managing HERBICIDE RESISTANCE in Northern NSW

YOU CAN AVOID THIS PROBLEM ...
A PADDOCK FULL OF GLYPHOSATE RESISTANT WEEDS

RESISTANCE is FUTILE

A guide to stopping and managing resistance in northern NSW with the key findings from the GRDC funded project 'Risk assessment and preventive strategies for herbicide resistance in the northern grain region'.

INSIDE

Why be concerned ?

Herbicide resistance is an increasing threat across Australia's northern grain region for both growers and agronomists. Already 10 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 NSW (NNSW), 8 weeds are confirmed resistant to Group A, B, C, K or M herbicides **(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 approximately 40 paddocks in the Liverpool Plains area of NNSW.

Table 1. List of confirmed resistant weeds in northern NSW

Weed	Herbicide Group	Areas with Resistance in NSW	Future Risk	Detrimental Impact
Wild oats	A eg Topik® & Wildcat® K eg Mataven®	Spread across the main wheat growing areas Western cropping areas	Areas growing predominantly winter crops	High High
Paradoxa grass	A eg Wildcat®	Spread across the main wheat growing areas	Areas growing predominantly winter crops	High
Common sowthistle, Indian hedge mustard, turnip weed, charlock	B eg Glean® & Ally®	Spread across the main wheat growing areas	Areas growing predominantly winter crops	Moderate
Barnyard grass	C eg atrazine	One paddock in Narrabri area	Areas growing predominantly sorghum	High
Annual ryegrass	A, B, M	A&B widespread in NSW M predominantly in the Liverpool Plains		High

Table 2. List of potential new resistant weeds in northern NSW

Weed	Herbicide Group	Future Risk	Detrimental Impact
Barnyard and liverseed grass	M eg glyphosate	Zero and minimum tilled systems	Very High
Common sowthistle	M eg glyphosate	Zero and minimum tilled systems using mostly glyphosate alone	High
Wild oats	M eg glyphosate B eg Hussar®	Zero and minimum tilled systems Western crop areas	High High
Other Brassica weeds eg turnip weed, charlock Indian hedge mustard	M eg glyphosate	Areas growing predominantly winter crops	Moderate
Fleabane	M eg glyphosate	Zero and minimum tilled systems	Moderate

Other broadleaf and grass weeds including black bindweed and bladder ketmia are also at risk of developing resistance to glyphosate

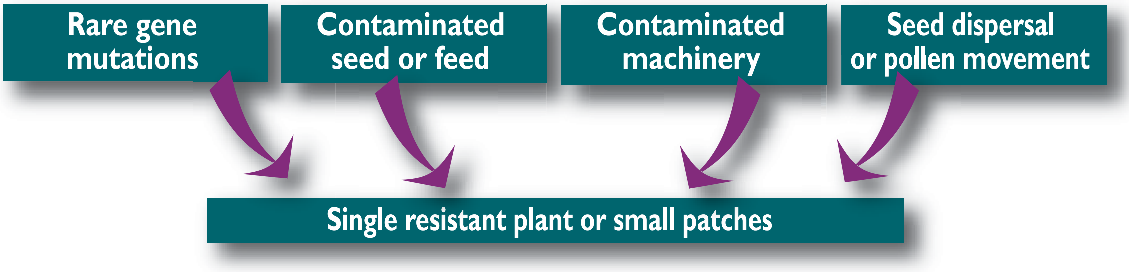
Resistance is a costly problem. If resistance develops, growers will have to use other control measures or herbicides, and these may be more expensive or less effective. In some cases, growers will not be able to grow certain crops, or may have to change their farming system to include more tillage. The impact will be larger in the more marginal cropping areas with lower and less consistant returns.

It is particularly important to give priority to preventing resistance to glyphosate, as this is likely to have the most adverse impact on cropping viability and sustainability. The measures needed to prevent or slow the development of herbicide resistance could be equated to the payment of an insurance premium. The cost of this premium is proportional to the risk level to be avoided.

How does resistance start ?

Resistance starts in a paddock in several ways. Some rare mutations can occur naturally in weeds already in the paddock, with the likelihood varying from 1 plant in 10,000 to 1 in a billion plants, depending on the weed and herbicide. Alternately, a grower may import weed seed with the herbicide resistant gene in contaminated feed, seed or machinery. Resistance may also be introduced by natural seed spread by wind and water or by pollen, which may blow short distances from a contaminate paddock **(see Figure 1).**

Figure 1. Factors influencing the initial introduction of herbicide resistant plants



How does resistance then become a problem ?

Once a few resistant plants are in a paddock, they will **only** become a widespread problem if the grower relies totally on those herbicides for weed control **(see Figure 2)**. Frequent applications of the same herbicide or same herbicide mode of action group will kill the susceptible part of the weed population, and eventually allow the rare plants with the resistance gene to increase and dominate. Higher risk management options that will lead to resistant weeds becoming a problem are presented in **Table 3.**

> Resistance evolves more rapidly with frequent use of the same herbicide group especially if no other control options are used

Figure 2. Resistance becoming a problem in a paddock when using high-risk management options

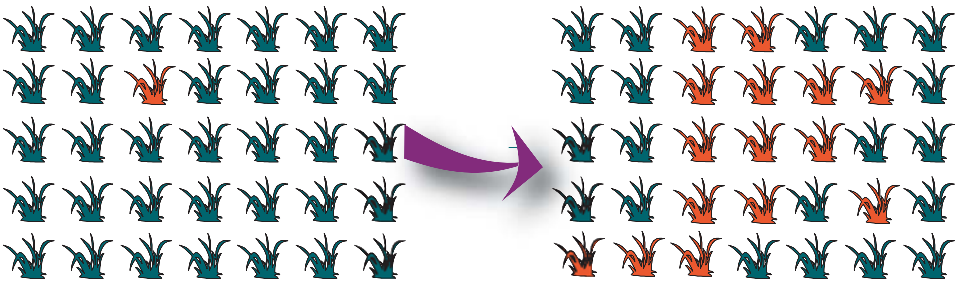


Table 3. Management options influencing risk of herbicide resistance development

Management option	Lower risk	Higher risk
Cropping system	Varied rotation	Crop monoculture
Cultivation system	Tillage controlling primary flush and/or weed escapes	Continuous zero tillage
Weed control strategy	Using Integrated Weed Management principles	Relying on herbicides only
Spray regime	Many modes of action for each target weed	Single mode of action
Herbicide control in previous years	100% control with no seed set	Few survivors setting seed
Weed numbers	Low	High
Monitoring of control level	Regular	Rarely

General principles to avoid resistance

Herbicides have a limited life before resistance develops, if they are used repeatedly and exclusively as the sole means of weed control, particularly in zero and minimum tilled systems. Resistance can develop within 4-8 years for Group A and B herbicides and after 15 years for Group L and M herbicides **(see Table 4).** This can be **avoided** by keeping weed numbers low, changing herbicide groups, using tillage, and rotating crops and agronomic practices.

Strategies to prevent or minimise the risk of resistance developing are based on integrated weed management (IWM) principles as outlined below.

- ☑ Ensure survivors do not set seed and replenish the soil seed-bank.
- ☑ Keep accurate paddock records of herbicide application and levels of control. Monitor weeds closely for low levels of resistance, especially in paddocks with a history of repeated use of the same herbicide group.
- ☑ Rotate between the different herbicide groups, and/or tank mix with an effective herbicide from another mode of action group. It is important to use effective 'stand-alone' rates for both herbicides in the mix.
- ☑ Aim for maximum effectiveness of control to keep weed numbers low. The primary aim of weed control is to minimise their impact on productivity, and resistance is much less likely to develop in paddocks with fewer weeds than in heavily infested paddocks. Apply herbicides with properly calibrated equipment under the best conditions. Treat small weeds.
- ☑ Use a wide range of cultural weed control tools in your weed management plan. Sowing different crops and cultivars provides opportunities to use different weed management options on key weeds. Tillage is useful when it targets a major weed flush and minimises soil inversion, as buried weed seed generally persists longer than on the soil surface. Competitive crops will reduce seed production on weed survivors.
- ☑ Avoid introduction or spread of weeds by contaminated seed, grain, hay or machinery. Also, manage weeds in surrounding non-crop areas to minimise risk of seed and pollen moving into adjacent paddocks.

Table 4. Rules of thumb for the number of years of herbicide application before resistance evolves (Source: Chris Preston)

Herbicide group	Years to resistance
A	6-8
B	4-6
C	10-15
D	10-15
L	15+
M	15+

Aim for maximum effectiveness of your control tactics, as resistance is unlikely to develop in paddocks with low weed numbers

Specific guidelines for reducing the risk of glyphosate resistance are outlined in **Table 5.** Aim to include as many as possible of the 'Risk decreasing' factors in your crop and weed management plans.

