

Integrated Weed Management (IWM)

Strategically plan how different tactics will be utilised to give the best overall results controlling existing weeds and reducing the weed seed bank. A short term approach to weed management may reduce costs for the immediate crop or fallow, but is unlikely to be cost effective over a five or ten year cropping plan. Over this duration, problems with species shift and the development of herbicide resistant weed populations are likely to occur unless weed control has been part of an integrated plan.

Develop a strategy

Having good records on crop rotations, herbicides and other tactics used as well as weed species present will help in developing a plan that identifies where there are particular risks in the system and also where there might be opportunities to incorporate additional tactics. The Herbicide Resistance Management Strategy (HRMS; available later in this chapter) can help to inform the effectiveness of combinations of tactics on reducing the weed seed bank as well as the risk of herbicide resistance.

Know your enemy

Consider what weed species are present. Ensure that weeds are correctly identified, and consider which tactics, or combination of tactics, are going to be most effective for your weed spectrum. A key resource that can assist with these decisions, WEEDpak and its associated ID guide, is available from cottoninfo.com.au/publications.



Identify any particular problem areas. Managing these patches more intensively may help prevent a problem weed or resistance from spreading.



Another valuable weed ID resource is the **Weeds of Australian Cotton app**.
cottoninfo.com.au/weeds-australian-cotton-app



Timing and targeting

Often the timeliness of a weed control operation has the largest single impact on its effectiveness. For example, herbicides are far more effective on rapidly growing small weeds, and may be quite ineffective in controlling large or stressed weeds. Ensure that products are available and equipment is fit-for-purpose. See the spray application chapter for more information on ensuring that sprays hit the target and control weeds effectively.

The Australian herbicide modes of action for herbicides changed from letters to numbers in 2021. Original MoA groups are indicated in this guide as a reference. For more information visit: croplife.org.au/resources/programs/resistance-management/herbicide-moa-alignment



Think about the whole farming system

Consider weed management in the context of other in-crop agronomic issues, other crops and across the whole farm, including non-crop areas.

Consider crop competition

An evenly established, vigorously growing cotton crop can compete strongly with weeds, especially later in the season. Plant into weedy fields last to provide more opportunity to control emerging weeds, and better conditions for cotton emergence and early vigorous growth. In irrigated crops, weed-free periods of 8-9 weeks from planting provide enough time for cotton to out-compete most later emerging weeds and significantly reduce weed seed production.

Plan weed management to fit with other operations

Look for opportunities in the cropping system to coordinate weed control tillage with other operations, such as pupae busting, fertiliser incorporation, seed bed preparation and irrigation furrow maintenance.

Consider the wider impacts of weeds

Good weed control is also integral to effective pest and disease management. Many cotton insect and mite pests utilise weed hosts and/or cotton volunteers prior to migrating into cotton fields. Some weeds and cotton volunteers/ratoons can act as a reservoir for plant viruses such as cotton bunchy top disease, or allow disease inoculum to build up in the soil, increasing the risk for subsequent crops. Weeds in fallow fields also reduce the starting soil moisture/nutrients available to the crop.

Mix it up with rotation crops

Rotation crops provide an opportunity to introduce a range of different tactics into the system, particularly herbicide groups that are not available in cotton. Mixing rotations may also vary the time of year non-selective measures can be used and when crop competition suppresses weed growth. Rotation between summer and winter cropping provides opportunities to use cultivation and knockdown herbicides in-fallow year round. If rotating with other crops, such as winter cereals or maize, retain the stubble cover from the rotation crops for as long as possible to reduce weed establishment and encourage more rapid breakdown of weed seed on the soil surface. In terms of the HRMS, treat rotation crops like a fallow and aim to use at least 2 non-glyphosate tactics within the crop.

Don't forget non-crop areas

Weeds in non-crop areas on the farm such as channels, tail drains, fence lines and roadsides can develop and introduce herbicide resistance into the farming system. Manage these areas as a fallow, using a range of tactics including residual herbicides, cultivation and chipping of weeds. Glyphosate (9/M) is also registered for many non-crop situations, but its use should be avoided where possible to minimise the risk of resistance. DO NOT rely on glyphosate only to manage weeds in these areas.

TABLE 20: Control of weeds in dry channels

Active ingredient	MoA group
Amitrole + ammonium thiocyanate	34(Q)
Imazapyr	2(B)
Pendimethalin	3(D)
Flumioxazin	14(G)
Diuron	5(C)
Glyphosate is also registered. Note: This information is provided as a guide only. Use in dry channels may not be a registered use for all products with that active. ALWAYS CHECK THE LABEL.	

Dryland cotton

Weeds are very efficient at robbing the soil of vital moisture and nutrients. Control weeds in winter crops and pre-cotton fallows to improve sowing opportunities. It is vital to run the weed seed bank down during this period to minimise in-crop weed management costs. Include residual herbicides in fallows and use pre-emergent herbicides at planting to provide ongoing in-crop weed control and reduce reliance on glyphosate.

Tactics such as rotating to other chemical MoAs for knockdown weed control are essential to minimise development of herbicide resistance (see the HRMS for available tactics).

Cultivation is often seen as detrimental in dryland systems due to moisture losses from cultivation passes, but late in-crop strategic cultivation to remove weed escapes is an ideal time use non-chemical weed control, where the impacts of moisture loss are reduced. Alternatively, consider using cover crops to reduce weed numbers and improve soil health while also trapping and storing valuable soil moisture. As with irrigated cotton, ensure that any surviving weeds are prevented from setting seed.

Come Clean. Go Clean.

To minimise the entry of new weeds, clean down boots, vehicles, and equipment between fields and between properties (give special attention to pickers and headers). Regularly check washdown areas for germinating

plants. Eradicate any new weeds while they are still in small patches and monitor patches frequently for new emergences. More biosecurity information is available at cottoninfo.com.au/biosecurity

Weed seeds can also be carried in irrigation water. Control weeds that establish on irrigation storages, supply channels and head ditches.

Control survivors BEFORE seed is set

To be effective in preventing resistance, weeds that survive a herbicide application must be controlled by another tactic before they are able to set seed. Monitor fields after each spray application to assess efficacy. Weeds may need to be examined closely, as some are capable of setting seed while very small. Many weeds respond to varying day-length, so a winter weed emerging in late winter or spring may rapidly become reproductive in response to lengthening daylight hours.

Preventing survivors from setting seed is critical to the longer term success of an IWM strategy. Research indicates that high efficacy with an alternative tactic is good, but high frequency control is even better. Cultivation after glyphosate application is likely to achieve 80% survivor control, whereas cultivation PLUS chipping should achieve 99.9% survivor control. Other supplementary tactics for survivor control (such as shielded or spot-spraying with an effective knockdown herbicide) could be equally as effective.



A patch of glyphosate-resistant awnless barnyard grass, likely to have started near a road. Consider whole of farm use of herbicides.  T.Cook, NSW DPIRD

TABLE 21: Herbicide plant-backs from rotation crops to cotton

Active ingredient	MoA	Plant-back to cotton	Notes
Aminopyralid + fluroxypyr	4(I)	9 months*	Plant-back interval on black cracking clay soils.
Aminopyralid + picloram + 2,4-D	4(I)	12 months* (northern NSW, Qld)	Under drought conditions conduct a bioassay before planting the next crop.
Atrazine	5(C)	6 months	Rates <1.4 kg/ha.
		18 months	Rates 1.4 to 3.3 kg/ha.
Atrazine + S-Metolachlor	5(C) + 15(K)	6 months	Rates <3.2 L/ha.
		18 months	Rates <3.2 L/ha. On alkaline soils, undertake a bioassay or analytical test.
Chlorsulfuron	2(B)	18 months	Where soil pH is 6.6-7.5 and 700 mm of rain has fallen. If soil pH >7.5, only grow cotton after growing a test strip.
Clopyralid	4(I)	3 months*	Rates <30 g/ha.
		6 months*	Rates 30 to 120 g/ha.
		24 months*	Rates >120 g/ha.
Diuron	5(C)	Refer to label	Do not replant treated areas within 2 years of application of diuron unless otherwise stated on the label.
			Do not replant treated areas to any crop within 1 year after last spray except cotton (along with maize or grain sorghum) which may be planted in the spring following year.
Flumetsulam	2(B)	2 years	For NSW and Qld a minimum of 50 mm and preferably 100 mm rain or more must have fallen over the warm months of the year.
Flumioxazin	14(G)	0 months	For zero plant-back for knockdown spike rates of 45 g/ha or below.
		2 months	For residual rates above 210 g/ha.
Imazamox	2(B)	10 months	Must have 800 mm of rainfall or irrigation.
Imazamox + imazapyr	2(B)	34 months	Registered for use in Clearfield® (or imidazolinone herbicide tolerant) crops – refer to label for varietal constraints.
Imazethapyr	2(B)	22 months	Dryland cotton.
		18 months	Irrigated only (providing rainfall and irrigation exceeds 2000 mm).
Isoxaflutole	27(H)	7 months	350 mm rainfall (excluding flood/furrow irrigation) between application and planting the subsequent crop.
Mefenpyr-diethyl + iodosulfuron-methyl sodium	2(B)	12 months	Rainfall <500 mm may result in extended re-cropping intervals for summer crops sown in the following season.
Metribuzin	5(C)	6 months	Rates <1.5 L/ha. Could be longer if there have been long dry periods between crops.
		12 months	Rates >1.5 L/ha.
Metsulfuron methyl	2(B)	Unknown	Registered for use in wheat, barley, triticale and as a desiccant in chickpea.
Metsulfuron-methyl + mefenpyr-diethyl	2(B)	12 months	Rainfall of less than 500 mm following application may result in extended re-cropping intervals for summer crops sown in the following year.
Picloram + 2,4-D	4(I)	12 months	(Nth NSW & Qld). Do not use on land to be cultivated for growing susceptible crops within 12 months of application. Based on normal rainfall.
Pyroxasulfone	15(K)	5 months	At least 150 mm rainfall. Less total rainfall between application and planting of the following crop than 150 mm may require extended plant-back period.
Simazine	5(C)	9 months	When up to 2.5 kg/ha are used. When rates exceed 2.5 kg/ha, plantings may not be possible for very long periods of time afterwards.
Sulfosulfuron	2(B)	Unknown	Registered for use in wheat and triticale.
Triasulfuron	2(B)	15 months	Soil pH <7.5; 700 mm rainfall between application and sowing the plant-back crop.
		18 months	Soil pH 7.6-8.5.
Tribenuron methyl	2(B)	Unknown	Registered for use in fallows.
Triclopyr + picloram + aminopyralid	4(I)	4 months*	Rates 0.2 L/ha.
		6 months	Rates 0.4 L/ha.

