

# Herbicide resistance in Australian cotton farming systems

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## Introduction

Herbicide resistance is now a real issue for the Australian cotton industry, with glyphosate resistant weeds being detected in both irrigated and dryland cotton situations. Throughout the world there are currently 218 species (129 dicots and 89 monocots) of weeds with herbicide resistance and resistance in 21 of the 25 known herbicide modes of action (International survey of herbicide resistant weeds, 2013). Herbicide resistance continues to impact Australian agriculture since it was first reported in annual ryegrass in 1982. Resistance to many modes of action have been documented in Australian production systems and is now a key constraint to crop production.

Resistance has been confirmed in thirty-six weeds in Australia. In the cotton growing areas populations of 4 common grass weeds – awnless barnyard grass, liverseed grass, windmill grass and annual ryegrass – and one broadleaf species – flaxleaf fleabane have resistance to glyphosate. Cases of multiple resistance have also been reported where for example, annual ryegrass proves resistant to two or more chemical groups. Research undertaken in two recent projects on herbicide resistance, has reviewed the propensity of 200 weed species to evolve and change in response to continued selection by

herbicides. The top ten weeds relevant to most cotton systems have been summarised in Table A.

Several species that aren't important in-crop are at high risk of resistance in other situations on cotton farms, such as in dams and channels. Cumbungi (*Typha* spp, score 7.0) and arrowhead (*Sagittaria montevidensis*, score 6.9) are the most important of these. Parthenium weed (*Parthenium hysterophorus*, score 6.9) can occur in non-crop areas and is also at risk. It is important to

**TABLE A: Top 10 species at risk of developing herbicide resistance with relevance to cotton farming systems.**

Common name	Botanical name	Score (out of 10)
Sweet summer grass	<i>Brachiaria eruciformis</i>	8.1
Flaxleaf fleabane	<i>Conyza bonariensis</i>	7.6
Liverseed grass	<i>Urochloa panicoides</i>	7.2
Feathertop Rhodes grass	<i>Chloris virgata</i>	7.0
Awnless barnyard grass	<i>Echinochloa colona</i>	6.9
Barnyard grass	<i>Echinochloa crus-galli</i>	6.9
Cobbler's pegs	<i>Bidens pilosa</i>	6.9
Common sowthistle	<i>Sonchus oleraceus</i>	6.9
Milkweed	<i>Euphorbia heterophylla</i>	6.9
Crowsfoot grass	<i>Eleusine indica</i>	6.3

Adapted from Weeds to watch out for!: 200 Australian weeds and their risk of evolving herbicide resistance; David Thornby, Jeff Werth, and Joe Vitelli (Qld DAFF) [http://glyphosateresistance.org.au/media%20releases/article\\_120703\\_Weeds%20to%20watch%20out%20for.pdf](http://glyphosateresistance.org.au/media%20releases/article_120703_Weeds%20to%20watch%20out%20for.pdf).

## Herbicide resistance is a numbers game

One Grower

One Surviving Weed

Seed set

One Community

Hundreds of resistant weeds



T.Cook NSW DPI



T.Cook NSW DPI

Stop survivor seed set and stay in the game  
 Because we are in this together  
[www.mybmp.com.au](http://www.mybmp.com.au)

Best Practice

remember that there is no relationship between resistance risk and weediness, invasiveness, or ease of control. Despite being at low risk of resistance, some low scoring species are nevertheless important and highly prevalent weeds, both of cropping (eg nutgrass, bladder ketmia) and non-cropping areas (eg salvinia, alligator weed).

No major new mode of action herbicide has been discovered for over 30 years., but a number of older products are being withdrawn for a variety of reasons. As the number of effective products is reduced, it is now more important than ever to approach weed management with a strategy that invests in successful weed control this year and for the long term.