Table 5. Balancing the risk for weeds developing glyphosate resistance, devised by the national Glyphosate Sustainability Working Group (www.weeds.crc.org.au/glyphosate) with minor modifications for our region

Risk increasing	Risk decreasing
Continuous reliance on glyphosate pre-seeding	Double knock technique
Lack of tillage	Strategic use of alternative knockdown groups
Lack of effective in-crop weed control	Full-disturbance cultivation at sowing
Inter-row glyphosate use (unregistered)	Effective in-crop weed control
Frequent glyphosate-based chemical fallow	Use alternative herbicide groups or tillage for inter-row and fallow weed control
High weed numbers	Non-herbicide practices for weed seed kill
Pre-harvest desiccation with glyphosate	Farm hygiene to prevent resistance movement

Know your herbicide groups

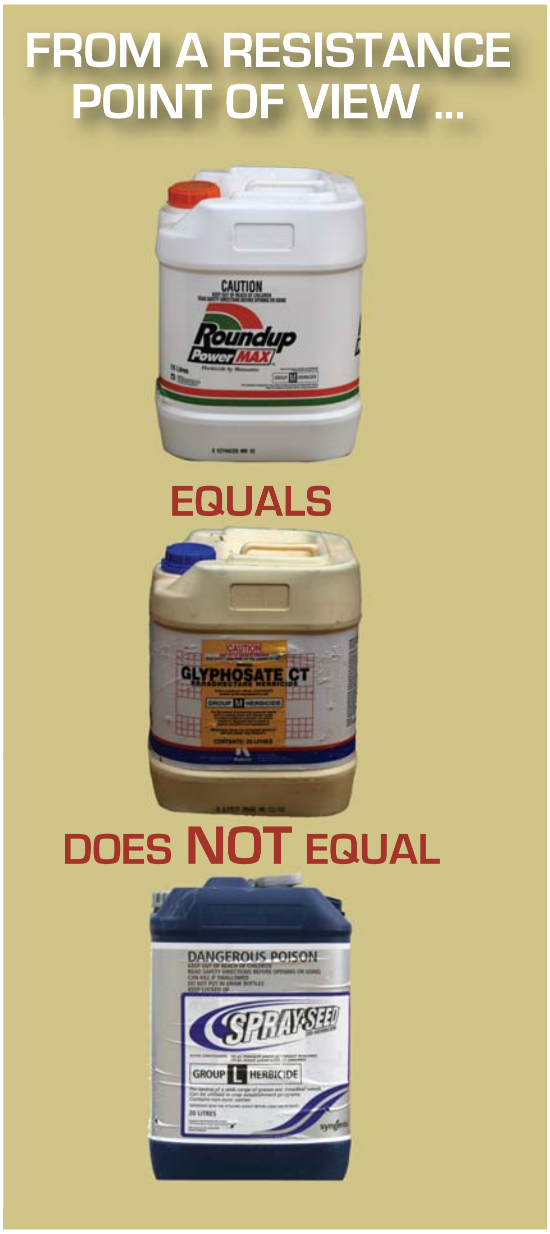
Despite the large number of herbicides marketed to control weeds, there are relatively few mechanisms of herbicide toxicity, which means that many different herbicides may have the same actions on plants **(see Table 6)**. For more information, see AVCARE website *(www.avcare.org.au)*.

Table 6. Herbicides are classified into mode of action groups, denoted by letters A – N, based on their main target activity

Groups	Herbicide examples
A	Achieve®; Correct®; Decision®; Falcon®; Fusilade®; Fusion®; Puma Progress®; Select®; Shogun®; Spear®; Targa®; Topik®; Tristar Advance®; Wildcat®; Verdict®
B	metsulfuron eg. Ally®; Atlantis®; Express®; Flame®; chlorsulfuron eg. Glean®; Harmony® M; Hussar®; Spinnaker®; Sempra®
C	atrazine eg. Gesaprim®; Basagran®; bromoxynil eg. Bromicide®; fluometuron eg. Cotoran®; prometryn eg. Gesagard®; simazine eg. Gesatop®; diuron eg. Diurex®
D	trifluralin eg. Treflan®; pendimethalin eg. Stomp® Xtra
E	Avadex® Xtra
F	Balance®; Brodal®
G	Affinity®; Blazer®; oxyfluorfen eg. Goal®; Hammer®
I	2,4-D amine; 2,4-D ester; MCPA amine; MCPA LVE; Surpass®; 2,4-DB eg. Buticide®; Tordon® 242; Banvel®; Cadence®; Starane®; Tordon® 75D; triclopyr eg. Garlon® 600
K	Dual® Gold; Mataven® 90
L	Spray.Seed®; paraquat; diquat
M	glyphosate
N	glufosinate eg. Basta®

It is very important to rotate between the different herbicide modes of action groups **(see Figure 3).** All herbicides sold in Australia carry a letter code designating their mode of action (mechanism of herbicide toxicity of that herbicide).

Figure 3. Rotate between modes of action, not within the same mode of action group, to prevent herbicide resistance



Do not rely on the same mode of action group

Wild oat

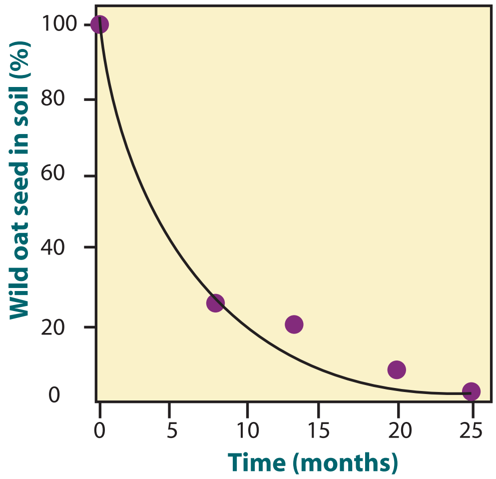
Know your weed

Wild oat, also known as black oat, is one of the most common weeds of winter crops and fallows across northern NSW. Populations are generally a mix of 2 species, *Avena ludoviciana* and *Avena fatua*, but the differences between these have little impact on management strategies. Wild oat is a highly competitive weed with low numbers able to cause substantial crop yield losses.

Seedling emergence is controlled by short-term seed dormancy, temperature (10 to 26°C) and soil moisture. The largest flush is generally in late autumn/early winter provided there is adequate soil moisture, but weeds will emerge periodically throughout the rest of winter and into spring. Seed production of a wild oat plant in wheat crops is estimated to be around 50 - 225 seeds depending on weed density.

Most wild oat seeds in the surface soil do not persist for long periods. Local research has shown that about three quarters of the seed-bank is lost after 1 year, and 98% after 2 years provided there was no seed replenishment **(see Figure 4 and Table 7).** The main mechanism of persistence is the deposition of new seeds as the result of reproduction from surviving weeds. Therefore, it is important to prevent seed production on escapes and survivors.

Figure 4. Persistence of wild oat seeds in the soil with no replenishment



Soil samples were collected at regular intervals from a farmer's paddock in North Star district. (Source: S Walker, QLD DPI&F, Toowoomba)

Hints for better management

The main aim of wild oat management should be to stop seed set. This is achieved by using a combination of:

- Crop rotation with winter and summer crops or long fallow in marginal rainfall areas.
- Effective use of pre-emergence and early post-emergence herbicides, followed by selective spray topping if necessary.
- Maximum crop competitiveness using high quality seed, optimum fertiliser, sowing depth, crop population and row spacing.

For weedy paddocks, an additional tactic is to use a strategic stubble burn followed by a late sowing. Local research reported that burning stubble in autumn could destroy approximately one third of the wild oat seeds in the surface soil. Late sowing allows for maximum weed emergence. These seedlings can then be effectively controlled with cultivation or a knockdown herbicide prior to crop sowing. Approximately 40% of wild oat seeds in the seed-bank germinate following the first major rain in late autumn/early winter, with another 10-30% germinating later in the season.

For better control with herbicides:

- Spray seedlings with 1-2 tillers for translocated herbicides, as smaller wild oats may regrow.
- Weed size is **more critical** for Group B and L herbicides than for Group A herbicides.
- Be aware of potential antagonism from glyphosate mixes with atrazine (Group C) and 2,4-D (Group I) herbicides .
- Mataven® 90 is more effective at higher temperatures (> 15°C).

Risk to Group A herbicides

Many wild oat populations have been identified as resistant to Group A herbicides in northern NSW. The risk for further development of Group A resistance is low in areas with rotations consisting of a mix of summer and winter crops, as growers can reduce the wild oat seed-bank during winter fallows. However, the risk is higher in areas with predominant winter cropping and are highly reliant on Group A herbicides.

Strategies to prevent or minimise the risk for Group A resistance

- ☑ **Include summer crops and control wild oats effectively in fallow with knockdown herbicides or tillage.**
- ☑ **Grow barley for greater crop competition (see Figure 10).**
- ☑ **Rotate to Avadex® Xtra (Group E) followed by selective spray-topping with Mataven® 90 (Group K) in wheat.**
- ☑ **Use selective spray-topping with Mataven® 90 (Group K) following a Group A application in wheat (see Figure 5).**
- ☑ **Rotate to Mataven® 90 (Group K) as early post-emergence, but only in combination with a competitive bread wheat crop and with low wild oat numbers.**

Selective spray-topping with Mataven® 90 should be applied when the weed begins elongation but prior to head emergence. This tactic can control seed production (up to 90%) on survivors of earlier applications of Group A or E herbicides, and/or on late emerging weeds. However, be aware that several wild oat populations were confirmed recently as resistant to Mataven® 90 (Group K) in NSW. Also, check wheat cultivar sensitivity as herbicide tolerance differs between cultivars.

Figure 5. Control of Group A "fop" resistant wild oats in wheat, Moree

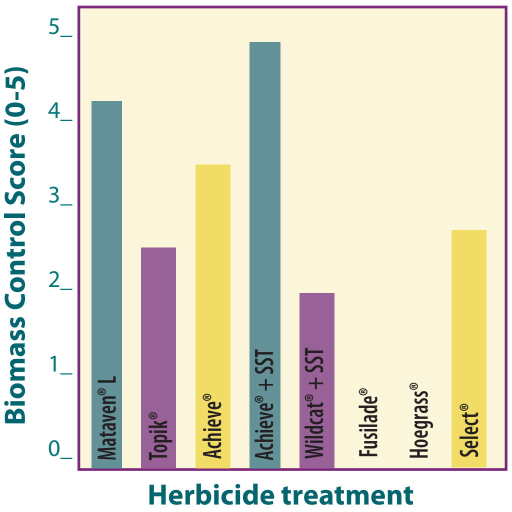


Table 7. Persistence of wild oat and other annual grass weed seeds in the soil with no replenishment

Weed	% remaining in soil (0-5 cm)			
	1 year	2 years	3 years	4 years
Wild oats	17	2	<1	<1
Paradoxa grass	14	2	<1	<1
Liverseed grass				<1

[Source: Ian Taylor, Steve Walker and Bruce Wilson]

Note:
- Selective spray-topping treatment (SST) of Mataven® 90 at 1.9 L/ha + 0.5% Uptake® was applied over selected treatments 37 days after EPE treatment.
- Wild oats at time of EPE applications – Z13 to Z15,24 (3 leaf - mid-tiller).
- Wild oats at time of SST applications – Z31 to Z32 (Stem elongation).
- Biomass control scores 0-1 = 0-40%, 1.1-2 = 41-60%, 2.1-3 = 61-80, 3.1-4 = 81-94%, 4.1-5 = 95-100% reduction.

