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GRDC GROWNOTES™

GRDC™ GRAINS RESEARCH & DEVELOPMENT CORPORATION

WHEAT

SECTION 6

WEED CONTROL

INTEGRATED WEED MANAGEMENT (IWM) | AGRONOMY | KEY WEEDS IN AUSTRALIA'S CROPPING SYSTEMS | STOPPING WEED SEEDSET | PASTURE SEEDSET CONTROL | HERBICIDE RESISTANCE | MANAGING THE WEED SEEDBANK | MANAGING WEED SEEDLINGS | HARVEST WEED-SEED CONTROL | OTHER NON-CHEMICAL WEED CONTROL | CROP COMPETITION | HERBICIDES EXPLAINED | PRE-EMERGENT HERBICIDES | IN-CROP HERBICIDES: KNOCK-DOWNS AND RESIDUALS | SELECTIVE SPRAYER TECHNOLOGY | STRATEGIES TO STOP THE SPREAD OF WEEDS

SECTION 6

Weed control

More information

Agriculture Victoria: Diagnostic services

GRDC: Weed Webinars

GRDC: Weed ID. The Ute Guide

Weeds cost Australian agriculture an estimated AU$2.5–4.5 billion per annum. For winter cropping systems alone, the cost is $1.3 billion, equivalent to ~20% of the gross value of the Australian wheat crop. Consequently, any practice that can reduce the weed burden is likely to generate substantial economic benefits to growers and the grains industry. [1]

Weed control is essential if wheat is to make full use of summer rainfall, and in order to prevent weed seeds from contaminating the grain sample at harvest. Weed management should be planned well before planting and options considered such as chemical and non-chemical control. [2]

Weed control is important, because weeds:

- rob the soil of valuable stored moisture
- rob the soil of nutrients
- cause issues at sowing time, restricting access for planting rigs (especially vine-type weeds such as melons, caltrop or wireweed, which wrap around tines)
- cause problems at harvest
- increase moisture levels of the grain sample (green weeds)
- contaminate the sample
- prevent some crops being grown where in-crop herbicide options are limited, i.e. broadleaf crops
- can be toxic to stock
- carry disease
- host insects

6.1 Integrated weed management (IWM)

Rapid expansion of herbicide resistance and the lack of new modes of action (MOA) require that non-herbicide tactics must be a significant component of any farming system and weed management strategy.

Inclusion of non-herbicide tactics is critical to prolong the effective life of remaining herbicides, as well as for new products and MOA.

Effective herbicides are key components of profitable cropping systems. Protecting their efficacy directly contributes to the future sustainability and profitability of cropping systems.

The last significant new herbicide MOA released in Australia was Group H chemistry, first launched in Australia in 2001. Prior to that, the most recent new MOA was Group B chemistry, when chlorsulfuron was commercialised in Australia in 1982.

Successful weed management requires a paddock-by-paddock approach. Weeds present and weed-bank status, soil types in relation to herbicide used, and cropping

1 GRDC (2014) Integrated weed management hub. GRDC, www.grdc.com.au/weedlinks

2 DAF Qld (2012) Wheat—planting information. Department of Agriculture and Fisheries Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/planting-information

More information

NHT: Introductory weed management manual

NSW DPI: WeedWise

Sydney Royal Botanic Gardens Herbarium: PlantNET

WA Herbarium: FloraBase

and pasture plans are critical parts of the picture. Knowledge of paddock history and of how much the summer and winter weeds have been subjected to selection for resistance (and to which herbicide MOAs) can also assist.

When resistance has been identified, knowledge of which herbicides still work becomes critical.

The following 5-point plan will assist in developing a management plan for each paddock:

1. Review past actions and history.
2. Assess current weed status.
3. Identify weed-management opportunities.
4. Match opportunities and weeds with suitably effective management tactics.
5. Combine ideas into a management plan. Use of a rotational plan can assist. [3]

6.1.1 Review past actions

The historical level of selection pressure can be valuable information for managers to gauge which weed–MOA groups are at greatest risk of breaking. Such knowledge can prompt more intensive monitoring for weed escapes when a situation of higher risk exists. Picking up newly developing resistance issues while patches are still small and before they spread can mean a big difference in the cost of management over time.

From all available paddock records, calculate or estimate the number of years in which different herbicide MOAs have been used. The number of years in which a herbicide MOA has been used is of far greater relevance than the number of applications in total. For most weeds, use of a herbicide MOA in two consecutive years presents a far greater selection pressure for resistance than two applications of the same herbicide MOA in the one year. If the entire paddock history is unavailable to you, state what is known and estimate the rest. Collate separate data on MOA use for summer and winter weed spectrums. Further subdivide these into broadleaf and grass weeds.

Account for double-knocks. Where survivors of one tactic would have been largely controlled by the use of another tactic, reduce the number of MOA uses accordingly. An example might be as follows. Trifluralin (Group D) has been used 20 times, but there were 6 years when in-crop Group A selectives were used and several more years when in-crop Group B products (targeting the same weed as the trifluralin) were used. These in-crop herbicides effectively double-knocked the trifluralin, thus reducing the effective selection pressure for resistance to trifluralin.

Review the data you have collected and identify which weed–MOA groups have been selected for at a frequency likely to lead to resistance in the absence of a double-knock. Trifluralin typically takes about 10–15 years of selection for resistance to occur (Table 1). Thus, in the above example, a 'watching brief' would be in place for trifluralin and other Group D MOA herbicides.

Paddock history can also provide useful information when evaluating the likely reasons for herbicide spray failures, in prioritising strategies for future use and deciding which paddocks receive extra time for scouting to find potential patches of weed escapes.

Information on MOA use history should be added to paddock records. [4]

[3] GRDC (2014) Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub

[4] GRDC (2014) Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub

More information

[WEEDpak Weed ID guide]

[Weeds Australia: Weed identification tool]

[Weeds Society of WA: Western Weeds]

Video

[Weed ID App]

Table 1: Typical number of years of use of mode of action (MOA) groups before weeds develop resistance

Herbicide Group	Typical years of application	Resistance risk
A (fops/dims/dens)	6–8	High
B (sulfonylureas, imidazolinones)	4	High
C (triazines, substituted ureas)	10–15	Medium
D (trifluralin, pendimethalin)	10–15	Medium
F (diflufenican)	10	Medium
I (phenoxies)	>15	Medium
L (paraquat/diquat)	>15	Medium
M (glyphosate)	>12	Medium

6.1.2 Assess the current weed status

Record the key broadleaf and grass weed species for summer and winter and include an assessment of weed density, with notes on weed distribution across the paddock. Include GPS locations or reference to spatial location of any key weed patches or areas tested for resistance.

Include any data, observations or information relating to the known or suspected herbicide-resistance status of weeds in this paddock.

Add this information to paddock records. [5]

6.1.3 Identify weed management opportunities

Identify which different herbicide and non-herbicide tactics could be cost-effectively added to the system and at what point in the crop sequence these can be added. For further information on the different IWM tactics see: IWM Section 4: Tactics. [6]

Ryegrass integrated management (RIM)

The RIM decision-support software provides insights into the long-term management of annual ryegrass in dryland broadacre crops facing development of herbicide resistance. RIM enables alternative strategies and tactics for ryegrass management to be compared for profit over time and for impact on weed numbers. The software's underlying model integrates biological, agronomic and economic considerations in a dynamic and user-friendly framework, at paddock scale and over the short and long term.

The tool tracks the changes through time on a 10-year crop cycle for ryegrass seed germination, seed production and competition with the crop. Financial returns are also estimated annually and as a 10-year average return.

A free download is available from: http://www.ahri.uwa.edu.au/RIM. [7]

6.1.4 Fine-tune your list of options

Which are your preferred options to add to current weed management tactics to add diversity and help drive down the weed seedbank? [8]

5 GRDC (2014) Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub

6 GRDC (2014) Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub

7 GRDC (2014) Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub

8 GRDC (2014) Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub

More information

NSW DPI: Weed management in winter crops

NSW DPI: Weed management in summer crops

GRDC Update papers

Biology and management of summer weeds

Brome and barley grass management in cropping systems of southern Australia

Fleabane ecology and control in cropping systems of southern Australia

Fodder rotations with cropping to manage weeds

Hardseeded annual legumes

Herbicide efficacy in no-till farming systems in southern NSW

Herbicides for control of clethodin-resistant annual ryegrass

Hitting the right target—what are our most costly weeds?

Impact of crop residues on summer fallow weeds

Managing annual ryegrass in cropping systems—pre and post emergent herbicide trial Barellan 2013

New herbicide challenges and solutions

New technology for improved herbicide use efficiency

NGA chickpea herbicide trials 2015

6.1.5 Combine and test ideas

Computer simulation tools can be useful to run a number of 'what if' scenarios to investigate potential changes in management and the likely effect of weed numbers and crop yield. Two simulation tools in use are the Weed Seed Wizard and RIM.

Combine ideas using a rotational planner, or test them by using decision-support software such as RIM and Weed Seed Wizard. [9]

Weed Seed Wizard

The Weed Seed Wizard helps growers to understand and manage weed seedbanks on farms across Australia's grain-growing regions.

Weed Seed Wizard is a computer simulation tool that uses paddock-management information to predict weed emergence and crop losses. Different weed-management scenarios can be compared to show how different crop rotations, weed control techniques, and irrigation, grazing and harvest management tactics can affect weed numbers, the weed seedbank and crop yields.

The 'Wizard' uses farm-specific information, and users enter their own farm-management records, their paddock soil type, local weather and one or more weed species. The Wizard has numerous weed species to choose from including annual ryegrass, barley grass, wild radish, wild oat, brome grass and silver grass in the southern states, and liverseed grass, barnyard grass, paradoxa grass, feather-top Rhodes grass, bladder ketmia, fleabane, sowthistle, sweet summer grass, cowvine and bellvine in the north.

A free download is available from: https://www.agric.wa.gov.au/weed-seed-wizard-0. [10]

Weed Seed Wizard

6.2 Agronomy

1. Know your weed species. Ask your local adviser or service provider or use the Sydney Botanic Gardens Plant ID and Diagnostic Services, which is free in most cases.
2. Conduct in-crop weed audits prior to harvest to know which weeds will be problematic the following year.
3. Ensure wheat seed is kept from a clean paddock (Figure 1).
4. Have a crop-rotation plan that considers not just crop type being grown but also what weed control options this crop system may offer, e.g. grass control with triazine-tolerant canola.

[9] GRDC (2014) Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub

[10] GRDC (2014) Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub

GRDC Update papers

[Optimising the impact of glyphosate](#)

[Seeding systems and pre-emergence herbicides](#)

[Summer weeds reduce moisture and nitrogen](#)

[Using crop competition for weed control in barley and wheat](#)

[Why the obsession with the ryegrass seed bank?](#)

Figure 1: Ensure wheat seed is kept from a clean paddock. (Photo: Penny Heuston)

6.2.1 Crop choice and sequence

Many agronomic and weed management issues arise from the sequence in which crops are sown:

- Rotations provide options for different weed-management tactics.
- Crop rotations can improve crop fertility and help to manage disease and insects. Healthy crops are more competitive against weeds.
- Many weeds are easier or more cost-effective to control in specific crops, pastures or fallows.

The ability to compete with weeds varies between crop type and variety. In paddocks with high weed pressure, a competitive crop will enhance the reduction in weed seedset obtained through other weed-management tactics. It will also reduce the impact that surviving weeds have on crop yield and the quantity of seedset by any surviving weeds. [11]

For a list of crop choice options to aid weed management, go to the tables within IWM Section 3: Agronomy.

Some key issues:

- Select crop sequences and varieties to deal with the significant pathogens and nematode issues for each paddock.
- Weeds are alternate hosts to some crop pathogens. Effective weed management can reduce disease pressure.
- *Rhizoctonia* can affect seedling crop growth, leaving the crop at greater threat from weed competition. Removing weeds for a period prior to sowing can significantly reduce the level of *Rhizoctonia* inoculum.
- Weed growth in the fallow or in-crop can increase moisture use and exacerbate yield loss from diseases such as crown rot.
- Residual herbicides used in the fallow or preceding crop may limit crop options. [12]

[11] GRDC (2014) Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub

[12] GRDC (2014) Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub

6.2.2 Improving crop competition

The impact of weeds on crop yield can be reduced and the effectiveness of weed-control tactics increased by crop competition. The rate and extent of crop canopy development are key factors influencing a crop's competitive ability with weeds. A crop that rapidly establishes a vigorous canopy, intercepting maximum sunlight and shading the ground and inter-row area, will provide optimum levels of competition.

Leaf area index at the end of tillering in wheat is highly correlated with the crop's ability to compete with weeds.

Canopy development is influenced by:

- crop type and variety
- row spacing, sowing rate and sowing depth (Figure 2)
- crop nutrition
- foliar and root diseases
- nematodes
- levels of beneficial soil microbes such as mycorrhizae
- environmental conditions including soil properties and rainfall
- light interception and crop row orientation

Each factor will in turn affect plant density, radiation adsorption, dry matter production and yield. Early canopy closure can be encouraged through good management addressing the above factors.

