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Arable Extra

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Integrated weed management

Introduction

Herbicide-based weed management is facing increasing challenges. Existing herbicides are being lost due to regulations and market demands. Almost no new modes of action are coming to market internationally and due to the small market size and difficulty of registration these may not be available in New Zealand.

On top of this, herbicide resistance in New Zealand is much more prevalent than previously understood and is likely to continue to increase [3]. At the start of the MBIE-funded herbicide resistance management project in 2018, 14 herbicide resistant weeds had been identified in New Zealand. Five years later another seven new resistance species had been found. However, the number of individual unique cases of resistance, (i.e., when a new resistance mutation occurs and is selected) is likely to be much larger. For example, based on the rate of new mutations conferring resistance and the size of the weed seed bank, there could be between 1 and 40,000 seeds per ha with a novel resistance mutation, waiting to be selected by poor herbicide use.

In the arable sector, multiple common weeds are resistant to groups 1 (inhibition of ACCase) and 2 (inhibition of ALS) with some resistance to groups 4 (auxin mimics), 5 (inhibition of photosynthesis PS II), 9 (inhibition of enolpyruvyl shikimate phosphate synthase), and limited resistance to groups 22 (PS I electron diversion), 34 (inhibition of lycopene cyclase) and 0 (Dalapon) Table 1.

Key points

- Herbicide resistance, reducing herbicide options and market demands are driving a move towards understanding non-chemical weed management options and developing integrated weed management (IWM) systems.
- Globally IWM is the primary approach to addressing herbicide resistance.
- IWM is a system-level approach to managing weeds, integrating multiple control tactics into a single weed management programme.
- IWM is often viewed through the four management 'toolboxes'; physical, chemical, biological and ecological.
- IWM requires a change in mindset from considering all non-crop plants as bad to an agroecological view that some non-crop plants are beneficial and therefore do not require control.

Table 1. Weed species in New Zealand and the herbicide groups to which they have resistance. Compiled from [11].

Weed species	Group 1	Group 2	Group 4	Group 5	Group 9	Group 10	Group 22	Group 34	Group 0
Annual poa	Haloxyfop	Iodosulfuron							
Black nightshade				Atrazine			Paraquat		
Blackgrass		Iodosulfuron							
Chickweed		Chlorsulfuron							
Fathen			Dicamba	Atrazine					
Giant buttercup		Flumetsulam	MCPA						
Italian ryegrass	Fops & dims				Glyphosate	Glufosinate		Amitrole	
Lesser canary grass	Fops	Group 2							
Needlegrass									Dalapon
Nodding thistle			2,4-D						
Onehunga weed			Clopyralid						
Perennial ryegrass	Fops & Dens	Sulfonylureas			Glyphosate	Glufosinate		Amitrole	
Prairie grass		Pyroxsulam							
Ripgut brome		Sulfonylureas							
Sow thistle		Sulfonylureas							
Summer grass		Sulfonylureas							
Wild oats	Fops								
Willow weed		Chlorsulfuron		Atrazine					
Winged thistle			2,4-D & MCPA						

Herbicide resistance surveys between 2019 and 2022 found up to 38% of farms had resistant ryegrasses (Table 2).

Table 2. Percentage of arable farms across New Zealand with weeds resistant to Groups 1 (inhibition of ACCase), 2 (inhibition of ALS) and 5 (inhibition of photosynthesis PS II) from random field surveys between 2019 and 2022. Compiled from [11].

Species	Herbicide Group		
	Group 1	Group 2	Group 4
Wild oat (*Avena fatua*)	14%	14%	
Prairie grass (*Bromus catharticus*)		6%	
Fathen (*Chenopodium album*)			42%
Summer grass (*Digitaria sanguinalis*)		13%	
Ryegrasses (*Lolium spp.*)	38%	38%	
Knotweeds (*Persicaria spp.*)		12%	
Canary grass (*Phalaris minor*)	2%	14%	
Poa grass (*Poa annua*)		15%	
Sow thistles (*Sonchus spp.*)		23%	
Chickweed (*Stellaria media*)		23%	

This means, it's not a case of keeping herbicide resistance 'off' your farm, as it's already in every paddock and new mutations are occurring all the time. Rather, it is a case of redesigning farm systems to make them hostile to herbicide resistant weeds. That redesign is integrated weed management (IWM) which, globally, is seen as the future of weed management [13].

What is integrated weed management?

Integrated weed management (IWM) is a system level approach to managing weeds. It combines multiple control methods into a single weed management programme. Control methods are divided into physical, chemical, biological and ecological 'toolboxes' (Figure 1).