[Source: Northern WR & DU, NSW DPI.]

Risk to Group M herbicides

The risk of wild oat becoming resistant to Group M herbicides ranges from low to high, depending on crop and herbicide rotation. The risk is greater in rotations that have predominantly summer crops, using minimum or zero tilled systems that rely mostly on glyphosate for fallow weed control.

The overall strategy to reduce the risk for glyphosate resistance is to ensure that no survivors of glyphosate applications are allowed to set seed. Use the general tactics considered to decrease the risk **(see table 5)** as well as specific tactics outlined below.

Fallow strategies to prevent or minimise the risk for Group M resistance

- **Double knockdown with glyphosate followed by Spray.Seed® or paraquat on survivors anytime in fallow.**
- **Double knock with glyphosate followed by full disturbance cultivation at sowing.**
- **Rotate with Spray.Seed® or paraquat (Group L) for main flush and ensure good spray coverage.**
- **Rotate with atrazine (Group C) in late winter or early spring fallow prior to sorghum, but following treatment with a knockdown herbicide. Local research: Atrazine at 3.6L/ha controlled wild oat for several months.**
- **Cultivate the main flush(s) in fallow.**

In-crop strategies to prevent or minimise the risk for Group M resistance

- **In-crop weed control is important in keeping weed numbers low using a combination of selective herbicides (Group A, B, E, K) and crop competition. This reduces the selection pressure for glyphosate resistance in the following fallows.**

Annual ryegrass

Know your weed

In northern NSW over 40 populations of annual ryegrass *[Lolium rigidum]* (ARG) have developed resistant to glyphosate (Group M). Annual ryegrass has the ability to rapidly increase its numbers by producing up to 45,000 seeds per m² and is a genetically variable species. ARG is highly competitive if it establishes before or at the same time as the crop. Annual ryegrass is a highly adaptable species and is spreading northward and westward.

Annual ryegrass is a winter/spring growing weed, emerging late autumn to early spring. Germination is greatest from 2-4 cm depth and reduces with increasing depth, ceasing at about 10 cm. The optimum temperature for germination is 11°C for buried seeds. The peak germination (80% of seeds) occurs after the first two falls of rain that exceeds 20 mm following a drop in air temperature. Newly formed seeds are dormant for 8 to 9 weeks. Seed can remain viable in undisturbed soil for least 4 years with a decline rate of 70-80% per annum.

Hints for better management

- Weed numbers must be kept low with a high level of in-crop and fallow control.
- Growing summer crops with a winter fallow may result in an over-reliance on glyphosate for fallow control.
- Use paraquat or Spray.Seed® on the first flush of ryegrass, or in autumn 3-5 days after a full rate of glyphosate as a double knockdown.
- Introduce a residual herbicide into the fallow, such as atrazine before sorghum, to control later germinations. **(See Table 9)**.
- Shallow cultivation in autumn following rain ("autumn tickle") can break seed dormancy and move the peak germination period forward, allowing control with a knockdown herbicide before sowing.
- Using pre-emergent herbicides such as trifluralin (Group D) can reduce pressure on post emergent selective herbicides.
- Cut badly infested crops and pastures for silage or hay, followed by an application of paraquat to kill regrowth.
- Spray-top pastures in spring with a knockdown herbicide following heavy grazing, two seasons before a winter crop.
- Sow seed that is free of ARG contamination.
- Improve crop competitive ability by sowing competitive crop types and cultivars at the optimum time and seeding rate with good nutrition. Keep row spacings of winter cereals < 30 cm. For wide row spacings (>30 cm) use inter-row shielded spraying with paraquat.
- Monitor levels of control and prevent survivors setting seed.

For better control with herbicides:

- ☑ **Spray small weeds (2-3 leaves).**
- ☑ **Use higher water application volumes for paraquat and Spray.Seed® to optimise spray coverage .**
- ☑ **Use fine to medium droplets (refer to nozzle manufacturer manual).**
- ☑ **Use effective herbicide rates. Cutting rates will give poor control.**

Risk to Group A herbicides

Highest risk is in areas dominated by winter cropping. Group A resistance is already common in the region, particularly further south and west.

Strategies to prevent or minimise the risk for Group A resistance

- ☑ **Include summer crops and control annual ryegrass effectively in fallow with knockdown herbicides.**
- ☑ **Cultivate or use knockdown herbicide in the winter/spring fallow post summer crop.**
- ☑ **Rotate to Group B (eg chlorsulfuron, triasulfuron, Hussar®). Check Group B resistance status first!**
- ☑ **Grow triazine-tolerant canola using simazine and atrazine (Group C).**
- ☑ **Introduce Group B residual herbicide (eg chlorsulfuron) into winter/spring fallow, post summer crop.**
- ☑ **Avoid Group A herbicides in fallow.**

Risk to Group B herbicides

Highest risk is in areas dominated by winter cropping.

Strategies to prevent or minimise the risk for Group B resistance

- Grow triazine-tolerant canola using simazine and atrazine (Group C).
- Use simazine (Group C) in chickpea.
- If conditions allow, include summer crops and use knockdown herbicides in fallow.
- Use pre-emergent herbicide such as Group D (eg trifluralin, Stomp® Xtra).
- Avoid using Group B herbicides in fallow, especially if applying Group B herbicides in preceding or following crop.

Risk to Group M herbicides

Highest risk in no-till cropping systems that rely solely on glyphosate for fallow and inter-row weed control.

Fallow strategies

- Use other MOA group knockdowns in fallow such as Group L (e.g. paraquat, Spray.Seed®).
- Cultivate the main flush of ARG.
- Use double knockdown - full rate of glyphosate followed 3-5 days later for glyphosate susceptible and up to 7-10 days for glyphosate resistant ARG by paraquat or Spray.Seed® at full label rates. [See Table 8.]
- Introduce residual herbicides such as atrazine (Group C) into winter/ spring fallow. [See Table 9.]
- Reduce the number of summer crops grown in the rotation as too many no-till winter fallows (heavy glyphosate use) lead to Group M resistance.

Table 8. Effectiveness of various double knock down treatments on glyphosate resistant annual ryegrass, Spring Ridge

Herbicide treatment following an initial application of glyphosate (450g/L) at 1.2L/ha			
2nd application treatment	Days after initial application	ARG growth stage	% control
No herbicide	N/A	N/A	45
Paraquat (250g/L) 1.5L/ha	4	2½ leaf - early til.	96
Spray.seed® 250 1.5L/ha	4	2½ leaf - early til.	94
Paraquat (250g/L) 2.0L/ha	8	3 leaf - early til.	97
Spray.seed® 250 2.0L/ha	8	3 leaf - early til.	93
Paraquat (250g/L) 2.0L/ha	18	Early to mid til.	96
Spray.seed® 250 2.0L/ha	18	Early to mid til.	93
Paraquat (250g/L) 2.5L/ha	22	Mid tillering	93
Spray.seed® 250 2.5L/ha	22	Mid tillering	89

ARG growth stage for the initial application of glyphosate was between 1 leaf and early tillering stage. NOTE: Rate of paraquat and Spray.seed® 250 was increased for later applications to compensate for the larger weed size. [Data source: Northern WR & DU NSW DPI.]

Table 9. Effectiveness of various residual treatments on glyphosate resistant annual ryegrass, Spring Ridge

Herbicide treatment	Herbicide groups	% control
Logran® B-Power	B + G	19.7
Paraquat (250g/L) 1.5L/ha + Logran® B-Power 50g/ha	L + B + G	93.3
Paraquat (250g/L) 1.5L/ha + atrazine (500g/L) 3.0L/ha	L + C	99.9
Paraquat (250g/L) 1.5L/ha + Dual® Gold 2.0L/ha	L + K	99.7
Paraquat (250g/L) 1.5L/ha + Glean® 20g/ha	L + B	99.6
Paraquat (250g/L) 1.5L/ha + Flame® 200mL/ha	L + B	100

ARG growth stage for the application of treatments was between 1 leaf and early tillering stage. NOTE: These herbicides were applied at tail end of the ARG emergence period. To test for longevity of treatments, further research will be conducted earlier in the season. [Data source: Northern WR & DU, NSW DPI]

In-crop strategies

- Keep weed numbers low.
- Grow competitive cereal crops, such as barley, on <25 cm row spacings.
- Grow triazine-tolerant canola using simazine and atrazine (Group C).
- Use simazine (Group C) in chickpea.
- Use pre-emergent herbicide such as Group D (eg trifluralin, Stomp® Xtra).

Phalaris/Paradoxa grass

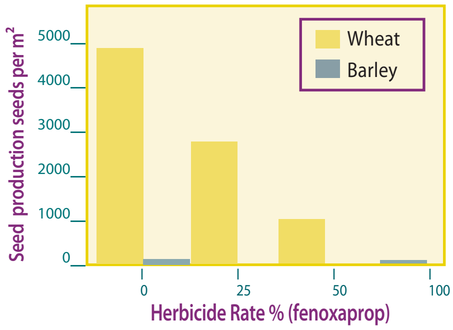
Know your weed

Phalaris *(Phalaris paradoxa)*, also known as paradoxa grass, is a common weed of winter crops and fallows across northern NSW. Another species of Phalaris, commonly called lesser canary grass *(Phalaris minor)* grows in similar situations however paradoxa grass is usually the dominant species. Both species grow on black/grey clays. Phalaris is a competitive weed with even low numbers able to cause up to 40% crop yield loss.

