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LENTIL

SECTION 8

WEED CONTROL

Weed control

Key points

- **Weeds cost Australian grain growers $3.3 billion a year.**
- **An integrated weed management system includes both herbicide and non-herbicide options.**
- **Lentil is weaker than lupin in terms of its poor ability to compete with weeds in the paddock**
- **In the absence of herbicide resistance, grass weeds are easier to control in broadleaf crops. Broadleaf weeds are easier to control in cereal crops.**
- **Large advanced weeds, not controlled prior to or during seeding, are the most difficult, and often impossible, to control with in-crop herbicides.**
- **The broadleaf weed risk always needs to be assessed prior to seeding lentil.**
- **Crops with weed burdens should be harvested first and the chaff removed.**
- **Conventional lentil varieties are sensitive to sulfonylurea residues and the imidazolinones.**
- **Seek advice before spraying recently released lentil varieties as they may differ in their tolerance to herbicides.**
- **PBA Herald XT⊕ and PBA Hurricane XT⊕ have tolerance to imidazolinone residues. They are not Clearfield® varieties.**
- **Lentil has limited tolerance to post-emergent broadleaf herbicides. The risk of herbicide damage needs to be weighed against potential yield loss from weed competition.**
- **Herbicide resistance has developed because of repeated and often uninterrupted use of herbicides with the same mode of action.**
- **Herbicide labels must be followed carefully for information on both crop and weed growth stages, and the best conditions for spraying.**

MORE INFOR[MATION] FEEDBACK

Go to Section 8.17 Appendix 1 – Common weed names for a list of all common weeds

Integrated Weed Management Manual, Section 6, 'Profile of Common weeds of cropping', www.grdc.com.au/IWMM

8.1 Introduction

The problem with weeds

Weeds affect the yield and management of broadacre crops across all seasons and can sometimes affect the price received for grain.[1]

Weeds may:

- lower crop yields by competing for soil moisture, nutrients, space and light;
- carry diseases and viruses that can infect crops;
- impede harvest;
- contaminate grain; and
- restrict cropping options due to limited herbicide options in pulse crops.[2]

Weed management aims to reduce the overall number of weeds competing with the crop and, in some cases, target particular 'hard to manage' weeds such as herbicide-resistant ryegrass. Crop rotations should consider crops that provide opportunities for weed control required in each paddock. Crop rotation should also allow for rotation of herbicide groups to minimise the build-up of herbicide resistance.

Planting a pulse crop as a break crop between cereals provides an ideal opportunity to target and control grass weeds.

Identifying weeds

The Grains Research and Development Corporation (GRDC) has developed an application (App) to assist in the identification of the most common weeds found in paddocks throughout Australia.

The app is called 'Weed ID: The Ute Guide' (https://grdc.com.au/resources-and-publications/app). Where possible, photos are shown for each stage of the weed's lifecycle, from seed and seedling through to mature and flowering plants.

Weeds are categorised by plant type, and results for each can be refined by state and lifecycle, and whether they are native, currently flowering, or have a distinctive smell.

The app allows users to search, identify, and compare photos of weeds in their own paddock to weeds in the App.

Photo 1: *Weed ID: The Ute Guide.*

1 W Hawthorne (2015) Residual Herbicides and Weed Control. Pulse Australia, http://www.pulseaus.com.au/growing-pulses/publications/residual-herbicides

2 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

Impact and cost of weeds

Weeds cost Australian grain growers $3.3 billion dollars a year. That is $2.6 billion in control costs and another $745 million in reduced yield. The cost to southern growers ranges from $105 per hectare (ha) in the low rainfall zones, up to $184/ha in the medium to high rainfall zones. These costs are rising each year.

Reducing the cost of weed management is one of the grains industry's largest challenges as good weed control is vital for successful and profitable crop production.

Weed management is a challenge because weeds are constantly evolving, with changes in weed types and their characteristics, such as herbicide resistance. The use of a variety of management techniques to overcome weed problems is increasing. This includes crop-topping, double-knockdowns (two spray applications using different herbicide groups to kill all weeds) and burning of narrow crop residue swaths.

Grasses are the most costly weeds in the southern region (Table 1). Brome grass has increased in importance since the previous rankings were determined in the year 2000.[3]

Table 1: Problem weeds in the western region.

Rank	Weed	Area (ha)	Weed	Yield loss (t)	Weed	Revenue loss
1	Ryegrass	4,273,599	Ryegrass	174,615	Ryegrass	$50.3m
2	Wild radish	4,272,973	Wild radish	144,304	Wild radish	$40.1m
3	Brome grass	292,090	Wild oats	6345	Wild oats	$1.9m
4	Wild turnip	147,168	Brome grass	4709	Brome grass	$1.4m
5	Wild oats	131,231	Doublegee	2574	Doublegee	$753.9k
6	Barley grass	85,807	Barley grass	2272	Barley grass	$610.2k
7	Fleabane	62,208	Cape weed	1744	Cape weed	$483.2k
8	Cape weed	61,150	Toadrush	541	Toadrush	$139.1k
9	Doublegee	59,532	Marshmallow	266	Marshmallow	$130.2k
10	Wireweed	43,861	Thistle species	147	Thistle species	$79.5k
11	Toadrush	27,433	Fleabane	117	Fleabane	$31.9k
12	Marshmallow	19,799	Wild turnip	53	Wild turnip	$13.8k
13	Wild mustard	12,624	-	-	-	-
14	Khaki weed	3217	-	-	-	-
15	Thistle species	2569	-	-	-	-
16	Silver grass	2120	-	-	-	-

Source: https://grdc.com.au/__data/assets/pdf_file/0027/75843/grdc_weeds_review_r8.pdf.pdf

3 R Llewellyn, D Ronning, M Clarke, A Mayfield, S Walker and J Ouzman (2016) Impact of weeds on Australian grain production - The cost of weeds to Australian grain growers and the adoption of weed management and tillage practices. Grains Research and Development Corporation, https://grdc.com.au/ImpactOfWeeds

MORE INFORMATION

There are several subscription services available to growers that provide local weed updates

Agriculture Victoria
General grains information is available on Twitter @VicGovGrains

Australia wide
The GRDC has a GrowNotes Alert for the latest weed, pest and disease issues in the users area. The GrowNotes Alert is delivered via App, SMS, voice, email, social media or web portal (or a combination of preferred methods). Subscription to the GrowNotes Alert is on the GRDC website. http://www.grdc.com.au

An **Australian Herbicide Resistance Initiative** video on narrow row spacing and weeds is available at: https://youtu.be/qM-Pl4vMliw

8.2 Integrated weed management (IWM)

An integrated weed management (IWM) system combining all available methods is the key to successful control of weeds. IWM includes both herbicide and non-herbicide options (Table 2).

Table 2: Weed control options for integrated weed management.

	Herbicide	Non-herbicide
Crop phase	• Use knockdown herbicides before sowing; • Use selective herbicides before and/or after sowing to ensure weeds do not set seed; • Avoid high-resistance risk herbicides; • Crop-topping; • Delay sowing to get maximum weed control before sowing; and • Brown manure crops.	• Rotate crops; • Rotate varieties; • Grow a dense and competitive crop; • Use cultivation; • Green manure crops; • Cut crops for hay/silage; • Burn stubbles/windrows; • Delay sowing; • Collect weed seeds at harvest and remove/burn; and • Destroy weed seeds harvested (Harrington Seed Destructor).
Pasture phase	• Spray topping; • Winter cleaning; and • Use selective herbicides and ensure escapee weeds do not set seed.	• Good pasture competition; • Cut for hay / silage; • Cultivated fallow; and • Grazing.

Strategy – paddock choice and crop rotation

A well-managed rotation in each paddock, which alternates broadleaf crops with cereal crops, and may also include pastures, is a very useful technique for controlling weeds. For example, **grass weeds are more easily and cheaply controlled chemically in broadleaf crops, whereas broadleaf weeds are much easier to control in cereal crops.** Good crop rotation management can substantially reduce the cost of controlling weeds with chemicals.

Pulses grown in rotation with cereal crops offer opportunities to easily control grass weeds with selective herbicides that cannot be used when the paddock is sown to cereal. An effective kill of grass weeds in pulse crops reduces root disease carryover and provides a 'break crop' benefit in following cereal crops. Grass-selective herbicides can control most grass weeds in pulses, along with volunteer cereals.

Metribuzin alone, and in mixtures with trifluralin in lentil, can be used to control some other grasses that are not readily controlled by selective grass herbicides.[4]

Good agronomic practice

Some crops and varieties are more competitive against weeds than others. Of the pulses, lentil is weaker than to lupin in terms of its poor ability to compete with weeds in the paddock (chickpea is only marginally improved). Faba bean and field pea are rated as having a medium competitive ability.[5]

4 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

5 Grains Research and Development Corporation (2014) Integrated Weed Management Hub. Grains Research and Development Corporation, https://grdc.com.au/weedlinks

MORE INFORMATION

GRDC Integrated weed management manual
https://grdc.com.au/resources-and-publications/all-publications/publications/2014/07/iwmm

GRDC booklet on summer fallow weed management
http://www.grdc.com.au/GRDC-Manual-SummerFallowWeedManagement

VIDEO

AHRI video: Narrow row spacing more crop, fewer weeds
https://youtu.be/qM-Pl4vMliw

Good agronomic practice results in a more competitive crop. Using weed-free seed (preferably registered or certified), seeding on time, optimal plant populations, and adequate nutrition, all contribute to good weed control.

All weeds growing in a paddock should be controlled before the crop emerges. **Large, advanced weeds, not controlled prior to or during seeding, are the most difficult, and often impossible, to control with in-crop herbicides.**[6]

Pre-plant weed control

Tillage is a valuable method for killing weeds and preparing seedbeds. There are varying combinations of mechanical and chemical weed control to manage fallows or stubbles.

Knockdown herbicides are generally used instead of cultivation for fallow commencement, as well as for pre-seeding weed control in autumn. Knockdown herbicides benefit soil structure and provide more timely and effective weed control. However, the risk of herbicide resistance must be understood and managed.[7]

Cultivation can spread grass weed seeds such as ryegrass, wild oat and brome grass, through the soil profile and prolong their seedbank dormancy. For these weeds a light cultivation (1–3 cm deep) in autumn can encourage germination and assist in depleting the seedbank. This can be combined with delayed seeding; however, yield penalties may apply.[8]

In-crop weed control

A wide range of pre-emergent and early post-emergent herbicides are available for grass weed control in lentil. With broadleaf weeds, post-emergent options are very limited.

Weeds should be removed from crops early, and certainly no later than 6 weeks after seeding to minimise yield losses. Yield responses depend on weed species, weed and crop density, and seasonal conditions.

The growth stage of the weed and the crop are vital factors to consider to successfully use post-emergent herbicides. The growth stages of lentil are detailed in Section 6 Plant and growth physiology.

Herbicide labels must be followed carefully for information on both crop and weed growth stages, and the best conditions for spraying.

The risk of crop damage from herbicide application should be balanced against the potential yield loss from weed competition. In heavy weed infestations, some crop damage can be tolerated, as it is easily offset by the yield loss avoided by reducing weed competition.

Managing weeds at harvest

Managing weeds at harvest is an effective way to reduce carryover of problem weeds, particularly those with herbicide resistance.

Most West Australian cropping weeds have seed that does not shatter before harvest. This major biological weakness provides the potential to remove the weed seed from the paddock at harvest.[9]

Research by the Australian Herbicide Resistance Initiative (AHRI) in 2014 found that ryegrass, wild radish, brome grass and wild oats all retained at least 75% of weed seeds at the first opportunity to harvest wheat. As lentil can be harvested before wheat this presents an excellent opportunity to reduce the weed seed carryover.

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6 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

7 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

8 Grains Research and Development Corporation (2012) Cropping with Herbicide resistance. Grains Research and Development Corporation, https://grdc.com.au/Resources/Factsheets/2012/05/Herbicide-Resistance

9 Grains Research and Development Corporation (2013) Ground Cover Supplement Issue 104 - Herbicide Resistance Supplement. Grains Research and Development Corporation, https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/GCS104

These same weeds will shed 0.8–1.5% of their seeds each day that harvest is delayed. To improve control of problem weeds, **crops with weed burdens should be harvested first and the chaff removed.**[10]

Options for removing weed seeds in chaff include:

- remove the weed-laden chaff via baling;
- tow a chaff cart and burn the heaps;
- concentrate the chaff into narrow swaths for burning;
- pulverise the chaff to crush and destroy the weed seeds (with the Harrington Seed Destructor) before they exit the harvester; and
- in controlled-traffic farming, chaff can be funnelled and confined onto tramlines. This contains the weeds in a hostile environment separate from the crop.

Reducing the seedbank

A weakness of weeds in southern Australian is that, for many, their seed does not remain viable in the soil for very long, and seedbanks decline rapidly if not replenished each year.

Control methods for weed seed at harvest can lower a very large seedbank of more than 1000 seeds/m^2 to 100 seeds/m^2 in only 4 years (e.g. annual ryegrass).[11] The level of reductions varies between weed species.

