Guidelines to managing key weed species across low-rainfall regions of south-eastern Australia

Practical strategies for effective integrated weed control
Cover photos: (Top) Joe Koch, (Bottom) Ben White and (Insets) Andrew Storrie, Agronoma Consulting.
Foreword

Weed control makes up a significant portion of the total cost of crop production across Australia’s cropping regions. The total cost of weeds (revenue loss plus expenditure) to Australian grain growers is estimated at $3.3 billion*. Reliance on chemicals alone is not a sustainable option due to the inevitability of herbicide resistance.

Effective long-term weed control requires careful planning to maximise production benefits while protecting and enhancing the natural resource base of our farming enterprises. Maximising ground cover (and so minimising erosion risk) is a critical part of any effective weed management plan.

Keeping weed seedbanks to a minimum, using a range of chemical and non-chemical control methods, including careful use of herbicides, strategic burning and cultivation, weed seed destruction and selective grazing is the key to sustainable weed management. A combination of chemical and non-chemical weed management strategies is essential to slow down the onset of herbicide resistance and so preserve herbicides for their best effect.

This practical guide provides a comprehensive, technically-up-to-date overview of integrated weed management (IWM) options growers across the low-rainfall regions of south-eastern Australia can employ to maximise their broadacre crop returns. The practices outlined in the following pages are sustainable and provide environmental benefits as well as offering cost-effective and successful weed control outcomes. The publication will appeal to growers, their advisers and those involved in natural resource management (NRM).

Special thanks to Jen Lillecrapp for her project coordination, Matt McCallum, Sam Trengove, Ben Fleet, Gurjeet Gill, Andy Bates and Catriona Nicholls for their editorial work, and to Megan Hele for her design and layout efforts; creating a publication that is a pleasure to read and provides a lasting legacy of the Delivering multiple benefit messages — A partnership with NRM project.

Mark Stanley
Executive Officer, Ag Excellence Alliance


Production and Environment Partnerships

Delivering multiple benefit messages — A partnership with NRM is an innovative project, which delivered technologies to growers across south-eastern Australia that have increased production and profitability while addressing key natural resource issues.

Working in partnership with seven NRM regions, the project brought together the expertise of the grains industry with natural resource networks in these regions to extend the uptake of new and improved farming practices.

A significant part of the project was developing and delivering four regional extension and communication projects to address high-priority regional issues around IWM and managing sandy soils.

This publication is a legacy of the two IWM projects carried out in partnership with the Northern Yorke NRM region — A Holistic Approach to Weed Management — All Weeds in All Years, and the Mallee Catchment Management Authority (CMA) and the Western Local Land Services (LLS) — Integrated Weed Management Strategies to Manage Brome Grass.

Photo: Andrew Storrie, Agronomo Consulting

Ag Excellence Alliance supports farming systems groups across south-eastern Australia, and providing linkages with natural resource management regions.

GRDC are the major funders of this project

GRDC Grains Research & Development Corporation
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NRM Organisations, Producer & Environment Partnerships, Grains Industry.
Guidelines for managing key weed species across low-rainfall districts of south-eastern Australia

These Guidelines for managing key weed species across low-rainfall districts of south-eastern Australia have been produced as part of the Delivering multiple benefit messages — A partnership with NRM project, with funding from the Grains Research and Development Corporation (GRDC).

Natural Resources — Northern and Yorke, Upper North Farming Systems (UNFS), Laura Ag Bureau and Nelshaby Ag Bureau were involved in this project.

More details can be found at www.agex.org.au

Compiled by Matt McCallum, McAg Consulting.

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Contents

Non-chemical weed control .......................................................... 4
Getting the best out of herbicides ........................................... 8
New technology in weed control ............................................... 12
Weed profiles
  Brome grass ........................................................................... 16
  Annual ryegrass ..................................................................... 18
  Barley grass ........................................................................... 20
  Wild oats ................................................................................ 22
  Silvergrass ............................................................................. 24
  Onion weed ........................................................................... 26
  Wild radish ............................................................................ 28
  Flaxleaf fleabane ................................................................... 30
  Statice ................................................................................... 32
  Buffel grass ........................................................................... 33
Websites and online resources .................................................. 34
Non-chemical weed control supports sustainable integrated strategy

- Relying on herbicides as single weed control strategy is fraught with danger and will increase the speed of onset of herbicide resistance.
- A range of non-chemical weed control options is available, which will prolong the life of current herbicides and offer a range of NRM benefits.
- Selecting suitable non-chemical weed control strategies will depend on the target weed, paddock history and available resources.

A wide range of non-chemical weed control options exists (Table 1) and it is critical growers use these alternative control methods to complement and protect the efficacy and longevity of currently-available herbicides.

Low-risk, low-cost non-chemical control options, such as those described here, that have a high chance of success are best suited to low-rainfall cropping areas.

**Increased crop competition**

Encouraging increased crop competition to suppress weed growth can be achieved in many ways, including: crop species and varietal selection, early sowing, reducing row spacing, increasing sowing density, and improving sowing accuracy.

Including more competitive crops (e.g. barley) in the rotation, and selecting varieties with greater early vigour reduces weed competition and seed set.

The sole reliance on herbicides for weed control is unsustainable given the increasing development of herbicide resistance, limited herbicide options for particular weeds or crop types and the ongoing change in behaviour of weed populations in response to ever-changing farming practices.

Narrow row spacings (18–25cm) and sowing rates at the higher end of district recommendations will increase competition through greater crop density. If tyne spacing is wider than 25cm, then ‘splitter boots’ can be used to effectively reduce row spacing.

Paying attention to sowing accuracy, with a particular focus on sowing depth (e.g. not too deep or shallow), is important in establishing a competitive crop.

Agronomic practices that limit root disease, insect damage and nutritional deficiencies also help to promote early crop vigour reducing the opportunity for weeds to compete with the crop.

When looking to use increased crop competition as a key weed control strategy, keep in mind that one major downside, particularly in low-rainfall areas, is the potential to exhaust limited soil moisture reserves during spring, leading to reduced grain yield and grain size. Keep sowing rates within district recommendations to limit this risk.
Crop row orientation
Research carried out in Western Australia has revealed sowing in an east–west direction can reduce weed competition and seed set in annual ryegrass. This is due to the crop intercepting more sunlight than the weeds when sown from east to west compared with a north–south orientation, giving the crop a competitive advantage, particularly early during the season.

Full-cut cultivation
Full-cut cultivation is effective if weeds have emerged (and reached the 3–4 leaf stage) at the time of cultivation. Although suited to most weed types, full-cut cultivation does not suit all soil types because of the high risk of erosion with this practice. Heavy clays are most suited to full-cut cultivation.

Weed-free seed
Keeping grain from ‘clean’ paddocks for future crop production and using a professional seed cleaner can both significantly reduce the number of weed seeds likely to be present in the crop seed, effectively reducing the overall weed seedbank and preventing further spread from paddock to paddock.

Hay production
Cutting and baling crops or pasture for hay can result in up to 95 per cent control of many weed species provided grazing or spray-topping is used to control regeneration or germination of weeds after hay is removed.
Table 1. Evaluation of non-chemical weed control methods for low-rainfall cropping regions of south-eastern Australia

<table>
<thead>
<tr>
<th>Weed control method</th>
<th>Likelihood of success in low-rainfall regions</th>
<th>Adoption cost</th>
<th>Potential issues, risks and considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased crop competition by manipulating crop species, variety, sowing time, row spacing, sowing density or sowing accuracy</td>
<td>High</td>
<td>Low</td>
<td>Too much crop competition can exhaust available soil moisture early leading to reduced yields and grain size. Narrow row spacing requires attention to residue management for problem-free sowing.</td>
</tr>
<tr>
<td>Crop row orientation (east–west)</td>
<td>Medium</td>
<td>Low</td>
<td>May not suit all paddocks.</td>
</tr>
<tr>
<td>Full-cut cultivation</td>
<td>High*</td>
<td>Medium</td>
<td>Increased erosion risk. May bury some weed seeds away from the region of herbicide activity.</td>
</tr>
<tr>
<td>Weed-free seed</td>
<td>High</td>
<td>Low^</td>
<td>Nil</td>
</tr>
<tr>
<td>Hay production</td>
<td>High</td>
<td>High</td>
<td>Specialised equipment or contractors may be required. High transport costs.</td>
</tr>
<tr>
<td>Stubble burn</td>
<td>Low</td>
<td>Low</td>
<td>Stubble loads in low-rainfall regions are often too low (&lt;2t/ha) for an effective burn. Stubble burning increases erosion risk and organic matter loss.</td>
</tr>
<tr>
<td>Grazing pastures</td>
<td>Low</td>
<td>Low</td>
<td>Grazing alone is ineffective, but when combined with spray-grazing, spray-topping or slashing it can provide adequate control.</td>
</tr>
<tr>
<td>Chaff cart</td>
<td>High**</td>
<td>High^^</td>
<td>Some logistical issues at harvest. Well suited to farms with livestock enterprises, where livestock can feed on chaff residues.</td>
</tr>
<tr>
<td>Narrow windrow burning</td>
<td>High**</td>
<td>Low</td>
<td>Risk of fire escaping windrows, some loss of nutrients. Requires additional work during autumn (e.g. burning and managing windrows). Success can be compromised if stubble is grazed over summer.</td>
</tr>
<tr>
<td>Harrington Seed Destructor (HSD) and Integrated Harrington Seed Destructor (iHSD)</td>
<td>High***</td>
<td>High</td>
<td>Loss of harvester capacity due to horsepower requirements (iHSD). On-going cost and maintenance (HSD). One-pass convenience.</td>
</tr>
</tbody>
</table>

Source: Adapted from a table compiled by Andy Bates, Bates Agricultural Consulting

* If weeds have emerged at time of cultivation.
** If seeds can be captured.
^ Low cost on a per hectare basis.
^^ High initial investment, but ongoing costs are low.
Guidelines for managing key weed species across low-rainfall regions of south-eastern Australia

Further information
- The Effectiveness of On-farm Methods of Weed Seed Collection at Harvest Time: http://www.grdc.com.au/CaseStudy-WeedSeedHarvest-Albany
- Integrated Harrington Seed Destructor: http://www.ihsd.com/

Stubble burning
Research from WA by Michael Walsh and Peter Newman (Australian Herbicide Resistance Initiative) determined the temperature and duration required to destroy weed seeds of annual ryegrass are >400°C for at least 10 seconds and >500°C for at least 10 seconds for wild radish. Temperatures for other weed species are yet to be determined, but are likely to be similar. These temperatures can be achieved in a whole-paddock burn if cereal stubble loads are >4t/ha.

