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GRDC
GROWNOTES™

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

WHEAT

SECTION 6

WEED CONTROL

PLANNING YOUR WEED CONTROL STRATEGY | HERBICIDE RESISTANCE | HARVEST WEED SEED CONTROL | OTHER NON-CHEMICAL WEED CONTROL | CROP COMPETITION | HERBICIDES EXPLAINED | PRE-EMERGENT HERBICIDES | IN-CROP HERBICIDES: KNOCK DOWNS AND RESIDUALS | HERBICIDE TOLERANCE RATINGS | POST-EMERGENT HERBICIDE DAMAGE | SELECTIVE SPRAYER TECHNOLOGY

SECTION 6

Weed control

More information

http://www.grdc.com.au/Media-Centre/Media-News/North/2013/05/Harvest-weed-seed-control-key-to-overcoming-resistance including video.

http://www.ahri.uwa.edu.au/page/Research/Management/Harvest-weed-seed-control-in-Australian-grain-cropping-systems

http://www.grdc.com.au/~/media/25C653C167C24A9A98C3451DFD16506C.pdf

http://www.grdc.com.au/uploads/documents/GRDC_HerbicideCard.pdf

http://www.dpi.nsw.gov.au/agriculture/pests-weeds/weeds/publications/nhrr

http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/155148/herbicide-resistance-brochure.pdf

Progress in developing weed competitive wheat

Brome and barley grass management in cropping systems of southern Australia

Integrated Weed Management - Crop Topping in wheat

Weed issues and action items

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

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

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

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, tarvine 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
- host insects

6.1 Planning your weed control strategy

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

1 GRDC (2005) Weed Links, Integrated weed management. GRDC, www.grdc.com.au/weedlinks

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

More information

The Royal Botanic Gardens Plant Identification & Botanical Information Service: http://www.rbgsyd.nsw.gov.au/plant_info/identifying_plants/plant_identification_service

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

More information

http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Herbicides-and-weeds-regional-issues-trials-and-developments

http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/The-mechanisms-of-herbicide-resistance

Herbicide resistance management, a local, in-field perspective

Genetic markers for herbicide resistance

Comparison of alternative mode of action herbicides for the control of Group I resistant wild radish (NSW field experiment 2014), Tony Cook. p62

6.2 Herbicide resistance

Herbicide resistance is an increasing threat across Australia's northern grain region for both growers and agronomists. Already 14 weeds have been confirmed as herbicide-resistant in various parts of this region, and more have been identified at risk of developing resistance, particularly to glyphosate.

In northern New South Wales (NSW), 14 weeds are confirmed resistant to herbicides of Group A, B, C, I, M or Z (see Table 1). As well, barnyard grass, liverseed grass, common sowthistle and wild oat are at risk of developing resistance to Group M (glyphosate) herbicides (see Table 2). Glyphosate-resistant annual ryegrass has been identified within ~80 farms in the Liverpool Plains area of northern NSW (Figure 2). [3]

For most herbicide modes of action there is more than one resistance mechanism that can provide resistance and within each target site, there are a number of amino acid modifications that provide resistance. This means that resistance mechanisms can vary widely between populations; although, some patterns are common. While some broad predictions can be made, a herbicide test is the only sure way of knowing which alternative herbicide will be effective on a resistant population. [4]

3 A Storrie *et al.* Managing herbicide resistance in northern NSW, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/155148/herbicide-resistance-brochure.pdf

4 GRDC (2014), The mechanisms of herbicide resistance. http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/The-mechanisms-of-herbicide-resistance

More information

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Non-herbicide-tactics-to-help-suppress-weed-growth

Figure 2: Glyphosate resistant annual ryegrass on the Liverpool Plains, NSW. (Photo: David Freebairn)

More information

http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Herbicides-and-weeds-regional-issues-trials-and-developments

Table 1: List of confirmed resistant weeds in northern NSW (current at February 2014)