Paradoxa grass seedlings emerge with winter cereals, commencing in May and the majority of germination occurs in June and July. Persistence of paradoxa grass in the seed bank is short-lived like most other weedy grasses in cropping systems. Paradoxa grass relies on replenishment of seed banks from survivors to persist. It is estimated that 2% of the orginal seed bank exists after 2 years. Seedlings emerge mostly from seed mixed in the top 10 cm when subjected to annual soil disturbance, and from seed buried at 2.5 and 5 cm depths in undisturbed soil. Seeds persisted longest when shed onto the soil surface and persisted least when the soil was tilled. Cultivation can be used to stimulate earlier and more pronounced emergence patterns, allowing control prior to sowing.

Persistence of paradoxa grass relies on the production of new seeds each season. It is therefore important to prevent seed production from escapes and survivors. Seed production can range from 3,500 to 21,500 seeds per plant and in severe infestations under favourable conditions up to 120,000 seeds per m² have been measured.

Figure 6. Effect of crop type and Wildcat® (fenoxaprop) rate on *Phalaris paradoxa* seed production



[Source: S Walker et al. Qld DPI&F, Toowoomba]

Hints for better management

The main aim of paradoxa grass management should be to stop seed set. This is achieved by using a combination of:

- Crop rotation with winter and summer crops or long fallow in lower rainfall areas.
- Effective use of pre-emergence and early post-emergence herbicides. **[See Table 10]**
- Growing competitive crops using quality seed, optimum fertiliser, sowing depth, and crop population and row spacings less than 30cm. **Figure 6** shows the effect of wheat and barley competition and herbicide rate on paradoxa grass seed production.

Research on the Darling Downs has shown that shallow cultivation following rain in autumn (autumn tickle) moves the peak germination forward, allowing control with knockdown herbicides before sowing and reducing the pressure on in-crop herbicides.

Delayed sowing of weedy paddocks allows for maximum weed emergence that can then be effectively controlled with cultivation or a knockdown herbicide prior to sowing.

Cutting a badly infested crop or pasture for silage or hay followed by paraquat to kill regrowth can reduce phalaris seed set by 70%.

Crop topping with a registered knockdown herbicide (varies depending on crop) on a short season cultivar can reduce weed seed set by up to 90%. This technique will work best in seasons with a quick finish.

For better control with herbicides:

- Spray small weeds. The ideal stage for most herbicides is between the 2 and 3 leaf stage.

- Group A herbicides used in pulse/canola crops (Fusilade® 212, Verdict® 520, Select®, Sertin® and Fusion® etc.) are less sensitive to weed growth stage and can be applied up to the 5 leaf (early tillering) stage so several flushes of paradoxa grass can be controlled. This tactic should be used no more than 2 times in a 5 year rotation to prevent the onset of herbicide resistance.
- Increase crop competition in winter cereals and faba beans with optimum sowing rates, ≤30 cm rows, sowing on time and using competitive varieties.

Risk to Group A herbicides

Several paradoxa grass populations are resistant to Group A herbicides in northern NSW. The risk for further development of Group A resistance is low in areas with rotations consisting of a mix of summer and winter crops, as growers reduce paradoxa grass seed-bank during winter fallows. However, the risk is higher in areas with predominantly winter cropping and a heavy reliance on Group A herbicides.

Trifluralin (Group D) along with a few Group B herbicides (eg. Glean® and Logran®) are the only registered in-crop pre-emergent herbicide options available to reduce resistance selection pressure on Group A herbicides.

Strategies to prevent or minimise the risk for Group A resistance

- Rotate to summer crops and control paradoxa grass effectively in fallow with knockdown herbicides or tillage.
- Sow barley for greater crop competition (see Figure 6).
- Rotate to Atlantis® or Hussar® (Group B) in wheat, use this option no more than 2 times in a 5 year rotation. Check Group B resistance status!
- Rotate to trifluralin eg.Treflan®480 (Group D) followed by an early post-emergence option (Group B) in wheat.
- In wide row crops use inter-row shielded spraying with paraquat or Spray.Seed® (Group L).
- Rotate to winter pulses or triazine tolerant canola and use simazine and atrazine (Group C). Although not specifically registered for paradoxa control, local research in chickpeas has shown that triazines can be very effective in reducing paradoxa grass numbers.
- Rotate to pasture phase such as lucerne and use "winter cleaning" with Spray.Seed® + diuron (Groups L + C). Grazing can also be used but needs to be heavy enough in spring to prevent seed set.
- Cut crop or pasture for silage / hay followed by paraquat (Group L) to control regrowth.

In-crop weed control = 20% herbicide and 80% competition

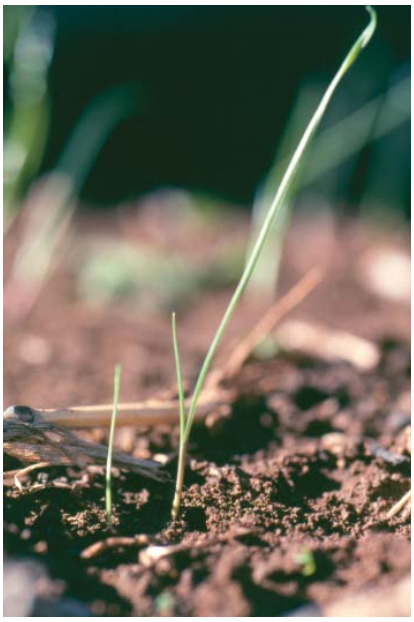
Risk to Group B herbicides

Chances of developing Group B herbicide resistance is high in regions that predominantly rely on winter cropping. Group B herbicides (e.g. Glean®) are extremely effective against paradoxa grass as a pre-emergent application or 1-2 leaf post emergence **(see Table 10)**.

Table 10. Pre-emergence control of Paradoxa grass in wheat, Moree

Herbicide(s)	Rate (/ha)	Herbicide Group(s)	% control
Avadex® BW + Glean®	2.1L + 20g	E + B	96
Trifluralin (400 g/L) + Glean®	1L + 20g	D + B	98
Trifluralin (400 g/L) + Glean®	1L + 15g	D + B	100
Glean®	20g	B	97
Trifluralin (400 g/L)	1L	D	55
Stomp® 330	1.2L	D	65

[Data source: Northern WR & DU, NSW DPI.]



Phalaris/Paradoxa grass

Strategies to prevent or minimise the risk for Group B resistance

- Control paradoxa grass in fallow with knockdown herbicides or tillage and rotate to summer crops.
- Sow barley for greater crop competition (see Figure 6).
- Rotate to Group A herbicides (eg. Wildcat® in wheat or Select®, Verdict® etc.. in pulses/canola), use this option at most 2 times in a 5 year rotation. Check Group A resistance status!
- Change pre-emergence option to trifluralin eg.Treflan®480 (Group D) if more than 2 applications of Group B have been made in past 5 years.
- In wide row crops use inter-row shielded spraying with paraquat or Spray.Seed® (Group L).
- Rotate to winter pulses or triazine tolerant canola and use simazine and atrazine (Group C).
- Rotate to pasture phase such as lucerne and use "winter cleaning" with Spray.Seed® + diuron (Groups L + C). Grazing can also be used but needs to be heavy enough in spring to prevent seed set.
- Cut crop or pasture for silage/hay followed by paraquat to control regrowth.

Risk to Group M herbicides

The risk to Group M herbicides ranges from low to high, depending on crop and herbicide rotation. The risk is greatest in no-till summer cropping systems. The overall strategy to reduce the risk for glyphosate resistance is to ensure that no survivors of glyphosate applications are allowed to set seed.

Fallow strategies to prevent or minimise the risk for Group M resistance

- Double knockdown with glyphosate followed by Spray.Seed® or paraquat in fallow.
- Double knock with glyphosate followed by full disturbance sowing.
- Use Spray.Seed® or paraquat (Group L) during autumn/early winter.
- Use atrazine (Group C) after a knockdown herbicide in winter fallow prior to sorghum.
- Cultivate the main flush(s) in fallow.

In-crop strategies to prevent or minimise the risk for Group M resistance

- In-crop weed control is important in keeping weed numbers low using a combination of selective herbicides (Group A, B, C, and D), good agronomy and crop competition.
- Wide row crops with inter-row shielded spraying with paraquat or Spray.Seed® (Group L).
- Use autumn tickle to promote early germination of main flush of phalaris prior to sowing.

Strategies for pasture

- In lucerne use "winter cleaning" with Spray. Seed® + diuron (Groups L + C). Grazing needs to be aimed at preventing seed set.
- Cut for silage/hay followed by paraquat to control regrowth.
- Spray top in spring with paraquat (Group L).

Barnyard and liverseed grasses

Know your weed

There are two common barnyard grass species, which are distinguished by presence or absence of awns attached to the seed. These are known as awnless barnyard grass *(Echinochloa colona) and* barnyard grass *(Echinochloa crus galli)*. Purple-red bands are sometimes seen on awnless barnyard grass leaves, particularly when the plant is stressed. Seedlings of liverseed grass *(Urochloa panicoides)*, also known as Urochloa, are easily distinguished because of their broad, pale yellow-green leaves with hairs on the leaf margins and sheaths.

