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FINDING AND FIXING GLYPHOSATE-RESISTANCE RISK IN DIVERSE SUB-TROPICAL AUSTRALIAN FARMING SYSTEMS

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ABSTRACT

Glyphosate-resistant weed populations are now present in sub-tropical Australian cropping systems and seem likely to become more common. To support the industry's approach to this problem, we developed a risk assessment framework for glyphosate resistance in these cropping systems that combines factors for weed species risk with weed control practices. We used the framework to assess a range of regionally important weeds currently controlled with glyphosate. Several species were identified as being at high risk, including both grasses and broadleaf species active in summer and winter, but other regionally important weeds were found to be at relatively low risk. The risk assessment framework was used to build an online toolkit that is now used by growers to assess resistance risk for individual fields, and to investigate the value of possible practice change. We used the online toolkit to generate a database of risk scores and management practices and analysed nearly 40 responses. Glyphosate resistance risks were found to be highest on average in fallows and non-irrigated glyphosate-resistant cotton crops, but risks and practices were found to vary substantially within and between common crops and fallows. So, while there are crops and farming practices that the broadacre farming industry across the region should regard as being high risk, individuals' own resistance risks are likely to be significantly different from the average for some phases of their rotation, and should be analysed and responded to separately.

Keywords: Farming systems, glyphosate, resistance, risk assessment.

INTRODUCTION

Since 2008, predictions made about the imminent arrival of glyphosate-resistant weeds in Australia's sub-tropical cropping systems (such as in Thornby and Walker 2009) have materialised. There are now more than 20 resistant populations of summer grasses in the region (Preston, 2011), so while confirmed resistant populations are still uncommon, their prevalence is increasing rapidly (Heap, 2011).

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Nevertheless, robust weed management systems have been predicted to be of value in maintaining glyphosate susceptibility (Werth *et al*., 2008). In order to arm the region's cotton and grain growers with better information, we developed and published an online tool (Thornby *et al*. 2010; www.dpi.qld.gov.au/26_16653.htm) for the assessment of glyphosate resistance risk at an individual field level. This tool assesses two sources of resistance risk; that due to weed characteristics ('species risk'), and that due to management-driven selection pressure ('management risk'). The tool can be used to assess either a current, past, or speculative situation.

The region's farming systems are highly variable (Osten *et al*., 2007), with a number of major and minor crops grown in rotations that are frequently changed in response to the rainfall in any particular season. These rotations rely heavily on glyphosate for weed control in fallows and for pre-planting preparation, but may also incorporate varying types and intensities of other weed control. This variability means that industry-wide assessments of and approaches to glyphosate resistance risk may not fit (to a varying extent) some farms, and proposed strategies and tactics may not be equally applicable for different years or sequences of years that may be substantially drier or wetter than average.

There is also an important distinction between species risk and species prevalence. Across the north-eastern subtropical area of Australia, weed floras differ according to local soil, climate, and farming system conditions. If we can reasonably assume that it is most useful to drive resistance prevention strategies around the weeds that are at highest risk, an assessment of individual circumstances must be made, as the most frequently controlled weeds on any farm or field may not be the ones at highest risk of evolving resistance to glyphosate.

To investigate these issues, we used a database of responses to our online risk assessment tool to measure variability in glyphosate resistance risks within the region and to analyse potential differences between prevalent species and species that are at high risk of resistance.

METHODS

We collected responses to the online risk assessment tool by having an automated email sent for collection into a database. The email contains all of the user's responses to the tool including: weed presence or absence for 30 regionally important species; the user's crop rotation which may be of up to five years; glyphosate and non-glyphosate herbicide use; tillage frequency; the frequency and effectiveness of actions taken specifically to control survivors of glyphosate applications; and calculated risk assessment scores for rotational phases (crops or fallows) and seasons (as per Thornby *et al*., 2010).

We compared species risk scores as used in the tool with two sources of information on species prevalence: reported species prevalence rates within the tool, and data from a series of on-ground weed surveys collated by Werth *et al*. (2010).