*Plant-back period may be significantly longer under drought conditions (i.e. less than 100 mm of rainfall over 4 or more months). This is a guide only – always read and follow product label directions.
Residual herbicide activity can be influenced by application rate, soil clay content, temperature, humidity, rainfall, soil moisture and soil organic matter.
Where fields have been treated with herbicides with no plant-back recommendations to cotton, determine cotton tolerance by growing through to maturity on a smaller scale before sowing larger areas.

Manual chipping or rogueing

Ideally suited to dealing with low densities of weeds, especially those that occur within the crop row, manual chipping (using an implement like a hoe) or rogueing (pulling weeds out) is normally used to supplement inter-row cultivation or spraying. As a tool to prevent survivors setting seed, chipping has been shown to be a very cost effective option.

Spot spraying

Spot sprayers can be a cheaper alternative to manual chipping for controlling low densities of weeds in-crop. Ideally, spray remaining or recently emerged weeds with a relatively high label rate of a herbicide from a different mode of action group to the herbicides most recently used to ensure that all weeds are controlled. This intensive tactic can be particularly useful for new weed infestations where weed numbers are low, or where weeds are outside the field and difficult to get to, such as roadside culverts.

New weed detection technologies provide an opportunity to use spot spraying (optical sprayers; e.g. See & Spray™, WeedSeeker® and WEED-IT) across large areas of fallow. This can provide an opportunity to reduce herbicide costs, while still ensuring robust label rates are applied to problem weeds. In addition, the development of green-on-green technology has the potential to add flexibility into the spraying operation by targeting weeds in-crop. Note that not all herbicide products have registrations for use with optical spot sprayer technology (OSST).

Refer to the herbicide label for specific information, such as plant-back limitations relevant to the rate applied. Follow manufacturer recommendations for speed and nozzle type, as well as allowable products to ensure each application is effective.

Check the APVMA website for the most up-to-date information regarding herbicide registrations and off-label permits: portal.apvma.gov.au/pubcris and portal.apvma.gov.au/permits

Fallow management

Weed management in the fallow is an important component of a weed management plan. Summer fallows following a Roundup Ready Flex® cotton crop where only glyphosate was used for weed control poses the greatest risk to glyphosate resistance developing. Continued use of glyphosate for controlling summer weeds means that these weeds are only exposed to one mode of herbicide action.

The Herbicide Resistance Management Strategy (HRMS; pages 97-100) recommends at least two non-glyphosate tactics in summer fallows in addition to two non-glyphosate tactics in the cotton crop. Residual herbicides and double knock tactics provide good alternatives in fallows (Table 21). For larger weeds that may be tolerant to herbicides, a strategic cultivation or manual chipping is recommended. Set up field activities such as fertiliser placement and bed cultivators to have adequate soil disturbance to eradicate weeds during these mechanical tasks, and this will lessen the pressure to control weeds with further actions.

In-crop tactics

Pre-plant/at planting

Prior to planting there is an excellent opportunity to incorporate a non-glyphosate herbicide or combination of herbicides, or to integrate cultivation with a pre-planting operation such as seed bed preparation. In irrigation systems, consider utilising pre-irrigation to cause a flush of weeds to emerge and be controlled using a non-glyphosate tactic before the cotton emerges.

Herbicides from Groups 5(C), 14(G), 4(I), 22(L), 9(M), 10(N) and 34(Q) can be used to target weeds that have emerged in the field (see the HRMS diagram on page 95). This can be made more effective when used as a double knock.

Residual herbicides remain active in the soil for months and can act on successive weed germinations. This can be particularly effective in managing the earliest flushes of in-crop weed, when the crop is too small to compete. Broadleaf and grass weeds can be targeted with residual herbicides from Groups 5(C), 3(D) or 15(K).

Most residual herbicides need to be incorporated into the soil for optimum activity. Adequate incorporation of some residual herbicides is achieved through rainfall or irrigation, but others require cultivation. Soil surfaces that are cloddy or covered in stubble may need some pre-treatment such as light cultivation or burning to prevent 'shading' during application. Ash from burnt stubble may inactivate the herbicide, and must be dissipated with a light cultivation or rainfall prior to herbicide application.

Crop safety is an important consideration when using residuals. How the herbicide moves in the soil following incorporation will depend on soil type, bed formation, solubility of the herbicide, the ability of the herbicide to bind to the soil and organic matter content, and the volume and timing of rainfall/irrigation, in addition to the method of applying irrigation. Growers can influence crop safety by the choice of herbicide, when it is applied, application rate, planting depth, planting date (to promote rapid crop establishment) and moisture management. Always follow label directions, and if you are inexperienced in the use of residuals in cotton you should discuss your circumstances with your consultant, chemical supplier or the manufacturer.

Residual herbicide persistence needs to be considered in order to avoid impacts on rotation crops. Persistence is complex – determined by factors including application rate, soil texture, organic matter levels, soil pH, rainfall/irrigation, temperature and the herbicide's characteristics.

For example, it is not usually the volume of rain, but the length of time the soil is moist that is the critical factor. Microbes that degrade many herbicides live near the soil surface and require moist soil to flourish. A couple of storms, where the soil surface dries out quickly, won't contribute as much to residue breakdown as a period of rain that moistens the soil surface for days. Refer to product labels for more information. If you suspect that a residual may still be active in the lead up to planting, look for the presence of susceptible weeds in the treated paddock or pot up soil from treated and untreated areas, sow the susceptible crop and compare emergence.

TABLE 22: Examples of plant-backs to cotton for Group 4 herbicides used in seedbed preparation

Active ingredient	2,4-D amine 700 g/L			dicamba 700 g/L			fluroxypyr 333 g/L			triclopyr 600 g/L
Rate (L/ha)	0.5	0.5-1.0	1.0-1.5	0.14	0.20	0.40	0.375	0.75	1.50	0.16
Plant-back ¹ (days)	10	14	21	7	7	14	14	14	28	14

¹ If applied to dry soil, at least 15 mm rain is required before plant-back period begins.

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In the 2024/25 cotton season, Metagen ran over 15 cotton field trials across 750 hectares from QLD's Darling Downs to Hay, NSW. Results showed an **average yield increase of 0.56 bales/ha** and a **return on investment of 3.6** when using Digester NP.

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TABLE 23: Efficacy of knockdowns in winter fallows measured 6 weeks after treatment

Herbicide	Weed control (%)			
	1-month-old		3-month-old	
Glyphosate + Tordon 75-D® (fb) Spray.Seed®	99	(97-100)	97	(92-100)
Glyphosate + 2,4-D (fb) Spray.Seed®	96	(93-100)	93	(87-97)
Glyphosate + 2,4-D (fb) Alliance®	96	(92-99)	90	(78-100)
2,4-D (fb) Spray.Seed®	97	(97-98)	83	(68-97)
Amitrole®#	90	(84-95)	96	(95-97)
Glyphosate + Tordon 75-D®	93	(86-99)	84	(62-98)
Glyphosate + 2,4-D	84	(62-100)	76	(63-96)
2,4-D#	88	(81-95)	53	(48-57)
Spray.Seed®#	84	(78-89)	22	(13-30)

Brackets indicate the range of efficacy across the experiments.
fb = followed by at a 7-day interval
= applied in only two of the four field experiments
Source: Steve Walker (QAAFI, University of Queensland), Michael Widderick, Andrew McLean and Jeff Werth (Qld DPI).

Where there is a concern, consider planting an alternative crop that is tolerant of the herbicide, or if cotton is to be used, plant the paddock last and pre-irrigate (if it is to be irrigated). Always ensure that best practice is followed in terms of capture and management of runoff water.

Post-emergence

Once cotton has emerged there are still many opportunities to incorporate different tactics. Check labels for application restrictions based on node development.

When targeting the over the top (OTT) application of glyphosate (Roundup Ready Flex®), aim to treat actively growing weeds, and do not allow weeds to become too large. Avoid using the same herbicide to control

successive generations of weeds, and ensure survivors are not able to set seed. Do not apply more than the allowable number of OTT applications. Refer to the 'Herbicide tolerance technology' section later in this chapter for more information.

Grass selective herbicides (Group 1/A) can be applied over the top of cotton, however repeated use is likely to lead to the development of Group 1(A) resistance (it is already present in several species). It is important that in managing glyphosate resistance, that resistance to other herbicides doesn't develop. Use Group 1(A) herbicides sparingly and ensure any survivors are controlled before they set seed, using another tactic, such as manual chipping.

Some metolachlor registrations now include over the top use in-crop from 4 node up to 18 node crop growth and can be used with glyphosate to provide additional residual control of grass weeds. If leaf spotting is a concern, use a directed or shielded spray. Other lay-by/shielded spray options include herbicides in Groups 5(C), 3(D), 14(G), and 15(K). Check the label to confirm usage is allowed for each product in your situation and for crop safety directions.

In-crop cultivation, and (if required) chipping, provide important non-herbicide options for controlling herbicide survivors. Cultivating when the soil is drying out is the most successful strategy for killing weeds and will reduce the damage to soil caused by tractor compaction and soil smearing from tillage implements. Take care during set-up to minimise crop damage. Be aware that inter-row cultivation may exacerbate issues with some soil-borne pathogens.

Post-harvest

Some weeds are likely to be present in the crop later in the season – even in the cleanest crop. While these weeds will produce few seeds in a competitive cotton crop, they can be very problematic in skip-row configurations or can take advantage of the open canopy created by defoliation and picking. Removing crop residues and weeds as soon after picking as practical greatly reduces the opportunity for these weeds to set seed. See also 'Management of volunteer and ratoon cotton' later in this chapter.

