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GROWNOTES™

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

CHICKPEA

SECTION 6

WEED CONTROL

INTEGRATED WEED MANAGEMENT (IWM) | PLANTING CONTROL STRATEGIES | HERBICIDES EXPLAINED | MODE OF ACTION (MOA) | SUMMER FALLOW WEED CONTROL | DOUBLE KNOCK STRATEGIES | PRE-EMERGENT HERBICIDES | POST-PLANT PRE-EMERGENT HERBICIDES | IN-CROP HERBICIDES: KNOCKDOWNS AND RESIDUALS | CONDITIONS FOR SPRAYING | HERBICIDE TOLERANCE RATINGS | MONITORING | POTENTIAL HERBICIDE DAMAGE EFFECT | HERBICIDE RESIDUES | HERBICIDE RESISTANCE | GRAZING FOR WEED CONTROL

Weed control

Key messages

- Chickpeas are poor competitors with weeds because of slow germination and early growth.
- Weed control is essential if the chickpea crop is to make full use of in-crop rainfall and stored soil moisture and nutrients and to prevent weed seeds from contaminating the grain sample at harvest.
- Weed management should be planned well before planting, with chemical and non-chemical control options considered.
- There are limited options for pre-emergent and post-emergent weed control.
- Broadleaf weeds must be heavily targeted in the preceding crop and/or fallow. Always assess the broadleaf weed risk prior to planting.
- Chickpeas should always be planted into planned paddocks that have low weed populations.
- Chickpeas are late-maturing compared with other pulses; hence, crop-topping to prevent ryegrass and other weed seed-set is reduced.

Weeds are estimated to cost Australian agriculture A$2.5–4.5 billion per annum, with winter cropping systems alone bearing a $1.3 billion cost. In-crop weed competition causes losses costing around $1 billion per annum for Western Australia (Table 1). Consequently, any practice that can reduce the weed burden is likely to generate substantial economic benefits to growers and the grains industry.

MORE INFORMATION

GRDC Weed management hub

Impact of weeds on Australian grain production

Table 1: *Yield loss and revenue loss for residual weeds in all crops.*

Area	Residual weeds for all crops			
	Yield loss (t)	Revenue loss	Yield loss (t/ha)	Revenue loss (per hectare)
WA Central	222,486	$63.4m	0.05	$14.64
WA Eastern	33,244	$8.7m	0.03	$6.87
WA – Sandplain - Mallee	27,084	$8.9m	0.03	$9.34
WA Northern	57,208	$15.9m	0.04	$11.69

Source: GRDC.

Weed control is essential if the chickpea crop is to make full use of stored summer rainfall, to prevent weed seeds from contaminating the grain sample at harvest and to stop weed seed set for future years. Weed management should be planned well before planting, with chemical and non-chemical control options considered.

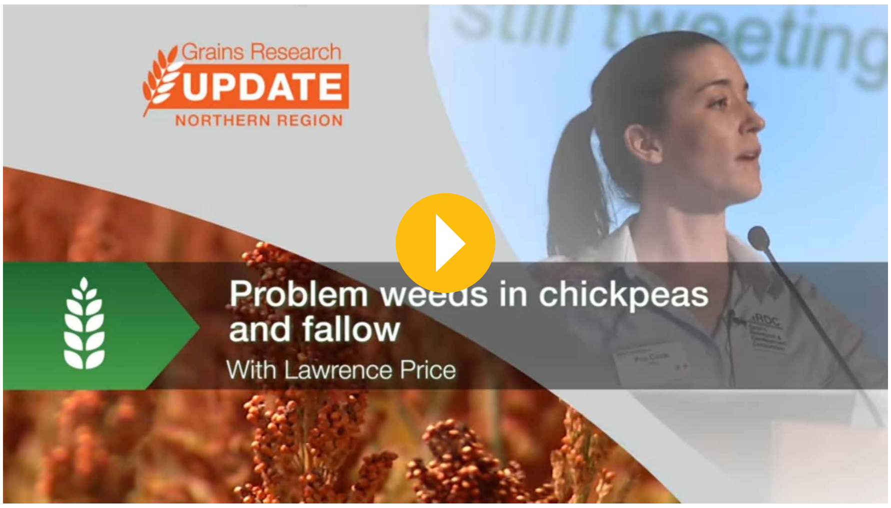
Chickpea crops are poor competitors with weeds because of their slow emergence and growth during winter. Kabuli chickpea competes poorly with weeds, particularly broad-leaved weeds such as radish, mustard, capeweed and doublegee. Effective weed control is essential to prevent yield loss and to avoid the build-up of troublesome weeds in the rotation. Because of the slow growth and open canopy in chickpeas, narrow or wide row spacing (30 *v.* 70 cm) makes little difference to the chickpea plant's ability to compete with weeds. The weed control strategy for growing a successful chickpea crop is based on substantially reducing the viable weed seedbank in the soil before the crop emerges, as post-emergence weed control options are limited. Broadleaf weed control options can be very limited in chickpeas, and this is a reason producers commonly give for not growing chickpeas.

The over-use of particular groups of herbicides through the rotation can lead to herbicide resistance, which has occurred in grass weeds and now some broadleaf weeds. To avoid resistance, weed management through the rotation should aim to minimise the need for herbicides, to avoid the overuse of any one group of herbicides and to use the least selective herbicide. Effective grass control in the chickpea crop has the benefit of reducing the need for selective grass herbicides in the following cereal year. [1]

Weed control is important, because weeds can:

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

WATCH: Grains research updates 2015: Problem weeds in Chickpea and Fallow.



6.1.1 Critical period for weed control

One study has found that chickpea must be kept weed free between the five leaf and full flowering stages (24–48 DAE), and from the four-leaf stage to beginning of flowering (17–49 DAE) in order to prevent >10% seed yield loss. The overall conclusion of this research was that chickpea should be weed free from 17–60 DAE, and that outside of this timeframe weeds are unlikely to significantly impact on yield. [2]

1 DAFWA. Desi Chickpea Essentials. https://www.agric.wa.gov.au/chickpeas/desi-chickpea-essentials

2 G Mohammadi, A Javanshir, FR Khooie, SA Mohammadi, S Zehtab Salmasi (2005) Critical period of weed interference in chickpea. Weed research, 45(1), 57–63.

6.2 Integrated weed management (IWM)

There are very effective strategic and tactical options available to manage weed competition that will increase crop yields and profitability. Weeds with herbicide resistance are an increasing problem in grain cropping enterprises. The industry and researchers advise that growers adopt integrated weed management (IWM) to reduce the damage caused by herbicide-resistant weeds.

The following five-point plan will assist in developing a management plan in each and every paddock.

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

Integrated weed management (IWM) is a system for long-term weed management and is particularly useful for managing and minimising herbicide resistance.

The Grains Research and Development Corporation (GRDC) supports integrated weed management. Download the Integrated Weed Management Manual.

An integrated weed management plan should be developed for each paddock or management zone.

In an IWM plan, each target weed is attacked using tactics from several tactic groups (see links below). Each tactic provides a key opportunity for weed control and is dependent on the management objectives and the target weed's stage of growth. Integrating tactic groups reduces weed numbers, stops replenishment of the seedbank and minimises the risk of developing herbicide-resistant weeds.

IWM tactics

- Reduce weed seed numbers in the soil
- Controlling small weeds
- Stop weed seed set
- Reduce weed seed numbers in the soil
- Hygiene - prevent weed seed introduction
- Agronomic practices and crop competition

Successful weed management also relies on the implementation of the best agronomic practices to optimise crop growth. Basic agronomy and fine-tuning of the crop system are the important steps towards weed management.

There are several agronomic practices that improve crop environment and growth, along with the crop's ability to reduce weed competition. These include crop choice and sequence, improving crop competition, planting herbicide tolerant crops, improving pasture competition, using fallow phases and controlled traffic or tramlining. [3]

Because management of herbicide resistance is case specific, it is difficult to prescribe 'recipes' for how to manage a problem. Instead, you need to understand your situation and choose from a range of methods, such as those outlined below.

Choose a method from the IWM tool box. Consider how these might fit into your farming system and seek advice from your local agronomist. These methods allow you to keep weed populations under control and delay the onset of resistance.

Method 1. Autumn tickle: use light scarification to stimulate weed germination, then spray (paying attention to rotating your chemical groups) before sowing.

3 DAFWA. (2016). Crop weeds: Integrated Weed Management (IWM). https://www.agric.wa.gov.au/grains-research-development/crop-weeds-integrated-weed-management-iwm

Method 2. Barley for weed control: barley is competitive against weeds and use of pre-emergence herbicides is effective. Its shorter growing season also allows for pre-sowing weed control.

Method 3. Catching: use a bin attachment on your harvester to collect weed seed. Then burn the seed. Harvest weed seed management strategies are increasingly being implemented.

Method 4. Crop-topping: Use a non-selective herbicide (paraquat-based) to mature or near-mature crops to reduce weed seed set. However, crop-topping is difficult to implement in chickpeas and is not common practice. Crop-topping in pulse crops can be very effective—weed wiping weeds in lentil crops as a prelude to crop-topping is also effective.

Method 5. Cultivation: Use cultivation to kill germinated weeds.

Method 6. Delayed sowing: Delay sowing for two or more weeks so that additional weeds can be killed by non-selective herbicide. However, yield penalties need to be considered before altering sowing dates.

Method 7. Double-knock strategy: Use a glyphosate application followed by paraquat-based application to control weeds before sowing.

Method 8. Harvest low, no spread, burn: This method has three stages: harvest the crop lower than usual, put the residue (containing weeds) into narrow rows for burning (allows for hotter fire).

Method 9. Hay: Use crop for hay. Trials in southern Australia showed that hay making was most effective—reducing seeds per square metre. Hay cutting alone doesn't guarantee success; you also need to graze or spray-top after it re-shoots to prevent seed on regrowth, and take care when feeding hay out that ryegrass seeds aren't spread to other paddocks.

Method 10. Heavy grazing: Weed seed set is reduced by timely intense grazing of paddocks not sown to crop (and seedbank is reduced).

Method 11. High crop sowing rate: Used to produce a higher crop plant density to reduce yield loss due to weeds and to suppress weed seed production.

Method 12. Manuring: Use the crop for 'green manure' before it matures to prevent weed seed set and increase organic matter.

Method 13. Mechanical pasture top: Slash the pasture before weed maturity.

Method 14. Spray-topping: Use a low-rate of non-selective herbicide applied to pastures to reduce weed seed set.

Method 15. Careful consideration of rotations (pasture phase instead of continuous cropping). A two-year (or more) pasture phase treated to reduce weeds before it goes back into crop. A pasture phase longer than two years is very effective (one year is not enough to reduce seedbank). It should be noted that it is not the pasture phase itself that helps to manage weeds, but it is what the phase allows you to do in addition, e.g. grazing and pasture topping. Crop rotations need to be managed carefully. Continuous cropping requires strong planning and management practices.

Method 16. Stubble burning: Stubble is burned in autumn to reduce viable weed seeds (but reduces organic matter).

Method 17. Windrowing for weed control: cutting crop near to full maturity and leave to dry in rows to reduce seed shatter (usually done in canola). Can be done in other crops but earlier than usual and lower than normal. [4]

MORE INFORMATION

[Herbicide resistance and integrated weed management (iwm) in crops and pasture monitoring tools]()

[GRDC IWM Hub]().

4 Agriculture Victoria. HERBICIDE RESISTANCE AND INTEGRATED WEED MANAGEMENT (IWM) IN CROPS AND PASTURE MONITORING TOOLS. http://agriculture.vic.gov.au/agriculture/farm-management/business-management/ems-in-victorian-agriculture/environmental-monitoring-tools/herbicide-resistance

6.3 Planting control strategies

Pulses grown in rotation with cereal crops offer farmers opportunities to easily control grassy weeds with selective herbicides that cannot be used in the cereal years. An effective kill of grassy weeds in the pulse crop will reduce root disease carry over and provide a 'break crop' benefit in the following cereal crop. Grass control herbicides are now available which will control most grassy weeds in pulses. Volunteer cereals can also be controlled with some of these herbicides. Simazine alone and in mixtures with trifluralin can be used to control some other grasses (such as silver grass) that are not readily controlled by the specific grass herbicides. [5]

Do not sow chickpea into a pasture paddock where broadleaf weed pressure will be high. Make the most of opportunities to reduce broadleaf weeds in the preceding crop when weed control is likely to be more effective, cheaper and cause less damage to that crop. Delaying chickpea sowing until after a germination of broadleaf weeds also assists in areas or seasons where this is possible. [6]

The use of rotations that include both broadleaf and cereal crops may allow an increased range of chemicals—three to five MOAs—or non-chemical tactics such as cultivation or grazing.

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

Strategic cultivation can provide control of herbicide-resistant weeds and those that continue to shed seed throughout the year. It can be used to target large, mature weeds in a fallow, for inter-row cultivation in a crop, or to manage isolated weed patches in a paddock. Take into consideration the size of the existing seedbank and the increased persistence of buried weed seed. [7]

It is important that broadleaf populations are considered when selecting a paddock for chickpea production. Broadleaf weeds should be heavily targeted in the preceding wheat or barley crop or fallow. Paddocks with severe broadleaf weed infestation should be avoided. [8] If broadleaf weeds that are not well controlled by registered broadleaf herbicides are present, then consider altering the cropping rotation until the weed species is controlled.

6.3.1 Managing wild oats in chickpeas

Chickpea rotations provide an opportunity to control wild oats, which is a costly weed in a wheat-based system if it shows levels of herbicide resistance. However, care should be taken to ensure that surviving weeds are identified and removed to reduce the chance of resistance developing. Herbicide-resistant wild oats are becoming a key threat to sustainable farming systems. Herbicide resistance in wild oats poses management problems in any crop where these herbicides have previously been relied upon, but the threat appears greater to chickpea production. Chickpea is most at risk because it is a poorly competitive crop and is often produced on wide rows. In addition, chickpea only has Group A herbicides available for post-emergent control. Effective use of crop rotation must be made to assist in management of wild oats. This will allow the use of the winter fallow and other effective herbicides (differing MOAs including knockdowns) as well as improved crop competition to reduce seed-set of wild oats. [9]

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5 GRDC Grain Legume Handbook – Weed control.

6 Pulses Australia. Chickpea Production: Southern and Western regions. http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/southern-guide

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

8 DAFF (2012) Chickpea—weed management. Department of Agriculture, Fisheries and Forestry, Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/chickpeas/weed-management

9 Storrie (2007) Managing wild oats in chickpeas—our practices must change. Northern Grower Alliance, http://www.nga.org.au/results-and-publications/download/45/australian-grain-articles/weeds-1/wild-oats-inchickpeas-tip-of-the-iceberg-september-2007.pdf

6.3.2 Row spacing

Why do narrow rows yield more?

- reduced weed competition
- early canopy closure
- increased light interception
- reduced evaporation
- reduced competition between crop plants within the row

The simple reason for reduced ryegrass seed set in narrow row spacing is light interception by the crop (Figure 1). In the 1990s, when no-till was being adopted, most growers had little choice but to adopt wide row spacing. Stubble retention and no-till go hand in hand, so burning for stubble handling became frowned upon for good reason. Harvester capacity was limited, so harvesting low was out of the question, and seeders struggled to handle stubble. Wide rows were the only option.

Figure 1: *Narrow v. wide row canola in 2009. No light reaching the ground in narrow row spacing plots. Ryegrass germinated about when this photo was taken and was not sprayed due to crop safety concerns. Very low ryegrass seed set in the 9 and 18 cm row spacing treatments (top) compared to 27 and 36 cm treatments (bottom).*

Source: UWA

In 2016 growers have harvesters that can harvest low (10–15 cm) and cut and spread the straw evenly. There are also seeders that can handle more stubble than their predecessors. Many growers in regions that regularly achieve wheat yields of 3 to 4 t/ha have successfully adopted 7" (19 cm) row spacing with both tine and disc machines. It is less convenient than wide rows and it costs more, but the benefits outweigh the negatives.

You don't have to achieve 7" row spacing

Seven inch row spacing may well be achievable for some, but it may be difficult in very high rainfall areas where wheat yields are 5 t/ha or greater. Researchers have suggested that most growers can achieve narrower row spacing than they are currently using, and that they will benefit from doing so.

Crop competition with weeds will continue to become more and more important as herbicide resistance worsens. If narrow row spacing isn't possible, growers may want to consider some of the other options to improve crop competition, such as East-West sowing, competitive cultivars and high seeding rates. East-West sowing is a good, free weed control tactic. But narrow row spacing is better than free; it makes more profit while improving weed control. Narrow row spacing is inconvenient, but the science is telling us that it is good for the crop and bad for the weeds. [10]

Trials have been conducted at the DAFWA research station at Merredin, 260 km east of Perth, Western Australia, exploring the effect of row spacing in weed control for a variety of crops. The trial began in 1987, but ryegrass measurement only commenced

10 University of WA (2016) Narrow row spacing—more crop, fewer weeds. http://ahri.uwa.edu.au/narrow-row-spacing/

in 2003. The site was on red loam salmon gum/gimlet soil. Average annual rainfall from 2003 to 2013 was 301 mm (range 168–400). Sown with a high box six rank combine that allows for a range of row spacing configurations with separate fertiliser tines deeper than the seed. Tynes were removed from the combine as row spacing widened. Narrow row spacing yielded more and had fewer ryegrass (Tables 2 and 3).

Table 2: *Crop yield (kg/ha).*

Year	Crop	Row Spacing			
		9 cm	18 cm	27 cm	36 cm
2003	Wheat	3210	3317	3099	3049
2004	Wheat	1823	1825	1760	1560
2005	Field pea	1995	2024	1761	1710
2006	Wheat	2585	2631	2358	2216
2007	Barley	366	385	394	441
2008	Chemical fallow	*	*	*	*
2009	Canola	929	887	832	766
2010	Wheat	1273	1077	988	1031
2011	Wheat	2140	2058	1969	1975
2012	Chickpea	176	148	119	141
2013	Wheat	2083	2021	2196	2035

Source: UWA

Table 3: *Annual ryegrass seed (per m^2) at harvest.*

Year	Crop	Row Spacing			
		9 cm	18 cm	27 cm	36 cm
2003	Wheat	324	296	702	382
2004	Wheat	318	312	757	1001
2005	Field pea	375	558	1930	1581
2006	Wheat	14	18	29	27
2007	Barley	25	54	424	789
2008	Chemical fallow	*	*	*	*
2009	Canola	140	319	3056	3468
2010	Wheat	17	24	36	173
2011	Wheat	159	162	334	552
2012	Chickpea	60	50	135	287
2013	Wheat	2	1	51	171

Source: UWA

WATCH: AHRI insight #70: Narrow row spacing, more crop, fewer weeds.

WATCH: Over the Fence West: Narrower rows result in more crops, fewer weeds in Mingenew.

MORE INFORMATION

UWA – Narrow Row spacing – more crop, fewer weeds.

IN FOCUS

Chemical and Non-chemical Weed Control in Wide Row Lupins and Chickpeas in Western Australia.

