NORTHERN REGION

CROPPING WITH HERBICIDE RESISTANCE

Herbicide resistance is spreading through the northern grains region. Integrated weed management can delay or prevent resistance developing by relying on a range of tactics, both chemical and non-chemical, to keep weeds successfully in check.

**KEY POINTS**

- Resistance develops when repeated applications of the same mode-of-action (MOA) herbicide kill susceptible weeds, and resistant weeds survive and set seed.
- Herbicide resistance will remain as long as there is resistant seed in the soil.
- Integrated weed management (iWM) is a diverse approach using chemical, non-chemical and agronomy tactics that targets weed seed-set. It is the best way to delay or prevent the development of herbicide resistance.
- Minimising the number of weed seeds in the soil (the seedbank) by preventing weeds from setting seed is the top priority.
- Herbicide-resistant weeds are always possible, whether they occur naturally or are introduced via wind, water or contamination. However, consistently applying iWM will achieve a relatively weed-free system.

The landscape and composition of weeds in Australia’s cropping regions has changed significantly. Many weeds that were once controlled by cultivation have been favoured by the widespread adoption of reduced tillage systems.

All weed populations will have a very small proportion of plants that are naturally herbicide resistant.

Broad-scale herbicide resistance develops when repeated applications of the same mode-of-action (MOA) herbicide lead to susceptible weeds being killed and resistant individuals surviving. These survivors then set seed, ensuring a higher proportion of resistant individuals in the next generation, leading to large populations of resistant weeds.

Each type of resistance that develops on-farm means one less tool available to the grower to manage weeds. Where multiple resistance exists, effective herbicide options become severely limited. See Table 1 for known herbicide-resistant populations.

**Be proactive**

The best way to stop resistance developing is to prevent any survivors of a herbicide application from setting seed and germinating. This is rarely achievable with a single weed management tactic.

Integrated weed management (iWM) involves a range of chemical, non-chemical and agronomy tactics, used together to provide optimal weed control. Resistance is spreading across the northern region, and growers need to be proactive about the adoption of iWM to delay or, if possible, prevent herbicide resistance developing.

By applying iWM practices, growers are aiming to reduce their weed seedbank across their farm and minimise the potential for herbicide resistance.

Group A resistant wild oats pose a serious threat to the chickpea industry. Chickpeas are poor competitors and even relatively low densities of wild oats in chickpeas can reduce yields significantly. Effective crop rotation allows the use of alternative herbicides in the winter fallow and increased sowing rates on narrow row spacing to improve crop competition. These are useful strategies in managing wild oat populations.
Major weeds of the northern region

Feathertop Rhodes grass

Feathertop Rhodes grass is difficult to control after early tillering, particularly with glyphosate. The seed remains in the soil surface. It germinates all year round with a preference for spring and autumn so requires attention in both fallow and crop phases. There are currently no known populations of feathertop Rhodes grass with herbicide resistance.

As with all weeds, best success is obtained when the small, actively-growing weeds are targeted.

Windmill grass

Windmill grass is a competitive weed that has been favoured by the move to reduced tillage and resistance to glyphosate has been confirmed. It is spreading at an increasing rate and can behave like an annual or a perennial, making it more persistent than some other weeds.

It has the potential to halve production in wheat and is difficult to control when mature. Double knock can increase the effectiveness of control tactics for windmill grass.

Flaxleaf fleabane

Flaxleaf fleabane is a major weed of the northern cropping region and in recent years has spread rapidly. This is due to changes in herbicide-use patterns linked to reduced tillage and wider row spacing in crops. It is a prolific seed producer (up to 110,000 seeds per plant) and will continue to flower and seed over a long period of time. These factors combined with the dispersal of its seed by wind over considerable distances make it a rapidly increasing problem.

Table 1: Known populations of herbicide resistance in Australia’s northern grains region

Weeds appearing in this table have had herbicide resistance confirmed through testing. Therefore, if a weed does not appear in the table, it does not necessarily mean that it is not herbicide resistant.