TABLE 24: Cotton herbicide plant-backs to rotation crops

Active ingredient	Plant-backs from cotton to rotation crops (months)																			
	Cereal grain-crops								Legume crops								Other crops			
	Barley	Maize	Millet	Oats	Sorghum	Triticale	Wheat	Adzuki bean	Chickpea	Cowpea	Faba bean	Field pea	Lablab	Lupin	Lucerne	Mungbean	Pigeon pea	Soybean	Canola	Safflower
Diuron	24	24	24	24	24	24	24	24	24	24	24	24	24	24	12	24	24	24	24	24
Fluometuron + prometryn	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Halosulfuron-methyl	24	2	24	24	2	24	3	24	24	24	24	24	24	24	24	24	24	24	24	24
Metolachlor	6	0	6	6	0 ¹	6	6	6	6	6	6	6	6	6	6	6	6	0	6	6
Pendimethalin	6	0 ²	12	12	12	—	—	—	—	—	—	—	—	—	6	—	—	—	6	—
Prometryn	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
S-Metolachlor	6	0	6	6	0 ¹	6	6	6	6	6	6	6	6	6	6	6	6	0	6	6
Trifloxysulfuron sodium	6	22	22	6	22	22	6	22	18	22	7	22	22	22	22	9	15	15	22	22
Trifluralin	12	12	12	12	12	12	12	FH	FH	FH	FH	FH	FH	FH	FH	FH	FH	FH	FH	FH

¹ Concep® II treated seed only.
² Maize can be resown immediately post-use in a failed crop provided it is sown below treated band of soil.
FH = following cotton harvest
— = no information

For further information see Weed control section in Summer and Winter Crop Publications from NSW DPIRD.

Notes on herbicide use

Note that registration of a herbicide does not constitute a recommendation for its use in a particular situation. The information in this publication is presented as a guide only to assist growers in planning their herbicide programs. Satisfy yourself that the product (or products) used is the best choice for the crop and weed. Carefully study the container label before using any herbicide, noting any specific instructions relating to mixing, rates, timing, application and safety.

IMPORTANT – avoid spray drift

Cotton crops are particularly sensitive to spray drift from Group 4 herbicides (phenoxy herbicides including 2,4-D), and every year there are reports of damage.

Take every precaution to minimise the risk of causing or suffering spray drift damage from ANY herbicide application:

- Plan your crop layout to avoid sensitive areas.
- Ensure spray contractors have details of any nearby sensitive areas.
- Consult with neighbours to minimise risks from spraying near property boundaries, refer to SataCrop at satacrop.com.au.
- Carefully follow all label directions.
- Pay particular attention to weather conditions before application (and use the WAND tower network to identify potential hazardous inversion conditions).
- Use buffer zones to reduce the impact of spray drift or over-spray.
- Keep detailed records.

See the *Spray application* chapter for more details. |||

USEFUL RESOURCES:

The **Australian Cotton Production Manual** also includes information on weed control tactics (including calculations for band spraying).

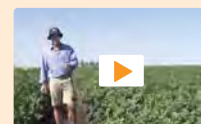
cottoninfo.com.au/publications/australian-cotton-production-manual



A range of weed-related videos can be found on the CottonInfo YouTube channel, including:

- IWM in cotton
- Late season weeds
- Sources of weed seed
- Minimising glyphosate resistance

www.youtube.com/CottonInfoAust



The WeedSmart website contains a wide range of resources articles, podcasts, case studies and webinar recordings on various aspects of weed management.

www.weedsmart.org.au



The ultimate super-weed?

Palmer amaranth (*Amaranthus palmeri*) can grow more than 2 metres high. It is highly competitive with an extended germination/emergence window, rapid growth, and drought tolerance. It can survive in a wide range of environments and produces prolific amounts of seed (~1 million per plant). Populations in the USA (where it is referred to as 'pigweed') have developed resistance to multiple classes of herbicides with different modes of action, including glyphosate, 2,4-D, dicamba and glufosinate, making it very difficult and expensive to control.

While not currently present in Australia, Palmer amaranth would thrive in our cotton cropping areas. Report suspicious plants to the Exotic Plant Pest Hotline on 1800 084 881.



Eric Koetz, NSW DPIRD/CottonInfo



Jeff Werth, Qld DPI



Jeff Werth, Qld DPI

Key weeds

These common weeds of cotton have a high risk of and/or have already developed resistance within Australia to one or more herbicide mode of actions (Tables 25 to 27 list weed species with confirmed resistance to glyphosate, paraquat and 2,4-D respectively).

Note the weed species present in your fields (take into account the likely composition of the weed seed bank) and make herbicide decisions early. Many weeds in cotton are prolific seed producers, although dormancy in grasses is often less than that of broadleaf species. Learn how to recognise weed species at the seedling stage so you can target young plants and prevent seed set.

Terms and symbols used in the specific management suggestions in this section include:

fb	followed by (as a herbicide double knock)
IBS	incorporation by sowing
OSST	optical spot spray technology
PPI	pre-plant incorporated
POST	post-emergent to crop and weeds (spraying live plants)
PRE	pre-emergent to crop and weeds
PSPE	post sowing pre-emergent application
⇒	indicates following crop or situation

Always consult herbicide label for plant backs, state registrations and application/incorporation requirements. Tradenames are provided as examples only and do not constitute an endorsement of the product.

Broadleaf weeds

The Asteraceae or 'daisy' family includes several key weed species, including the fleabanes, sowthistle, and tridax daisy. Other broadleaf species with confirmed resistance to these products can be found in Tables 25-27.

Fleabanes (*Conyza* spp.)

Often seen as roadside weeds, fleabanes (Asteraceae family) are prolific wind-dispersed seeders. Seeds have relatively low dormancy, so while they can germinate quickly from the soil surface in favourable conditions, preventing plants from setting seed set is likely to minimise fleabane species in the soil seed bank. **Flaxleaf fleabane** (*Conyza bonariensis*) is often the species of most concern within cotton production from a herbicide resistance management perspective. Plants are generally less than 1 metre tall with multiple erect branches.

Two related species also found in cotton regions are **tall fleabane** (*Conyza sumatrensis*), and **Canadian fleabane** (*Conyza canadensis*), both of which usually grow more than 1 metre high on a single stem.

Flaxleaf fleabane is an annual or short-lived perennial that can germinate from seeds on the soil surface. It can emerge in late autumn or early winter, growing very slowly above ground while developing an extensive root system, allowing it to grow quickly when spring temperatures increase. A combination of poor control by glyphosate and prolific fecundity (up to 100 000 seeds/plant) has contributed to its success. Flaxleaf fleabane is very small seeded, and very susceptible to cultivation, and it has become a difficult weed to control with the move to reduced or zero tillage.



Flaxleaf fleabane. © Graham Charles and Eric Koetz, NSW DPIRD

For effective control of flaxleaf fleabane, a long term integrated farming system approach is needed (over at least 2-3 years), using a combination of pre- and post-emergent herbicides, crop competition, spot spraying and cultivation.

Fleabane should also be managed in non-crop areas, such as roads, irrigation channels and fence lines, to prevent re-infestation into the cropping area.

Key pre-emergent herbicides:

- Isoxaflutole (Balance®) at 100 g/ha ⇒ Fallow
- Terbutylazine (Terbyn Xtreme®) at 0.86-1.2 kg/ha PSPE or lay-by ⇒ Cotton
- Flumioxazin (Valor®) at 210 to 280 g/ha ⇒ Fallow; 180 g/ha IBS ⇒ Chickpea
- Saflufenacil (Sharpen®) at 34 g/ha ⇒ late application in Wheat
- Saflufenacil + trifludimoxazin (Voraxor®) at 200 mL/ha PRE ⇒ Wheat and Barley.

Key post-emergent herbicides:

- Xtendimax® 2 at 1.17 L/ha + Roundup Ready® PL at 1.9 L/ha + 1% v/v VapourGrip® Xtra ⇒ Xtendflex® cotton varieties (see label for application restrictions)
- Glufosinate (Biffo®) at 3.75 L/ha ⇒ Fallow and Xtendflex® cotton varieties, or at 10 L/100 L OSST ⇒ Fallow (less than 30% weed cover)
- Research has shown the Xtendimax® + Roundup Ready® PL fb Biffo® provides consistent control
- 2,4-D (Colex-D®) fb paraquat at 1 (autumn/winter) to 1.69 (spring/summer) L/ha fb 1.6-2 L/ha ⇒ Fallow; 6.16 L/ha OSST ⇒ Fallow (less than 30% weed cover)
- Clopyralid (Lontrel® Advanced) at 150 mL/ha ⇒ Winter cereals
- Paraquat (Gramoxone® 360 Pro) at 4.17 to 6.25 L/100L OSST ⇒ Fallow (less than 30% weed cover).



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Red pigweed (*Portulaca oleracea*)

A prostrate, succulent annual herb germinating in spring and summer that often forms dense mats. It has the potential to produce up to 240 000 seeds/plant. Seeds are very small, but also very hard and can persist in the soil for extended periods.

Weed fragments created by cultivation can regrow if not fully desiccated. The succulent nature of the plant means that a combination of tactics is needed to ensure control of plants beyond the seedling stage. Consider using a double knock approach combined with cultivation if possible. Monitor the field to ensure adequate control has been achieved. The use of pre-emergent herbicides with post-emergent follow-up will likely achieve satisfactory control. Due to red pigweeds high fecundity and persistence in the seed bank, it is critical to prevent seed production.

Key pre-emergent herbicides:

- Fluometuron + prometryn (Cotogard® WG) at 1.4–2.9 kg PRE or 1.7–2.9 kg/ha PSPE or 855 g to 1.4 kg/ha EPOST or 1.1 to 1.9 kg/ha directed ⇒ Cotton
- Diuron at 1–2 kg/ha PSPE or lay-by ⇒ Cotton
- Pendimethalin (Stomp® Xtra) at 2.2 L/ha PPI or 3.3 L/ha PSPE ⇒ Cotton
- Terbutylazine (Terbyne Xtreme®) at 0.86–1.2 kg/ha PSPE or lay-by ⇒ Cotton; 1.2 kg/ha PRE or PSPE ⇒ Sorghum
- Trifluralin (TriflurX®) at 1.2–2.3 L/ha PPI ⇒ Cotton
- Flumioxazin (Valor®) at 210 to 280 g/ha ⇒ Fallow; 90 g/ha lay-by ⇒ Cotton.