Wide row sowing systems (greater than 50 cm wide rows) are becoming more common in Western Australia, allowing growers to control inter-row weeds by inter-row cultivation for organic crops or by spraying non-selective herbicides using shielded sprayers. In one study, inter-row shielded spraying was found to be the most effective treatment for annual ryegrass control in the 66 cm wide rows, but future herbicide resistance will be a major limitation. With shielded spraying, some form of intra-row weed control will still be necessary to significantly reduce weed seed set. Automatic tractor steering control would also be essential for commercial growers to adopt shielded spraying. In 2006, inter-row cultivation reduced annual ryegrass biomass by 63% and the number of annual ryegrass heads by 43%, but this did not result in a significant increase in lupin yield. To be most effective, it is suggested that inter-row cultivation should be done relatively early while the weeds are small, and when the soil is relatively warm and dry with rain not predicted for a day or two. In 2006 and 2007, inter-row shielded spraying with glyphosate gave the best ryegrass control averaging 94%. Weed seed head trimming or cutting weeds above the crop prior to weed seed maturity may be a useful non-chemical method to reduce the number of weed seeds set if the weed seed is above the crop canopy and the cutting height is well controlled. Indian hedge mustard (*Sisymbrium orientale*) seed collected in the 2005 chickpea harvest samples was reduced by around 35% with all trimming treatments. In 2006, the late flower trimming reduced the seed number of wild oats and volunteer wheat in chickpeas. Lupin and chickpea grain yield was slightly reduced by trimming in 2005, but with improved height control did not reduce yields in 2006. Given the difficulties in controlling weeds by the growers due to widespread development of herbicide resistance in these weeds within the WA wheatbelt, this novel non-chemical way of weed control is a viable and promising option to reduce the soil weed seed bank. [11]

6.4 Herbicides explained

6.4.1 Residual and non-residual

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

The persistence of residual herbicides is determined by a range of factors including application rate, soil texture, organic matter levels, soil pH, rainfall and irrigation, temperature and the herbicide's characteristics. The persistence of herbicides will affect the enterprise's sequence (a rotation of crops, e.g. wheat–barley–chickpeas–canola–wheat).

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

6.4.2 Post-emergent and pre-emergent

These terms refer to the target and timing of herbicide application. Post-emergent refers to foliar application of the herbicide after the target weeds have emerged from the soil, whereas pre-emergent refers to application of the herbicide to the soil before the weeds have emerged. [12]

6.5 Mode of Action (MOA)

Resistance has developed primarily because of the repeated and often uninterrupted use of herbicides with the same mode of action. Selection of resistant strains can occur in as little as 3–4 years if attention is not paid to resistance management. Remember that the resistance risk remains for products having the same MOA. If

11 GP Riethmuller, A Hashem, SM Pathan (2009) Chemical and non-chemical weed control in wide row lupins and chickpeas in Western Australia. Australian Journal of Multi-Disciplinary Engineering, 7(1), 15–26.

12 T McGillion, A Storrie (Eds.) (2006) Integrated weed management in Australian cropping systems—A training resource for farm advisors. Section 4: Tactics for managing weed populations. CRC for Australian Weed Management, Adelaide http://www.grdc.com.au/~/media/A4C48127FF8A4B0CA7DFD67547A5B716.pdf

you continue to use herbicides with the same MOA and do not follow a resistance-management strategy, problems will arise.

6.5.1 MOA labelling

In order to facilitate management of herbicide-resistant weeds, all herbicides sold in Australia are grouped by MOA. The MOA is indicated by a letter code on the product label. The MOA labelling is based on the resistance risk of each group of herbicides. Australia was the first country to introduce compulsory MOA labelling on products, and the letters and codes used in Australia are unique. Labelling is compulsory and the letters and codes reflect the relative risk of resistance evolving in each group. Since the introduction of MOA labelling in Australia, other countries have adopted MOA classification systems; however, caution is advised if cross-referencing MOAs between Australia and other countries, as different classification systems are used. The herbicide MOA grouping and labelling system in Australia was revised in 2007. This is the first major revision of the classification system since its introduction.

The original groupings were made based on limited knowledge about MOAs. Groupings have been changed to improve the accuracy and completeness of the MOAs to enable more informed decisions about herbicide rotation and resistance management. The general intent of groups based on their risk has not changed.

6.5.2 Grouping by mode of action and ranking by resistance risk

Growers and agronomists are now better assisted to understand the huge array of herbicide products in the marketplace in terms of MOA grouping and resistance risk by reference to the MOA chart. All herbicide labels now carry the MOA group clearly displayed, such as:

Group	**G**	**Herbicide**

Know your herbicide groups to make use of this labelling.

Not all MOA groups carry the same risk for resistance development. Therefore, specific guidelines for Groups E, G, H, N, O, P and R have not been developed, because there are no recorded cases of weeds resistant to members of these groups in Australia.

Products represented in Group A (mostly targeted at annual ryegrass and wild oats) and Group B (broadleaf and grass weeds) are HIGH RESISTANCE RISK herbicides, and specific guidelines are written for use of these products in winter cropping systems.

Specific guidelines are also available for the MODERATE RESISTANCE RISK herbicides: Group C (annual ryegrass, wild radish and silver grass), Group D (annual ryegrass and fumitory), Group F (wild radish), Group I (wild radish and Indian hedge mustard), Group J (serrated tussock and giant Parramatta grass), Group L (annual ryegrass, barley grass, silver grass and cape weed), Group M (annual ryegrass, barnyard grass, fleabane, liverseed grass and windmill grass), Group Q (annual ryegrass), and Group Z (wild oats and winter grass).

Specific guidelines for Group K have been developed due to the reliance on this MOA to manage annual ryegrass, and the possibility of future resistance development. [13]

6.5.3 Specific guidelines for Group A herbicides

High resistance risk.

13 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

Group A resistance exists in Australia in the grass weeds, including annual ryegrass, wild oats, phalaris, brome grass, crab grass, goose grass and barley grass. Resistance has developed in broadacre and vegetable situations.

Research has shown that as few as six applications to the same population of annual ryegrass can result in the selection of resistant individuals. A population can go from a small area of resistant individuals to a whole paddock failure in one season.

Fops, dims and dens are Group A herbicides and carry the same high resistance risk. Where a Group A herbicide has been used on a particular paddock for control of any grass weed, avoid using a Group A herbicide to control the same grass weed in the following season, irrespective of the performance it gave.

Frequent application of Group A herbicides to dense weed populations is the worst scenario for rapid selection of resistance.

Where resistance to a member of Group A is suspected or known to exist, there is a strong possibility of cross-resistance to other Group A herbicides. Therefore, use other control methods and herbicides of other MOA groups in a future integrated approach.

The above recommendations should be incorporated into an integrated weed management (IWM) program. In all cases, try to ensure that surviving weeds from any treatment do not set and shed viable seed. Keep to integrated strategies, including rotation of MOA groups.

The following charts have been compiled from chemical labels on the APVMA website and PIRSA Spraying charts and in consultation with chemical companies (Table 4).

Table 4: *Active ingredients of Group A MOAs.*

Chemical family	Active constituent (first registered trade name)
Group A. Inhibitors of acetyl coA carboxylase (inhibitors of fat synthesis/ACCase inhibitors)	
Aryloxyphenoxypropionates (fops)	Clodinaafop (Topik®), cyhalofop (Barnstorm®), diclofop (Cheetah® Gold, Decision®*, Hoegrass®, Tristar® Advance*), fenoxaprop (Cheetah® Gold*, Tristar® Advance*, Wildcat®), fluazifop (Fusilade®, Fusion®*), haloxyfop (Motsa®*, Verdict®), propaquizafop (Shogun®), quizalofop (Targa®)
Cyclohexanediones (dims)	Butroxydim (Falcon®, Fusion®*), clethodim (Motsa®*, Select®), profoxydim (Aura®), sethoxydim (Cheetah® Gold*, Decision®*, Sertin®), tepraloxydim (Aramo®), tralkoxydim (Achieve®)
Phenylpyrazoles (dens)	Pinoxaden (Axial®)

*This product contains more than one active constituent
Source: CropLife Australia 'Herbicide Resistance Management Strategies—September 2011'

6.5.4 Specific guidelines for Group B herbicides

High resistance risk.

Group B resistance exists in Australia in the grass weeds, annual ryegrass, barley grass, brome grass, wild oats and crab grass, and in at least 16 broadleaf weeds including: wild radish, common sowthistle, climbing buckwheat, turnip weed, wild mustard, Indian hedge mustard, prickly lettuce, wild turnip and African turnip weed. Resistance has developed in broadacre, rice and pasture situations. With respect to rice, three broadleaf weeds have been discovered: dirty dora, arrowhead and starfruit.

Research has shown that as few as four applications to the same population of annual ryegrass can result in the selection of resistant individuals and as few as six applications for wild radish. A population can go from a small area of resistant individuals to a whole paddock failure in one season.

Avoid applying more than two Group B herbicides in any four year period on the same paddock.

Broadleaf weed control

If a pre-emergent application is made with a Group B herbicide for broadleaf weed control, monitor results and, if required, apply a follow-up spray with a non-Group B herbicide for control of escapes and to reduce seed-set.

If a post-emergent application is made with a Group B herbicide for broadleaf weed control, it should preferably be as an APVMA-approved tank-mix with another MOA that controls or has significant activity against the target weed. If no APVMA-approved tank-mix is available, then monitor results and if required, apply a follow-up spray with a non-Group B herbicide for control of escapes and to reduce seed-set.

A Group B herbicide may be used alone on flowering wild radish only if a Group B herbicide has not been previously used on that crop.

Grass-weed control

If there are significant escapes following the herbicide application, consider using another herbicide with a different mode of action or another control method to stop seed-set (Table 5).

Table 5: *Active ingredients for Group B MOAs.*

Chemical family	Active constituent (first registered trade name)
Group B. Inhibitors of acetolactate synthase (ASL inhibitors)	
Sulfonylureas (SUs)	Azimsulfuron (Gulliver®), bensulfuron (Londax®), chlorsulfuron (Glean®), ethoxysulfuron (Hero®), foramsulfuron (Tribute®), halosulfuron (Sempra®), iodosulfuron (Hussar®), mesosulfuron (Atlantis®), metsulfuron (Ally®, Harmony®*M, Trounce®*, Ultimate Brushweed®* Herbicide), prosulfuron (Casper®*) rimsulfuron (Titus®), sulfometuron (Oust®), sulfosulfuron (Monza®), thifensulfuron (Harmony®*M), triasulfuron (Logran®, Logran® B-Power*) tribenuron (Express®), trifloxysulfuron (Envoke®, Krismat®*)
Imidazolinones (imis)	Imazamox (Raptor®, Intervix®*), imazapic (Flame®, Midas®*, OnDuty®*), imazapyr (Arsenal Xpress®*, Midas®*, OnDuty®*, Intervix®*, Lightning®*), imazethapyr (Spinnaker®, Lightning®*)
Triazolopyrimidines (sulfonamides):	Flumetsulam (Broadstrike®), florasulam (Conclude®*, Torpedo®*, X-Pand®*), metosulam (Eclipse®), pyroxsulam (Crusader®)
Pyrimidinylthiobenzoates	Bispyribac (Nominee®), pyrithiobac (Staple®)

*This product contains more than one active constituent
Source: CropLife Australia 'Herbicide Resistance Management Strategies—September 2011'

6.5.5 Specific guidelines for Group C herbicides

Moderate resistance risk.

Group C resistance exists in Australia in the weeds annual ryegrass, wild radish, liverseed grass, silver grass, stinging nettles and barnyard grass. Resistance has developed in broadacre, horticultural and non-crop situations.

CropLife Australia gives specific guidelines for the use of Group C herbicides in TT canola and in winter legume crops, following increasing reports of resistance development.

Avoid using Group C herbicides in the same paddock in consecutive years. Growing TT canola in a paddock treated with triazine herbicides in the previous season is a high resistance risk and is not recommended.

Watch and record for weed escapes, especially in paddocks with a long history of Group C use.

Consult the 'Integrated Weed Management Strategy for TT Canola' for further details. The resistance status of the 'at-risk' weeds should be determined prior to sowing. Always use the label rate of herbicide, whether a single active ingredient (e.g. bromoxynil) or combination of active ingredients is applied (e.g. bromoxynil/MCPA, pyrasulfotole/bromoxynil). Apply to weeds at the labelled growth stage and ensure that no weeds set and shed viable seed. To prevent seed-set, control survivors with a herbicide of different MOA from Group C, or use another weed-management technique (Table 6).

Table 6: *Active ingredients in Group C MOAs.*

Chemical family	Active constituent (first registered trade name)
Group C. Inhibitors of photosynthesis at photosystem II (PS II inhibitors)	
Triazines	Ametryn (Amigan®*, Primatol Z®, Gesapax® Combi*, Krismat®), atrazine (Gesaprim®, Gesapax® Combi*, Primextra® Gold*), cynazine (Bladex®), prometryn (Gesagard®, Cotoguard®*, Bandit®*), propazine (Agaprop®), simazine (Gesatop®) terbuthylazine (Terbyne®), terbutryn (Amigan®*, Igran®, Agtryne® MA*)
Triazinones	Hexazinone (Velpar® L, Velpar® K4*), metribuzin (Sencor®)
Uracils	Bromacil (Hyvar®, Krovar®*), terbacil (Sinbar®)
Pyridazinones	Chloridazon (Pyramin®)
Phenylcarbamates	Phenmedipham (Betanal®)
Ureas	Diuron (Karmex®, Krovar®*, Velpar® K4*), fluometuron (Cotoran®, Cotoguard®*, Bandit®*), linuron (Afalon®), methabenzthiazuron (Tribunil®), siduron (Tupersan®), tebuthiuron (Graslan®)
Armides	Propanil (Stam®)
Nitriles	Bromoxynil (Buctril®, Buctril® MA*, Barrel®*, Jaguar®*, Velocity®*, Flight®*), ioxynil (Totril®, Actril DS*)
Benzothiadiazinones:	Bentazone (Basagran®, Basagran® M60*)

*This product contains more than one active constituent
Source: CropLife Australia 'Herbicide Resistance Management Strategies—September 2011'

6.5.6 Specific guidelines for Group D herbicides

Moderate resistance risk.

Resistance to Group D herbicides is known for an increasing number of populations of annual ryegrass and fumitory. Resistance has generally occurred after 10–15 years of use of Group D herbicides.

Where possible, avoid the use of Group D herbicides on dense ryegrass populations. Consider using alternative methods of weed control to reduce weed numbers before applying herbicides.

Rotate with herbicides from other MOA. For annual ryegrass, consider rotating trifluralin with products such as Boxer Gold®.

These recommendations should be incorporated into an IWM program (Table 7). Try to ensure that surviving weeds from any treatment do not set and shed viable seed. Use integrated strategies, including rotation of MOA groups.

Table 7: *Active ingredients of Group D MOAs.*

Chemical family	Active constituent (first registered trade name)
Group D. Inhibitors of microtubule assembly	
Dinitroanilines (DNAs)	Oryzalin (Surflan®, Rout®*), pendimethalin (Stomp®), prodiamine (Barricade®), trifluralin (Treflan®)
Benzoic acids	Chlorthal (Dacthal®, Prothal®*)
Benzamides	Propyzamide (Kerb®)
Pyridines	Dithiopyr (Dimension®), thiazopyr (Visor®)

*This product contains more than one active constituent
Source: CropLife Australia 'Herbicide Resistance Management Strategies—September 2011'

6.5.7 Specific guidelines for Group F herbicides

Moderate resistance risk.

Resistance to Group F herbicides is known for a small number of populations of wild radish. Resistance has generally occurred after a long history of use of Group F herbicides. The number of populations with Group F resistance is increasing following increased use of these herbicides.

Group F includes herbicides that reduce carotenoid biosynthesis through inhibition of phytoene desaturase (PDS).

Avoid applying Group F herbicides in any two consecutive years unless one application is a mixture with a different MOA that is active on the same weed, or a follow-up spray is conducted (using a different MOA) to control escapes. Always use the label rate of herbicide, whether a single active ingredient (e.g. diflufenican) or combination of active ingredients is applied (e.g. diflufenican/MCPA, picolinafen/MCPA). Apply to weeds at the labelled growth stage and ensure that no weeds set and shed viable seed. To prevent seed-set, control survivors with a herbicide of different MOA from Group F, or use another weed-management technique.

If applicable, apply a follow-up spray with a non-Group F herbicide for control of escapes and to reduce seed-set. Aim to ensure that surviving weeds from any treatment do not set and shed viable seed.

These recommendations should be incorporated into an IWM program. Try to ensure that surviving weeds from any treatment do not set and shed viable seed. Use integrated strategies including rotation of MOA groups (Table 8).

Table 8: *Active ingredients for Group F MOAs.*

Chemical family	Active constituent (first registered trade name)
Group F. Bleachers: Inhibitors of carotenoid biosynthesis at the phytoenede saturase step (PDS inhibitors)	
Nicotinanilides	Diflufenican (Brodal®, Jaguar®*, Tigrex®*, Chipco Spearhead®*)
Picolinamides	Picolinafen (Paragon®*, Sniper®, Flight®)
Pyridazinones	Norflurazon (Solicam®)

*This product contains more than one active constituent
Source: CropLife Australia 'Herbicide Resistance Management Strategies—September 2011'

6.5.8 Specific guidelines for Group I herbicides

Moderate resistance risk.

Resistance to Group I herbicides is known for a number of populations of wild radish and Indian hedge mustard. Resistance has occurred after a long history of use of Group I herbicides. The number of populations with Group I resistance is increasing.

It is of particular concern that in addition to Group I resistance in wild radish—which is the most important broadleaf weed in broadacre agriculture—some populations are cross-resistant to other MOAs, e.g. Group F herbicides, which can be important for control of wild radish in lupins where other selective, non-Group I options are limited. Because of the long soil life of wild radish seed, measures to reduce the return of seed to the soil would be useful for this weed. Wild radish seed that is confined to the top 5 cm soil has a shorter life than seed buried deeper.

As a rule, in situations of high resistance risk:

- Avoid applying two applications of Group I herbicides alone onto the same population of weeds in the same season.
- Where possible, combine more than one MOA in a single application. Each product should be applied at rates sufficient for control of the target weed alone to reduce the likelihood of weeds resistant to the Group I herbicide surviving.

These recommendations should be incorporated into an IWM program. Try to ensure that surviving weeds from any treatment do not set and shed viable seed. Use integrated strategies, including rotation of MOA groups (Table 9).

Table 9: *Active ingredients of Group I MOAs.*

Chemical family	Active constituent (first registered trade name)
Group I. Disruptors of plant cell growth (synthetic auxins)	
Phenoxycarboxylic acids (phenoxys)	2,4-D (Amicide®, Actril DS®*, Pyresta®*), 2,4-DB (Trifolamine®), dichlorprop (Lantana 600®), MCPA (MCPA, Buctril® MA*, Banvel M®*, Conclude®*, Midas®*, Paragon®*, Tigrex®*, Barrel®*, Tordon 242®*, Basagran® M60*, Chipco Spearhead®*, Agtryne® MA*, Precept®*, Flight®*) MCPB (Legumine®), mecoprop (Mecopropamine®, Mecoban®, Methar Tri-Kombi®*)
Benzoic acids	Dicamba (Banvel®, Banvel M®*, Barrel®*, Mecoban®, Methar Tri-Kombi®*)
Pyridine carboxylic acids (pyridines)	Aminopyralid (Hotshot®*,Grazon Extra®*), clopyralid (Lontrel®, Torpedo®*, Chipco Spearhead®*), fluroxypyr (Starane®, Hotshot®*), picloram (Tordon®, Tordon 242®*, Grazon®*, Grazon Extra®*), triclopyr (Garlon®, Grazon®*, Grazon Extra®*, Ultimate Brushweed®* Herbicide)

*This product contains more than one active constituent
Source: CropLife Australia 'Herbicide Resistance Management Strategies—September 2011'

6.5.9 Specific guidelines for Group J herbicides

Moderate resistance risk.

There are isolated cases of weeds resistant to Group J in Australia. Two populations of serrated tussock and six populations of giant Parramatta grass are confirmed resistant to flupropanate.

To assist in delaying the onset of resistance, consider alternating with herbicides from other MOA.

The recommendations should be incorporated into an IWM program. Try to ensure surviving weeds from any treatment do not set and shed viable seed. Use integrated strategies, including rotation of MOA groups (Table 10).