Weed	Herbicide group and product/chemical (examples only)	Areas with resistance in NSW	Future risk	Detrimental impact
Wild oats	A. Topik® and Wildcat® B. Atlantis® Z. Mataven®	Spread across the main wheat-growing areas. More common in western cropping areas	Areas growing predominantly winter crops	High
Paradoxa grass	A. Wildcat®	North and west of Moree	Areas growing predominantly winter crops	High
Awnless barnyard grass	C. Triazines M. Glyphosate	Mainly between Goondiwindi and Narrabri	No-till or minimum tilled farms with summer fallows	High Very high
Charlock, black bindweed, common sowthistle, Indian hedge mustard, turnip weed	B. Glean®, Ally®	Spread across the main wheat growing areas	Areas growing predominantly winter crops	Moderate
Annual ryegrass	M. Glyphosate B. Glean® A. Verdict®	Group M widespread in Liverpool Plains. Group A and B resistance in central west NSW	Areas with predominantly summer fallows. Winter cropping areas	High High
Fleabane	M. Glyphosate	Spread uniformly across the region	Cotton crops and no-till or minimum tilled systems	Moderate
Wild radish	I. 2,4-D amine	Central-west NSW	Continuous winter cereal cropping	High

Weed	Herbicide group and product/ chemical (examples only)	Areas with resistance in NSW	Future risk	Detrimental impact
Windmill grass	M. Glyphosate	Central-west NSW	Continuous winter cropping and summer fallows	High
Liverseed grass	M. Glyphosate	A few isolated cases	No-till or minimum tilled systems	Moderate
Sowthistle[A]	M. Glyphosate	Liverpool Plains	Winter cereal dominated areas with minimum tillage	High

[A] Testing under way to confirm glyphosate resistance. Plants are surviving label rates of glyphosate in the field and similar responses were seen under controlled environment experiments; likely to be confirmed resistant in 2014.

Table 2: List of potential new resistant weeds in northern NSW (as at February 2014)

Weed	Herbicide group and product/chemical (examples only)	Future risk	Detrimental impact
Barnyard, liverseed and windmill grasses	A. Verdict® L. Paraquat	No-till and minimum tilled systems	Very high Very high
Common sowthistle	I. 2,4-D amine	Winter cereals	High
Paradoxa grass	B. Glean®, Atlantis®	Western wheat growing areas	High
Other brassica weeds including wild radish	B. Glean®,, Ally®	Areas growing predominantly winter crops	Moderate
Annual ryegrass	L. Paraquat	Areas with predominantly summer fallows	Very high
Wireweed, black bindweed, melons and cape weed	I. 2,4-D amine, Lontrel®, Starane®	Areas growing predominantly winter crops	High
Fleabane	I. 2,4-D amine L. Paraquat	Cotton crops and no-till or minimum tilled systems	Very high Very high
Other fallow grass weeds	M. Glyphosate	No-till or minimum tilled systems	High

Table 3: Summary of herbicide resistance levels in ryegrass in continuous cropped irrigation in the Murray Shire of southern NSW

Herbicide Group	Common product names	Averaged resistance testing results (%)
Group A (fops)	Verdict, Hoegrass, Targa/Targabolt	80% +
Group A (dims/dens)	**Select**, Achieve, Axial, **Factor**	10-30%
Group B (SU's)	Glean, Logran, Hussar, Atlantis	80% +
Group B (imi's)	Intervix, Raptor, On-duty	50-70%
Group C (triazines)	Atrazine/Simazine, Terbyne	0-30%
Group D	Trifluralin, Stomp, Propyzamide	<5%
Group J	Boxer Gold, Avadex	0%
Group K	Sakura, Dual Gol	0%
Group L	Gramoxone, Sprayseed	0%?
Group M	Round-up	<5%
Group N	Basta	Never tested
Group Q	Amitrol T	Never tested

Source: http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Herbicide-resistance-management-a-local-infield-perspective

More information

http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/155148/herbicide-resistance-brochure.pdf

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/04/Strategies-for-optimising-the-life-of-Group-A-herbicides-and-patterns-of-herbicide-resistance-in-wild-oats

http://www.grdc.com.au/uploads/documents/GRDC_NorthernWeeds.pdf

http://www.nga.org.au/results-and-publications/download/311/grdc-update-papers-weeds/summer-fallow-weed-management/grdc-update-weeds-resistance-mungindi-march-2014.pdf

Testing services

For testing of suspected resistant samples, contact:

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

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

6.2.1 Be a WeedSmart farmer

The Australian grain industry stands at the crossroads with two options. Which direction will it take?