In low-rainfall cropping regions, stubble loads are often 2t/ha or less, making stubble burning an ineffective strategy for controlling weeds. Stubble burning also substantially increases the risk of wind erosion.

Narrow windrow burning after harvest is a far better option in low-rainfall cropping regions to control weeds and protect soils.

Grazing pastures
Grazing pasture in itself is generally ineffective in controlling weeds unless combined with slashing, cultivation and/or spray-topping or spray grazing, where weed control can be up to 95 per cent for many common weeds.

Harvest weed seed management
Collecting and destroying weed seeds at, or soon after, harvest is gaining popularity among growers as an effective non-chemical control measure, particularly for annual ryegrass. Seed retained in the head of many annual weeds can be collected by the harvester if the crop is harvested low (<15cm). Most of these weed seeds are then present in the chaff fraction of the harvest residue. This chaff fraction (containing the weed seeds) can then be destroyed by burning (narrow windrow, chaff pile) or with a seed destruction device attached to the harvester (e.g. Harrington Seed Destructor). This technique is less suited to weeds that mature rapidly and shed a portion of their seed before harvest (e.g. brome grass).

However, as outlined in the Australian Herbicide Resistance Initiative publications — Harvest Weed Seed Control — the most troublesome annual weed species of Australian cropping systems produce mature seed on upright plant structures at the time of harvesting wheat. Annual ryegrass, wild radish and wild oats all retain high proportions (>70 per cent) of total seed production above harvest cutting height (15cm) at the commencement of the wheat harvest.

Above: Collect weed seeds at harvest for subsequent destruction through burning or devices such as the Harrington Seed Destructor. Photo: Sam Trengove, Trengove Consulting
Left: Grazing is most effective when combined with other non-chemical and chemical control methods. Photo: Catriona Nicholls
Herbicide resistance was first reported in annual ryegrass on farm during 1982 near Bordertown, South Australia. Since then the problem of herbicide-resistant weeds in annual cropping systems has increased dramatically. Currently, there are 39 different weed species with confirmed herbicide resistance in Australia.

As outlined in this publication employing a strategic integrated weed management (IWM) program will prolong the life and efficacy of existing herbicides, slow down the rate of herbicide resistance in important weed species and play a role in protecting the natural resources we rely on for profitable and productive crops.

Understanding how herbicide resistance develops and following some key herbicide management strategies will help you get the most out of this important control option well into the future.

Herbicide resistance — the basics
Initially, the number of plants in any given weed species population with a natural resistance to the herbicides designed to control them exist at low levels. When a herbicide is applied to a population of weeds it will control most of the susceptible population. The naturally-resistant plants survive and set seed, increasing the proportion of resistant weeds in any given paddock over time if a herbicide with the same mode of action (MoA) is used repeatedly or survivors are not controlled using another method.

The sole reliance on the same MoA herbicides to control weeds season after season increases the speed at which resistance occurs (the actual rate of resistance also depends on the risk level of the herbicide and the genetic make-up of the weed species) — it’s only a matter of time. Hence it is important to rotate the MoA groups of herbicides used to control specific weeds to delay the onset of herbicide resistance. Combining a strategic chemical control program with non-chemical methods also will help to remove resistant weeds from the system.

Not all herbicides are high risk
Herbicides are grouped based on their MoA and not all groups carry the same risk of developing resistance in weed populations (Table 2). Group A and B herbicides are the highest-risk herbicides as weed populations develop resistance rapidly.
under continued use of these herbicides — as is the case with annual ryegrass. Understanding the risk profile of different herbicide options allows growers to develop a more strategic application program to slow the development of resistance and increase the overall efficacy of your weed-control program.

Testing for herbicide resistance

Many growers wait until a herbicide completely fails before they recognise they have a serious resistance problem. Regular herbicide-resistance testing of weed seedlings or weed seeds in individual paddocks is critical to prolonging the life of existing herbicide options and to delay and manage the financial impacts of herbicide resistance.

Understanding the herbicide resistance profile of your paddocks also is important when planning an IWM program, which involves rotating herbicide MoA groups in combination with some form of non-chemical weed control.

Pre-emergent herbicides and no-till cropping systems

No-till cropping and stubble retention (NTSR) systems have resulted in substantial benefits to Australian agriculture spanning the past 40 years. However NTSR systems rely heavily on pre-emergent herbicides to control weeds — primarily grass weeds.

Understanding the basic properties of these herbicides and paying careful attention to application practices will ensure these products have the best chance of success.

The key properties of pre-emergent herbicides to consider include the solubility (how easily they dissolve in a soil solution) and how tightly they bind to soil organic matter (SOM) and stubble (Table 3).

Highly-soluble herbicides, such as triasulfuron (e.g. Logran®) tend to require less soil moisture to be activated and absorbed by a germinating weed seedling, but can move rapidly away from the top soil and germinating seedlings after a significant rainfall event (>10mm). In contrast, herbicides with lower solubility, such as trifluralin (e.g. Treflan®) bind more tightly to SOM and stubble and therefore do not move into the soil solution or ‘wash off’ stubble as easily as more soluble products.

It is worth noting that insoluble or low-solubility herbicides, which bind tightly to SOM and stubble, are less effective if more than 50 per cent of the soil surface is covered with stubble.

Tips for improving the efficacy of pre-emergent herbicides in the presence of stubble:
- Increase water rates (80L/ha as a minimum) to improve overall coverage.
- Keep as much stubble standing as practical to maximise the amount of herbicide reaching the soil surface and emerging weed seedlings.
- Slow the spraying speed (16km/hr or less) to minimise ‘sheeting’ of herbicide on stubble.
- Spray in the same direction as the stubble rows to increase the chance of herbicide hitting the soil surface and emerging weed seedlings.
- Consider combining herbicides with different properties into the same application (always check compatibility first).
- Always use recommended herbicide rates — off-label rates will not save money and may reduce efficacy.

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Basic principles of the S.T.A.R. program

Stress — can reduce herbicide efficacy and increase crop effect. Before spraying ask:
- Is the soil waterlogged?
- When did it last rain?
- Are there insect pests or disease present?
- Have there been frosts?
- Is crop nutrition sufficient?

Timing — early spraying, when weeds are small, is usually the most effective option, returning the highest crop yields. Spraying at the optimal time:
- ensures adequate penetration and coverage
- minimises weed competition
- maximises yield
- optimises herbicide efficacy.

Be prepared to spray twice to control later-germinating weeds.

Application — correct application optimises results.
- Check equipment, keep it clean and change nozzles regularly.
- Follow directions on water volume, droplet size and spraying speed.
- Only mix products that are compatible as indicated on the product label.

Rate — cutting application rates does not save money and may reduce efficacy.
- Always use recommended rates.


Post-emergent herbicide success

Poor weed control results are not always due to the presence of herbicide-resistant weeds. Timing, coverage, weed size and environmental factors all influence herbicide success. The S.T.A.R. (stress / timing / application / rate) program provides a simple set of guidelines to help growers optimise herbicide efficacy and minimise the risk of failure.

Crop topping

Crop topping is an effective pre-harvest management strategy to stop seed set of weeds that have escaped pre-emergent and selective herbicide applications throughout the season. Crop topping involves applying a non-selective herbicide to flowering weeds that remain after previous applications. Timing is critical to ensure weed seeds are not filling, and the crop is advanced enough so as not to impact on grain quality. It is critical to only use a product that is specifically registered for crop topping (Table 4).
### Table 2. Common herbicides used in low-rainfall cropping regions and number of years before herbicide resistance is likely to be a problem

<table>
<thead>
<tr>
<th>Herbicide group</th>
<th>Common actives (product example) used in low-rainfall cropping regions</th>
<th>Years of application before resistance is likely to be a problem</th>
<th>Resistance risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>A ‘fop’</td>
<td>Haloxyfop (Verdict®), clodinafop (Topik®), quizalofop (Targa®)</td>
<td>6</td>
<td>High</td>
</tr>
<tr>
<td>A ‘dim’</td>
<td>Clethodim (Select®), butroxydim (Factor®), tralkoxydim (Achieve®)</td>
<td>8</td>
<td>High</td>
</tr>
<tr>
<td>B</td>
<td>Chlorsulfuron (Glean®), triasulfuron (Logran®), imazapyr + imazamox (Intevix®), metsulfuron (Ally®), flumetsulam (Broadstrike®)</td>
<td>4</td>
<td>High</td>
</tr>
<tr>
<td>C</td>
<td>Simazine (Simazine 900DF®), diuron (Diuron 900DF®), terbuthylazine (Terbyne®), metribuzin (Lexone®)</td>
<td>10–15</td>
<td>Moderate</td>
</tr>
<tr>
<td>D</td>
<td>Trifluralin (Treflan®), propyzamide (Kerb®)</td>
<td>10–15</td>
<td>Moderate</td>
</tr>
<tr>
<td>F</td>
<td>Diflufenican (Brodal®)</td>
<td>10</td>
<td>Moderate</td>
</tr>
<tr>
<td>G</td>
<td>Oxyfluorfen (Goal®), carfentrazone (Hammer®, Affinity®)</td>
<td>&gt;15</td>
<td>Moderate</td>
</tr>
<tr>
<td>I</td>
<td>2,4-D (2,4-D Amine 625®), MCPA (Agritone 750®), LVE MCPA (LVE Agritone®), cloypraid (Lontrel®), dicamba (Banvel®)</td>
<td>&gt;20</td>
<td>Moderate</td>
</tr>
<tr>
<td>J</td>
<td>Triallate (Avadex®), prosulfocarb (BoxerGold®)</td>
<td></td>
<td>Moderate</td>
</tr>
<tr>
<td>K</td>
<td>Metolachlor (DualGold®, BoxerGold®), pyroxasulfone (Sakura®)</td>
<td>&gt;15</td>
<td>Moderate</td>
</tr>
<tr>
<td>L</td>
<td>Diquat (Reglone®, SpraySeed®), paraquat (Gramoxone®, SpraySeed®)</td>
<td>&gt;15</td>
<td>Moderate</td>
</tr>
<tr>
<td>M</td>
<td>Glyphosate (Roundup®)</td>
<td>&gt;12</td>
<td>Moderate</td>
</tr>
<tr>
<td>Z</td>
<td>Flumetsulam (Prill®)</td>
<td></td>
<td>Moderate</td>
</tr>
</tbody>
</table>


* This product contains more than one active
Table 3. Water solubility and binding characteristics of some common pre-emergent herbicides