Table 10: *Active ingredients of Group J MOAs.*

Chemical family	Active constituent (first registered trade name)
Group J. Inhibitors of fat synthesis (not ACCase inhibitors)	
Chlorocarbonic acids	2,2-DPA (Dalapon®), flupropanate (Frenock®)
Thiocarbamates	EPTC (Eptam®), molinate (Ordram®), pebulate (Tillam®), prosulfocarb (Boxer® Gold*), thiobencarb (Saturn®), triallate (Avadex®), vernolate (Vernam®)
Phosphorodithioates	Bensuilde (Prefar®)
Benzofurans	Ethofumesate (Tramat®)

*This product contains more than one active constituent
Source: CropLife Australia 'Herbicide Resistance Management Strategies—September 2011'

6.5.10 Specific guidelines for Group K herbicides

Moderate resistance risk.

Resistance to Group K herbicides is possible in Australia and may develop in broadacre situations.

Where possible, avoid the use of Group K herbicides on dense populations of ryegrass. Consider using alternative methods of weed control to reduce weed numbers before applying herbicides.

Rotate with herbicides from other modes of action (Table 11). The recommendations should be incorporated into an IWM program. Try to ensure surviving weeds from any treatment do not set and shed viable seed. Use integrated strategies, including rotation of MOA groups.

Table 11: *Active ingredients for Group K MOAs.*

Chemical family	Active constituent (first registered trade name)
GROUP K. Inhibitors of cell division/inhibitors of very long chain fatty acids (VLCFA inhibitors).	
Acetamides	Napropamide (Devrinol®)
Chloroacetemides	Dimethenamid (Frontier®-P), metolachlor (Boxer® Gold*, Dual® Gold, Primextra® Gold*), propachlor (Ramrod®, Prothal®*)
Isoxazoline	Pyroxasulfone (Sakura®)

*This product contains more than one active constituent
Source: CropLife Australia 'Herbicide Resistance Management Strategies—September 2011'

6.5.11 Specific guidelines for Group L herbicides

Moderate resistance risk.

Group L resistance exists in Australia in annual ryegrass, barley grass (two species), silver grass, cape weed and square weed. Most instances have occurred in long-term lucerne stands treated regularly with a Group L herbicide, but Group L-resistant barley grass has also occurred in no-till situations.

The following factors are common to all cases of Group L resistance:

- A Group L herbicide is the major or only herbicide used.
- A Group L herbicide has been used for 12–15 years or more.
- There has been minimal or no soil disturbance following application.

The risk of resistance to Group L herbicides is higher in no-tillage broadacre cropping. Other situations of high resistance risk include irrigated clover pivots, orchards, vineyards or pure lucerne stands where frequent applications of a Group

L herbicide are made each season, cultivation is not used and there is reliance on a Group L herbicide alone for weed control.

Below are strategies to reduce the risk of Group L resistance developing in situations of high resistance risk.

No-tillage

Rotate Group L herbicides with other knockdown herbicides with a different mode of action.

Consider utilising the double-knock technique, with glyphosate sprayed first followed within 1–7 days by a paraquat application. A full label rate for the weed size targeted should be used for the paraquat application for resistance management. Consider occasional mechanical cultivation to aid weed control.

Lucerne

If using a Group L herbicide for winter cleaning, where possible include another MOA, e.g. diuron (Group C).

Use alternative MOA to selectively control grass and broadleaf weeds. Rotate Group L herbicides with other knockdown herbicides with a different MOA prior to sowing lucerne and prior to sowing future crops in that paddock.

Horticulture

Rotate Group L herbicides with other knockdown herbicides with a different MOA. Where possible use residual herbicides (that are effective on the same weeds as the Group L herbicides) where applicable, either alone or in mixture with Group L herbicides. Where possible, use an alternative MOA to selectively control grass and broadleaf weeds. Consider using the double-knock technique, with glyphosate sprayed first followed within 1–7 days by a paraquat application. A full label rate for the weed size targeted should be used for the paraquat application for resistance management.

These recommendations should be incorporated into an IWM program. Try to ensure surviving weeds from any treatment do not set and shed viable seed. Always try to apply herbicides to the smallest weed density. Use integrated strategies, including rotation of MOA groups (Table 12).

Table 12: *Active ingredients of Group L MOAs.*

Chemical family	Active constituent (first registered trade name)
Group L. Inhibitors of photosynthesis at photosystem I (PSI inhibitors)	
Bipyridyls	Diquat (Reglone®, Spray.Seed®*), paraquat (Gramoxone®, Spray.Seed®*, Alliance®*)

*This product contains more than one active constituent
Source: CropLife Australia 'Herbicide Resistance Management Strategies—September 2011'

6.5.12 Specific guidelines for Group M herbicides

Moderate resistance risk.

Group M resistance occurs in Australia in annual ryegrass, awnless barnyard grass, fleabane, liverseed grass and windmill grass.

Herbicide resistance to glyphosate was first discovered in annual ryegrass in Australia in 1996. Since then, several new cases of glyphosate resistance in annual ryegrass, awnless barnyard grass, fleabane, liverseed grass and windmill grass have been confirmed.

The following factors are common to all cases of Group M resistance:

- A Group M herbicide is the major or only herbicide used.
- A Group M herbicide has been used for 12–15 years or more.

- There has been minimal or no soil disturbance following application.

Given the important role of glyphosate in Australian farming systems, the Australian agricultural industry has developed strategies for sustainable use of glyphosate.

For more information, refer to the Australian Glyphosate Sustainability Working Group website.

All cases of glyphosate resistant weeds confirmed to date share three common factors:

- Intensive (year-to-year) use of glyphosate.
- Lack of rotation of other herbicide modes of action.
- Little or no tillage or cultivation following the application of glyphosate.

Several cases of ryegrass resistance to glyphosate have occurred in horticultural and non-cropping situations (e.g. firebreaks, fence lines, driveways, irrigation ditches), with the balance occurring in no-till, broadacre cropping systems.

Given the demonstrated propensity of annual ryegrass to develop resistance to multiple herbicide classes, IWM principles should be incorporated wherever possible to minimise the risk of selecting for glyphosate-resistant ryegrass. Strategies may include the use of cultivation, the double-knock technique (using a full-cut cultivation OR the full label rate of a paraquat-based product (Group L) following the glyphosate (Group M) knockdown application), strategic herbicide rotation, grazing and baling.

Try to ensure that surviving weeds from any treatment do not set and shed viable seed. Always try to apply herbicides to the smallest weed density. Use the integrated strategies mentioned, including rotation of MOA groups (Table 13).

Table 13: *Active ingredients of Group M MOAs.*

Chemical family	Active constituent (first registered trade name)
Group M. Inhibitors of EPSP synthase	
Glycines	Glyphosate (Roundup®, Trounce®*,Illico®*, Arsenal Xpress®*, Broadway®*)

*This product contains more than one active constituent
Source: CropLife Australia 'Herbicide Resistance Management Strategies—September 2011'

6.5.13 Specific guidelines for Group Z herbicides

Moderate resistance risk.

Group Z resistance exists in Australia in wild oats resistant to flamprop. Many of these flamprop-resistant wild oats also show cross-resistance to Group A herbicides. Resistance to endothal is confirmed in winter grass.

To assist in delaying the onset of resistance, rotate with herbicides from other MOAs. Consider using alternative methods of weed control to reduce weed numbers before applying herbicides. These may include summer crop rotations, delayed sowing to control wild oats with a knockdown herbicide, higher seeding rates and brown manuring to stop seed-set.

The recommendations should be incorporated into an IWM program. Try to ensure that surviving weeds from any treatment do not set and shed viable seed. Use integrated strategies, including rotation of MOA groups (Table 14).

Table 14: *Active ingredients of Group Z MOAs.*

Chemical family	Active constituent (first registered trade name)
Group Z. Herbicides with unknown and probably diverse sites of action	
Arylaminopropionic acids	Flamprop (Mataven L®)
Dicarboxylic acids	Endothal (Endothal®)
Organoarsenicals	DSMA (Methar®), MSMA (Daconate®)

*This product contains more than one active constituent
Source: CropLife Australia 'Herbicide Resistance Management Strategies—September 2011'

Refer to the APVMA website to obtain a complete list of registered products from the PUBCRIS database.

6.5.14 Herbicide use according to growth stage

It is important to consider growth stage of the chickpea crop before applying herbicides (Table 15).

Table 15: *Herbicide use according to growth stage in chickpeas.*

Herbicide	Use	Growth stage
Group A		
butroxydim	Do not graze or cut for stockfeed within 14 days of application	Vegetative growth stage, prior to flowering, podding and seven weeks prior to harvest
butroxydim + fluazifop	Up to seven weeks before harvest	Vegetative growth stage, prior to flowering, podding and seven weeks prior to harvest
clethodim	Up to full flowering	Vegetative growth stage, prior to flowering, podding
fluazifop	Up to seven weeks before harvest	Vegetative growth stage, prior to flowering, podding and seven weeks prior to harvest
haloxyfop	Second branch through to flowering	Vegetative growth stage, prior to flowering, podding
propaquizafop	Up to 12 weeks before harvest	Vegetative growth stage
sethoxydim	Up to prior to flowering	Vegetative growth stage, prior to flowering, podding
tepraloxydim	Up to 12 weeks before harvest	Vegetative growth stage
Group B		
flumetsulam	Apply from four to six branches and no later than six weeks after emergence	Vegetative growth stage

Source: DPI NSW

NOTE: For chickpea, the window for application for selective grass control herbicides (Group As) is generally dictated by regulatory requirements to avoid residues in produce that exceed levels acceptable to various markets. Check the labels for individual herbicides but chickpea crop safety for most Group As is not influenced by growth stage up to at least flowering.

For up-to-date chemical Withholding Periods and other label information, see the APVMA search facility.

6.5.15 Getting the best results from herbicides

1. Control weeds as early as possible in the first six weeks after sowing.
2. Make sure that the crop and weeds are at the correct growth stage for the herbicide to be used.
3. Do not spray outside the recommended crop growth stages as damage may result.
4. Do not spray when the crop or weeds are under any form of stress such as drought, waterlogging, extreme cold, low soil fertility, disease or insect attack, or a previous herbicide.
5. Some herbicides should not be used when weeds are wet with rain or dew or if rain is likely to occur within three or four hours.
6. Do not spray in windy conditions (>10–15 km/hr) as drift from herbicides can cause damage to non-target crops. Herbicide spray can also drift in very calm conditions, especially with air temperature inversions.
7. Use sufficient water to ensure a thorough, uniform coverage regardless of the method of application.
8. Use good quality water. Hard, alkaline or dirty water can reduce the effectiveness of some herbicides.
9. Maintain clean, well-cared-for equipment. A poorly maintained spray unit will cost you money in breakdowns, blocked jets, poor results and, perhaps worse, crop damage through misapplication.
10. After products such as Atlantis®, chlorsulfuron, Hussar® metsulfuron or triasulfuron have been used in equipment, it is essential to clean that equipment thoroughly with chlorine before using other chemicals. After using Affinity®, Broadstrike® or Eclipse® decontaminate with liquid alkali detergent.
11. Seek advice before spraying recently released pulse varieties. They may differ in their tolerance to herbicides. [14]

6.6 Summer fallow weed control

In a winter cropping system, the return on investment from managing weeds in summer fallow (i.e. the period between crops) is high. Economic benefits flow from both extra amounts of high value water and nitrogen, crop establishment benefits and reduced issues with weed vectored disease and insect pests.

Stopping weed growth in the fallow can lead to yield increases in the following crop via several pathways. These include:

- Increased plant available water
- A wider and more reliable sowing window
- Higher levels of plant available N
- Reduced levels of weed vectored diseases and nematodes
- Reduced levels of rust inoculum via interruption of the green bridge
- Reduced levels of diseases vectored by aphids that build in numbers on summer weeds, and
- Reduced weed physical impacts on crop establishment.

How farming country is managed in the months or years before sowing can be more important in lifting water use efficiency (WUE) than in-crop management. Of particularly high impact are strategies that increase soil capture and storage of fallow rainfall to improve crop reliability and yield.

Practices such as controlled traffic farming and long term no-till seek to change the very nature of soil structure to improve infiltration rates and improve plant access to stored water by removal of compaction zones.

14 GRDC (2008) Grain Legume Handbook—Weed control

MORE INFORMATION

Summer fallow weed management for growers in the Southern and Western region

Shorter term management decisions can have an equal or even greater impact on how much plant available water (PAW) is stored at sowing. These include decisions such as crop sequence/rotation that dictate the length of the fallow and amount of stubble cover, how effectively fallow weeds are managed, stubble management and decisions to till/not to till at critical times.

While many factors influence how much plant available water is stored in a fallow period, good weed management consistently has the greatest impact. [15]

6.7 Double knock strategies

Getting the best bang for your buck

The use of glyphosate as the first knock followed within one to seven days with the second knock application of paraquat or paraquat + diquat is increasing in southern Australia. A well-timed and executed double knock is a very useful first step to reducing weed pressure and keeping a lid on glyphosate resistant annual ryegrass. Building the double knock treatment into a whole-of-season weed management plan provides opportunities to get more 'bang for your buck'.

The first knock is to kill all plants still susceptible to glyphosate—applying a lower rate risks higher survival rates, increasing the pressure on the second knock products. The second knock of Spray.Seed® or paraquat is to kill plants that survived the glyphosate. Reducing the rate of the second knock risks survival of potentially glyphosate resistant individuals and damages the integrity of the double knock tactic. Remember that paraquat and Spray.Seed® are contact herbicides and require robust water rates to ensure adequate coverage, and allow for losses on stubble.

If the main weed problem is annual ryegrass then using paraquat on its own as the second knock is an appropriate choice. If there are also broadleaf weeds present, then the paraquat + diquat combination (e.g. Spray.Seed®) will be more effective overall. Mixing the glyphosate and paraquat together is both ineffective and not registered. Applying the two sprays between one and seven days apart is optimum timing.

If there is a mix of weeds present it can be useful to include a compatible herbicide 'spike' such as 2-4D low volatile ester, carfentrazone, or oxyflouren to enhance control of broadleaf weeds. Be very mindful of plant-back requirements of some herbicide 'spikes' before planting sensitive crops such as pulses and canola.

Don't rely on a pre-sowing double knock alone. Use pre-emergent herbicides, and focus on increasing the level of crop competition with narrow row spacing and varieties with vigorous early growth. Sow crops at the optimal time to maximise competitiveness.

In weedy paddocks, consider the value of break crops such as pulses, canola, or hay as a way of incorporating other in-crop and non-chemical options to manage annual ryegrass, such as grass-selective post-emergent herbicides, crop-topping, desiccation, spraying under the swath or narrow windrow burning where appropriate. [16]

6.8 Pre-emergent herbicides

Pre-emergent herbicides are applied to the soil either before or directly after sowing and prior to weed emergence.

The pre-emergent herbicides alone will not adequately control large weed populations, and so they need to be used in conjunction with paddock selection and pre-seeding weed control.

15 GRDC (2014). Summer fallow weed management. https://grdc.com.au/Resources/Publications/2014/05/Summer-fallow-weed-management

16 WeedSmart. 2015. How can I get the best best for my buck with a double knock? http://www.weedsmart.org.au/ask-an-expert/how-can-i-get-the-best-bang-for-my-buck-with-a-double-knock/

Selection of the appropriate pre-emergent herbicide can only be made after assessing such factors as weed spectrum, soil type, farming system and local experience. For best results, refer to the complete product label for directions for use, application rates, weeds controlled and conditions.

Pre-sowing application is possible with some products and is often safer than post-sowing application, because the sowing operation removes a certain amount of the herbicide from the crop row. Higher rates can often be used pre-sowing, but in both cases the rate must be adjusted to soil type, as recommended on the product label.

6.8.1 Standard pre-sowing weed control practice—WA

Paddocks are generally selected at the end of a long cereal rotation where the pH is suitable for growing chickpeas. Ryegrass, wild turnip, mustard, wild radish and doublegee are generally the troublesome weeds to contend with. Standard pre-sowing weed control generally consists of a 'double knock' of glyphosate and Esteron™LV followed by Spray.Seed®, Diuron and Simazine or Terbuthylazine immediately before sowing (IBS), followed by Balance® Herbicide post sowing pre-emergent (PSPE). [17] Note that plant-back periods of 24D prior to planting can be an issue and that growers might want to reconsider adding this active ingredient unless specific in of the plant-back labels is mentioned. Table 16 lists products registered for pre-sowing application in kabuli chickpeas.

Table 16: *Registered herbicides for use with kabuli chickpea crops at pre-sowing stage (2005).*

Herbicide	Rate	Comments
Cyanazine (Bladex®)	2 L/ha	Pre-sowing. Most grasses and broadleaved weeds. May suppress rather than kill.
Simazine 50% flowable	1–2 L/ha	Pre-sowing or post-sowing pre-emergent. Most grasses and broadleaved weeds.

Source: DAFWA

6.8.2 Why use pre-emergent herbicides?

Pre-emergent herbicides are an essential part of a conservation farming system for a number of reasons:

- They can offer alternative modes of action to post-emergent knockdown herbicides.
- Many are very effective on hard-to-kill weeds such as annual ryegrass and barley grass.
- Pre-emergent herbicides control weeds early in crop life and potentially over multiple germinations, maximising crop yield potential.
- They suit a no-till seeding system with knife points and press wheels and/or disc seeders.
- They can be cost effective. [18]
- There is also limited options for post emergent weed control in pulses. [19]

Whilst pre-emergent herbicides can be used in conservation farming systems, they must be used in conjunction with herbicide/crop rotation management plans and other non-chemical weed control techniques (Figure 2). These methods usually aim to minimise weed seed production and may include fallows, crop rotations including pastures and/or cutting hay, burning full paddocks or windrows, chaff carts, and weed seed destructors. [20]

17 Dow AgroSciences. http://msdssearch.dow.com/PublishedLiteratureDAS/dh_08bc/0901b803808bc88f.pdf?filepath=au/pdfs/noreg/012-10811.pdf&fromPage=GetDoc

18 Haskins, B. NSW DPI. Using pre-emergent herbicides in conservation farming systems.

19 Stuchbery J. (2016) Personal communication.

20 B Haskins. NSW DPI. Using pre-emergent herbicides in conservation farming systems.

Figure 2: *Trials have identified pre-emergent product combinations that provided significantly better control (right) than the district standard practice (left) for herbicide resistant annual ryegrass.*

Source: WeedSmart

6.8.3 Herbicide options

Chickpea is late maturing compared to other pulses, hence crop-topping to prevent ryegrass and other weed seed set is not often possible, even in the earliest of maturing varieties (e.g. GenesisTM 079). Chickpea is relatively slow to emerge with slow early growth during the colder winter months. As a consequence, it is a poor competitor with weeds. Even moderate weed infestations can cause large yield losses and harvest problems.

The weed control strategy for growing a successful chickpea crop depends on substantially reducing the viable weed seed bank in the soil before the crop emerges. Control the majority of weeds before seeding, either by cultivation or with knockdown herbicides such as glyphosate or Spray Seed®.

A technique used with varying success by growers has been to sow chickpea and then use a knockdown herbicide tank mixed with a pre-emergent herbicide to control germinating weeds before the crop emerges. Chickpea crops may take up to 21 days to emerge under cool, drying soil conditions but under favourable warm, moist soil conditions plants may emerge after 7 days. Growers considering this option should sow deeper (10–15 cm) and carefully check their paddocks for the emergence of the chickpea immediately before spraying. Done correctly, this can be an effective weed control option.

The pre-emergent herbicides will not adequately control large weed populations by themselves, and so they need to be used in conjunction with paddock selection and pre-seeding weed control. Incorporation by sowing (IBS) is generally considered safer on the crop than post-sowing pre-emergence with most herbicides used in modern no-till sowing systems. Most of these products work best if thoroughly incorporated with soil either mechanically or by irrigation or rainfall. The aim of incorporation is to produce an even band of herbicide to intercept germinating weed seeds.

Simazine is the most widely used herbicide for broadleaf weed control, and can provide relatively cheap control of cruciferous weeds. Efficacy is very dependent on receiving rainfall (20–30 mm) within 2–3 weeks of application, and consequently weed control is often disappointing under drier conditions.