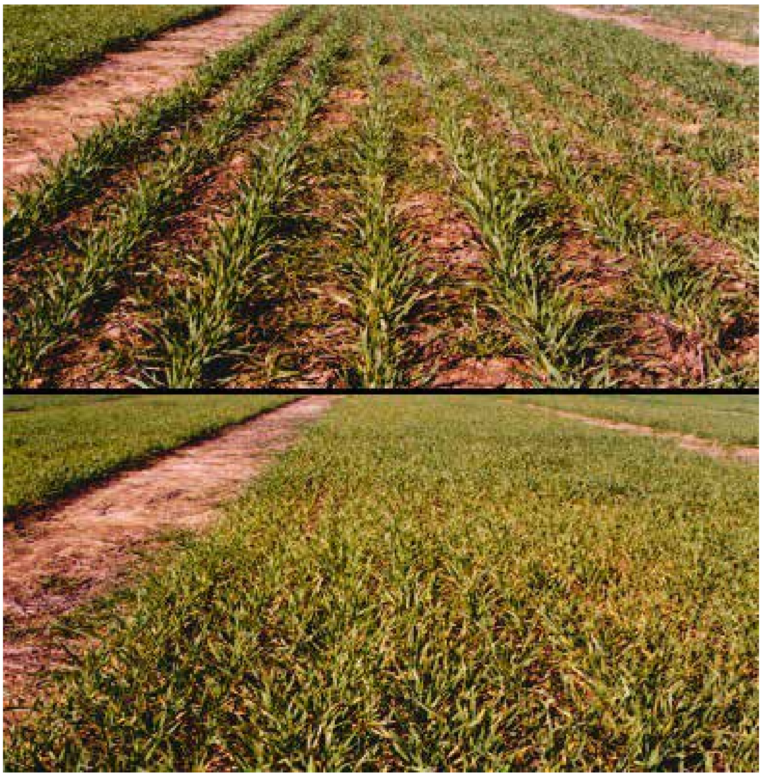

Figure 2: Difference in crop competition between low (top) and high (bottom) seeding rates. (Photo: D. Minkey)

Key issues:

- Good agronomy generally means a competitive crop.
- A competitive crop greatly improves weed control by reducing weed biomass and seedset (Figure 3).
- Different crops and varieties compete with and suppress weeds differently.

- High crop sowing rates reduce weed biomass and weed-seed production and may improve crop yield and grain quality. Optimising for yield and quality is advised.
- Take care to sow seed at optimum depth.
- Fertiliser placement can improve crop growth, yield and competitive ability.
- Many studies show a reduction in weeds with increased sowing rate and narrower rows.
- Furrow-sowing or moisture-seeking techniques at sowing can help establish the crop before the weeds.
- Sowing at the recommended time for the crop type and variety maximises crop competitive ability, which will reduce weed biomass and seedset.
- When delaying sowing to allow for control of the first germination of weeds, choose the crop type and variety most suited to later sowing to minimise yield loss.
- Sow problem weedy paddocks last to allow a good weed germination and subsequent kill prior to sowing.

A summary table of some of the key research in Australia to assess the effect of increasing crop sowing rate in the presence of weeds can be found in IWM Section 3: Agronomy.

Figure 3: Common sowthistle growing in-fallow (no competition) v. growing in-crop (wheat and barley), Condamine, Qld. There was no in-crop herbicide applied to control the weed. The lack of sowthistle in-crop is entirely due to crop competition. The season had a relatively dry start, so the crop established before the weeds. (Photo: M. Widderick)

6.2.3 Crop type

Crops with herbicide-tolerance traits bred using conventional methods have been used in Australia for many years. They include imidazolinone-tolerant (IT) wheat (Clearfield®), introduced in 2001.

Herbicide-tolerant crops are tolerant to a herbicide that would normally cause severe damage. Thus, they offer the option of weed-control tactics from different herbicide MOA groups that would not normally be able to be used in these crops.

With the ease and high levels of weed kill often experienced with glyphosate use in Roundup Ready® (RR) crops, the frequency of use of other control tactics has declined. Diversity in weed-management tactics has decreased and selection pressure for the development of resistance to glyphosate has increased. In an attempt to offset this, many of the stewardship packages associated with herbicide-tolerance technologies require the use of alternative technologies in situations where weed density or the evaluated risk of resistance to that herbicide is high.

Specific herbicide-tolerance crop-technology stewardship programs are a source of more detailed information. For example, the Clearfield® Stewardship Program.

Advantages of herbicide-tolerant crops:

- They provide additional crop choice, enabling use of alternative weed management tactics.
- They can sometimes enable a crop type to be grown where herbicide residues may be present in the soil from a previous crop.
- They can reduce the total amount of herbicide used and/or weed-control costs.
- They provide another option to use some herbicides. This should always be used in an IWM program and within the guidelines for the relevant stewardship program for that technology.

Herbicide-resistance management guidelines for Australia for MOA groups can be downloaded from the CropLife Australia Limited website.

Some requirements of the stewardship packages include:

- Use technologies and weed management strategies that are appropriate to the weed spectrum and pressure.
- Adhere to all herbicide label directions.
- Maintain good paddock management records.
- Use agronomic practices to minimise outcrossing with other crops.

6.2.4 Improving pasture competition

Pastures represent an important component of many rotations and provide a valuable opportunity to manage weed problems by using tactics not available in cropping situations. These include grazing, mechanical manipulation and herbicides. Dense stands of well-adapted pasture species compete against weeds, reducing weed numbers and weed seedset. Competitive pastures greatly improve the effectiveness of other tactics to manage weeds in the pasture phase.

Some weeds such as fleabane have few viable management options in pastures, and this is where blowouts often occur.

Identification and management notes on a large range of weeds of pasture are available at NSW WeedWise.

6.2.5 Fallow phase

Fallows are defined as the period between two crops, or between a crop and a defined pasture phase. Fallows are used to store and conserve soil moisture and nitrogen (N) for the next crop, reduce the weed seedbank and stop weed growth that could impede the sowing operation.

Benefits:

- A fallow period on its own, or in sequence with a number of crops, can be highly effective in reducing the weed seedbank.
- A fallow period can incorporate several tactics to reduce weed seedbanks.
- A double-knock of glyphosate followed by paraquat can gives high levels of weed control and can assist control of some hard-to-kill or glyphosate-resistant survivors.
- If planned, it is sometimes possible to use other herbicide MOA groups with residual activity (Groups C, B, I or K) in fallow.
- In a fallow, it is easier to spot escapes and take action to stop seedset than in a crop.

Key factors for success:

- Control weeds of fallows when they are small.
- Try to include a range of tactics that include different MOA groups, paraquat and residual herbicides to avoid over-reliance on glyphosate alone. Occasional tillage should also be considered when there is a drying seedbed.

More information

GRDC: Summer fallow weed management manual

Integrated Weed Management Section 3: Agronomy

GRDC Fact Sheets

Break crop benefits. Western Region

Group A herbicides in fallow

Choosing break crops. Southern Region

Crop placement and row spacing. Southern Region

Summer fallow spraying. Northern, Southern and Western Regions

Time of sowing. Northern, Southern and Western Regions

Weed control in wheel tracks. Northern, Southern and Western Regions

GRDC Update Papers

Biology and management of summer weeds

Compete with weeds—give your crop heaven and your weeds hell

Crop sequencing—what are the key issues to making profitable and sustainable crop sequencing decisions?

Impact of crop residues on summer fallow weeds

Landscape and weed influence on pest and beneficial insect populations

For Southern and Western Regions, further information can be found in the Summer Fallow Weed Management Manual. [13]

6.2.6 Controlled traffic for optimal herbicide application

Controlled traffic (or 'tramlining') refers to a cropping system designed to limit soil damage by confining all wheel traffic to permanent lanes for all paddock operations, including seeding, harvesting and all spraying (Figure 4).

Some form of traffic lane will reduce compaction between the tramlines, resulting in increased health of the crop through improved soil characteristics, thus improving the competitive ability of the crop. This form of precision agriculture results in;

- more efficient use of pesticide application through reduced overlaps
- ability to treat weeds in the inter-row more easily
- easier management of weed seeds at harvest

Accurately spaced tramlines provide guidance and a firmer pathway for more timely and accurate application of herbicide, which in turn improves weed control and reduces input costs by 5–10%.

In wide-row controlled-traffic systems, inter-row-shielded and band spraying as well as inter-row tillage may be options. Precision-guidance technology potentially makes such options more practical, but there are very few registrations allowing use of herbicides in this manner. [14]

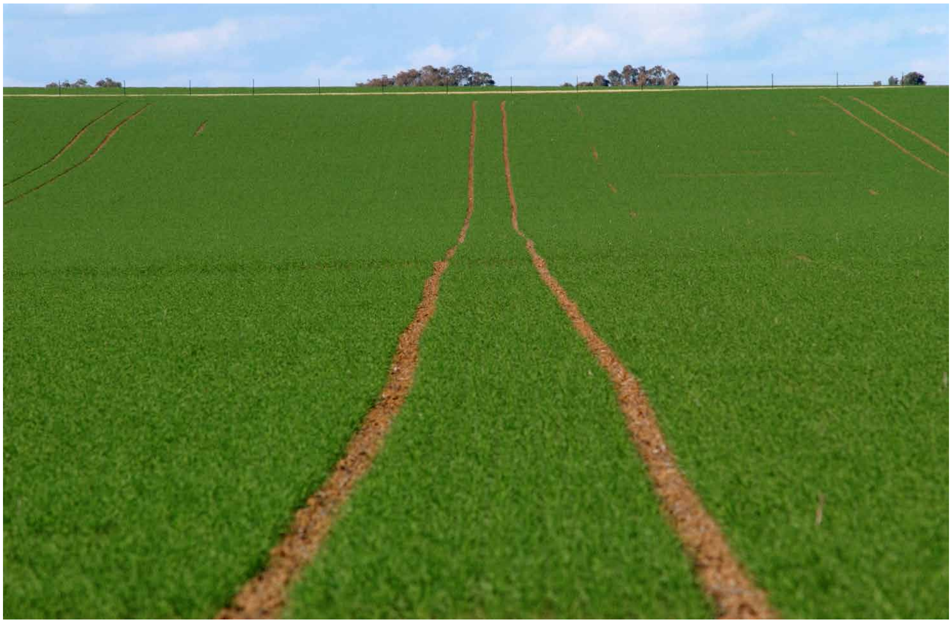

Figure 4: Controlled traffic cropping allows more options for weed control and management. (Photo: A. Mostead)

[13] GRDC (2014) Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub

[14] GRDC (2014) Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub

GRDC Update Papers

Non-herbicide tactics to help suppress weed growth

Progress in developing weed competitive wheat

Seeding systems and pre-emergence herbicides

Summer weeds reduce moisture and nitrogen

Using crop competition for weed control in barley and wheat

More information

AGT: Weed tolerance and suppression in wheat

AWC research paper: Canola competition for weed suppression

AWC research paper: Competitive effects of sorghum cultivars and densities on weed suppression

AWC research paper: Cover cropping as a weed management tool in southern Australian farming systems

AWC research paper: Managing herbicide resistance in Southern Australian farming systems using Roundup Ready® canola

AWC research paper: Weed suppression by crop competition in three crop species in Western Australia

GIWA research paper: Aim for the narrowest possible row spacing WA

WeedSmart You Tube video: Diverting weed seed onto permanent tramlines

6.3 Key weeds in Australia's cropping systems

Click on each weed for more information

Annual ryegrass (*Lolium rigidum*)

Barley grass (*Hordeum* spp.)

Barnyard grasses (*Echinochloa* spp.)

Black bindweed (*Fallopia convolvulus*)

Bladder ketmia (*Hibiscus trionum*)

Brome grass (*Bromus* spp.)

Capeweed (*Arctotheca calendula*)

Doublegee (*Emex australis*)

Feathertop Rhodes grass (*Chloris virgata*)

Fleabane (*Conyza* spp.)

Fumitory (*Fumaria* spp.)

Indian hedge mustard (*Sisymbrium orientale*)

Liverseed grass (*Urochloa panicoides*)

Muskweed (*Myagrum perfoliatum*)

Paradoxa grass (*Phalaris paradoxa*)

Silver grass (*Vulpia* spp.)

Sweet summer grass (*Brachiaria eruciformis*)

Turnip weed (*Rapistrum rugosum*)

Wild oats (*Avena fatua* and *A. ludoviciana*)

Wild radish (*Raphanus raphanistrum*)

Windmill grass (*Chloris truncata*)

Wireweed (*Polygonum aviculare* and *P. arenastrum*) [15]

6.4 Stopping weed seedset

6.4.1 Seedset control tactics

Seedset control tactics include spray-topping with selective and non-selective herbicides, wick wiping, windrowing and crop desiccation, and techniques such as hand-roguing, spot-spraying, green and brown manuring, hay or silage production and grazing. Harvest weed-seed control tactics include narrow windrow burning, chaff-lining and chaff carts.

Seedset control tactics are particularly effective in low-level weed populations.

In-crop management of weed seedset is used to minimise the replenishment of seedbanks and/or reduce grain contamination. This is achieved by intercepting the seed production of weeds that have escaped, survived or emerged after application of weed-management tactics earlier in the cropping season.