<table>
<thead>
<tr>
<th>Herbicide</th>
<th>Solubility</th>
<th>Ability to bind to soil organic matter (SOM) and stubble</th>
<th>Comments</th>
<th>Suitability to be used in high stubble loads (&gt;50% cover)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trifluralin (e.g. Treflan®)</td>
<td>Very low</td>
<td>High</td>
<td>Ties up on SOM and stubble. Does not move far in soil. Placement relative to weed seed is very important.</td>
<td>Maybe</td>
</tr>
<tr>
<td>Triallate (e.g. Avadex®)</td>
<td>Low</td>
<td>High</td>
<td>Ties up on SOM and stubble. Does not move far in soil. Placement relative to weed seed is very important.</td>
<td>Maybe</td>
</tr>
<tr>
<td>Triasulfuron (e.g. Logran®)</td>
<td>High</td>
<td>Low</td>
<td>Very mobile in soil solution. Application relative to weed seed position not critical. Little moisture required to ‘activate’ herbicide.</td>
<td>Yes</td>
</tr>
<tr>
<td>Proslufocarb (BoxerGold™)</td>
<td>Low</td>
<td>High</td>
<td>Slight mobility. Rainfall required after application to ‘activate’. Poor weed control possible if high level of stubble.</td>
<td>Yes</td>
</tr>
<tr>
<td>Metolachlor (BoxerGold™)</td>
<td>High</td>
<td>Medium</td>
<td>Little rainfall required to ‘activate’ and quite mobile in soil solution.</td>
<td>Yes</td>
</tr>
<tr>
<td>Pyroxasulfone (Sakura®)</td>
<td>Low</td>
<td>Medium</td>
<td>Low water solubility so apply close to weed seeds. Can move a bit in soil solution in soils with low SOM.</td>
<td>Yes</td>
</tr>
<tr>
<td>Diuron (e.g. Diuron 90DF®)</td>
<td>Medium</td>
<td>High</td>
<td>Requires little water to ‘activate’ but binds tightly to SOM and stubble. Can be quite mobile in sands where SOM levels are low.</td>
<td>Yes</td>
</tr>
<tr>
<td>Simazine (e.g. Simazine 90DF®)</td>
<td>Medium</td>
<td>Medium</td>
<td>Requires little rainfall to ‘activate’. More mobile than diuron.</td>
<td>Yes</td>
</tr>
<tr>
<td>Metribuzin (e.g. Lexone®)</td>
<td>High</td>
<td>Low</td>
<td>Very mobile in soil solution. Prone to moving into crop seed row with rainfall.</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Source: Adapted from tables compiled by Andy Bates, Bates Agricultural Consulting (unpublished) and Barry Haskins (2012).

Haskin, B (2012) Using pre-emergent herbicides in conservation farming systems, NSW DPI.

* This product contains more than one active

Table 4. Registration status for late-season herbicide use by crop type*

<table>
<thead>
<tr>
<th>Crop</th>
<th>Paraquat</th>
<th>Diquat</th>
<th>Glyphosate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Barley</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Canola</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Chickpeas</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Lentils</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Faba beans</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Field peas</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>


* Always check product labels before application

Resistance testing services
- Peter Boutsalis
- Charles Sturt University

Crop topping
New technology targets cost-effective weed control

Weeds are rarely distributed uniformly across paddocks, however most weed control tactics are delivered in a blanket approach regardless of weed density and distribution. This blanket approach results in excessive and inefficient herbicide use, with product being over or under applied across the whole paddock. Management strategies that target individual weeds, or ‘weedy patches’, either in crop or during the summer fallow are more cost efficient.

Identify and locate the target weed

Growers can identify and map the location of target weeds species in several ways: ground-based visual estimation, remote and proximal sensors, machine vision or by soil type.

Many growers try ‘patching out’ weeds, usually based on their own observation of weed patches and the weed map they have in their mind. This can be successful, but often the reality is they should have sprayed more or sprayed the whole paddock because they missed weeds and this was obvious later in the season when the weeds went to seed. This experience indicates the weed map was not accurate enough.

Either more effort needs to be invested in developing the weed map, or a more robust and reliable method needs to be employed. However, a lack of reliable and robust mapping methods remains the biggest stumbling block to the uptake of SSWM, which current research efforts are addressing.

A range of new technology is available, enabling growers to target weeds with more precision and cost effectiveness through site-specific weed management (SSWM).

Identifying and locating weeds across the paddock is the first step towards targeted weed control.

Remote and proximal sensing technology can discriminate weed infestations from weed-free crop areas, but still requires ground-truthing for appropriate chemical selection and application.

Machine vision weed sensors will be the next generation of sensors that advance the capability of site-specific weed management.

Optical sensing devices can be used to ‘spot spray’ weeds during summer resulting in savings of up to 90 per cent in herbicide costs, while improving the management of ‘hard-to-control’ weeds.

Key facts

- A range of new technology is available, allowing growers to better target weeds through ‘site-specific weed management’ (SSWM) — reducing the amount and cost of herbicide and increasing the target-specificity of weed control efforts.

The four main steps to implementing an effective SSWM program include:

1. identifying and locating the target weed
2. determining the control tactic
3. applying the control tactic
4. documenting the application.
Ground-based visual estimates: Ground-based visual estimates can produce accurate weed maps. Methods for recording this information include touch-sensitive screens flagging weed presence and density with GPS location. This can be carried out while performing other paddock operations, such as harvest, spraying and spreading. However, the accuracy of a map generated this way depends upon the skill, experience and attention to detail of the operator, particularly when identifying weeds at lower densities.

Remote and proximal sensor: Remote and proximal sensor measurements of vegetation indices, most commonly the normalised difference vegetation index (NDVI), can discriminate weed infestations from weed-free crop areas based on the change in reflectance due to increased biomass associated with increased weed density.

The NDVI identifies the location of weed infestations, but cannot identify the weed species, so requires ground-truthing for appropriate chemical selection and application. Sensing platforms can include satellite, aeroplane, unmanned aviation vehicles (UAV), and vehicle-mounted sensors such as GreenSeeker™, N-Sensor™, Crop Circle™ and Crop Spec™. The success of this approach and the weed densities that can be detected are affected by differences in growth rates of weed and crop, time of emergence, differences in vigour and timing of flowering and maturity. This approach can also be used during the fallow period to identify weed patches. In general, this is an opportunistic approach to mapping weeds that will only be possible when the right set of crop and weed conditions are present. That is, when the crop is relatively uniform and the weed patches of interest have big enough leaf area to affect the vegetative index.

Machine vision weed sensors: Machine vision weed sensors are the next generation of sensors that advance the capability of SSWM. These sensors identify weeds within a growing crop based on shape parameters from high-resolution images. Crop and weed shape features are extracted from the image and compared to a database for classification.

A South Australian Grains Industry Trust (SAGIT)-funded project is currently investigating the capability of the H-Sensor for application in South Australian cropping systems. Developed in Germany by Agricon it is designed to identify weeds within a growing crop. It uses leaf shape and size parameters to classify different plants into different shape classifications and has been successfully tested in Europe on wheat, canola, sugar beet and maize to target both broadleaf and grass weeds in these crops. The sensor can directly control a sprayer or can be used to generate a map for later use.

Soil type: Soil type can be used to map some weeds indirectly where weed density is related to soil type. Soil type characteristics can be mapped with sensors such as EM38, gamma radiometrics, Veris pH, organic carbon (OC) and electrical conductivity (EC) or yield data can be used to identify different production zones often related to soil properties. Ground truthing is always required in these situations to ensure the soil zones properly reflect the weed patches.
Determine the weed control tactic

The most effective weed control tactics will depend on the weed in question and the crop scenario. Some SSWM tactics are detailed in Table 5.

Growers have successfully controlled annual ryegrass, brome grass, wild oats, wild radish and skeleton weed by using weed maps to target high-density weed patches. Often targeted control approaches, such as in-crop desiccation of weedy patches during spring with high rates of herbicide to ensure 100 per cent control, are more aggressive and effective than a standard ‘whole-paddock’ treatment, which effectively only targets 10–15 per cent of the paddock in many cases.

Practical strategies, where growers are using SSWM include:

- **Desiccation**: weedy patches are sprayed with a non-selective herbicide (e.g. glyphosate) before weeds have set any viable seed. Generally, desiccation is considered a targeted brown manure strategy, which requires crop to be sacrificed.
- **Hay production**: annual ryegrass patches in wheat and barley crops are cut for hay.
- **Narrow windrow burning**: high-weed-density patches are harvested separately from the rest of the paddock and narrow windrows are burnt during autumn.
- **Stubble burning**: a fire break is formed around patches of annual ryegrass so the stubble can be burnt after harvest to destroy weed seeds.

Optical sensing technology

A number of companies now produce optical-sensing devices, which can detect plants by using near infra-red reflectance (NIR) technology to measure the chlorophyll reflected by plants when exposed to a light source. At this stage the technology does not discriminate between crops and weeds, so is used when there is no actively-growing crop present, (e.g. summer fallow).

When combined with a solenoid that switches the spray nozzle on and off, this technology can be used to ‘spot spray’ weeds. Optical-sensing technology has been proven to reduce summer weed spraying costs by up to 90 per cent and help kill ‘hard-to-control’ summer weeds (e.g. fleabane, onion weed, Lincoln weed) by using higher doses of herbicide and/or more expensive products.