RESULTS

At the time of writing there had been 39 legitimate responses to the online risk assessment tool. The responses to the tool reflected the variability of farming systems in the region. Responses were grouped into rotations that were either identical or varied by only one crop or fallow from others in the same group, and under this analysis there were 28 different rotations in the dataset. No crops or fallows were reported by all growers. Cotton was the most common crop: 67% of growers reported including some form of cotton cropping (irrigated- or non-irrigated crops that were either glyphosate resistant or conventional). The next three most common phases were winter fallow (59%); wheat (54%); and summer fallow (51%).

Weed Prevalence and Resistance Risks

All 30 weed species included in the tool (Thornby *et al*., 2010) were selected by more than one respondent as being targets for control in the field being assessed. Frequency of selection of individual species varied between 15 and 54 %. Only one species, flaxleaf fleabane (*Conyza bonariensis*), was present in the majority of fields (Table-1).

Weed prevalence data of the top 10 weeds are compared with the results of field surveys reviewed by Werth *et al*. (2010) in Table-1. Of the 15 most-reported weeds in the online tool dataset, six did not appear in the top 15 weeds in previous field surveys. Results most closely reflected the 2009 surveys with a few exceptions: notably, substantially increased reported prevalence of turnip weed (*Rapistrum rugosum*) and pigweed (*Portulaca oleracea*), and reduced reported prevalence of peach vine (*Ipomoea lonchophylla*).

Glyphosate resistance risk scores for each species used in the risk assessment process are also shown in Table-1. There is no correlation between estimated species risk level and their frequency of reporting as species being controlled during use of the tool (coefficient of correlation = -0.31).

Management Variability

The wide differences in strategies used to manage weeds in the region are illustrated by the range of management risk scores reported in the online tool. A full explanation of the risk assessment protocol is available in Thornby *et al*. (2010), but in brief the management risk scores are obtained by subtracting mitigating factors (uses of non-glyphosate herbicides, follow-up activities etc.) from the number of glyphosate sprays per phase. On average, summer fallow and non-irrigated glyphosate-resistant cotton were under the most risky management, but individuals' scores varied substantially both between and within phases, as shown in Table-2.

Table-1. Frequency of reporting of weed presence in an online tool and previous field surveys in north-eastern Australia, and predicted resistance risk scores.

Species	Rank of frequency of reporting (% of respondents)	Rank in 2001 surveys[1]	Rank in 2009 surveys[2]	Glyphosate resistance risk score[3]
Conyza bonariensis	1 (54 %)	14	2	8.15
Portulaca oleracea	2 (46 %)	3	7	1.85
Hibiscus trionum	3 (44 %)	1	1	1.11
Echinochloa spp.	3 (44 %)	5	7	6.85
Rapistrum rugosum	5 (41 %)	>15	>15	1.85
Sonchus oleraceus	5 (41 %)	7	3	6.85
Tribulus terrestris	7 (38 %)	4	6	1.11
Ipomoea plebeia	7 (38 %)	>15	>15	1.85
Avena spp.	9 (36 %)	>15	15	3.52
Sisymbrium thellungii	9 (36 %)	>15	>15	1.85
Polygonum aviculare	11 (33 %)	>15	>15	2.59
Malva parviflora	11 (33 %)	>15	>15	1.11
Amaranthus macrocarpus	11 (33 %)	5	11	1.85
Lolium rigidum	14 (31 %)	>15	>15	6.11
Ipomoea lonchophylla	15 (28 %)	4	5	1.11

1. Mean rank across two 2001 surveys summarised in Werth *et al.* (2010)
2. Mean rank in 2009 follow-up surveys from the same fields as in 2001 surveys (Werth *et al.*, 2010)
3. Species risk scores calculated as reported in Thornby *et al.* (2010)

In the case of non-glyphosate-resistant irrigated cotton crops, all of the respondents recorded using enough non-glyphosate tactics in the crop to reduce risk to nil (n=4). Similarly in the case of 'other summer crops', risks were uniformly low to moderate, ranging from zero to 0.85. In all other crops and fallows, some (but not all) respondents reported using high risk, glyphosate-dominant practices (ranges 1.64-5.00), and at least one respondent in each phase reported using enough non-glyphosate tactics to record a nil risk score. Overall summer and winter scores (the weighted contribution of all winter or summer phases in each respondent's rotation) showed that while summer practices were on average more risky than winter practices, there were individual scores at both low and very high risk levels for both seasons.