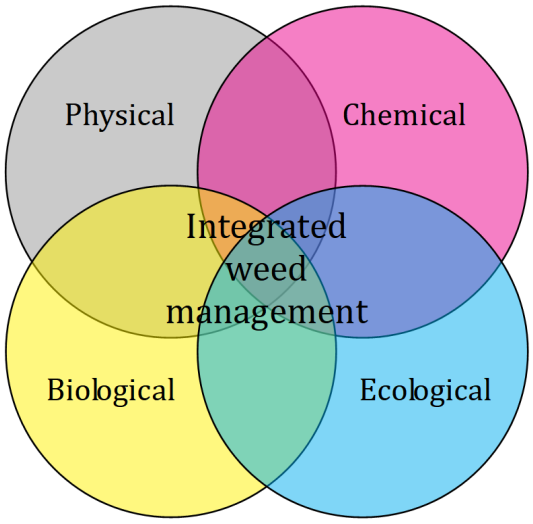

Figure 1. Combining the physical, chemical, biological and ecological toolboxes to form integrated weed management (IWM).

Physical techniques include interrow hoeing and electrothermal weeders. Chemical weeding uses herbicides (synthetic and naturally occurring chemical herbicides permitted in organic agriculture). Biological techniques include introductory (classical) biocontrol where a weed's natural enemies (e.g., insects or pathogens) are introduced to a country. Ecological management involves manipulating the interactions between crop and weeds, for example intercropping.

IWM requires a sequence, or stacked set of control methods. None of the methods above will likely achieve sufficient management of weeds on their own, but, in combination, good weed management can be achieved.

IWM also requires a change in mindset away from the "war on weeds" and towards an agroecological [4] perspective, where not all non-crop plants are viewed as weeds. The aim is not for complete eradication of all non-crop plants, rather to remove only the non-crop plants that cause harm, (i.e. reduce yield or contaminate the harvest) [8]. In the European Union, the Farm to Fork Strategy aims to "reduce the overall use and risk of chemical pesticides by 50% and the use of more hazardous pesticides by 50% by 2030."[2]. This has driven an increased emphasis on IWM. To address this challenge, Riemens *et al.* proposed a new IWM framework [13]. This Arable Extra summarises this framework.

The Riemens *et al.* IWM framework

The framework is divided up into five pillars:
1. Diverse cropping system
2. Cultivar choice and establishment
3. Field/soil management
4. Direct control
5. Monitoring and evaluation

All five pillars are used in a combined approach.

Pillar 1 - Diverse cropping system

Increasing the diversity of cropping systems, such as having more crops in the rotation and using techniques such as intercropping, is key to addressing multiple issues on farm, not just weed management. For example, pest and pathogen management, improving soil health and conservation biological control [9, 10].

Diversification for weed management means that weeds that thrive or are hard to manage in one crop are suppressed or easier to manage in another. For example, grass weeds that do well in cereals can be better managed in broadleaf crops. In Australian arable systems, a double break of two years of broadleaf crops has become the norm to control herbicide resistant ryegrass in cereals crops [12]. Different crops also allow different management tactics (different herbicide modes of action, or aggressive mechanical weeding in potatoes).

Pillar 2 - Cultivar choice and establishment

Plant breeding is increasingly focused on making cultivars more competitive against weeds, and also more tolerant of competition from them. There are also multiple establishment techniques that can improve crop competition. For example, increasing the sowing rate, changing row spacings or sowing patterns (e.g., checkerboard patterns) changing sowing dates, sowing depth and fertiliser placement (e.g., sub-surface banding).

Pillar 3 - Field/soil management

In tillage systems, primary and secondary tillage are important tactics. For example, occasional use of the plough to bury grass weed seeds, and false seedbeds (see Arable Extra 136). Field and soil management also includes strategic use of irrigation and fertilisers, e.g., not applying fertilisers at establishment when the crop is unable to use them and they are instead taken up by the weeds, rather timing application to match crop demand. Timing of tillage operations either to encourage weed flushes or when problematic weed species are unable to germinate. The use of residue mulches, e.g., crimping of cover crops [7]. As well as post-harvest techniques such as shallow tillage to encourage the germination of shed crop and weed seeds.

Pillar 4 - Direct control

Herbicides have been the mainstay of direct control but, as noted in the introduction, there are multiple reasons to reduce their use. There are now a large number of physical weeding approaches to achieve direct control. Examples include contiguous weeders such as spring tine weeders, and incontiguous weeders like the parallelogram hoe (see Arable Extra 97). Other simple techniques such as mowing can be highly effective as well as more high-tech approaches such as electrothermal and robotic weeders. Finally, harvest weed seed control (HWSC) (see Arable Extra 98) can play a valuable role in minimising the weed seed rain.