Controlling weed seedset contrasts with early in-crop weed management tactics, which aim to maintain or maximise crop yield by reducing weed competition. There is minimal grain yield benefit in the current crop from seedset control tactics, because most weed

15 GRDC (2014) Section 8. Profile of common weeds of cropping. Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub/Section-8-Profiles-of-common-weeds-of-cropping

competition occurs earlier during the vegetative stages of the crop. For this reason, seedset control tactics should always be used with other types of tactic. [16]

6.4.2 Selective spray-topping

Selective spray-topping is the application of a post-emergent, selective herbicide to weeds at reproductive growth stages to prevent seedset of certain weeds. The technique is aimed at weed seedbank management (i.e. reducing additions to the weed seedbank) but with minimal impact on the crop.

Selective spray-topping largely targets broadleaf weeds (especially *Brassica* weeds). The tactic should not be confused with pasture spray-topping, which occurs in a pasture phase, involves heavy grazing, uses a non-selective herbicide and largely targets grass weeds (see spray-topping in IWM Section 4: Tactics).

The strategy can be used to control 'escapes', as a late post-emergent salvage treatment, or for managing herbicide resistance.

The rapid spread of Group B resistance in *Brassica* weeds and Group A and Z resistance in wild oat (Avena spp.), along with the uncertain supply of the herbicide Mataven® (flamprop-M-methyl; for wild oats), has significantly reduced the potential application of this tactic (see below: *6.6 Herbicide resistance*).

Wild radish seeds can be viable once an embryo is visibly formed in the pod. This can occur within 21 days of flowering. [17]

6.4.3 Crop-topping with non-selective herbicides

Crop-topping is the application of a non-selective herbicide (e.g. glyphosate or paraquat) prior to harvest when the target weed is at flowering or early grainfill. Crop-topping aims to minimise production of viable weed seed while minimising loss of crop yield.

The efficiency of the crop-topping process depends on sufficient gap in physiological maturity between crop and weed. Non-selective herbicide crop-topping registrations are largely limited to use in pulse crops and predominantly target annual ryegrass.

Crop-topping can reduce annual grass weed seedset, reducing additions to the seedbank. Reductions in seedset achieved by crop-topping can be increased if used in conjunction with selective herbicide treatments such as pre-emergent herbicides.

Crop-topping can deliver a number of benefits in addition to reducing weed seedset, for example:

- Even maturity of crops (particularly pulses) can deliver improved harvest.
- Desiccating late weed growth in seasons with late rain improves harvest, grain quality and storage.

The ideal time for crop-topping is when the annual ryegrass is just past flowering and the pulse crop is as mature as possible. More often than not some crop yield loss will occur. Product labels should be consulted for specific directions.

Crop-topping should not be performed on crops where the grain is intended for use as seed or for sprouting; the herbicide can affect seedling vigour and viability. [18]

See crop-topping in IWM Section 4: Tactics.

More information

GRDC Fact Sheet: Pre-harvest herbicide use

[16] GRDC (2014) Section 5. Stopping weed seedset. Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub/Section-5-Stopping-weed-seed-set

[17] GRDC (2014) Section 5. Stopping weed seedset. Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub/Section-5-Stopping-weed-seed-set

[18] GRDC (2014) Section 5. Stopping weed seedset. Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub/Section-5-Stopping-weed-seed-set

6.4.4 Weed wiping

Wick wiping, blanket wiping, carpet wiping and rope wicking are all forms of weed-wiping technology that are aimed at reducing weed seedset by using a range of devices to wipe low volumes of concentrated herbicide onto weeds that have emerged above the crop (Figure 5). Weed wiping is selective because of the application method rather than the herbicide used.

Weeds must be at least 30 cm taller than the crop. Care is needed to ensure that excess herbicide does not drip on to the crop and cause damage.

Weed wiping is most effective when the target weed is most vulnerable. For *Brassica* weeds, wiping at flowering to early podfill stages will achieve the greatest reduction in seedset. The level of weed control decreases after the weed reaches mid podfill.

Weed wipers have developed significantly and include models with multiple ropes, carpets, sponges, revolving cylinders and pressurised supply, which make them significantly more effective. [19]

More information

IWM Section 4. Tactics

INLAND: Eliminator weed wiper

C-Dax Eliminator weed wiper

Figure 5: Blanket wipers use a sheet (blanket) moistened with herbicide to wipe the weeds above the crop. (Photo: A. Storrie)

6.4.5 Crop desiccation and windrowing

Crop desiccation with a non-selective herbicide and windrowing (also called 'swathing') are harvest aids; the growth stage of any weeds present is not a consideration. However, if conducted when weeds are green and growing, windrowing and crop desiccation can significantly reduce weed seedset.

These tactics are conducted at or just after crop physiological maturity. The greatest levels of weed control will occur if the crop matures before the weeds, so short-season cultivars are best suited.

Windrowing and desiccation can:

- encourage even ripening of crops
- increase harvest speed and efficiency
- minimise yield loss from shattering or lodging
- enhance seed quality
- overcome harvest problems caused by late winter or early summer weed growth
- minimise weather damage during harvest by increasing the speed of drying, while protecting the crop in the windrow
- improve the yield of following crops by halting water use by the current crop. Crops can continue to use soil water when past physiological maturity.

19 GRDC (2014) Section 5. Stopping weed seedset. Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub/Section-5-Stopping-weed-seed-set

Any weed regrowth must be controlled to minimise seed production.

Harvest withholding periods must be known before using herbicides for crop desiccation. [20]

See IWM Section 4: Tactics.

6.4.6 Manuring, mulching and hay freezing

Sacrificing of a portion of the crop as a way to manage weed patches that have escaped control can be an effective management tool.

Crops and pastures can be returned to the soil by burial, mulching or chemical desiccation with the key aims of reducing weed seedbanks, improving soil fertility and maintaining soil organic matter.

Green manuring incorporates green plant residue into the soil with a cultivation implement, and brown manuring uses non-selective herbicides (Figure 6).

Mulching is similar to brown manuring but involves mowing or slashing the crop or pasture and leaving the residue laying on the soil surface.

Hay freezing is similar to brown manuring with the additional aim of creating standing hay. In this case, herbicide is applied earlier than if the crop were to be mown for conventional haymaking.

If performed before weed seedset and all weed regrowth is controlled, reductions in weed seedset of >95% are possible. [21]

Figure 6: Hay cutting (left) and brown manuring (right)—two options to stop weed seedset. (Photo: A. Douglas)

More information

IWM Section 4: Tactics

GRDC Fact Sheets: Manuring of pulse crops

6.5 Pasture seedset control

6.5.1 Pasture spray-topping

Pasture spray-topping involves application of a non-selective herbicide at flowering of the weeds, followed by heavy grazing, to reduce weed seedset.

Pasture spray-topping is possible because annual grasses become more sensitive to non-selective knockdown herbicides during flowering. This increased sensitivity allows lower rates of herbicide to be used to prevent the formation of viable grass seeds, with limited effect on desirable pasture species.

20 GRDC (2014) Section 5. Stopping weed seedset. Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub/Section-5-Stopping-weed-seed-set

21 GRDC (2014) Section 5. Stopping weed seedset. Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub/Section-5-Stopping-weed-seed-set

Usually, only one species can be targeted with pasture spray-topping because of differences in the time of flowering between species. Seed production of annual ryegrass can be reduced by up to 90%, whereas barley grass (Hordeum spp.) is reduced by ~65% owing to its extended head emergence.

Pasture spray-topping should be used for 2 years before growing a cereal crop, to reduce grass numbers and potential for crop root disease. It is not a substitute for long fallow.

Although pasture spray-topping is targeting a different plant growth stage, (i.e. flowering and seedset), a plant already resistant to that herbicide MOA will exhibit little or no effect. [22]

See IWM Section 4: Tactics.

6.5.2 Silage and hay

Silage and haymaking can be used to manage weeds by:

- reducing the quantity of viable seed set by target weeds, and
- removing viable weed seeds so that they are not added to the soil seedbank.

Silage and haymaking can reduce weed seed numbers by >95% if conducted before weed seedset, and any regrowth is controlled by herbicide or heavy grazing. [23]

See IWM Section 4: Tactics.

6.5.3 Grazing to manage weeds actively

Grazing management can aid weed management by:

- reducing weed seedset
- reducing weed competition
- encouraging domination by desirable species

The impact is intensified when the timing of grazing coincides with the vulnerable stages of the weed life cycle. This can be achieved through:

- timing grazing pressure to manipulate pasture composition
- grazing being used in conjunction with herbicides (spray-grazing) to manage weeds effectively (e.g. winter application of sublethal rate of MCPA on broadleaf weeds in clover-based pasture)
- exploiting differences in species acceptability to sheep, which can reduce weed numbers (e.g. grasses are more palatable in autumn)

Problems encountered by farmers when using grazing to manage weeds include:

- grazing pressure often not high enough to prevent selective grazing (Figure 7)
- incorrect timing of practices to obtain the desired level of weed control
- risk of livestock importing weeds or transporting them to other paddocks [24]

22 GRDC (2014) Section 5. Stopping weed seedset. Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub/Section-5-Stopping-weed-seed-set

23 GRDC (2014) Section 5. Stopping weed seedset. Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub/Section-5-Stopping-weed-seed-set

24 GRDC (2014) Section 5. Stopping weed seedset. Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub/Section-5-Stopping-weed-seed-set

More information

IWM Section 4: Tactics

GRDC Fact Sheets: Manuring of pulse crops

GRDC Update Papers: Fodder rotations with cropping to manage weeds

GRDC Update Papers: Integrated weed management - Crop topping in wheat

WeedSmart videos: Control harvest weed seed set with windrows and crop topping

Figure 7: Sheep are effective weed managers if stocking rates can be kept high enough. (Photo: A. Storrie)

6.6 Herbicide resistance

Herbicide resistance is an increasing threat across Australia's grain regions for both growers and agronomists. For most herbicide MOAs, more than one resistance mechanism can provide resistance, and within each target site, a number of amino acid modifications provide resistance. This means that resistance mechanisms can vary widely between populations; however, some patterns are common. Although some broad predictions can be made, a herbicide test is the only sure way of knowing which alternative herbicide will be effective on a resistant population. [25]

6.6.1 Testing services

For testing of suspected resistant samples, contact:

Charles Sturt University Herbicide Resistance Testing
School of Agricultural and Wine Sciences
Charles Sturt University
Locked Bag 588
Wagga Wagga, NSW 2678
02 6933 4001
http://www.csu.edu.au/weedresearchgroup/herbicide-resistance

Plant Science Consulting
22 Linley Ave
Prospect, SA 5082
0400 664 460
info@plantscienceconsulting.com.au, www.plantscienceconsulting.com

[25] C Preston (2014) The mechanisms of herbicide resistance. GRDC Update Papers, 5 March 2014, http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/The-mechanisms-of-herbicide-resistance

Video

Weed Smart

6.6.2 Ten ways to weed out herbicide resistance

1. Act now to stop weeds from setting seed:
   - Destroy or capture weed seeds.
   - Understand the biology of the weeds present.
   - Remember that every successful WeedSmart practice can reduce the weed seedbank over time.
   - Be strategic and committed—herbicide-resistance management is not a 1-year decision.
   - Research and plan your WeedSmart strategy.
   - You may have to sacrifice yield in the short term to manage resistance—be proactive.
   - Find out what other growers are doing, and visit www.weedsmart.org.au.
2. Capture weed seeds at harvest. Options to consider are:
   - Tow a chaff cart behind the header.
   - Check out the new Harrington Seed Destructor.
   - Create and burn narrow windrows.
   - Produce hay where suitable.
   - Funnel seed onto tramlines in controlled traffic farming systems.
   - Use crop-topping where suitable (Southern and Western Regions).
   - Use a green or brown manure crop to achieve 100% weed control and build soil N levels.
3. Rotate crops and herbicide MOAs:
   - Look for opportunities within crop rotations for weed control.
   - Understand that repeated application of effective herbicides with the same MOA is the single greatest risk factor for evolution of herbicide resistance.
   - Protect the existing herbicide resource.
   - Remember that the discovery of new, effective herbicides is rare.
   - Acknowledge that there is no quick chemical fix on the horizon.
   - Use break crops where suitable.
   - Growers in high-rainfall zones should plan carefully to reduce weed populations in the pasture phase prior to returning to cropping.
4. Test for resistance to establish a clear picture of paddock-by-paddock weed status:
   - Sample weed seeds prior to harvest for resistance testing to determine effective herbicide options.
   - Use the 'Quick Test' option to test emerged ryegrass plants after sowing to determine effective herbicide options before applying in-crop selective herbicides.
   - Visit the WeedSmart website, http://www.weedsmart.org.au/ or www.ahri.uwa.edu.au for more information on herbicide-resistance survey results.
5. Aim for 100% weed control and monitor every spray event:
   - Stop resistant weeds from returning into the farming system.
   - Focus on management of survivors in fallows.
   - Where herbicide failures occur, do not let the weeds seed. Consider cutting for hay or silage, fallowing or brown manuring the paddock.
   - Patch-spray areas of resistant weeds only if appropriate.
6. Do not automatically reach for glyphosate:
   - Use a diversified approach to weed management.
   - Consider post-emergent herbicides where suitable.
   - Consider strategic tillage.
7. Never cut the on-label herbicide rate and carefully manage spray drift and residues:
   - Use best management practice in spray application. Consult GRDC Fact Sheets, available at www.grdc.com.au.
   - Consider selective weed sprayers such as WeedSeeker® or WEEDit®.