Balance® (isoxaflutole) is a systemic herbicide belonging to the relatively new class of isoxazole herbicides (Group H). Balance provides more consistent and reliable control of susceptible weeds for longer and across a broader range of seasonal conditions. Ideally it is applied to a level seedbed post sowing pre emergence. This prevents rainfall moving herbicide treated soil into the furrows. Balance® is used specifically in chickpeas for broadleaf weed control in broadacre cropping situations. It provides a weed control option unique to chickpea and enables rotation of herbicide groups across the cropping sequence.

Terbyne is the newest triazine herbicide to be introduced in Australia and is registered for pre-emergent weed control in chickpeas, lupin, field peas, faba beans, lentils and triazine tolerant canola. Terbyne can be applied pre or post sowing.

Terbyne controls a wide range of broadleaf weeds, with some suppression of grasses, particularly if there is good soil moisture. Sufficient rainfall (20–30 mm) to wet the soil through the weed root zone is necessary within 2–3 weeks of application.

Spinnaker® (700 g/kg imazethapyr) works for the pre- or post-emergence control of certain weeds in centrosema (Cavalcade), chickpeas, faba beans, field peas, lucerne, mung beans, peanuts, serradella, soybeans and subterranean clover as per the directions for use table. On lighter sandy soils, some herbicide damage can be observed early in the crops growth.

In chickpea crops sown on wide rows, there is increasing adoption of 'directed sprays' of Broadstrike®, either alone or in tank-mixes with simazine. This largely avoids the problem of crop damage and improves weed control through the ability to safely add wetters or mineral oils to the spray mix.

While chickpea does have a degree of tolerance to glyphosate during the vegetative stage, caution is still required as the lower branches arising from the main stem contribute a large proportion of the total chickpea yield. Upright varieties such as Amethyst and Jimbour are more suited to this technique than the more prostrate types, and small chickpea plants are more susceptible to damage than older plants. [21]

Contact the Department of Agriculture, Western Australia (DAFWA) or your local consultant for up-to-date information on herbicide registrations.

An early series of trials were conducted to evaluate the selectivity of a range of herbicides in chickpeas (Table 17). Trifluralin had a narrow safety margin and rates in excess of 0.56 kg/ha were damaging. Pendimethalin produced similar damage at rate of 0.99 kg/ha and 1.98 kg/ha to trifluralin at rate of 0.84 kg/ha and 1.12 kg/ha. These herbicides reduced plant establishment by 15–38% with the greatest reduction at the higher rates. Where trifluralin reduced chickpea stands to below 40 plants/m^2 a significant yield reduction of 14.5% occurred. The wild oat herbicide triallate, was safe on chickpea at rate of up to 2.24 kg/ha. When trifluralin was added to triallate damage tended to be slightly worse than with trifluralin alone. [22]

Table 17: *Tolerance of chickpeas to pre-plant incorporation of herbicides.* [23]

Herbicide	Rate (kg a.i./ha)	No. of experiments (all harvested)	Significant reductions*	Average Yield (s.e.) (% site maximum)	Tolerance rating
Tri-allate	0.56-0.8	2	0	90.5 92.1)	T
	1.12-2.24	2	0	89.5 (9.2)	T
Pendimethalin	0.99	1	0	100	MT
	1.98	1	0	79	MS
Trifluralin	0.56	4	0	89.8 (5.0)	T-MT
	0.84	2	0	87.5 (4.9)	MT-MS
	1.12	2	1	85.5 (9.2)	MS
Trifluralin + Tri-allate	0.56+0.56	2	0	84.5 (12.0)	MT
Cyanazine+Trifluralin	2.0+0.40	1	0	89	T
Prodiamine	0.398	1	0	100	T
Unweeded control	-	4	1	86.3 (8.4)	
Handweeded control	-	3	0	96.3 (3.2)	-

* Number of experiments where yield < site maximum ($P = 0.05$)

21 Pulses Australia. Chickpea Production: Southern and Western regions. http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/southern-guide

22 G Kay, M, McMillan (1990) Pre and post emergent herbicides in chickpeas I. Crop tolerance. Proceedings of the 9th Australia Weed Conference.

23 G Kay, M, McMillan (1990) Pre and post emergent herbicides in chickpeas I. Crop tolerance. Proceedings of the 9th Australia Weed Conference.

6.8.4 Application

Most products work best if incorporated into soil, either mechanically or by irrigation or rainfall. The aim of incorporation is to produce an even band of herbicide to intercept germinating weed seeds. Some herbicide incorporation occurs when sowing is done with knife-points, provided sowing speed is adequate to throw soil into the inter-row without throwing into the adjacent seed furrow. Hence, these products are still compatible with the shift to minimum tillage and reduced-tillage farming practices. However, there may be insufficient soil throw with some low-disturbance, disc seeding systems. Typically, a follow-up, post-emergent grass weed herbicide is still required to provide the level of grass weed control desired by growers, particularly in the seed furrow.

WATCH: GCTV16: Spray application workshop.

WATCH: Over The Fence West: Summer weed management drives quality, yield returns.

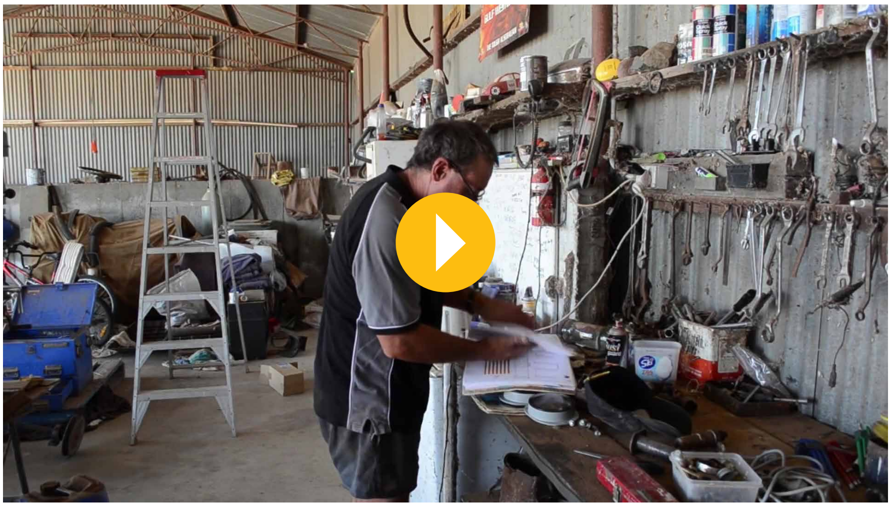


Table 18 lists products for application at sowing for kabuli chickpeas.

Table 18: *Registered herbicides for use with kabuli chickpea crops, to be incorporated at sowing stage (2005).*

Herbicide	Rate	Comments
Pendimethalin (Stomp®)	2 L/ha	Annual ryegrass and wireweed, and suppression of silvergrass and wild oat.
Triallate (e.g. Avadex®)	1.6 L/ha	Immediately before sowing. Wild oat.
Trifluralin (400 ai/L)	1–2 L/ha	Wire-weed, fumitory and annual ryegrass. Suppression of wild oat and brome grass.

Source: DAFWA

6.9 Post-plant pre-emergent herbicides

Post sowing pre-emergent (PSPE) is when a pre-emergent herbicide is applied after sowing (but before crop emergence) to the seedbed (Table 19).

These herbicides are primarily absorbed through the roots, but there may also be some foliar absorption (e.g. Terbyne®). When applied to soil, best control is achieved when the soil is flat and relatively free of clods and trash. Sufficient rainfall (20-30 mm) to wet the soil through the weed root-zone is necessary within 2-3 weeks of application. If applied pre-sowing and sown with minimal disturbance, incorporation will essentially be by rainfall after application. Weed control in the sowing row may be less effective because a certain amount of herbicide will be removed from the crop row.

The absence of cost-effective and safe post-emergent herbicides effectively limits broadleaf weed control options in chickpea to a small number of pre-emergent herbicides. Most of these chemicals are very dependent on rainfall soon after application, and as a consequence often result in inconsistent or partial weed control under drier conditions. [24]

Table 19: *Registered herbicides for use with kabuli chickpea crops, post-sowing pre-emergent (after levelling the seeding furrows). (2005).*

Herbicide	Rate	Comments
Isoxaflutole (Balance®)	100 g/ha	Post-sowing pre-emergent. Mustard, radish and capeweed.
Simazine 50% flowable	1–2 L/ha	Most grasses and broadleaved weeds.
Metribuzin (Lexone®)	150–300 g/ha	Most grasses, brassicas, capeweed, doublegee, fumitory, toadrush, wireweed. Use lower rates on coarser textured soil types. Results from 2005 suggest that lower rates need to be used for Almazↁ. Check rates – products vary in ai concentration.

Source: DAFWA

An early series of trials were conducted to evaluate the selectivity of a range of herbicides in chickpeas (Table 20). The herbicides which performed best under post-plant pattern were all triazines. In one experiment, mixtures with simazine were more damaging than herbicides applied alone at comparable total rate of the active triazine. Chickpea has consistently shown a high tolerance to registered herbicide cyanazine at rates up to 3.0 kg/ha and to prometryn at rates of 2.0 kg/ha or less. Damage symptoms were temporary and did not affect yields. Metribuzin was usually safe at a rate of 0.21 kg/ha but in one weed-free experiment a significant yield reduction occurred at this rate.

24 Pulses Australia. Chickpea Production: Southern and Western regions. http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/southern-guide

Table 20: *Tolerance of chikpea post-sowing, pre-emergence herbicides.* [25]

Herbicide	Rate (kg a.i./ha)	No. of experiments (all harvested)	Significant reductions*	Average Yield (s.e) (% site maximum)	Tolerance rating
Acifluorfen	0.224-0.896	7 (7)	0	93.8 (5.4)	T-MT
Atrazine	1.0	3 (3)	2	49.0 (40.0)	T
Cynazine	1.5	9 (8)	0	4.9 (4.9)	T
	2.0	5 (4)	0	88.0 (1.6)	T-MT
	3.0	1 (1)	0	98	T-MT
Dimethazone	0.9	1 (1)	1	59	HS
Imazaquin	0.3	1 (1)	1	41	HS
Imazethapyr	0.05-0.07	2 (2)	2	77.5 (3.5)	S
Linuron	1.5	1 (1)	0	92	MT
Methabenzthiazuron	1.75	2 (1)	0	94	T-MT
Metribuzin	0.21	10 (8)	2	88.9 (10.6)	T-MT
	0.28	3 (3)	3	61.0 (26.2)	MT-MS
	0.42	1 (1)	1	70	MS
Prometryn	0.75	3 (3)	0	95.3 (4.0)	T
	1.5	9 (8)	1	92.8 (5.8)	T
	2.0	2 (2)	0	94.5 (7.8)	T-MT
	3.0	1 (1)	0	87	MS
Simazine	0.75	6 (5)	1	87.8 (6.3)	T
	1.0	3 (3)	1	88.7 (1.2)	T
	1.25	1 (1)	1	85	T-MT
	1.5	6 (5)	2	87.0 (8.5)	T-MT
	2.5	1 (1)	1	55	MS
Terbutryn	2.0	2 (2)	1	78 (2.8)	T-MT
Cyanazine + metolachlor	2.0 + 1.44	1 (1)	0	82	T
Cyanazine + simazine	0.75-1.0+0.75	6 (5)	1	89.4 (8.7)	T-MT
Metribuzin + simazine	0.105-0.14+0.75	6 (5)	0	91.6 (6.2)	MT
Prometryn + simazine	0.75+0.75	6 (5)	1	91 (6.5)	T-MT
	1.5+0.75	3 (3)	0	89 (4.2)	MT
Unweeded control	-	13 (12)	5	76.9 (23.0)	-
Handweeded control	-	10 (9)	0	94.6 (4.7)	-

* Number of experiments where yield < site maximum (P = 0.05)

Results with simazine suggest that chickpeas were tolerant to rates less than 1 kg/ha (of active ingredient) but significant yield reductions due to poor weed control occurred at these rates in two experiments. Some variation was found on different soil types. In one trial on grey clay soils chickpea yield was reduced by 0.4 t/ha in the simazine 1.25 kg/ha treatment but on other soil types, no yield reduction occurred at 1.5 kg/ha. Damage symptoms developed slowly and usually increased as the season

25 G Kay, M, McMillan (1990) Pre and post emergent herbicides in chickpeas I. Crop tolerance. Proceedings of the 9th Australia Weed Conference.

progressed. Yield losses from simazine were greater than would be expected from visual damage ratings. [26]

More recently, the herbicide tolerance of two desi chickpea varieties (Howzat⚘ and ICCV96836) were compared to Tyson. All three varieties showed similar tolerance to a range of herbicides (Table 21). Simazine, Balance + Simazine and Spinnaker applied PSPE had little effect on yield, whereas Broadstrike applied Early Post Emergent on stressed plants it suppressed yield. For the main weeds in the trial (prickly lettuce, milk thistle) the best weed control option was Balance + Simazine. In paddocks where musk is a problem the best control option will be Spinnaker. [27]

Table 21: *Crop yields for three chickpea varieties following application of a range of herbicides.*

Herbicide	Cost $/ha	Tyson	Howzat⚘	ICCV96836
Control		1.3	1.1	1.2
Simazine 1L	6.25	1.6	1.5	1.4
Simazine 2L		1.8	1.7	1.6
Balance 100g + Simazine 1L	XXX	1.9	1.8	1.7
Balance 200g + Simazine 1L		2.0	1.8	1.8
Spinnaker 0.2L	22.00	1.7	1.6	1.5
Spinnaker 0.4L		1.6	1.4	1.4
Broadstrike 25g	14.50	1.1	1.2	1.1
Broadstrike 50g		0.9	0.9	0.9
Significant difference		P<0.001 LSD=0.2	P<0.001 LSD=0.2	P<0.001 LSD=0.1

Source: Online Farm Trials

See Section 6.12 Herbicide tolerance ratings for more information.

IN FOCUS

Effect of row spacing, nitrogen and weed control on crop and weed in a wheat—lupin or wheat—chickpea rotation in WA.

Key messages:

- Despite a very dry season in 2012, dimethenamid (e.g. Outlook®) herbicide in a chickpea crop was more effective on annual ryegrass than simazine in the two long-term rotational trials at Merredin.
- Sakura® reduced annual ryegrass head numbers more effectively than trifluralin at N_25 and flexi N50 compared to N50 at Merredin.
- Grain yields of both crops at Merredin were very poor. Despite poor grain yields of crops at Merredin, yields of both crops were greater at 44 cm row spacing than at 22 cm row spacing.

In 2012, rotation trials of three years duration were initiated at Merredin (wheat – chickpea) to examine the effect of crop row spacing, herbicides and applied nitrogen (in wheat only) on crops and weeds. In the wheat – chickpea rotation at Merredin, wheat crop (cv. Wyalkatchem) was sown at two row spacings (22 cm and 44 cm) with two herbicides (trifluralin 2 L/

26 G Kay, M, McMillan. (1990). Pre and post emergent herbicides in chickpeas I. Crop tolerance. Proceedings of the 9th Australia Weed Conference.

27 Birchup Cropping Group. (2001). Herbicide tolerance of new chickpea varieties. Online Farm Trials. http://www.farmtrials.com.au/trial/13615

ha and Sakura® 118 g/ha) and three nitrogen treatments: N_25 (25 kg N/ha drilled in front of tynes as urea), N50 (50 kg N/ha drilled in front of tynes as urea) and Flexi N50 (50 kg N/ha placed at about 7 to 8 cm depth as flexi N). Chickpea (cv. PB Slasher⫽) was sown at two row spacings (22 cm and 44 cm) with two herbicides (simazine 2 L/ha and Outlook® (dimethenamid) 1 L/ha)). Both crops at Merredin were sown on 14 June 2012.

Results

The season of 2012 was very dry with significantly less than average rainfall during the growing season. During the 2012 growing season, the Merredin site had 60% of the average rainfall of 193 mm from April to September. As such crop growth, particularly wheat, was very poor.

Weed control: In the wheat crop, annual ryegrass was the main weed species but the average weed density of annual ryegrass was only 2 plants/m². This means that both herbicides effectively controlled annual ryegrass with no significant difference between trifluralin and Sakura®.

Despite no difference in initial weed control efficacy, Sakura® reduced annual ryegrass head numbers more effectively than trifluralin, particularly at N_25 and flexi N50 compared to N50 (Figure 3). It may be possible that under low rainfall situations, surviving ryegrass plants had greater access to applied N at N50 than N_25 or flexi N50, resulting in a greater number of annual ryegrass heads produced per unit area. No influence of crop row spacing was found on weed control.

In the chickpea crop, Outlook® controlled annual ryegrass plants measured at 4 weeks after emergence, more effectively than simazine (Outlook® 2 plants/m² versus simazine 8 plants/m² of annual ryegrass).

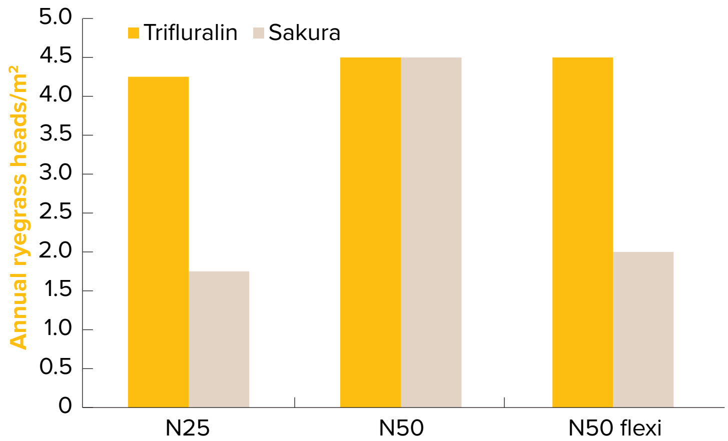


Figure 3: *Effect of herbicides and applied nitrogen on the head numbers of annual ryegrass in wheat, at seed filling stage of crop, at Merredin in 2012.* [28]

Crop grain yield: The overall grain yield of both wheat and chickpea crops was very low due to extremely poor crop growth. It was also too difficult to lift and harvest such a short crop with the harvester.

28 A Hashem, W Vance, R Brennan, R Bell (2013) DAFWA 2013 Crop Updates. Effect of row spacing, nitrogen and weed control on crop and weed in a wheat – lupin or wheat – chickpea rotation.

MORE INFORMATION

Wide rows and stubble management.

On the average, wheat grain yield was 257 kg/ha and chickpea grain yield was 90 kg/ha. Despite very poor crop growth, wheat and chickpea grain yields at 44 cm row spacing were significantly greater than at 22 cm, indicating the benefit of wide row cropping in low rainfall areas (data not presented). No effect of herbicides or applied nitrogen was found on wheat yield.

Conclusions

Rainfall was extremely low in the 2012 season, leading to very poor crop growth. Dimethenamid (e.g. Outlook®) herbicide was more effective on annual ryegrass than simazine in chickpea crops. Even though grain yields of crops were very low, yields of both crops at Merredin were greater at 44 cm row spacing than at 22 cm row spacing. These results show the benefit of wide row spacing in a dry season like 2012 in low rainfall areas such as Merredin. [29]

6.10 In-crop herbicides: knockdowns and residuals

Chickpea can be grown in wider rows in a stubble system that allows inter-row herbicide application with shielded sprayers.

Problem weeds or situations that require special attention include:

- Group A ('dims' and 'fops') resistant wild oats (and other grass species).
- Late germinations of weeds (e.g. ryegrass, brome grass) that would normally be prevented from setting seed in other pulses through croptopping.
- Snail medic, which can escape Balance®.
- hoary cress, soursob, tares, wild vetch, bedstraw, bifora, muskweed, wild radish and volunteer pulses [30]

Table 22 lists herbicides registered for use in kabuli chickpeas in WA.