Key post-emergent herbicides:

- Aminopyralid + fluroxypyr (Hotshot®) at 500 ml/ha + glyphosate ⇒ Fallow
- Roundup Ready® PL at 660 mL to 1.9 L/ha ⇒ Cotton
- Fluroxypyr (Starane® Advanced) at 300–450 mL/ha ⇒ Sorghum/Maize/Millet
- Xtendimax® 2 at 335 mL to 1.17 L/ha + 1% v/v VapourGrip® Xtra ⇒ Xtendflex® cotton varieties (see label for application restrictions)
- Paraquat + diquat (Spray.seed®) at 2.4 L/ha ⇒ Fallow
- Glufosinate (Biffo®) at 3.75 L/ha ⇒ Fallow and Xtendflex® cotton varieties.



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Sowthistle (*Sonchus oleraceus*)

A surface germinating, prolific (up to 25 000 seeds/plant), wind-dispersed weed that can emerge all year round. Seed have no innate dormancy and are able to germinate straight away. Sowthistle is somewhat susceptible to seed burial with 30–50% of seed buried below 2 cm persisting and remaining viable. Seed left on the surface for six months resulted in less than 5% being viable. Seed buried at depths of 5 to 10 cm can remain viable for over 30 months.

A long term (2–3 years), whole farm, integrated approach is needed for its effective control. It can be controlled using a combination of pre- and post-emergent herbicides, crop competition, spot spraying and cultivation. Sowthistle should also be managed in non-crop areas, such as roads, irrigation channels and fence lines, to prevent re-infestation into the cropping area.

Key pre-emergent herbicides:

- Isoxaflutole (Balance®) at 100 g/ha ⇒ Fallow; PSPE Chickpeas
- Terbutylazine (Terbyne Xtreme®) at 0.86–1.2 kg/ha PSPE or lay-by ⇒ Cotton; 1.2 kg/ha PRE or PSPE ⇒ Sorghum; 0.86–1.2 kg/ha PRE or PSPE ⇒ Chickpeas
- Flumioxazin (Valor®) at 210 to 280 g/ha ⇒ Fallow; 120 g/ha IBS ⇒ Wheat (not Durum)
- Saflufenacil (Sharpen®) at 34 g/ha ⇒ late application in Wheat
- Saflufenacil + trifludimoxazin (Voraxor®) at 200 mL/ha PRE ⇒ Wheat and Barley.

Key post-emergent herbicides:

- Xtendimax® 2 at 1.17 L/ha + Roundup Ready® PL 1.9 L/ha + 1% v/v VapourGrip® Xtra ⇒ Xtendflex® cotton varieties (see label for application restrictions)
- Glufosinate (Biffo®) at 3.75 L/ha ⇒ Fallow and Xtendflex® cotton varieties
- Research has shown the Xtendimax® + Roundup Ready® PL fb Biffo provides consistent control
- 2,4-D (Colex-D®) at 430 mL/ha to 1.25 L/ha ⇒ Fallow; 6.16 L/ha OSST ⇒ Fallow (less than 30% weed cover)
- Paraquat (Gramoxone® 360 Pro) at 4.17–6.25 L/100L OSST ⇒ Fallow (less than 30% weed cover).



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Tridax daisy (*Tridax procumbens*)

Also known as 'coat buttons', tridax daisy is a perennial, semi-prostrate herb with 'toothed' leaves and small daisy-like flowers on hairy stems about 30 cm long. It is a common environmental weed in the tropics and sub-tropics and is particularly hard to control once a taproot establishes. Glyphosate resistance was first reported in the Ord region in 2016.

It produces at least 1500 wind-bourne seeds per plant, and is becoming a dominant species in many northern cotton production areas. Feathery bristles on the seed allow it to attach to people and vehicles as a hitchhiker. It can also develop roots where stem nodes touch the ground.

Tridax daisy is also a potential host for cotton aphid, silverleaf whitefly, two spotted mites and charcoal rot.



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Grasses

Annual ryegrass (*Lolium rigidum*)

A cool season annual grass with high seed production (up to 45 000 seeds per plant). Seed typically germinates in autumn, winter and spring and forms a persistent soil seed bank with seeds viable for several years. This species is notorious for herbicide resistance, with resistance to a number of modes of action. Management tactics:

- Use tillage to bury seed at depth to minimise emergence
- Use double knocks to ensure clean fields prior to planting a crop
- Use a combination of pre- and post-emergence herbicides to reduce emergences and control escapes
- Ensure no plants are able to set seed
- Undertake resistance testing of control failures.

Key pre-emergent herbicides:

- Prosulfocarb + S-Metolachlor (Boxer Gold®) at 2.5 L/ha PRE/IBS or 1.75 L/ha PRE/IBS fb 0.75 L/ha POST or 2.5–3 L/ha POST ⇒ Wheat and Barley, or 2.5 L/ha PRE/IBS ⇒ Chickpeas
- Fluometuron + prometryn (Cotogard® WG) at 1.4–2.9 kg PRE or 1.7–2.9 kg/ha PSPE or 855 g to 1.4 kg/ha EPOST or 1.1–1.9 kg/ha directed ⇒ Cotton
- Diuron at 1–2 kg/ha PSPE or lay-by ⇒ Cotton
- Aclonifen + pyroxasulfone + diflufenican (Mateno® Complete) at 0.75–1.0 L/ha PRE/IBS ⇒ Wheat (not durum)
- Trifluralin (TriflurX®) at 1.2–2.3 L/ha PPI ⇒ Cotton
- Pyroxasulfone (Sakura®) at 118 g/ha PRE/IBS ⇒ Chickpeas, Wheat (not durum)
- Cinmethylin (Luximax®) at 500 mL/ha PRE/IBS ⇒ Wheat (not durum)
- Tri-allate (Avadex® Xtra) at 3.2 L/ha PRE or PRE/IBS ⇒ Wheat, Barley.

Key post-emergent herbicides:

- Clethodim (Platinum® Xtra 360) at 165–330 mL/ha ⇒ Cotton
- Butoxydim (Encode® 500 WG) at 40–90 g/ha ⇒ Chickpeas, Faba beans
- Haloxypol at 75–100 mL/ha ⇒ Chickpeas, Faba beans
- Saflufenacil (Sharpen®) at 17–34 g/ha plus label rate of glyphosate or paraquat ⇒ Fallow
- Saflufenacil + Trifludimoxazin (Voraxor®) at 100 mL/ha plus label rate of glyphosate or paraquat ⇒ Fallow
- Roundup Ready® PL at 660 mL to 1.9 L/ha ⇒ Cotton
- Paraquat (Gramoxone® 360 Pro) at 1.1–1.67 L/ha ⇒ Fallow.



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Awnless barnyard grass (*Echinochloa colona*)

A small seeded, fast growing annual grass that can produce up to 40,000 seeds per plant and is a strong competitor in no-till cropping and fallow systems.

The key to its management lies in managing the seed bank and preventing new seed from entering the soil:

- Use tillage to bury seed, and pre-emergent herbicides to reduce numbers of seedlings emerging
- Monitor emergence and control weeds when small
- Use double knocks to control plants and prevent seed set.

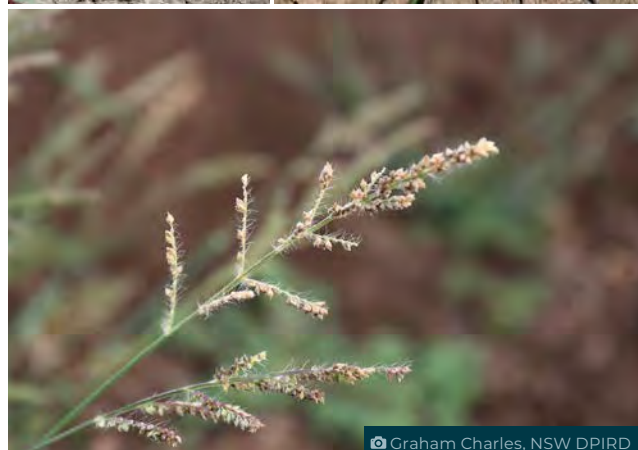
Awnless barnyard grass can last in the seed bank for up to 4 – 5 years. Targeted management for this period of time will have a major impact on driving down the seed bank.

Key pre-emergent herbicides for reducing emergences:

- S-Metolachlor (Dual Gold®) at 1 L/ha PRE/PSPE or OTT/directed @ 4-8 nodes ⇒ Cotton, or 1-2 L/ha ⇒ Fallow
- Pendimethalin (Stomp® Xtra) at 2.2 L/ha PPI or 3.3 L/ha PSPE ⇒ Cotton
- Flumioxazin (Valor®) at 210–280 g/ha ⇒ Fallow
- Diuron at 1-2 kg/ha PSPE or lay-by ⇒ Cotton
- Isoxaflutole (Balance®) at 100 g/ha ⇒ Fallow (suppression).

Key post-emergent herbicides:

- Haloxypol at 150 mL/ha fb paraquat 1.6–2.4 L/ha ⇒ Fallow; 100–150 mL/ha ⇒ Cotton
- Clethodim (Platinum® Xtra 360) at 165–330 mL/ha ⇒ Cotton
- Paraquat (Gramoxone® 360 Pro) at 2.08–6.25 L/100L OSST ⇒ Fallow (less than 30% weed cover)
- Glufosinate (Biffo®) at 10 L/100 L OSST ⇒ Fallow (less than 30% weed cover)
- Research has shown that the combination of clethodim (330 ml/ha) fb glufosinate (3.75 L/ha) at a 7–10 day interval provides control.
- Roundup Ready® PL at 660 mL to 1.9 L/ha ⇒ Cotton.



