System solutions for reduced-herbicide broadacre agriculture

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Abstract

The triple issues of pesticide resistance, grain buyer demands, and social license to use key pesticides are intersecting to hasten the probability of substantive changes in pest management in field crop production systems in developed countries. Proposed or implemented pesticide-use restrictions or bans in a growing number of countries are forcing those growers and land managers to reactively plan, develop or implement alternative pest management practices and maybe even entire farming systems. Herbicides continue to be the main tool for managing problematic agricultural weeds, with recommended non-herbicidal practices used when convenient and deemed effective. However, farmers usually fail to appreciate the synergies in weed control that can be achieved by stacking effective non-herbicidal tactics within the framework of a farming 'system'. I would argue that we have most of the technologies or components to implement farming systems with reduced herbicide dependency. We just need to learn how to best integrate them for maximum profitability and simplicity with minimum time and labour through automation. Globally, the best route to achieving reduced herbicide dependency is precision weed management – based on prescription maps or in real time.

Keywords

Herbicide resistance management, integrated weed management, precision weed management

Introduction

The mission of the Australian Herbicide Resistance Initiative (AHRI) is to research, develop and communicate innovative herbicide-resistant (HR) weed science and technology. Our vision is "more crop, fewer weeds, enduring profitability, and less herbicide dependency". Integrated weed management (IWM) means different things to different people: IWM vs. herbicide resistance weed management (HRWM) vs. integrated herbicide management. The latter (herbicide diversity) is not IWM. In my view, the most successful IWM programs are synonymous with reduced herbicide use or reduced dependency on herbicides while maintaining good weed control (minimal weed seed bank replenishment). The latter is important since most weed populations in arable fields are now resistant to one or more herbicide modes of action (MOA). In the United States, herbicide use in corn, soybean, cotton, rice and wheat has approximately doubled between the period 1990 and 2015 (Kniss 2018). In Western Australia, there are an average of 6.3 herbicide applications in a field each year (Harries et al. 2020). I would largely agree with this quote: "Non-chemical methods are often adopted as a means of compensating for reduced herbicide efficacy, due to increasing resistance, rather than as alternatives to herbicides" (Moss 2018). The primary goal should be to reduce herbicide resistance selection pressure in weed populations wherever and whenever possible. Most important is simultaneously reducing herbicide MOA-use intensity and annual weed species population abundance. Therefore we need to reduce the frequency of herbicides always doing the heavy lifting, and use effective combinations of non-herbicidal practices that aid both herbicide performance and crop competition to suppress weed growth and fecundity. In this paper, I summarize the global herbicide resistance challenge and the importance of the 'Big 6' IWM building blocks in Australia. Additionally, I provide my perspective on integration and automation of weed management technologies and tactics for robust and durable farming systems and the promise and potential of precision or site-specific weed management.

Global herbicide resistance challenge

Until recently, there had been over a 30-year drought in introduction of new herbicide MOAs, with the last major MOA being HPPD inhibitors in the 1980s. At the other end, there was a significant rate of loss of pesticides from the marketplace; for example, in Europe the number of available pesticides declined from 945 in 1999 to 336 in 2009, a 64% reduction (Moss 2010). What happens in Europe is usually a prelude for things to come elsewhere. Meanwhile, the number of HR weed biotypes continues to increase (509 to date) with an average of 12 new cases per year (Heap 2021). Australia ranks second behind the United States in the number of HR weed biotypes (currently 89). The five top economic weeds in Australia are annual ryegrass (*Lolium rigidum*), wild radish (*Raphanus raphanistrum*), wild oats (*Avena* spp.), brome grass (*Bromus* spp.) and barnyard grass (*Echinochloa* spp.). Australia is home to 21 of the 55 weed species worldwide that are resistant to glyphosate. The fate of glyphosate, our most important herbicide, lies not only with evolved resistance but its future commercial availability (social license, grain buyer restrictions, etc.). Although wheat is the third largest crop by global planted area after corn and rice, it is the crop with the greatest number of HR weed species. The Poaceae or grass family are over-represented in terms of number of selected HR weed species (86). For example, annual ryegrass is resistant to up to 14 herbicide MOA, followed by barnyard grass (*Echinochloa crus-galli*) at 11 MOA and annual bluegrass/winter grass (*Poa annua*) at 10 MOA; there are currently over 100 weed species with resistance to multiple MOA and 60 species resistant to multiple MOA within a population (Heap 2021). This is the greatest global herbicide resistance challenge.