Table 22: *Registered herbicides for use with kabuli chickpea crops, post-emergent (2005).*

Herbicide	Rate	Comments
Flumetsulam (Broadstrike®)	25 g/ha	Apply at the 4–6 leaf stage. Capeweed, doublegee, brassicas (suppression only).
Pyridate (Tough®)	2 L/ha	Capeweed, fumitory.
Fusion®, Select®, Motsa®, Fusilade®, Verdict®, Correct®, Shogun®, Targa®, Aramo®, Sertin®	—	A range of grass selective herbicides are available. Refer to label for use.

Source: DAFWA

Broadstrike® usually causes some transient crop yellowing and can cause reddish discoloration and height suppression. Flowering may be delayed (Figure 4), resulting in yield suppression.

29 A Hashem, W Vance, R Brennan, R Bell (2013) DAFWA 2013 Crop Updates. Effect of row spacing, nitrogen and weed control on crop and weed in a wheat – lupin or wheat – chickpea rotation.

30 Pulses Australia. Chickpea Production: Southern and Western regions. http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/southern-guide

Figure 4: *To control turnip weed, a single boom width of Broadstrike® was applied. Flowering and maturity of treated chickpeas (left) was delayed significantly, so they are still green compared with the untreated chickpeas that have matured (right).*

Photo: G Cumming, Pulse Australia

Broadstrike® is used mainly in salvage situations (as a last resort), and even then should be applied only under good growing conditions. Figure 5 depicts effective use of Broadstrike® against turnip weed adjacent to a chickpea crop.

With the shift into row-crop chickpeas, some growers are successfully using Broadstrike® as a directed spray into the inter-row area. This keeps a large proportion of the herbicide off the chickpea foliage and minimises crop damage.

Figure 5: *The same single boom width of Broadstrike® applied along the chickpea crop edge (centre) alongside the unsown, weedy headland (right) and untreated crop (far left). Broadstrike® did an excellent job on the turnip weed (centre and unsown front) compared with the untreated headland (right).*

Photo: G Cumming, Pulse Australia

6.10.1 Directed sprays

Though row-cropping chickpeas on wide rows in the Western region is less common, it provides an opportunity for the use of 'directed sprays' of Broadstrike®, either alone or in tank-mixes with simazine. This largely avoids crop damage and improves weed control through the ability to add wetters or mineral oils safely to the spray mix.

6.10.2 Shielded sprayers

Shielded sprayers are becoming increasingly more common in some areas, as they provide very cheap control of grass and broadleaf weeds with glyphosate. Although chickpea does have a degree of tolerance to glyphosate during the vegetative stage, caution is still required as the lower branches arising from the main stem make a large contribution to the total chickpea yield. Issues that need to be considered include:

- Selection and operation of spray shields (speed, nozzle type, etc.).
- Height of the crop (small chickpea plants are more susceptible).

- Variety (upright types are more suited to this technique than the more prostrate types). [31]

6.11 Conditions for spraying

When applying herbicides, the aim is to maximise the amount reaching the target and to minimise the amount reaching off-target areas. This results in:

- improved herbicide effectiveness
- reduced damage and/or contamination of off-target crops and areas.

In areas where several agricultural enterprises coexist, conflicts can arise, particularly from the use of herbicides. All herbicides are capable of drift.

When spraying a herbicide, you have a moral and legal responsibility to prevent it from drifting and contaminating or damaging neighbours' crops and sensitive areas.

All grass herbicide labels emphasise the importance of spraying only when the weeds are actively growing under mild, favourable conditions (Figure 6). Any of the following stress conditions can significantly impair both uptake and translocation of the herbicide within the plant, likely resulting in incomplete kill or only suppression of weeds:

- moisture stress (and drought)
- waterlogging
- high temperature–low humidity conditions
- extreme cold or frosts
- nutrient deficiency, especially effects of low nitrogen
- use of pre-emergent herbicides that affect growth and root development; i.e. simazine, Balance®, trifluralin, and Stomp®
- excessively heavy dews resulting in poor spray retentions on grass leaves

Figure 6: *Boom spray on crop.*

Photo: Brad Collis, Source: GRDC

Ensure that grass weeds have fully recovered before applying grass herbicides.

31 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited

Group A herbicides can occasionally cause leaf spotting in chickpea (Figure 7). This is usually associated with either frost or high temperatures occurring soon after spray application. [32]

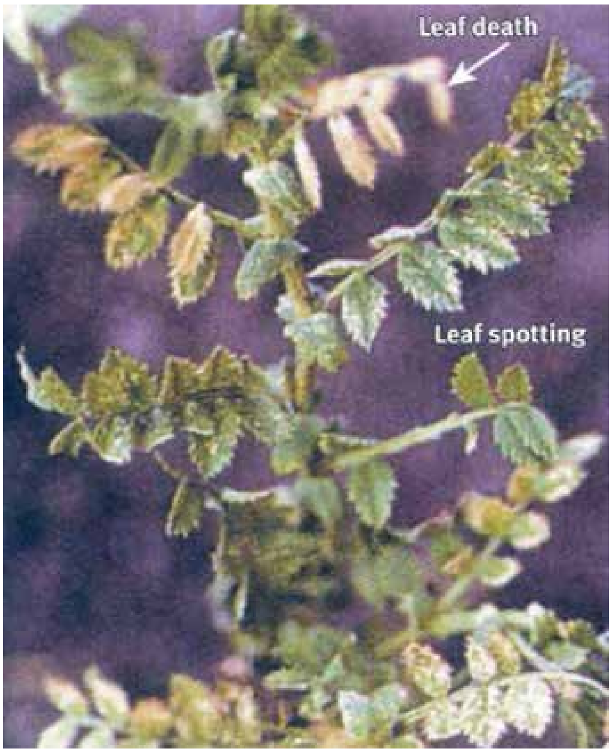


Figure 7: *Group A grass selective herbicide injury.*

Photo: T Bretag

6.11.1 Minimising spray drift

Before spraying

- Always check for susceptible crops in the area, for example broadleaf crops such as grape vines, cotton, vegetables and pulses, if you are using a broadleaf herbicide.
- Check sensitive areas such as houses, schools, waterways and riverbanks.
- Notify neighbours of your spraying intentions.

During spraying

- Always monitor weather conditions carefully and understand their effect on 'drift hazard'.
- Do not spray if conditions are not suitable, and stop spraying if conditions change and become unsuitable.
- Record weather conditions (especially temperature and relative humidity), wind speed and direction, herbicide and water rates, and operating details for each paddock.
- Supervise all spraying, even when a contractor is employed. Provide a map marking the areas to be sprayed, buffers to be observed and sensitive crops and areas.
- Spray when the temperature is <28°C.
- Maintain a downwind buffer. This may be in-crop, for example keeping a boom's width from the downwind edge of the field.
- Minimise spray release height.

32 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited

- Use the largest droplets that will give adequate spray coverage.
- Always use the least-volatile formulation of herbicide available.
- If there are sensitive crops in the area, use the herbicide that is the least damaging.

6.11.2 Types of drift

Sprayed herbicides can drift as droplets, as vapours or as particles:

- *Droplet drift* is the easiest to control because, under good spraying conditions, droplets are carried down by air turbulence and gravity, to collect on plant or soil surfaces. Droplet drift is the most common cause of off-target damage caused by herbicide application. For example, spraying of fallows with glyphosate under the wrong conditions often leads to severe damage to establishing crops.
- *Particle drift* occurs when water and other herbicide carriers evaporate quickly from the droplet, leaving tiny particles of concentrated herbicide. This can occur with herbicide formulations other than esters. This form of drift has damaged susceptible crops up to 30 km from the source.
- *Vapour drift* is confined to volatile herbicides such as 2,4-D ester. Vapours may arise directly from the spray or evaporation of herbicide from sprayed surfaces. Use of 2,4-D ester in summer can lead to vapour drift damage of highly susceptible crops such as tomatoes, cotton, sunflowers, soybeans and grapes. This may occur hours after the herbicide has been applied.

In 2006, the Australian Pesticides and Veterinary Medicines Authority (APVMA) restricted the use of highly volatile forms of 2,4-D ester. The changes are now seen with the substitution of lower volatile forms of 2,4-D and MCPA. Products with lower 'risk' ester formulations are commonly labelled with LVE (low volatile ester). These formulations of esters have a much lower tendency to volatilise, but caution should remain as they are still prone to droplet drift.

Vapours and minute particles float in the airstream and are poorly collected on catching surfaces. They may be carried for many kilometres in thermal updraughts before being deposited.

Sensitive crops may be up to 10,000 times more sensitive than the crop being sprayed. Even small quantities of drifting herbicide can cause severe damage to highly sensitive plants.

6.11.3 Factors affecting the risk of spray drift

Any herbicide can drift. The drift hazard, or off-target potential, of a herbicide in a particular situation depends on the following factors:

- Volatility of the formulation applied. Volatility refers to the likelihood that the herbicide will evaporate and become a gas. Esters volatilise (evaporate), whereas amines do not.
- Proximity of crops susceptible to the particular herbicide being applied, and their growth stage. For example, cotton is most sensitive to Group I herbicides in the seedling stage.
- Method of application and equipment used. Aerial application releases spray at 3 m above the target and uses relatively low application volumes, while ground-rigs have lower release heights and generally higher application volumes, and a range of nozzle types. Misters produce large numbers of very fine droplets that use wind to carry them to their target.
- Size of the area treated. The greater the area treated the longer it takes to apply the herbicide. If local meteorological conditions change, particularly in the case of 2,4-D ester, then more herbicide is able to volatilise.
- Amount of active ingredient (herbicide) applied. The more herbicide applied per hectare, the greater the amount available to drift or volatilise.

- Efficiency of droplet capture. Bare soil does not have anything to catch drifting droplets, unlike crops, erect pasture species and standing stubbles.
- Weather conditions during and shortly after application. Changing weather conditions can increase the risk of spray drift.

Volatility

Many ester formulations are highly volatile compared with the non-volatile amine, sodium salt and acid formulations. Table 23 is a guide to the more common herbicide active ingredients that are marketed with more than one formulation.

Table 23: *Relative herbicide volatility.*

Form of active	Full name	Product example
NON-VOLATILE		
Amine salts		
MCPA dma	Dimethylamine salt	MCPA 500
2,4-D dma	Dimethylamine salt	2,4-D Amine 500
2,4-D dea	Diethanolamine salt	2,4-D Amine 500 Low Odour®
2,4-D ipa	Isopropylamine salt	Surpass® 300
2,4-D tipa	Triisopropanolamine	Tordon® 75-D
2,4-DB dma	Dimethylamine salt	Buttress®
Dicamba dma	Dimethylamine salt	Banvel® 200
Triclopyr tea	Triethylamine salt	Tordon® Timber Control
Picloram tipa	Triisopropanolamine	Tordon® 75-D
Clopyralid dma	Dimethylamine	Lontrel® Advanced
Clopyralid tipa	Triisopropanolamine	Archer®
Aminopyralid K salt	Potassium salt	Stinger®
Aminopyralid tipa	Triisopropanolamine	Hotshot®
Other salts		
MCPA Na salt	Sodium salt	MCPA 250
MCPA Na/K salt	Sodium & potassium salt	MCPA 250
2,4-DB Na/K salt	Sodium & potassium salt	Buticide®
Dicamba Na salt	Sodium salt	Cadence®
SOME VOLATILITY		
Ester		
MCPA ehe	Ethylhexyl ester	LVE MCPA
MCPA ioe	Isooctyl ester	LVE MCPA
Triclopyr butoxyl	Butoxyethyl ester	Garlon® 600
Picloram ioe	Isooctyl ester	Access®
2,4-D ehe	Ethylhexyl ester	2,4-D LVE 680
Fluroxypyr M ester	Meptyl ester	Starane® Advanced

Source: Mark Scott, former Agricultural Chemicals Officer, NSW Agriculture

Minimising drift

A significant part of minimising spray drift is the selection of equipment to reduce the number of small droplets produced. However, this in turn may affect coverage of the target, and therefore the possible effectiveness of the pesticide application. This aspect of spraying needs to be carefully considered when planning to spray.

As the number of smaller droplets decreases, so does the coverage of the spray. A good example of this is the use of air-induction nozzles that produce large droplets that splatter. These nozzles produce a droplet pattern and number unsuitable for targets such as seedling grasses that present a small vertical target.

In 2010, APVMA announced new measures to minimise the number of spray drift incidents (Table 24). The changes are restrictions on the droplet-size spectrum an applicator can use, wind speed suitable for spraying and the downwind buffer zone between spraying and a sensitive target. These changes should be evident on current herbicide labels. Hand-held spraying application is exempt from these regulations.

Table 24: *Nozzle selection guide for ground application.*
Volume median diameter (VMD): 50% of the droplets are less than the stated size and 50% greater. For flat-fan nozzle size, refer to manufacturers' selection charts as droplet size range will vary with recommended pressure; always use the lowest pressure stated to minimise the small droplets.

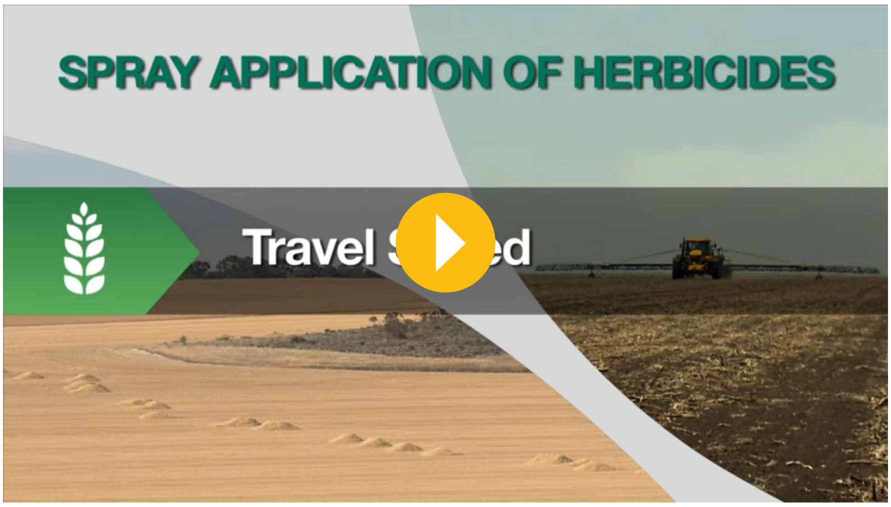
Distance downwind to susceptible crop	**<1 km**	**1 to >30 km**
Risk	High	Medium
Preferred droplet size (British Crop Protection Council) (to minimise risk)	Coarse to very coarse	Medium to coarse
Volume median diameter (µm)	310	210
Pressure (bars)	2.5	2.5
Flat-fan nozzle size	11,008	11,004
Recommended nozzles (examples only)	*Raindrop:* Whirljet® *Air induction:* Yamaho Turbodrop®, Hardi Injet®, AI Teejet®, Lurmark Drift-beta®	*Drift reduction:* DG TeeJet®, Turbo TeeJet®, Hardi® ISO LD 110, Lurmark® Lo-Drift
CAUTION	Can lead to poor coverage and control of grass weeds. Require higher spray volumes	Suitable for grass control at recommended pressures. Some fine droplets

Adapted from P Hughes, DPI, Queensland

Source: DPI NSW

WATCH: Nozzle Selection

WATCH: Travel Speed



Spray release height

- Operate the boom at the minimum practical height. Drift hazard doubles as nozzle height doubles. If possible, angle nozzles forward 30° to allow lower boom height with double overlap. Lower heights, however, can lead to more striping, as the boom sways and dips below the optimum height.
- 110° nozzles produce a higher percentage of fine droplets than 80° nozzles, but they allow a lower boom height while maintaining the required double overlap.
- Operate within the pressure range recommended by the nozzle manufacturer. Production of driftable fine droplets increases as the operating pressure is increased.

WATCH: Spray deposition

Size of area treated

When large areas are treated, greater amounts of active herbicide are applied and the risk of off-target effects increases due to the length of time taken to apply the herbicide. Conditions such as temperature, humidity and wind direction may change during spraying.

Application of volatile formulations to large areas increases the chances of vapour drift damage to susceptible crops and pastures.

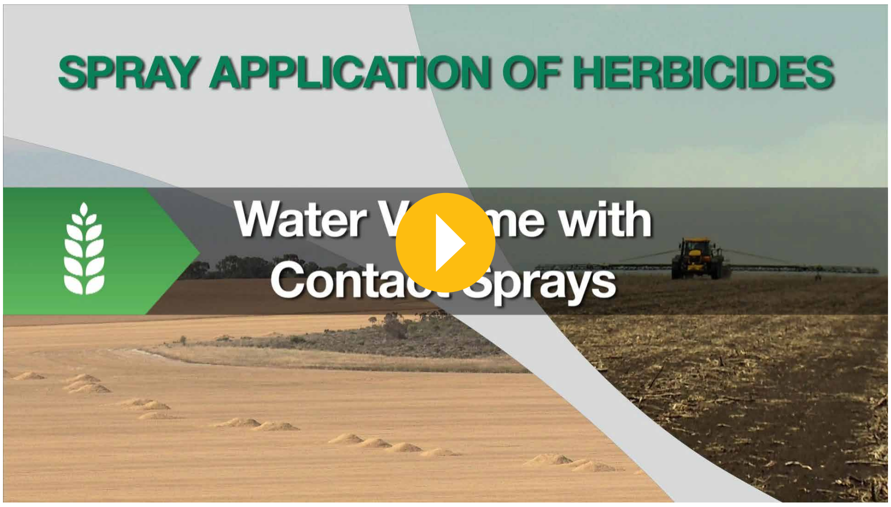
Capture surface

Targets vary in their ability to collect or capture spray droplets. Well grown, leafy crops are efficient collectors of droplets. Turbulent airflow normally carries spray droplets down into the crop within a very short distance.

Fallow paddocks or seedling crops have poor catching surfaces. Drift hazard is far greater when applying herbicide in these situations or adjacent to these poor capture surfaces.

The type of catching surface between the sprayed area and susceptible crops should always be considered in conjunction with the characteristics of the target area when assessing drift hazard.

WATCH: Water volume with contact sprays



WATCH: Application volume in stubble

Weather conditions to avoid

Turbulence

- Updrafts during the heat of the day cause rapidly shifting wind directions. Spraying should be avoided during this time of day.

Temperature

- Avoid spraying when temperatures exceed 28°C.

Humidity

- Avoid spraying under low relative humidity conditions, i.e. when the difference between wet and dry bulbs (ΔT) exceeds 10°C.
- High humidity extends droplet life and can greatly increase the drift hazard under inversion conditions. This results from the increased life of droplets <100 microns.

Wind

- Avoid spraying under still conditions.
- Ideal safe wind speed is 3–10 km/h, a light breeze (when leaves and twigs are in constant motion).
- A moderate breeze of 11–14 km/h is suitable for spraying if using low-drift nozzles or higher volume application, say 80–120 L/ha. (Small branches move, dust is raised and loose paper is moving.)