• Feathertop Rhodes grass (*Chloris virgata*)

A small-seed annual that can produce >40,000 seeds per plant. It can germinate after rainfall events as small as 5 mm, and is capable of producing seed 6 weeks after germination. Often recruiting more than one cohort per year, this weed can germinate across a wide range of temperatures. It can establish quickly on lighter textured soils, but rapidly becomes stressed under dry conditions.

The key to its management lies in managing the seed bank and preventing new seed from entering the soil by:

- Using strategic deep tillage to bury seed, and pre-emergent herbicides to reduce numbers of seedlings emerging
- Monitoring emergences and controlling seeds when they are small
- Utilising the double knock tactic to control plants and prevent seed set.

Target all stages of the lifecycle and ensure control of plants in non-crop areas. Its seed bank life is relatively short (approximately 2 years), so intensive management for up to two years will have a major impact.

Key pre-emergent herbicides for reducing emergences:

- Isoxaflutole (Balance®) at 100 g/ha ⇒ Fallow
- S-Metolachlor (Dual Gold®) at 1 L/ha ⇒ Cotton – PRE/PSPE or OTT/directed @ 4–8 nodes, or 1-2 L/ha ⇒ Fallow
- Flumioxazin (Valor®) at 210–280 g/ha ⇒ Fallow.
- Key post-emergent herbicides:
- Haloxypol at 150 mL/ha fb paraquat 1.6–2.4 L/ha ⇒ Fallow
- Clethodim (Platinum® Xtra 360) at 165–330 mL/ha ⇒ Cotton
- Research has shown that the combination of clethodim (330 ml/ha) fb glufosinate (3.75 L/ha) at a 7–10 day interval provides control



Liverseed grass (*Urochloa panacoides*)

A prolific seeding annual summer grass favoured by reduced tillage systems. Seedlings have much broader leaves than most grass weeds. Fresh seed has a strong dormancy and therefore most seed germinates in the following season, with emergence usually occurring in one large mid-spring to early summer flush. Seed viability on the surface is short but persistence increases with seed burial.

- Shallow tillage can be effective on seedlings as the majority of seedlings emerge from the top 5 cm
- Avoid burying seed as this will increase their persistence in the soil seedbank (20% survival at 20 cm after 2 years)
- Double knock tactics at robust rates can reduce grass seed production on survivors from several thousand seeds per square metre to zero.

Target small weeds (2-3 leaves) when using knockdown herbicides. Effective management over 2-3 years in zero tilled systems can therefore reduce the seed-bank to minimal levels.

Seed production on surviving weeds can be markedly reduced by increasing crop competition. Rotating to sorghum in solid 1 m rows with a high planting rate can reduce seed bank replenishment by more than half.

Key pre-emergent herbicides:

- S-Metolachlor (Dual Gold®) at 1 L/ha ⇒ Cotton – PRE/ PSPE or OTT/directed @ 4–8 nodes, or 1–2 L/ha ⇒ Fallow
- Pendimethalin (Stomp® Xtra) at 2.2 L/ha PPI or 3.3 L/ha PSPE ⇒ Cotton
- Flumioxazin (Valor®) at 210–280 g/ha ⇒ Fallow
- Diuron at 1–2 kg/ha PSPE or lay-by ⇒ Cotton.

Key post-emergent herbicides:

- Haloxypol at 150 mL/ha fb paraquat 1.6–2.4 L/ha ⇒ Fallow
- Clethodim (Platinum® Xtra 360) at 165–330 mL/ha ⇒ Cotton
- Glufosinate (Biffo®) at 3.75 L/100 L ⇒ Fallow
- Roundup Ready® PL at 660 mL to 1.9 L/ha ⇒ Cotton.



Windmill grass (*Chloris truncata*)

A short-lived perennial species that has recently been identified as resistant to glyphosate. Summer dominant and a prolific seeder (>20,000 per plant), germination occurs throughout spring, summer and autumn, however peak emergence occurs with increasing soil moisture in September–October.

The increase in prevalence of this weed coincides with zero tillage practices as seed is dispersed by wind onto the soil surface. Management tactics include:

- Using tillage to bury seed
- Monitoring emergences and control weeds when they are small
- Using double knocks to control plants and prevent seed set.

Seed persistence in the soil is short lived and seeds struggle to emerge from deeper than 3 cm. Stopping seed-set for up to two years will deplete the soil seed bank. The double knock tactic is most effective on windmill grass when applied before early tillering.

No pre-emergent herbicides are registered for control of windmill grass, however herbicides used for feathertop Rhodes grass may provide some control. Key post-emergent herbicides include:

- Haloxypol at 150 mL/ha fb paraquat 1.6–2.4 L/ha ⇒ Fallow
- Butroxydim (Encode® 500 WG) at 60–90 g/ha ⇒ Cotton
- Research has shown that the combination of clethodim (330 mL/ha) fb glufosinate (3.75 L/ha) at a 7–10 day interval provides control.

III



Herbicide resistance management

The Australian lettering mode of action (MoA) classification system for herbicides changed in 2021 to match the international numbering system. Both systems are included in this edition for ease of reference. A searchable database of Australian herbicide classifications is available at

croplife.org.au/resources/programs/resistance-management/herbicide-moa-alignment

Weed populations are naturally genetically diverse, so it is likely that a small number of individuals may exist that are able to survive exposure to a particular herbicide mode of action (MoA). When a herbicide from this MoA is used upon the population, individuals that have this gene present may survive and set seed, whereas the majority of plants without the gene (susceptible plants) are killed. While it might only be one or two individuals surviving at first, continued use of the same herbicide MoA will result in an ever-increasing proportion of the population being able to survive those herbicide applications. In Australia, herbicides are currently grouped according to their MoA which is represented by a number code on the label and are ranked according to their resistance risk. Research has shown that weeds can develop resistance to any single control tactic used alone, not only herbicidal ones. For example, regular mowing of annual bluegrass, *Poa annua*, in golf courses selected strains for lower grass seed heads, which is essentially a resistance to mechanical control.

By Mid-2025, there were 534 unique cases (species x mode of action) of herbicide resistant weeds recorded globally across 273 species. Weeds have evolved resistance to 21 of the 31 known herbicide sites of action and to 168 different herbicides, and herbicide-resistant weeds have been reported in 101 crops in 72 countries.

While historically the Australian cotton industry has had a strong integrated weed management system, the extensive use of herbicide tolerant cotton varieties since 2006 has led to an over-reliance on glyphosate. More than half of the confirmed glyphosate-resistant weed species in Australia listed in Table 25 occur widely in cotton farming systems.

TABLE 25: Glyphosate-resistant weeds in Australia

Grasses	First documented
Annual ryegrass (<i>Lolium rigidum</i>)	1996*
Awnless barnyard grass (<i>Echinochloa colona</i>)	2007*
Liverseed grass (<i>Urochloa panicoides</i>)	2008
Windmill grass (<i>Chloris truncata</i>)	2010
Great brome (<i>Bromus diandrus</i>)	2011
Red brome (<i>Bromus rubens</i>)	2014
Sweet summer grass (<i>Brachiaria eruciformis</i>)	2014
Feathertop Rhodes grass (<i>Chloris virgata</i>)	2015*
Winter grass (<i>Poa annua</i>)	2017
Northern barley grass (<i>Hordeum glaucum</i>)	2018
Wild oats (<i>Avena</i> spp.)	2018
Johnson grass (<i>Sorghum halapense</i>)	2019
Broadleaf weeds	
Flaxleaf fleabane (<i>Conyza bonariensis</i>)	2010*
Wild radish (<i>Raphanus raphanistrum</i>)	2010
Sowthistle (<i>Sonchus oleraceus</i>)	2014*
Prickly lettuce (<i>Lactuca serriola</i>)	2014
Tridax daisy (<i>Tridax procumbens</i>)	2016
Tall fleabane (<i>Conyza sumatrensis</i>)	2017
Willow-leaved lettuce (<i>Lactuca saligna</i>)	2017
Capeweed (<i>Arctotheca calendula</i>)	2021

*Resistance documented at more than 100 sites within Australia.

An industry-wide strategy

Experience with conventional insecticide resistance has encouraged a proactive culture to resistance issues within the Australian cotton industry. The Herbicide Resistance Management Strategy (HRMS) draws together available information, enabling growers and agronomists to understand and manage the risks of herbicide resistance in Australian cotton farming systems.

The HRMS enables you to determine which other weed control tactics can be incorporated into your management system by providing guidance on how much extra time they will give you until resistance develops, and demonstrating the effect they will have on the weed seed bank, which is critical to effectively managing resistance.

Non-cropping areas and the HRMS

Areas adjacent to cotton fields such as irrigation channels, head ditches, tail drains, roadways, fence lines and areas next to stock routes can be a significant entry source for resistant weed seeds. Where possible, use a range of tactics to manage weeds in these areas, and do NOT rely on glyphosate to manage weeds in these areas. Prevent survivors of herbicide application from setting seed.

TABLE 26: Species that have developed resistance to paraquat (Group 22/L) in Australia

Species	Common name	Year	State	Crop	Resistance to other MoAs/herbicides
<i>Hordeum glaucum</i>	Northern barley grass	1983	Vic	Lucerne	Diquat (22/L)
<i>Arctotheca calendula</i>	Capeweed	1984	Vic	Lucerne	Diquat (22/L)
<i>Hordeum leporinum</i>	Barley grass	1988	Vic	Lucerne	Diquat (22/L)
<i>Vulpia bromoides</i>	Silver grass	1990	Vic	Lucerne	Diquat (22/L)
<i>Mitracarpus hirtus</i>	Small square weed	2007	Qld	Mangoes	Diquat (22/L)
<i>Lolium rigidum</i>	Annual ryegrass	2010	SA	Pasture seed	1(A)/9(M) – 2 populations
<i>Gamochaeta pensylvanica</i>	Cudweed	2015	Qld	Tomatoes, sugarcane	
<i>Solanum nigrum</i>	Blackberry nightshade	2015	Qld	Tomatoes, sugarcane	
<i>Eleusine indica</i>	Crowsfoot grass	2015	Qld	Tomatoes, sugarcane	
<i>Conyza bonariensis</i>	Flaxleaf fleabane	2016	NSW	Grape vines	
<i>Conyza sumatrensis</i>	Tall fleabane	2018	Qld	Wheat/fallow	



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Rotate crops and pastures

Crop and pasture rotation is the recipe for diversity

- Use break crops and double break crops, fallow and pasture phases to drive the weed seed bank down.
- In summer cropping systems, use diverse rotations of crops including cereals, pulses, cotton, oilseed crops, millets and fallows.
- Add greater diversity to weed management strategies by adopting herbicide tolerance traits.