There are currently two commercially-available optical-sensing systems available in Australia — the WeedSeeker™ and WEEDIT™ spray systems (Figure 1).
Table 5. A range of site specific weed management tactics and their requirements

<table>
<thead>
<tr>
<th>Site specific control</th>
<th>Requirements and comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Non-chemical control</strong></td>
<td></td>
</tr>
<tr>
<td>Hay cutting and baling</td>
<td>Hay equipment and a weed map.</td>
</tr>
<tr>
<td>Stubble burning</td>
<td>A fire break will be required around the weed patches.</td>
</tr>
<tr>
<td>Increased crop competition through increased sowing rates</td>
<td>A georeferenced prescription map based on weed density can be used to automatically adjust crop sowing rates. This relies on a historical weed map. Most modern sowing equipment is fitted with GPS-ready rate controllers. Alternatively sowing rates can be doubled by completing a second sowing pass, or adjusted by using a manually-operated variable seed rate controller.</td>
</tr>
<tr>
<td><strong>In-crop herbicide control</strong></td>
<td></td>
</tr>
<tr>
<td>On/off decision</td>
<td>A conventional boomspray and a weed map can be set up for automatic switching through a rate controller or switched on/off manually by the operator.</td>
</tr>
<tr>
<td>Add an extra herbicide to a base tank mix where the weed patches are</td>
<td>This approach can only be achieved with a standard boomspray by spraying the base tank mix in one application and then completing another pass across the paddock with the additional herbicide — only turning on the boom over the weed patches. A boom set up with direct injection and dual lines can achieve the same thing in one pass. The base mix is mixed in the tank and sprayed through the first boom line. Additional herbicides can be injected into the second boom line, which is also primed with the base tank mix. When the additional herbicide is required the second boom line is switched on and the first boom line switched off. Direct injection into a single line alone cannot be used for variable-rate herbicide application due to the long lag time from the point of injection to the time it reaches the last nozzle.</td>
</tr>
<tr>
<td>Adjust the rate of a herbicide mix</td>
<td>Currently the only way rates can effectively be adjusted in real time is by adjusting the spray carrier volume as this can be changed instantly and equally across the boom. Limitations to this process include the relationship between nozzle flow rate and droplet size distribution, and all herbicides in the mix are altered by the same percentage. With conventional booms and nozzles the limitation of the nozzle flow rate restricts the amount the carrier volume can be varied, however this can be compensated for somewhat by adjusting ground speed. Dual line systems, variable orifice nozzles (VariTarget), nozzle banks (Arag Seletron and Hypro Duo React), and pulse width modulation (Aim Command Case IH, Pinpoint Capstan, Hawkeye Raven and Dynajet Flex 7120 TeeJet) provide more flexibility in flow rate and so carrier volume can be varied more without sacrificing ground speed. Flow rates from 1x up to 8x can be achieved at the same ground speed. The latter two options allow independent rate control of the individual nozzle, increasing application resolution compared with most other options that operate at the resolution of the boom section or whole boom.</td>
</tr>
<tr>
<td>Apply a different herbicide mix to different weed zones</td>
<td>Multi-tank boomsprays are designed as two or more sprayers on the same chassis. The boom consists of two or more tanks and each has a separate pump, lines and nozzles that can be controlled independently. Different herbicides or herbicide mixes can be added to each tank and they can be turned on or off based on separate prescription maps. The rates of each tank mix can be varied as for a normal boom. There are examples of growers plumbing a second (smaller) tank into the second boom line allowing two different tank mixes to be applied independently.</td>
</tr>
</tbody>
</table>

Source: Sam Trengove, Trengove Consulting

- **In-crop ‘spot spraying’**: wild radish patches in pulse crops are sprayed with a late-season application of glyphosate using a second spray tank in conjunction with insecticide applications.
- **Fallow ‘spot spraying’**: patches of skeleton weed are sprayed using 2,4-D amine in a second spray tank during summer spraying.
- **Increased herbicide rates**: pre-emergent rate of herbicides are increased in high-density annual ryegrass, brome grass and wild oat areas to improve weed control.
- **Variable rate sowing**: higher sowing rates are employed across high weed density patches to out-compete weeds.

**Documentation**

Documentation is important for compliance, quality assurance and for future reference. Knowledge of herbicide use and other weed control tactics is important for understanding herbicide resistance issues and potential plant back issues in cropping rotations. Therefore it is important to have an accurate record of where treatments have been applied.

**Further information**

Guidelines for managing key weed species across low-rainfall regions of south-eastern Australia

**Brome grass**
* (Bromus rigidus and Bromus diandrus)

**Key facts**
- During the past 15–20 years the adoption of no-till cropping has favoured the emergence of brome grass as a major grass weed in low-rainfall regions.
- Brome grass is highly competitive and yield losses of 30–50 per cent in wheat can occur when grass populations are >100 plants/m².
- Herbicide-resistant populations of brome grass are increasing, with resistance to groups A, B and M becoming more common.
- Three consecutive years of seed-set control is required to sufficiently reduce brome grass populations.

**Brome grass is drought tolerant**, can thrive in low-phosphorus soils, responds to nitrogen and large individual plants can produce up to 3000 seeds. This grass weed is adapted to a broad range of soil types and has become widespread across the region. The effective control of brome grass is most challenging on non-wetting sands.

**Survival mechanisms suit no-till cropping systems**

There are several mechanisms that enable brome grass to thrive in no-till cropping systems. Sunlight inhibits seedling germination and the preferred seed burial depth is 10mm. Therefore, the one-pass no-till sowing system provides an ideal environment for brome grass to germinate.

The combination of no-till and early sowing has increased the level of dormancy in many brome grass populations on farms across south-eastern Australia, and later-germinating weeds are likely to escape pre-emergent herbicide treatments.

**Research has shown that 20–30 per cent of brome grass seeds can remain dormant in the soil and germinate the following year. Three consecutive years of seed-set control is required to sufficiently reduce populations in problem paddocks.**

Compared with other grass weeds, brome grass matures quite early making it well adapted to dry springs. Later control measures (crop topping, harvest weed seed collection) can have limited success.

**Control options for brome grass**

There is a range of control options for brome grass—both chemical and non-chemical (Table 6). The best approach is an integrated weed management (IWM) strategy, which aims to kill existing weeds, prevent seed set, deplete the seedbank and avoid reintroducing seeds into the system.

Knockdown and pre-emergent herbicides can be effective, although their range of success is highly variable (Table 6).

The two most common brome grass species in south-eastern Australia (Bromus rigidus and Bromus diandrus) are considered among the most competitive of the grass weeds present in Australian annual crops and pastures. Brome grass can also host some cereal root diseases, can contaminate grain and wool, and seeds can physically injure livestock.
Non-chemical control options

- **Stubble burning**
  Burning stubble following harvest can reduce the overall weed seed burden in a paddock if the stubble load is >4t/ha. If the stubble load is <4t/ha, then narrow windrow burning is likely to be a better option.

- **Early hay cutting**
  Early hay cutting will prevent brome seed from setting seed and work towards depleting the seedbank.

- **Grazing**
  Brome grass is palatable and non-toxic to stock. Grazing is an excellent tool for delaying the development and maturity of brome grass, which increases the efficacy of pasture spray-topping.

- **Harvest weed seed management**
  Weed seed collection at harvest varies in its rate of success due to the rapid maturity of brome grass and the ability of the plant to shed a portion of its seed as early as 26 days after flowering. Collecting brome grass seed is worthwhile if crops are harvested early. Most captured seed can be destroyed by burning (narrow windrow, chaff pile) or a seed destruction device (e.g. Harrington Seed Destructor).

The variable response of these herbicides, in combination with early sowing and no-till cropping practices, have contributed to the proliferation of brome grass on many farms.

By far the biggest success in brome grass control in cereal crops during the past 5–15 years has been the development of imidazolinone (group B)-tolerant varieties of both wheat and barley. Growing tolerant cereal varieties allows growers to apply group B herbicides in-crop, which can provide excellent control (up to 95 per cent). However, this technology does have some downsides. These herbicides are highly residual and can severely limit crop and pasture options the following year, especially in low-rainfall seasons. In addition to this, group B-tolerant cereals often incur a 5–10 per cent yield penalty compared with the highest-yielding conventional cereal varieties.

Herbicide resistance levels to post-emergent group As is still relatively low in brome grass compared with annual ryegrass. Therefore break crops and legume pastures are still effective in reducing brome grass populations, particularly if pasture spray-topping and crop-topping are also used in that year.

Employing a combination of chemical and non-chemical methods can be a successful way to control brome grass. An example of this is using some form of pre-sowing tillage (pre-drilling fertiliser, prickle or disc chain) to initiate germination and enable a more effective result with knockdown herbicides. A more successful knockdown of brome grass will substantially reduce the reliance of pre-emergent and post-emergent herbicides for control.

Herbicide efficacy depends heavily on the susceptibility of the weed population. Herbicide-resistant populations of brome grass are increasing in low-rainfall regions. Resistance to groups A, B and M are becoming more common. Of these, group B resistance is the most rapidly increasing.

### Table 6. Expected results of various brome grass control strategies

<table>
<thead>
<tr>
<th>Control strategy</th>
<th>Control of brome grass weed seeds or plants (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Most likely</td>
</tr>
<tr>
<td><strong>Non-chemical</strong></td>
<td></td>
</tr>
<tr>
<td>Stubble burning (&gt;4t/ha stubble load)</td>
<td>70</td>
</tr>
<tr>
<td>Early hay cutting</td>
<td>60</td>
</tr>
<tr>
<td>Grazing</td>
<td>50</td>
</tr>
<tr>
<td>Seed collection at harvest</td>
<td>70</td>
</tr>
<tr>
<td><strong>Chemical</strong></td>
<td></td>
</tr>
<tr>
<td>Knockdown before sowing</td>
<td>80</td>
</tr>
<tr>
<td>Pre-emergent herbicides</td>
<td>70</td>
</tr>
<tr>
<td>Herbicide tolerant crops — group B</td>
<td>80</td>
</tr>
<tr>
<td>Selective post-emergent herbicides</td>
<td>70</td>
</tr>
<tr>
<td>Pasture spray-topping</td>
<td>75</td>
</tr>
<tr>
<td>Chemical fallow</td>
<td>80</td>
</tr>
</tbody>
</table>

Source: IWM Hub GRDC, expert opinion and grower experience
Annual ryegrass
(Lolium rigidum)

Annual ryegrass has been the most widespread and costly grass weed of annual cropping systems across much of southern Australia for the past 30 years. Its success as a weed species is due to its ability to rapidly develop resistance to a wide range of herbicides.

- Low-cost pre-emergent herbicides are now ineffective on many farms in low-rainfall areas — an integrated weed management (IWM) strategy is the best control option available.
- If seed set is prevented, annual ryegrass seed reserves can be almost exhausted within 3–5 years.

**Key facts**

Dense populations of annual ryegrass (>50 plants/m²) can produce 10,000–45,000 seeds/m², which result in a significant seedbank if left uncontrolled. Reduced crop yield, grain contamination, and annual ryegrass toxicity (ARGT) are common impacts of annual ryegrass infestation.

The preferred seed depth for successful germination of ryegrass is 20mm, which is similar to the depth most growers aim to sow their cereal crops (20–25mm).

Annual ryegrass has a variable pattern of emergence, and can germinate from late autumn through to late spring, however most ryegrass (up to 80 per cent) emerges after the ‘break of season’ during autumn through to early winter. Higher populations of later-germinating ryegrass occur where cropping frequency has been greater, largely because herbicide control measures (knockdown, pre-emergent) are mostly targeted at early-germinating ryegrass.

Annual ryegrass and herbicide resistance

By far the most significant attribute of ryegrass is its ability to develop resistance to commonly-used herbicides. Annual ryegrass has known resistance to groups A, B, C, D, L and M herbicides, and many populations have multiple resistance to several of these groups. This presents a real challenge for managing annual ryegrass in annual cropping systems. However, with a combination of chemical and non-chemical control measures, the ryegrass seedbank can be depleted in 3–5 years.