One road is for every grower to make 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 double-knock 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 option is for growers to think 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.

More information

www.weedsmart.org.au

Video

Richard Daniel, NGA Discusses Herbicide Resistance Tactics: http://www.weedsmart.org.au/media-releases/rethinking-weed-control/

Jump on board WeedSmart and take the road of least resistance. [5]

6.2.2 Ten ways to weed out herbicide resistance

1. Act now to stop weeds from setting seed.
   - Destroy or capture weed seeds.
   - Understand the biology of the weeds present.
   - Remember that every successful WeedSmart practice can reduce the weed seedbank over time.
   - Be strategic and committed—herbicide resistance management is not a 1-year decision.
   - Research and plan your WeedSmart strategy.
   - You may have to sacrifice yield in the short term to manage resistance—be proactive.
   - Find out what other growers are doing, and visit www.weedsmart.org.au.
2. Capture weed seeds at harvest. Options to consider are:
   - Tow a chaff cart behind the header.
   - Check out the new Harrington Seed Destructor.
   - Create and burn narrow windrows.
   - Produce hay where suitable.
   - Funnel seed onto tramlines in controlled traffic farming (CTF) systems.
   - Use crop-topping where suitable (southern and western grains region).
   - Use a green or brown manure crop to achieve 100% weed control and build soil nitrogen levels.
3. Rotate crops and herbicide modes of action:
   - Look for opportunities within crop rotations for weed control.
   - Understand that repeated application of effective herbicides with the same mode of action (MOA) is the single greatest risk factor for evolution of herbicide resistance.
   - Protect the existing herbicide resource.
   - Remember that the discovery of new, effective herbicides is rare.
   - Acknowledge that there is no quick chemical fix on the horizon.
   - Use break crops where suitable.
   - Growers in high-rainfall zones should plan carefully to reduce weed populations in the pasture phase prior to returning to cropping.
4. Test for resistance to establish a clear picture of paddock-by-paddock weed status:
   - Sample weed seeds prior to harvest for resistance testing to determine effective herbicide options.
   - Use the 'Quick Test' option to test emerged ryegrass plants after sowing to determine effective herbicide options before applying in-crop selective herbicides.
   - Visit the WeedSmart website, www.weedsmart.org.au or www.ahri.uwa.edu.au for more information on herbicide-resistance survey results.
   - Collaborate with researchers by collecting weeds for surveys during the double-knock program (northern region).
5. Aim for 100% weed control and monitor every spray event:
   - Stop resistant weeds from returning into the farming system.
   - Focus on management of survivors in fallows (northern grains region).
   - Where herbicide failures occur, do not let the weeds seed. Consider cutting for hay or silage, fallowing or brown manuring the paddock.
   - Patch-spray areas of resistant weeds only if appropriate.
6. Do not automatically reach for glyphosate:
   - Use a diversified approach to weed management.

[5] WeedSmart, http://www.weedsmart.org.au

More information

www.weedsmart.org.au

http://www.ahri.uwa.edu.au

http://www.grdc.com.au/BGC00001

http://www.grdc.com.au/Resources/IWMhub/Section-1-Herbicide-resistance

More information

http://www.grdc.com.au/MR-HarvestWeedSeedControl

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2012/04/Harvest-weed-seed-control

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2012/04/What-percent-of-northern-weed-seed-might-it-be-possible-to-capture-and-remove-at-harvest-time-A-scoping-study

- » Consider post-emergent herbicides where suitable.
- » Consider strategic tillage.