Increase crop competition

Optimise crop growth

- Adopt at least one competitive strategy, but two is better.
- Target higher plant populations using increased seeding rates, weed-free seed tested for germination, vigour and 1,000 seed weight.
- Aim for even seed distribution and establishment.
- Sow competitive crop types and varieties.
- Improve soil health (fertility and structure) and crop nutrition, e.g., soil amelioration (if necessary), no-till, stubble retention, nutrient budgeting.
- Utilise early sowing and adopt East/West sowing if practical.
- Reduce row spacing where possible.

Mix and rotate herbicides

Rotating buys you time, mixing buys you shots

- Rotate between herbicide modes of action.
- Mix different modes of action within the same herbicide mix or in consecutive applications.
- Always use full label rates.
- Incorporate multiple modes of action in a double knock e.g., glyphosate/ Group 1/Group 2 knockdown followed by paraquat and Group 14 and pre-emergent herbicide.
- Test weeds for resistance to know what herbicides will and won't work for you.
- In cotton systems, aim to target both grasses and broadleaf weeds using two non-glyphosate tactics in crop and two non-glyphosate tactics during the summer fallow, and always remove any survivors (2 + 2 & no survivors).

Optimise spray efficacy

Make every droplet count

- To maximise efficacy and reduce spray drift, follow spray application guidelines and ensure the correct speed, nozzles, water volume, boom height, and adjuvants are used. Avoid antagonistic tank mixes.
- Always use the largest spray droplet feasible that gives the highest efficacy and consider water quality.
- Avoid spraying during inversions (particularly from evening through to early morning), in high temperatures, frost and dew conditions, and when the wind speed is below 5km/h or above 20km/h.

Stop weed seed set

Take no prisoners

- Aim for 100% control of weeds and diligently monitor for survivors in all post weed control inspections.
- Crop top or pre-harvest spray in crops to manage weedy paddocks.
- Consider hay or silage production, brown manure or long fallow in high-pressure situations.
- Use all appropriate strategies in the pasture phase to reduce the weed seed bank prior to cropping phase.
- Consider shielded spraying, optical spot spraying technology, targeted tillage, inter-row cultivation or chipping.
- Windrow (swath) to collect early shedding weed seed.
- Use two or more different weed control tactics (herbicide or non-herbicide) to control survivors.
- In cotton farming systems, consider late season strategic tillage operations for better overall weed and Helicoverpa pupae control.

Implement harvest weed seed control

Capture weed seed survivors

- Capture weed seed survivors at harvest using weed seed impact mills, chaff lining, chaff tramlining/decking, chaff carts, narrow windrow burning, or bale direct.
- Ensure optimal harvester set-up.



TABLE 27: Weed species with populations resistant to 2,4-D (Group 4/I)

Species	Year	State	Crop	Herbicide	Also resistant to MoAs
Wild radish <i>Raphanus raphanistrum</i>	1999	WA	Winter cereal	2,4-D	
	2006	SA	Winter cereal	2,4-D, MCPA	2(B), 12(F)
	2009	Vic	Winter cereal	2,4-D	2(B)
	2010	WA	Winter cereal	2,4-D	2(B), 12(F), 9(M)
	2011	Vic	Winter cereal	2,4-D	
	2011	NSW	Winter cereal	2,4-D	
	2013	NSW	Winter cereal	2,4-D	
Indian hedge mustard <i>Sisymbrium orientale</i>	2005	SA	Winter cereal	2,4-D, MCPA	2(B)
	2015	SA	Winter cereal	2,4-D	12(F)
	2016	Vic	Winter cereal	2,4-D	
	2016	Vic	Winter cereal	2,4-D	2(B), 12(F)
Sowthistle <i>Sonchus oleraceus</i>	2015	Vic	Winter cereal	2,4-D	
	2015	SA	Winter cereal	2,4-D, dicamba, clopyralid	
Capeweed <i>Arctotheca calendula</i>	2015	SA	Winter cereal	2,4-D	

Why does the strategy include weed seed bank as well as herbicide resistance risk?

The key to good weed management is having low weed seed bank numbers. Not only does this reduce impact on the crop, but it also reduces the herbicide resistance risk. The more weed seeds present, the more likely that an individual containing herbicide resistance genes will be present and hence become a problem.

Strategies should be aimed at driving down the seed bank and preventing seed bank replenishment. See tables B and C in the HRMS for information on seedbank levels and management options.

Do I have to adhere to the HRMS?

The HRMS is not intended to be prescriptive, and is aimed to be an industry mechanism for communicating the herbicide resistance risks from different tactics. It has been designed to present the risk related to a range of combinations of tactics, to allow growers and consultants to make their own informed decisions.

What does herbicide resistance look like?

Resistance begins 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.

For other resistance mechanisms, the symptoms may appear as a 'sick' plant that subsequently recovers and may look similar to 'underdosing' or poor application. If a



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

Assessing your own risk

For a more detailed assessment of the glyphosate resistance risks for individual paddocks, use Qld DPI's Online Glyphosate Resistance Toolkit



cottoninfo.com.au/glyphosate-resistance-toolkit

This tool allows you to check what your current level of risk is for developing glyphosate-resistant weed populations on your farm. 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. It will then calculate a glyphosate resistance risk score for the paddock, and a level of risk for each weed identified.

The **Barnyard Grass Understanding and Management (BYGUM)** tool enables the resistance risk from summer weed control to be considered in the context of economics and seed bank management.



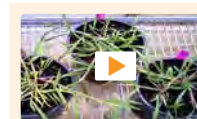
This weed management scenario testing tool combines biological, agronomic and economic factors to examine the economics of current summer grass management strategies and compare with new tactics.

cottoninfo.com.au/barnyard-grass-understanding-and-management-bygum

higher application rate is required to kill these individuals in subsequent years this indicates non-target site resistance is present.

Many of the symptoms of herbicide resistance can also be explained by other causes of spray failure. Regularly maintain and calibrate spray equipment, spray under appropriate conditions and keep good records to ensure maximum spray efficacy.

Resistant weed seeds can also be transported into fields and other farm areas through irrigation channels, vehicle tyres, or blow in on the wind (in the case of species such as fleabane), and consequently can be relatively widespread before they are noticed.



A demonstration of weed resistance

youtu.be/y73j1laiSLk



Why should I get weeds tested?

Testing plant populations for the presence of herbicide resistant individuals is an important tool for growers and advisors, as the results can confirm if there is still efficacy within some of the MoA groups. Generally, seed is collected from the suspect plants and is sent for testing (see below). It can take several months to receive results from seed samples. Results are usually available by the end of April when samples are received before January.

An alternative 'quick test' method uses actual plants from the field. The quick test is limited to grass weeds only and is best targeted at seedlings or 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. When plants are sent for Quick Tests, results are usually available within 4-8 weeks.

It is recommended to take seed samples from surviving plants in summer and mark the sites to enable seedling collections the following autumn or spring if required.

Collecting samples (seed test):

- Collect 2000-3000 seeds from plants you suspect are resistant (e.g. for barnyard grass this is about 1 cup full).
- If testing for more than 3 modes of action, collect additional seed.
- Shake seed heads into a bucket to ensure only ripe seed is collected.
- 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.
- Store samples in a paper bag at room temperature, away from sunlight, moisture and heat.
- Post as soon as possible.

Collecting plant samples (quick test):

- For each mode of action to be tested: collect 50 plants per field from areas where you suspect resistance.
- Gently pull out plants and wash roots.
- Wrap in paper towel. Do not moisten.
- Place in waterproof plastic bag.
- Collect weeds early in the week, and Express Post as soon as possible. Do not store or post over the weekend. If plants cannot be posted on the same day, store overnight in the fridge.

Sending samples to testing services

Contact one of the testing services below so they know to expect the sample. Follow the collecting instructions above and send samples together with a sample registration form (noting testing required), field and weed management history, and your contact details to:

 **Dr Peter Boutsalis**
Plant Science Consulting (Seed or Quick test)
22 Linley Avenue, Prospect SA 5082
0400 664 460
info@plantscienceconsulting.com
csu.edu.au/weedresearchgroup/herbicide-resistance

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



An annual ryegrass survivor. © Eric Koetz, CottonInfo/NSW DPIRD

How do I manage resistant weeds?

The strategy to **manage** weeds resistant to glyphosate (or other herbicide products) is similar to the strategy to **prevent** resistance – integrate a range of different tactics throughout the weed lifecycle to rapidly deplete the soil weed seed bank, and prevent further seed set/recruitment. This means that the HRMS is just as relevant to managing resistant weeds as it is preventing them.

If detected early, managing known patches of herbicide resistant weeds by applying an intensive program of different tactics and ensuring weeds do not set seed, may be effective in preventing the problem from spreading.