**Control options for annual ryegrass**

There is a range of control options for annual ryegrass — both chemical and non-chemical (Table 7).
Non-chemical control options

- **Weed-free seed**
  Sowing weed-free seed reduces the risk of introducing resistant annual ryegrass to the paddock with crop seed. A professional seed cleaner is a worthwhile investment.

- **Hay production**
  Cutting paddocks for hay is most commonly used in low-rainfall regions where there is a problem paddock of resistant annual ryegrass. Following up with herbicides or grazing after hay is removed to control regrowth ensures 95 per cent weed control.

- **Harvest weed seed management**
  Collecting annual ryegrass seed at harvest is rapidly gaining popularity among growers as an effective non-chemical control measure. Of all the grass weeds, ryegrass is the most suited to this technique because of its maturity time and seed retention. Collected seed can be destroyed by burning (narrow windrow, chaff pile) or a seed destruction device (e.g. Harrington Seed Destructor). Narrow windrow burning is particularly well suited to low-rainfall cropping systems primarily because cereal stubbles are often less than 4t/ha. The internet is a great source of information for growers interested in narrow windrow burning.

### Table 7. Expected results of various annual ryegrass control strategies

<table>
<thead>
<tr>
<th>Control strategy</th>
<th>Control of annual ryegrass weed seeds or plants (%)</th>
<th>Most likely</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Non-chemical</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weed-free crop seed</td>
<td>85</td>
<td>50–99</td>
<td></td>
</tr>
<tr>
<td>Crop competition</td>
<td>50</td>
<td>20–80</td>
<td></td>
</tr>
<tr>
<td>Stubble burning (&gt;4t/ha stubble load)</td>
<td>50</td>
<td>0–90</td>
<td></td>
</tr>
<tr>
<td>Hay production</td>
<td>80</td>
<td>70–95</td>
<td></td>
</tr>
<tr>
<td>Grazing</td>
<td>50</td>
<td>20–80</td>
<td></td>
</tr>
<tr>
<td>Seed collection at harvest</td>
<td>65</td>
<td>40–80</td>
<td></td>
</tr>
<tr>
<td><strong>Chemical</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knockdown before sowing</td>
<td>80</td>
<td>30–95</td>
<td></td>
</tr>
<tr>
<td>Double-knock before sowing</td>
<td>95</td>
<td>80–99</td>
<td></td>
</tr>
<tr>
<td>Pre-emergent herbicides</td>
<td>70</td>
<td>50–90</td>
<td></td>
</tr>
<tr>
<td>Selective post-emergent herbicides</td>
<td>85</td>
<td>20–95</td>
<td></td>
</tr>
<tr>
<td>Pasture spray-topping</td>
<td>80</td>
<td>30–99</td>
<td></td>
</tr>
<tr>
<td>Crop-topping</td>
<td>70</td>
<td>50–90</td>
<td></td>
</tr>
<tr>
<td>Chemical fallow</td>
<td>85</td>
<td>75–95</td>
<td></td>
</tr>
</tbody>
</table>

Herbicide efficacy depends heavily on the susceptibility of the weed population. Herbicide resistance testing is recommended for problem paddocks with suspected resistance. Alternative chemistry is available for annual ryegrass control (pyroxasulfone, prosulfocarb+S-metolachlor, propyzamide), but these products are more expensive and their effective life will be short-lived if growers rely on them as the sole control strategy. The sole reliance on herbicides will lead to resistance — its only a matter of time.

### Further information

Barley grass (Hordeum leporinum) is an annual weed, which can occur in high densities in crops and pastures. Barley grass grows on most soil types, is palatable to stock and can provide a valuable source of early winter feed, but seeds can damage the skins, carcases and eyes of sheep impacting liveweight gains and wool and skin quality.

Barley grass (Hordeum leporinum) is becoming increasingly difficult to manage in low-rainfall cropping regions because of its change in dormancy pattern, limited in-crop herbicide control options in cereals, and increasing herbicide resistance.

Germination of barley grass after autumn rains can now vary between 0–80 per cent, resulting in a knockdown before sowing being far less effective than in the past.

Herbicide-resistant group A populations of barley grass are becoming more prevalent and resistance to groups B and L also have been recorded.

If seed set is prevented, barley grass seed reserves can almost be exhausted in 2–3 years.

Barley grass is highly competitive and a major host of the cereal root disease take-all (Gaeumannomyces graminis var, tritici)—yield losses in wheat due to barley grass infestation can be as high 80 per cent.

Historically 80–90 per cent of barley grass germinated during March and April after autumn rains across southern Australia. However, this now varies between 0–80 per cent because many barley grass populations have evolved to be highly dormant. An increase in cropping frequency combined with earlier sowing practices is likely to have contributed to this shift in the population dynamics of barley grass.

Recent research has identified that highly dormant populations of barley grass require cold stratification (‘chilling’) to trigger seed germination. It was found that barley grass seeds may require 1–5 weeks of 3–4°C to break seed dormancy. This means highly dormant barley grass populations can avoid knockdown, pre-emergent, and early post-emergent herbicide applications.

Herbicide-resistant populations of barley grass are increasing across low-rainfall regions. Resistance to groups A, B and L has been identified. Group A resistance is the most rapidly increasing area of barley grass herbicide resistance.

Control options for barley grass

There is a range of control options for barley grass, both chemical and non-chemical (Table 8).

Historically, a combination of a knockdown (e.g. glyphosate) with a low-cost pre-emergent (e.g. trisulfuron, trifluralin) controlled barley grass when 80–90 per cent of the population germinated during March–April after autumn rains. Highly-dormant barley grass populations can now avoid knockdown, pre-emergent and even early post-emergent herbicide applications. A change in the control strategies for barley grass is required to respond to this shift in dormancy patterns.
Non-chemical control options

- **Stubble burning**
  Burning stubble following harvest can reduce the overall weed seed burden in a paddock if the stubble load is >4t/ha. If the stubble load is <4t/ha, then narrow windrow burning is potentially a better option if enough seed can be captured at harvest.

- **Early hay production**
  Early hay cutting will prevent barley grass seed from setting seed and work towards depleting the seedbank.

- **Harvest weed seed management**
  Similar to brome grass, weed seed collection at harvest varies in its rate of success due to ability of barley grass to shed a portion of its seed early. However, recent on-farm monitoring has shown that collecting barley grass seed is worthwhile if crops are harvested early. Most captured seed can be destroyed by burning (narrow windrow, chaff pile) or a seed destruction device (e.g. Harrington Seed Destructor).

### Table 8. Expected results of various barley grass control strategies

<table>
<thead>
<tr>
<th>Control strategy</th>
<th>Control of barley grass weed seeds or plants (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Non-chemical</strong></td>
<td></td>
</tr>
<tr>
<td>Stubble burning (&gt;4t/ha stubble load)</td>
<td>50 0–75</td>
</tr>
<tr>
<td>Early hay production</td>
<td>50 30–80</td>
</tr>
<tr>
<td>Grazing</td>
<td>30 0–50</td>
</tr>
<tr>
<td>Seed collection at harvest</td>
<td>60 20–80</td>
</tr>
<tr>
<td><strong>Chemical</strong></td>
<td></td>
</tr>
<tr>
<td>Knockdown before sowing</td>
<td>80 40–90</td>
</tr>
<tr>
<td>Double-knock before sowing</td>
<td>80 60–95</td>
</tr>
<tr>
<td>Pre-emergent herbicides</td>
<td>70 50–90</td>
</tr>
<tr>
<td>Selective post-emergent herbicides</td>
<td>90 60–95</td>
</tr>
<tr>
<td>Herbicide-tolerant crops — group B</td>
<td>85 70–95</td>
</tr>
<tr>
<td>Pasture spray-topping</td>
<td>60 50–90</td>
</tr>
<tr>
<td>Chemical fallow</td>
<td>85 75–95</td>
</tr>
</tbody>
</table>

Source: IWM Hub GRDC, expert opinion and grower experience

Group B-tolerant varieties of both wheat and barley provide a herbicide option to control barley grass from early crop stages (3-4 leaf stage) up until later crop stages (first node–flag leaf emergence). Growing these varieties allows the application of imidazolinone (group B) herbicides in-crop, which can provide excellent control (up to 95 per cent). However, this technology does have some downsides. These herbicides are highly residual and can severely limit crop and pasture options in the following year, especially during low-rainfall seasons. In addition to this, Group B-tolerant cereal varieties often incur a 5–10 per cent yield penalty compared with the highest-yielding conventional cereal varieties.

Resistance levels to post-emergent group A herbicides is increasing in barley grass. Therefore, break crops and legume pastures will become less effective in reducing barley grass populations over time. As well as group A herbicide resistance, populations resistant to groups B and L also have been recorded. Alternative chemistry is available for barley grass control (pyroxasulfone, prosulfocarb+S-metolachlor, propyzamide), but these products are more expensive and their effective life will be short-lived if growers rely on them as the sole control strategy.

Employing a combination of chemical and non-chemical methods can be a successful way to control barley grass and delay herbicide resistance. For example, grazing alone will not control barley grass, but it is an excellent tool for delaying the development and maturity of barley grass plants, which increases the effectiveness of pasture spray-topping.

**Further information**

Wild oats
(Avena fatua and Avena ludoviciana)

Key facts

Wild oats is a competitive weed and yield losses of up to 80 per cent can occur in wheat when wild oat populations are high (up to 100 plants/m²). A staggered germination pattern enables wild oats to avoid pre-emergent and early post-emergent herbicide applications. Herbicide-resistant populations of wild oat are steadily increasing, with resistance to groups A, B and Z becoming increasingly common. Attention to detail with farm hygiene will help prevent wild oats being spread across farms.

Wild oats are well adapted to most soil types, although they often occur in fairly distinct patches within paddocks. An ability to stagger germination enables wild oats to persist in annual cropping systems. About 40 per cent of wild oat seeds will germinate during autumn after the ‘break of season’, and some 10–30 per cent will emerge later during the season. This germination pattern enables some wild oat plants to avoid pre-emergent and early post-emergent herbicide applications. Later-emerging wild oats are still competitive enough to grow and produce seed to replenish the seedbank for following years. Some form of control later in the season (e.g. a hay production or weed seed collection) is needed to reduce the seedbank of wild oat in problem paddocks. A combination of chemical and non-chemical control measures can deplete the seedbank of wild oats in 3–5 years.