<table>
<thead>
<tr>
<th>Weed species</th>
<th>Herbicide group (see Table 2)</th>
<th>Example herbicide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Awnless barnyard grass</td>
<td>C – triazines</td>
<td>atrazine</td>
</tr>
<tr>
<td></td>
<td>M – glycines</td>
<td>glyphosate</td>
</tr>
<tr>
<td>Liverseed grass</td>
<td>C – triazines</td>
<td>atrazine</td>
</tr>
<tr>
<td></td>
<td>M – glycines</td>
<td>glyphosate</td>
</tr>
<tr>
<td>Paradoxa grass</td>
<td>A – ‘fops’</td>
<td>fluazifop</td>
</tr>
<tr>
<td></td>
<td>A – ‘dims’</td>
<td>clethodim</td>
</tr>
<tr>
<td>Wild oats</td>
<td>A – ‘fops’</td>
<td>diclofop</td>
</tr>
<tr>
<td></td>
<td>A – ‘dims’</td>
<td>tralkoxydim</td>
</tr>
<tr>
<td></td>
<td>B – sulfonyureas</td>
<td>mesosulfuron</td>
</tr>
<tr>
<td></td>
<td>Z – arylaminopropionic acids</td>
<td>fl胺prop-methyl</td>
</tr>
<tr>
<td>Windmill grass</td>
<td>M – glycines</td>
<td>glyphosate</td>
</tr>
<tr>
<td>Annual ryegrass (NSW only)</td>
<td>A – ‘fops’</td>
<td>diclofop</td>
</tr>
<tr>
<td></td>
<td>A – ‘dims’</td>
<td>clethodim</td>
</tr>
<tr>
<td></td>
<td>B – sulfonyureas</td>
<td>chlorsulfuron</td>
</tr>
<tr>
<td></td>
<td>B – imidazolinones</td>
<td>imazapic, imazapyr</td>
</tr>
<tr>
<td></td>
<td>M – glycines</td>
<td>glyphosate</td>
</tr>
<tr>
<td>Broadleaf weeds</td>
<td>African turnip weed</td>
<td>chlorsulfuron</td>
</tr>
<tr>
<td></td>
<td>Black bindweed</td>
<td>chlorsulfuron</td>
</tr>
<tr>
<td></td>
<td>Charlock</td>
<td>chlorsulfuron</td>
</tr>
<tr>
<td></td>
<td>Common sowthistle</td>
<td>chlorsulfuron</td>
</tr>
<tr>
<td></td>
<td>Indian hedge mustard</td>
<td>chlorsulfuron</td>
</tr>
<tr>
<td></td>
<td>Starfruit</td>
<td>bensulfuron</td>
</tr>
<tr>
<td></td>
<td>Turnip weed</td>
<td>chlorsulfuron</td>
</tr>
<tr>
<td></td>
<td>Wild radish</td>
<td>chlorsulfuron</td>
</tr>
</tbody>
</table>

Compiled by Andrew Storrie, 2012

Fleabane is relatively unresponsive to knock down herbicides when mature due to heat or moisture stress. The best strategy is to control it at the seedling stage.

Barnyard and liverseed grass

Both awnless barnyard grass and liverseed grass are highly competitive summer weeds that have become even more problematic with the widespread uptake of minimum and reduced tillage.

Barnyard grass has the ability to germinate at any time in most summer crops following decent rain, while liverseed grass will mostly emerge in one large flush in late spring.

In northern NSW and southern Queensland, weed control strategies for summer fallows that rely almost exclusively on glyphosate have led to the emergence of resistant populations of these two weeds. Populations resistant to triazines have also been detected.

Knock down (non-selective) herbicides for fallow and pre-sowing control on small (two to three-leaf) weeds, and double knock for denser populations, should provide good control.

Pre-emergent herbicides are effective provided adequate rainfall is received. Atrazine mixed with metolachlor is more reliable than atrazine alone.

Common sowthistle

Common sowthistle can germinate at any time of year and is widespread throughout the northern region, so it should be monitored and managed through all phases of the rotation.

In poorly competitive crops it can contribute to green matter at harvest and lead to grain-quality issues. Improving crop competition results in lower weed pressure. If grazing is an option after harvest, it will help to control escapes in fallow because stock will preferentially graze sowthistle.

Wild oats

Resistance to multiple herbicide MOAs in wild oats is causing problems for growers in northern NSW and the Goondiwindi region. Uncontrolled, wild oats can cause yield losses in wheat as high as 80 per cent.

Staggered germination makes long-term control difficult, with the main flush emerging.
in autumn and early winter. These can be controlled with pre-emergent or early post-emergent herbicides. However, wild oats will continue to germinate in small numbers through to spring, and these plants produce enough seed for the following season.