Minimising glyphosate resistance

youtu.be/cke-mamGe2o



This infestation 'blow-out' of glyphosate resistant barnyard grass was due to an extremely wet summer that prevented access to the paddock and hence there was no effective treatment at an early growth stage. © T.Cook, NSW DPIRD

Information on resistant weeds has been partially sourced from I.Heap, The International Survey of Herbicide Resistant Weeds, June 2025. Visit the international herbicide-resistant weed database at: www.weedscience.org

III

USEFUL RESOURCE:



Weedsmart

weedsmart.org.au



TABLE 28: Resistance risk for herbicides used in cotton

Herbicide active ingredient	Pre plant	At plant	Post plant	Mode of action	Years to resistance	Resistance status
Amitrole + paraquat	Y	N	N	34(Q) + 22(L)	>15	Rare
Amitrole + ammonium thiocyanate	Y	N	N	34(Q)	>15	Rare
S-Metolachlor or Metolachlor	Y	Y	Y ¹	15(K)	>15	Rare
Saflufenacil	Y	N	N	14(G)	>15	Rare
Glufosinate-ammonium	Y	N	N ²	10(N)	10-15	Rare
Dicamba ³	Y	N	N ²	4(I)	10-15	Rare
Fluroxypyr	Y	N	N	4(I)	10-15	Rare
Fluroxypyr+ aminopyralid	Y	N	N	4(I)	10-15	Rare
Diuron	Y	Y	Y	5(C)	10-15	Rare
Fluometuron + prometryn	Y	Y	Y	5(C)	10-15	Rare
Prometryn	Y	Y	Y	5(C)	10-15	Rare
Triclopyr	Y	N	N	4(I)	10+	Rare
Triclopyr + picloram	Y	N	N	4(I)	10+	Rare
Triclopyr + picloram + aminopyralid	Y	N	N	4(I)	10+	Rare
Carfentrazone-ethyl	Y	N	N	14(G)	10	Rare
Flumioxazin ⁴	Y	N	Y	14(G)	10	Rare
Oxyfluorfen	Y	N	N	14(G)	10	Rare
Isoxaflutole ³	Y	N	N	27(H)	10	Rare
Paraquat	Y	Y	Y	22(L)	>15	Occasional
Paraquat + diquat	Y	Y	N	22(L)	>15	Occasional
2,4-D ³	Y	N	N	4(I)	10-15	Occasional
Pendimethalin	Y	Y	Y ⁵	3(D)	10-15	Occasional
Trifluralin	Y	Y	N	3(D)	10-15	Occasional
Bromoxynil	Y	N	N	5(C)	10-15	Occasional
Glyphosate ⁶	Y	Y	Y	9(M)	>12	Widespread
Butroxydim	N	N	Y	1(A)	6-8	Widespread
Clethodim	N	N	Y	1(A)	6-8	Widespread
Fluazifop-p	N	N	Y	1(A)	6-8	Widespread
Haloxyfop	N	N	Y	1(A)	6-8	Widespread
Propaquizafop	N	N	Y	1(A)	6-8	Widespread
Halosulfuron-methyl	N	N	Y	2(B)	4	Widespread
Trifloxysulfuron sodium	N	N	Y	2(B)	4	Widespread
Lowest resistance risk	Note that Group 1(A) herbicides already exhibit widespread resistance in several species. Controlling survivors is essential.					
Moderate resistance risk						
Highest resistance risk						

Always read the label for detailed use patterns and application rates.

¹ Dual Gold® formulation.

² XtendFlex® varieties only, using specific formulation registrations.

³ See label for rainfall required before plant-back period begins.

⁴ Valor® formulation only.

⁵ Rifle® formulations.

⁶ Roundup Ready Flex® varieties only.

Refer to Tables 21, 22 and 24 for plant-back periods.

Herbicide Resistance Management Strategy 2025/26

An integrated weed management system relies on a large number of complementary components, including chemical and non-chemical control tactics combined with cultural practices such as crop competition, rotation, farm hygiene and crop scouting. Effective strategies to delay herbicide resistance and manage resistant populations are essential for long-term sustainability of cotton farming.



Apply 6 different modes of action on grasses and broadleaves every 2 years, and allow NO SURVIVORS to set seed

CHOOSE 6 TACTICS	Fallow Strategic cultivation Double knock Optical sprayers Patch management Cover crops	Pre/at plant Cultivation Double knock Knockdowns Group 5/C bromoxynil Group 14/G pyraflufen, flumioxazin, saflufenacil, oxyfluorfen, carfentrazone Group 4/I dicamba, fluroxypyr Group 22/L paraquat, diquat Group 22-L/34-Q amitrole/paraquat Group 10/N glufosinate Group 9/M glyphosate Residuals³ Group 5/C prometryn, terbutylazine, diuron Group 3/D pendimethalin, trifluralin Group 15/K S-metolachlor, metolachlor	Post-emergent In-crop cultivation Manual chipping Rogueing Spot spraying Post-emergent OTT Group 1/A ² sethoxydim, clethodim, butoxydim, haloxyfop, propaquizafop Group 15/K ⁴ S-metolachlor Lay-by, directed or shielded spray Group 5/C prometryn, terbutylazine, diuron Group 3/D pendimethalin Group 14/G ⁴ flumioxazin Group 15/K ⁴ S-metolachlor	Maturing crops Cultivation Chipping Rogueing Spot spraying <i>Aim for 100% control of survivors</i>
	Fallow herbicides Group 9/M glyphosate Group 5/C bromoxynil, terbutylazine Group 14/G flumioxazin, pyraflufen, saflufenacil Group 27/H isoxaflutole Group 22/L paraquat, diquat Group 22/L+34/Q paraquat+amitrole Group 10/N glufosinate Group 4/I 2,4-D, dicamba, fluroxypyr Rotation Crops³ Crop competition Rotate modes of action Plant back restrictions Cover crops			
NO SURVIVORS	Target survivors — aim for 100% control			
	In fallow survivor control Cultivation, chipping or spot spraying (refer above for options) Optical sprayer	Pre-plant survivor control Cultivation, chipping or spot spraying flumioxazin pyraflufen-ethyl (added to complementary product) carfentrazone-ethyl bromoxynil	Post-emergent Inter-row cultivation, chipping or spot spraying	Post-harvest Root cutting for crop destruction Cultivation, chipping or spot spraying carfentrazone-ethyl, pyraflufen-ethyl bromoxynil fluroxypyr
COMMENTS	- Survivors MUST be controlled with a different MOA prior to seed set. - Read and follow all label directions. - Rotate herbicide mode of action (MoA). - Come Clean. Go Clean. to avoid importing weed seeds. - Scout fields regularly for weeds and monitor after spraying for survivors. - Keep accurate field records. - Ensure volunteers/ratoons are controlled. - DO NOT rely solely on glyphosate or any other in-crop herbicide for non-field weed control. - Take a farming systems approach to weed management, considering winter, summer and non-field area weed control.			
	Footnotes: 1. APVMA permits: 88120, 90223 for fallow use. 2. Group 1/A herbicides already exhibit widespread resistance. Controlling survivors is essential. 3. Refer to label for plant-back restrictions to following crop. 4. Limited formulations are registered for this use. Please check label.			

Revised Herbicide Resistance Management Strategy (HRMS) explained

The HRMS is designed as a tool to manage the risk of herbicide resistance in irrigated and dryland farming systems incorporating herbicide tolerant cotton. The strategy has been developed in response to the escalating problem of herbicide resistance across multiple weed species to a number of herbicide modes of action (MoA). This is the second version of the HRMS, following on from the original 2+2+0 strategy that saw the cotton industry adopt world's best, and most effective, glyphosate resistance management. This version of the HRMS focuses on a glyphosate, glufosinate and dicamba tolerant cotton system (XtendFlex® cotton); however, we are constantly alert to the fact that other herbicides could become at-risk for resistance if used more than once every year. Many herbicides, including the ones listed, already have a history of use in cotton fields, indicating that some selection for resistance for any registered herbicide could already have occurred.

A sustainable system requires a high level of diversity and zero tolerance for survivors of herbicide sprays. Using 6 different methods/modes of action across every 2 years (such as 3 in fallow plus 3 in crop, for a dryland situation), plus additional actions if required to prevent seed set on survivors, provides a sustainably low risk (but not zero risk) system.

The formula to delay or manage resistance

The most effective way to delay the evolution of herbicide resistance is to target weed control across the whole farming system with a diversity of tactics. A focus on reducing weed numbers in fallows or rotation crops will reduce the reliance on in-crop weed control. Aim to drive down weed numbers and ensure no weeds set seed after herbicide applications, and use a diverse program of 6 modes of action every 2 years. This can be done by using:

- a minimum of 3 different weed control tactics effective on the weeds being controlled in crop, and 3 more in summer fallows (or non-cotton crops). If more controls are needed, make use of fallow periods to get access to a range of products that can be used where no crop is present needing protection. Take note: where both grasses and broadleaves are present, 'three different modes of action' must apply to both types of weed species, meaning more than three in total may need to be applied. Check the tables in this guide for the wide range of available tactics at different crop stages.
- AND ensure that no survivors set seed. Effective post-spray monitoring (with follow-up action) is critical for ensuring control of survivors.

Examples of the influence of various weed management tactics on herbicide resistance risk are provided in Table A.

Table A: Risk reducers and risk promoters for herbicide resistance

Effect on resistance risk	Tactic	Notes
Strongly reduces risk	Spot-spray glyphosate at high rates through optical detection system	Glyphosate at the highest allowable rate, applied to small proportions of the field, remains very effective for seedbank and resistance management, including protecting other herbicide groups under pressure of resistance.
Strongly reduces risk	Apply glyphosate as part of double knock	Whenever there is the opportunity to follow glyphosate with a fast-acting knockdown herbicide, it should be taken. In the absence of paraquat, glufosinate or cultivation can be useful double knock partners. Other suitable sequences of tactics may be used.
Reduces risk	Late season survivor control	Additional tactics used specifically to control survivors in crop prior to seed set are fundamentally important.
Reduces risk	Apply glufosinate as part of double knock	Glufosinate is a moderately at risk herbicide for resistance. Preserve its susceptibility by attempting to use it as part of mixed strategies with other modes of action.
Reduces risk	Apply key herbicides in mixtures	Glufosinate and dicamba are at risk for resistance. Using them in mixtures with compatible products can help reduce resistance risk.
Increases risk	Weed species known for evolving resistance (annual ryegrass, barnyard grass, feathertop Rhodes grass, flaxleaf fleabane)	Several such species are present in various regions. Currently susceptible biotypes of key species should be treated as being at risk of resistance in the short to medium term. Consult your agronomist about the herbicide resistance history of your weed species.
Highly increases risk	Cross-seasonal species (often germinates out of expected season)	Adaptable species such as annual ryegrass can generate large seedbanks by appearing out of their expected season, and going uncontrolled.
Highly increases risk	Multiple generations per year	These highly fecund species can evolve very rapidly, and must be controlled with multiple modes of action.
Highly increases risk	Relying on 1-2 herbicides	

Increased time to resistance

Research into glyphosate resistance has indicated that typically glyphosate failure may appear in grass weeds after approximately 13 years (dryland) and 19 years (irrigated) in a glyphosate only system. Resistance to glyphosate in broadleaf weeds can be slower to emerge and usually takes around 18 years in both irrigated and dryland systems. Some non-glyphosate modes of action share similar or slightly longer timeframes (e.g. Group 4 herbicides, glufosinate), while others have substantially shorter timeframes (Group 1, Group 2 herbicides). However, it is important to remember that the most reliable herbicides in our system, including but not limited to glyphosate, have now been in frequent use for one to two decades in nearly all cropping situations in Australia. This means that time frames to resistance for populations on farm could appear to be much shorter, since we are unlikely to be starting with a truly wild type, unselected population. It is helpful to know your herbicide use history on weeds that have been on farm for many years. Assume that resistance could appear much more quickly than these indicative timeframes, if the system begins to favour a particular herbicide.