Inversions

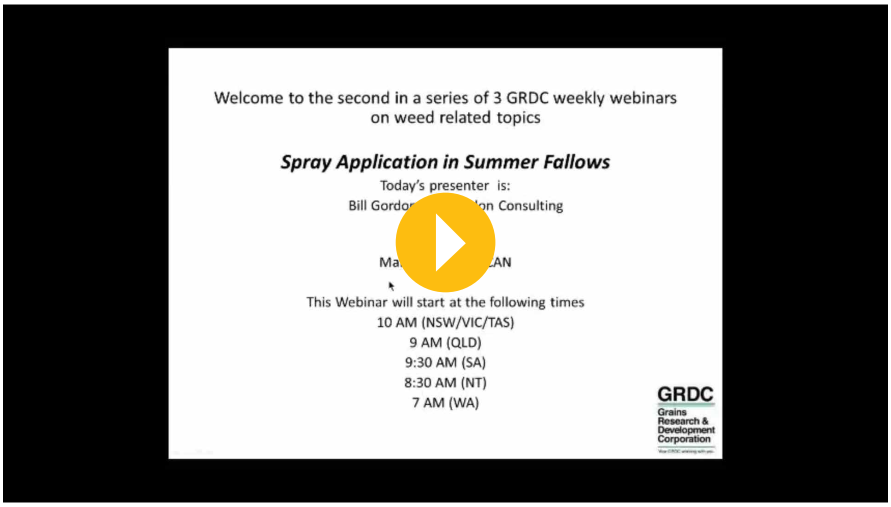
The most hazardous condition for herbicide spray drift is an atmospheric inversion, especially when combined with high humidity. An inversion exists when temperature increases with altitude instead of decreasing. An inversion is like a cold blanket of air above the ground, usually less than 50 m thick. Air will not rise above this blanket, and smoke or fine spray droplets and particles of spray deposited within an inversion will float until the inversion breaks down.

Do not spray under inversion conditions.

Inversions usually occur on clear, calm mornings and nights. Windy or turbulent conditions prevent inversion formation. Blankets of fog, dust or smoke and the tendency for sounds and smells to carry long distances indicate inversion conditions.

Smoke generators or smoky fires can be used to detect inversion conditions. Smoke will not continue to rise but will drift along at a constant height under the inversion 'blanket'. [33]

WATCH: Advances in weed management—Webinar 2—Spray application in summer fallows



6.12 Herbicide tolerance ratings

Within many broad acre crop species, cultivars have been found to vary in sensitivity to commonly used herbicides and tank mixes, thereby resulting in potential grain yield loss, and hence reduced farm profit. With funding from GRDC and State Government Agencies across Australia, a series of cultivar by herbicide tolerance

33 A Storrie (2015) Reducing herbicide spray drift. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/content/agriculture/pests-weeds/weeds/images/wid-documents/herbicides/spray-drift

MORE INFORMATION

Cultivar herbicide tolerance trial protocols

National Variety Trials

trials are conducted annually. The trials aim to provide grain growers and advisers with information on cultivar sensitivity to commonly used in-crop herbicides and tank mixes for a range of crop species including chickpeas, lupins, peas, lentils and faba beans. The intention is to provide data from at least two years of testing at the time of wide scale commercial propagation of a new cultivar. [34]

IN FOCUS

Herbicide tolerance of new chickpea varieties 2013 trial report, WA

Summary: Simazine, Outlook® and Balance® at the label rates were tolerated well with good crop safety margin, by all the varieties. Terbyne® and Lexone® registered low crop safety margin across all the varieties. Broadstrike® (with basal simazine or Terbyne®) reduced grain yield of Neelam⫽ and CICA 1016 (Table 25).

Table 25: *Trial details.*

Property	Darrin Lee's, Mingenew – Morawa Road.
Soil type (0–10 cm)	Red loam with soil pH 5.5 ($CaCl_2$) and organic carbon 0.67%
Crop/varieties	Chickpea, varieties - Neelam⫽, PBA Striker⫽ and CICA 1016
Paddock rotation	2012: wheat
Treatments	See Table 2
Replicates	Three with systematic untreated control plots
Plot size	12 m x 1.1 m. To convert plot yield to kg/ha, 1.8 m plot width used (plot to plot centre)
Seed treatment before sowing	P-Pickle T 200 mL/100 kg seed
Sowing date	17 May 2013
Seeding rate	120 kg/ha
Fertiliser	17 May 2013–seeding: DAP 70 kg/ha
Rhizobium inoculation	ALOSCA® group N granular inoculant 10 kg/ha applied with seed
Seeding machinery	Coneseeder with knife points and press wheels followed by rollers
Seeding depth	4–5 cm
Soil moisture at seeding (Gravimetric method)	7% (0–10 cm), 11% (10–20 cm)
Herbicide application machinery	Spray rig fitted with Teejet AIXRI11002 nozzles which produce very course droplets and 80 L/ha water volume used
Treatment application dates	16 May 2013–pre-seeding 22 May–immediately post plant/post seeding pre-emergence (IPP/PSPE) 13 June: 4–6 nodes

34 Ramsey C, Wheeler R, Churchett J, Walker S, Lockley P, Dhammu H, Garlinge J. (2010). Cultivar herbicide tolerance trial protocols. http://www.nvtonline.com.au/wp-content/uploads/2013/02/Herbicide-Tolerance-Protocols.pdf

Property	Darrin Lee's, Mingenew – Morawa Road.
Blanket spray(/s)	27 June 2013: Select® 0.5 L/ha and Bravo® 1.5 L/ha 26 August 2013: Bravo® 1.5 L/ha 10 September 2013: Dimethoate 400 mL/ha
Harvesting date	8 November 2013
Growing season rainfall	392 mm (May to October) 8% higher than the last five years' average (2009–13)

Source: DAFWA

Higher than label rates of the herbicides were included in the trial to determine the crop safety margin of the herbicides at the maximum label rates.

Good crop safety margin means that a herbicide at its maximum label rate and at the higher rate was tolerated well by a crop variety.

Whereas, a narrow crop safety margin for a particular herbicide indicates that the variety tolerated the maximum label rate well, but at higher than the label rate there was significant yield loss.

A low or narrow crop safety margin also implies that when spraying at the label rate under less than optimal conditions, herbicide damage and yield loss may occur.

For example, when: overlapping herbicide, spraying under wet conditions (for soil active and residual herbicides) or when there are stressed plants due to abiotic/biotic factors.

Table 26: *Effect of herbicides on grain yield (% of control) of chickpea varieties at Mingenew during 2013.*

Number	Herbicides	Rate/ha	Timing	Neelam⦶ grain yield (kg/ha)	PBA Striker⦶ grain yield (kg/ha)	CICA 1016 grain yield (kg/ha)
0 (untreated control)	–	–	–	100 1,267	100 1,457	100 1,212
1	Simazine 500	2.0 L	PS1	99.0	103.3	106.1
2	Simazine 500	Higher rate	PS1	108.2	102.9	107.8
3	Terbyne® (Terbuthylazine)	1.4 kg	PS1	95.0	96.5	100.7
4	Terbyne®	Higher rate	PS1	85.8*	83.7*	89.9*
5	Outlook® (Dimethenamid-P)	1 L	PS1	102.1	100.4	105.4
6	Outlook®	Higher rate	PS1	96.3	98.2	110.0
7	Simazine fb2 Balance®	1.5 L + 100 g	PS fb IPP/PSPE3	101.0	102.4	97.6
8	Simazine fb2 Balance®	1.4 kg + 100 g	PS fb IPP/PSPE3	97.0	93.7*	98.8

Number	Herbicides	Rate/ ha	Timing	Neelam⦶ grain yield (kg/ ha)	PBA Striker⦶ grain yield (kg/ha)	CICA 1016 grain yield (kg/ha)
9	Balance® (Isoxaflutole)	100 g	IPP/ PSPE3	102.5	99.6	107.0
10	Balance®	Higher rate	IPP/ PSPE3	97.9	97.4	102.6
11	Lexone® (Metribuzin)	280 g	IPP/ PSPE3	92.6*	99.5	99.0
12	Lexone®	Higher rate	IPP/ PSPE3	84.2*	85.2*	88.7*
13	Simazine fb2 Broadstrike®	2.0 L + 25 g	PS fb 4–6 nodes	89.3*	94.6	94.8
14	Simazine fb2 Broadstrike®	1.4 kg +25 g	PS fb 4–6 nodes	87.7*	96.2	90.3*

1PS = pre-seeding,
2 fb = followed by,
3 IPP/PSPE = immediately post plant/post seeding pre-emergence
* Figures are significantly lower than the untreated control. The names in parentheses are the herbicide chemical names. Broadstrike = Flumetsulam. Simazine 500 2 L = Simazine 900 1.1 kg

Source: DAFWA

Results

The effect of herbicides during early crop growth stages, at flowering and on grain yield (Table 26, above) of chickpea varieties was as follows:

- Simazine and Terbyne® at the higher rate, applied before crop seeding, caused around 10–15% necrosis across all the varieties. These symptoms were outgrown by the time crop reached flowering stage; however, Terbyne® (at the higher rate) resulted in significant yield reduction across all varieties.
- Lexone® at the higher rate, applied PSPE, caused visible necrosis and yellowing across all the varieties and the yellowing or light green colour continued to be visible up to flowering stage. This treatment also recorded around 20% less pods (per plant or on area basis) and resulted in significant yield loss across the varieties.
- Lexone® at the label rate also registered significant yield loss in Neelam⦶.
- Balance® at 100 g/ha and at the higher rate continued to be safe to all the varieties.
- Simazine 1.5 L/ha or Terbyne® 1.4 kg/ha applied pre-seeding followed by Balance® at 100 g/ha PSPE were also safe to all the varieties except that the Terbyne® and Balance® combination caused significant yield loss in PBA Striker⦶.
- Broadstrike® at 25 g/ha applied at 4–6 node stage (with basal simazine 2 L or Terbyne® 1.4 kg/ha) caused significant yield loss in Neelam⦶ and CICA 106.

Conclusion

Simazine, Outlook® and Balance® were tolerated well with good crop safety margin by all the varieties.

Lexone® (Metribuzin) and Broadstrike® (especially sequential application with simazine) results were in line with the previous results.

Terbyne® at 1.4 kg/ha registered low crop safety margin for all the varieties. These results are contrary to the previous three years' results.

During 2010 at Mingenew on sandy loam soil, Simazine at the higher rate caused significant yield loss across all the varieties under heavy rainfall situations that filled the seeding furrows soon after seeding. In that trial Terbyne® at the label and the higher rate was safe to all varieties. [35]

WATCH: GCTV16: Pulse Herbicide Tolerance.

6.13 Monitoring

Monitoring of weed populations before and after any spraying is an important part of management:

- Keep accurate records.
- Monitor weed populations and record results of herbicide used.
- If herbicide resistance is suspected, prevent weed seed-set.
- If a herbicide does not work, find out why.
- Check that weed survival is not due to spraying error.
- Conduct your own paddock tests to confirm herbicide failure and determine which herbicides remain effective.
- Obtain a herbicide resistance test on seed from suspected plants, testing for resistance to other herbicide (MOA) groups.
- Do not introduce or spread resistant weeds in contaminated grain or hay.

Regular monitoring is required to assess the effectiveness of weed management and the expected situation following weed removal or suppression. Without monitoring, we cannot assess the effectiveness of a management program or determine how it might be modified for improved results. Effective weed management begins with monitoring weeds to assess current or potential threats to crop production, and to determine best methods and timing for control measures.

Regular monitoring and recording the details of each paddock allows the grower to:

- spot critical stages of crop and weed development for timely cultivation or other intervention;

35 H Dhammu, DAFWA (2015) Herbicide tolerance of new chickpea varieties 2013 trial report. https://www.agric.wa.gov.au/chickpeas/herbicide-tolerance-new-chickpea-varieties-2013-trial-report?page=0%2C0

- identify the weed flora (species composition), which helps to determine best short- and long-term management strategies; and
- detect new invasive or aggressive weed species while the infestation is still localised and able to be eradicated.

Watch for critical aspects of the weed-crop interaction, such as:

- weed seed germination and seedling emergence;
- weed growth sufficient to affect crops if left unchecked;
- weed density, height, and cover relative to crop height, cover, and stage of growth;
- weed impacts on crops, including harbouring pests, pathogens, or beneficial organisms; or modifying microclimate, air circulation, or soil conditions; as well as direct competition for light, nutrients, and moisture;
- flowering, seed-set, or vegetative reproduction in weeds; and
- efficacy of cultivations and other weed management practices.

Information gathered through regular and timely field monitoring helps growers to select the best tools and timing for weed-control tactics. Missing vital cues in weed and crop development can lead to costly efforts to rescue a crop—efforts that may not be fully effective. Good paddock scouting can help the grower to obtain the most effective weed control for the least fuel use, labour cost, chemical application, crop damage and soil disturbance.

6.13.1 Tips for monitoring

To scout weeds, walk slowly through the paddock, examining any vegetation that was not planted. In larger paddocks, walk back and forth in a zigzag pattern to view all parts of the paddock, noting areas of particularly high or low weed infestation. Identify weeds with the help of a good weed guide or identification key for your region, and note the weed species that are most prominent or abundant. Observe how each major weed is distributed through the paddock. Are the weeds randomly scattered, clumped or concentrated in one part of the paddock?

Keep records in a field notebook. Prepare a page for each paddock or crop sown, and take simple notes of weed observations each time the paddock is monitored. Over time, your notes become a timeline of changes in the weed flora over the seasons and in response to crop rotations, cover crops, cultivations and other weed control practices. Many growers already maintain separate records for each paddock. Weed observations (species, numbers, distribution, size) can be included with these.

When to scout, and what to look for in a new paddock or farm

When purchasing farmland, it is important to look at the weeds. Presence of highly aggressive or hard-to-kill weeds, intense weed pressure, stressed and nutrient-deficient weeds, or a weed flora indicative of low or unbalanced soil fertility or pH or salt may foretell problems that should be considered when deciding whether to buy or rent, or how much to offer.

During your first year or two on a new farm or paddock, study the weeds carefully throughout the season, and be sure to get correct identification of the 5–10 most common weeds.

Note the weeds that emerge, grow or reproduce at different times of the annual cropping cycle:

- over winter
- after primary tillage and during seedbed preparation
- after crop planting
- during crop growth and maturation
- after harvest
- over summer or during cover crop emergence and establishment

Questions to ask include:

- What are the main weed species present at different times of year?
- When does each weed species emerge, flower, and set seed?
- What paddocks or areas have the worst weed pressure? The least?

6.14 Potential herbicide damage effect

Pulse crops can be severely damaged by some herbicides whether as residues in soil, contaminants in spray equipment, spray drift onto the crop or by incorrect use of the herbicide.

Leaching

Some soil active herbicides used for weed control in pulses can damage crops where conditions favour greater activity and leaching.

Herbicides move more readily in soils with:

- low organic matter
- more sand, silt, or gravel.

Herbicide movement is much less in soils with higher organic matter and higher clay contents. Damage from leaching is also greater where herbicides are applied to dry, cloddy soils than to soils which have been rolled and which are moist on top from recent rainfall. The pH of a soil can also strongly influence the persistence of herbicides. Many labels have warnings about high pH (≥8.0) and the need to reduce application rates to avoid crop damage. Heavy rainfall following application may cause crop damage. This will be worse if the crop has been sown shallow (less than 3-5 cm), where there is light soil and where the soil surface is ridged. The soil surface should not be ridged as this can lead to herbicides being washed down and concentrated in the crop row. [36]

Whilst trifluralin is relatively immobile in the soil, Boxer Gold may move from the point of placement, particularly in sandy soils prone to leaching. Therefore care must be taken in soils with a higher leaching potential and where previous history has shown potential for damage from herbicides with a higher leaching index such as Dual Gold, metribuzin and the triazine herbicides. [37]

Metribuzin leaches at almost three times the rate of simazine and seven times the rate of diuron. The relative tolerance of the crop type and variety will also affect crop damage from these herbicides. For example, lupins are more tolerant to simazine than are the other pulses. For more specific details on soil active herbicides and the risk of crop damage in your cropping situation seek advice from an experienced agronomist.

Herbicide residues can last for several years, especially in more alkaline soils and where there is little summer rainfall. The pulses emerge and grow normally for a few weeks and then start to show signs of stress. Leaves become off-colour, roots may be clubbed, plants stop growing, and eventually die. Refer to the labels for recommendations on plant-back periods for pulses following use of any herbicides.

Contamination of Spray Equipment

Traces of sulfonylurea herbicides (such as chlorsulfuron, metsulfuron or triasulfuron) in spray equipment can cause severe damage to legumes when activated by some of the grass control herbicides (Figure 8). The risk of residue damage is greater in the presence of grass-selective herbicides. Always clean spray tanks and lines with chlorine, according to recommendations, after using sulfonylurea herbicides and before using these grass control herbicides. Traces of Affinity® can also damage pulse crops. Decontaminate with alkali detergent.

36 GRDC (2008). Grain Legume Handbook – Weed control.

37 Douglas A. (2008) Weeds Update, Western Australia.

Figure 8: *Hygiene between spraying operations is essential. After using herbicide, make sure the boom spray is cleaned out with chlorine before starting on grass control in legumes. The effect, as shown above, is dramatic.*

Source: GRDC

Spray Drift

Pulse crops can be severely damaged by some herbicide sprays, such as 2,4-D ester, drifting into the crop (Figure 9). This can happen when these sprays are applied nearby in very windy or still conditions, especially where there is an inversion layer of air on a cool morning. When using these herbicides, spray when there is some wind—to mix the spray with the crop. Do not use excessively high spray pressure, as this will produce too fine a spray, which is more likely to drift onto a neighbouring pulse crop. [38]

Figure 9: *Severe metsulfuron-methyl damage in chickpea plants.*

Source: DAFQ in Crop IT

6.14.1 Avoiding herbicide damage

Some herbicides can severely damage chickpea crops through residues in soil, contaminants in spray equipment, spray drift onto the crop or by incorrect use of the herbicide.

38 GRDC (2008). Grain Legume Handbook—Weed control.

MORE INFORMATION

Field crop herbicide injury: The Ute Guide

Chickpea Disorders: The Ute Guide

The importance of cleaning and decontaminating spray equipment before the application of herbicides cannot be overstressed. Traces of sulfonylurea herbicides (such as chlorsulfuron, metsulfuron or triasulfuron) in spray equipment can cause severe damage to chickpea and other legumes when activated by grass control herbicides.

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

- Do not apply residual herbicides if rain is imminent.
- Maintain at least 7.5–10 cm soil coverage.
- Avoid leaving a furrow or depression above the seed that could allow water (and chemical) to concentrate around the seed or seedling.
- Avoid leaving an exposed, open slot over the seed with disc-openers and avoid a cloddy, rough tilth with tined-openers. [39]

6.14.2 Plant-back intervals

Plant-back periods are the obligatory times between the herbicide spraying date and safe planting date of a subsequent crop.

Some herbicides have a long residual. The residual is not the same as the half-life. Although the amount of chemical in the soil may break down rapidly to half the original amount, what remains can persist for long periods (e.g. sulfonylureas (chlorsulfuron)). This is shown in the Table 27 and 28 where known. Herbicides with long residuals can affect subsequent crops, especially if they are effective at low levels of active ingredient, such as the sulfonylureas. On labels, this will be shown by plant-back periods, which are usually listed under a separate plant-back heading or under the "Protection of crops etc." heading in the "General Instructions" section of the label.

Part of the management of herbicide resistance includes rotation of herbicide groups. Paddock history should be considered. Herbicide residues (e.g. sulfonyl urea, triazines etc.) may be an issue in some paddocks. Remember that plant-back periods begin after rainfall occurs. [40]

Table 27: *Residual persistence of common pre-emergent herbicides, and note residual persistence in broad-acre trials and paddock experiences.* [41]

Herbicide	Half-life (days)	Residual persistence and prolonged weed control
Logran® (triasulfuron)	19	High. Persists longer in high pH soils. Weed control commonly drops off within 6 weeks.
Glean® (chlorsulfuron)	28-42	High. Persists longer in high pH soils. Weed control longer than Logran.
Diuron	90 (range 1 month to 1 year, depending on rate)	High. Weed control will drop off within 6 weeks, depending on rate. Has had observed longlasting activity on grass weeds such as black/stink grass (Eragrostis spp.) and to a lesser extent broadleaf weeds such as fleabane.