In paddocks with low ryegrass burdens, harvest weed seed methods reduced ryegrass emergence by as much as 90%. Paddocks with high ryegrass burdens (>2,000 seeds/m^2) were less responsive, with 30–40% reduction in ryegrass emergence. This means that harvest weed seed management takes longer to lower ryegrass populations in highly infested paddocks where the residual seedbank is still being exhausted.

Trials in South Australia and New South Wales show that narrow swath burning and the use of a chaff cart are as effective at removing ryegrass seed as the Harrington Seed Destructor and at a similar cost.[12]

Alternatives to harvesting the crop

Operations such as cutting hay or silage, or green or brown manuring provide an opportunity for improved weed control when compared with harvesting crops for grain. These techniques are particularly valuable where herbicide-weeds are a problem. When timed well they can prevent almost all seedset.[13]

Additional benefits of manuring include boosting soil nitrogen and conserving soil moisture to benefit yield in subsequent years.[14]

Green manuring uses cultivation and brown manuring uses chemical control to stop the growth of both crop and weed.

While green and brown manuring cost money without providing an income, the benefits for subsequent years can make it worthwhile. Manuring is usually suited to longer-seasoned forage crops, crop-topping for earlier-maturing grain crops. If income is important, crop-topping and grain harvest may be a more economically viable option even though yield may be reduced by topping.[15]

MORE INFORMATION

For more information go to:

GRDC webpage: Managing weeds at harvest https://grdc.com.au/resources-and-publications/iwmhub/section-7-managing-weeds-at-harvest

Weedsmart webpage: Capturing weed seeds at harvest http://www.weedsmart.org.au/10-point-plan/capture-weed-seeds-at-harvest/

AHRI Webpage: Rules of thumb for weed seeds http://ahri.uwa.edu.au/rules-of-thumb/

VIDEO

GRDC Video: Harvest the time to get on top of resistant weeds https://youtu.be/uURyKaaq-_I

VIDEO

GRDC Video: Harvest Weed Seed Control for the high rainfall zone https://youtu.be/RrvQQYqSmdE

10 Australian Herbicide Resistance Initiative (2014) Rules of thumb. Australian Herbicide Resistance Initiative, http://ahri.uwa.edu.au/rules-of-thumb/

11 Grains Research and Development Corporation (2016) Weed ID: The Ute Guide. Grains Research and Development Corporation, https://grdc.com.au/resources-and-publications/app

12 Grains Research and Development Corporation (2014) Integrated Weed Management Hub. Grains Research and Development Corporation, https://grdc.com.au/weedlinks

13 A Glover, I Trevethan, L Watson, M Peoples, T Swan (2013) Break crops in cropping systems: impacts on income, nitrogen and weeds 2012. Riverine Plains, pp. 38-41, http://www.farmtrials.com.au/trial/16519

14 Grains Research and Development Corporation (2013) Manuring of Pulse Crops. Grains Research and Development Corporation, https://grdc.com.au/Resources/Factsheets/2013/09/Manuring-of-Pulse-Crops

15 E Armstrong (2015) Weigh up the risks, benefits of pulse harvest. Ground Cover Supplement, Issue 155: Profitable pulses and pastures, GRDC, https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-115-Profitable-pulses-and-pastures/Weigh-up-the-risks-benefits-of-pulse-harvest

8.3 Managing weeds in lentil

Weed control strategy

The weed control strategy for growing a successful lentil crop depends on substantially reducing the viable weed seedbank in the soil before the crop emerges as post-emergence weed control options are limited.

Selecting paddocks that are relatively free, or carry a low burden of grass and broadleaf weeds, is very important.

Broadleaf weeds need to be heavily targeted in the preceding crop and/or fallow. **The broadleaf weed risk always needs to be assessed prior to seeding lentil**. This should be based on:

- grower's experience;
- the previous crop and weeds and herbicides used; and
- an assessment of winter weeds germinating in the paddock prior to planting.

Paddocks with a severe broadleaf or grass weed problem that cannot be controlled in-crop should be avoided.

Lentil can be relatively slow to emerge, but has rapid early growth, even during the colder winter months. As a consequence, they are poor competitors with early weeds. Even moderate weed infestations can cause large yield losses and harvest problems.

Lentil can mature too late in some extended seasons for weed seedset control, so crop-topping may either have to be delayed or conducted before physiological maturity, risking yield and quality losses.

The risk with or inability to crop-top to prevent weed seedset is one of the main reasons growers give for not growing lentil in southern Australia. Broadleaf weed control options post-emergent are available, but can be damaging or limited in the weed spectrum they control in lentil. Although a common reason for not growing conventional lentil, new herbicide-tolerant (Group B) varieties (PBA Hurricane XT⦶ and PBA Herald XT⦶) are offering more and safer options.

In general, options for broadleaf weed control with selective herbicides in lentil are limited, compared to the treatments available for use in other pulse crops and cereal crops.

Decision-tools

Managing weeds is complicated and requires a long-term strategy. Decision-support models can be useful to assist with planning weed management strategy.

The Weed Seed Wizard (https://www.agric.wa.gov.au/weed-seed-wizard-0) is a computer simulation tool to help growers understand and manage weed seedbanks for a range of different weeds and is relevant to all Australian grain-growing areas. It uses farm management records to simulate how different crop rotations, weed control techniques, irrigation, grazing and harvest management tactics can affect weed numbers, the weed seedbank and yields.

Ryegrass Integrated Management (RIM) (http://ahri.uwa.edu.au/research/rim/) is a decision-support tool to evaluate the long-term profitability of strategic and tactical ryegrass control methods. It allows growers to test their ideas to reduce ryegrass populations while improving profitability.

Specific issues

Special attention is required for the following weed issues in lentil:

- Crop-topping cannot always be conducted at the optimum stage for preventing ryegrass seedset and be safe for the lentil plant.
- Late germination of weeds (ryegrass and brome grass) can safely be prevented from setting seed by crop-topping in earlier maturing pulses.
- Early maturing varieties (PBA Bolt⊕, PBA Blitz⊕ and PBA Flash⊕) are safer to crop-top than later maturing varieties (Nugget). This is because crop-topping may not be timely or fully effective in the later maturing lentil varieties without affecting yield and quality or efficacy of preventing seedset of ryegrass.
- Lentil can initially be a poor competitor with weeds across southern Australia because of slow germination, small plant structure and an extended period before the ground is covered at canopy closure.
- Lentil is often sown early or into dry soil, which limits the opportunity for 'knock down' weed control before seeding and increases the reliance on herbicides and low weed numbers for in-crop weed control.

Problem weeds in lentil, that require special attention or are difficult to fully control include:

- annual ryegrass that is resistant to Group A products ('dims' and 'fops'), particularly where high rates of clethodim are required;
- annual ryegrass that is resistant to trifluralin;
- snail medic and other medics;
- wild radish. There are no fully safe treatments available post-emergent in conventional lentil varieties, and germinations occur over an extended period; and
- hoary cress, soursob and tares.

Positives for weed control when growing lentil include:

- Availability of herbicide-tolerant (XT) varieties like PBA Hurricane XT⊕ and PBA Herald XT⊕. These XT varieties have increased herbicide options for broadleaf weeds and improved crop safety to Group B herbicides applied in-crop or as residues (herbicides with APVMA registration or permits are the only ones able to be applied in-crop);
- Delayed seeding is possible in higher rainfall areas, or with early maturing varieties. This enhances the opportunity for knockdown weed control before seeding;
- Lentil can be grown in wider rows in a stubble system that might allow inter-row herbicide application with shielded sprayers; and
- If seeding into dry soil, there can be a delay of 14–21 days before lentil emerges after germinating rains, depending on soil temperatures and depth of seeding. In the right circumstances, this might allow a non-selective knockdown herbicide application to kill emerged weeds prior to lentil emergence.[16]

Weed competition in lentils

Preventing increases in resistant ryegrass numbers during the lentil phase of rotations is essential for maximum crop yield and sustainable cropping systems in southern Australia. Preventing weed seedset is the aim of most lentil growers. Lentil is a poor early competitor against ryegrass and other weeds, but has a relatively low plant population. Hence, low numbers of weeds can grow without necessarily inhibiting early development of lentil. If weeds are present, they can affect yield and become a problem by setting seed later in the season, often necessitating desiccation to enable harvest.

16 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

Yield loss in lentil due to weed presence occurs, but has not often been documented in research trials. Medic can be very damaging to lentil yields. Good control of medic can also lead to damaged lentil.[17]

Impact of weed seedset and carryover to subsequent years may be more significant than yield loss per se, especially where weeds like ryegrass or late broadleaf weeds are present and not controlled. As well, weed seeds can affect grain quality and influence quality grades obtainable at delivery. This is particularly a problem with wild vetch seed contamination, which can be very hard to clean out of some varieties.

Photo 2: *Broadleaf weed contaminants in lentil.*

(Photo: M. Raynes, formerly Pulse Australia)

Photo 3: *Grass weeds in lentil.*

(Photo: W. Hawthorne, formerly Pulse Australia))

17 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

MORE INFORMATION

For more information on XT lentil read the GRDC GroundCover™ article:

Effective weed management is critical for successful pulse production and system sustainability. https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-115-Profitable-pulses-and-pastures/Weed-control-benefits-whole-system

VIDEO

GRDC Video: Pulse herbicide tolerance https://youtu.be/j7JEfzclUfg

'IMI'-tolerant lentil varieties

Due to lentil's poor competitive nature, breeding in Australia has focused on developing variety types more tolerant to herbicides.

The first two varieties with specific herbicide tolerances have been released: PBA Herald XT⍭ in 2012 and PBA Hurricane XT⍭ in 2014.

Photo 4: *'IMI' damage to a conventional lentil variety (left) compared to an 'IMI'-tolerant (XT) variety (PBA Herald XT⍭ (right).*

(Photo: W. Hawthorne, formerly Pulse Australia))

These varieties have tolerance to imazethapyr. The minor use permit (14369) for imazethapyr use is for these XT lentil type varieties only. These XT varieties allow a lentil crop to be grown without the risk of yield loss from herbicide damage. Weed control now be achieved on weeds that may, otherwise, have been difficult to control.

Even with improved tolerances, product registrations, product label rates, plant-back periods and directions for use in lentil must still be adhered to in XT varieties.

There are no registrations for use of other 'IMI' or sulfonylurea products in XT lentil.

The use of imazethapyr increases options for managing particularly difficult to control weeds, such as bifora and bedstraw. Bifora and bedstraw are both "Declared Weeds" in South Australia and are significant weed threats to that state's primary production industries. Bifora is spreading to Victoria's lentil areas and is becoming a bigger issue. Bedstraw is a problem weed for Victorian growers.

Imazethapyr also provides better and safer options (pre-emergent and post-emergent) in XT lentil varieties, including management of two other important broad-leaf weeds, Indian hedge mustard and wireweed.

In addition, the weed spectrum controlled with pre-emergent application of imazethapyr covers a broad range of the important broadleaf weeds (bifora, bedstraw, capeweed, deadnettle, Indian hedge mustard, turnip weed, wild radish and wireweed). Prickly lettuce is developing resistance to Group B herbicides and IMIs are regarded as 'weak' in controlling this weed. Also, IMIs are not very effective in controlling capeweed. IMIs are effective in controlling brassica weeds.

Another difficult to control Declared Weed in South Australia and the Wimmera region of Victoria is muskweed (*Myagrum perfoliatum*). Limited trials have shown imazethapyr has strong activity on this weed, showing promise for further work in this area.[18]

Difficult weeds in Western Australia include fleabane which is widespread across the southern districts, particularly in Esperance, and herbicide-resistant ryegrass and radish.

18 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

How XT varieties were developed

XT lentils were developed via mutation using ethyl methane sulfonate (EMS), similar to how the current Clearfield® wheat, canola, barley and other varieties were developed and which are now commercialised internationally. The varieties are not genetically modified.[19]

PBA Herald XT⛗ and PBA Hurricane XT⛗ are NOT Clearfield® varieties.

As there is limited information available on levels of tolerance of lentil to imidazolinones, comparisons are made with field pea. The levels of tolerance of PBA Herald XT⛗ to the range of imidazolinones indicates that PBA Herald XT⛗ has much better tolerance to imidazolinone herbicides than current field pea varieties. Crop damage is less likely using the allowable rates of imazethapyr, which are those currently recommended for field pea.

Avoiding over-use of 'IMI' chemistry

In Canada, within 4 years of IMI-tolerant (Clearfield®) lentil being available, herbicide resistance to its chemistry became a major issue.[20]

Although the release of 'imi' tolerant (XT) lentil varieties in Australia is being heralded as a major breakthrough in controlling problem weeds, it must be managed carefully to ensure the initial advantage is not lost through overuse of IMI chemistry in the rotation.

Australia already has IMI-tolerant varieties of canola, wheat and barley. All have tolerance to IMI residues from the previous crop. Other pulses like field pea and faba bean have IMI products registered for use.