### How does herbicide resistance occur

Weed populations can contain a large amount of natural genetic diversity and it is likely that within the population a small number of individuals exist that are able to survive exposure to a particular herbicide group due to their genetic makeup. When a herbicide from this group is used, many of these individuals survive and set seed, whereas the majority of susceptible plants are killed. Continued use of the same type of herbicide will result in an ever-increasing proportion of the population being able to survive those herbicide applications. Herbicides have been grouped according to their mode of action (the way they work) and the resistance risk. Some of the factors that can influence the evolution of resistance include:

- **How often an herbicide or mode of action group is applied to a weed population** – The higher the frequency of use, the higher the selection pressure and the greater the risk of herbicide resistance developing.
- **The biology and density of the weed** – Weed species that produce large numbers of seed, emerge in dense populations, and have a large amount of natural diversity are more likely to evolve to resistance.
- **Mode of action** – The frequency of genes with resistance to some herbicide groups, such as Groups A and B is quite high, and therefore resistance risk is quite high. Refer to Table B.
- **Intensity of selection pressure** – The more weeds that are present, the more likely that an individual containing herbicide resistance genes will be present and hence likely to become a problem. The fewer times a different method of weed control (another type of herbicide or a non-herbicide tactic) is used, the more pressure there is for the weed population to evolve resistance to the most commonly-used herbicide.

**TABLE B: Years of herbicide application before resistance evolves.**

Herbicide group	Years of application	Herbicide resistance risk
A (Fops, Dims, Dens).	6-8	High
B (SUs: Glean, Ally. IMLs: Flame, Spinnaker)	4	High
C (atrazine, prometryn, fluometuron).	10-15	Medium
D (trifluralin, pendamethalin)	10-15	Medium
F (norflurazon)	10	Medium
I (phenoxies)	not known	Medium*
L (paraquat/diquat)	15+	Medium*
M (glyphosate)	15+	Medium*
N (glufosinate)	not known	Medium*

Adapted from Preston et al, 1999

- **Preventing seed set of survivors by effective control with a different tactic** – after the application of a herbicide, the control of survivors through use of a follow up tactic such as cultivation, chipping, or alternative mode of action herbicide, will prevent or significantly delay resistance evolution.

### How long does herbicide resistance last?

The challenge with herbicide resistant weeds is that you can't tell by just looking that they are resistant. This means that if a survivor of a herbicide spray is allowed to set seed, then the resistance will last at least until all those seeds either germinate and are controlled before they can set seed, or remain in or on the soil and die. Where germination does not necessarily occur all in the same flush, this can mean that groups of resistant weeds are germinating over a season, or over years. If this next generation is able to set seed, the resistance will continue through to a third generation, even if selection pressure isn't applied again.

### What does herbicide resistance look like?

Herbicide resistance is normally present at very low frequencies in weed populations before the herbicide is first applied. Using



A patch of glyphosate resistant awnless barnyard grass, likely to have started near a road. Consider whole of farm use of herbicides. (Photo: T.Cook NSW DPI)



Glyphosate resistant barnyard grass was confirmed in 2007. This infestation had a 'blow-out' as the previous summer period was extremely wet and prevented access to the paddock and hence no effective treatment at an early growth stage. (Photo: T.Cook NSW DPI)



Surviving glyphosate resistant awnless barnyard grass plants amongst dead susceptible plants and dead plants of other species.

the herbicide creates the selection pressure that increases the resistant individuals' likelihood of survival compared to 'normal' or susceptible individuals. The underlying frequency of resistant individuals within a population will vary greatly with weed species and herbicide mode of action. Resistance can begin with the survival of one plant and the seed that it produces. Early in the development of a resistant population, resistant plants are likely to occur only in isolated patches these are often surrounded by dead 'susceptible' plants of the same species, or other species usually controlled by the herbicide applied. This is the critical time to identify the problem. Options are much more limited if resistance has spread over large areas before it is diagnosed. Many of the symptoms of herbicide resistance can also be explained by other causes of spray failure. Evaluate the likelihood of other possible causes of herbicide failure. Evaluate your risk of resistance, the higher your risk the more a further investigation of possible resistance is warranted.