39 Pulses Australia. Chickpea Production: Southern and Western regions. http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/southern-guide

40 B Haskins (2012) Using pre-emergent herbicides in conservation farming systems. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/431247/Using-pre-emergent-herbicides-in-conservation-farming-systems.pdf

41 B Haskins (2012) Using pre-emergent herbicides in conservation farming systems. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/431247/Using-pre-emergent-herbicides-in-conservation-farming-systems.pdf

Herbicide	Half-life (days)	Residual persistence and prolonged weed control
Atrazine	60–100, up to 1 year if dry	High. Has had observed long lasting (>3 months) activity on broadleaf weeds such as fleabane.
Simazine	60 (range 28–149)	Med./high. 1 year residual in high pH soils. Has had observed long lasting (>3 months) activity on broadleaf weeds such as fleabane.
Terbyne® (terbulthylazine)	6.5–139	High. Has had observed long lasting (>6 months) activity on broadleaf weeds such as fleabane and sow thistle
Triflur® X (trifluralin)	57–126	High. 6–8 months residual. Higher rates longer. Has had observed long lasting activity on grass weeds such as black/stink grass (Eragrostis spp.).
Stomp® (pendimethalin)	40	Medium. 3–4 months residual.
Avadex® Xtra (triallate)	56–77	Medium. 3–4 months residual.
Balance® (isoxaflutole)	1.3 (metabolite 11.5)	High. Reactivates after each rainfall event. Has had observed long lasting (> 6 months) activity on broadleaf weeds such as fleabane and sow thistle.
Boxer Gold® (prosulfocarb)	12–49	Medium. Typically quicker to break down than trifluralin, but tends to reactivate after each rainfall event.
Sakura® (pyroxasulfone)	10–35	High. Typically quicker breakdown than Trifluralin and Boxer Gold, however, weed control persists longer than Boxer Gold.

Table 28: *Minimum re-cropping intervals and guidelines (NOTE: always read labels to confirm).*

Group and type	Product	pH (H2O) or product rate (ml/ha) as applicable	Minimum re-cropping interval (months after application), and conditions
B, sulfonyl urea (SU)	Chlorsulfurons eg Glean®, Seige®, Tackle®	<6.5	3 months
		6.6–7.5	3 months, minimum 700 mm
		7.6–8.5	18 months, minimum 700 mm
B, sulfonyl urea (SU)	triasulfuron, eg Logran®, Nugrain®	7.6–8.5	12 months, >250 mm grain, 300 mm hay
		>8.6	12 months, >250 mm grain, 300 mm hay
B, Sulphonamide	Flumetsulam eg Broadstrike®		0 months
B, sulfonyl urea (SU)	metsulfuron eg Ally®, Associate®	5.6–8.5	1.5 months

Group and type	Product	pH (H2O) or product rate (ml/ha) as applicable	Minimum re-cropping interval (months after application), and conditions
		>8.5	Tolerance of crops grown through to maturity should be determined (small scale) previous season before sowing larger area.
B, sulfonyl urea (SU)	Metsulfuron + thifensulfuron Eg Harmony® M	7.8–8.5 Organic matter >1.7%	3 months
		>8.6 or organic matter <1.7%	Tolerance of crops grown through to maturity should be determined (small scale) previous season before sowing larger area.
B, sulfonyl urea (SU)	Sulfosulfuron eg Monza®	<6.5	0 months
		6.5–8.5	10 months

Source: Pulse Australia

Herbicides with long residuals can affect subsequent crops, especially if they are effective at low levels of active ingredient, such as the sulfonylureas. On labels, this will be shown by plant-back periods, which are usually listed under a separate plant-back heading or under the "Protection of crops etc." heading in the "General Instructions" section of the label. [42]

Conditions required for breakdown

Warm, moist soils are required to breakdown most herbicides through the processes of microbial activity. For the soil microbes to be most active they need good moisture and an optimum soil temperature range of 18°C to 30°C. Extreme temperatures above or below this range can adversely affect soil microbial activity and slow herbicide breakdown. Very dry soil also reduces breakdown. To make matters worse, where the soil profile is very dry it requires a lot of rain to maintain topsoil moisture for the microbes to be active for any length of time.

For up-to-date plant-back periods, see Weed control in winter crops.

MORE INFORMATION

Avoiding crop damage from residual herbicides

6.15 Herbicide residues

Pulse growers need to be aware of possible herbicide residues that may affect crop rotation choices or cause crop damage. Herbicide residue impacts are more pressing where rainfall has been minimal. After a dry season, herbicide residues from previous crops could influence choice of crop and rotations more than disease considerations. The opposite occurs after a wet year.

Pulse crop types differ in their sensitivity to residual herbicides, so check each herbicide used against each pulse type. Residues of sulfonylurea herbicides can persist in some soils. These residues can last for several years, especially in more alkaline soils and where there is little summer rainfall. The pulses emerge and grow normally for a few weeks, and then start to show signs of stress.

42 B Haskins (2012) Using pre-emergent herbicides in conservation farming systems. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/431247/Using-pre-emergent-herbicides-in-conservation-farming-systems.pdf

Picloram (e.g. Tordon® 75-D) residues from spot-spraying can stunt any pulse crop grown in that area. This damage is especially marked in faba beans, where plants are twisted and leaves are shrunken. In more severe cases, bare areas are left in the crop where this herbicide had been used, in some cases more than five years ago. Although this damage is usually over a small area, correct identification of the problem avoids confusion and concern that it may be some other problem such as disease.

In wheat–chickpea rotations, the use of fallow and in-crop residual herbicides such as Broadstrike®, Eclipse®, Flame® Grazon®DS, Lontrel® and metsulfuron (Ally®, Associate®, Lynx®) Harmony®M should be avoided.

The use of long-term residual sulfonylurea herbicides such as Monza®, chlorsulfuron (Glean®, Lusta®), and Logran® in wheat should be avoided when re-cropping to chickpeas. [43]

Stay up to date with chemical labels and recommendations by visiting the APVMA and PubCRIS websites.

6.15.1 Sulfonylurea residues, Group B

Sulfonylurea products include:

- metsulfuron (Ally®, Associate®, Lynx®)
- thifensulfuron plus metsulfuron (Harmony®M)
- sulfosulfuron (Monza®)
- chlorsulfuron (Glean®, Lusta®, Logran®)

Usually, Glean® or Logran® damage is not serious when these products are used as directed, although there is an increased risk of damage given:

- very dry or drought conditions;
- highly alkaline (pH >8.5) soils; or
- excessive overlapping during application.

Sulfonylurea breakdown occurs by hydrolysis, and is favoured by warm, moist conditions in neutral to acid soils. Residues will tend to persist for longer periods under alkaline and/or dry conditions. Persistence of residues is greater for Glean® and Logran®, than for Ally® or Harmony®M.

Residues are root absorbed and translocated to the growing points; therefore, both roots and shoots are affected.

Moderate residue levels

Plant emergence will be patchy, and the first true leaves elongated and narrow. Plants remain stunted, with severe chlorosis of the uppermost leaves (Figure 10).

43 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

Figure 10: *Yellowing of new growth (left) and plant stunting (right).*

Photo: A Storrie, NSW DPI

Seedlings develop symptoms as the roots reach the sulfonylurea residue layer in the soil. This may occur in the early seedling stage on heavy clay soils, or slightly later on light sandy soils due to movement of residues down the soil profile. Symptoms are often more severe where there is soil compaction, e.g. in wheel tracks.

Symptoms include:

- Spear-tipping of lateral roots (root pruning).
- Yellowing of uppermost leaves, which can progress to older, lower leaves in severe cases.
- Development of zinc-deficiency symptoms—narrow, cupped leaves.
- Stunted growth.

Highly sensitive crops (in order of susceptibility)

- lentils
- chickpea (0.5 ppb)

Highly susceptible indicator weeds

- brassicas (turnip, mustard, radish)
- red pigweed, mintweed
- native jute
- parthenium weed
- paradoxa grass

Strategy

Avoid using Glean® or Logran® on very high pH soils (pH >8.5) if you intend growing chickpea after wheat. Reassess risk if Glean® or Logran® has been used and drought conditions have been experienced during the wheat crop and in the subsequent fallow. [44]

6.15.2 Imidazolinone (imi) residues, Group B

Imidazolinone products include:

- imazapic + imazapyr (Midas®, OnDuty®)

44 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

- imazamox + imazapyr (Intervix®)
- imazapic (Flame®)
- imazethapyr (Spinnaker®, various imazethapyrs)
- imazamox (Raptor®)

Figure 11: *Spinnaker injury to the emerging new chickpea growth.*

Photo: G Cumming, Pulse Australia

Imazethapyr (e.g. Spinnaker®) can be damaging (Figure 11). Damage from residues of other 'imi' products should not be serious when used as directed, although there is an increased risk of damage where:

- plant-back periods or rainfall requirements are not adhered to;
- very dry or drought conditions have prevailed (often 150–200 mm rainfall required);
- soils are highly alkaline (pH >8.5);
- extensive overlapping has occurred during application; or
- heavy rainfall after application concentrates treated soil in plant furrows.

Persistence of imi residues is greater for Intervix® and Midas® or OnDuty® than for Flame®.

Residues are root-absorbed and translocated to the growing points; therefore, both roots and shoots are affected.

Moderate residue levels

Plant emergence will be patchy, and the first true leaves elongated and narrow. Plants remain stunted, with severe chlorosis of the uppermost leaves.

Low residue levels

Seedlings develop symptoms as the roots hit the imi residue layer in the soil. This may occur in the early seedling stage on heavy clay soils, or slightly later on light sandy soils due to movement of residues down the soil profile. Symptoms are often more severe where there is soil compaction, such as in wheel tracks.

Symptoms include:

- Spear-tipping of lateral roots (root pruning).
- Yellowing of uppermost leaves, which can progress to older, lower leaves in severe cases.
- Development of zinc-deficiency symptoms—narrow, cupped leaves.
- Stunted growth.

Highly sensitive crops (in order of susceptibility)

- conventional canola
- lentil

- safflower
- oats

Strategy

Avoid using imi products on very acidic soils if you intend growing chickpeas after a Clearfield® wheat or canola in an area with marginal rainfall. Reassess risk if imi products have been used and drought conditions have been experienced during the prior wheat, canola crop or fallow. Be wary of using imi products in short-term chemical fallows or for summer weed control where chickpeas are to be sown. [45]

6.15.3 Triazine residues (atrazine), Group C

Chickpeas have some tolerance to very low rates of atrazine, but triazine carry-over from previous crops should be avoided (see Figure 12). Atrazine significantly increases the frost sensitivity of the crop. Risk of damage increases where there are low levels of subsoil moisture. Crops in this situation are largely surface-rooted and vulnerable to damage when there is herbicide recharge after each rainfall event.

Figure 12: *Narrowing of the leaflets and multiple branching are signs of triazine residues (left). Similar distortion is seen in the roots (right).*

Photo: G Cumming, Pulse Australia

Atrazine breakdown is strongly influenced by soil type and climatic conditions. Rates of breakdown slow considerably under dry conditions, and can stop altogether under drought.

Atrazine is more persistent under the following conditions:

- alkaline soils (especially pH >8.0)
- increasing clay content (i.e. black earths)
- low soil temperatures
- low soil moisture levels.

Atrazine is root-absorbed and translocated up into the shoots, where it accumulates and inhibits photosynthesis. Plants usually emerge, but begin to show symptoms of stunting and chlorosis at 2–6 weeks of age. Atrazine initially accumulates in the tips and margins of the lower leaves. This results in bleaching and necrosis of the leaf margins. Plants are often stunted and plant growth is slow. Other Group C herbicides such as diuron and fluometuron cause similar symptoms, mainly on the older, lower leaves.

Highly susceptible indicator weeds

- mintweed (turnip, mustard, radish)
- brassicas
- black pigweed [46]

45 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

46 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

6.15.4 Group I

Products include:

- 2,4-D products (amines, esters)
- dicamba (e.g. Cadence®)
- triclopyr (e.g. Garlon®)
- fluroxypyr (e.g. Lontrel®)

Residues of 2,4-D persist for a relatively short period, and they can be overlooked. Figure 13 shows residual damage from 2,4-D. Table 29 shows the plant-back period for various rates of products. The most important value here is the minimal rainfall requirement prior to sowing. In 2006 there was significant 2,4-D damage in chickpea resulting from an application of a 2,4-D product as a late fallow spray and/or knockdown spray prior to sowing. The re-cropping interval was not the cause; rather, the damage was due to not having received the minimal rainfall requirement of 15 mm before this period commenced. [47]

Figure 13: *Residual 2,4-D damage, showing narrowing and thickening of leaflets on younger growth.*

Photo: J Flemming, NSW DPI

47 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

Table 29: *Chickpea plant-back intervals and conditions after spikes in Group I knockdown herbicides.*

Active Ingredient	Products	Rates (/ha)	Period	Comments
2,4-D	2,4-D amine (625 g/L)	Up to 0.56 L	7 days	At least 15 mm of rain must fall prior to commencement of the plant-back period
	2,4-D ester (800 g/L)	Up to 0.35 L		
	Baton® (800 g/kg) (amine)	Up to 0.4 kg		
	2,4-D amine (625 g/L)	0.56–1.1 L		
	2,4-D ester (800 g/L)	0.35–0.7 L	14 days	
	Surpass® (300 g/L) (amine)	1.1–2.3 L		
	Baton® (800 g/kg) (amine)	0.4–0.9 kg		
	2,4-D amine (625 g/L)	1.1–17 L		
	2,4-D ester (800 g/L)	0.7–1.1 L	21 days	
	Surpass® (300 g/L) (amine)	2.3–3.4 L		
	Baton® (800 g/kg) (amine)	0.9–1.3 kg		
	Cadence®	140 g		
Dicamba (700 g/kg)	Cadence®	200 g	Not determined	When applied to dry soil, at least 15 mm of rainfall is required prior to commencement of the plant-back period
	Dicamba 500	400 g	21 days	
		200 mL	28 days	
Dicamba (500 g/L)	Dicamba 500	280 mL	Not determined	
	Garlon® 600, Invader® 600	560 mL	21 days	
	Safari® 600	Up to 160 mL	28 days	
Triclopyr (600 g/L)	Starane® 200, Flagship®	Up to 375 mL	7 days	
Fluroxypyr (200 g/L)			7 days	

Source: Pulse Australia

6.15.5 Group I residual herbicides

Products include:

- clopyralid (Lontrel®)
- picloram (Tordon® 75-D, Tordon® 242, Grazon® DS)
- aminopyralid + fluroxypy (e.g. Hotshot®)

These products are used for in-crop or fallow weed control and can persist for long periods under dry conditions. Lontrel® is used in canola, wheat, barley, triticale and oats, so care with a subsequent chickpea crop is required. It can persist on crop stubble for long periods and then it can become activated when leached into the soil following rainfall. Lontrel® is being used more often for residual control of fleabane. Picloram residues are relatively stable in the soil, with residues fixed onto clay particles and remaining concentrated in the top 10–15 cm of soil. Residues are slowly broken down by microbial action, with decomposition slowing during the colder, winter months. Up to 25% of the applied dose can persist for up to 12 months, or longer under very dry conditions.

Some symptoms of low-level residue damage are not always readily visible in chickpeas, for example:

- retarded, slow growth;
- thickening and callousing of the lower stem, usually just above ground level, which can be accompanied by cracking and splitting of the stem in more severe cases; or
- proliferation of short, lateral roots.

There may also be some slight twisting and bending of the main stem. Higher rates of residue can also affect leaf shape, with a narrowing and thickening of leaflets. A severe reaction may cause cupping and stunting of leaflets.

Strategy

Avoid using Lontrel® or Grazon® DS in the fallow period prior to chickpeas. [48]

Caution needs to be taken when using Lontrel before cereal and canola crops. Make sure to adhere to re-cropping guidelines, and be cautious of rate and stubble retention.

Agronomist's view

6.15.6 Management of herbicide residues in the soil

Using soil-persistent herbicides can provide very effective weed control; however, issues can arise when sensitive crops are planted in the next season. The main factors that influence whether crop damage occurs are: rainfall from application to sowing, temperature when the soil is wet, soil pH, soil organic matter, the sensitivity of the crop to the herbicide, and the relative persistence of the herbicide in the soil. Risk of damage to subsequent crops is greatest when conditions after application are dry from spring until autumn.

Herbicides can be broken down by chemical and/or microbial means. Both require moisture and temperature to be effective. Herbicides break down more slowly in winter when moisture may be available, but temperatures are low. In a Mediterranean climate, there is usually little or no herbicide breakdown over summer, where temperature is high, but there is no moisture available in the top soil. Most herbicide breakdown will occur in spring and autumn.

To achieve sustained breakdown of herbicides, the top 2 cm of the soil needs to be moist for a period of seven days or more. This is because in summer, the soil microbes shut down due to lack of water and it takes time for their populations to build up again. Small rainfall events in summer will be quickly evaporated from the topsoil, so as a general rule the rainfall events of less than 10 mm in summer should not be counted towards the amount of rainfall required for herbicide breakdown. It is those larger events, typically those of 25 mm or more, which will contribute most to herbicide breakdown.

Soil type and soil pH are also important, as they will affect how far the herbicide moves down the soil profile. Most of the microbial activity occurs in the top few centimetres of the soil and if the herbicide moves below this layer, it may be broken down more slowly. For example, sulfonylurea herbicides are much more mobile in alkaline soils, and this contributes to their longer persistence in alkaline soils. Soil organic matter is important as it provides food for the microbes. Microbial populations are typically smaller in soils with low organic matter than in those with higher organic matter.