Early seed shedding makes harvest management difficult. Agronomic tactics such as crop choice and sequence and crop competition can play a role. If cutting for silage or hay, harvest prior to wild oat grain fill to control regrowth.

**Annual ryegrass**

Annual ryegrass resistance is not yet a problem for Queensland growers, but most growers on the Liverpool Plains now have to manage populations of glyphosate-resistant annual ryegrass.

A double knock of glyphosate followed by paraquat reduces the likelihood of glyphosate resistance persisting. This combined with a pre-emergent herbicide in the fallow can control later germinations given adequate rainfall.

With all weed control, target small weeds and follow-up with monitoring and eradication of any survivors.

**Know which herbicides still work**

If a certain MOA has been used for many years (Table 2) surviving weeds should be tested to see which herbicides are still effective. Studies have shown that resistance can vary from paddock to paddock.

Start testing the high-risk paddocks and test 20 per cent of paddocks each year to clarify what is happening in each field. See Useful Resources at the end of this fact sheet for contact details of herbicide resistance testing services.

**Glyphosate resistance**

Glyphosate is the most valuable herbicide in Australian agriculture. It is a cheap and highly effective non-selective herbicide with a unique mode-of-action that has a low environmental and toxicological risk.

It is the default fallow and pre-seeding weed control option at the expense of a more comprehensive IWM program. Glyphosate takes longer to develop resistance in weeds than many other herbicides, such as ‘fops’, ‘dims’ and sulfonyleureas (Table 2). Extensive use over long periods in both agricultural and non-agricultural sectors has inevitably led to resistance.

Growers running continuous cropping systems are at greater risk of having weed populations developing glyphosate resistance than those with mixed cropping and grazing enterprises, that is, with some pasture in the system.

Glyphosate is commonly used to control weeds around buildings, tracks, roadsides, irrigation channels and fencelines, leading to resistant weed populations in these types of areas.

**Do the job right**

The over-reliance on glyphosate for weed control in fallows has led to the development of resistance, because a reasonably high kill rate is often considered sufficient. This leaves behind a small percentage of survivors potentially with glyphosate-resistant genes.

If the survivors are not targeted with another control, they are able to set seed and increase their numbers in subsequent seasons.

To preserve the effectiveness of glyphosate, it is critical that a greater level of monitoring after spraying takes place and any survivors eradicated.

For all herbicides application, the use of appropriate nozzles, water rates and adjuvants, applied in optimal conditions of appropriate nozzles, water rates and adjuvants, applied in optimal conditions to small and actively growing weeds, will provide the best chance of success.

**Integrated weed management**

The benefits of integrated weed management extend beyond herbicide resistance management; it has been shown to be the most effective method of long-term weed population management.

Economic returns averaged over a 20-year period for IWM systems are greater than herbicide-only systems, due to the lower seedbank numbers in the IWM system and fewer weeds to manage on an ongoing basis.

Rarely will a single tactic, whether chemical or non-chemical, provide 100 per cent control, but each tactic adds a degree of control. Stacking tactics within the season means the grower can keep weeds successfully in check.

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**Table 2: Years of application before herbicide resistance develops**

<table>
<thead>
<tr>
<th>Herbicide group</th>
<th>Typical years of application before herbicide resistance develops</th>
</tr>
</thead>
<tbody>
<tr>
<td>B (SUs, IMIs)</td>
<td>4</td>
</tr>
<tr>
<td>A (fops, dims)</td>
<td>6–8</td>
</tr>
<tr>
<td>C (triazines)</td>
<td>15+</td>
</tr>
<tr>
<td>D (trifluralin, dinitroanilines, DNAs)</td>
<td>15+</td>
</tr>
<tr>
<td>I (phenoxys)</td>
<td>&gt;20</td>
</tr>
<tr>
<td>L (paraquat/diquat)</td>
<td>&gt;15</td>
</tr>
<tr>
<td>M (glyphosate)</td>
<td>&gt;12</td>
</tr>
</tbody>
</table>

Source: Dr Chris Preston
led to development of group M resistant where continuous summer cropping has alternative non-chemical options. fallows, with glyphosate an option for fallow sorghum means that there will be two winter inclusion of a strategic summer crop such as cultivation or grazing.

Manage the weed seedbank
Most problem crop weeds in Australia rely on the establishment of a seedbank to ensure their ongoing survival. The priority for any grower considering their weed management strategy should be to drive down this weed seedbank where practical. This means targeting weed seed production and preventing viable seed being added to the seedbank.