7. Never cut the on-label herbicide rate and carefully manage spray drift and residues:
   - » Use best management practice in spray application. The GRDC has produced a series of Fact Sheets, available at www.grdc.com.au.
   - » Consider selective weed sprayers such as WeedSeeker or WeedIt.
8. Plant clean seed into clean paddocks with clean borders:
   - » It is easier to control weeds before the crop is planted.
   - » Plant weed-free crop seed to prevent the introduction of new weeds and the spread of resistant weeds.
   - » A recent Australian Herbicide Resistance Initiative (AHRI) survey showed that 73% of grower-saved crop seed was contaminated with weed seed.
   - » The density, diversity and fecundity of weeds are generally greatest along paddock borders and areas such as roadsides, channel banks and fence lines.
9. Use the double-knock technique:
   - » Double knock is the use of any combination of weed control that involves two sequential strategies; the second application is designed to control survivors of the first method of control used.
   - » Access GRDC research results at www.grdc.com.au or www.nga.org.au.
10. Employ crop competitiveness to combat weeds:
    - » Consider narrow row spacing and seeding rates.
    - » Consider twin-row seeding points.
    - » Use barley and varieties that tiller well.
    - » Use high-density pastures as a rotation option.
    - » Consider brown manure crops.
    - » Rethink bare fallows. [6]

6.3 Harvest weed seed control

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

For information on harvest weed-seed control and its application for the northern grains region, see *Section 12: Harvest*.

6.4 Other non-chemical weed control

Crop rotation, especially with summer crops, can be an effective means of managing a spectrum of weeds that result from continuous wheat cropping. Barley is a more vigorous competitor of weeds than is wheat, and it may be a suitable option for weed suppression. Increased planting rates and narrow rows may also help where the weed load has not developed to a serious level. [7]

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

Where continuous summer cropping has led to development of Group M resistant annual ryegrass, a winter crop could be included in the rotation and a Group A, B, C,

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

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

A 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

Videos

Videos produced for GRDC's Integrated Weed Management tutorial series: http://www.youtube.com/playlist?list=PL2PndQdkNRHGRipNhkDYN2dJWAY1-oH9W

http://www.grdc.com.au/Media-Centre/Ground-Cover-Supplements/GCS104/Lift-sowing-to-outcompete-weeds

http://www.ahri.uwa.edu.au

http://www.agronomo.com.au/giving-a-rats/

More information

http://www.grdc.com.au/Media-Centre/Hot-Topics/Herbicide-Resistance

D, J or K herbicide used instead, along with crop competition and potential harvest management tactics.

For summer grasses, consider a broadleaf crop such as mungbean, because a Group A herbicide and crop competition can provide good control.

Strategic cultivation can provide control for herbicide-resistant weeds and those that continue to shed seed throughout the year. It can be used to target large mature weeds in a fallow, for inter-row cultivation in a crop, or to manage isolated weed patches in a paddock. Take into consideration the size of the existing seedbank and the increased persistence of buried weed seed, but never rule it out.

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 occurs early in the life cycle of the weed. [8]

6.5 Crop competition

A recent field trial near Warwick, Queensland, showed that fleabane density and seed production could be substantially manipulated using crop competition in the absence of herbicides. The site received a considerable amount of rain during the 2010 crop-growing season, which promoted fleabane emergence and good early crop growth, but barley foliar disease in the latter part of the season. The major disease outbreak resulted in poor barley growth and therefore did not provide the anticipated crop competitiveness.