48 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

Following a dry spring and summer, it is generally those large rainfall events in autumn that do most of the work in breaking down herbicides. The larger these events are and the earlier they occur, the lower the risk of crop damage. One added risk is that the first large rainfall event after a long dry summer will release herbicides into the soil water quickly. Planting too soon after that first large rainfall event can result in greater crop damage than waiting for a week to sow. The re-cropping intervals on product labels are a good guide to the likely risks of crop damage. When in doubt, it is good practice to sow a more tolerant crop. [49]

6.16 Herbicide resistance

Herbicide resistance fact box

- Resistance is the inherited ability of an individual plant to survive and reproduce following a herbicide application that would kill a 'wild type' individual of the same species.
- Thirty-six weed species in Australia currently have populations that are resistant to at least one herbicide mode-of-action (MOA).
- As at June 2014, Australian weed populations have developed resistance to 13 distinct MOAs (click here for up to date statistics).
- Herbicide-resistant individuals are present at very low frequencies in weed populations before the herbicide is first applied.
- The frequency of naturally resistant individuals within a population will vary greatly within and between weed species.
- A weed population is defined as resistant when a herbicide at a label rate that once controlled the population is no longer effective (sometimes an arbitrary figure of 20% survival is used for defining resistance in testing).
- The proportion of herbicide resistant individuals will rise (due to selection pressure) in situations where the same herbicide MOA is applied repeatedly and the survivors are not subsequently controlled.
- Herbicide resistance in weed populations is permanent as long as seed remains viable in the soil. Only weed density can be reduced, not the ratio of resistant-to-susceptible individuals. The exception is when the resistance gene(s) carry a fitness penalty so that resistant plants produce less seed than susceptible ones, but this is rare. [50]

Herbicide resistance is the inherited ability of an individual plant to survive a herbicide application that would kill a normal population of the same species. During the 1940s and '50s, Australian agriculture relied heavily on the use of broad-spectrum pesticides to control pests. Selective herbicides began to appear in the mid-1970s and have been a fundamental tool for cropping and pasture since. However, as reliance on chemicals has grown over the years we are continuing to see more weeds that have developed resistance to herbicides. In other words, a number of chemicals that we have available to us have become less useful. Herbicide resistance was first recognised in Australia in 1981 where some annual ryegrass developed resistance to diclofop-methyl (Figure 14). [51]

49 GRDC Update Papers. (2016). Can we beat grass weeds or will they beat us. https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/08/Can-we-beat-grass-weeds-or-will-they-beat-us

50 GRDC. Integrated weed management hub – Section 1: Herbicide resistance. https://grdc.com.au/Resources/IWMhub/Section-1-Herbicide-resistance

51 Agriculture Victoria. HERBICIDE RESISTANCE AND INTEGRATED WEED MANAGEMENT (IWM) IN CROPS AND PASTURE MONITORING TOOLS. http://agriculture.vic.gov.au/agriculture/farm-management/business-management/ems-in-victorian-agriculture/environmental-monitoring-tools/herbicide-resistance

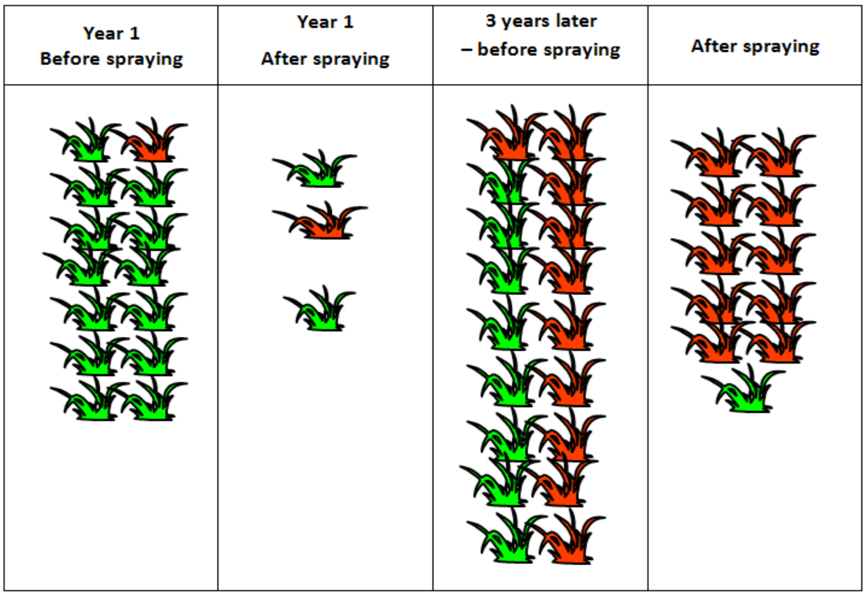


Figure 14: *How a weed population becomes resistant to herbicides.*

Source: GRDC

Herbicide use since the 1980s has seen the development of herbicide resistance across Australia in a range of cropping weeds, including annual ryegrass, wild oats, Indian hedge mustard, wild radish, wild turnip, and prickly lettuce as well as barley grass and capeweed (Table 30). Herbicide resistance is a major threat to Australian grain growers, but whilst herbicide resistance is here to stay, it need not spell the end of profitable cropping. Delaying the onset and/or reducing the impact of herbicide resistant weed populations calls for the implementation of a wide range of weed control strategies, that will in turn help sustain profitable grain production. [52]

Table 30: *Resistance status of a number of weeds. Note: Resistance status will vary from paddock to paddock and not all populations have these characteristics.*

Weed species	Resistance status
Annual Ryegrass *(Lolium rigidum)*	Very high resistance to Group A (e.g. Diclofop) and Group B herbicides (Sulfonylureas). Some resistance to Group D (Trifluralin) and Glyphosate (Group M herbicides).
Wild Oat *(Avena fatua)*	Diclofop-methyl (Group A herbicides) resistance Resistance to Group K (flamprop-methyl)
Barley grass (*Hordeum leporinum*)	Paraquat and Diquat resistance
Capeweed *(Arciotheca calendula)*	Paraquat and Diquat resistance
Barnyard Grass *(Echinochloa crus-galli)*	Resistance to Group C herbicides
Wild Radish	Resistance to chlorosulfron has increased threefold over last four years. Some resistance to Atrazine and 2, 4-D-amine.
Brome grass (*Bromus spp.*)	Resistant to Group A (Verdict) and Group B imi resistance.
Indian hedge mustard, prickly lettuce, wild turnip, sow thistle, black bindweed, silvergrass, summer grass, salvation jane.	New additions of resistant weeds with resistance to one or more groups of herbicides.

Source: AgVic

52 GRDC (2008). Grain Legume Handbook – Weed control

Annual ryegrass herbicide resistance

A number of weed species have developed resistance to herbicides. Of the greatest concern is Annual Ryegrass (*Lolium rigidum*) because it has developed cross-resistance to a number of different herbicide groups. Annual Ryegrass is one of the most significant weeds for cropping enterprises—and we are rapidly running out of chemical options to deal with it. Table 31 shows the resistance status of Annual Ryegrass to a number of Group A, B, D, and M herbicides—a herbicide program made up of two to three years use of any of these can fail due to cross resistance. Resistance to trifluralin is increasing rapidly.

Table 31: *Estimated number of herbicide applications before resistance develops.*

Product	Low ryegrass number	High ryegrass numbers
Group A	7 to 10	4
Group B		4
Group D (trifluralin)	15	10
Group L		12
Group M		15
Double Knock		30 +

Source: PIR.SA

Thirty-six weed species in Australia currently have populations that are resistant to at least one herbicide 'mode of action' (MOA) group (Figure 15).

Figure 15: *Pots of annual ryegrass tested for plyphosate resistance; susceptible (left) and strongly resistance (right).*

Photo: Peter Boutsalis, Source: DAFWA

MORE INFORMATION

DAFWA – Herbicide resistance.

Herbicide resistance is normally present at very low frequencies in weed populations before the herbicide is first applied. Variation exists within every population, with some individuals having the ability to survive the herbicide application.

A weed population is defined as resistant when a herbicide that once controlled the population is no longer effective (sometimes an arbitrary figure of 20% survival is used). The proportion of herbicide resistant individuals will rise due to selection pressure in situations where one herbicide MOA group is applied repeatedly. [53]

Glyphosate resistance

Glyphosate resistance was first documented for annual ryegrass (Lolium rigidum) in 1996 in Victoria. Since then glyphosate resistance has been confirmed in 11 other weed species (Figure 16).

53 DAFWA (2016) Herbicide resistance. https://www.agric.wa.gov.au/grains-research-development/herbicide-resistance?page=0%2C0

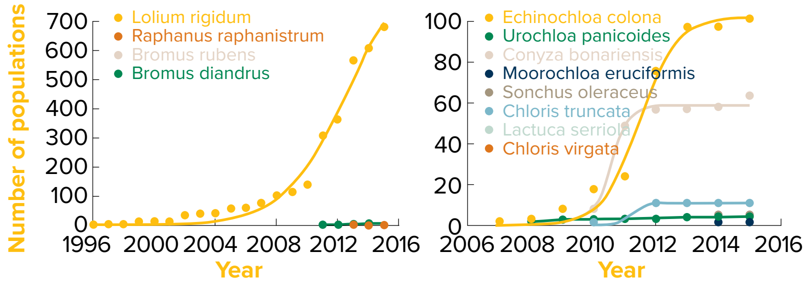


Figure 16: *Increase in confirmed cases of Glyphosate resistance in winter weeds (left) and summer weeds (right) between 1996 and 2016.*

Source: AGSWG

Resistance is known in eight grass species and four broadleaf species. There are four winter-growing weed species and eight summer-growing weed species. The latter have been selected mainly in chemical fallows and on roadsides.

The most number of resistant populations is for annual ryegrass (Tables 32 and 33) followed by barnyard grass and then fleabane.

Table 32: *Number of Glyphosate resistance weed populations recorded in WA.*

Glyphosate resistant weed	Number of population found in WA
Annual ryegrass	164
Barnyard grass	1
Windmill grass	1

Source: AGSWG

Table 33: *Glyphosate resistant annual ryegrass has occurred in the following situations.*

Situation		Number of Sites	States
Broadacre cropping	Chemical fallow	34	NSW
	Winter grains	393	WA, SA, Vic, NSW
	Summer grains	1	NSW
	Irrigated crops	1	SA
Horticulture	Tree crops	10	SA, NSW
	Vine crops	25	WA, SA
	Vegetables	2	Vic
Other	Driveway	6	WA, SA, Vic, NSW
	Fenceline/crop margin	91	WA, SA, Vic, NSW
	Around buildings	2	NSW
	Irrigation channel/drain	14	SA, Vic, NSW
	Airstrip	1	SA
	Railway	2	WA, NSW
	Roadside	95	WA, SA, NSW
	Pasture	1	WA

Source: AGSWG

All of the glyphosate resistant weed populations have occurred in situations where there has been intensive use of glyphosate, often over 15 years or more, few or no other effective herbicides used and few other weed control practices are used. This suggests the following are the main risk factors for the evolution of glyphosate resistance:

- Intensive use of glyphosate—every year or multiple times a year for 15 years or more.
- Heavy reliance on glyphosate for weed control.
- No other weed controls. [54]

WATCH: GCTV9: Glyphosate resistant weeds.

An evaluation of farming systems in low rainfall areas has found that (Table 34):

- As cropping intensity increased, higher average returns are possible, but it is imperative to reduce the number of ryegrass to a very low level prior to, or as soon as possible in the rotation and then using a full range of practices to keep the number low.
- The initial reduction in ryegrass numbers must be carried out with as little selection for resistance as possible. Selective herbicide can be used without the population of ryegrass increasing its resistance if spray topped or green manured before seed set.
- To avoid the build-up in resistance to Group M (glyphosate), the additional cost of the double knock system is justified, particularly in more intensive systems that rely on glyphosate for early weed control in rotations.
- Ryegrass numbers also compete strongly with the crop limiting yield and returns (Figure 17).

54 Australian Glyphosate Sustainability Working Group (2016) Glyphosate resistant weeds in Australia. http://glyphosateresistance.org.au/RegisterSummary.pdf

Table 34: *Percent Ryegrass Control with different management treatments.*

Treatment	Average % Control Resistant Population	Average % Control
Trifluralin	30 to 40	80
Trifluralin + Avadex	75	85
Boxer Gold	80 to 90	80 to 90
Sakura	80 to 90	80 to 90
Double knock (application of glyphosate followed by Sprayseed three days later)	40%	40%
Crop topping		75%
Spray topping (low rate of paraquat or glyphosate) at flowering / milky dough		70%
Brown manure (high rate of glyphosate)		95%
Hay cutting		85%
Stubble burning – grazed		40%
Stubble burning – standing stubble ungrazed		75%
Windrow burning in canola, lupins and beans	85	85% plus
Wheat stubbles from < 2.5 t/ha grain crops		85% plus
Burning chaff dumps		90%
Seed catching		60%
Harrington seed destructor		95%

Source: PIR.SA

Figure 17: *Glyphosate resistant annual ryegrass in crop paddock.*

Source: GRDC

6.16.1 Practices to minimise herbicide resistance

The threat of herbicide resistance does not mean that herbicides should not be used; however, it does mean farmers should avoid over reliance on herbicides that have the same action on plants ('mode of action'). All herbicide labels now indicate what herbicide group the active ingredient belongs to. Cases of glyphosate resistance in annual ryegrass and of paraquat resistance in barley grass in direct-drill cropping systems sounds a warning on heavy reliance on even 'low risk' herbicides.

Growers should aim to use as many different methods of weed control as practical in the overall paddock management including the following:

- rotation of cultivation and herbicide groups
- crop competition
- use of knockdown
- pasture topping herbicides for seedset
- hay making preparation
- grazing
- burning
- seed capture
- crop-topping
- weed wiping (short crops)

Care must be taken when introducing control methods into the overall paddock plan. For example, weed numbers, especially resistant populations, can increase dramatically under pulses due to the poor competition offered by these crops.

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

Field testing and/or seed testing, as well as planning management strategies, can provide a guide to the resistance status of weed populations. [55]

6.16.2 WeedSmart farming

The Australian grain industry stands at a crossroads. Which direction will it take?

One road leads to every grower making herbicide sustainability their number one priority, so that it influences decision -making and practices on all Australian grain farms. Armed with a clear 10–point–plan for what to do on-farm, grain growers have the knowledge and specialist support to be WeedSmart.

On this road, growers are capturing and/or destroying weed seeds at harvest. They are rotating crops, chemicals and modes of action. They are testing for resistance and aiming for 100% weed kill, and monitoring the effectiveness of spray events.

In addition, they are not automatically reaching for glyphosate, they do not cut on-label herbicide rates, and they carefully manage spray drift and residues. Growers are planting clean seed into clean paddocks with clean borders. They use the doubleknock technique and crop competitiveness to combat weeds.

On this road, the industry stands a good chance of controlling resistant weed populations, managing difficult-to-control weeds, prolonging the life of important herbicides, protecting the no-till farming system, and maximising yields.

The other road leads to growers thinking that resistance is someone else's problem, or an issue for next year, or something they can approach half-heartedly. If herbicide resistance is ignored, it will not go away. Managing resistance requires an intensive, but not impossible, effort. Without an Australia-wide effort, herbicide resistance threatens the no-till system, land values, yields and your hip pocket. It will drive down the productivity levels of Australian farms.

55 GRDC (2008). Grain Legume Handbook – Weed control

WeedSmart 10-point plan

1. Act now to stop weed seed set
- Research and plan your WeedSmart strategy.
- Understand the biology of your weeds.
- Be strategic and committed.

2. Capture weed seeds at harvest
- Consider your options—chaff cart, narrow windrow burning, baling, Harrington Seed Destructor.
- Compare the financial cost per hectare.

3. Rotate crops and herbicide modes of action
- Protect the existing herbicide resource.
- Repeated application of effective herbicides with the same MOA is the single greatest risk factor for herbicide resistance evolution.

4. Test for resistance to establish a clear picture of paddock-by-paddock farm status
- Resistance continues to evolve.
- Sample weed seeds prior to harvest for resistance testing.

5. Never cut the rate
- Always use the label rate.
- Weeds resistant to multiple herbicides can result from below the rate sprays.

6. Don't automatically reach for glyphosate
- Consider diversifying
- Consider post-emergent herbicides where suitable.
- Consider strategic tillage.

7. Carefully manage spray events
- Use best management practice in spray application.
- Patch spray area of resistant weeds if appropriate
- No escapes

8. Plant clean seed into clean paddocks with clean borders
- Plant weed-free crop seed
- The density, diversity, and fecundity of weeds is generally greatest along paddock borders and areas such as roadsides, channel banks and fencelines.

9. Use the double knock technique
- Any combination of weed control that involves two sequential strategies
- A second application to control survivors from the first

10. Employ crop competitiveness to combat weeds
- Increase your crop's competitiveness to win the war against weeds.
- Row spacing, seeding rate, and crop orientation can all be tactics to help crops fight. [56]

MORE INFORMATION

WeedSmart website.

6.16.3 Testing for herbicide resistance

There are a number of different methods of testing for herbicide resistance. Tests can be performed in situ (in the paddock during the growing season), on seed collected from the suspect area, or by sending live plant samples to a testing service.

Testing can be conducted on-farm or by a commercial resistance testing service.

In-situ testing

An in-situ test can be performed following herbicide failure in a paddock. The test should be done at the earliest opportunity, remembering that the weeds will be larger than when the initial herbicide was applied. Test strips should be applied using

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

herbicide rates appropriate to the current crop growth stage and weed size, plus a double rate. The test strips should only be applied if the weeds are stress free and actively growing. To more accurately assess the level of control, conduct weed plant counts before and after application. Green or dry plant weights can be calculated for more accurate results.

Herbicide resistance seed tests

Seed tests require collection of suspect weed seed from the paddock at the end of the season. This seed is generally submitted to a commercial testing service.

There are two commercial seed testing services in Australia:

- Peter Boutsalis, Plant Science Consulting
- John Broster, Charles Sturt University, +61 (0)2 6933 4001

Approximately 3,000 seeds of each weed (an A4-sized envelope full of good seed heads) are required for a multiple resistance test. This equates to about one cup of annual ryegrass seed and six cups of wild radish pods.

Syngenta herbicide resistance Quick-Test™

The Syngenta herbicide resistance Quick-Test™ (QT) uses whole plants collected from a paddock rather than seeds, eliminating the problem of seed dormancy and enabling a far more rapid turnaround time. In addition, the tests are conducted during the growing season rather than out of season over the summer. A resistance status result for a weed sample is possible within 4–6 weeks. The QT, which was developed by Dr Peter Boutsalis while working for Syngenta in Switzerland, is patented in Australia.

For each herbicide to be tested, 50 plants are required. To reduce postage costs, plants can be trimmed to remove excess roots and shoots. Upon arrival at the testing service, plants are carefully trimmed to produce cuttings and transplanted into pots. After appearance of new leaves (normally 5–7 days), plants are treated with herbicide in a spray cabinet. The entire procedure, from paddock sampling to reporting results, takes between 4–6 weeks, depending on postage time and the herbicides being tested. Unlike paddock tests, the QT is performed under controlled conditions, so it is not affected by adverse weather conditions. The age of the plants is also less critical to the testing procedure. Trimming the plants prior to herbicide application means that herbicides are applied to actively growing leaves, thus mimicking chemical application to young seedlings. The Quick-Test™ has been used to test resistance in both grass and broadleaf weed species. During testing, both known sensitive and resistant biotypes are included for comparison.

Quick-Tests can be done with Peter Boutsalis, Plant Science Consulting. [57]

6.17 Grazing for weed control

Grazing is an alternative non-chemical option in weed control (Figure 18). Most weeds are susceptible to grazing. Weed control is achieved through reduction in seed-set and competitive ability of the weed. The impact is optimised when the timing of the grazing is early in the life cycle of the weed.

57 DAFWA (2016) Herbicide resistance. https://www.agric.wa.gov.au/grains-research-development/herbicide-resistance?page=0%2C0

Figure 18: *Sheep grazing crop in Condingup, WA.*

Photo: A Fowler, Source: GRDC

Plants vary in their palatability, and under the 'right' stocking rate, animals will selectively graze the more palatable plants. This knowledge is useful when previously grown crops volunteer in the sown crop and herbicides are not available, or their use would damage the crop. For example, graze peas in a chickpea crop. The relative palatability for some crops has been determined by the University of Adelaide and is shown in Table 35. The palatability was rated as: highly palatable (most of the crop eaten) or low palatability (very little of the crop eaten).

For best results:

- Introduce sheep early, before crop canopy closes.
- Use older sheep.
- Use low stocking rates.
- Spray weeds along fence line to concentrate sheep in crop.
- Remove sheep before they do much damage to crop.
- Remove sheep before flowering.

Observe grazing withholding periods if any chemicals are used in crop. [58]

Table 35: *Relative palatability of various crops to sheep.*

Highly palatable	Moderately palatable	Low palatability
9 weeks after sowing		
Field peas, lathyrus, fenugreek, lentils, canola, wheat, safflower, lupin, blanchefleur and Languedoc vetch.	Chickpeas	Coriander, faba bean, narbon bean
13 weeks after sowing		
Field peas, lathyrus, canola	Lentils, lupins	Chickpeas, coriander, faba beans, narbon bean, fenugreek

Source: GRDC

58 GRDC (2008) Grain Legume Handbook—Weed control

6.17.1 Grazing stubbles or failed crops

When putting stock onto crop stubbles or failed crops, there are several considerations, the most important being:

- pulpy kidney
- acidosis, also known as grain poisoning
- nitrates or cyanides in weeds
- wind erosion of soil, and
- withholding periods.

Some simple actions can overcome these issues:

- Ensure that stock have had their 5-in-1 vaccinations and boosters.
- Pulpy kidney is the weakest of the vaccines in 5-in-1, and it is cheap insurance to vaccinate again.
- Ensure that stock have a full rumen prior to going onto a crop.
- This can be easily done by providing hay or stubble as gut-fill.
- This will avoid over gorging on weeds or grain and give the rumen time to adjust to the change in feed.
- Spread large piles of grain out to minimise excessive intakes and risk of acidosis.
- Double-check previous crop chemical treatments and make sure all withholding periods are met before introducing stock.
- Slowly introduce stock to feed by allowing increasing periods over a week, starting with two hours.

Watch stock closely for the first week to ensure no problems occur, including unpalatability, which will result in decreased intake and loss of condition. [59]

59 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.