Often growers observe the steady increase and spread of wild oats across their farms over a number of years. This is because wild oats can easily spread as a contaminant of seed, hay, vehicles and machinery. Attention to detail with farm hygiene will help prevent the spread of wild oats across farms.

Control options for wild oats

There is a range of control options for wild oats, both chemical and non-chemical (Table 9). A combination of knockdown, pre-emergent and post-emergent herbicides are often needed to control wild oats because of its staggered germination pattern. Compared with annual ryegrass, herbicide resistance is still relatively low for wild oats, so most chemical options in cereals, break crops and legume pastures remain viable. Herbicide resistant populations of wild oat are steadily increasing with resistance to groups A, B and Z becoming more common as more plants are being tested.

Two wild oat species (Avena fatua and Avena ludoviciana) are prevalent across south-eastern Australia, and usually occur as mixed populations. In a favourable environment with no limiting conditions, a patch of wild oats can produce up to 20,000 seeds/m². Wild oats host a number of cereal root diseases, and their highly competitive ability can reduce wheat yields by up to 80 per cent.
Non-chemical control options

- **Weed-free seed**
  Sowing weed-free seed reduces the risk of introducing wild oats to the paddock with crop seed. A professional seed cleaner is a worthwhile investment.

- **Hay production**
  Early hay production is one of the most successful strategies to control wild oats. Following up with herbicides or grazing after hay is removed to control regrowth can result in almost 100 per cent control.

- **Grazing**
  Wild oats are palatable and non-toxic to stock and provide a valuable source of early winter feed.

- **Harvest weed seed management**
  Similar to brome grass, weed-seed collection at harvest varies in its rate of success due to the ability of wild oat to shed a portion of its seed early. Collecting wild oat seed is worthwhile if crops are harvested early. Most captured seed can be destroyed by burning (narrow windrow, chaff pile) or a seed destruction device (e.g. Harrington Seed Destructor).

To preserve herbicide options in the long term it is important to employ an integrated weed management (IWM) approach for wild oats that incorporates non-chemical options.

### Table 9. Expected results of various wild oat control strategies

<table>
<thead>
<tr>
<th>Control strategy</th>
<th>Control of wild oat weed seeds or plants (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Most likely</strong></td>
<td><strong>Range</strong></td>
</tr>
<tr>
<td><strong>Non-chemical</strong></td>
<td></td>
</tr>
<tr>
<td>Sow weed-free seed</td>
<td>85</td>
</tr>
<tr>
<td>Crop competition</td>
<td>70</td>
</tr>
<tr>
<td>Stubble burning (&gt;4t/ha stubble load)</td>
<td>40</td>
</tr>
<tr>
<td>Early hay production</td>
<td>97</td>
</tr>
<tr>
<td>Grazing</td>
<td>75</td>
</tr>
<tr>
<td>Seed collection at harvest</td>
<td>70</td>
</tr>
<tr>
<td>Farm hygiene (weed-free vehicles and machinery)</td>
<td>80</td>
</tr>
<tr>
<td><strong>Chemical</strong></td>
<td></td>
</tr>
<tr>
<td>Knockdown before sowing</td>
<td>80</td>
</tr>
<tr>
<td>Double-knock before sowing</td>
<td>99</td>
</tr>
<tr>
<td>Pre-emergent herbicides</td>
<td>80</td>
</tr>
<tr>
<td>Selective post-emergent herbicides</td>
<td>80</td>
</tr>
<tr>
<td>Pasture spray-topping</td>
<td>80</td>
</tr>
<tr>
<td>Crop-topping</td>
<td>30</td>
</tr>
<tr>
<td>Chemical fallow</td>
<td>85</td>
</tr>
</tbody>
</table>

*Source: IWM Hub GRDC, expert opinion and grower experience*

Further information

- **Integrated Weed Management Hub wild oats profile:**

**BELOW:** Early hay production is one of the most successful non-chemical control strategies available to control wild oats. Photo: Megan Hele.
Silver grass infestations are becoming more prevalent in some annual crop and pasture systems due to the introduction of no-till systems, tolerance to selective herbicides, the ability to mature early, and poor palatability and nutritional value for livestock.

Delayed sowing is an important strategy to control silver grass with most populations of silver grass emerging soon after the 'break of season'.

Populations of silver grass resistant to groups C and L herbicides have been discovered.

If seed set is prevented, silver grass seed reserves can be almost exhausted in 2–3 years.

Key facts

Silver grass is less competitive than some other annual grass weeds, such as barley and brome grass, but dense stands can cause significant production losses, host cereal root diseases, injury to livestock and contamination of wool and meat. Silver grass residues have an allelopathic (inhibiting) effect on emerging cereal crops, which gives it a competitive advantage over cereal establishment.

As a pasture species, silver grass has poor nutritional value for livestock and palatability decreases with maturity. Stock will selectively graze other annual grasses in preference to silver grass, and will completely avoid grazing silver grass after it has set seed.

Germination occurs across a wide temperature range (10–30°C), and 80–90 per cent of plants emerge after the 'break of season'. Most silver grass seeds germinate from a soil depth of 0–10mm, and emergence decreases with depth, such that seeds deeper than 50mm are unlikely to germinate. No-till cropping and volunteer pastures provide a favourable environment for silver grass.

Low seed dormancy is a significant advantage when developing a strategy to control silver grass. More than 95 per cent of silver grass seed will usually germinate in a single year, so if seed set is prevented for 2–3 years, silver grass seed reserves can be almost exhausted.

Control options for silver grass

There is a range of control options for silver grass, both chemical and non-chemical (Table 10).

A knockdown before sowing can effectively control silver grass because of its germination pattern. Emerged silver grass plants need to be at least the two-leaf stage to provide an adequate surface area for herbicide uptake. A delay in sowing
Guidelines for managing key weed species across low-rainfall regions of south-eastern Australia

Non-chemical control options

- **Stubble burning**
  Burning stubble (>4t/ha) following harvest has a role but is not as effective compared with its use against other annual grass weeds. Burning silver grass residues will reduce the potential allelopathic effect on cereals.

- **Early hay production**
  Cutting hay early will prevent silver grass seed from setting seed and work towards depleting the seedbank.

- **Cultivation**
  Cultivation before sowing is an effective tactic in controlling a significant proportion of silver grass.

Table 10. Expected results of various silver grass control strategies

<table>
<thead>
<tr>
<th>Control strategy</th>
<th>Control of silver grass weed seeds or plants (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>非-化学</td>
<td></td>
</tr>
<tr>
<td>铁杆燃烧 (&gt;4t/ha 铁杆负载)</td>
<td>50 30–70</td>
</tr>
<tr>
<td>早割草生产</td>
<td>上至90</td>
</tr>
<tr>
<td>前期耕作</td>
<td>70 50–90</td>
</tr>
<tr>
<td>化学</td>
<td></td>
</tr>
<tr>
<td>打击前播种</td>
<td>上至90</td>
</tr>
<tr>
<td>早期除草剂</td>
<td>80 70–95</td>
</tr>
<tr>
<td>选择性除草剂——组C</td>
<td>上至95 50–95</td>
</tr>
<tr>
<td>耐草剂作物——组C</td>
<td>95 90–99</td>
</tr>
<tr>
<td>牧草喷雾补种</td>
<td>上至85</td>
</tr>
<tr>
<td>化学休耕</td>
<td>85 75–95</td>
</tr>
</tbody>
</table>

*Source: IWM Hub GRDC, expert opinion and grower experience*

Compared with other annual grass weeds, silver grass is quite tolerant of selective grass herbicides, which most often only suppress the weed for a period of time, not control it. Pasture spray-topping can be effective if silver grass is sprayed early during spring before flowering. This is likely to compromise pasture production and medic seed set.

Compared with annual ryegrass, herbicide resistance is still relatively low in silver grass, however populations resistant to group C and L herbicides have been discovered.

**Further information**


paddocks containing silver grass is often necessary to ensure this is the case. A spray volume of at least 70L/ha is also recommended to ensure adequate coverage.

Triazine tolerant (TT) canola provides an effective control measure for silver grass because a number of group C herbicides are effective in controlling this weed. However, the residual nature of group C products means lower rates are recommended on alkaline soils in low-rainfall regions.

**Further information**

Onion weed
(Asphodelus fistulosus L.)

Onion weed is re-emerging as a problem in low-rainfall cropping regions of south-eastern Australia.

- Onion weed populations tend to build up during the pasture phase of the cropping rotation.
- No-till farming and the reduction in the use of sulfonylurea (SU) herbicides has lead to an increase in onion weed populations.
- Effective herbicide options in pastures remain limited.
- A double-knock herbicide application during summer is often necessary, particularly to control mature plants.

### Key facts

- Onion weed can germinate throughout the year, but it usually germinates after summer rain. It prefers neutral to alkaline soil and can survive prolonged dry periods due to its drought tolerance. The weed thrives in run-off areas, such as roadsides, depressions, creek lines and non-arable rocky outcrops.

### Impact in no-till cropping systems

The introduction of sulfonylurea (SU) herbicides, in combination with minimum till, during the 1980s effectively controlled onion weed in low-rainfall cropping systems across south-eastern Australia. However, since the adoption of no-till and the reduced use of SUs, onion weed populations have increased during the past 15–20 years, particularly in seasons with above-average summer rainfall.

Onion weed populations tend to build up during the pasture phase of a rotation, particularly if two or more years of pasture are grown before the cropping phase. Although onion weed is of low toxicity to livestock, it is unpalatable and not controlled by grazing. Herbicide control options for onion weed in pastures are limited.

### Control options for onion weed

A combination of chemical and non-chemical strategies can be used to control onion weed. Non-chemical options include increased crop competition, (increasing sowing rates or reducing row spacing) and full-cut cultivation. In most years it will require some form of double-knock during summer. Effective herbicide options are available for onion weed control during summer, which reduce the need for cultivation and the level of exposure of soil to erosion.

### Pre-cropping chemical control options

Various farming systems groups (including the Upper North Farming Systems group — UNFS) and government agencies...
have tested a range of herbicide options in field trials over the years. Two of the most successful chemical control options are glyphosate mixed with metsulfuron (e.g. Ally®) and paraquat during summer–early autumn. A double knock using paraquat, usually applied either 2–4 weeks after the first spray or after a subsequent rainfall event, is often required to achieve near 100 per cent control.

Achieving 100 per cent control of onion weed with herbicides during summer can be expensive. The use of precision spray technologies (i.e. WeedSeeker™ or WEEDit™ systems) in the future will help reduce herbicide costs.

Chemical control options in pasture

During 2015, Bates Agricultural Consulting in partnership with SARDI tested 12 different herbicide options to control onion weed in medic pasture. Of these options, only paraquat (250g/L) at 600mL/ha resulted in effective control (95 per cent). However, this treatment also resulted in a significant reduction in medic biomass (46 per cent) compared with the nil (control) treatment.