For wheat, there were trends to lower fleabane numbers with increasing crop population and narrower row spacing (Figure 4). On average, weed density decreased by 26% as crop population increased from 50 to 100 plants/m^2, and by 44% as row spacing decreased from 50 to 25 cm. These treatments also had impacts on seed production, as indicated by seed head counts (Figure 3). Row spacing tended to have a much greater effect than crop population. The data indicate that durum wheat responded very similar to bread wheat. [9]

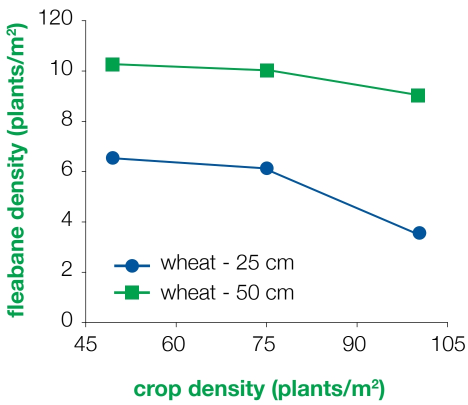

Figure 3: Fleabane density (plants/m^2) in wheat of different row spacing and plant density (DAFF Qld).

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

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

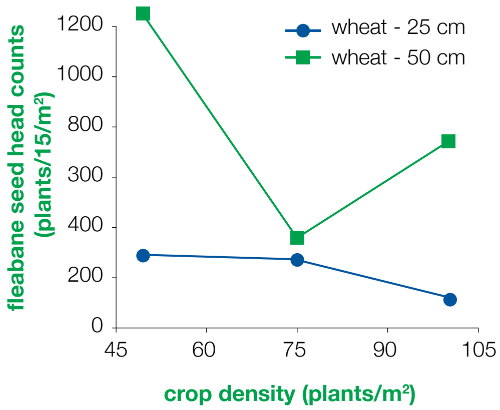

Figure 4: Average fleabane seed head counts (plants/15 m²) in wheat, durum and barley across different row spacing and plant density (DAFF Qld).

For information on sowing rates and plant population, see *Section 3: Planting*.

NGA trials show the use of a disc planter for incorporation by sowing (IBS) of residual herbicides resulted in significantly reduced wheat emergence for all four herbicides evaluated

2. The disc planter 'set-up' actually increased the risk of crop damage

3. These results reinforce the need to only use narrow point tynes when using residual herbicides with IBS recommendations.

For more information, see http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Pre-emergent-herbicides-part-of-the-solution-but-much-still-to-learn [10]

More information

http://www.grdc.com.au/Media-Centre/GRDC-Gallery/Video/loACpykKja0

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/04/Keeping-on-top-of-fleabane-incrop-strategies-the-role-and-impact-of-residual-herbicides-crop-competition-and-doubleknock

http://www.grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-68-Integrated-Weed-Management-Supplement/Weeds-dont-like-the-competition

http://www.grdc.com.au/~/media/BCA0DBBB35754362ADC9522BEDC6A6AE.pdf

6.6 Herbicides explained

6.6.1 Residual *v.* non-residual

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

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

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

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

6.6.2 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, while pre-emergent refers to application of the herbicide to the soil before the weeds have emerged. [11]

More information

http://www.grdc.com.au/Resources/IWMhub

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

11 GRDC Integrated weed management, Section 4: Tactics for managing weed populations, http://www.grdc.com.au/~/media/A4C48127FF8A4B0CA7DFD67547A5B716.pdf

More information

https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Understanding-pre-emergent-cereal-herbicides

Pre-emergent herbicides part of the solution but much still to learn

Seeding systems and pre emergence herbicides

6.7 Pre-emergent herbicides

The important factors in getting pre-emergent herbicide to work effectively while minimising crop damage are: to understand the position of the weed seeds in the soil; the soil type (particularly amount of organic matter and crop residue on the surface); the solubility of the herbicide; and its ability to be bound by the soil.[12]

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

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

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

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

Benefits

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

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

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

Practicalities

Planning is needed to use pre-emergent herbicides as an effective tactic.

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

1. Weed species and density

When deciding to use a pre-emergent herbicide it is important to have a good understanding of the expected weed spectrum. Use paddock history and observations of weed species and densities from at least 12 months prior to application. Correct identification of the weed species present is vital.