Table-2. Risk score means and ranges for all phases reported in the online tool.

Phase	Mean risk score	Risk score range	CV
Summer fallow	1.49	5.00	1.02
Non-irrigated GR cotton	1.37	2.92	0.91
Irrigated GR cotton	1.05	2.82	1.17
Winter fallows	0.85	4.00	1.26
Other winter crops	0.45	2.97	1.98
Sorghum	0.38	3.92	2.82
Other summer crops	0.21	0.85	2.00
Barley	0.21	1.64	2.83
Wheat	0.13	1.79	3.29
Irrigated cotton	0	0	0
Summer average	0.86	3.92	1.28
Winter average	0.34	2.13	1.93

*CV – coefficient of variance, GR – glyphosate resistant

DISCUSSION

The information gained through the online tool to date indicates that the north-eastern Australian cotton and grains farming industries face particular challenges in preventing and managing glyphosate resistance. These challenges are directly related to the high variability in cropping and weed management practices present in the region, as confirmed by the data on crop frequency and rotations. In particular, the variability in crop rotations used in the region indicates that best management strategies and recommendations for practice change are not likely to be ‘one size fits all’.

Similarly, the variation in levels of risk predicted for individuals’ management practices in common crops and fallows is high. High range and CV scores show that there are, for nearly all phases reported in the tool, some growers who operate at a low risk. These growers incorporate several tactics into an integrated weed management strategy. Other growers manage the same phases with a high risk, relying entirely or substantially on glyphosate. Table 1 demonstrates that the weeds commonly managed in the region are a mixture of high- and low-risk species. The high risk species include both summer- and winter-dominant species. Growers, therefore, would be best served by identifying their at-risk weeds and driving their glyphosate-resistance prevention strategies around those, rather than assuming their most prevalent weeds are also those at risk of resistance.

While national and regional risk reduction strategies are valuable and broadly applicable, it is clear that high variability in this region means individuals must use those strategies in a targeted way. In most cases, there are potential practice changes that could be made that would reduce the likelihood of a glyphosate-resistant weed population developing in any individual field, but the nature and best timing of those practice changes appear to be highly individual. Growers with already low-risk winter fallows, for example, may not achieve meaningful risk reduction by making practice changes in that phase, however convenient it may be. This would particularly be the case if their species at highest intrinsic risk appeared in the summer months.

Overall the challenging, variable nature of the region demonstrates the value of a tool such as this – one that allows growers to estimate their individual risk and that is detailed enough to investigate the value of practice changes specifically designed to fit local weed floras, risks, and rotations.

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REFERENCES CITED

Heap, I. 2011. The International Survey of Herbicide Resistant Weeds. Online. Internet. May 10, 2011. Available www.weedscience.com.

Osten, V., S. Walker, A. Storrie, M. Widderick, P. Moylan, G. Robinson and K. Galea. 2007. Survey of weed flora and management relative to cropping practices in the north-eastern grain region of Australia. Australian Journal of Experimental Agriculture, 47:57-70.

Preston C. 2011. Australian Glyphosate Resistance Register. Published on-line www.glyphosateresistance.org.au (Adelaide Australia).

Thornby, D. and S. Walker, 2009. Simulating the evolution of glyphosate resistance in grains farming in northern Australia. Annals of Botany, 104(4):747-756.

Thornby, D., J. Werth, , M. Curr and S. Walker. 2010. Risks and RATs: assessing glyphosate resistance risk in paddocks in north-eastern Australia. In Zydenbos, S.M. (ed). Proceedings of the17th Australasian Weeds Conference, New Zealand Plant Protection Society pp 246-249.

Werth, J., D. Thornby, S. Walker, G. Charles and McDonald, C. 2010. Species shift and resistance: challenges for Australian cotton systems. In Zydenbos, S.M. (ed). Proceedings of the17th Australasian Weeds Conference, New Zealand Plant Protection Society pp 20-23.

Werth, J.A., C.P. Preston, I.N. Taylor, G.W.Charles, G.N. Roberts and J. Baker. 2008. Managing the risk of glyphosate resistance in Australian glyphosate-resistant cotton production systems. Pest Management Science, 64: 417-421.