Barnyard grass seedling

Awnless Barnyard grass

Barnyard grass

Liverseed grass

Liverseed grass seedling

Source: A. Storrie

Newly shed seed of barnyard grass and liverseed grass exhibit strong dormancy, and thus most of this seed will not germinate until the following season. Barnyard grass emerges throughout late spring and during summer following significant rain, whereas liverseed grass will mostly emerge in one large flush in late spring. Emergence is mostly from seed near the soil surface. Local research showed that 30-70% of liverseed grass seeds emerged during the first two years after shedding, and no seeds persisted in the soil after 4 years.

Hints for better management

For better control with herbicides:

- Target small weeds (2-3 leaves) when using knockdown herbicides particularly paraquat and Spray.Seed® in fallows. **(See Figures 7 & 8).**
- Use higher glyphosate rates for moisture stressed weeds.
- Use double knockdown technique with glyphosate followed by paraquat or Spray.Seed® for dense populations.
- Be aware of potential antagonism with tank mixes of glyphosate and atrazine for populations mixed with grasses and broadleaf weeds. Apply sequential sprays or increased glyphosate rates.
- Apply pre-plant atrazine as close as possible to the next rain for effective incorporation.
- Add Dual® Gold to atrazine to improve annual grass control particularly for liverseed grass.
- Incorporate mechanically pre-emergence applications of atrazine plus Dual® Gold for maximum effectiveness.

Risk to Group C herbicides

A few populations of liverseed grass have been confirmed resistant to atrazine (Group C) in paddocks where sorghum was grown as the pre-dominant crop with regular atrazine use for 10-15 years. A population of barnyard grass has developed Group C resistance in northern NSW. Elsewhere, the summer grasses have a relatively low risk of developing resistance to Group C herbicides in rotations with winter and summer crops.

Strategies to prevent or minimise the risk for Group C resistance

- ☑ **Apply atrazine mixed with Dual® Gold (Group K) in sorghum.**
- ☑ **Cultivate between the crop rows.**
- ☑ **Grow winter crops and focus on lowering the seed-bank with effective fallow control.**
- ☑ **Include other summer crops such as mungbean, sunflower and cotton, and use other grass selective herbicides (Group A, B and D).**

Resistance is unlikely to develop in paddocks with low weed numbers

Risk to Group M herbicides

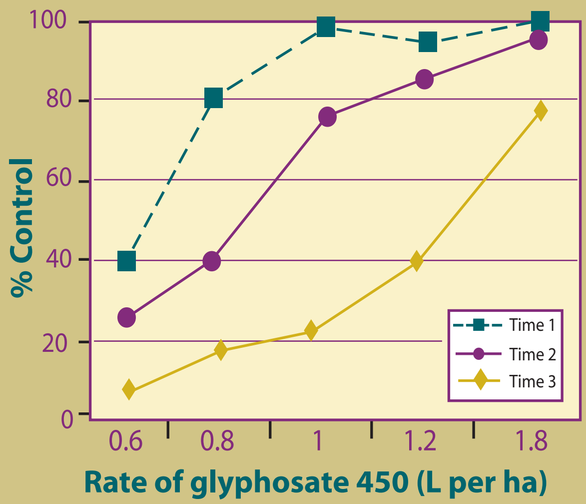
The summer grasses have a high risk of developing glyphosate resistance, particularly for growers practicing minimum or zero tillage. In a typical winter cereal/chickpea/sorghum rotation, these weeds are sprayed 16-17 times with glyphosate with minimal use of other herbicides apart from atrazine (Group C) over 5 years.

The overall strategy to reduce the risk for glyphosate resistance is to ensure that no survivors of glyphosate applications are allowed to set seed. Use the general tactics considered to decrease risk **(see Table 3)** as well as specific tactics outlined below.

Fallow strategies to prevent or minimise the risk for Group M resistance

- Apply Flame® (Group B) to a clean paddock, or mixed with a knockdown herbicide to a weedy paddock, in early summer fallows prior to wheat or chickpea. Avoid using in paddocks known to have potentially dense grass populations. Local NSW Data: Flame® gave very good residual control of barnyard grass for 2-3 months.
- Apply atrazine (Group C) in early spring fallow prior to sorghum. Local research: Pre-plant atrazine is most effective when applied as close as possible to the next rain, as this incorporates the herbicide into the grass germinating zone and minimises losses from volatilisation.
- Rotate with Spray.Seed® or paraquat (Group L) for small weeds.
- Double knockdown with glyphosate followed by Spray.Seed® or paraquat on survivors anytime in fallow.
- Double knock with glyphosate followed by full-disturbance cultivation at sowing.
- Cultivate.

Figure 7. Effect of application timing and glyphosate rate on control of Liverseed grass, Moree, NSW

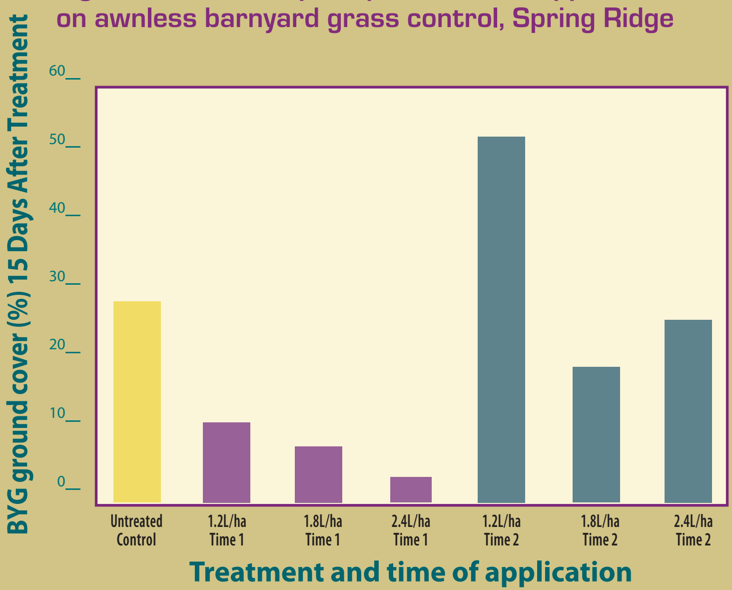


NOTE: Time 1 application, Liverseed grass was 3 to 3 ½ leaf stage; Time 2 was mid tillering stage and Time 3 was late tillering to early panicle emergence. [Data source: Northern WR & DU, NSW DPI.]

In-crop strategies to prevent or minimise the risk for Group M resistance

- Ensure maximum control in sorghum, such as atrazine (Group C) + Dual® Gold (Group K). Local research: Atrazine 2.5L + Dual Gold® 2L incorporated at sowing consistently gave > 95% season long control for the summer grasses.
- Cultivate between wide-row crops, or apply paraquat or Spray.Seed® with a shielded sprayer.
- Use grass selective herbicides effectively in other summer crops, such as Verdict (Group A), Spinnaker® (Group B) or trifluralin (Group D) in mungbeans; and several group A herbicides eg Verdict®; pendimethalin eg Stomp® (Group D), or Dual® Gold (Group K) in sunflowers.

Figure 8. Effect of paraquat rate and application timing on awnless barnyard grass control, Spring Ridge



BYG growth stage for the application time 1 was between 2 and 3½ leaf and for time 2 was between 3½ leaf and early tillering stage. [Data source: Northern WR & DU, NSW DPI.]

Black bindweed/Climbing buckwheat

Know your weed

Black bindweed *(Fallopia convolvulus)* is one of the major broadleaf weeds of cropping in the northern region. The weed has increased in importance with the move to wider row spacings (>25 cm) which reduces crop competition and delays crop canopy closure. Also the increase in the area sown to pulse crops which are poor competitors and the lack of few effective herbicides registered in these crops has increased its incidence. Black bindweed is tolerant of a range of herbicides, particularly once larger than 2 true leaves.

Black bindweed emerges mid winter to mid spring, when soil temperatures at 5-10cm reach 11 to 13°C. There appears to be dormancy that releases in late winter, which then re-instates when temperatures begin to rise. Like wireweed, new seed is thought to have dormancy that is broken by a period of low temperatures. This later emergence results in plants often establishing after the early post emergent herbicide application. These plants survive past harvest into the summer fallow period.

Black bindweed can produce up to 2500 seeds per m² per season, with up to 1000 seeds per plant. Local research shows that narrow row early planted cereals can withstand up to 290 bindweed plants per m² without significant yield loss. On the other hand North American data shows that when the cereal crop emerges at the same time as the bindweed up to 50% yield loss can occur. It also slows harvest, causing blockages in tined tillage equipment, and seed contaminates grain.

Hints for better management

Black bindweed emerges mid winter through spring. This is a distinct advantage for earlier sown cereal crops that can compete strongly with bindweed. Black bindweed is a major problem with winter pulse crops, particularly chickpeas, so avoid sowing pulses in paddocks with high bindweed populations. The relatively high levels of initial dormancy in bindweed seed ensures a relatively long-lived seed bank so seed set must be prevented each year to lower the numbers. If crop competition is maximised in winter cereals, high levels of control with a range of herbicides is possible.

Table 11. Spraying small weeds greatly improves herbicide efficacy

Herbicide treatment	Mode of action group	Rate of product per ha	Black bindweed control (%)		
			Trial A - Bellata Cotyledon to 2 leaf	Trial B - Manilla 6 leaf	Trial C – Bellata 1-2 leaf
bromoxynil	C	1.4L	95	91	99
bromoxynil	C	2.1L	97	98	N/A
bromoxynil + dicamba + MCPA (Broadside®)	C + I	1.0L	N/A	71	85
bromoxynil + MCPA (Bromoxynil® MA)	C + I	2.1L	97	78	99
Tordon® 242	I	1L	97	0	60
Tordon® 50-D	I	0.47L	98	9	N/A
dicamba + MCPA (Banvel® M)	I	1.7L	50	0	78
chlorsulfuron (Glean® etc)	B	20g	66	7	50

Note: Trial B – poor control from chlorsulfuron, Banvel® M, Tordon® 242 and Tordon® 50-D due to weeds >2 leaf stage at time of spraying.
[Data Source: Northern WR & DU trials, NSW DPI.]

