

Herbicide resistance: Can German researchers and farmers learn from experiences in Australia and North America?

Herbizidresistenz: Können deutsche Wissenschaftler und Landwirte von den Erfahrungen in Australien und Nordamerika lernen?

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Abstract

Herbicide resistance is a significant and increasing problem for growers and land managers in input-intensive agricultural systems worldwide. In Australia and North America, herbicides are the main tools 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'. All of us can learn something from herbicide resistance experiences (good or bad) in other parts of the world; the question is how relevant, practical and useful will the different tactics or strategies be when applied or adapted to my particular agroclimatic region and farming system? The answers may only become known after local research and demonstration studies.

Keywords: herbicide resistance management; integrated weed management; precision weed management, site-specific weed management; weed resistance

Zusammenfassung

Herbizidresistenzen sind weltweit für Landwirte in intensiv bewirtschafteten landwirtschaftlichen Systemen ein bedeutendes und zunehmendes Problem. In Australien und Nordamerika sind Herbizide das wichtigste Mittel zur Bekämpfung problematischer Unkräuter in der Landwirtschaft, wobei empfohlene nicht-chemische Maßnahmen eingesetzt werden, wenn ihr Einsatz leicht umsetzbar erscheint und als wirksam erachtet wird. Die Landwirte erkennen jedoch in der Regel nicht die Synergien, die sich bei der Unkrautbekämpfung durch die Kombination verschiedener wirksamer nicht-chemischer Maßnahmen im Rahmen eines landwirtschaftlichen "Systems" erzielen lassen. Wir alle können etwas von den (guten oder schlechten) Erfahrungen mit Herbizidresistenz in anderen Teilen der Welt lernen. Die Frage ist, wie relevant, praktisch umsetzbar und nützlich die verschiedenen Taktiken oder Strategien sind, wenn sie in den individuellen agroklimatischen Regionen und Anbausystemen angewendet werden. Die Antworten auf diese Frage werden möglicherweise erst nach regionalen Forschungs- und Demonstrationsstudien feststehen.

Stichwörter: Herbizidresistenz, integrierte Unkrautkontrolle, Resistenzmanagement, teilflächenspezifische Unkrautkontrolle

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

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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 maize, soybean, cotton, rice and wheat has approximately doubled between the period 1990 and 2015 (KNISS, 2018). In Western Australia, there are averages 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 describe the ‘Big 6’ IWM building blocks advocated 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). 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 *Lolium rigidum*, *Raphanus raphanistrum*, *Avena* spp., *Bromus* spp. and *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 planted area after maize 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, *Lolium rigidum* is resistant to up to 14 herbicide MoA, followed by *Echinochloa crus-galli* at 11 MOA and *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 (Fig. 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 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 agregions 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

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 harvester. It has been a transformational practice in reducing the field abundance of *Lolium rigidum* and some other troublesome weeds in Australia.

THE BIG 6

ROTATE CROPS AND PASTURES -
 diverse herbicide choices, diverse cultural practices.

- Use double break crops, fallow and pasture phases to drive the weed seedbank down over consecutive years.

DOUBLE KNOCK -
 to preserve glyphosate.

- Follow glyphosate with a high rate of paraquat to control survivors in a fallow or pre-sowing situation.

MIX AND ROTATE HERBICIDES -
 rotating buys you time, mixing buys you shots.

- Rotate between herbicide groups;
- Use different groups within the same herbicide mix;
- Always use full rates.

STOP WEED SEED SET -
 take no prisoners.

- Crop top canola, pulses and feed barley (currently under permit) in weedy paddocks;
- Consider hay, brown manure or long fallow in high-pressure paddocks;
- Spray top/spray fallow pasture prior to the cropping phase.

CROP COMPETITION -
 stay ahead of the pack.

- Adopt at least one competitive strategy (but two is better), including reduced row spacing, higher seeding rates, east-west sowing and competitive varieties.

HARVEST WEED SEED CONTROL -
 the holy grail.

- Capture weed seed survivors at harvest using chaff lining, chaff tramlining, chaff carts, narrow windrow burning or integrated weed seed destructors.

WEEDSMART WISDOM

- Make spray applications effective – choose correct nozzles, adjuvants and water rates
- Know the susceptibility of your weed populations – test suspect weeds for resistance
- Don't jeopardise clean paddocks – ensure clean seed and clean borders

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

Abbildung 1 Die 'Big 6' für das integrierte Unkrautmanagement in Australien (<http://www.weedsmart.org.au>)

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, Germany and elsewhere (BECKIE and HARKER, 2017; ULBER and RISSEL, 2018). With continuing advancements in 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.

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

30. Deutsche Arbeitsbesprechung über Fragen der Unkrautbiologie und -bekämpfung, 22. – 24. Februar 2022 online 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. 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 incentivized 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'. 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. Herbicides do and will continue to do the heavy lifting in weed management unless growers are forced to reduce the use of specific herbicides or usage overall due to herbicide resistance, government regulations/policies or grain market demands. Globally, the best route to achieving reduced herbicide dependency is precision weed management – based on prescription maps or in real time. Can German researchers and farmers learn from experiences in Australia and North America? Perhaps. Keep in mind that the United States, Australia and Canada are the top three countries for number of HR weed biotypes. We all can always learn something from what is done (or not done) in other parts of the world and try to assess the advantages and disadvantages in our own farming system, given our unique problematic weed species and our unique environment (climate, soils).

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