### What are my glyphosate resistance risks?

Start by taking the self assessment on this page. The more questions to which you have confidently answered 'Yes', the more a further investigation of possible resistance is warranted. You can now assess the level of risk of your own practices via the online risk assessment tool. This tool allows you to check what your current level of risk is for developing glyphosate-resistant weed populations on your farm. You can use it more than once, to rate different paddocks on your farm or to try out different scenarios. The tool allows you to enter information on your current practices (including crop rotation, crop density, and weed control tactics) and to identify which weed species you usually have to control. The tool will then calculate a glyphosate resistance risk score for the paddock, and a level of risk for each weed identified. The risk assessment tool can show you the areas of greatest risk in your crop rotation and herbicide use, and whether there are any weed species you need to treat carefully. Use these suggestions to get the best results from any changes you make.

The Glyphosate Resistance Toolkit is available online through [www.myBMP.com.au](http://www.myBMP.com.au) or Qld DAFF website. The toolkit also contains a herbicide resistance quiz which explains the important drivers in herbicide resistance development.

If you have answered 'Yes' to most of the questions, including 8–10 on field history, or the glyphosate resistance toolkit has indicated your practices and/or species are at high risk, take action:

- Collect samples and send for testing.
- Remove surviving plants from the field to limit the amount of seed going into the soil seed bank.
- Develop a management plan for continued monitoring of the sites and the use of alternative weed control strategies.

Note that a low risk level only means that resistance is unlikely to develop in this scenario. Resistant weeds can still come in through contaminated machinery, water, seed etc. Resistance doesn't need high-risk practices to occur, it can just be a result of bad luck, like a header breakdown that introduces resistant seeds!!

### How can I confirm if my weeds are resistant?

Testing a plant population for the presence of herbicide resistant individuals involves growing large numbers of plants in 'ideal' conditions, then at particular growth stages applying the herbicide at a range of rates and observing the responses. Generally, seed is collected from the suspect plants



SELF ASSESSMENT – LIKELIHOOD OF HERBICIDE RESISTANCE		Y/N
1.	Was the rate of herbicide applied appropriate for the growth stage of the target weed?	<input type="checkbox"/>
2.	Are you confident you were targeting a single germination of weeds?	<input type="checkbox"/>
3.	Were the weeds actively growing at the time of application?	<input type="checkbox"/>
4.	Having referred to your spray log book, were weather conditions optimal at the time of spraying so that herbicide efficacy was not compromised?	<input type="checkbox"/>
5.	Are you confident the suspect plants haven't emerged soon after the herbicide application?	<input type="checkbox"/>
6.	Is the pattern of surviving plants different from what you associate with a spray application problem?	<input type="checkbox"/>
7.	Are the weeds that survived in distinct patches in the field?	<input type="checkbox"/>
8.	Was the level of control generally good on the other target species that were present?	<input type="checkbox"/>
9.	Has this herbicide or herbicides with the same mode of action been used in the field several times before?	<input type="checkbox"/>
10.	Have results with the herbicide in question for the control of the suspect plants been disappointing before?	<input type="checkbox"/>

and is sent for testing. However, the dormancy mechanism in some species, such as barnyard grass, creates problems with this process. It is difficult to get sufficient quantities of seed to germinate uniformly in short time frames. An alternative sampling method is to collect actual plants out of the field for the 'Quick test'. This process is limited to seedling/small plants as large numbers need to be collected and posted. Upon arrival they are potted up and once re-established, herbicide treatments are applied. In mid-summer conditions plants are less likely to survive the trip than if collected in cooler times of the year. It is recommended to take seed samples from the surviving plants in summer and mark these sites to enable seedling collections in the following autumn or spring if they are needed. The timeline for obtaining results from sending seed samples can be several months. Results are usually available by the end of April when samples are received before January. When plants are sent for Quick tests, results are usually available within 4–8 weeks.