For better control with herbicides in winter cereals

- ☑ **Spray small, actively growing seedlings [2 leaves and definitely no more than 4 leaves]. See Table 11.**
- ☑ **Increase cereal sowing rates and ensure adequate nutrition.**
- ☑ **Use narrow [less than 25 cm] row spacings in cereals.**
- ☑ **Plant longer season cereal varieties in May in bindweed problem paddocks.**
- ☑ **Control late flushes with selective herbicides or pre-harvest sprays instead of waiting for the first fallow spray after harvest.**

For those able to grow summer crops, a winter fallow with knockdown herbicides and atrazine is an effective form of control **(See Table 13).** Atrazine gives good residual control if applied late winter before a sorghum

or maize crop. Flame® applied in late winter-early spring will also give good control of bindweed in fallow prior to next years winter cereal or chickpeas.

Spray.Seed® alone is highly effective on small bindweed plants. Glyphosate is far less effective and needs to be applied at 1.6 L/ha (450 g/L) for 4 leaf plants and greater than 2.4 L/ha for flowering plants. More reliable control is achieved with a tank-mix partner such as Starane® 200 or Tordon® 75-D but not 2,4-D or metsulfuron. **[See Table 13].**

Winter pulse crops should be avoided, however there are some management options available. Trifluralin at higher rates will give useful suppression of black bindweed, although it is not registered specifically for this purpose.

In ***fababean*** Spinnaker® 700 WDG at higher rates will give good control, although in spring bindweed will begin to establish and a pre-harvest desiccation with Reglone® may be required.

Chickpeas are poor competitors with weeds, however weed competition doesn't affect yield until spring when the chickpeas begin to grow rapidly. Local research at Coonamble from 2002 to 2004 showed that chickpeas sown on wide rows and inter-row sprayed with Sprayseed® at 2 L/ha gave an average of 90% control of flowering bindweed plants with no effect on yield.

Risk to Group B herbicides

In the mid 1990's a population developed resistance to the Group B herbicides, such as chlorsulfuron (e.g.Glean®) and metsulfuron (e.g. Ally®) in southern Queensland. The risk of more weeds developing Group B resistance is high in winter crop rotations, where Group B herbicides are used repeatedly without mixing with other effective herbicide groups.

Strategies to prevent or minimise the risk for Group B resistance

- ☑ **Rotate to Group I herbicides, such as Tordon® 242, Tordon® 75-D, and fluroxypyr (Starane® 200), and /or apply mixes of Group B and I herbicides.** [See Tables 12 and 13].
- ☑ **Avoid using sulfonylurea herbicides (Group B – eg. Glean® and Ally®) in fallows and crops.**
- ☑ **Use a late post emergent application of selective herbicide or a pre-harvest salvage knockdown to prevent seed set of late germinations and survivors.**
- ☑ **Minimise seed production by survivors and maximise herbicide efficacy by using crop competition.**

Table 12. Control of black bindweed at 5 leaf with a range of herbicides – in barley, Inverell, NSW

Herbicide	Mode of action group	Rate of product/ha	Black bindweed (% control) 3 MAT
Lontrel® U	I	300mL	100
Lontrel® U	I	500mL	100
Lontrel® + MCPA amine	I	300mL + 1L	99
Lontrel + MCPA amine	I	500mL + 1L	100
Tordon® 242	I	1L	100
Tordon® 75-D	I	300mL	100
Tordon® 75-D + 2,4-D amine	I	300mL + 500mL	100
Starane® 200	I	750mL	100
Grazon® DS U	I	500mL	100
untreated 52 plants/m²		------	0

U = Uptake™ spraying oil 0.5%v/v (surfactant + oil) MAT = months after treatment
[Source: Nothern WR & DU, NSW DPI.]

Table 13. Control of black bindweed at 5 leaf with a range of herbicides – no crop, Inverell, NSW

Herbicide	Mode of action group	Rate of product/ha	% control 3 MAT
2,4-D amine P	I	1.5L	42
glyphosate 450 U	M	1.2L	55
Lontrel® U	I	300mL	97
untreated		--------	0
2,4-D amine L	I	1.5L	30
Grazon® DS U	I	500mL	100
Grazon® DS U	I	300mL	99
Starane® 200	I	1L	94
Lontrel® + MCPA amine	I	300mL + 1L	99
glyphosate 450 U	M	2.4L	64
Lontrel® U	I	500mL	100
Starane® 200	I	500mL	91
glyphosate 450 + Surpass® 300	M + I	1.2L + 2.5L	66
2,4-D amine	I	1.5L	61
2,4-D amine U	I	1.5L	48
metsulfuron + MCPA LVE	B + I	5g + 1L	-3.4
Spray.Seed® + diuron 500	L + C	2.4L + 3.5L	100
Spinnaker®	B	300mL	100
Flame®	B	200mL	100
atrazine 500 g/L	C	3L	100
Arsenal®	B	1L	100

P = Primabuff® at 0.1% v/v (pH stabilising agent) **U** = Uptake® spraying oil 0.5%v/v (surfactant + oil) **L** = LI 700® 1%v/v **MAT** = months after treatment

[Source: Nothern WR & DU, NSW DPI.]

Black bindweed/Climbing buckwheat

Strategies to prevent or minimise the risk for Group B resistance (con't)

- Use winter fallow/summer crop that allows the use of atrazine (Group C).
- With wide rows (>25 cm) use inter-row spraying with Spray.Seed® (Group L).
- Use trifluralin (Group D) as a pre-emergent.

Risk to Group M herbicides

Black bindweed has a moderate risk of developing glyphosate resistance, particularly in cropping systems that are zero-tilled and reliant on glyphosate alone for fallow weed control. Typically, glyphosate is applied more than 20 times in 5 years with many of these applications potentially targeting black bindweed, particularly in sorghum/summer crop rotations. Glyphosate applied alone is only effective at higher rates. The most common tank-mix partner, 2,4-D, is ineffective on bindweed.

The overall strategy to reduce the risk for glyphosate resistance is to ensure that no survivors of glyphosate applications are allowed to set seed.

Fallow strategies to prevent or minimise the risk for Group M resistance

- Mix glyphosate with a sufficiently high rate of a Group I such as Starane® 200 (0.5-0.75 L/ha), Tordon® 75-D (0.3 L/ha), or dicamba (eg. Cadence® 200 g/ha).
- Rotate with Spray.Seed® (Group L). Local research: post harvest applications extremely effective in reducing seed set.
- Double knockdown with glyphosate followed by Spray.Seed® on survivors anytime in fallow.
- Apply atrazine (Group C) in late winter or spring fallow prior to sorghum to clean paddock or after treatment with a knockdown herbicide. Table 13 shows that atrazine at 3.0 L/ha controlled black bindweed for at least three months under average rainfall conditions.
- Use tillage, grazing, chipping, or detector sprayer with alternative mode of action (different herbicide group) herbicide to control and stop survivors setting seed.

In-crop strategies to prevent or minimise the risk for Group M resistance

- In-crop weed control is important in keeping weed numbers low using a combination of selective herbicides and crop competition. This reduces the selection pressure for glyphosate resistance in the following fallows.
- Use Spray.Seed® for in-crop application with a shielded sprayer with wide rows.
- Rotate to Group I herbicides, such as Tordon® 242, Tordon® 75-D, and fluroxypyr (Starane® 200), and/or apply mixes of Group B and I herbicides. (See Tables 11, 12 and 13).
- Use a late post emergent application of selective herbicide or a pre-harvest salvage knockdown to prevent seed set of late germinations and survivors.
- Minimise seed production by survivors and maximise herbicide efficacy by using crop competition.

Fleabane

Key ecology facts

Flaxleaf fleabane *(Conyza bonariensis)* has become one of the most difficult-to-control weeds in dryland cropping systems in recent years. The weed problem is thought to have resulted from recent changes in farming practices to greater use of zero tillage, and possibly from the recent seasonal effects that have favoured fleabane growth.

Some preliminary studies indicated that the seed emerged only on or near the soil surface, and that seed persistence was relatively short. The weed emerged throughout the year, but peak emergence was during spring, which is favoured by wet conditions. One mature plant can produce an average of 110,000 seeds.

Fleabane effectively controlled in sorghum using pre-plant fallow application of atrazine 4L/ha [right] compared with untreated (left)
[Source: Hanwen Wu]

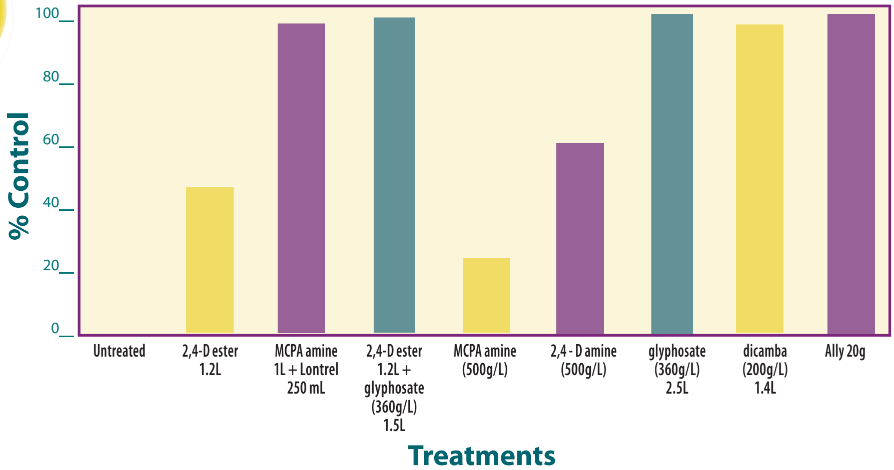
Hints for better management

Research is currently investigating the following management strategies. These involve regular scouting for new flushes; spraying small weeds and using glyphosate mixtures, double knock, and atrazine in fallows; Group B herbicides and mixtures in wheat; atrazine mixtures in sorghum; growing competitive winter cereals and avoiding wide row crops; and strategic tillage on stressed weeds.

