that resilience, there must be increases in native species abundance and diversity following control. However, in some instances native species abundance and diversity do not increase following bridal creeper control (Turner and Virtue 2006, Turner *et al*. 2008b). A suite of native and exotic plants will benefit following bridal creeper control, and species that readily germinate from the seedbank will replace bridal creeper (Turner and Virtue 2006). The species most likely to dominate are other weeds, as invaded sites have large exotic seedbanks that readily germinate (Turner *et al*. 2008a). Additional restoration will be necessary to prevent those weeds from establishing. In addition, the tuberous mats of older bridal creeper plants can leave a detrimental legacy. Large, dead tuber mats may remain many years after control. These mats can prevent native plant root growth and establishment and can continue to impact native vegetation long after bridal creeper plants are killed (Turner and Virtue 2006, Turner 2008). These impacts will be highest at sites where bridal creeper has dominated over the longer term.

Linking other restoration techniques with bridal creeper management will be necessary to build ecosystem resilience after bridal creeper control. For example, the use of fire as a restoration tool could help increase the germination rate of native species, and may help tip the balance back towards native species, by increasing the ratio of native to exotic germinations (Turner *et al.* 2008a). Fire can be an important restoration tool when used in conjunction with bridal creeper management. Fire may also stimulate the regeneration of some native plants and speed up the recovery of bridal creeper-invaded ecosystems, provided that bridal creeper and other secondary weeds are kept at a low post-fire density (Turner and Virtue 2009).

Where to from here?

So in light of all the negative impacts that weeds may impart, how can we assist nature in re-building resilient ecosystems after weed control? As mentioned, there are not sufficient studies to quantify the impacts of all weeds, or even *all* of the impacts of any weed, but if weeds like bridal creeper and bitou bush are causing the type of damage described above, then it is critical to increase restoration efforts.

Many restoration programs depend on native regeneration from the seedbank and natural dispersal – 'letting nature take its course". However we know from the studies mentioned above that this will not necessarily provide the 'missing' species, or species in high enough densities, to return ecosystem resilience. If native seed is not present in the seedbank and there is a low chance that it will naturally disperse into the site, restoration work must be done to increase the species diversity following weed control. Due to budget constraints, most restoration work currently involves re-planting three or four different species in low densities across the site. These species, at most, usually represent two or three ecosystem layers (e.g. vines, shrubs or perhaps tree species) but almost *never* represent all ecosystem layers (grasses, herbs, vines, shrubs and trees). Furthermore, the species planted are often species that are *already* present, so they do not increase diversity or assist in re-establishing 'missing' species. Woody invaders, such as bitou bush, can have very strong negative impacts on the smaller, more cryptic species in the lower layers, that is herbs and grasses, and these should be a focus during post-control restoration efforts (Mason *et al*. 2009).

To build resilient ecosystems, the full complement of species should ideally be re-established in the area being restored. All of the species that were present *before* the weed invasion should be present *after* restoration, both in terms of number and composition. Although this may not be possible in many cases, at the least replanting should involve several species from all layers, thus increasing diversity, and species should be planted as densely as resources and space allow. In other words, each layer should have a suite of species and each of these should be as abundant as possible. This will provide an ecological 'backup,' so that if something should eliminate one species in a layer (disease, drought, etc), there will be another species there to provide similar function in the ecosystem. Another benefit to re-planting densely (in high abundance) is that very few spaces will remain for undesirable species, such as weeds, to fill, thus providing some protection from re-invasion. While re-planting at high density means some native species will die due to over-crowding, it is better to sacrifice these rather than leaving empty spaces for weeds to fill.

Re-building resilient ecosystems after weed control, especially if the area is long-invaded, will require significant investment in resources and participation at all levels of Natural Resource Management (NRM). Guidelines are currently being developed to guide restoration efforts in coastal habitats following bitou bush control (Wallace and French in prep.). These guidelines will focus on rebuilding ecosystem resilience and will provide a template to: 1) assess what native species *should* be present at the site, 2) assess what species are present at the site post-weed control, 3) determine what species are 'missing', and 4) provide information on how to restore those species. It is hoped that these types of monitoring and adaptive management tools for restoration can be expanded and incorporated into NRM efforts nationally.

Restoring resilient ecosystems will also require greater participation from the nursery industry, as they will need to grow the 'missing' species, many of which are small, cryptic plants like herbs and grasses that are not currently available on the market. To complicate matters, many of these species are difficult to propagate and new techniques must be developed before they can be grown commercially. But to create this market demand and provide resources, there must also be a change in the direction of NRM policy such that long-term restoration efforts to re-build resilient ecosystems are supported as fundamental work. This is a big ask in a climate of increasing demand on NRM funds. But another consideration that should be taken into account is climate change. As NRM policies evolve to account for adaptation to climate change, building ecosystem resilience should be a key consideration, as those ecosystems that are healthy and resilient will likely be the best equipped to respond to the demands of a warming climate.

For further information on the impacts of bitou bush, see http://www.uow.edu.au/science/biol/icb/weedecology/

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