Weeds such as feathertop Rhodes grass, barnyard grass, annual ryegrass, wild oats, fleabane and sowthistle have seeds that are short-lived in the soil. A few years of preventing seed-set can reduce the seedbank by up to 99 per cent.

Using a range of weed-control methods in the one season and between seasons is the key to managing the seedbank and preventing the development of herbicide resistance.

Crop sequences
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.

In the management of wild oats, the inclusion of a strategic summer crop such as sorghum means that there will be two winter fallows, with glyphosate an option for fallow weed control. Grazing and/or cultivation are alternative non-chemical options.

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

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

Strategic cultivation
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.

Grazing
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 weed life cycle.

Pre-emergent herbicides
Reduced tillage systems have led to an over-reliance on post-emergent herbicides. Residual herbicides now need to be considered for fallow knock downs or selective in-crop applications.

Effectiveness is dependent on post-application rainfall, soil properties and the right herbicide selection. The judicious use of pre-emergent takes pressure off post-emergence options. For the greatest benefit, they should be applied before the largest expected emergence flushes.

Pre-emergent herbicides will not provide full control. Like any other weed control measure, they should be used with other tactics, such as delayed sowing for control of liverseed grass. Residual herbicides can have cropping plant-back periods that must be followed.

Double knock
Double knock refers to any two different weed control tactics practised in close succession, where the second measure controls survivors of the first; for example, any sequence that includes a herbicide and a non-chemical measure such as heavy grazing or cultivation.

It most commonly refers to two herbicide applications from different MOA groups, between two and 10 days apart. This is often glyphosate (Group M) or glyphosate plus 2,4-D (Group I) followed by paraquat or paraquat plus diquat (both Group L).

Including a residual herbicide in the second knock can provide excellent longer-term control against notoriously difficult weeds such as barnyard grass and fleabane.

However, the technology is not perfect. On feathertop Rhodes grass in particular, growers have reported mixed results which are thought to be related to the interval between knocks and the state of the plant when it receives the second knock.

Double knock requires attention to detail and can be expensive, but when executed well is highly effective. It has been proven to delay the onset of herbicide resistance.

Target small weeds
Most weeds are less responsive to chemical control once they have grown beyond seedling stage. It is crucial to target small (pre to early tillering/small rosette) actively growing weeds when spraying. For example, control of flaxleaf fleabane with glyphosate mixes and double knock can decline by as much as 40 per cent on an older rosette (two months old) compared to...
a young rosette (one month old). Monitor paddocks post-spraying and clean up any survivors.

Note the limitations with registration of some of the common herbicides. Some labels state only a particular growth stage and not beyond. For example, paraquat’s effectiveness diminishes as weeds become larger and the weed populations denser. Liverseed grass and windmill grass are difficult to kill at most stages of their life cycle.

Crop competition
Crop competition is driven by crop type and variety choice and works by using the crop uniformity and density, vigour and good agronomy to out-compete weeds. The weeds that emerge before or with the crop are the ones that are most competitive. Before crop competition kicks in, aim to control with herbicides to gain a head start.

Fleabane and sowthistle are weeds whose density and seed production can be substantially manipulated using crop competition, at least until after harvest.

Late-season herbicide use
Non-selective crop-topping is the application of a non-selective herbicide such as glyphosate (wheat and pulses) or paraquat (pulses only) prior to harvest when the target weed is at flowering/early grain fill.

The selectivity of the crop-topping process is dependent on a sufficient gap in maturity between crop and weed and will be determined by crop type and seasonal conditions.

Selective spray-topping is the technique of using selective herbicides to control seed production of a weed within a crop prior to head emergence and thus reduce future weed populations. Correctly executed selective spray-topping can result in a 90 per cent reduction in weed seed-set, but it should only be used on populations that are still susceptible to the MOA. It is not a substitute for early weed control.

See Useful Resources for more information on late-season herbicide use.

Brown manuring
Brown manuring involves incorporating plant residue into the soil following the use of a non-selective herbicide to desiccate the crop and weeds at flowering. It can reduce seed-set by preventing seed from returning to the paddock.

It can be used to patch-treat problem areas and prevent weed seed being spread by the harvester. It is a good option for managing wild oats in winter crops. It also has benefits for managing other crop pests and diseases.