Pre-emergent herbicides are particularly beneficial if high weed densities are expected. Post-emergent herbicides are often unreliable when applied to dense weed populations, as shading and moisture stress from crowding result in reduced control. Pre-emergent herbicides have the advantage of controlling very small weeds, whereas post-emergent herbicides can be applied to larger, more tolerant/robust plants.

2. Crop or pasture type

The choice of crop or pasture species will determine the herbicide selection. Some crops have few effective post-emergent options. For example, weed control in grain sorghum is strongly reliant on the pre-emergent herbicides atrazine and metolachlor. For chickpea, faba bean and lentil, there are few effective, broadleaf post-emergent herbicides. In these cases, it is important to have a plan of attack, which is likely to include the use of a pre-emergent herbicide.

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

More information

www.nga.org.au

www.grainorana.com.au.

http://www.dpi.nsw.gov.au/agriculture/broadacre/guides/weed-control-winter-crops

https://portal.apvma.gov.au/pubcris

http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/431247/Using-pre-emergent-herbicides-in-conservation-farming-systems.pdf

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2012/07/Preemergent-herbicides-and-glyphosate-resistance-management

The competitive nature of the crop should also be considered. Chickpea, lupin and lentil are poor competitors with weeds and need pre-emergent herbicides to gain a competitive advantage.

3. Soil condition

Soil preparation is a critical first step in the effective use of pre-emergent herbicides. The soil is the storage medium by which pre-emergent herbicides are transferred to weeds.

Soil surfaces that are cloddy or covered in stubble may need some pre-treatment such as light cultivation or burning to prevent 'shading' during application.

Too much black ash from burnt stubble may inactivate the herbicide, and therefore, ash must be dissipated with a light cultivation or rainfall prior to herbicide application.

Less-soluble herbicides such as simazine need to be mixed with the topsoil for best results. This process, called incorporation, mixes or cultivates the top 3–5 cm of soil for uniform distribution of the herbicide in the weed root-zone.

Herbicides such as the sulfonylureas and imidazolinones may not need mechanical incorporation, as they move into the topsoil with water (rain or irrigation). Some herbicides need to be incorporated to prevent losses from photodegradation (e.g. atrazine) or volatilisation (e.g. trifluralin).

4. Rotation of crop or pasture species

All pre-emergent herbicides persist in the soil to some degree. Consequently, herbicides may carry over into the next cropping period. The time between spraying and safely sowing a specific crop or pasture without residual herbicide effects (the plant-back period) can be as long as 36 months, depending on herbicide, environmental conditions and soil type. [13]

For more information on current and continuing GRDC weeds research, see *Section 16: Current research* or visit http://www.grdc.com.au/weedlinks

For zone-specific weeds research, visit
http://www.nga.org.au/results-and-publications/browse/40/project-reports-weeds
http://www.grainorana.com.au/documents
http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/431247/Using-pre-emergent-herbicides-in-conservation-farming-systems.pdf

Visit the APVMA (Australian Pesticides & Veterinary Medicines Authority) website for an up-to-date list of registered herbicides. Also see NSW DPI's Weed control in winter crops, Click on the link below. (Relevant tables are on pages 42 and 43.)

http://www.dpi.nsw.gov.au/agriculture/broadacre/guides/weed-control-winter-crops

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

6.7.1 Avoiding crop damage from residual herbicides

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

What are the issues?

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

[13] GRDC Integrated weed management, Section 4: Tactics for managing weed populations, http://www.grdc.com.au/~/media/A4C48127FF8A4B0CA7DFD67547A5B716.pdf

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

A real difficulty for growers lies in identifying herbicide residues before they cause a problem. Currently, we rely on information provided on the labels about soil type and climate. Herbicide residues are often too small to be detected by chemical analysis, or if testing is possible, it is too expensive to be part of routine farming practice. Once the crop has emerged, diagnosis is difficult because the symptoms of residual herbicide damage can often be confused with, and/or make the crop vulnerable to, other stresses, such as nutrient deficiency or disease. [14]

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

More information

Hear US herbicide residue specialist Dr Dale Shaner explain the effects soil-applied herbicides to crop residues: http://www.grdc.com.au/Media-Centre/GRDC-Gallery/Video/3tnKn3qn4BA

For a recording of Dr Shaner's full GRDC webinar '*Stubble and soil binding of pre-emergent herbicides'* (13 Dec. 2013), visit: http://www.grdc.com.au/Resources/Education-and-Training/Weed-Webinars/Stubble-and-soil-binding-of-pre-emergent-herbicides.