The use of paraquat in medic-based pastures to control onion weed is a trade-off between weed control and pasture production, as such, cultivation is still used as an effective control measure. In permanent grass-based pasture systems in the Upper North, a combination of 2,4-D ester and metsulfuron has been used to successfully control onion weed.

Non-chemical control

- **Crop competition**
  If onion weed numbers are relatively low (<5/m²), cereal crops will compete reasonably well, especially if row spacings are kept narrow (18–25cm) and sowing rates are at the higher end of district recommendations.

- **Strategic tillage**
  Strategic soil disturbance with full-cut cultivation can effectively control onion-weed-infested pasture paddocks coming into cropping.

Further information

- Upper Northern Farming Systems Stubble Management Guidelines — Onion weed management

Below: Paraquat (applied on right) is still the only effective herbicide for onion weed control in medic pasture. Photo: Peter Baker, Fenceline Consulting
Wild radish (Raphanus raphanistrum) is highly competitive in annual cropping systems, has complex dormancy mechanisms and produces masses of seed of notable longevity. Wild radish has known resistance to groups B, C, F, I and M herbicides and many populations have multiple resistance to several of these groups. Strict farm hygiene will prevent wild radish spread. It takes at least six years to reduce the wild radish seedbank to manageable levels in problem paddocks.

Key facts:

- Wild radish is a prolific seed producer — producing up to 45,000 seed/m². Although this highly-competitive weed can germinate year round, most plants emerge during autumn and winter. Wild radish grows on most soil types, although it thrives on slightly acidic sandy soils. This could explain why it is not as widespread in low-rainfall areas of south-eastern Australia (predominately alkaline soils) when compared with Western Australia.

- A complex seed dormancy pattern is one of the most significant attributes allowing wild radish to be a highly successful weed in annual cropping systems. Some of wild radish’s seed dormancy mechanisms include:
  - seed dormancy at maturity, with up to 70 per cent of seed remaining dormant until the following season (about 18 months later)
  - higher dormancy of seeds within the pod compared with those exposed to the environment

- Wild radish (Raphanus raphanistrum) is one of the most competitive weeds in low-rainfall cropping systems across southern Australia. Crop yield losses of up to 90 per cent have been seen in wheat, canola and lupins and seeds from later-germinating weeds can contaminate grain at harvest. Wild radish also has allelopathic activity and can host a range of crop insect pests (e.g. aphids) and diseases (e.g. beet western yellows virus).

- Seeds produced from early-emerging wild radish plants have higher levels of dormancy compared with seeds produced by later-emerging plants
- Seed dormancy in plants with yellow flowers is lower than radish plants with purple and white flowers
- Seed dormancy in plants growing in cooler/longer-season environments is greater than those in warmer/shorter-season environments
- Increased dormancy at depth — seeds remain more dormant if buried deeper than 40mm below the soil surface.

Together with dormancy, the ability of wild radish to develop resistance to herbicides makes control difficult. Wild radish has known resistance to groups B, C, F, I and M herbicides and many populations have multiple resistance to several of these groups. Most of these resistant populations have been found in WA, but some are now being detected in SA and Victoria.
Table 11. Expected results of various wild radish control strategies

<table>
<thead>
<tr>
<th>Control strategy</th>
<th>Control of wild radish weed seeds or plants (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Most likely</td>
</tr>
<tr>
<td><strong>Non-chemical</strong></td>
<td></td>
</tr>
<tr>
<td>Weed-free crop seed</td>
<td>95</td>
</tr>
<tr>
<td>Stubble burning (&gt;4t/ha stubble load)</td>
<td>70</td>
</tr>
<tr>
<td>Hay production</td>
<td>80</td>
</tr>
<tr>
<td>Grazing</td>
<td>70</td>
</tr>
<tr>
<td>Seed collection at harvest</td>
<td>75</td>
</tr>
<tr>
<td><strong>Chemical</strong></td>
<td></td>
</tr>
<tr>
<td>Knockdown before sowing</td>
<td>80</td>
</tr>
<tr>
<td>Selective post-emergent herbicides</td>
<td>90</td>
</tr>
<tr>
<td>Herbicide-tolerant canola (groups B and C)</td>
<td>90</td>
</tr>
<tr>
<td>Pasture spray-topping</td>
<td>80</td>
</tr>
<tr>
<td>Crop-topping</td>
<td>80</td>
</tr>
<tr>
<td>Chemical fallow</td>
<td>85</td>
</tr>
</tbody>
</table>

Source: IWM Hub GRDC, expert opinion and grower experience

Control options for wild radish

Increasing levels of herbicide resistance present a challenge for controlling wild radish in problem paddocks, but by adopting an integrated weed management (IWM) strategy, which combines both chemical and non-chemical control methods (see Table 11) will mean control is still possible. Correct identification of wild radish seedlings is important for effective control as they can easily be confused with wild turnip (Brassica tournefortii), turnip weed (Rapistrum rugosum), charlock (Sinapis arvensis), garden radish (Raphanus sativus) and capeweed (Arctotheca calendula). Meticulous farm hygiene can play a key role in controlling wild radish. Contaminated crop and pasture seed, hay, livestock, vehicles and machinery have contributed to the spread and increased prevalence of wild radish across cropping districts of southern Australia. To limit wild radish infestation always use weed-free crop seed and fodder, and clean equipment used in paddocks containing wild radish thoroughly before moving to a new paddock or property.

Imidazolinone (group B)-tolerant and triazine (group C)-tolerant canola varieties provide effective early control of wild radish, but do not control later-emerging populations. Collecting (and subsequently destroying) weed seeds at harvest needs to be used in conjunction with herbicide-tolerant canola varieties to control wild radish.

Non-chemical control options

- **Weed-free crop seed**
  Sowing weed-free seed is essential to manage wild radish. Do not keep seed from paddocks containing wild radish for re-sowing.

- **Hay production**
  Cutting crops or pastures for hay before wild radish sets seed is an effective control strategy for wild radish if followed by herbicides or grazing after baling to control weed regrowth. Early hay cutting may be required to ensure early seed formation hasn’t commenced (21 days after first flower).

- **Harvest weed seed management**
  Collecting weed seed at harvest varies in its rate of success due to the ability of wild radish to shed a portion of its seed at plant maturity. This approach is worthwhile in early-harvested crops. Most captured seed can be destroyed by burning (narrow windrow, chaff pile) or a seed destruction device (e.g. Harrington Seed Destructor).

At present, the range of selective post-emergent herbicide options in cereals in SA is adequate because of the relatively low level of herbicide resistance compared with WA. For effective control in cereals, spray wild radish twice to combat its staggered germination pattern. Spraying two populations of small plants (2–6 leaf stage) during the season and using a combination of at least two herbicide groups (B, C, F, G, H, I) with each application is the best strategy and will prolong the effective life of these herbicides. Conversely, only spraying a mixed population of smaller (2–6 leaf stage) and larger plants (>6 leaf stage up to flowering) once with a single herbicide group is likely to result in poor control and will lead to rapid development of herbicide resistance.

Selective post-emergent options to control wild radish in pulse crops and legume pastures are limited compared with the options for other broadleaf weeds. Grazing in combination with pasture spray-topping is effective in legume pastures, and crop-topping followed by collecting seed at harvest will provide effective control in pulse crops.

Further information

Flaxleaf fleabane (Conyza bonariensis)

**Key facts**
- Fleabane is emerging as a major summer weed problem in no-till systems across south-eastern Australia.
- Fleabane has a natural tolerance to the uptake of herbicides due to fine, dense hairs and a thick leaf surface.
- Most fleabane seedlings emerge from late August through to November.
- Young (one month old or less) fleabane seedlings can be easily controlled but when they develop strong root systems, control is difficult.
- A double-knock herbicide application during summer is often necessary to control larger fleabane plants.

**Fleabane has been present in many areas** of south-eastern Australia as a summer weed along roadsides and around yards but has not caused problems in cropping paddocks until recently. It can produce large amounts of seed, with individual plants producing up to 120,000 seeds. Strong winds easily disperse these small, light-weight seeds, with about one per cent of seed travelling 10km or more. Managing seed levels can be difficult as neighbouring paddocks, roadsides and non-arable areas can be a continual source of reinfestation.

**No-till systems provide ideal conditions**
Fleabane thrives in no-till stubble-retention (NTSR) farming systems as seed does not need to be incorporated deeply to germinate — most seeds germinate from the top 10mm of soil. Fleabane emerges when air temperatures are between 10–30°C, with optimal temperatures between 20–25°C. Provided there is adequate moisture, plants can germinate in crops and pastures from late August through to November.

Fine, dense hairs on a thick cuticle (leaf surface) provide fleabane with a natural armoury, protecting the plant against the uptake of herbicides. If treated with an application of glyphosate at one month old or less, susceptible fleabane plants can be controlled. Mature fleabane plants with well-developed roots systems, are difficult to control with glyphosate, regardless of their resistance status. Control is often difficult when plants are sprayed post-harvest during summer, as they are well established and spray conditions are often sub-optimal.

**Fleabane control critical to protect soil moisture**
Controlling fleabane is important for conserving soil moisture over summer. Research in SA has proven effective fleabane control can result in significant soil moisture retention for following crops (see Table 12).
Guidelines for managing key weed species across low-rainfall regions of south-eastern Australia

Non-chemical control options

- **Crop competition**
  Flaxleaf fleabane is a poor competitor. Increased crop competition from cereals using higher sowing rates and narrow row spacing can suppress growth and weed seed production.

- **Strategic tillage**
  Strategic soil disturbance is an effective option in areas of high infestation or going into a crop with limited in-crop control options.

- **Grazing**
  Grazing and spray grazing are effective tools to control fleabane, which is palatable to both sheep and cattle.

**Control options for fleabane**

A combination of chemical and non-chemical strategies can be used to control fleabane. Effective herbicide options are available for fleabane for most stages of the cropping cycle.

Herbicides combined with light grazing can effectively control fleabane during summer. This option reduces the need for cultivation and reduces the risk of soil erosion.

**Pre-harvest chemical control options**

A range of pre-emergent and in-crop products will help control emerging fleabane plants. Based on experience from Northern NSW, pre-emergent herbicides such as Triasulfuron (e.g. Logran®), metribuzin, simazine, Terbyne® (Terbutylazine), and Balance® (Isoxaflutole) all have some activity on fleabane. In-crop applications of 2,4-D amine, metsulfuron (e.g. Ally®) and clopyralid (e.g. Lontrel®) can effectively control newly-emerged and younger fleabane plants.