Pillar 5 - Monitoring and evaluation

Effective crop weed monitoring is essential when using multiple weed management approaches as it allows you to take timely action using the best approach. Also evaluate the results of any direct control intervention to determine its effectiveness and whether any further action is required. This is of particular relevance for herbicide resistance; if cases are identified as early as possible, they can be managed before the resistant weeds spread across the whole paddock or farm. Robotics is already having a role in scouting and mapping paddocks for resistant weeds, e.g., after spraying.

The framework

The five pillars are then combined into an overall framework Figure 2.

Figure 2. Framework for the planning and design of holistic IWM strategies that require combinations of individual management tools appropriately selected from each of the five pillars of IWM: Diverse cropping systems, cultivar choice and establishment, field and soil management, direct control and the cross-cutting pillar of monitoring and evaluation. From [13] under the CC BY license creativecommons.org/licenses/by/4.0/.

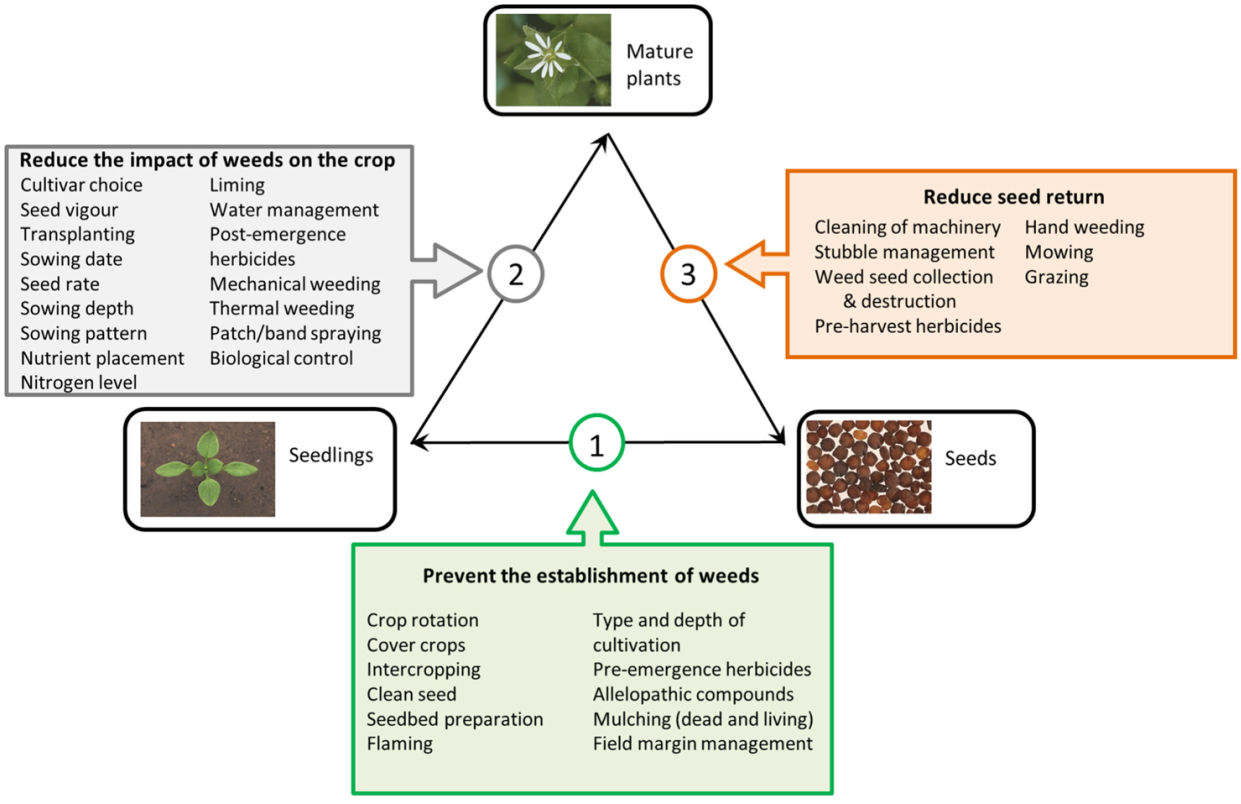

Figure 3. Weed control tactics are mentioned where they are expected to have maximum effect on weed survival. Weed control tactics affecting weed survival at different stages of their life cycle. From [13] under the CC BY license creativecommons.org/licenses/by/4.0/.

Conclusions

The Riemens *et al.* framework provides a complete overview of a whole-of-system approach to IWM, breaking it down into five pillars. Each pillar groups a diverse range of individual weed management tactics. Many of those tactics are themselves composed of many sub-tactics, such as mechanical weeding, herbicides and intercropping, which can be mixed and matched to achieve effective farm level weed management. This mix and match approach is what makes IWM such a good approach to managing weeds and herbicide resistance.

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