8. Plant clean seed into clean paddocks with clean borders:
   - It is easier to control weeds before the crop is planted.
   - Plant weed-free crop seed to prevent the introduction of new weeds and the spread of resistant weeds.
   - A recent Australian Herbicide Resistance Initiative (AHRI) survey showed that 73% of grower-saved crop seed was contaminated with weed seed.
   - The density, diversity and fecundity of weeds are generally greatest along paddock borders and areas such as roadsides, channel banks and fence lines.
9. Use the double-knock technique:
   - Double-knock is the use of any combination of weed control that involves two sequential strategies; the second application is designed to control survivors of the first method of control used.
   - Access GRDC research results at www.grdc.com.au or www.nga.org.au.
10. Employ crop competitiveness to combat weeds:
   - Consider narrow row spacing and seeding rates.
   - Consider twin-row seeding points.
   - Use high-density pastures as a rotation option.
   - Consider brown manure crops.
   - Rethink bare fallows. [26]

More information

Agronomy Australia: The extent of herbicide resistance in Tasmanian wild radish populations

6.7 Managing the weed seedbank

The weed seedbank is defined as the mature seeds that exist in the soil. At any given time, the soil seedbank contains viable weed seeds produced in several previous years (the seedbank). These seeds (of different ages) will either be able to germinate when the conditions are favourable (suitable temperature, adequate water and enough oxygen) or be dormant.

When new seed is prevented from entering the seedbank, persistence can be determined by measuring the time taken for the number of weed seeds in the soil to diminish to negligible levels. This will vary with weed species due to the differing levels and types of dormancy.

There are two ways to diminish the seedbank:

- Weed seed germination and subsequent seedling emergence. Factors including light, soil conditions such as temperature and moisture, the soil's gaseous environment and nutrient status all affect the seed's dormancy and ability to germinate. Tillage can affect seed germination by redistributing the seed to a different profile in terms of moisture, temperature, etc. or changing the amount of available light. Autumn tickle stimulates germination of some weed species by placing seed in a better physical position in the soil. (Note: this is not applicable to surface-germinating weeds.) A well-timed autumn tickle will promote earlier and more uniform germination of some weed species for subsequent control. Tickling often needs to be used in conjunction with delayed sowing.
- Seed loss other than germination. Most seeds fail to emerge as seedlings. Some are buried at depths too great to permit emergence, and a large fraction simply lose viability over time and die of old age. After long-term reduced tillage or no-tillage, most weed seed is at or close to the soil surface.

Some weed seeds may also be eaten or attacked by pathogens. A study in the Western Australian wheatbelt found that 81% of the original annual ryegrass seed and 46% of wild radish seed had been removed by ants (seed predation).

Natural mortality rates of weed seed are far higher in no-till systems where weed seed is left on the soil surface than in systems where weed seed is mixed in the top

26 WeedSmart, http://www.weedsmart.org.au

few centimetres of soil. Burying some types of weed seeds can increase seedbank dormancy and slow the rate at which the seedbank is depleted. [27]

6.7.1 Burning residues

Fire can be used to kill weed seeds on the soil surface if there is sufficient fuel load and the fire is hot enough (Figure 8). Burning over summer poses an unduly high fire hazard and is illegal in most regions. An autumn burn often poses a lower fire hazard and leaves crop residue in place to protect soil from wind and water erosion for a longer period. Maintaining stubble for longer also benefits soil water capture and retention, provided summer weed growth is controlled.

To obtain high levels of control of weeds such as annual ryegrass and wild radish, a hot fire is needed. This is obtained by windrow burning, where crop residues from cereal, canola or pulse crops is concentrated with weed seed in a narrow windrow and then burnt. [28]

Figure 8: Chaff dumps can be burnt in autumn killing a high proportion of seeds present. (Photo: A. Storrie)

6.7.2 Encouraging insect predation of seed

The contribution that insects make to seedbank reduction is often overlooked, despite weed seeds comprising a major component of many insect diets (Figure 9). This predation of seed contributes to 'natural mortality' and partly explains why less seed germinates than is produced.

Understanding the role that insects play in removing weed seeds could help the development of farming systems that encourage greater removal of seeds from the seedbank. In New South Wales, seed theft by ants has commonly caused failure of pastures, and data from Western Australia show that ants can remove 60% or more of annual ryegrass in no-till systems, where weed seed is on the soil surface and

27 GRDC (2014) Section 3. Managing the weed seedbank. Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub/Section-3-Managing-the-weed-seedbank

28 GRDC (2014) Section 3. Managing the weed seedbank. Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub/Section-3-Managing-the-weed-seedbank

accessible. Therefore, weed seedbanks could be also decreased by encouraging ant predation. [29]

Figure 9: Grass seeds collected by ants. (Photo: A. Storrie)

6.7.3 Autumn tickle

Autumn tickling (also referred to as an 'autumn scratch' or shallow cultivation) stimulates germination of weed seeds by improving seed contact with moist soil. At a shallow depth of 1–3 cm, the seed has better contact with moist soil and it is protected from drying. Because weeds that germinate after an autumn tickle can be controlled, such a process will ultimately deplete weed seed reserves.

An autumn tickle can be conducted with a range of equipment including tined implements, skim ploughs, heavy harrows, pinwheel (stubble) rakes, dump rakes and disc chains.

Tickling can increase the germination of some weed species but has little effect on others. Tickling needs to be used in conjunction with delayed sowing to allow time for weeds to emerge and to be controlled prior to seeding. [30]

6.7.4 Delayed sowing

Delayed sowing (seeding) is the technique of planting the crop beyond the optimum time for yield in order to maximise weed emergence and control prior to sowing. Weeds that emerge in response to the break in season can then be killed by using a knockdown herbicide or cultivation prior to crop sowing (Figure 10).

This tactic is most commonly employed for paddocks that are known to have high weed burdens. Paddocks with low weed burdens are given priority in the sowing schedule, leaving weedy paddocks until later. This allows sufficient delay for the tactic to be beneficial on the problem paddock without interrupting the whole-farm sowing operation.

[29] GRDC (2014) Section 3. Managing the weed seedbank. Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub/Section-3-Managing-the-weed-seedbank

[30] GRDC (2014) Section 3. Managing the weed seedbank. Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub/Section-3-Managing-the-weed-seedbank

Choosing a crop or cultivar with a later optimum sowing time can reduce yield impact of a later sowing date. [31]

Figure 10: Delayed sowing allows use of knockdown herbicides or cultivation to control small weeds prior to sowing, reducing the pressure on selective in-crop herbicides. (Photo: D. Holding)

6.8 Managing weed seedlings

Killing weeds with cultivation has been the focus of weed management since agriculture was first developed. Since the release of glyphosate and Group A and B herbicides in the early 1980s, herbicides have been the primary tool for controlling weeds because they are cost effective, do not disturb soil and crop residue, have high levels of control and are easy to use. However, this approach to controlling weeds has led to the development of herbicide resistance. Despite herbicide resistance, herbicides remain an important tool, but require support from a range of non-herbicide tactics to remain effective.

Tactics that assist include fallow, pre-sowing and interrow cultivation, double-knock, alternate pre- and post-emergent herbicides, roguing individual plants, weed-detector spraying, and harvest weed-seed control.

'Used alone, none of the currently available cultural techniques provide an adequate level of weed control. However when used in carefully planned combinations extremely effective control can be achieved.' (Gill and Holmes 1997) [32]

Video

Strategic tillage

6.8.1 Killing weeds with tillage

Cultivation can kill many weeds, including herbicide-resistant and hard-to-kill populations. Cultivation is useful as a 'one-off' tactic in reduced-tillage or no-till operations. Well-timed cultivation in a no-till system can give a range of benefits with manageable reduction on conservation farming goals. [33] Planned cultivation can also be used as a non-herbicide component of a double-knock system (see IWM Section 4: Tactics).

[31] GRDC (2014) Section 3. Managing the weed seedbank. Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub/Section-3-Managing-the-weed-seedbank

[32] GRDC (2014) Section 4. Managing weed seedlings. Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub/Section-4-Managing-weed-seedlings

[33] Y Dang *et al.* (2013) Tillage impact in long term no-till. GRDC Update Papers, 27 Feb. 2013, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Tillage-impact-in-long-term-no-till

Benefits

1. Well-timed cultivation in a drying soil effectively kills weeds. Cultivation destroys weeds in a number of ways, including:
    - plant burial
    - seed burial, thus reducing the ability to germinate if sufficiently deep
    - severing roots
    - plant desiccation, where plants are left on the soil surface to die
    - breaking seed dormancy or seed being placed in a more favourable environment to encourage germination for subsequent control
2. In preparing a seedbed, cultivation provides a weed-free environment for the emerging crop and can improve soil surface conditions for even application of pre-emergent herbicides.
3. Cultivation can control weeds in situations where herbicides are ineffective or not an option.
4. Pre-sowing cultivation or full disturbance cultivation at sowing reduces reliance on knockdown herbicides and therefore the likelihood of weed populations developing herbicide resistance.
5. Shallow cultivation to incorporate pre-emergent herbicides reduces loss due to volatilisation and photodegradation.

Whole-farm benefits

Weed management can have an additional benefit where cultivation is used for:

- incorporating soil ameliorants (e.g. lime or gypsum)
- overcoming stratification of non-mobile nutrients such as phosphorus or redistribution of potassium that has been concentrated in surface zones after years of no-till
- breaking up a hard pan or subsoil restriction

Issues with tillage

The term 'strategic tillage' has been widely quoted. In many instances when tillage is used to combat herbicide-resistant weeds, the timing of tillage is driven more by weed escapes than by good planning:

- Using tillage at the start of a summer fallow will degrade soil cover, leaving the soil more exposed to wind and water erosion and evaporation over the summer period.
- In wet soil conditions, the percentage weed kill delivered by tillage is often poor due to replanting of weeds back into moist soil.
- Compaction can occur, particularly in wet soils.
- It speeds breakdown of stubble and reduces protection from water and wind erosion.
- In the weeks prior to sowing, it can lead to a loss of soil water needed for crop establishment.
- In cracking clay soils, tillage can close surface cracks and reduce the soil's ability to accept high-intensity, summer storm rainfall, with ensuing runoff and soil loss.
- Tillage will bury weed seeds, which may prolong seedbank dormancy in many weed species and can reduce efficacy of some pre-emergent herbicides used at sowing.
- Tillage often costs more, requires greater capital investment and more labour, and is slower than spraying.

More information

GRDC Fact Sheets: Strategic tillage

Video

Herbicide Innovation Partnership

Tillage works best in dry or drying soil environments. Weeds are easier to kill when small with smaller root systems. Larger plants may need a more aggressive implement and/or multiple passes. [34]

6.8.2 Killing weeds with herbicides

The rapid development of resistance to glyphosate in several weeds has placed increased reliance on in-crop weed management. Many selective herbicides already have resistance issues; therefore, an increase in reliance on pre-emergent herbicides is forecast while these remain effective.

The last significant new MOA groups released into the Australian herbicide market were Group B, when chlorsulfuron was launched in 1982, and Group H in 2001. No new post-emergent herbicides appear anywhere near commercialisation, so it is clear that the supply of new chemistries is limited.

The only new MOAs on the horizon (and they are not great in number) are all pre-emergent chemistries.

Hence, we need to look after what is available for as long as possible. [35]

Further information on registered chemicals can be obtained from APVMA and CropLife Australia, and Regional weed control references.

Knockdown (non-selective) herbicides for fallow and pre-sowing control

Knockdown herbicides are key tools to enable no-till fallows to be managed economically and efficiently. They are also used in the crop, especially glyphosate in RR crops.

Knockdown herbicides also represent a key component of other weed management tactics, including:

- controlling weeds before sowing (see delayed sowing and agronomy in IWM Section 3)
- herbicide-tolerant crops (agronomy)
- controlling weeds in fallow (agronomy)
- crop-topping
- use of wiper methods (see tactic 3.1 in IWM Section 4)
- crop desiccation (see tactic 3.1)
- pasture spray-topping (see tactic 3.2)
- brown manuring and hay freezing (see tactic 3.4)

Since its release in the late 1970s, glyphosate has become the most widely used herbicide in the world. Prior to this, paraquat was more commonly used. Developed to deal with capeweed in southern Australian farming systems, SPRAY.SEED® (paraquat + diquat) also improved the control of *Erodium* spp., capeweed (*Arctotheca calendula*) and black bindweed (Fallopia convolvulus) over paraquat used alone.

In unselected weed populations, genes carrying resistance to glyphosate are rare, and selection for 15+ years is required before the frequency of resistant individuals is likely to lead to a spray failure.

The Australian Glyphosate Sustainability Working Group provides up-to-date information on glyphosate and paraquat resistance.