**Post-harvest chemical control options**

Most research to date has focussed on fleabane control during summer after the crop has been harvested and fleabane plants have started to mature. During recent times, Ben Fleet and Gurjeet Gill from the University of Adelaide have evaluated a range of herbicide options for fleabane control during summer, some of which are presented in Table 13.

**Further information**

- Barry Haskins on fleabane [https://www.youtube.com/watch?v=YYgZKzNe0bc](https://www.youtube.com/watch?v=YYgZKzNe0bc)
- Fleet, B and Gill, G (2013) Fleabane ecology and control in cropping systems of southern Australia, University of Adelaide, GRDC Adviser Update

---

Table 12. The impact of fleabane control on residual soil moisture

<table>
<thead>
<tr>
<th>Fleabane control (%)</th>
<th>Increased soil moisture over control (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>52</td>
<td>17</td>
</tr>
<tr>
<td>62</td>
<td>29</td>
</tr>
<tr>
<td>80</td>
<td>45</td>
</tr>
<tr>
<td>99</td>
<td>71</td>
</tr>
</tbody>
</table>

Adapted from Fleet and Gill (2013)

Table 13. Herbicide efficacy on fleabane at Bute and Pinnaroo during summer 2012

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Fleabane control (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>First knock (glyphosate only)*</td>
</tr>
<tr>
<td>Untreated</td>
<td>0</td>
</tr>
<tr>
<td>Glyphosate 1L/ha</td>
<td>30</td>
</tr>
<tr>
<td>Glyphosate 2L/ha</td>
<td>55</td>
</tr>
<tr>
<td>Glyphosate 3L/ha</td>
<td>89</td>
</tr>
<tr>
<td>Glyphosate 4L/ha</td>
<td>93</td>
</tr>
</tbody>
</table>

Note: Glyphosate was 570g/L formulation and the rate of paraquat in the second knock was 2.4L/ha of the 250g/L formulation. Assessments on percentage control for main herbicide treatment alone (first knock), and with the addition of a subsequent paraquat application (second knock).

In contrast to the experience from NSW, high rates of glyphosate (3–4L/ha) provided excellent control even when a second knock was not implemented. However, using glyphosate alone as a strategy maybe short-lived, as populations of glyphosate-resistant fleabane have been found in SA, NSW and Queensland.

These trials showed that fleabane control was significantly better where a second knock of paraquat was applied, particularly when the first herbicide application provided at least 50 per cent control or better.

Achieving 100 per cent control with herbicides during summer can be expensive. Spray grazing or the use of precision spray technologies (i.e. WeedSeeker™ or WEEDit™ systems) can help reduce herbicide costs.
Statice (Limonium lobatum)

Key facts

No-till cropping and reduced use of sulfonylurea (SU) herbicides has contributed to increased statice infestations across the low-rainfall cropping regions of south-eastern Australia.

- Currently there are no registered herbicides to control statice, however a number of herbicides have shown promising levels of control.
- Non-chemical control methods have not been formally evaluated, but crop competition and cultivation are likely to offer up to 50 per cent control.

Statice germinates during autumn and winter, flowering and setting seed during summer. It is not known to be toxic to livestock, but is generally considered unpalatable.

Statice populations tend to build up in run-off areas, such as roadsides, depressions and creek lines, before infesting adjoining paddocks. The adoption of no-till cropping practices and the reduced use of sulfonylurea (SU) herbicides have contributed to the increase in statice populations.

Herbicide control options

Currently there are no registered herbicides to control statice. However, a number of experiments during the past 25 years have identified specific herbicide treatments with the potential to control up to 90–100 per cent of statice populations (Table 14).

Little data exists on the efficacy of non-selective summer herbicide options however, grower experience suggests glyphosate mixed with carfentrazone is more successful than glyphosate alone.

Non-chemical control

Little data is available on the efficacy of non-chemical methods to control statice. Observations suggest crop competition and cultivation are likely to provide up to 50 per cent control of a population. Grazing is ineffective due to the unpalatability of statice. Narrow windrow burning is a potential option, however there is no data on the temperature and duration of heat required to destroy statice seeds.

<table>
<thead>
<tr>
<th>Crop stage</th>
<th>Herbicide (product example)</th>
<th>Likely control (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-emergent</td>
<td>Chlorsulfuron (Glean®)</td>
<td>80</td>
</tr>
<tr>
<td>Post-emergent</td>
<td>Bromoxynil + Pyrasulfotole (Velocity®)</td>
<td>95</td>
</tr>
</tbody>
</table>

* Based on experiments carried out by state-based government departments, University of Adelaide and Birchip Cropping Group (BCG)

Further information


Table 14. Potential herbicide control options for statice

**ABOVE: No-till cropping and reduced sulfonylurea (SU) herbicide use have contributed to escalating statice populations in low-rainfall cropping regions. Photo: Andrew Storrie, Agronomo Consulting and Sally Pettzer, Department of Agriculture and Food WA.**

*Originally introduced to Australia as a garden ornamental, statice (Limonium lobatum) or winged sea lavender has emerged as a challenging weed species in many low-rainfall districts across southern Australia. Statice can be annual or a short-lived perennial, that is widely adapted to alkaline, sodic and moderately saline soils.*
**Buffel grass**  
* (Cenchrus ciliaris)

Buffel grass (*Cenchrus ciliaris*) was introduced as a perennial pasture species for northern Australia during the early 1900s. It was widely planted for many decades because of its ability to grow rapidly after rain (providing fodder) and its high grazing and drought tolerance.

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**Key facts**
- Buffel grass is a highly-invasive perennial grass weed with the potential to invade and threaten low-rainfall cropping regions across south-eastern Australia.
- Buffel grass is a deep-rooted perennial, which produces an abundance of seed and can tolerate long periods of drought.
- Early control of small patches will prevent the spread of buffel grass and is essential for managing this weed.
- A combination of herbicides, burning and cultivation is likely to be the most successful control strategy.

**Buffel grass thrives across a range of soil types**, but is particularly suited to lighter-textured soils. This long-lived perennial grass has a high demand for nitrogen and phosphorus and will deplete these nutrients from the soil over time.

Buffel grass is major threat to the biodiversity of native vegetation in the arid and semi-arid regions of SA. In cropping regions of SA, buffel grass has been identified along the major transport routes and is a potential threat to grain production, as a highly-active summer weed, if weed infestations become widespread.

Similar to other grass weeds in agriculture, buffel grass is a prolific seed producer and has moderate seed dormancy. Established buffel grass plants mainly flower during October in SA and produce seed during summer. New germinations of buffel grass can grow and set seed within 3–6 weeks, when conditions are favourable.

Seeds are easily dispersed by wind, water, animals, on clothing and by vehicles. Plant reproduction can also occur vegetatively through rhizomes or stolons. It is estimated individual tussocks of buffel grass can live for up to 20 years.

Buffel grass is deep-rooted and can store carbohydrates at the base of its stems, which allows the grass to tolerate long periods of drought and then respond rapidly to rainfall events.

When left uncontrolled, buffel grass forms a dense monoculture that outcompetes other species. Dry buffel grass foliage is highly flammable, but can survive and regenerate after a fire event.

**Herbicide control options**

There are a few herbicides registered to control buffel grass (Table 15). Plants need to be actively growing for herbicide applications to be effective — spray young plants or regrowth following a rainfall event. Established plants may require 2–3 applications for effective control. Anecdotal evidence suggests a mix of glyphosate and flupropanate is the most effective herbicide option, and when used in conjunction with burning can provide successful control.

**Table 15. Registered herbicides for the control of buffel grass**

<table>
<thead>
<tr>
<th>Herbicide</th>
<th>Dose and Formulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paraquat and diquat (e.g. Sprayspray®)</td>
<td></td>
</tr>
<tr>
<td>Haloxyfop (e.g. Verdict®)</td>
<td></td>
</tr>
<tr>
<td>Glyphosate (e.g. Roundup®)</td>
<td></td>
</tr>
<tr>
<td>Flupropanate (e.g. Taskforce®)</td>
<td></td>
</tr>
<tr>
<td>Fluazifop (e.g. Fusilade® Forte)</td>
<td></td>
</tr>
</tbody>
</table>

**Non-chemical control**

The threat of buffel grass can be significantly reduced if growers and land managers are disciplined in applying an integrated weed management (IWM) plan that combines herbicide application, burning and cultivation to control small areas of weed infestations along roadsides, preventing the spread into paddocks.

**Further information**

- Biosecurity SA (2012). South Australia Buffel Grass Strategic Plan: A plan to reduce the weed threat of buffel grass in South Australia. Government of South Australia
Websites and online resources

- **Australian Herbicide Resistance Initiative**
  http://ahri.uwa.edu.au
  The Australian Herbicide Resistance Initiative is a group of research leaders in herbicide resistance and its management in cropping systems carrying out research and extension to encourage sustainable cropping and weed control across Australia.
  The AHRI website contains a blog, research outcomes, videos and tools to help growers better understand and manage herbicide resistance.

- **GRDC Integrated Weed Management (IWM) hub**
  One of the key resources in the IWM Hub is the Integrated Weed Management Manual. This manual is a road map to information, which summarises the role, use and benefits of different weed management tactics.
  The many links embedded in these web pages provide access to a myriad of more detailed on-line multimedia resources. These links provide access to the detailed information that readers will need on the topics being researched for on-farm adoption.
  It is intended this manual will continue to evolve with links added and updated on a regular basis as new material comes to hand.

- **Weed identification (Weeds Australia)**
  This online tool allows users to search for weeds by location, common name and scientific name. Search results will provide full-colour images and a detailed description for each stage of the weed lifecycle.
  Control options are not included.

- **Weed Seed Wizard**
  The Weed Seed Wizard is a computer simulation tool which:
  - applies to all Australian grain-growing regions.
  - helps growers understand and manage weed seedbanks on their farms.
  - 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.
  - uses farm-specific management and site-specific weather.
  - is multi-species:
    - annual ryegrass, wild radish, wild oats, barley grass, rigid brome grass, rip-gut brome grass, fleabane and silvergrass in the southern regions
    - barnyard grass, liverseed grass, sweet summer grass, feathertop Rhodes grass, bladder ketmia, sowthistle, fleabane, cowvine and bellvine in the north.

- **WeedSmart**
  http://www.weedsmart.org.au
  WeedSmart is an industry-led initiative to enhance on-farm practices and promote the long-term sustainability of herbicide use.
  The WeedSmart smartphone application provides a simple tool to gauge herbicide-resistance and weed seedbank management.