Which herbicides are residual?

The herbicides listed in Table 4 all have some residual activity or planting restrictions.

Table 4: Active constituent by herbicide group (may not include all current herbicides)

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

How do herbicides break down?

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

14 DEPI (2013) Avoiding crop damage from residual herbicides, Department of Environment and Primary Industries Victoria, http://www.depi.vic.gov.au/agriculture-and-food/farm-management/chemical-use/agricultural-chemical-use/chemical-residues/managing-chemical-residues-in-crops-and-produce/avoiding-crop-damage-from-residual-herbicides

A 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

For these reasons, degradation of each herbicide needs to be considered separately and growers need to understand the soil type and climate when trying to interpret recropping periods on the product label for each paddock. [15]

How can I avoid damage from residual herbicides?

Select a herbicide appropriate for the weed population you have.

Make sure you consider what the recropping limitations may do to future rotation options.

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

If residues could be present, choose the least susceptible crops (refer to product labels). Optimise growing conditions to reduce the risk of compounding the problem with other stresses such as herbicide spray damage, disease and nutrient deficiency. These stresses make a crop more susceptible to herbicide residues. [16]

Group B: Sulfonylureas

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

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

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

Group B: Triazolopyrimidines (sulfonamides)

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

Group B: Imidazolinones

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

Group C: Triazines

Usage of triazines has increased to counter Group A resistance in ryegrass, in particular in triazine-tolerant canola. Atrazine persists longer in soil than simazine. Both generally persist longer on high pH soils, and cereals are particularly susceptible to damage.

15 DEPI (2013) Avoiding crop damage from residual herbicides, Department of Environment and Primary Industries, http://www.depi.vic.gov.au/agriculture-and-food/farm-management/chemical-use/agricultural-chemical-use/chemical-residues/managing-chemical-residues-in-crops-and-produce/avoiding-crop-damage-from-residual-herbicides

16 DEPI (2013) Avoiding crop damage from residual herbicides, Department of Environment and Primary Industries Victoria, http://www.depi.vic.gov.au/agriculture-and-food/farm-management/chemical-use/agricultural-chemical-use/chemical-residues/managing-chemical-residues-in-crops-and-produce/avoiding-crop-damage-from-residual-herbicides

More information

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Accelerated-triazine-degradation-in-soil

Recent research in the US indicates that breakdown rates tend to increase when triazines are used regularly, as the number of microbes able to degrade the herbicide can increase. This may mean that breakdown can take an unexpectedly long time in soils that have not been exposed to triazines for some years.

Group D: Trifluralin

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

Group H: Isoxazoles

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

Group I: Phenoxys

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

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

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

Group K: Metolachlor

Metolachlor is used in canola crops. The replanting interval is 6 months. [17]

Group K: Pyroxasulfone

Pyroxasulfone relies on microbial degradation, which is favoured by in-season rainfall. Label plant-back periods are important particularly for oats, durum wheat and canola. Residues will lead to crop stunting. [18]

For more information, visit www.apvma.gov.au.

6.8 In-crop herbicides: knock downs and residuals

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

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

1. Consider application timing—the younger the weeds the better. Frequent crop monitoring is critical.
2. Consider the growth stage of the crop.