34 GRDC (2014) Section 4. Managing weed seedlings. Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub/Section-4-Managing-weed-seedlings

35 GRDC (2014) Section 4. Managing weed seedlings. Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub/Section-4-Managing-weed-seedlings

More information

GRDC: Summer fallow weed management

Video

Double knock timing

With widespread use over a prolonged period and often few if any other measures taken to control weed escapes, populations of weeds resistant to glyphosate have increased exponentially. This increase is forecast to continue.

In winter crop, no-till rotations, the selection pressure for resistance to glyphosate is placed more on summer weeds. Glyphosate resistance has developed in multiple grass weeds as well as fleabane. No-tillage has enabled the wheat belt to expand into lower rainfall rangeland country because it has enabled far better management and storage of limited rainfall. Increasingly, however, widespread resistance to glyphosate threatens the base technology of many current cropping systems.

With widespread use of herbicides comes increased potential for spray drift. Weather conditions, droplet size, proximity to adjoining crops are critical issues. [36]

Double-knockdown or double-knock

Double-knock is the sequential application of two different weed-control tactics where the second tactic controls any survivors from the first tactic.

An example in common use is the sequential application of glyphosate (Group M) followed by paraquat/diquat (Group L), at an interval of 1–14 days. Each herbicide must be applied at a rate sufficient to control weeds if it were used alone. The second herbicide is applied to control any survivors from the first herbicide application. Control of weeds that germinate during the interval between the two applications of herbicide is an incidental benefit.

Other double-knock strategies include following a herbicide with burning or grazing, or seed capture and removal or burning. Increased levels of crop competition can also provide a partial double-knock to reduce the number of weed seeds set after application of an in-crop herbicide.

Double-knock strategies delay the onset of herbicide resistance; however, modelling shows that if many years of selection take place in which survivors of glyphosate applications are allowed to set seed before double-knock strategies are used, the benefit of double-knock as a delaying strategy for the onset of resistance to glyphosate is greatly diminished. [37]

Using a double-knock strategy reduces the number of glyphosate-resistant weeds to be controlled in-crop and improves the general level of weed control obtained.

Some key grass and broadleaved weeds can only be reliably controlled using double-knockdown sprays.

Populations of grass weeds that have developed resistance to glyphosate:

- annual ryegrass (*Lolium rigidum*)
- awnless barnyard grass (*Echinochloa cruss-galli*)
- great brome grass (*Bromus* spp.)
- red brome (*Bromus rubens)*
- liverseed grass (*Urochloa panicoides*)
- windmill grass (*Chloris truncata*)
- flaxleaf fleabane (*Conyza bonariensis*)
- wild radish (*Raphanus raphanistrum*)
- sowthistle (*Sonchus* spp.)

[36] GRDC (2014) Section 4. Managing weed seedlings. Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub/Section-4-Managing-weed-seedlings

[37] DT Thornby, SR Walker, JPM Whish (2008) Modeling to estimate glyphosate resistance risk in barnyard grass in the northern Australian grain region. Proceedings of the 16th Australian Weeds Conference, http://www.caws.org.au/awc/2008/awc200815131.pdf

Weeds that are naturally tolerant of glyphosate:

- feathertop Rhodes grass (*Chloris virgata*)

Fleabane can be effectively controlled in the early rosette stage by double knockdown where paraquat alone or in-mix with diquat is applied 5–7 days after glyphosate, mixed with a suitably efficacious Group I herbicide.

Note that there are residual/re-crop issues for following crops when using Group A herbicides in fallow.

Key issues for double-knock

Where glyphosate and paraquat are appropriate products to use, glyphosate should be applied first and followed by paraquat or paraquat–diquat.

The ideal time between applications will vary with the main target weed species.

Almost all annual species benefit from 1 day or more between applications. In some species, longer delays of 1–2 weeks are beneficial, but delaying too long can lead to regrowth of weeds and poorer results.

Apply the first herbicide when the weeds are most likely to be killed, (i.e. when small and actively growing).

Maximum control of annual ryegrass results from an application of herbicide at the 3–4-leaf stage. Annual ryegrass sprayed at the 0–1-leaf stage can regrow from seed reserves. Later application, when the annual ryegrass is tillering, risks incomplete control because little translocation takes place within the plant.

When applying contact herbicides or Group A herbicides, increase spray carrier volume and avoid very coarse droplet sizes, because excellent spray coverage is needed for success. Seasonal conditions and spraying capacity will influence the scale of on-farm implementation.

More information

GRDC: Summer fallow weed management

Target this tactic to paddocks with the highest weed populations because these are at higher risk of selection for resistance.

Be aware that use of double-knock strategy on a percentage of land each year will add logistical stress to spray operations. This needs to be planned for. [38]

Pre-emergent herbicides

Pre-emergent herbicides control weeds at the early stages of the life cycle, between radical (root and shoot) emergence from the seed and seedling leaf emergence through the soil.

Some pre-emergent herbicides also have post-emergent activity through leaf absorption and they can be applied to newly emerging weeds.

The residual activity of a pre-emergent herbicide controls the first few flushes of germinating weeds (cohorts) while the crop is too small to compete. As a result, pre-emergent herbicides are often excellent at protecting the crop from early weed competition.

Factors to consider when using pre-emergent herbicides:

- Weed species and density. Knowing which weeds to expect is critical. Pre-emergent herbicides are particularly useful at stopping early weed competition, especially if high weed densities are expected.
- Crop or pasture type. What is registered, how competitive is the crop, and which post-emergent options exist?
- Soil condition. Cloddy soil surfaces, large amounts of stubble or an excess of ash from stubble burning can affect the performance of some pre-emergent herbicides.

[38] GRDC (2014) Section 4. Managing weed seedlings. Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub/Section-4-Managing-weed-seedlings

Less soluble herbicides such as simazine need to be mixed with the topsoil for best results. The more mobile herbicides such as sulfonylureas and imidazolinones may not need mechanical incorporation, because they move into the topsoil with water (rain or irrigation). Some herbicides need incorporation or coverage to prevent UV losses (e.g. atrazine) or volatilisation (e.g. trifluralin).

- Rotation of crop or pasture species. All pre-emergent herbicides persist in the soil to some degree. Some post-emergent herbicides may also persist in the soil. Consequently, herbicides may carry over into the next cropping period. The time between spraying and safely sowing a specific crop or pasture without residual herbicide effects (the plant-back period) varies, depending on herbicide, environmental conditions and soil type.

The following influence the fate of herbicides in the soil (Table 2):

- herbicide adsorption and solubility
- herbicide mechanism of breakdown (i.e. chemical or microbial)
- soil texture
- soil pH (for some herbicides)
- organic matter
- previous herbicide use
- soil moisture
- initial application rate
- soil temperature
- volatilisation
- photodegradation

More information

IWM Section 4: Tactics

Table 2: Soil attributes that contribute to herbicide availability

Higher herbicide availability	Lower herbicide availability
Sandy soils	Clay soils
Low organic matter	High organic matter
High pH (triazines and sulfonyl ureas)	Low pH
Low pH (imidazolinones)	High pH
Wet conditions	Dry conditions

When using pre-emergent herbicides, consider how the herbicide kills weeds, how it gets into the weed zone and where it will be when weeds are germinating (Table 3). Typically, situations that reduce availability will require higher application rates to achieve equivalent control. Properties that reduce availability also tend to increase the length of herbicide persistence in the soil, thus increasing rotational crop constraints.

A pre-emergent herbicide that is sitting on a dry soil surface at the time of weed emergence is unlikely to have sufficient soil moisture for uptake by the weed or sufficient contact with the emerging weeds to kill them. This might occur if the herbicide was applied immediately post-sowing while weeds were already germinating and if there was no rain or mechanical incorporation to take the herbicide into the germination zone where it can be taken up by the young weeds. Weed escapes in such situations are likely.

Crop safety is also an important issue when using pre-emergent herbicides. Crop tolerance of several pre-emergent herbicides (i.e. trifluralin, pyroxasulfone, prosulfocarb) is often related to spatial separation of the young crop from the herbicide. This, in turn, is related to the solubility and potential movement in the soil of the herbicide, the crop establishment process, the level of soil displacement over the crop row, follow-up rainfall and the physical nature of the seed furrow. [39]

[39] Section 4. Managing weed seedlings. Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub/Section-4-Managing-weed-seedlings

Table 3: Positive and negative aspects of using pre-emergent herbicides

Positive	Negative
Relatively inexpensive	Strongly dependent on soil moisture
Optimises crop yield through control of early weed germinations	Because weeds are not yet visible, must have paddock history/knowledge of previous weeds/ weed seedbank
Different modes of action to most post-emergent herbicides	Plant-back periods limit crop rotation
Timing of operation: generally have a wide window of opportunity for application options	Crop damage if sown too shallow or excessive quantities of herbicide move into root-zone
Best option for some crops where limited post-emergent options exist	Seedbed preparation: soil may need cultivation and herbicide may need incorporation, which can lead to erosion, soil structural decline and loss of sowing moisture
Effective on some weeds that are hard to control with post-emergent herbicides (e.g. wireweed and black bindweed)	Not suitable when dense plant residues or cloddy soils are present
Extended period of control of multiple cohorts; good for weeds with multiple germination times	Varying soil types and soil moisture across paddock can be reflected in variable results

Selective post-emergent herbicides

Selective post-emergent herbicides control emerged weeds in the crop or pasture.

The first selective post-emergent developed was a Group I herbicide, 2,4-D (released ~1945). Group A and B herbicides were released in the 1980s.

Selective post-emergent herbicides belong to MOA Groups A (e.g. diclofop), B (e.g. metsulfuron), C (e.g. diuron), F (e.g. diflufenican), G (e.g. carfentrazone), I (e.g. 2,4-D, dicamba, picloram), J (e.g. flupropanate) and R (e.g. asulam).

Many new selective post-emergent herbicides have been released in recent years; however, all of them have been from known MOA groups. No new post-emergent herbicides from new MOA groups are likely to be released in the near future.

Selective post-emergent herbicides give high levels of control (often >98%) when applied under recommended conditions on susceptible populations. When used early in crop development, at recommended rates and timings, selective post-emergent herbicides also result in optimum yield with potential for significant economic returns.

Early use on small susceptible weeds improves control levels achieved and removes weeds before significant crop yield loss occurs.

In addition to post-emergent activity, some post-emergent herbicides have pre-emergent activity on subsequent weed germinations. This is particularly the case with some Group B, C, F and I herbicides. Group A products have sufficient residual activity that they may affect cereal crops if sown too soon after use.

When choosing a selective post-emergent herbicide for a particular situation, consider the following factors:

- target weed species and growth stage
- herbicide resistance status of target weeds
- crop safety (variety, environmental conditions, effect of previously applied herbicide on crop)
- grazing and harvest withholding periods and plant-back periods
- cost
- spray drift risk
- mix partners

Application of post-emergent herbicides to stressed crops and weeds can result in reduced levels of weed control and increased crop damage.

Crops that are usually tolerant can be damaged when stressed by waterlogging, frost or dry conditions because they cannot produce sufficient levels of the enzymes that normally break the herbicide down; for example, when sulfonylureas are applied to cold and waterlogged crops and high levels of crop impact are seen. Group A herbicides often fail to kill weeds if applied too soon after a severe cold stress (frost).

Good crop competition improves the efficacy of post-emergent herbicides. Barley was shown to be more competitive than wheat against black bindweed (*Fallopia convolvulus*) and turnip weed (*Rapistrum rugosum*), and higher crop populations improve the effectiveness of herbicides against these species (Figure 11).

In a study on the effect of crop type and herbicide rate on seedset of paradoxa grass, barley was more competitive than wheat at all rates of herbicide (Figure 12).

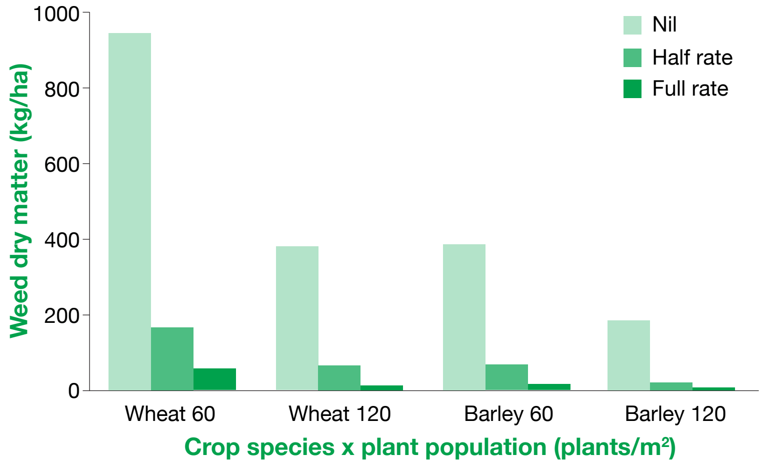

Figure 11: Effect of wheat and barley population and herbicide rate on the dry matter production of turnip weed and black bindweed measured at crop anthesis. (Source: Marley and Robinson 1990)

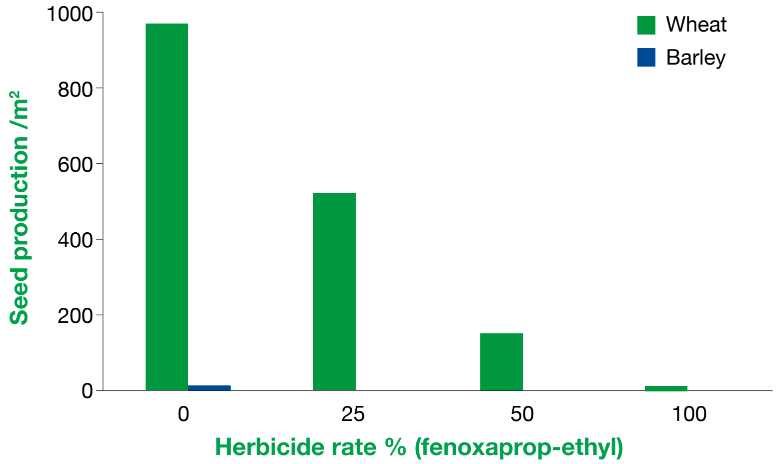

Figure 12: Effect of crop type and herbicide rate on paradoxa grass seed production. (Source: Walker et al. 1998)

When using selective post-emergent herbicides, it is important to use the correct application technique. Particular attention should be paid to:

- Equipment. Nozzles, pressure, droplet size, mixing in the tank, boom height and groundspeed should be set to maximise the efficiency of herbicide application to the target.
- Meteorological conditions. Suitable conditions are indicated by Delta T (ideally <8°C) when air movement is neither excessively windy nor still. (Delta T is an indication of evaporation rate and droplet lifetime and is calculated by subtracting the wet bulb temperature from the dry bulb temperature).