Using an IMI product in each of these crops in a sequence would quickly lead to resistance developing in targeted weeds. To avoid resistance developing, at least one or more of these IMI-tolerant crops must be grown in the rotation without the IMI being used on it.

For example, an XT lentil can be grown because of its tolerance to IMI residues rather than use an 'imi' product on the actual crop. Alternatively, an IMI-tolerant cereal may be grown and a non-IMI product used so that the 'imi' product can be used on the XT lentil.

Current herbicide products for conventional and XT lentil varieties

Not all herbicide products registered and commonly used in other pulses are registered for use in lentil. Examples of products not registered for use in lentil include simazine and triallate.

Herbicide options for conventional lentil varieties include:

- pre-seeding (metribuzin, cyanazine, terbuthylazine, trifluralin);
- post-seeding pre-emergent (diuron, metribuzin, trifluralin); and
- post-emergent (diflufenican, flumetsulam).

Under adverse conditions, most post-seeding pre-emergent herbicides are capable of causing damage to lentil. Adverse conditions include:

- varying soil types;
- unevenness in a paddock; and
- instances of heavy rainfall after seeding resulting in herbicide being washed into furrows.

These scenarios can all pose difficulties in determining the balance between applying herbicide rates for adequate weed control while minimising crop damage.

Registered products available for post-emergent applications can cause crop damage and yield reduction in some circumstances in currently grown conventional

19 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

20 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

FEEDBACK

MORE INFORMATION

See Variety Management Packages (VMP's) at: http://www.pulseaus.com.au/growing-pulses/crop-protection-products

http://www.nvtonline.com.au/herbicide-tolerance/

VIDEO

For more information on the development of herbicide tolerance in lentil click on the link to go to GRDC GroundCover™ TV Episode 16: Pulse Herbicide Tolerance. https://youtu.be/j7JEfzclUfg

lentil varieties. Some varieties are more sensitive than others (Table 5). This information is advised on the herbicide labels.

Research trials conducted by the South Australian Research and Development Institute (SARDI) on alkaline soils over 7 years (1994–2010) have shown yield losses of up to 25% in trials using flumetsulam and up to 24% yield loss in trials using diflufenican. Of the five post-emergent products registered for lentil these two herbicides have caused the most instances of crop damage and yield loss.[21]

Delayed seeding is an option to enable several weed kills before seeding. However, this can limit crop yield potential in lower rainfall areas, and in seasons when drier springs occur. Lentil crops, being very short, require more care and specialised harvesting equipment to harvest efficiently, and delayed seeding can result in very short crops, which are more difficult to harvest.

Controlling many broadleaf weeds in lentil crops can be difficult to achieve. These broadleaf weeds include: bedstraw, bifora, clovers, medics, tares, vetches, wild radish and self-sown pulses.

Photo 5: *Herbicide screening at Mingenew 2015 showing imazethapyr tolerance of XT germplasm. All conventional germplasm was unharvestable.*

(Photo: DPIRD and PBA)

21 Grains Research and Development Corporation (2016) National Variety Trials: Herbicide Tolerance. Grains Research and Development Corporation, http://www.nvtonline.com.au/herbicide-tolerance/

Table 5: Lentil herbicide tolerance (NVT South Australia).

Herbicide		Broadstrike®	Brodal Options®	Boxer Gold®	Diuron	Dual Gold®*	Lexone®	Lexone®*	Simazine*	Simazine*	Simazine + Diuron500*	Status®*	Terbyne®*	Terbyne®
		Flumetsulam	Diflufenican	Prosulfocarb + S-metolochlor	Diuron	S-metolochlor	Metribuzin	Metribuzin	Simazine	Simazine	Simazine + Diuron	Clethodim	Terbuthylazine	Terbuthylazine
Variety	**Years tested**	**1994–2015**	**1994–2015**	**2015**	**1996–2015**	**1997–2000**	**1994–2015**	**2005–2008**	**2004–2015**	**2001–2004**	**1992–2002**	**2014**	**2009–2013**	**2014–2015**
PBA Ace(d)	2012–2014	N (1/3)	✓(3)	-	✓(3)	-	30 -35 (2/3)	-	21 -35 (2/3)	-	-	✓(1)	N (2/2)	10 (1/1)
PBA Blitz(d)	2010–2012	10-13 (2/3)	✓(3)	-	N (1/3)	-	10 (1/3)	-	N (3/3)	-	-	-	N (3/3)	-
PBA Bolt(d)	2013–2015	14 (1/3)	✓(3)	✓(1)	✓(3)	-	12 (1/3)	-	28 (1/3)	-	-	✓(1)	29 (1/1)	✓(2)
Boomer	2005–2009	7-19 (2/5)	7-11 (2/4)	-	✓(5)	-	19 (1/5)	34 (1/4)	✓(5)	-	-	-	N (1/1)	-
PBA Bounty(d)	2009–2011	12 (2/3)	9 (1/3)	-	N (1/3)	-	N (2/3)	-	9 (1/3)	-	-	-	11 (1/3)	-
Cassab	1999–2001	N (1/3)	7 (1/3)	-	N (2/3)	8 (1/2)	N (2/3)	-	-	✓(1)	N (1/3)	-	-	-
Cobber	1994–2002	10 (1/4)	22 (1/4)	-	N (1/2)	✓(1)	12 (1/4)	-	-	-	-	-	-	-
Digger	1994–2001	8-18 (2/7)	15-23 (2/7)	-	N (3/5)	N (2/3)	32 (1/7)	-	-	✓(1)	6 (1/3)	-	-	-
PBA Flash(d)	2006–2013	10-14 (3/8)	N (3/8)	-	N (1/8)	-	N (5/8)	42 (1/3)	42 (1/8)	-	-	-	26 (1/5)	-
PBA Greenfield(d)	2014–2015	N (1/2)	N (1/2)	✓(2)	✓(2)	-	✓(2)	-	✓(2)	-	-	-	-	✓(2)
PBA Giant(d)	2014–2015	✓(2)	✓(2)	✓(2)	✓(2)	-	✓(2)	-	✓(2)	-	-	-	-	✓(2)
PBA Herald XT(d)	2012–2014	✓(3)	✓(3)	-	✓(3)	-	13 - 21 (3/3)	-	13-39 (3/3)	-	-	✓(1)	N (2/2)	✓(1)
PBA Hurricane XT(d)	2013–2015	✓(3)	✓(3)	✓(1)	✓(3)	-	N (1/3)	-	10-33 (2/3)	-	-	✓(1)	N (1/3)	✓(2)
PBA Jumbo2(d)	2014–2015	✓(2)	N (1/2)	13 (1/1)	✓(2)	-	30 (1/2)	-	8-25 (1/2)	-	-	✓(1)	-	N (1/2)
PBA Jumbo(d)	2011–2012	12 (1/2)	✓(2)	-	✓(2)	-	N (2/2)	-	N (2/2)	-	-	-	N (1/2)	-
Nipper(d)	2004–2015	8-20 (5/12)	7 (1/12)	✓(1)	N (3/12)	-	10-25 (7/12)	26-52 (3/4)	13-64 (4/12)	N (1/2)	✓(1)	✓(1)	21-40 (2/5)	✓(2)
Northfield	1994–2004	10-25 (3/9)	16-24 (3/9)	-	14 (1/7)	21 (1/2)	17-19 (2/9)	14 (1/1)	✓(1)	N (2/3)	12 (1/4)	-	-	-
Nugget	1999–2005	6-20 (3/6)	11 (1/6)	-	N (1/6)	N (1/2)	6 (1/6)	✓(2)	✓(2)	7 (1/3)	15 (1/4)	-	-	-
Rates (product/ha)		20 g	150 mL	2.5 L	1 kg	500 mL	280 g	180 g	1 kg	1.2 L	500 mL + 500 mL	1 L	1 kg	1 kg
Crop stage at spraying		6 weeks	6 weeks	IBS	PSPE	PSPE	PSPE	3 node	PSPE	6 weeks	PSPE	3 node	PSPE	IBS

– Not tested or insufficient data ✓(z) No significant yield reductions at recommended rates or higher than recommended rates in (z) trials
N (w/z) narrow margin, significant yield reductions at higher than recommended rate, but not at recommended rate, significant event ocurring w years out of z years tested. e.g. (2/5) = tested for 5 years, 2 years returning a significant yield loss
x% (w/z) yield reduction (warning) significant yield reduction at recommended rate in 1 trial only in z years of testing
x-y% (w/z) yield reductions (warning) significant yield reductions at recommended rate in w years out of z years tested

* Denotes an off-label use. This use is not endorsed by this data and no responsibility will be taken for its interpretation.

Always follow label recommendations. All pesticide applications must accord with the currently registered label for that particular pesticide, crop, pest and region. Any research regarding pesticides or their use reported in this document does not constitute a recommendation for that particular use by the authors, the authors' organisations or ACAS.

It must be emphasised that crop tolerance and yield responses to herbicides are strongly influenced by seasonal conditions.

Source:: National Variety Trials: Herbicide Tolerance (2016) Grains Research and Development Corporation http://www.nvtonline.com.au/herbicide-tolerance/

8.4 Using herbicides

Herbicides that are registered for use in lentil can be found using the Australian Pesticides and Veterinary Medicines Authority (APVMA) database. An iOS app is also available. Seek the advice of your local agronomist or reseller.

It is important to ensure information on the registration status of herbicides is current. Specifically, this refers to rates of application, warnings related to withholding periods, occupational health and safety, residues, and off-target effects.

Herbicides must only be used if they are legally registered for the particular use in the particular crop at the listed label rates. Using products off-label risks reduced efficacy, exceeded Maximum Residue Limits (MRLs) and litigation.

The product label and Safety Data Sheet (SDS) must always be read prior to using herbicides.

Residue limits in any crop are at risk of being exceeded or breached where pesticides are applied:

- at rates higher than the maximum specified;
- more frequently than the maximum number of times specified per crop;
- within the specified withholding period; and
- where they are not registered for the particular crop.

The National Residue Survey (NRS) is part of an Australian Government and industry strategy to minimise chemical residues and environmental contaminants in Australian food products. NRS programs support primary producers and commodity marketers by confirming Australia's status as a producer of clean food and facilitating access to key domestic and export markets. The compliance rate for pulses in 2013-14 was 99.5%.[22]

Getting best results from herbicides

Successful results from herbicide application depends heavily on numerous interacting factors.

Annual weeds compete with cereals and broadleaf crops mainly when the crops are in their earlier stages of growth. Weeds should be removed no later than 6 weeks after seeding to minimise losses. Early post-emergence control nearly always results in higher yields than treatments applied after branching in broadleaf crops.[23]

Points to remember for the successful use of herbicides:

- Plan the operation. Check paddock sizes, tank capacities, water availability and supply.
- Do not spray outside the recommended crop growth stages as damage may result.
- Carefully check crop and weed growth stages before deciding upon a specific post-emergent herbicide.
- Read the label. Check to make sure the chemical will do the job. Note any mixing instructions, especially when tank mixing two chemicals.
- Follow the recommendations on the label.

Conditions inhibiting plant cell growth, such as stress from drought, waterlogging, poor nutrition, high or low temperatures, low light intensity, disease or insect attack, or a previous herbicide application, are not conducive to maximum herbicide uptake and translocation.

22 National Residue Survey (2014) Residue results for 2013-14. Australian Government, Department of Agriculture and Water Resources, http://www.agriculture.gov.au/ag-farm-food/food/nrs/nrs-results-publications

23 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

FEEDBACK

MORE INFORMATION

For more information go to:

APVMA webpage: Registration database https://portal.apvma.gov.au/pubcris

APVMA webpage: Permits database https://portal.apvma.gov.au/permits

APVMA app: Permit app for ios http://apvma.gov.au/node/10831#iphone_app

Pulse Australia webpage: Permits for pulses http://pulseaus.com.au/growing-pulses/crop-protection-products

Grain Producers booklet: Safely managing risks with crop inputs and grain on farm http://grainsguide.grainproducers.com.au/

MORE INFORMATION

A GRDC Booklet on spraying 'Spray application manual' is at https://grdc.com.au/GrowNotesSprayApplication

A GRDC spray application workshop video is at https://youtu.be/UskthCWjeug

And a GRDC webinar on spray application in summer fallows is at https://youtu.be/kDuz6ADMjA0

- Use good quality water, preferably from a rainwater tank. Water quality is very important.
- Hard, dirty or muddy water can reduce the effectiveness of some herbicides.
- Use good equipment checked frequently for performance and output.
- Use sufficient water to ensure a thorough, uniform coverage regardless of the method of application.
- Check boom height with spray pattern operation for full coverage of the target;
- Check accuracy of boom width marking equipment.
- Check wind speed.
- A light breeze helps herbicide penetration into crops.
- Do not spray when wind is strong (>10–15 kilometres per hour).
- Do not spray if rain is imminent or when heavy dew or frost is present.
- Calculate the amount of herbicide required for each paddock and tank load. Add surfactant where recommended.
- Select the appropriate nozzle type for the application.
- Beware of compromising nozzle types when tank-mixing herbicides with fungicides or insecticides.
- Be aware of spray conditions to avoid potential spray drift onto sensitive crops and pastures, roadways, dams, trees, watercourses or public places.