The 'Big 6' WeedSmart in Australia: integrated weed management building blocks
WeedSmart is an industry-sponsored extension platform for communicating IWM in Australia (Figure 1). It is strongly supported by both industry and academia, with a consistent messaging around IWM and HRWM. AHRI has been, and continues to be involved in research, development and extension (RDE) in each of the six components, from wheat and canola competition field trials to exploring the power of herbicide mixtures in HRWM. The different harvest weed seed control techniques, such as weed seed destruction via mechanical mills, chaff lining or chaff tramlining (narrow chaff windrows left behind the combine harvester), and chaff collection via chaff carts or crop residue baling, are now widely adopted in Australia and are being assessed in other agroregions globally. Harvest weed seed control is best suited for weed species whose seeds do not readily shatter before harvest and can be captured above the cutting height of the swather or combine harvester. It has been a transformational practice in reducing the field abundance of annual ryegrass and some other troublesome weeds in Australia.

Integration and automation of weed management technologies and tactics for robust and durable farming systems
Each of the Big 6 components are not standalone solutions; ideally three or more of the Big 6 need to be stacked or combined for effective synergistic weed management. Crop rotation diversity (annuals and perennials, cereals and dicots, fall/winter and spring/summer crops) remains the cornerstone of IWM and HRWM in Australia and elsewhere (Beckie and Harker 2017; Ulber and Rissel 2018). With continuing advancements is agricultural engineering technologies and platforms, the ongoing shortage and high cost of labour, and necessity of timeliness in operational efficiency within a growing season, IWM tactics will need to be applied in the field through increased automation, such as highlighted in autonomous/robotic controlled traffic farming and precision (variable rate, site-specific) weed management.

Figure 1. The 'Big 6' for integrated weed management in Australia (http://www.weedsmart.org.au).

The promise and potential of precision weed management

Precision weed management is already proven successful in fallow weed control ('green on brown') through the use of optical sprayers such as Weed-It or GreenSeeker. These sprayers may even be operated autonomously. Herbicide savings of up to 90% have been documented. A recent development in Australia is the Weed Chipper, which has mounted optical cameras that can sense green material against bare soil and 'chip out' weeds through individual hydraulically-controlled tines and thus maintains surface crop residue cover. Precision weed management, either via prescription weed maps to delineate management zones in the following crop or real time 'green on green' enabled by various sensors, is the most promising route to achieving reduced herbicide dependency. In Australia, the Bilberry real-time weed detection system using artificial intelligence-based algorithms claim to achieve up to 90% broadleaf weed control in cereal crops with travel speeds of 20 km h^{-1}. However, the promise and potential of grass weed control in cereal crops remains unknown and the greatest challenge. To date, there is a big divide between the promise/potential and implementation/adoption of precision weed management in broadacre agronomic crops that needs to be closed.

Conclusion

Globally, reduced herbicide dependency is not a reality except in EU member countries where it is incentivised or mandated to varying degrees. International grain markets will likely drive future restrictions on use of specific herbicides in exporting countries through maximum residue levels (MRLs) in importing (key market) countries. Consumer/societal pressures on how their food is grown (traceability) will only continue to increase; grain buyer contracts will become more 'demanding'. From a risk mitigation perspective, are Australian growers prepared agronomically for a possible future scenario of farming in a restricted herbicide world? Modelling simulations are fine, but there's nothing like the real thing. As echoed by previous weed scientists and practitioners, this is a call to action for greater investment in reduced-herbicide agronomic farming systems RDE (3-6 year projects) in low and high rainfall areas of the northern, southern and western regions on determining how best to integrate and automate technologies and tactics that maximizes profitability, operational efficiency and environmental protection. We already have most of the technologies or components to implement farming systems with reduced herbicide dependency. The challenge is to assemble the pieces for a seamless fit.

References

Beckie HJ and Harker KN (2017). Our top 10 herbicide-resistant weed management practices. Pest Management Science 73, 1045–1052.

Harries M, Flower KC, Scanlan CA, Rose MT and M. Renton M (2020). Interactions between crop sequences, weed populations and herbicide use in Western Australian broadacre farms: findings of a six-year survey. Crop and Pasture Science 71, 491–505.

Heap I (2021). International herbicide-resistant weed database (http://www.weedscience.org).

Kniss AR (2018). Genetically engineered herbicide-resistant crops and herbicide-resistant weed evolution in the United States. Weed Science 66, 260–273.

Moss S (2010). Herbicide resistance in northern Europe: current status, future issues. In: Proceedings of the Pan-American Weed Resistance Conference, Miami, FL, USA, pp. 44–45.

Moss S (2018). Integrated weed management (IWM): why are farmers reluctant to adopt non-chemical alternatives to herbicides? Pest Management Science 75, 1205–1211.

Ulber L and Rissel D (2018). Farmers' perspective on herbicide-resistant weeds and application of resistance management strategies: results from a German survey. Pest Management Science 74, 2335–2345.