Harvest weed seed control
Many northern growers are still able to get reasonable in-crop control and, due to the different weed species in the north (seeds shatter and are on the ground prior to harvest), harvest weed seed management has not yet gained a foothold.

However, recent weed surveys across the northern region have shown that a large number of weed species are setting a lot of seed at harvest and this indicates there is a potential role for harvest weed seed management, especially in chickpeas.

Harvest weed seed control includes narrow windrow burning, chaff carts, deep inversion of seed banks and the new Harrington Seed Destructor, which destroys seed at harvest. All rely on getting the weed seeds into the harvester. Therefore the closer the harvest is to weed maturity, the greater the proportion of weed seeds collected.

WeedSeeker® permit
NSW growers using a WeedSeeker® now have access to a permit (PER11163). This allows the use of a wider range of herbicides, and at higher rates, to manage larger, stressed or harder-to-control weeds.

Weedseeking technologies are useful in managing glyphosate resistance. Group A herbicides and paraquat can be useful in controlling some grass weeds. The new permit will allow the use of these herbicides and at robust rates.

Applying Group A herbicides in fallows can be risky because it can select for Group A resistance and there are potential problems with crop plant-back periods. Appropriate warnings are listed on the permit to prevent this.

For most situations a follow-up spray with paraquat prevents any survivors producing seed. If all else fails, cultivation must be used to ensure survivors do not set seed.

Monitor
With any weed-control measure, always scout for surviving weeds, which could indicate potential resistance. Follow-up with spot spraying and/or another control method.

If paddocks are not monitored soon after spraying, weed control failures will not be evident until harvest. This will be too late to prevent a weed blow-out that will need years of hard work and expense to bring under control. Driving across the paddock along different transects will reveal whether weed control measures are working.

Knowing the status of weed populations and consistently using the optimal IWM strategies for specific weed problems will ultimately lead towards a relatively weed-free operation.
**FREQUENTLY ASKED QUESTIONS**

**How do I know if I have a problem with resistance?**

Normally resistance is first noticed as patches of uncontrolled weeds following a herbicide application. Take samples from these patches for testing. See Useful Resources for contact details for testing services.

**What herbicides should I test?**

The aim of testing is to find out what still works. Discuss with the test provider which herbicides you are likely to use in the future.

**What do I put in for first and second knock in a double knock treatment?**

Double knock refers to any two different weed control tactics, chemical or non-chemical, practised in close succession, where the second measure controls survivors of the first. Although it most commonly refers to two herbicide applications from different MOA groups, you need to consider the target weed and any existing resistance issues before deciding on which measure to apply for each knock.

Most commonly glyphosate is the primary herbicide as it controls a broad spectrum of weeds.

**What timing should I apply between knocks in a double knock treatment?**

Generally between two and 10 days, although the interval can be anything from one to 14 days, depending on the mix of herbicides to be used, conditions and weed species.

**Will using tank mixes reduce the chance of glyphosate resistance developing?**

To be effective in reducing the risk of glyphosate resistance, the tank mix partner must be fully compatible with glyphosate and must be applied at a rate that will kill any glyphosate-resistant plants in the treated population.

**Can tillage lower the risk of resistant weeds?**

Yes, but only if the survivors are killed by the cultivation. For this to happen, the cultivation needs to be well timed and executed.

**How do I control mature plants?**

Double knock with higher rates of herbicide, for example spot spraying, may provide control, but in some instances cultivation may be the only option remaining.

**USEFUL RESOURCES**

**For testing suspected resistant samples:**

- **Charles Sturt University**
  Herbicide Resistance Testing, School of Agricultural and Wine Sciences
  Locked Bag 588
  Wagga Wagga NSW 2678
  02 6933 4001
  jbroster@csu.edu.au
  www.csu.edu.au/research/rahmcentre/producers/herbideresistancetesting.htm

- **Plant Science Consulting**
  22 Linley Ave
  Prospect SA 5082
  0400 644 460
  info@plantscienceconsulting.com.au
  www.plantscienceconsulting.com

- **Australian Herbicide Resistance Initiative (AHRI)**
  www.ahti.uwa.edu.au

- **Current Herbicide Resistance Status (International)**
  www.weedscience.org

- **Glyphosate Resistance**
  Australian Glyphosate Sustainability Group
  www.glyphosateResistance.org.au

- **GRDC Weeldinks**

- **Integrated Weed Management in Australian Cropping Systems**

- **Late Season Herbicide Use**

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