[17] Dual Gold® herbicide, http://www.herbiguide.com.au/Descriptions/hg_Dual_Gold.htm

[18] DEPI (2013) Avoiding crop damage from residual herbicides, Department of Environment and Primary Industries Victoria, http://www.depi.vic.gov.au/agriculture-and-food/farm-management/chemical-use/agricultural-chemical-use/chemical-residues/managing-chemical-residues-in-crops-and-produce/avoiding-crop-damage-from-residual-herbicides

3. Consider the crop variety being grown and applicable herbicide tolerances.
4. Know which species were historically in the paddock and the resistance status of the paddock (if unsure, send plants away for a 'Syngenta Quick-Test' (see link).
5. Do not spray a crop stressed by waterlogging, frost, high or low temperatures, drought or, for some chemicals, cloudy/sunny days. This is especially pertinent for frosts with grass-weed chemicals.
6. Use the correct spray application:
   - Consider droplet size with grass-weed herbicides, water volumes with contact chemicals and time of day.
   - Observe the plant-back periods and withholding periods.
   - Consider compatibility if using a mixing partner.
   - Add correct adjuvant.

For information on cereal growth stages, see *Section 4: Plant growth and physiology*.

More information

Syngenta Quick-Test: http://www.plantscienceconsulting.com

http://www.dpi.nsw.gov.au/agriculture/broadacre/guides/weed-control-winter-crops

www.apvma.gov.au

6.9 Herbicide tolerance ratings

Within many broadacre crop species, cultivars have been found to vary in sensitivity to commonly used herbicides and tank mixes, thereby resulting in potential grain yield loss and reduced farm profit. With funding from GRDC and state government agencies across Australia, a series of cultivar x herbicide tolerance 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 wheat, barley, triticale, oats, lupin, field pea, lentil, chickpea and faba bean. The intention is to provide data from at least 2 years of testing at the time of wide-scale commercial propagation of a new cultivar.

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

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

The four projects have recently been combined under a national program.

More information

http://www.nvtonline.com.au/wp-content/uploads/2013/03/NSW-Wheat-2012.pdf

http://www.nvtonline.com.au/wp-content/uploads/2013/03/QLD-Prelim-Wheat-2012.pdf

http://www.daff.qld.gov.au/__data/assets/pdf_file/0009/49509/Sensitivity-barley-wheat-cultivars-herbicides.pdf

6.10 Post-emergent herbicide damage

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

Factors that can contribute to herbicide damage are:

1. Crop variety grown
2. Weather conditions at time of application
3. Mixing partner
4. Growth stage of crop
5. Nutritional status of crop

More information

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/04/Strategies-for-optimising-the-life-of-Group-A-herbicides-and-patterns-of-herbicide-resistance-in-wild-oats

6.11 Selective sprayer technology

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

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

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

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

The introduction of weed-detecting technology is timely as it is well suited to detecting patches of weeds across large areas. Sales of the two systems available in Australia, WeedSeeker® (FIgure 5) and WEEDit®, have increased by at least 30% annually over the past 2 years.

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

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

Figure 5: Selective sprayer technologies use optical sensors to turn on spray nozzles only when green weeds are detected. (Photo: CropOptics)

Special permit

Weed-detecting technology (via WeedSeeker®) is being used to manage glyphosate-resistant grasses in northern NSW fallows with the aid of a minor use permit. This allows growers in the region to use selective grass herbicides and higher rates of paraquat and diquat (bipyridyl herbicides, Group L). The permit (PER11163) is in force until 28 February 2015 to cover all Australian states and will be reviewed annually.

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

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

More information

http://www.grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-104-May-June-2013/Detection-technology-maximises-fallow-control

Stuart Gall, WeedSmart, 'How to use a selective sprayer': http://www.youtube.com/watch?v=j95fpUqtYVc&feature=youtu.be

http://www.grdc.com.au/Media-Centre/Over-the-Fence/2013/10/Crop-chemical-rotation-the-key-to-weed-control-at-Edgeroi

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

The new technology also has the potential to map troublesome weed patches so that these areas can be targeted with a pre-emergent herbicide before sowing. [19]

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

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