Seek advice before spraying recently released lentil varieties as they may differ in their tolerance to herbicides. Information on herbicide tolerance is available in the variety management package for the variety.

Keep appropriate spray records for each spray operation.

Current minor use permits (MUP)

Some products may be available under permit, with conditions attached, until enough data is generated for full registration. In other cases, a temporary permit may be granted when there is a particular seasonal issue.

Pulse Australia holds several minor use permits (MUP) on behalf of the pulse industry and is actively involved in the pursuit of new permits and label registrations to meet industry needs.

8.5 Herbicide performance

Characteristics that determine herbicide performance and activity are:

- Herbicide uptake: how and where the chemical is taken up by the plant;
- Herbicide solubility: how readily it dissolves or leaches in soil water;
- Herbicide adsorption: how much is lost by binding to the soil; and
- Herbicide persistence: how long it will last in the soil, affected by:
  - Volatilisation: loss to the atmosphere;
  - Leaching potential: how much is lost below the root zone; and
  - Decomposition by light: loss of product by decomposition.

Understanding these factors will assist in ensuring more effective herbicide use.

For best performance, pre-seeding and pre-emergence herbicides should be placed within the top 5–7 cm of soil. They must enter the germinating weed seedling in order to kill it. These herbicides can be mixed in by cultivation, rainfall, or sprinkler irrigation, depending on the herbicide. They are also used in incorporation by seeding (IBS) systems where they are applied to the soil surface and covered during the seeding operation.

Poor herbicide efficacy can occur under dry conditions at application. Some soil-active herbicides (terbuthylazine or simazine) can damage lentil where wetter

FEEDBACK

MORE INFORMATION

For more information go to:

GRDC Update paper: Optimising the impact of glyphosate https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Optimising-the-impact-of-glyphosate

VIDEO

Double-knock timing
https://youtu.be/tNNRziB3MKc

VIDEO

Double Knock Applications - Double Knock Strategies for Resistant Weed Populations
https://youtu.be/bL0sbdQAYK0

VIDEO

Double knock applications – a grower's experience
https://youtu.be/pEIEGsQDzBg

conditions favour greater activity and leaching. Figure 1 illustrates how herbicides are broken down.

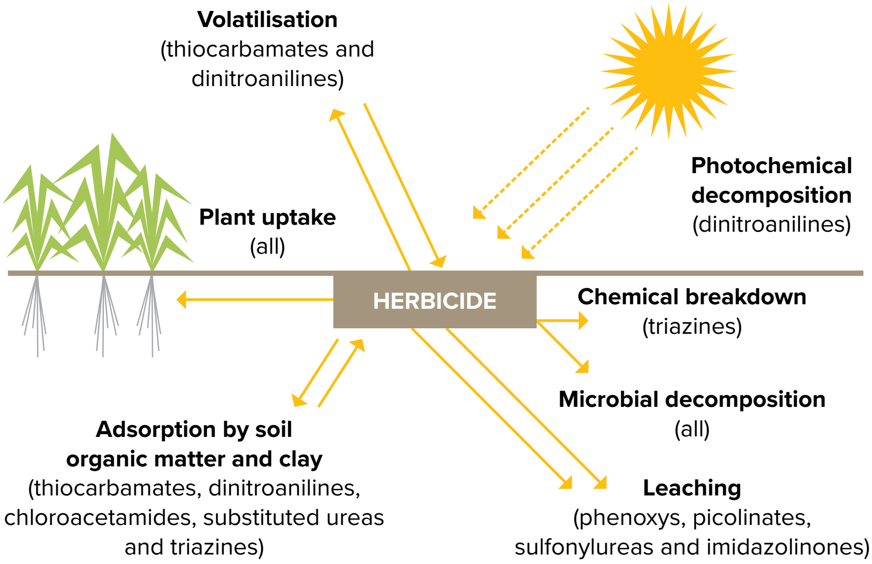


Figure 1: *Fate of applied herbicides in soil, plant and sunlight.*

8.6 Herbicide types

Knockdown herbicides

The most important part of the pulse weed control strategy is to control the majority of weeds before seeding, either by cultivation or with knockdown herbicides such as glyphosate (Group M) and/or Spray Seed® (Group L).

A technique used with varying success by growers has been to seed lentil and then use a knockdown herbicide tank-mixed with a pre-emergent herbicide to control germinating weeds just before the crop has time to emerge. Lentil crops may take up to 21 days to emerge under cool, drying soil conditions. Under favourable warm, moist soil conditions, it is important to be aware that lentil may emerge in as little as 7–10 days. If considering this option, lentil should be sown deeper (6–8 cm) and paddocks checked carefully for the emergence of lentil immediately before spraying. Done well, this can be an effective weed control option.[24]

Double-knockdown is the sequential application of two different weed control tactics where the second tactic controls survivors from the first.[25] A common technique is to apply glyphosate (Group M), followed 2–10 days later by paraquat/diquat (Group L). Non-chemical options such as burning or grazing may also be used.[26]

Pre-seeding herbicides

The resistance status of the weeds present, particularly ryegrass, must be known to determine which products and mixtures can be used pre-seeding.

Incorporation by seeding is generally considered safer on the crop than post-seeding pre-emergence (PSPE) with most herbicides used in modern no-till seeding systems. There is, however, little herbicide protection within the seeding row, and there is potential for crop damage if soil is thrown or washed back into the seeding furrow.

24 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

25 Grains Research and Development Corporation (2014) Integrated Weed Management Hub. Grains Research and Development Corporation, https://grdc.com.au/resources-and-publications/all-publications/publications/2014/07/iwmm

26 Grains Research and Development Corporation (2012) Cropping with Herbicide resistance. Grains Research and Development Corporation, https://grdc.com.au/Resources/Factsheets/2012/05/Herbicide-Resistance

FEEDBACK

Trifluralin, pendimethalin, cyanazine, terbuthylazine and some diuron brands are registered for use on lentil.

Triallate and simazine are NOT registered for use in lentil.

Most of the above herbicides require or benefit from mechanical incorporation by seeding, and are often used in mixtures.[27]

Post-seeding pre-emergent herbicides

Pre-emergent herbicides are essential because there are limited post-emergent options for broadleaf weed control in lentil.

Pre-emergent herbicides offer the following advantages:

- alternative modes of action to post-emergent and knockdown herbicides;
- many are very effective on hard-to kill weeds, such as annual ryegrass and barley grass;
- herbicide resistance to pre-emergent herbicides is low in some chemicals or some areas;
- pre-emergent herbicides control weeds early in crop life and potentially over several germinations, maximising crop yield potential;
- they suit a no-till seeding system with knife points and press-wheels and/or disc seeders, as well as conventional tillage systems; and
- can be cost effective.

These pre-emergent herbicides are primarily absorbed through the roots, but there may also be some foliar absorption.

When applied to soil, best control is achieved when the soil is flat and relatively free of clods and trash. While most pre-emergent herbicides are suitable for use in high stubble load paddocks, product labels will suggest adequate control with 50% ground cover.

Sufficient rainfall (20–30mm) to wet the soil through the weed root zone is necessary within 2–3 weeks of application. Best weed control is often achieved from a post-seeding application because rainfall provides the best incorporation (moisture or rainfall is still required to activate pre-seeding herbicide applications).

Mechanical incorporation is less uniform and so weed control may be less effective. If applied pre-seeding and sown with minimal disturbance, incorporation will essentially be by rainfall after application. Weed control in the seeding row may be less effective because a certain amount of herbicide will be removed from the crop row through the seeding operation.

The residual activity of a pre-emergent herbicide controls the first few flushes of germinating weeds 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.[28]

Pre-emergent herbicides will not adequately control large weed populations by themselves. They need to be used in conjunction with paddock selection, crop rotation and pre-seeding weed control.

In no-till seeding systems, incorporation by seeding (IBS) is generally considered safer on the crop than post-seeding pre-emergent (PSPE). This is because there is no herbicide over the seeding row that can get washed down into the root zone. Movement of soil, after incorporation by seeding or post-seeding pre-emergent spraying, can move concentrate herbicide over the seed row, thus increasing the risk of damage.[29]

To avoid PSPE damage deep seeding is recommended. The herbicide should be applied to moist soil, not dry, and not applied if there is heavy rain forecast. The soil

27 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

28 Grains Research and Development Corporation (2014) Integrated Weed Management Hub. Grains Research and Development Corporation, https://grdc.com.au/resources-and-publications/all-publications/publications/2014/07/iwmm

29 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

FEEDBACK

MORE INFORMATION

More information: See Section 6.8.4

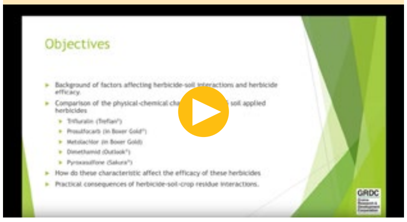
WeedSmart webinar: Understanding pre-emergent herbicides
http://weedsmart.org.au/webinars/setting-crops-up-for-success/

VIDEO

Pre-emergent herbicides – solubility and binding
https://youtu.be/s63GYYyflzw

VIDEO

Webinar - Stubble & soil binding of pre-emergent herbicides for annual ryegrass control in winter crops
https://youtu.be/mrJvg5ZmdOU



surface should be level to limit the possibility of herbicide concentrating in the furrow. Lower herbicide rates are recommended on lighter soils.[30]

Post-emergent herbicides

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 the yield benefit provides significant economic returns.[31]

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

Stress from waterlogging, frost or dry conditions results because crops cannot produce sufficient levels of the enzymes that normally break down the herbicide.[32]

Only two broadleaf herbicides are currently registered for post-emergence use in conventional lentil varieties.

Flumetsulam and diflufenican are registered products available for post-emergent applications. However, they can cause crop damage and yield reduction in conventional lentil varieties.

Some varieties are more sensitive than others and this is advised on these herbicide labels. Yield losses of up to 25% using flumetsulam and up to 24% yield loss using diflufenican have been recorded. Of the herbicide products registered for lentil these two post-emergent herbicides have caused the most instances of crop damage and yield los.

Directed sprays in-crop

With the shift to cropping lentil on wide rows, weeds will have more time to become established between the rows but there are also more opportunities to use inter-row spraying. This can be combined with banding of fertiliser during seeding to favour the crop over the weed.[33]

Shielded sprayers

Shielded sprayers are becoming increasingly more common in or around cotton-growing areas as they provide very cheap grass and broadleaf weed control with glyphosate.

Lentil has little tolerance to glyphosate during the vegetative stage, so caution is required as the basal branches may not be fully erect and could be sprayed during this process. Basal branches contribute a large proportion of the total lentil yield.

Issues that need to be considered include:

- selection and operation of spray shields (speed, nozzle type etc);
- height of the crop (small lentil plants are more susceptible); and
- variety can also be important. Upright types such as PBA Bolt$^{(D)}$ are more suited to this technique than the more prostrate or lodging types like PBA Jumbo$^{(D)}$.

Weed wiping

Weed wiping (or 'wick' wiping) is done by wiping herbicide (usually glyphosate) onto the weeds that stand above the crop canopy, without affecting the crop itself. It is being successfully used in lentils to prevent weed seedset of herbicide-resistant ryegrass and other tall weeds in the crop. Weeds must be taller than the lentil plants. Hence crop height and erectness also needs to be a consideration in lentil variety choice for weed wiping opportunities. Also, lentil sown into standing stubble need to be taller than the standing cereal stubble to enable effective weed wiping.

30 B Haskins, G Brooke, A Schipp (2011) Weed control in winter crops 2012. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/weed-control-winter-crops

31 Grains Research and Development Corporation (2014) Integrated Weed Management Hub. Grains Research and Development Corporation, https://grdc.com.au/resources-and-publications/all-publications/publications/2014/07/iwmm

32 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

33 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

Paddocks with high levels of herbicide-resistant ryegrass numbers should be avoided when choosing paddocks to grow lentil because of the poor relative competitiveness of lentil. However, where weed numbers are manageable and because lentil plants are short in height, there is an opportunity for weed wiping to prevent the taller ryegrass plants from setting seed.

Photo 6: *A weed wiper can be useful to prevent seedset of tall weeds in lentil, and help dry those weeds for easier and earlier harvest management.*

(Photo: W. Hawthorne, formerly Pulse Australia)

Photo 7: *Crop damage from using a weed wiper that has either been set too low or has bounced due to excessive speed.*

(Photo: W. Hawthorne, formerly Pulse Australia))

FEEDBACK

MORE INFORMATION

GRDC booklet: Soil behaviour of pre-emergent herbicides in Australian farming systems
https://grdc.com.au/SoilBehaviourPreEmergentHerbicides

Photo 8: *Use of a weed wiper to prevent weed seedset in lentil may be limited if the standing stubble is cut too tall at harvest or the lentil plantss are short through lack of moisture or variety choice.*

(Photo: W. Hawthorne, formerly Pulse Australia))

8.7 Herbicide residues

Pulse types differ in their sensitivity to residual herbicides.[34] It is important to check each herbicide prior to use for sensitivity to residues.