Spraying should not be conducted in inversion conditions and ideally should be done when temperatures are <28°C.

To get the best performance from the herbicide being applied, use the adjuvant recommended on the herbicide label. Because plants have different leaf surfaces, an adjuvant may be needed to assist with herbicide uptake and leaf coverage. Some adjuvants can also increase performance by lowering the pH, water hardness, compatibility, rain-fastness or drift. For more detailed information on adjuvants, see the GRDC publication Adjuvants—oils, surfactants and other additives for farm chemicals.

Selective post-emergent herbicides applied early and used as a stand-alone tactic often have little impact on weed seedbanks.

Early post-emergent herbicide use is aimed at maximising yield by removing weed competition at crop establishment stages. Any weed that germinates after or survives this application will set seed that will return to the seedbank, thus maintaining weed seedbank numbers and ensuring continuation of the weed problem.

To drive the weed seedbank down over time, use later season seedbank management tactics in association with early post-emergent tactics (Table 4). Seedbank capture and management tactics work similarly to help drive the weed seedbank down.

Table 4: Effect of annual applications of different herbicide treatments on wild oat seedbank numbers after 5 years (Cook 1998)

Herbicide treatment	Percentage change in wild oat numbers over 5 years
Pre-emergent alone	+15
Post-emergent alone	–40
Post-emergent + selective spray topping	–96

The effectiveness of selective post-emergent herbicides is influenced by a range of plant and environmental factors.

Inactivation of herbicides can occur from:

- leaf and cuticle structure
- dust particles
- washing product off the leaf due to rainfall or dew [40]

6.8.3 Spot spraying, chipping, hand roguing and wiper technologies

When weed numbers are low or when still contained in patches, hand weeding, spot spraying and other methods, including selective crop destruction, can be used to stop weed seedset and seedbank replenishment.

Wiper technologies are useful when there is a height differential between the crop and weeds to allow a weed wiper to apply concentrated herbicide to the weed while avoiding contact with the crop's plants.

Where new weed infestations occur in low numbers, eradication may be possible. In such situations, more intensive tactics to remove weeds can be used in addition to ongoing management tactics that aim to minimise weed impact.

Some key points:

- Stay vigilant for new or isolated weeds.
- Be prepared to hand-pull weeds.
- Keep a rubbish bag handy for weeds that already have seeds developed.
- Correctly identify new weeds and appropriate control measures.

40 GRDC (2014) Section 4. Managing weed seedlings. Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub/Section-4-Managing-weed-seedlings

More information

[Tactic 2.4 of IWM Section 4: Tactics]

- Manage and isolate outbreaks and hot spots.
- Stop weed seedset.
- Plan follow-up observation and management.
- Mark isolated weed patches by GPS and diary to check for later germinations. [41]

6.8.4 Weed-detector sprays

Weed detector sprayers are used for the control of scattered weeds in crop fallows. Weed-detector-activated sprayers detect the presence of weeds using infrared reflectance units linked to a single nozzle. When a weed is detected, a solenoid turns on an individual nozzle and the weed is sprayed.

This technology is in use in the Southern Grains Region, where it is reducing the volume of herbicide used in fallow per hectare by 80–95% depending on the density of the fallow weeds and the sensitivity settings of the sprayer.

This technology allows the use a range of herbicide MOAs and/or higher than usual rates while remaining economical.

A national APVMA minor use for the WeedSeeker® Permit (PER11163) allows several different MOAs to be used in fallows (valid until February 2019). Go to the APVMA site and enter the permit number.

Some added benefits and issues of this technology include:

- Drift risk is lower because coarse droplets are used and only a low percentage of the paddock is sprayed.
- Infrared signal enables use at night. Group L herbicides are often used as the second spray in double-knock programs and they tend to be more effective when sprayed late afternoon, in the evening or under cloudy conditions. A disadvantage of night spraying is a greatly elevated risk of inversion drift conditions.
- Weeds in wheat stubble should be larger than ~ 5 cm for reliable detection.
- Maintaining correct boom height, staying within design travel speeds and avoiding spraying in strong winds are essential for reliable performance. [42]

More information

AWC: Inter- and intra-row herbicide application strategies for the control of annual ryegrass in wide-row faba beans

AWC: Pyroxsulam for broad-spectrum weed control in wheat

CSIRO: Overview—Biological control of weeds

GIWA: Natural and environmentally friendly way of managing weeds without herbicides

GRDC: Adjuvants—Oils, surfactants and other additives for farm chemicals

GRDC: Regional weed control references

GRDC: Summer fallow weed management FAQ

GRDC Ground Cover: Advice at hand for fallow grass-weed control

IWM Section 4: Tactics

QAAFI: Double knock for controlling flaxleaf fleabane

Syngenta: SPRAY.SEED®

Weeds Australia: Target species for biological control

6.8.5 Biological control

Biological control for the management of weeds uses the weed's natural enemies (biological control agents). These include herbivores, such as insects and sheep, where there is direct consumption of the weed. Natural enemies also include microorganisms such as bacteria, fungi and viruses, which can cause disease, reduce weed vigour and competitiveness relative to the crop, and decay the weed seed in the seedbank. Other plants can also be included here, where they release substances that suppress weed growth—this is known as allelopathy. [43]

6.9 Harvest weed-seed control

Controlling weed seeds at harvest is emerging as the key to managing the increasing levels of herbicide resistance, which are putting Australia's no-till farming system at risk.

For information on harvest weed-seed control and its application for the southern grains region, see GrowNotes Wheat South Section 12. Harvest.

41 GRDC (2014) Section 4. Managing weed seedlings. Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub/Section-4-Managing-weed-seedlings

42 GRDC (2014) Section 4. Managing weed seedlings. Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub/Section-4-Managing-weed-seedlings

43 GRDC (2014) Section 4. Managing weed seedlings. Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub/Section-4-Managing-weed-seedlings

GRDC Fact Sheets

In-crop herbicide use (Northern, Southern and Western Regions)

Practical tips for spraying (Northern, Southern and Western Regions)

Pre-emergent herbicides (Northern, Southern and Western Regions)

Pre-harvest herbicide use (Northern, Southern and Western Regions)

Pre-season sprayer checks (Northern, Southern and Western Regions)

Spray equipment (Northern, Southern and Western Regions)

Spray height control (Northern, Southern and Western Regions)

Spray water quality (Northern, Southern and Western Regions)

Strategic tillage (Northern and Southern Regions)

Summer fallow spraying (Northern, Southern and Western Regions)

Weed control in wheel tracks (Northern, Southern and Western Regions)

GRDC Update Papers

Achieving good pre-emergent spray results

Getting the right mix

Hardseeded annual legumes

Herbicide efficacy in no-till farming systems in southern NSW

6.10 Other non-chemical weed control

Crop rotation, especially with summer crops, can be an effective means of managing a spectrum of weeds that result from continuous wheat cropping. Barley is a more vigorous competitor of weeds than is wheat, and it may be a suitable option for weed suppression. Increased planting rates and narrow rows may also help where the weed load has not developed to a serious level. [44]

The use of rotations that include both broadleaf and cereal crops may allow an increased range of chemicals—say three to five MOAs—or non-chemical tactics such as cultivation or grazing. For the management of wild oats, the inclusion of a strategic summer crop such as sorghum means two winter fallows, with glyphosate an option for fallow weed control. Grazing and/or cultivation are alternative, non-chemical options.

Where continuous summer cropping has led to development of Group M-resistant annual ryegrass, a winter crop could be included in the rotation and a Group A, B, C, D, J or K herbicide used instead, along with crop competition and potential harvest-management tactics.

Strategic cultivation can provide control for herbicide-resistant weeds and those that continue to shed seed throughout the year. It can be used to target large mature weeds in a fallow, for inter-row cultivation in a crop, or to manage isolated weed patches in a paddock. Take into consideration the size of the existing seedbank and the increased persistence of buried weed seed.

Most weeds are susceptible to grazing. Weed control is achieved through reduction in seedset and competitive ability of the weed. The impact is optimised when the timing of the grazing occurs early in the life cycle of the weed. [45]

6.11 Crop competition

A recent field trial near Warwick, Queensland, showed that fleabane density and seed production could be substantially manipulated by using crop competition in the absence of herbicides. The site received considerable rainfall during the 2010 crop-growing season, which promoted fleabane emergence and good early crop growth.

For wheat, there were trends to lower fleabane numbers with increasing crop population and narrower row spacing (Figure 13). On average, weed density decreased by 26% as crop population increased from 50 to 100 plants/m^2, and by 44% as row spacing decreased from 50 to 25 cm. These treatments also had impacts on seed production, as indicated by seed head counts (Figure 14). Row spacing tended to have a much greater effect than crop population. The data indicate that durum wheat responded in a manner similar to bread wheat. [46]

44 DAF Qld (2012) Wheat—planting information. Department of Agriculture and Fisheries, Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/planting-information

45 GRDC (2012) Cropping with herbicide resistance. Herbicide resistance Fact Sheet. GRDC, http://www.grdc.com.au/Media-Centre/Hot-Topics/Herbicide-Resistance

46 GRDC (2011) Keeping on top of fleabane—in-crop strategies, the role and impact of residual herbicides, crop competition and double-knock. GRDC Update Papers, 20 April 2011, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/04/Keeping-on-top-of-fleabane-incrop-strategies-the-role-and-impact-of-residual-herbicides-crop-competition-and-doubleknock

GRDC Update Papers

[Herbicide management in the summer fallow]

[Herbicides for control of clethodim-resistant annual ryegrass]

[Hitting the right target—what are our most costly weeds?]

[New technology for improved herbicide use efficiency]

[NGA chickpea herbicide trials 2014]

[Pre-emergent herbicides and seeding system interactions]

[Protecting glyphosate in summer fallows—mixes with pre-emergent herbicides and double knocking trials]

[Seeding systems and pre-emergence herbicides]

[The strategic use of tillage in conservation farming]

GRDC Videos

[Advances in weed management: Spray application in summer fallows]

[Advances in weed management: Stubble and soil binding of pre-emergent herbicides for annual ryegrass control in winter crops]

[Crop competition for weed management—narrow row spacings]

[Double knock applications—a grower's experience]

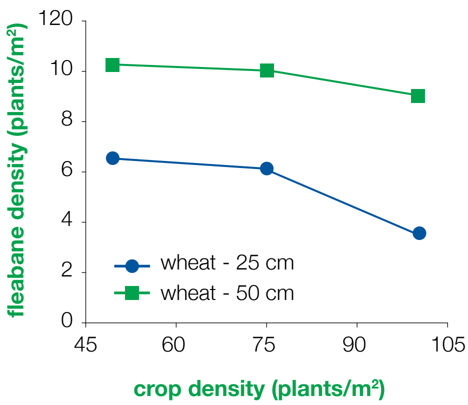

Figure 13: Fleabane density (no. of plants/m²) in wheat of different row spacing and plant density. (DAF Qld)

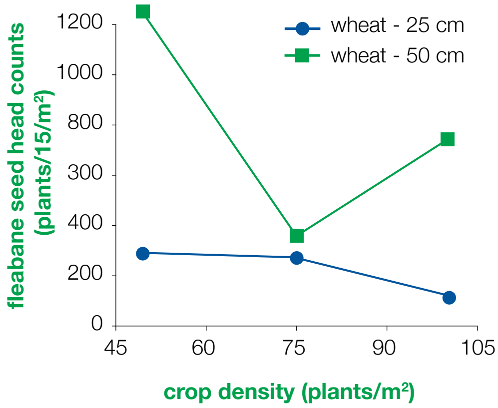

Figure 14: Average fleabane seedhead counts (no. of plants/15 m²) in wheat across different row spacing and plant density. (DAF Qld)

For information on sowing rates and plant population, see [GrowNotes Wheat South Section 3. Planting].