#### Collecting seed samples:

- Collect 2000–3000 seeds from plants you suspect are resistant. Barnyard grass = 1 cup full.
- If testing >3 modes of action, collect additional seed.
- Avoid collecting large amounts of seed from just a few large plants.
- Follow a 'W' shaped pattern stopping every ~20 m if survivors are widespread. If survivors are localised, collect from within this area.
- Bash seed heads into a bucket to ensure only ripe seed is collected.
- Store samples in a paper bag at room temperature, away from sunlight, moisture and heat. Post as soon as possible.

#### Collecting plant samples for the Quick test:

- For each mode of action to be tested: collect 50 plants/field from areas where you suspect resistance.
- Gently pull out plants and wash roots.
- Wrap in moistened paper towel.
- Place in waterproof plastic bag.
- Keep in fridge and Express Post on the next Monday.

#### Sending samples to resistance testing services

Follow the instructions above and send samples together with contact details, field and weed management history and testing required to either of the testing services below.

**Dr Peter Boutsalis** (seed or Quick test)  
**Plant Science Consulting**  
 22 Linley Avenue,  
 Prospect SA 5082  
 Phone: 0400 664 460  
 Email: info@plantsscienceconsulting.com  
 Website: www.plantsscienceconsulting.com

**John Broster** (seed test only)  
**Charles Sturt University**  
 Herbicide Resistance Testing Service,  
 PO Box 588  
 Wagga Wagga NSW 2678  
 Phone: (02) 6933 4001  
 Email: jbroster@csu.edu.au

#### What is species shift?

Species shift refers to a change in the spectrum of problem weeds in a system due to reliance on a particular tactic. For example no-till systems favour small seeded weeds that germinate from on or near the soil (top 20mm), such as fleabane and sow thistle. These weeds become problematic as they are no longer being controlled by cultivation and seed burial. While species shift is different to herbicide resistance, it can be an early sign that the system is too reliant on a small number of tactics.

#### How do I manage glyphosate resistant weeds?

Experience tells us that even where some species have developed resistance to glyphosate, glyphosate remains an important weed management tool in the system. The key is to focus on how glyphosate is supported by other tactics. The strategy to manage glyphosate resistant weeds is similar to the strategy to prevent glyphosate resistance – integrate a range of different tactics throughout the weed lifecycle to rapidly deplete the soil seedbank, and prevent further seed set/recruitment.

Integrated weed management (IWM) is the term used to describe the strategy to not only manage existing herbicide resistance and prolong the use of life of each herbicide, but also reduce the rate of species shift, manage the cost of future weed control by depleting the number of weed seeds in the soil, and of course help to improve crop productivity through effective weed management. Refer to Weed management tactics – tool box for Australian cotton for more information.

#### For more information:









**Australian glyphosate sustainability working group** <http://www.glyphosateresistance.org.au/>  
**CropLife Australia Mode of actions** [http://www.croplifeaustralia.org.au/default.asp?V\\_DOC\\_ID=1954](http://www.croplifeaustralia.org.au/default.asp?V_DOC_ID=1954)

# Weeds to watch out for!

Common weeds of cotton with a high risk of developing herbicide resistance

**Make herbicide decisions early – target young growth stages**

**Too late for glyphosate – control before seed set**

 <p><b>SWEET SUMMER GRASS</b></p> <p>M.Conway, DAFF Qld</p>	 <p>M.Conway, DAFF Qld</p>
 <p><b>FLAXLEAF FLEABANE</b></p> <p>G.Charles, NSW DPI</p>	 <p>G.Charles, NSW DPI</p>
 <p><b>LIVERSEED GRASS</b></p> <p>G.Charles, NSW DPI</p>	 <p>G.Charles, NSW DPI</p>
 <p><b>FEATHER TOP RHODES</b></p> <p>G.Charles, NSW DPI</p>	 <p>G.Charles, NSW DPI</p>

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AWNLESS BARNYARD GRASS

G.Charles, NSW DPI



G.Charles, NSW DPI



COBBLER'S PEG

G.Charles, NSW DPI



G.Charles, NSW DPI



COMMON SOWTHISTLE

G.Charles, NSW DPI



G.Charles, NSW DPI



MILKWEED

G.Charles, NSW DPI



G.Charles, NSW DPI