Group B

- **Conventional lentil is sensitive to sulfonylurea residues and the imidazolinones**.
- Lentil should immediately follow after bean or field pea if IMIs or sulfonamides were used.
- Lentil and chickpea are most vulnerable to sulfonylurea residues, with field pea, faba and broad bean the least. Residues persist longer in high pH soil.
- Lentil, faba and broad bean, and lupin are more sensitive to sulfonamide residues particularly on shallow duplex soils where breakdown is slower.
- At low pH (<6.5) faba and broad bean are more sensitive to Monza® residues (sulfonylurea) than lentil, chickpea, lupin and field pea. All are sensitive at higher pH (>6.5).

Group I

- All pulses are vulnerable to pyridine residues (Lontrel®). Lontrel® is more likely to persist in stubble-retention systems.
- Spikes (dicamba) added to knockdown sprays may persist under dry conditions and can reduce pulse crop establishment. Dicamba plant-back periods start after 15 mm of rain. **Lentil and faba bean are not listed on label.**
- Picloram and aminopyralid applied to previous summer fallows are more likely to persist and damage crops under dry conditions.

Group C

- Triazine and diuron herbicides applied in-crop can potentially cause crop damage in some circumstances.

34 P Matthews, D McCaffery, L Jenkins (2016) Winter crop variety sowing guide 2016, NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre/guides/winter-crop-variety-sowing-guide

FEEDBACK

All residual herbicides require moist soil to break down. Where dry conditions have persisted between herbicide application and seeding there will be a higher risk of residual herbicide damage.

Some of the newer broadleaf herbicides used in cereals now have plant-back for lentil.

MORE INFORMATION

See also Section 4.6 Herbicide residues

8.8 Herbicide damage

The risk of herbicide damage needs to be weighed against potential yield loss from weed competition. In heavy weed infestations some herbicide crop damage can be tolerated as this is more than offset by the yield loss avoided by removing competing weeds. Weeds at harvest can also lead to harvest and marketability problems.

If herbicide is applied to dry soils, the risk of movement and crop damage is increased greatly after rainfall, particularly if the soil is left ridged and herbicide washes into the seed row. Incorporation by seeding (IBS) may be more appropriate in dry conditions, or, alternatively, a split application to minimise risk. Post-seeding pre-emergent (PSPE) herbicides should be applied to moist soil regardless of the seeding time.

Herbicides move more readily in soils with low organic matter and more sand, silt or gravel. Herbicide movement is much less in soils with higher organic matter and higher clay contents. Damage from leaching is also greater where herbicides are applied to dry, cloddy soils, than to soils which have been rolled and which are moist from rainfall prior to the herbicide application.

Herbicide damage can result from:

- residues in the soil;
- drift from outside the crop;
- leaching within soil profile;
- pre and post-emergent herbicides applied to the crop; and
- spray tank contamination.

Damage from pre and post-emergent herbicides can be minimised by careful application and by understanding the tolerance of lentil varieties.

Timing of rolling can also influence herbicide damage. Rolling immediately after PSPE or incorporation before seeding spraying (IBS) can 'push' more herbicide in the seed row, increasing the risk of damage. This risk is increased on lighter-textured soils where there is more soil movement during rolling.

Plants weakened by herbicide injury are more susceptible to diseases. The most common problems come from residual herbicides applied to prior cereal crops. However, non-residual herbicides have also been implicated.[35]

35 P Matthews, D McCaffery, L Jenkins (2016) Winter crop variety sowing guide 2016, NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre/guides/winter-crop-variety-sowing-guide

Table 3: The relative leaching potential of some soil-active herbicides (1 = the least leaching).

Chemical	Example of product	Leaching index
pendimenthalin	Stomp®	1
trifluralin	Treflan®	1
diuron	Diuron	2
prometryn	Prometryn	3-4
simazine	Simazine	5
s-metalochlor	Dual Gold®	6
terbuthylazine	Terbyne®	8*
atrazine	Atrazine	10
metribuzin	Sencore®	14

* Estimated

Source: Southern Lentil: Best Management Practices Training Course (2016), Pulse Australia

Metribuzin leaches at almost three times the rate of simazine and seven times the rate of diuron.

The relative tolerance of the crop type and variety will also affect crop damage from these herbicides. For example, lupin is more tolerant to simazine than are the other pulses.

Symptoms of herbicide damage

Pulses have narrow crop safety margins to most registered herbicides. They can be severely damaged by some herbicides. This might be due to soil residues from previous applications, contaminants in spray equipment, spray drift onto the crop or by incorrect use of the herbicide.

Symptoms of crop injury from herbicides do not always mean a grain yield loss will occur. Recognition of crop injury symptoms allows the cause of the injury to be identified and possibly prevented in future crops. The type of injury depends on how the herbicide works in the plant, the site on the plant, and seasonal conditions.

Herbicide injury may be very obvious (e.g. scorched leaves) or it may be subtler (e.g. poor establishment or delayed maturity). Herbicide crop injury symptoms can easily be confused with symptoms produced by other causes, such as frost, disease or nutrition.

Care should be taken when using crop oils and penetrants with herbicides as these can increase the uptake of active chemicals and exceed crop tolerance. Always follow the herbicide label.

Taking some general precautions can help to reduce the likelihood of crop damage with residual herbicide use:

- Do not apply if rain is imminent.
- Maintain up to 8 cm soil coverage.
- Avoid leaving a furrow or depression above the seed that could allow water (and chemical) to concentrate around the seed/seedling.
- Avoid leaving an exposed, open slot over the seed with disc openers and avoid a cloddy, rough tilth with tyned openers.

MORE INFORMATION

Field crop herbicide injury: The Ute Guide https://grdc.com.au/resources-and-publications/all-publications/bookshop or as an app App: Herbicide Injury: The Ute Guide http://www.uteguides.net.au/UteGuides

Lentil: The Ute Guide https://grdc.com.au/resources-and-publications/all-publications/publications/2008/11/lentils-the-ute-guide

Photo 9: *Group C. Crops grown on lighter soils are more prone to metribuzin damage.*

(Photo: W. Hawthorne, formerly Pulse Australia)

Photo 10: *Group C. High rates of simazine can damage lentil. Lower leaves turn brown and die back from the edge.*

(Photo: W. Hawthorne, formerly Pulse Australia)

Photo 11: *Group C. Herbicide damage affecting emergence and survival of seedlings.*

(Photo: W. Hawthorne, formerly Pulse Australia)

Photo 12: *Simazine damage on one row where shallower sown, or deeper seeding, furrow remained.*

Photo: W. Hawthorne, formerly Pulse Australia

Photo 13: *Group C. Triazine injury (front) on sandier soil, causing stunted growth.*

Photo: A. Mayfield, Grain Legume Handbook, formerly Pulse Australia

Photo 14: *Group I. Bean seedlings affected by Lontrel® residue in soil.*

(Photo: W. Hawthorne formerly Pulse Australia)

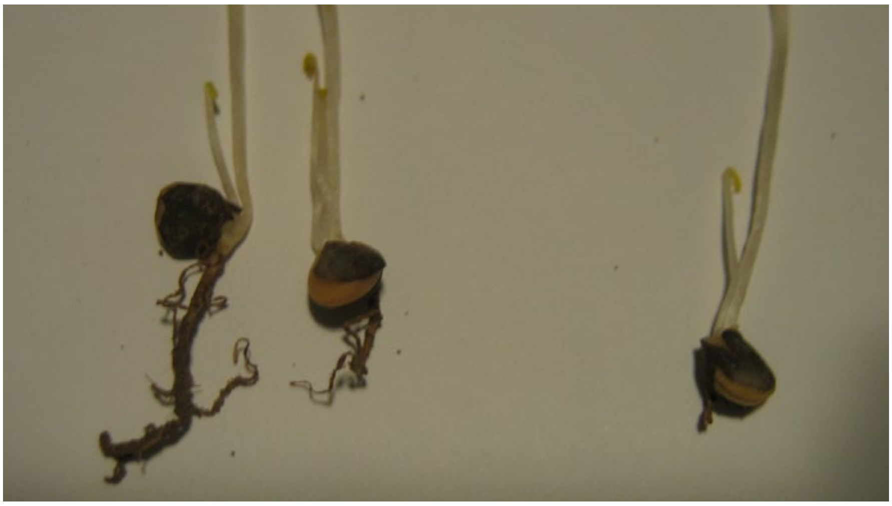


Photo 15: *Group D. Trifluralin injury (left) causing stunted growth. It can also cause development of multiple growing points.*

(Photo: I Koch, J& D Southwoods)

Photo 16: *Group B. Damage caused by Broadstrike®.*

(Photo: W. Hawthorne formerly Pulse Australia)

Photo 17: *Group B. Broadstrike® damage*

(Photo: W. Hawthorne formerly Pulse Australia)

Photo 18: *Group I. 2,4-D spray drift causing narrow leaves with crinkled edges.*

(Photo: Canadian Phytopathological Society, via SasPulse Growers Handbook).

Photo 19: *Group I. Damage from Lontrel® drift.*

(Photo: T. Bray formerly Pulse Australia)

Photo 20: *Group M. Pre-harvest glyphosate damage (R) after a 7-day germination test.*

(Photo: Canadian Phytopathological Society, via SasPulse Growers Handbook)

8.9 Herbicide resistance

Heavy reliance on the very effective grass and/or broadleaf herbicides since the 1980s has seen herbicide resistance across southern Australia develop in a range of cropping weeds.

In 2014 there were 39 weed species in Australia with resistance to one or more herbicide modes of action.

Herbicide resistance is one of the biggest agronomic threats to the sustainability of Australia's cropping systems, although it need not spell the end of profitable cropping.

It does mean that over-reliance on herbicides with the same mode of action should be avoided.

Delaying the onset of and/or reducing the impact of herbicide-resistant weed populations requires the implementation of a wide range of weed control strategies, that will, in turn, help sustain profitable grain production. Resistance can be managed through good crop rotation, rotating herbicide groups, and by combining both chemical and non-chemical methods of weed control.[36]

Evolution

Herbicide resistance evolves following the intensive use of herbicides for weed control.

In any weed population there are likely to be a small number of individuals that are naturally resistant to herbicides due to genetic diversity, even before the herbicides are used. When herbicide is used, these individual weeds survive and set seed, whereas the majority of susceptible plants are killed. Continued use of one herbicide, or herbicide group, will eventually result in a significant fraction of the weed population with resistance.[37]

There are four main factors that influence the evolution of resistance:

1. The intensity of selection pressure.

This refers to how many weeds are killed by the herbicide. It is good practice to use labelled rates of herbicides to control weeds, as this will lead to the highest and most consistent levels of weed control. Failure to control weeds adequately will lead to increases in weed populations and put pressure on all herbicides used.

2. The frequency of use of one herbicide or mode of action group.

For most weeds and herbicides, the number of years of herbicide use is a good measure of selection intensity. The more often herbicide is applied, the higher the selection pressure and the higher the risk of herbicide resistance developing.

3. The frequency of resistance present in untreated populations.

If the frequency of resistant genes in a population is relatively high, such as with Group B herbicides, resistance will occur quickly. If the frequency is low, such as with Group M herbicides, resistance will occur more slowly.

4. The biology and density of the weed.

Weed species that produce large numbers of seed, and have a short seedbank life in the soil, will evolve resistance faster than weed species with long seedbank lives. Weed species with greater genetic diversity are more likely to evolve resistance. Resistance is also more likely to be detected in larger weed populations.

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36 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

37 CropLife Australia Resistance Management Review Group and industry researchers (2016) Herbicide Resistance Management Strategies. CropLife Australia, https://www.croplife.org.au/resistance-strategy/2016-herbicide-resistance-management-strategies/

MORE INFORMATION

For up-to-date herbicide mode of action groups go to Croplife: https://www.croplife.org.au/resistance-strategy/2016-herbicide-moa-table/

Current impact on weed management

The confirmed resistance (in 2014) of 39 grass and broadleaf weed species is to 11 distinctly different herbicide chemical groups. This significantly reduces herbicide options for grain growers. Cases of multiple resistances have also been commonly reported where, for example, annual ryegrass proves resistant to two or more chemical groups.[38]

Mode of action

Mode of action is important

The main reason resistance has developed is because of the repeated and often uninterrupted use of herbicides with the same mode of action.

Selection of resistant strains can occur in as little as 3–4 years if no attention is paid to resistance management.

Mode of action labelling in Australia

All herbicides sold in Australia are grouped by mode of action. The mode of action is indicated by a letter code on the product label. The mode of action labelling is based on the resistance risk of each group of herbicides.