Northern Grower Alliance trials show that the use of a disc planter for incorporation by sowing (IBS) of residual herbicides resulted in significantly reduced wheat emergence for all four herbicides evaluated. The disc planter set-up actually increased the risk of crop damage. These results reinforce the need to use only narrow-point tines when using residual herbicides with IBS recommendations. [47]

6.12 Herbicides explained

6.12.1 Residual *v.* non-residual

Residual herbicides remain active in the soil for an extended period (months) and can act on successive weed germinations. Residual herbicides must be absorbed through the roots or shoots, or both. Examples of residual herbicides include imazapyr, chlorsulfuron, atrazine and simazine.

The persistence of residual herbicides is determined by a range of factors including application rate, soil texture, organic matter levels, soil pH, rainfall and irrigation, temperature and the herbicide's characteristics.

Persistence of herbicides will affect the enterprise's sequence (a rotation of crops, e.g. wheat–barley–chickpeas–canola–wheat).

[47] GRDC (2014) Pre-emergent herbicides: part of the solution but much still to learn. GRDC Update Papers, 5 March 2014, http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Pre-emergent-herbicides-part-of-the-solution-but-much-still-to-learn

GRDC Videos

[Double knock applications—double knock strategies for resistant weed populations](#)

[Double knock applications—target weed species and application strategy](#)

[GCTV10: Double knock timing](#)

[GCTV11: Strategic tillage, does no-till mean never till?](#)

[Spray application of herbicides—application volume in stubble](#)

[Spray application of herbicides—applying Group A (ACCAse inhibitor) herbicides](#)

[Spray application of herbicides—nozzle selection](#)

[Spray application of herbicides—spray deposition](#)

[Spray application of herbicides—travel speed](#)

[Weed seed bank destruction—Weed Seeker](#)

Videos

[SANTFA: Summer weed control](#)

[WeedSmart: Understanding pre-emergent herbicides](#)

[WeedSmart: When is it worth rotating from Select to Factor?](#)

Non-residual herbicides, such as the non-selective paraquat and glyphosate, have little or no soil activity and they are quickly deactivated in the soil. They are either broken down or bound to soil particles, becoming less available to growing plants. They also may have little or no ability to be absorbed by roots.

6.12.2 Post-emergent and pre-emergent

These terms refer to the target and timing of herbicide application. Post-emergent refers to foliar application of the herbicide after the target weeds have emerged from the soil, whereas pre-emergent refers to application of the herbicide to the soil before the weeds have emerged. [48]

6.13 Pre-emergent herbicides

The important factors in getting pre-emergent herbicide to work effectively while minimising crop damage are to understand:

- the position of the weed seeds in the soil
- the soil type (particularly amount of organic matter and crop residue on the surface)
- the solubility of the herbicide
- the herbicide's ability to be bound by the soil [49]

Choice of herbicides for weed control in wheat will depend on the specific weed species present in the paddock and the crop being grown. Consult your agronomist to discuss specific strategies.

Pre-emergent herbicides control weeds at the early stages of the life cycle, between radicle (root shoot) emergence from the seed and seedling leaf emergence through the soil. Of the 14 herbicide MOA groups, eight are classed as having pre-emergent activity.

Pre-emergent herbicides may also have post-emergent activity through leaf absorption and they can be applied to newly emerging weeds. For example, metsulfuron methyl is registered for control of emerged weeds but it gives residual control typical of many pre-emergent herbicides.

Many herbicide treatments are solely applied pre-emergent (e.g. trifluralin).

6.13.1 Benefits

The residual activity of a pre-emergent herbicide controls the first few flushes of germinating weeds (cohorts) when the crop or pasture is too small to compete. The earliest emerged weeds are the most competitive. Therefore, pre-emergent herbicides are ideal tools to prevent yield losses from these early-season weeds.

The residual activity gives control of a number of cohorts, not just those germinating around the time of application.

Ideally, pre-emergent herbicides should be applied just prior to, or just after, sowing the crop or pasture. This maximises the length of time that the crop will be protected by the herbicide during establishment.

6.13.2 Practicalities

Planning is needed for the use of pre-emergent herbicides to be an effective tactic.

There are four main factors to consider when using pre-emergent herbicides.

1. Weed species and density. When deciding to use a pre-emergent herbicide, it is important to have a good understanding of the expected weed spectrum. Use

48 GRDC. Integrated weed management, Section 4: Tactics for managing weed populations. GRDC/CRC for Australian Weed Management, http://www.grdc.com.au/~/media/A4C48127FF8A4B0CA7DFD67547A5B716.pdf

49 GRDC (2014) Understanding pre-emergent cereal herbicides. GRDC Update Papers 4 March 2014, https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Understanding-pre-emergent-cereal-herbicides

paddock history and observations of weed species and densities from at least 12 months prior to application. Correct identification of the weed species present is vital. Pre-emergent herbicides are particularly beneficial if high weed densities are expected. Post-emergent herbicides are often unreliable when applied to dense weed populations, because shading and moisture stress from crowding result in reduced control. Pre-emergent herbicides have the advantage of controlling very small weeds, whereas post-emergent herbicides can be applied to larger, more tolerant/robust plants.

2. Crop or pasture type. The choice of crop or pasture species will determine the herbicide selection. For chickpeas, faba beans and lentils, there are few effective, broadleaf post-emergent herbicides. In these cases, it is important to have a plan of attack, which is likely to include the use of a pre-emergent herbicide. The competitive nature of the crop should also be considered. For example, chickpeas, lupins and lentils are poor competitors with weeds and need pre-emergent herbicides to gain a competitive advantage.
3. Soil condition. Soil preparation is a critical first step in the effective use of pre-emergent herbicides. The soil is the storage medium by which pre-emergent herbicides are transferred to weeds. Soil surfaces that are cloddy or covered in stubble may need some pre-treatment such as light cultivation or burning to prevent 'shading' during application. Too much black ash from burnt stubble may inactivate the herbicide; therefore, ash must be dissipated with a light cultivation or rainfall prior to herbicide application. Less-soluble herbicides such as simazine need to be mixed with the topsoil for best results. This process, called incorporation, mixes or cultivates the top 3–5 cm of soil for uniform distribution of the herbicide in the weed root-zone. Herbicides such as the sulfonylureas and imidazolinones may not need mechanical incorporation, as they move into the topsoil with water (rain or irrigation). Some herbicides need to be incorporated to prevent losses from photodegradation (e.g. atrazine) or volatilisation (e.g. trifluralin).
4. Rotation of crop or pasture species. All pre-emergent herbicides persist in the soil to some degree. Consequently, herbicides may carry over into the next cropping period. The time between spraying and safely sowing a specific crop or pasture without residual herbicide effects (the plant-back period) can be as long as 36 months, depending on herbicide, environmental conditions and soil type. [50]

Visit Australian Pesticides & Veterinary Medicines Authority for an up-to-date list of registered herbicides.

See NSW DPI Weed control in winter crops (table 7 on pages 42 and 43.)

The choice of herbicides for use in wheat will depend on the specific weed species and the crop situation. Consult with your agronomist for further details.

More information

GRDC Integrated Weed Management Hub

NGA: Project reports—weeds

GRDC: Grain Orana Alliance

6.13.3 Avoiding crop damage from residual herbicides

When researching the residual activity and cropping restrictions following herbicide application, the herbicide label is the primary source of information and it should be read thoroughly. The information below provides an explanation of how herbicides break down and extra notes on some specific herbicides used in broadacre cropping.

What are the issues?

Some herbicides can remain active in the soil for weeks, months or years. This can be an advantage, in that it ensures good long-term weed control. However, if the herbicide stays in the soil longer than intended, it may damage sensitive crop or pasture species sown in subsequent years.

For example, chlorsulfuron (Glean®) is used in wheat and barley, but it can remain active in the soil for several years and damage legumes and oilseeds.

50 GRDC. Integrated weed management, Section 4: Tactics for managing weed populations. GRDC/CRC for Australian Weed Management, http://www.grdc.com.au/~/media/A4C48127FF8A4B0CA7DFD67547A5B716.pdf

A real difficulty for growers lies in identifying herbicide residues before they cause a problem. We rely on information provided on the labels for soil type and climate. Herbicide residues are often too small to be detected by chemical analysis, or if testing is possible, it is too expensive to be part of routine farming practice. Once the crop has emerged, diagnosis is difficult because the symptoms of residual herbicide damage can often be confused with, and/or make the crop vulnerable to, other stresses, such as nutrient deficiency or disease. [51]

An option for assessing the potential risk of herbicide residues is to conduct a bioassay involving hand-planting small test areas of crop into the field in question.

Which herbicides are residual?

The herbicides listed in Table 5 all have some residual activity or planting restrictions.

Table 5: Active constituent by herbicide group (may not include all current herbicides)

Herbicide group	Active constituent
Group B. Sulfonylureas	Chlorsulfuron (Glean®), iodosulfuron (Hussar®), mesosulfuron (Atlantis®), metsulfuron (Ally®), triasulfuron (Logran®)
Group B. Imidazolinones	Imazamox (Raptor®), imazapic (Flame®), imazapyr (Arsenal®)
Group B. Triazolopyrimidines (sulfonamides)	Florasulam (Conclude®)
Group C. Triazines	Atrazine, simazine
Group C. Triazinones	Metribuzin (Sencor®)
Group C. Ureas	Diuron
Group D. Dinitroanilines	Pendimethalin (Stomp®), trifluralin
Group H. Pyrazoles	Pyrasulfotole (Precept®)
Group H. Isoxazoles	Isoxaflutole (Balance®)
Group I. Phenoxy carboxylic acids	2,4-Ds
Group I. Benzoic acids	Dicamba
Group I. Pyridine carboxylic acids	Clopyralid (Lontrel®)
Group K. Chloroacetamides	Metolachlor
Group K. Isoxazoline	Pyroxasulfone (Sakura®)

How do herbicides break down?

Herbicides break down via chemical or microbial degradation. The speed of chemical degradation depends on the soil type (clay or sand, acid or alkaline), moisture and temperature. Microbial degradation depends on a population of suitable microbes living in the soil to consume the herbicide as a food source. Both processes are enhanced by heat and moisture. However, these processes are impeded by herbicide binding to the soil, and this depends on the soil properties (pH, clay or sand, and other compounds such as organic matter or iron).

For these reasons, degradation of each herbicide needs to be considered separately and growers need to understand the soil type and climate when trying to interpret re-cropping periods on the product label for each paddock. [52]

How can I avoid damage from residual herbicides?

Select an appropriate herbicide for the weed population present. Make sure you consider what the re-cropping limitations may do to future rotation options.

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51 Agriculture Victoria (2013) Avoiding crop damage from residual herbicides. DEDJTR Victoria, http://www.depi.vic.gov.au/agriculture-and-food/farm-management/chemical-use/agricultural-chemical-use/chemical-residues/managing-chemical-residues-in-crops-and-produce/avoiding-crop-damage-from-residual-herbicides

52 Agriculture Victoria (2013) Avoiding crop damage from residual herbicides. DEDJTR Victoria, http://www.depi.vic.gov.au/agriculture-and-food/farm-management/chemical-use/agricultural-chemical-use/chemical-residues/managing-chemical-residues-in-crops-and-produce/avoiding-crop-damage-from-residual-herbicides

Users of chemicals are required by law to keep good records, including weather conditions, but particularly spray dates, rates, batch numbers, rainfall, soil type and pH (including different soil types in the paddock). In the case of unexpected damage, good records can be invaluable.

If residues could be present, choose the least susceptible crops (refer to product labels). Optimise growing conditions to reduce the risk of compounding the problem with other stresses such as herbicide spray damage, disease and nutrient deficiency. These stresses make a crop more susceptible to herbicide residues. [53]

Group B. Sulfonylureas

The sulfonylureas persist longer in alkaline soils (pH >7), where they rely on microbial degradation.

Residual life within the sulfonylurea family varies widely, with chlorsulfuron persisting for ≥2 years, depending on rate, and not suitable for highly alkaline soils. Triasulfuron persists for 1–2 years and metsulfuron (Ally®) generally persists for <1 year.

Legumes and oilseeds, particularly lentils and medic, are most vulnerable to sulfonylureas. However, barley can also be sensitive to some sulfonylureas—check the label.

Group B. Triazolopyrimidines (sulfonamides)

Debate remains about the ideal conditions for degradation of these herbicides. However, research in the alkaline soils of the Victorian Wimmera and Mallee, and the Eyre Peninsula in South Australia, has shown that the sulfonamides are less likely to persist than the sulfonylureas in alkaline soils. Plant-back periods should be increased in shallow soils.

Group B. Imidazolinones

The imidazolinones are very different from the sulfonylureas; the main driver of persistence is soil type, not soil pH. They tend to be more of a problem on acid soils, but carryover does occur on alkaline soils. Research has shown that in sandy soils, such as on the Eyre Peninsula, they can break down very rapidly (within 15 months in alkaline soils), but in heavy clay soils in Victoria they can persist for several years. Breakdown is by soil microbes. Oilseeds are most at risk. Widespread use of imidazolinone-tolerant canola and wheat in recent years has increased the incidence of imidazolinone residues.