More information is available on the Weeds CRC website at (www.weeds.crc.org.au/publications) and DPI&F website (www.dpi.qld.gov.au).

Resistance remains for many years, until all resistant weed seeds are gone from the soil seed-bank

Figure 9. Control of fleabane using various fallow and in-crop herbicides, Tamworth, NSW



Fleabane growth stage was between 5 and 15cm diameter rosette stage.
[Data source: Northern WR & DU, NSW DPI.]

Risk to Group M herbicides

A preliminary study by the University of Sydney indicated that a population has developed resistance to glyphosate in the Goondiwindi region. However, some growers and agronomists believe that the weed has become more difficult to control with glyphosate over time, whereas others consider that fleabane has always been difficult to control with glyphosate alone. The local situation needs clarification, especially as Canadian fleabane is now resistant to glyphosate extensively in North America, and populations of flaxleaf fleabane have been recorded as glyphosate resistant in South Africa and Spain *(www.weedscience.com)*.

Ideal size to spray

Difficult to control at this stage

Know your weed

Common sowthistle *(Sonchus oleraceus)* is currently the most prevalent weed of cropping in the northern region. The weed has increased in importance in the last few decades, particularly as farming systems moved towards reduced and zero tillage. It is similar to spiny sowthistle *(Sonchus asper)*, which has thicker leaves with spiny margins.

The weed is not restricted to any season, as seed can germinate at any temperatures from 5°C to 35°C. Fresh seeds have no innate dormancy, enabling them to germinate immediately following dispersal onto moist soil or after the next rain. As such, emergence patterns are determined mostly by rainfall. Therefore, it is important to monitor for weed emergence after each rainfall event. The majority of seed emerges from the top 2cm of soil, and no seed emerges from 5cm or deeper, which is one of the reasons for its increased prevalence in reduced till systems.

Table 14. How long weed seeds persist in the top 5cm of soil in the Darling Downs

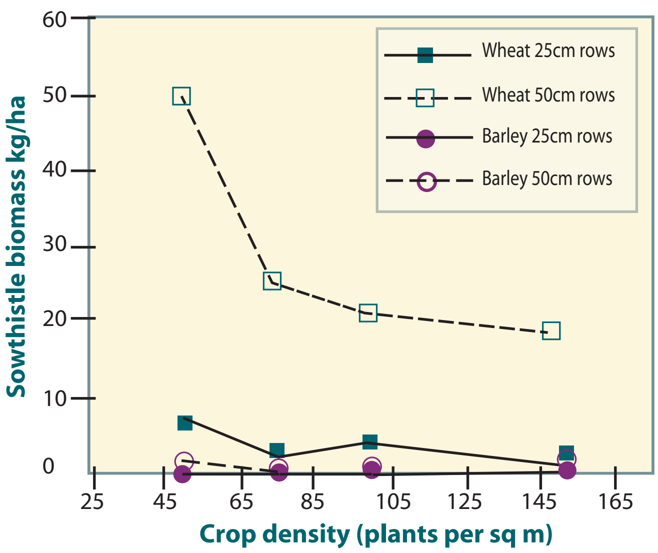
Weed	Seed remaining in soil seed-bank (%)			
	1 year	2 years	3 years	4 years
Barnyard grass [A]	20			
Black bindweed [B]				6
Common sowthistle (0-1cm) [C]	12	<1	<1	
Common sowthistle (5-10cm) [C]	43	14	5	
Liverseed grass [A B]	17			<1
Paradoxa grass [D]	14	2	<1	<1
Turnip weed [E]	56	28	15	7
Wild oats [E]	17	2	<1	<1

Data supplied by Hanwen Wu[A]; Bruce Wilson[B]; Michael Widderick[C]; Ian Taylor[D]; Steve Walker[E]

The weed is a prolific seed producer with a single plant producing up to 25 000 viable seeds in a fallow, highlighting the importance for follow-up control measures to prevent major replenishment of the seed-bank. Although most seed moves only several metres from the parent plant, a small percentage may disperse greater distances up to 65m. Thus, it is important to control plants prior to flowering along fence lines, adjacent land and roadsides to prevent new sources of infestation.

Darling Downs research has shown that the majority of the seed on the soil surface does not persist for more than a year, but a portion of seed buried at depths ≥ 5cm will persist for at least 3 years **(see Table 14).** Thus, an important part of this weed's management strategy is to ensure seed remain on the soil surface. Then, control all emerged seedlings for at least a year, which will result in major depletion of the seed-bank, provided there has been no seed replenishment.

Figure 10. Competitive winter cereals greatly reduced common sowthistle growth



Data from trial at Condamine (Source: M Widderick, QLD DPI & F, Toowoomba)

Hints for better management

Since the weed emerges all year, rotation of crops is a less useful tactic than for weeds that grow predominantly in winter or summer, and management should focus on all phases of the rotation to **keep weed numbers low.**

Crop competition greatly impedes common sowthistle growth, particularly in winter cereals **(see Figure 10).** This tactic is important, as it reduces seed production on survivors or escapes from herbicide application.

For better control with herbicides:

- Spray small seedlings (2-5 leaves).
- Use higher spray application volumes for atrazine, paraquat and Spray.Seed®, to optimise coverage.
- Do not mix glyphosate with 2,4-D or metsulfuron (eg Ally®) due to potential antagonism.
- Control late flushes in winter crops with selective herbicides or pre-harvest sprays instead of waiting for the first fallow spray after harvest.

Common sowthistle

Risk to Group B herbicides

In the last two decades, numerous populations of common sowthistle in nothern NSW have developed resistance to the Group B herbicides, such as chlorsulfuron (eg Glean®) and metsulfuron (eg. Ally®). The risk for more weeds developing Group B resistance is high in winter crop rotations, where Group B herbicides are used repeatedly without mixing with other effective herbicide groups.

Strategies to prevent or minimise the risk for Group B resistance

- ☑ **Rotate to Group I herbicides, such as Tordon® 242, MCPA, 2,4-D, Tordon® 75D and Starane®, and/or apply mixes of Group B and I herbicides. Local research: Ally® + MCPA gave 100% control of small seedlings.**
- ☑ **Avoid using Group B herbicides in fallows, if applying Group B herbicides in the preceding or following crop.**
- ☑ **Minimise seed production on survivors using crop competition.**

Risk to Group M herbicides

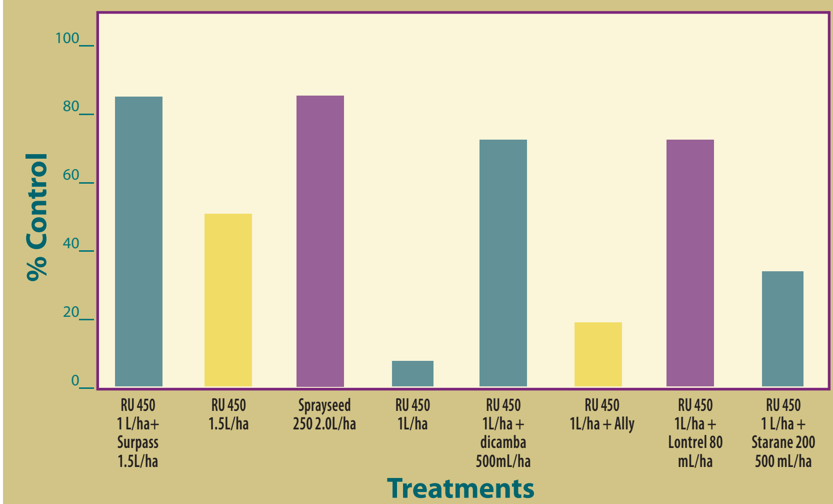
Common sowthistle has a moderate risk of developing glyphosate resistance, particularly in cropping systems that are zero-tilled and reliant on glyphosate alone for fallow weed control. Typically, glyphosate is applied more than 20 times in 5 years with many of these targeting sowthistle.

The overall strategy to reduce the risk for glyphosate resistance is to ensure that no survivors of glyphosate applications are allowed to set seed. Use the general tactics considered to decrease the risk **(see table 5)** as well as the specific tactics outlined below.

Fallow strategies to prevent or minimise the risk for Group M resistance

- ☑ **Mix glyphosate with Starane®, Surpass® 300, Lontrel® or Cadence® [dicamba] (Group I) (Figure 11).**
- ☑ **Rotate with Spray.Seed®or paraquat (Group L).**
- ☑ **Double knockdown with glyphosate followed by Spray.Seed® or paraquat e.g. Gramoxone 250 on survivors anytime in fallow.**
- ☑ **Double knock with glyphosate followed by full disturbance cultivation at sowing. Local research: Cultivation was much more effective on common sowthistle less than 10cm diameter.**
- ☑ **Apply atrazine (Group C) in late winter or spring fallow prior to sorghum after treatment with a knockdown herbicide. Local research: Atrazine at 3.6L/ha controlled common sowthistle for several months.**
- ☑ **Use tillage, grazing, chipping, or detector sprayer with alternative mode of action herbicide to control and stop survivors setting seed.**

Figure 11. Control of sowthistle using various fallow herbicide options, Croppa Creek, NSW



Sowthistle growth stage was between 5 cm diameter rosettes and 50 cm tall flowering plants at herbicide application. [Data source: Northern WR & DU, NSW DPI.]