Groupings of herbicides have changed over the years to improve the accuracy and completeness of the modes of action. Ultimately, this enables informed decisions to be made about herbicide rotation and resistance management.

Grouping by mode of action and ranked by resistance risk

All herbicide labels now carry the mode of action group clearly displayed (see below). This enables users to better understand the mode of action grouping and resistance risk by reference to the mode of action chart.

GROUP	G	HERBICIDE

HIGH RESISTANCE RISK herbicides

Group A (mostly targeted at annual ryegrass and wild oats); and

Group B (broadleaf and grass weeds).

Specific guidelines are written for use of these products in winter cropping systems.

MODERATE RESISTANCE RISK herbicides

Group C (annual ryegrass, wild radish and silver grass);

Group D (annual ryegrass and fumitory);

Group F (wild radish);

Group I (wild radish and Indian hedge mustard);

Group J (serrated tussock and giant Parramatta grass);

Group L (annual ryegrass, barley grass, silver grass, square weed and capeweed);

Group M (annual ryegrass, barnyard grass, fleabane, liverseed grass and windmill grass);

Group Q (annual ryegrass); and

Group Z (wild oats and winter grass).

38 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

FEEDBACK

VIDEO

For information on the development of tolerance in lentil to Group C herbicides click on the link to go to GRDC GroundCover™ TV Episode 16: Pulse Herbicide Tolerance.
https://youtu.be/j7JEfzclUfg

VIDEO

Click on the link to watch GRDC GroundCover™ TV Episode 19 to learn more about glyphosate resistance in feathertop Rhodes grass
https://youtu.be/Yk95mS_hvhM

VIDEO

Glyphosate-resistant weeds
https://youtu.be/Ke8klYNQzl8

Group K

Specific guidelines have been developed for Group K due to the reliance on this mode of action to manage annual ryegrass, and the possibility of future resistance development.

NO GUIDELINES

Group E

Group G

Group H

Group N

Group O

Group P

Group R

There are no recorded cases of weeds resistant to members of these groups in Australia.

Herbicide-resistant weeds

Herbicide-resistant weeds include annual ryegrass, wild oats, Indian hedge mustard, milk thistle, wild radish, wild turnip and prickly lettuce as well as barley grass and capeweed.[39]

Glyphosate (Group M)

Continued reliance on glyphosate is leading to increased resistance. The potential inability to use glyphosate due to resistant weeds will increase the cost of weed management. Glyphosate-resistant weeds have a lower fitness and are more vulnerable to IWM techniques. Controlling weeds using IWM is more costly, but has long-term benefits in delaying resistance development and reducing weed seedbanks.[40]

Resistance mainly occurs in situations where glyphosate has been used as the main weed control tactic, no other effective herbicides are used, and few other weed management practices are employed. These include chemical fallows, fence lines, irrigation channels, vineyards and roadsides.

In 2014, glyphosate resistance was present in annual ryegrass, awnless barnyard grass, liverseed grass, brome grass, red brome grass, windmill grass, flaxleaf fleabane, milk/sow thistle and wild radish.[41]

In 2016 feathertop Rhodes grass was the latest weed species to have confirmed populations of glyphosate resistance. Resistant populations have been found in South Australia and the weed has spread into the western region as well.

Growers are encouraged to use paraquat for crop-topping in pulses rather than rely on glyphosate, which is frequently used for topping in other crops. However, paraquat resistance is also increasing so weeds should be tested before planning a management strategy.

39 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

40 C Preston (2014) UA00104 - Understanding and management of weed resistance to glyphosate. Grains Research and Development Corporation, https://grdc.com.au/research/reports/report?id=3772

41 Grains Research and Development Corporation (2014) Integrated Weed Management Hub. Grains Research and Development Corporation, https://grdc.com.au/weedlinks

Paraquat (Group L)

In 2014, paraquat-resistant weeds included capeweed, northern barley grass, barley grass, annual ryegrass, small square weed and silvergrass.[42]

Ryegrass that is resistant to both glyphosate and paraquat has been found in South Australia.[43]

IN FOCUS

Other herbicides

Annual ryegrass in Australia is now resistant to 8 different herbicide groups.[44] The major herbicides are Group A (>20,000 sites in Australia), Group B (>20,000 sites) and Group D (>5,000 sites). Resistance to trifluralin (Group D) and the Dims (Group A) is increasing in southern Australia.[45]

Clethodim (Group A) resistance is a major issue in pulse production.[46] Clethodim is the last Group A herbicide that provides effective control of herbicide-resistant ryegrass.[47] A clethodim/butroxydim mix controls many populations of ryegrass that are resistant to clethodim or butroxydim.[48]

In wild oats frequency of resistance to all of the Group A herbicides is common (Fops, Dims and Dens).[49]

42 Grains Research and Development Corporation (2014) Integrated Weed Management Hub. Grains Research and Development Corporation, https://grdc.com.au/resources-and-publications/all-publications/publications/2014/07/iwmm

43 Grains Research and Development Corporation (2012) Cropping with Herbicide resistance. Grains Research and Development Corporation, https://grdc.com.au/Resources/Factsheets/2012/05/Herbicide-Resistance

44 CropLife Australia (2016) Herbicide resistant weeds, CropLife Australia, http://www.croplife.org.au/resistance-strategy/2016-herbicide-resistant-weeds-list/

45 G Brooke, C McMaster (2017) Weed control in winter crops 2017. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/weed-control-winter-crops

46 C Preston, P Boutsalis, S Kleemann, R Saini and G Gill (2015) Managing resistant ryegrass in break crops and new herbicides for resistant ryegrass. Grains Research and Development Corporation, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Managing-resistant-ryegrass-in-break-crops-and-new-herbicides-for-resistant-ryegrass

47 Grains Research and Development Corporation (2013) Ground Cover Issue 102 - Emerging Issues with Diseases Weeds and Pests Supplements. Grains Research and Development Corporation, https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/GCS102

48 G Gill, P Boutsalis, C Prestong (2016) How can I best control herbicide resistant annual ryegrass in canola. Grains Research and Development Corporation, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/07/How-can-I-best-control-herbicide-resistant-annual-ryegrass-in-canola-crops

49 G Brooke, C McMaster (2017) Weed control in winter crops 2017. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/weed-control-winter-crops

MORE INFORMATION

For more information, see:

WeedSmart at www.weedsmart.org.au

Australian Herbicide Resistance Initiative www.ahri.uwa.edu.au

Australian Glyphosate Sustainability Working Group http://glyphosateresistance.org.au/

GRDC www.grdc.com.au

MORE INFORMATION

For more information go to: http://ahri.uwa.edu.au/research/rim/

Preventing herbicide resistance – WeedSmart

WeedSmart (http://www.weedsmart.org.au/10-point-plan/) lists ten ways to weed out herbicide resistance:

1. Act now to stop weeds from setting seed
2. Capture weed seeds at harvest
3. Rotate crops and herbicide modes of action
4. Test for resistance to establish a clear picture of paddock-by-paddock status
5. Never cut the rate
6. Don't automatically reach for glyphosate
7. Carefully manage spray events
8. Plant clean seed into clean paddocks with clean borders
9. Use the double-knock technique
10. Employ crop competitiveness to combat weeds.

WEED smart
every weed every seed
every farm every year

Annual ryegrass

Annual ryegrass has higher levels of resistance than any other weed. Preventing ryegrass from setting seed and removing weed seeds at harvest before they fall to the ground is the top priority.[50]

The recommendation is to aim for 3 years with no weed seedset.

Techniques to manage resistant ryegrass include:

- Know your resistance status. What herbicides is the ryegrass resistant to?
- Use crop rotation to access different treatment options.
- Use double-knockdowns before seeding.
- Consider crop-topping even if yield will be reduced.
- Consider green or brown manuring or cutting for hay.
- Capture and destroy weed seeds at harvest.
- Control ryegrass in non-crop areas such as fence lines, channel banks.[51]

Ryegrass Integrated Management (RIM) is a decision-support tool to evaluate the long-term profitability of strategic and tactical ryegrass control methods. It allows growers/users to test ideas to reduce ryegrass populations while improving profitability.

50 Grains Research and Development Corporation (2012) Cropping with Herbicide resistance. Grains Research and Development Corporation, https://grdc.com.au/Resources/Factsheets/2012/05/Herbicide-Resistance

51 L Pearce (2015) Herbicide resistance management, a local, in-field perspective. Grains Research and Development Corporation, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Herbicide-resistance-management-a-local-infield-perspective

Monitoring for herbicide resistance

Monitoring of weed populations before and after any spraying is an important management tool.

- Keep accurate records.
- Monitor weed populations and record results of herbicide used.
- If herbicide resistance is suspected, prevent weed seedset.
- If a herbicide does not work, find out why.
- Check that weed survival is not due to spraying error.
- Conduct paddock tests to confirm herbicide failure and what herbicides are still effective.
- Have a herbicide-resistance test carried out on seed from suspected plants, testing for resistance to other herbicide groups.
- Do not introduce or spread resistant weeds in contaminated grain or hay.

Following weed removal or suppression, regular monitoring is required to assess the effectiveness of weed management and the expected situation afterwards. Without monitoring, the impact of a management program or how it might be modified in the future is not understood. Effective weed management begins with monitoring weeds to assess current or potential threats to crop production, and to determine the best methods and timing of control measures.

Regular monitoring and recording details of each paddock allows:

- the identification of critical stages of crop and weed development for timely cultivation or other intervention;
- the identification of weed species and composition, which helps determine the best short and long-term management strategies; and
- detection of new, invasive or aggressive weed species, whilst the infestation is still localised and possible to eradicate.

Thorough monitoring allows for assessment of critical aspects of the weed–crop interaction, such as:

- weed seed germination and seedling emergence;
- weed growth sufficient to affect crops if left unchecked;
- weed density, height, and cover relative to crop height, cover, and stage of growth;
- weed impacts on crops. This includes harbouring pests, pathogens, or beneficial organisms. It also includes modifying microclimate, air circulation, or soil conditions. Lastly, direct competition for light, nutrients, and moisture can be assessed;
- wlowering, seedset, or vegetative reproduction in weeds; and
- efficacy of cultivations and other weed management practices.

FEEDBACK

MORE INFORMATION

For more information on herbicide resistance:

CropLife webpage: Herbicide mode of action table http://www.croplife.org.au/resistance-strategy/2016-herbicide-moa-table/

CropLife webpage: Herbicide resistant weeds in Australia http://www.croplife.org.au/resistance-strategy/2016-herbicide-resistant-weeds-list/

GRDC fact sheet: Herbicide resistance https://grdc.com.au/Resources/Factsheets/2012/05/Herbicide-Resistance

CropLife Booklet: Herbicide resistance management strategies http://www.croplife.org.au/resistance-strategy/2016-herbicide-resistance-management-strategies/

Webpage: WeedSmart 10-point plan http://www.weedsmart.org.au/10-point-plan/

Website: Australian Glyphosate Sustainability Working Group http://www.glyphosateresistance.org.au/

App: WeedSmart to estimate paddock risk (iOS only) https://grdc.com.au/apps

AHRI decision-support tool: Ryegrass Integrated Management (RIM) http://ahri.uwa.edu.au/research/rim/

GRDC Updates: Herbicide resistance management, a local, in-field perspective https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Herbicide-resistance-management-a-local-infield-perspective

Herbicide-resistance testing

There are two types of commercial tests for herbicide resistance:[52]

Seed testing is suitable for pre and post-emergent herbicides and takes 4–5 months. This requires 3,000 seeds of each weed, which is approximately 1 cup of annual ryegrass seed or 6 cups of wild radish pods.

The quick test for post-emergent herbicides only uses live plant seedlings and results are available within 6 weeks. This requires 50 plants (or 20 large tillering plants) for each herbicide tested.

There are no testing services available in Western Australia. Samples for testing should be sent to either:

Plant Science Consulting offers both seed testing and the quick test.

22 Linley Avenue, Prospect, SA 5082.
Ph: 0400 66 44 60
Email: info@plantscienceconsulting.com.au
http://www.plantscienceconsulting.com.au/

Charles Sturt University offers the seed test only.

Herbicide Resistance Testing, School of Agricultural and Wine Sciences, Charles Sturt University, Locked Bag 588, Wagga Wagga, NSW, 2678.
Ph: John Broster 02 6933 4001 or 0427 296 641
Email: jbroster@csu.edu.au
https://www.csu.edu.au/weedresearchgroup/herbicide-resistance

8.10 Water quality for herbicide application

Clean, good quality water is important when mixing and spraying herbicides. Poor quality water can reduce the effectiveness of some herbicides and damage spray equipment.[53]

Effects of water quality

Water quality will vary with the source of the water (rain-fed tank, dam, river, bore or aquifer) and the season (heavy rain or drought). There are several characteristics of water quality that affect chemical performance.

Turbid or muddy water

Dirty water has very small soil particles (clay and silt) suspended in it. These soil particles can absorb and bind the chemicals' active ingredient and reduce its effectiveness. This applies especially to glyphosate, paraquat and diquat.