Group C. Triazines

Usage of triazines has increased to counter Group A resistance in ryegrass, in particular in triazine-tolerant canola. Atrazine persists longer in soil than simazine. Both generally persist longer on high pH soils, and cereals are particularly susceptible to damage. Research in the US indicates that breakdown rates tend to increase when triazines are used regularly, because the number of microbes able to degrade the herbicide can increase. This may mean that breakdown can take an unexpectedly long time in soils that have not been exposed to triazines for some years.

Group D. Trifluralin

Trifluralin tends not to leach through the soil, but it can be moved into the seedbed during cultivation or ridging. Trifluralin binds strongly to stubble and organic matter and is more likely to be a problem in paddocks with stubble retention. Be particularly careful with wheat, oats and lentils. Barley is more tolerant. Use knife-points to throw soil away from seed and sow deep; not suited to disc seeders.

53 Agriculture Victoria (2013) Avoiding crop damage from residual herbicides, DEDJTR Victoria, http://www.depi.vic.gov.au/agriculture-and-food/farm-management/chemical-use/agricultural-chemical-use/chemical-residues/managing-chemical-residues-in-crops-and-produce/avoiding-crop-damage-from-residual-herbicides

Group H. Isoxazoles

Persistence in acid soils (pH <7) has not been fully tested, but research shows that isoxazole persistence is expected to be longer than the label recommendations for legume crops and pastures. Isoxazoles will also persist longer in clay soils and those with low organic matter. Cultivation is recommended prior to re-cropping.

Group I. Phenoxies

Clopyralid and aminopyralid can be more risky on heavy soils and in conservation cropping, where they can accumulate on stubble. Even at low rates they can cause crop damage up to 2 years after application. They cause twisting and cupping, particularly for crops suffering from moisture stress.

2,4-D used for fallow weed control in late summer may cause a problem with autumn-sown crops if plant-back periods are not observed. Changes have been made to the 2,4-D label recently and not all products can be used for fallow weed control—check the label.

The label recommends that you not sow sensitive crops, especially canola, until after a significant rainfall event. Oilseeds and legumes are very susceptible to injury from 2,4-D.

Group K. Metolachlor

Metolachlor is used in canola crops. The replanting interval is 6 months. [54]

Group K: Pyroxasulfone

Pyroxasulfone relies on microbial degradation, which is favoured by in-season rainfall. Label plant-back periods are important particularly for oats, durum wheat and canola. Residues will lead to crop stunting. [55]

More information

Australian Pesticides and Veterinary Medicines Authority

6.14 In-crop herbicides: knock-downs and residuals

When selecting a herbicide, it is important to know crop growth stage, weeds present and plant-back period. For best results, spray weeds while they are small and actively growing. Herbicides must be applied at the correct stage of crop growth, or significant yield losses may occur. Check product labels for up-to-date registrations and application methods.

How to get the most out of post-emergent herbicides:

- Consider application timing—the younger the weeds the better. Frequent crop monitoring is critical.
- Consider the growth stage of the crop.
- Consider the crop variety being grown and applicable herbicide tolerances.
- Know which species have been in the paddock and the resistance status of the paddock (if unsure, send plants away for a Syngenta Quick-Test).
- Do not spray a crop stressed by waterlogging, frost, high or low temperatures, drought, or, for some chemicals, cloudy or sunny days. This is especially pertinent for frosts with grass-weed chemicals.
- Use the correct spray application:
  - » Consider droplet size with grass-weed herbicides, water volumes with contact chemicals and time of day.
  - » Observe the plant-back periods and withholding periods.
  - » Consider compatibility if using a mixing partner.
  - » Add the correct adjuvant.

[54] Dual Gold® herbicide

[55] Agriculture Victoria (2013) Avoiding crop damage from residual herbicides, DEDJTR Victoria, http://www.depi.vic.gov.au/agriculture-and-food/farm-management/chemical-use/agricultural-chemical-use/chemical-residues/managing-chemical-residues-in-crops-and-produce/avoiding-crop-damage-from-residual-herbicides

For information on cereal growth stages, see GrowNotes Wheat South Section 4. Plant growth and physiology.

6.14.1 Herbicide tolerance ratings

Within many broadacre crop species, cultivars have been found to vary in sensitivity to commonly used herbicides and tank mixes, thereby resulting in potential loss of grain yield and reduced farm profit. With funding from GRDC and state government agencies across Australia, trials into cultivar x herbicide tolerance are conducted annually.

The trials aim to provide grain growers and advisers with information on cultivar sensitivity to commonly used in-crop herbicides and tank mixes for a range of crop species including wheat, barley, triticale, oats, lupins, field peas, lentils, chickpeas and faba beans. The intention is to provide data from at least 2 years of testing at the time of wide-scale commercial propagation of a new cultivar.

Fortunately, >70% of all crop varieties are tolerant to most herbicides. The remaining varieties can experience yield losses of 10–30%, and in some cases, 50% yield loss has been recorded. This occurs with the use of registered herbicides applied at label rates under good spraying conditions at the appropriate crop growth stage.

To provide growers with clear information about the herbicide interactions of a variety for their region, four regionally based, herbicide-tolerance screening projects were established. The four projects have recently been combined under a national program.

6.14.2 Post-emergent herbicide damage

Crop yield can be compromised by damage from herbicides, even when products are applied according to the label rate.

Factors that can contribute to herbicide damage are:

- crop variety grown
- weather conditions at time of application
- mixing partner
- growth stage of crop
- nutritional status of crop

6.15 Selective sprayer technology

A new permit in place across Australia will help growers to tackle herbicide-resistant grasses with weed-detecting technology.

Increased use of no-till cropping and an increasing incidence of summer rain have stimulated many growers to include a predominantly glyphosate fallow over summer to remove weeds and conserve moisture for the next crop.

To reduce the risk of glyphosate resistance developing in fallow weeds, some growers are using weed-detecting technology to detect individual weeds that have survived the glyphosate application and spraying these with an alternative knockdown herbicide.

The key to successful resistance management is killing the last few individuals, but this is difficult on large-scale properties. Left uncontrolled, these last few weeds result in significant seed production and a resetting of the weed seedbank.

The introduction of weed-detecting technology is timely, because it is well suited to detecting patches of weeds across large areas. Sales of the two systems available in Australia, WeedSeeker® and WEEDit®, have increased by at least 30% annually over the past 2 years.

The technology uses optical sensors to turn on spray nozzles only when green weeds are detected, greatly reducing total herbicide use per hectare (Figure 15). The units have their own light source so can be used day or night.

Rather than spray a blanket amount of the herbicide across a paddock, the weed-detecting technology enables the user to apply higher herbicide rates (per plant), which results in more effective weed control and saves on herbicide costs.

Figure 15: Selective sprayer technologies use optical sensors to turn on spray nozzles only when green weeds are detected. (Photo: CropOptics)

6.15.1 Special permit

Weed-detecting technology (via WeedSeeker®) is being used to manage glyphosate-resistant grasses in northern New South Wales fallows with the aid of a minor use permit. This allows growers in the region to use selective grass herbicides and higher rates of paraquat and diquat (bipyridyl herbicides, Group L). The permit (PER11163) is in force until 28 February 2019 to cover all Australian states.

The permit allows the use of about 30 different herbicides from groups with seven MOA. Additional MOAs are likely to be added to the permit over time.

Some herbicide rates have been increased to enable control of larger or stressed weeds. For example, the glyphosate 450 (450 g glyphosate/L) rates are 3–4 L/ha (using a set water rate of 100 L/ha), which exceeds the label blanket rates of 0.4–2.4 L/ha. Similar increases in rate have also been permitted for paraquat (Gramaxone®).

The WeedSeeker® permit system is a lifesaver for no-till and minimum-tillage systems battling glyphosate-resistant weeds. It represents a more economical way to carry out a double-knock and avoids the need to cultivate for weed-seed burial.

The new technology also has the potential to map troublesome weed patches so that these areas can be targeted with a pre-emergent herbicide before sowing. [56]

For more information on fallow weed control, see GrowNotes Wheat South Section 1. Planning and paddock preparation.

An area of weed management that many farmers fail to implement is the stopping of unwanted seeds and propagules (corms, tubers, etc.) coming onto, or being spread within, the property. This has led to the introduction of a new species of weed, or one with glyphosate or paraquat resistance from external or internal sources.

56 T Cook (2013) Selective spraying to cut costs. GRDC Ground Cover Supplements, 6 May 2013, http://www.grdc.com.au/Media-Centre/Ground-Cover-Supplements/GCS104/Selective-spraying-to-cut-costs

6.16 Strategies to stop the spread of weeds

Risk-aware growers can implement strategies to reduce and avoid unnecessary introduction and spread of weeds.

Weed importation and spread can be impeded at several critical points, namely:

- sowing of the seed
- fencelines and non-cropped areas in cropping paddocks (e.g. water courses)
- machinery and vehicle usage
- stock feed and livestock movement
- in fields following floods and inundation

More information

IWM section 4: Tactics

A well-managed, on-farm hygiene strategy will address each of these elements.

6.16.1 Sow weed-free seed

Weed seed is regularly spread around and between farms as a contaminant of sowing seed. Seed for sowing is commonly grower-saved and usually contaminated with weed seeds, frequently at very high levels. Various 'seed-box' surveys have shown that less than a quarter of farmers surveyed sow weed-free seed. On average, ungraded seed had 25 times more foreign seeds than graded seed.

To avoid these problems follow the following guidelines:

- Know the weed status of any farm from which you buy seed.
- Plan seed purchases ahead of time and inspect the paddock where the seed is being grown.
- Obtain a sample of the seed and have it analysed for weed seed contamination and germination.
- Determine the herbicide-resistance status of weeds present on the source farm and paddock, and avoid purchasing seed from paddocks with known resistance.
- Grade seed to reduce weed numbers. [57]

More information

IWM section 4: Tactics

6.16.2 Manage weeds in non-crop areas

Weed infestations often commence in non-crop areas (e.g. around buildings, along roadsides, along fencelines, around trees) (Figure 16). Controlling these initial populations will prevent weeds from spreading to other parts of the property. These areas have become primary sources of glyphosate-resistant weeds, which then spread into paddocks. This is particularly important for weeds with wind-blown seed such as fleabane and sowthistle.

Weeds along fencelines, paddock edges and non-crop areas of crop paddocks can be controlled by a combination of knockdown herbicides, hay or silage cutting, and/or cultivation. Unlike other activities, timing for fenceline weed control is reasonably flexible with a wide window of opportunity, although control should be carried out before seed is viable. [58]

Video

Herbicide resistance

57 GRDC (2014) Section 7. Managing farm hygiene. Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub/Section-7-Managing-farm-hygiene

58 GRDC (2014) Section 7. Managing farm hygiene. Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub/Section-7-Managing-farm-hygiene

Figure 16: Flaxleaf fleabane along this fence will easily spread into neighbouring fields. (Photo: A. Storrie)

More information

IWM section 4: Tactics

6.16.3 Clean farm machinery and vehicles

Machinery and vehicles are major sources for the introduction of new weeds. Earth-moving equipment, harvesters, balers and slashers are particular problems.

Ensure that machinery and vehicles have been cleaned prior to entry on the farm, or cleaned at a specially designed wash station. Within the farm, harvest from cleanest to dirtiest paddock to minimise the spread of weed seeds. Where breakdowns require in field repair, mark the position with a GPS and diary to check for weed germinations. [59]

More information

IWM section 4: Tactics

6.16.4 Livestock feeding and movement

Weeds can be introduced in stock feed and in livestock over long distances, particularly during droughts. Ensure that you know the source of fodder. New stock or stock returning from agistment need to be kept in a holding paddock for 7 days to enable the bulk of seed in their intestines to be excreted. [60]

More information

IWM section 4: Tactics

6.16.5 Monitor paddocks following flood inundation

Floods and inundation of fields are a common source of new weed infestations through the transport of seeds and vegetative propagules such as stolons, rhizomes and tubers (Figure 17).

Effective monitoring to identify new weed incursions and patches is needed. Hand-roguing a few plants every year can help when weed numbers are very low, even on very large properties. [61]

59 GRDC (2014) Section 7. Managing farm hygiene. Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub/Section-7-Managing-farm-hygiene

60 GRDC (2014) Section 7. Managing farm hygiene. Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub/Section-7-Managing-farm-hygiene

61 GRDC (2014) Section 7. Managing farm hygiene. Integrated weed management manual. Integrated Weed Management Hub, GRDC, http://www.grdc.com.au/Resources/IWMhub/Section-7-Managing-farm-hygiene

More information

[IWM section 4: Tactics]

[AWC: Risk of weed movement through vehicles, plant and equipment: results from a Victorian study]

[CottonInfo: Come Clean Go Clean]

[Farm biosecurity: Grains]

[AWC: Seed box survey of field crops in Victoria during 1996 and 1997]

[AWC: Weed seed contamination in cereal and pulse crops]

GRDC Videos

[GRDC webinar on managing weeds on fencelines]

[Weed seed bank destruction—farm hygiene and weed management]

Figure 17: This creek line is infested with glyphosate-resistant annual ryegrass and a range of other weeds. During the next flood, these seeds will spread across previously clean paddocks. (Photo: A. Storrie)