In-crop strategies to prevent or minimise the risk for Group M resistance

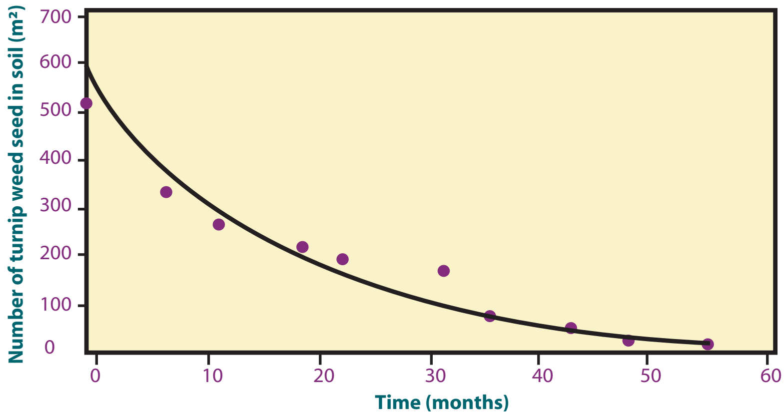
- ☑ **In-crop weed control is important in keeping weed numbers low using a combination of selective herbicides and crop competition. This reduces the selection pressure for glyphosate resistance in the following fallows.**
- ☑ **Cultivate between wide-row crops, or apply paraquat or Spray.Seed® with a shielded sprayer.**

Know your weed

The main weeds of this group in northern New South Wales are turnip weed *(Rapistrum rugosum)*, charlock *(Sinapis arvensis)*, wild radish *(Raphanus raphanistrum)*, muskweed *(Myagrum perfoliatum)*, wild turnip *(Brassica tournefortii)* and mustards *(Sisymbrium* spp.*)*

Brassicas are very competitive, especially in winter pulse crops with 40 plants per m² reducing chickpea yields by 50%. These weeds have increased in importance with adoption of no-tillage and the move to wider row spacings (>25 cm) which reduces crop competition and delays crop canopy closure.

Figure 12. Persistance of turnip weed seeds in soil with no replenishment



Data from trial on Darling Downs
(Source: S Walker, QLD DPI&F, Toowoomba)

All the brassica weeds have potential to increase their range, particularly wild radish and muskweed, which currently have restricted distributions. Turnip weed, charlock and wild turnip weed dominate under hotter and drier climatic conditions. These weeds have increased their importance in different areas. In western areas such as Walgett, charlock is a significant problem in chickpea crops. Seed dormancy and longevity are key mechanisms in the persistence of these cropping weeds **[See Figure 12].** They lack stringent requirements for germination, hence sporadic germination from autumn to early spring. They have a very high level of seed production with single charlock plants producing 30,000 to 50,000 seeds, and 8,000 seeds per m².

Seed persistence is greatest when seed is buried at depth. Decline in number of viable seeds is greatest in top 1 cm of soil. Tillage, besides stimulating emergence, also affects seed longevity through burying seeds at greater depths. Turnip weed seed (and likely the same with other species) persists longer in the seed bank than most grasses and sowthistle. Approximately 10% of turnip weed seed remained in the soil seed-bank after 4 years of 100% weed control.

Hints for better management

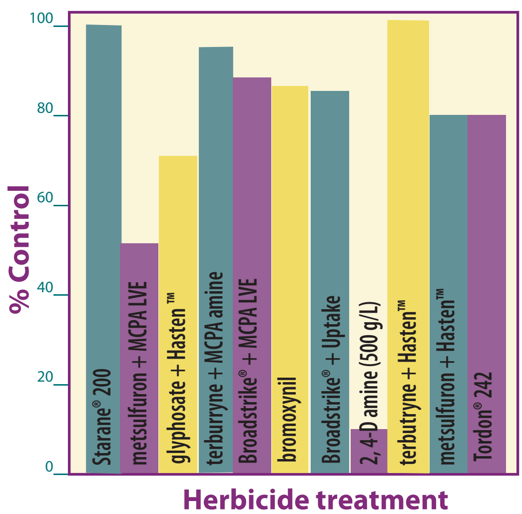
Integrated weed management is required in controlling the brassica weeds as seed has long persistence. Brassica weeds are susceptible to competition from winter cereals and can be controlled with Group I herbicides such as MCPA and 2,4-D, or with tank mixes of Groups B+I, such as metsulfuron + MCPA.

It is important to correctly identify your brassica weed as wild radish and muskweed are harder to control than turnip weed *(Rapistrum)*. These species usually require an early post emergent application of a tank mix of herbicides from Groups B+I, followed by a selective spray-topping of Group B or I to control later germinations.

Refer to 'Crop Weeds of Northern Australia' by B Wilson, D Hawton and A Duff for identification at seedling and mature stages.

- Grow competitive crops at optimum seed rates, row spacing and nutrition combined with effective herbicide control. Chickpeas are particularly susceptible to brassica weeds due to poor competitive ability and lack of effective herbicides.
- Sow weed free seed.
- Sow weedy paddocks last and use a knockdown herbicide to reduce weed numbers before planting.

Figure 13. Control of muskweed in wheat using different herbicides applied post emergent - 9 weeks after treatment. Quirindi, NSW



[Source: Northern WR & DU, NSW DPI Tamworth.]

Hints for better management (con't)

- Where wide rows are used, inter-row shielded spray with a registered knockdown herbicide.
- Use selective spray-topping in winter cereals with either a Group B (check resistance) such as triasulfuron, or Group I such as 2,4-D, to control escapes and later germinations.
- Pre-harvest desiccation can control brassica weeds that escape the initial control or germinate later. Local research showed 99% control of wild radish in wheat with 2 L/ha of 2,4-D amine (500 g/L), after the dough stage (Z80), with a 10% wheat yield reduction.


Turnip weed (Rapistrum)

Table 15. Post emergent control of wild radish & turnip weed in wheat. Gunnedah, NSW

Herbicide	Herbicide MOA Group	Crop growth	% Control
MCPA amine (500g/L) 0.7 L/ha	I	5-leaf	100
2,4-D amine (500g/L) 2 L/ha	I	Till-Jointing	100
Affinity® + MCPA amine 0.5 L/ha	G + I	5-leaf	100
MCPA L.V.E. 2 L/ha	I	5-leaf	99
Bromoxynil + MCPA 2 L/ha	C + I	4-leaf	97
Tigrex® 1 L/ha	I & F	4-leaf	94

(Source: Nothern WR & DU, NSW DPI.)


Charlock

Risk to Group B herbicides

Identify seedlings before spraying

Northern NSW has confirmed group B resistance in charlock, turnip weed, Indian hedge mustard and wild radish. Herbicide usage records showed that resistance has developed after 3-10 years of selection with chlorsulfuron (Glean®). Wild radish has developed resistance after 6 applications of group B. The risk is greatest for the cropping systems using zero tillage winter crop rotations, particularly in the southern and western parts of the region.


Musk weed

Strategies to prevent or minimise the risk for Group B resistance

- ☑ Rotate to Group I phenoxy herbicides such as MCPA and 2,4-D alone or in tank mixes. Group I herbicides such as dicamba, Lontrel® and fluroxypyr (eg Starane® 200) are ineffective on brassica weeds when used alone.
- ☑ Do not apply more than 2 group B herbicides in any 4-5 year period in the same paddock.
- ☑ If using group B as pre-emergent, monitor control, and kill any survivors.
- ☑ If using group B as post-emergent, tank-mix with a Group I phenoxy herbicide such as MCPA.
- ☑ Spray very small seedlings (2-4 leaves).
- ☑ Avoid using Group B herbicides such as metsulfuron in fallow, if a Group B herbicide has been used in a preceding crop, or will be used in the next crop.
- ☑ Use trifluralin (Group D) as a pre-emergent and MCPA or 2,4-D post emergent.
- ☑ Use selective spray topping in cereals with MCPA or 2,4-D.
- ☑ Use wick/blanket wiper in shorter pulse crops such as chickpeas once the weeds are above the crop.
- ☑ Keep weed numbers low.

What to do if you think you have resistant weeds

When resistance is first suspected, we recommend that growers contact their local agronomist. The following steps are then recommended:

1. Consider the possibility of other common causes of herbicide failure by asking:
   - Was the herbicide applied in conditions and at a rate that should kill the target weed?
   - Did the suspect plants miss herbicide contact or emerge after the herbicide application?
   - Does the pattern of surviving plants suggest a spray miss or other application problem?
2. Has the same herbicide or herbicides with the same mode of action been used in the same field or in the general area for several years?
3. Has the uncontrolled species been successfully controlled in the past by the herbicide in question or by the current treatment?
4. Has a decline in the control been noticed in recent years?
5. Is the level of weed control generally good on the other susceptible species?

If resistance is still suspected:

6. Contact one of the researchers below for advice on sampling suspect plants for testing of resistance status.
7. Ensure all suspect plants do not set any seed.
8. If resistance is confirmed, develop a management plan for future years to reduce the impact of resistance and likelihood of further spread.

For more information

AVCARE's Herbicide resistance management strategies www.avcare.org.au
CRC for Australian Weed Management (IWM Manual) www.weeds.crc.org.au
National Glyphosate Sustainability Working Group www.weeds.crc.org.au/glyphosate
Western Australian Herbicide Resistance Initiative www.wahri.agric.uwa.edu.au
Australian Cotton CRC (Weedpak) www.cotton.pi.csiro.au

Project team: (back) Glen Wright, Alan Maguire, Steve Walker, Tony Cook, Michael Widderick; (front) Paul Moylan, Vikki Osten, Kathryn Galea, Andrew Storrie, and Geoff Robinson

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GRDC Grains Research & Development Corporation

NSW DEPARTMENT OF PRIMARY INDUSTRIES

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CRC Weed management

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