Dirt can also block nozzles, lines and filters and reduce the sprayer's overall performance and life. As a guide, **water is considered dirty when it is difficult to see a 10-cent coin in the bottom of a household bucket of water.**

Water hardness

Water is termed hard when it has a high percentage of calcium and magnesium. Hard water won't lather with soap and can cause some chemicals to precipitate. Susceptible chemicals often have agents added to overcome this problem.

Formulations of 2,4-DB are particularly sensitive to hard water (>250 ppm $CaCO_3$ equivalent). Other herbicides such as glyphosate, 2,4-D amine and MCPA amine, Lontrel™ and Tigrex® can also be affected.[54]

52 Grains Research and Development Corporation (2014) Integrated Weed Management Hub. Grains Research and Development Corporation, https://grdc.com.au/resources-and-publications/all-publications/publications/2014/07/iwmm

53 G Brooke, C McMaster (2017) Weed control in winter crops 2017. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/weed-control-winter-crops

54 G Brooke, C McMaster (2017) Weed control in winter crops 2017. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/weed-control-winter-crops

Hard water can affect the balance of the surfactant system and affect properties such as wetting, emulsification and dispersion. Very hard water can reduce the efficiency of agents used to clear dirty water. Also, some agents used to clear turbid water can increase hardness.

Hardness can be ameliorated with ammonium sulfate.

Water pH

pH is a measure of acidity and alkalinity scaled on a range between 1 and 14. A pH of 7 is neutral, less than 7 acid and more than 7 alkaline. Most natural waters have a pH between 6.5 and 8.

In highly alkaline water (pH>8) many chemicals undergo a process called alkaline hydrolysis. This process causes the breakdown of the active ingredient into other compounds, which can reduce the effectiveness of the pesticide over time (some insecticides are particularly sensitive). This is one reason why **spray mixes should not be left in spray tanks overnight.**

Very acidic water can also affect the stability and physical properties of some chemical formulations.

Dissolved salts

The total amount of mineral salts dissolved in water is usually measured by the electrical conductivity (EC) of the water.

The EC of bores and dams depends largely on the salt levels in the rock and soil that surrounds them. During a drought the salinity of water increases.

Very salty water can cause blockages in equipment and is more resistant to pH changes.

There are general limits for spraying water with regard to salt, pH ad hardness.

Organic matter

Water containing organic matter, such as leaves or algae, can block nozzles, lines and filters. Algae can also react with some chemicals, reducing their effectiveness.

Temperature

Very hot or cold water can affect the performance of some chemicals.

Improving water quality

Water needs to be tested to see whether it will affect chemical performance. There are commercial products available to reduce pH (Primabuf® BB5, LI700, Hotup®, ammonium sulfate), soften hard water and clear dirty water. To reduce the effects of very salty water, water may need to be mixed from several sources.

The effect of water quality on some herbicides is summarised in Table 4.

Table 4: Herbicide tolerances to water qualities.

Hebicide	Water quality				
	Muddy	Saline	Hard	Alkaline (pH>8)	Acidic (pH<5)
2,4-DB			X	NR	
2,4-D or MCPA amine	✓	✓	X	NR	
2,4-D or MCPA ester	✓	test	test	✓	✓
Associate®	✓	✓	✓	Marginal	X
Brodal®		✓	✓	X	
Dicamba	✓	✓	NR	NR	
Diuron	✓	test	✓	✓	
Diuron + 2,4-D amine	✓	test	X	NR	
Diuron + MCPA amine	✓	test	X	NR	
Fusilade® Forte	✓	✓	✓	NR	X
Tackle®	✓	✓	✓	marginal	X
Glyphosate	X	✓	X		✓
Gramoxone®	X	✓	✓	✓	✓
Logran®B-Power	✓	✓	✓	marginal	X
Lontrel™ Advanced	✓	✓	X	X	
Simazine	✓	X	✓	NR	
Spray.Seed®	X	✓	✓	✓	✓
Elantra® Xtreme®	✓	✓	✓	✓	✓
Tigrex®	✓	X	X	NR	
Trifluralin		✓	✓	✓	✓
Verdict™	✓	✓	✓	NR	✓

√= OK X = Do not use NR = Not recommended but use quickly if there is no alternative test = Mix herbicides and water in proportion and observe any instability marginal = Not ideal, but acceptable.

Source: Weed control in winter crops 2017, (2017), NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/content/agriculture/broadacre/guides/weed-control-winter-crops

8.11 Tips for tank-mixing herbicides

Tank-mixing herbicide is a common practice to improve weed control and broaden the weed spectrum. There may also be some advantages in helping avoid herbicide-resistance problems.

Many tank mixes are included on registered herbicide labels. Where herbicides are registered for a particular use, they may be tank-mixed, provided they are compatible and label mixing instructions are followed.

Note that some herbicides, although being physically compatible, can be antagonistic to weed control. This information is usually outlined on herbicide labels under 'Compatibility'.

The order that herbicides are mixed is also important and the following mixing sequence is usually followed.

1. Water conditioning agents.
2. Water dispersible granules and dry flowable products (including those in water soluble bags).
3. Wettable powders.
4. Flowables or suspension concentrates.
5. Emulsifiable concentrates.
6. Water soluble concentrates.
7. Surfactants and oils.
8. Soluble fertilisers.

The order that herbicides are mixed in the spray tank is important.

8.12 Adjuvants

An adjuvant is any additive to a herbicide which is intended to improve the effectiveness of the herbicide.[55]

Adjuvants can result in a dramatic improvement in grass weed control when using Group A herbicides. This is primarily through improved leaf coverage and absorption through the leaf cuticle.

Herbicide label directions and recommendations should always be followed when selecting a suitable adjuvant. Generalisations should not be made, as what works best with one chemical may not necessarily work best with other Group A herbicides. The herbicide label will state the required adjuvant to use.

Using adjuvants, surfactants and oils with herbicides

There are many products which have been developed to assist herbicides, firstly, to contact the weed target and, secondly, to remain and penetrate the weed leaf.

Adjuvants can be classified as follows:

- surfactants;
- crop oils;
- penetrants;
- acidifying/buffering agents; and
- compatibility agents.[56]

55 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

56 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

Surfactants

These adjuvants increase the spread of droplets, or the wetting of waxy or hairy leaf surfaces.

Surfactants consist of three different types:

1. Non-ionic. These are the most commonly used agricultural surfactants. They are non-reactive (no electrical charge). They remain on the leaf once dry and allow 'rewetting' after rain, permitting additional herbicide uptake.
2. Anionic. These adjuvants have a negative charge and are not often used with herbicides.
3. Cationic. Cationic adjuvants have a positive charge, such as many domestic detergents, and are rarely used with herbicides.

Crop oils

Most crop oils contain emulsifiers that allows them to mix with water. Some crop oils contain various levels of surfactants.

The benefits of crop oils are:

- reduced rainfast periods;
- more uniform droplet size (less chance of drift);
- less spray evaporation; and
- better penetration of herbicide into waxy leaves.

Oils can be divided into three main groups:

1. Mineral oils.
2. Vegetable oils.
3. Esterified vegetable oils.

Mineral oils. These products are usually a blend of mineral oil and non-ionic surfactant. Products such as Ad-Here® and D-C-Tron® have low levels of surfactant, whilst Uptake® and Supercharge® have higher levels. These products have lower potential of crop phytotoxicity as they are more refined.

Vegetable oils. These products are a blend of vegetable oils and non-ionic surfactant. Vegetable oils are sometimes called crop oil concentrates. Examples include Synertrol® and Codacide®.

Esterified Vegetable oils. These oils are the more commonly used products and are produced by reacting vegetable oil with alcohol and then blending with a high level of non-ionic surfactant. The physical and chemical properties are quite different to that of vegetable oil. They have claims of superior wax-modifying characteristics and penetrating ability. They should be used strictly according to the label with selective herbicides. Hasten® and Kwickin® are examples of these products.

Penetrants

Penetrants are specific compounds that help dissolve waxy cuticles.

Acidifying/buffering agents

Acidifying/buffering agents make spray solutions more acidic by lowering the pH. Herbicides are most stable when the pH of the solution is between 6 and 7 (neutral or slightly acidic). Examples include LI-700® and Primabuff BB5®.

Compatibility agents

Compatibility agents are materials that reduce the likelihood of antagonism from other agents in the spray solution. The most commonly used compatibility agent is ammonium sulfate. Compatibility agents are also used to neutralise the effect of hard water on amine formulations, such as glyphosate. Examples of these products are Liase®, and Liquid Boost®.

Other

Some adjuvants combine a number of roles. For example, Hot-up® contains surfactant, a compatibility agent, and oil.

There are also a range of other adjuvants which are added to herbicides during formulation, which improve the efficacy, increase crop safety, or ease of herbicide use. These include thickeners, spreaders, stickers, anti-foamers and safeners.[57]

Factors affecting adjuvant use

Crop safety

Addition of an adjuvant can reduce crop safety margins and, therefore increase crop damage. This is not an issue for fallow and pre-emergent herbicides.

Effectiveness or activity

Adjuvants are usually added to increase the effectiveness of herbicides. However, use of the wrong type or rate can reduce effectiveness, such as decreasing herbicide retention on leaves.

Water hardness

Hard water can lead to poor mixing of the chemical with water. This occurs particularly with emulsifiable concentrates. High levels of calcium and magnesium ions bind with the amine formulations causing them to be less soluble and, therefore, less effective.

Water temperature

Low water temperature can lead to 'gelling' in the spray tank. High concentration herbicides might not mix and surfactants might perform ineffectively.

8.13 Spraying issues

Spray drift

All herbicides are capable of drifting from neighbouring paddocks.

Pulses are particularly vulnerable to damage from phenoxy herbicides (Group I). Phenoxy herbicides are more prone to drift as a vapour, both during or after application.[58]

Spray drift can occur when herbicides are applied nearby in very windy or still conditions, especially where there is an inversion layer of air on a cool morning, late afternoon or evening.

Chemical users have a moral and legal responsibility to prevent herbicides from drifting and contaminating or damaging neighbouring paddocks and sensitive areas.

Contamination of spray equipment

The importance of cleaning and decontaminating spray equipment for the application of herbicides is critical.

Traces of sulfonylurea herbicides (such as chlorsulfuron, metsulfuron or triasulfuron) and Group G carfentrazone in spray equipment can cause severe damage to lentil and other legumes when activated by grass-control herbicides and/or adjuvants.

Product labels should always be referred to for specific product recommendations on decontamination.

57 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

58 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

Minimising damage from pre and post-emergent herbicides

Herbicide damage does not always result in reduced grain yield. Damage may be very obvious, such as scorched leaves, or it may be subtle, such as poor establishment or delayed maturity. Symptoms can be easily confused with symptoms produced by other causes, such as frost, disease or nutrition.

The risk of crop damage from a herbicide should be balanced against the potential yield loss from weed competition. In heavy weed infestations some herbicide crop damage can be tolerated. This is because some damage is easily offset by the yield loss avoided by removing competing weeds.

Some precautions for using pre-emergent residual herbicides can reduce the likelihood of crop damage:

- do not apply if rain is imminent;
- plant seed up to 8 cm deep;
- avoid leaving a furrow or depression above the seed that could allow water (and chemical) to concentrate around the seed/seedling;
- avoid leaving an exposed, open slot over the seed with disc openers; and
- avoid a cloddy, rough tilth with tyned openers.

If herbicide is applied to dry soils, the risk of movement and crop damage is increased greatly after rainfall. This is particularly so if the soil is left ridged and herbicide washes into the seed row. Incorporation by seeding (IBS) may be more appropriate in dry conditions or, alternatively, a split application will also minimise risk.

Metribuzin leaches at almost three times the rate of simazine and seven times the rate of diuron. The relative tolerance of the crop type and variety will also alter the level of crop damage from these herbicides.[59]

Some spray oils used with post-emergent selective grass herbicides can cause minor leaf spotting and/or burning, which should not be confused with disease symptoms.

Advice from an experienced agronomist should always be sought for specific details on soil active herbicides and the risk of crop damage in any particular situation.[60]

8.14 Selective sprayer technology

As a result of an increase in the use of no-till cropping and the incidence of summer weeds many growers have adopted a spray fallow system which has predominantly used glyphosate 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 becomes rather 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 as it is well suited to detecting patches of weeds across large areas.

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

59 Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia

60 P Matthews, D McCaffery, L Jenkins (2016) Winter crop variety sowing guide 2016, NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre/guides/winter-crop-variety-sowing-guide

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 as well as saving on herbicide costs.

Photo 21: *Selective sprayer technology, uses optical sensors to turn on spray nozzles only when green weeds are detected.*

Source: http://www.mcintoshdistribution.com.au/machinery/show/weedseeker-australia

Permits for herbicides using weed detectors

Weed-detecting technology (via WeedSeeker®) is being used to manage glyphosate-resistant grasses in northern NSW 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 and is for all Australian states.

This permit allows the use of about 30 different herbicides from groups with seven modes of action. Additional modes of action 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, glyphosate (450 g glyphosate/L) rates range from 3–4 L/ha (using a set water rate of 100L/ha), which far exceeds the label blanket rates of 0.4–2.4 L/ha. Similar increases in rate have also been permitted for paraquat (e.g. Gramoxone®).

The WeedSeeker® permit system is a great help for zero and minimum-tillage systems battling glyphosate-resistant weeds as it represents a more economical way to carry out a double-knock and avoids the need to cultivate for weed seed burial. It also results in significant savings in chemical costs.

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.[61]

8.15 Exotic weeds of lentil

Branched broomrape (*Orobanche* spp.)

Source: Pulse Australia (2016) Southern Lentil: Best Management Practices Training Course. Pulse Australia.

Description and life cycle

Branched broomrape is a serious parasitic pest of lentil (and faba bean) in the Middle East.

Orobanche spp., commonly known as broomrape, is a parasitic plant that attacks the roots of a considerable number of plant species. This includes a wide range of vegetables, pulses and pasture legumes.

Suitable hosts in Australia include lentil, faba bean, broad bean, chickpea, vetch, field pea, clover, cabbages, canola, capsicums, carrots, cauliflowers, celery, eggplant,

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

lettuce, melons, potato, and tomato. Major crops attacked overseas include sunflowers and tobacco.

Orobanche spp. drains its hosts of nutrients causing anything from 10 to 70% yield losses. Lentil and chickpea, for example, can suffer up to 50% yield loss with remaining seed being of poor quality.

Of the 20 or so *Orobanche* spp. worldwide, five are particularly weedy. These are *O. aegyptiaca, O. cernua var. cernua, O. crenata, O. cumana* and *O. ramosa*. Only three *Orobanche* spp. are known to be present in Australia. *O. cernua* var. *australiana* is a native that does not attack crops.

Lesser broomrape (*O. minor*) is a common minor weed. An infestation of *O. ramose*, or branched broomrape, has been found in South Australia. One *O. ramosa* plant can produce up to 500,000 seeds. As well as parasitising a range of pulse and vegetable crops, *O. ramosa* is the only broomrape to attack *Cannabis sativa*.

All *Orobanche* spp. are Australian Quarantine and Inspection Service (AQIS) prohibited imports. However, the seeds are very small, like dust, and could enter the country undetected.

The seeds can be spread in contaminated soil, on machinery, or by livestock. Even if these parasites become established in one location, Australian export markets could be affected as many of our trading partners prohibit *Orobanche* spp.

As *Orobanche* spp. has been identified as a major exotic threat, development of an emergency response is a priority.

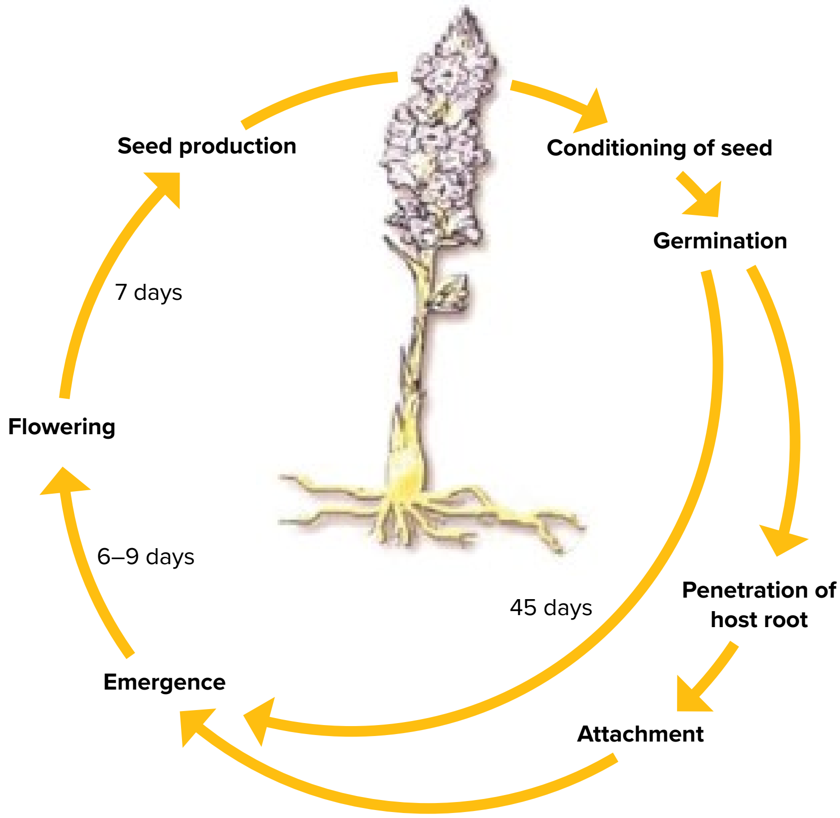

Figure 2: *Diagram of the life cycle of branched broomrape.*

Photo 22: *Flowering branched broomrape.*

(Photo: Grain Legume Handbook)

Photo 23: *Branched broomrape setting seed on capeweed.*

(Photo: Grain Legume Handbook)

Flowers/seed head

Flowers: Pale blue, tubular and two-lipped. Lower lip three-lobed and upper lip shallowly two-lobed. An erect spike of flowers appears in spring and summer.

Description

Mature plants are about 20 cm tall with several branches from ground level. Stems have dense soft woolly hairs on the upper part. Leaves are reduced to a few brown scales to 8 mm long. The capsule is enclosed in persistent corolla. Seeds are pepper-like, up to 40,000 per plant.

Distinguishing features

Branched yellow-brown glandular-hairy stems; absence of green parts; blue flowers.

Dispersal

Spread by seed.

Confused with

Other species of *Orobanche* in Australia; see a specialist to confirm identification.

Surveillance

As symptoms may be characteristic of a number of seedling weeds of lentil, plant samples of unknown or suspicious looking weeds should be sent for diagnosis.

Entry potential

High. Entry through seed, debris or soil contamination.

Establishment and spread potential

High, as has a fine, powder-like seed. Also spread by soil and debris to become problematic.

Economic impact

High. Yield and possible market losses could occur.

Overall risk

High

MORE INFORMATION

For details on Branched Broomrape, please see the Plant Health Australia website: http://www.planthealthaustralia.com.au/wp-content/uploads/2013/03/Branched-broomrape-FS.pdf

8.16 Legal considerations of herbicide use

Prior to making decisions on which herbicide to use the following must be done in relation to the proposed herbicide:

- registration status confirmed;
- rates of application and warnings related to withholding periods confirmed;
- all aspects of occupational health and safety (OH&S) considered; and
- residues and off-target effects obtained.

This information is available from state Department Chemical Standards Branches, chemical resellers, the Australian Pesticides and Veterinary Medicines Authority (APVMA) and the pesticide manufacturer.

Registration

Users should be aware that all pesticides (including herbicides) undertake a process called registration. Registration is authorised (registered) by APVMA and states the pesticide is for use:

- against specific pests;
- at specific rates of product;
- in prescribed crops and situations; and
- where risk assessments have been evaluated that these uses are:
  - » effective (against the pest, at that rate, in that crop or situation);
  - » safe (in terms of residues not exceeding the prescribed Maximum Residue Level (MRL)); and
  - » not a trade risk.

Labels

A major outcome of the registration process is the approved product label, a legal document, that prescribes the pest and crop situation where a product can be legally used, and how.

SDS

Safety Data Sheets (SDS) are also essential reading. These document the hazards posed by the product, and the necessary and legally enforceable, handling and storage safety protocols.

Permits

In some cases, a product may not be fully registered but is available under a permit with conditions attached. The permit often requires the generation of further data for eventual registration.

APVMA

The Australian Pesticides and Veterinary Medicines Authority is based in Canberra. Details of product registrations and permits are available via the APVMA's website www.apvma.gov.au

Always read the label

Apart from questions about the legality of such an action, the use of products for purposes, or in manners, not on the label involves potential risks. These risks include reduced efficacy, exceeded MRLs, and litigation.

Pesticide-use guidelines on the label are there to protect product quality and Australian trade by keeping pesticide residues below specified MRLs. Residue limits in any crop are at risk of being exceeded or breached where pesticides are:

- applied at rates higher than the maximum specified;
- applied more frequently than the maximum number of times specified per crop;
- applied within the specified withholding period; and
- not registered for the crop in question.

8.17 Appendix 1 – Common weed names

Broadleaf weeds

Amaranth: *Amaranthus* spp.

Amsinckia: *Amsincka* spp.

Bathurst burr: *Xanthium spinosum*

Bedstraw: *Galium tricornutum*

Bifora: *Bifora testiculata*

Black bindweed: *Galium tricornutum*

Blackberry nightshade: *Solanum nigrum*

Bladder ketmia: *Hibiscus trionum*

Boggabri weed: *Amaranthus mitchelli*

Buchan weed: *Hirschfeldia incana*

Caltrop: *Tribulus terrestris*

Capeweed: *Arctotheca calendula*

Catsear: *Hypochaeris radicata*

Charlock: *Sinapis arvensis*

Chickweed: *Stellaria media*

Chinese lantern: *Physalis minima*

Cockspur (Maltese): *Centaurea melitensis*

Common cotula: *Cotula australis*

Crassula: *Crassula helmsii*

Deadnettle: *Lamium amplexicaule*

Dock: *Rumex* spp.

Fat hen: *Chenopodium album*

Fumitory – common: *Fumaria officinalis*

Fumitory – red: *Fumaria densiflora*

Fumitory – white: *Fumaria parviflora*

Geranium: *Erodium* spp.

Goose foot: *Chenopodium pumilio*

Goose berry (wild): *Physalis minima*

Hares ear: *Conringia orientalis*

Heliotrope (white): *Heliotropium europaeum*

Hexham scent: *Melilotus indicus*

Hoary cress: *Cardaria draba*

Hogweed: *Polygonum aviculare*

Horehound: *Marrubium vulgare*

Ice-plant: *Gasoul crystallinum*

Lesser loose strife: *Lythrum hyssopifoli*

Lesser swine cress: *Coronopus didymus*

Lettuce-prickly: *Lactuca serriola*

Medic: *Medicago* spp.

Melon camel/afghan: *Citrullus lanatus*

Melon paddy/prickly: *Cucumis myriocarpus*

Mintweed: *Salvia reflex*

Muskweed: *Myagrum perfoliatum*

Mustard – ball: *Neslia paniculata*

Mustard – Indian hedge: *Sisymbrium orientale*

New Zealand spinach: *Tetragonia tetragonoides*

Noogoora burr: *Xanthium occidentale*

Oxalis: *Oxalis* spp.

Ox tongue: *Helminthotheca echioides*

Paterson's curse: *Echium plantagineum*

Peach vine: *Ipomea lonchophylla*

Pepercress: *Lepidium* spp.

Pigweed: *Portulacca oleracea*

Poppy – rough: *Papaver hybridum*

Radish: *Raphanus raphanistrum*

Saffron thistle: *Carthamus lanatus*

Scotch thistle: *Onopordum acanthium*

Sheep weed: *Buglossoides arvensis*

Shepherd's purse: *Capsella bursa-pastoris*

Sorrel: *Rumex acetosella*

Soursob: *Oxalis pes-caprae*

Sowthistle: *Sonchus* spp.

Speedwell - ivy leaf: *Veronica hederifolia*

Spear/black thistle: *Cirsium vulgare*

Spiny emex: *Emex* spp.

Storksbill: *Erodium* spp.

Tares: *Vicia* spp.

Three corner jack: *Emex* spp.

Toadrush: *Juncus bufonius*

Treacle mustard: *Conringia orientalis*

Turnip – long fruited: *Brassica tournefortii*

Turnip – short fruited: *Rapistrum rugosum*

Variegated thistle: *Silybum marianum*

Ward's weed: *Carrichtera annua*

White ironweed: *Buglossoides arvensis*

Wild radish: *Raphanus raphanistrum*

Wild turnip: *Brassica tournefortii*

Wireweed: *Polygonum* spp.

Yellow burr weed: *Amsinkia* spp.

Grasses

Barley grass: *Hordeum* spp.

Barnyard grass: *Enchinochloa crus-galli*

Brome grass: *Bromus* spp.

Canary grass: *Phalaris canariensis*

Johnson grass: *Sorghum halepense*

Liverseed grass: *Urochloa panicoides*

Paradoxa grass: *Phalaris paradoxa*

Phalaris: *Phalaris minor*

Prairie grass: *Bromus catharticus*

Annual Ryegrass *Lolium rigidum*

Sand fescue: *Vulpia fasciculata*

Silver grasses: *Vulpia bromoides*

Storksbill: *Erodium* spp.

Summer grass: *Digitaria* spp.

Vulpia: *Vulpia bromoides*, *Vulpia myuros*

Wild oats: *Avena fatua*, *Avena ludoviciana*

Winter grass: *Poa annua*