Herbicide resistance can be delayed by 4-6 years with good survivor control and product rotations and mixtures, and the same strategies are very effective for managing resistant populations that do occur. To drive down weed numbers and eradicate resistant biotypes, additional tactics such as intensive patch management are required.

Other management considerations

Any rotation or cover crop should be managed similarly to a fallow, with at least 3 modes of action recommended. Rotation and cover crops provide an opportunity to incorporate other tactics, rotate to herbicide groups not used in cotton, vary the time of year crop competition suppresses weeds, and produce stubble loads or mulch that can reduce subsequent weed germinations.

Aim for 100% control of survivors after each herbicide application. Effective post-spray monitoring to detect survivors is critical. The use of cultivation to control any survivors after a herbicide application is predicted to achieve 80% survivor control, whereas cultivation plus follow-up chipping is predicted to achieve close to 100% survivor control. Other tactics for survivor control can be equally effective, such as shielded or spot-spraying with an effective knockdown herbicide. Even very small mature weeds may produce viable seeds, and if those carry resistance genes, a long-term problem can begin to emerge. Get suspect weed survivors tested for resistance.

Residual herbicides need back up, such as tillage, chipping and knockdown herbicide applications to control survivors. When using residual herbicides, consider plant-back periods and crop safety. Be aware that prolonged dry periods may extend plant-back periods.

Control weeds in adjacent areas (channels, tail drains, fencelines and roadsides) to minimise the seed bank and eliminate unknown weed seed sources. Do NOT rely solely on glyphosate to manage weeds in non-crop areas.

Be aware of weed seed contamination sources (e.g. waterways, vehicle/machinery, and farm inputs).

Establish and maintain Come Clean. Go Clean. to prevent the introduction and transport of resistant seeds.

Use patch management strategies – control any weeds in and around problem patches with a different mode of action from ones that the patch may have recently survived. Be ready for the tendency of patches to spread if not controlled well.

Use IWM best practice when employing tactics, including:

- Optical Spot Spray Technology, particularly where spot spraying allows for high herbicide rates on a small proportion of the paddock.
- Regular scouting and ensuring correct weed identification. Check with an agronomist if you are unsure of a weed's identification. Be on the lookout for any new weeds and eradicate problematic new weeds before they become an issue.
- Frequent post-spray monitoring.
- Good record keeping.
- Timely implementation of tactics – hitting weeds when they're small and vulnerable.
- Rotate and mix herbicide mode of action groups.
- Always follow label recommendations.
- Consider other aspects of crop agronomy.

Poor seedbank control over 5-10 years strongly correlates with increased herbicide resistance risk.

The medium-term success of moderate-high resistance risk strategies depends greatly on the history of exposure to the MOAs used in crop. If a weed population is already at 1-10% resistance due to historical practice, full-blown resistance can appear within 3-4 years of even a moderate risk strategy.

The success of moderate risk strategies is highly responsive to summer fallow actions in dryland cotton. Crops grown 1 year in 3 with a very low-risk, robust summer fallow program can sustain somewhat less diverse in-crop strategies. Back-to-back irrigated crops, where summer fallow control is not available, should stick with low risk strategies in crop.

Assessing your own risk

Refer to pages 92-95 of this publication for information on recognising potential herbicide resistance how to get weeds tested.

More information and tools related to herbicide resistance and weed management in cotton is available from:

 cottoninfo.com.au or  weedsmart.org.au

The HRMS in practice

Implementing the HRMS in cotton requires fitting a range weed control tactics into real situations with lots of variables. Finding room for 6 different tactics every two years is feasible but can be challenging. A few of the important considerations are:

- What weed species are you actually dealing with?
- What's your crop rotation?
- When, and how often, can you include soil disturbance for weed management?

Tables B and C include some example IWM strategies in-crop and during fallows, rated for resistance risk and seedbank control. The most diverse strategies (at the top of each table) maximise seedbank control and minimise resistance risk, but potentially have the highest input costs.

In order to fit the HRMS requirements of 6 different tactics every 2 years, aim for a strategy similar to those in the green rows (low or low-moderate risk). Avoid high or very high risk strategies where possible, and remember that if high risk strategies are used in one part of your rotation (e.g. in-crop), you'll need an even greater focus on reducing risk in the following year to reach the HRMS target.

Table B: Example IWM strategies for in-crop weed management

Resistance risk level	Strategy	#MoA/season	Seedbank control*	Comments
Low	2-3 OTT glyphosate + double knock prior to planting + 2 different residuals (at/near planting, layby) + OTT dicamba + double knock glyphosate/glufosinate OTT + tillage/spot spraying late season for survivor control	5-6	Very high	Fallow choices for broadleaf control are important (avoid 2,4-D). In the absence of paraquat, double knock with glyphosate fb glufosinate or other suitable sequences
Low-moderate	2-3 OTT glyphosate + 2 different residuals at planting and layby + double knock glyphosate/glufosinate OTT + inter-row cultivation + spot spraying for survivor control	5	High	Glufosinate is best used as part of double knocks, from the point of view of overall resistance management
Low-Moderate	2 OTT glyphosate + double knock prior to planting + residual at planting + up to 2 dicamba and glufosinate OTT	4	High-moderate	Not ideal for cross-season species or species producing multiple generations per year. Can be very successful when supplemented with best practice summer fallows.
Moderate-high	2 OTT glyphosate + residual at planting + up to 2 dicamba and glufosinate OTT	4	Moderate	Requires very aggressive summer fallow program for sustainability
High	2-3 OTT glyphosate 2-3 OTT dicamba and glufosinate	3	Moderate-low	Especially susceptible to dicamba resistance if 2,4-D or similar products used in fallow
Very high	Glyphosate alone or with occasional clean-up tactics	1-2	Moderate-low	History demonstrates glyphosate alone is too high risk for resistance to be recommended in any situation

Table C: Example IWM strategies for summer fallows

Resistance risk level	Strategy	#MoA/season	Seedbank control*	Comments
Low	Glyphosate (applied in double knocks or at high rates via optical sprayer wherever possible) x2-3 + 2 different residual MoAs, early and mid-fallow + broadleaf herbicide ¹ + consistent survivor control + includes cultivation ²	5-6	High	In the absence of paraquat, use glufosinate as a double knock partner – but preferably only as part of double knocks in fallow. Aim to use double knocks for half of all glyphosate applications.
Low-moderate	Glyphosate (broadacre) x2-3 + early season residual + grass selective + glufosinate + late survivor control with spot spraying	4-5	Generally high	
Moderate	Glyphosate (mostly applied in double knock/optical sprayer) x3 + 2 different residuals	3	Moderate-high	Seedbank control is variable, depending on residual choice and existing glyphosate resistance. Choose residuals not used in crop if possible. Be aware of plantback restrictions.
Moderate	Glyphosate x2-3 always applied as double knocks + early residual		Variable	
High	Glyphosate x2-3 + 2,4-D or other group 4 + glufosinate used alone		Moderate	Seedbank control depends on resistance level and can be lost quickly.
High	Glyphosate alone, with occasional cleanup tactics		Moderate-low	Seedbank control depends on resistance level – generally good for various susceptible species and very poor for any resistant ones.

¹ It is preferable to avoid, or carefully manage, broadleaf herbicides with known cross-resistance effects to dicamba, including 2,4-D, clopyralid and fluroxypyr in fallow. Follow any applications from this group with monitoring and robust survivor control.

² Incorporating cultivation somewhere in fallow can be beneficial for seedbank control of surface germinating species. Consider residuals incorporated by tillage.

*Seed bank control key (seeds/m²): Very high <10; High 10-100; Moderate 100-500; Low 500-1500; Very low >1500.

Herbicide tolerance technology:

XtendFlex® cotton Bayer Crop Science

Cotton varieties containing the XtendFlex® herbicide tolerance trait (XtendFlex® cotton) are tolerant to glyphosate, dicamba, and glufosinate-ammonium herbicides. This provides growers with multiple modes of action to target glyphosate-resistant and hard-to-kill weed species.

Weed resistance management in XtendFlex® cotton

Herbicide resistant weeds have been a reality in Australia for decades – no herbicide is immune, and while the problem is significant, it is also manageable. Prudent management of XtendFlex® cotton technology and mitigation of resistance risks, will ensure these options for weed control are available to Australian cotton growers well into the future.

Growing XtendFlex cotton

There are several requirements that growers need to be aware of when planting XtendFlex cotton. These registered products are: Roundup Ready® herbicide with PLANTSHIELD®, Roundup Ready PL herbicide with Plantshield Technology, XtendiMax® 2 herbicide with VapourGrip® Technology (XtendiMax 2), Roundup Xtend® 2 herbicide with VapourGrip Technology and Nufarm BIFFO® herbicide.

The requirements are designed to support the longevity and effectiveness of the trait and herbicides, which include:

- Completion of an XtendFlex® cotton accreditation course prior to planting cotton containing the XtendFlex® herbicide tolerance trait for the first time.
- Reporting any suspected glyphosate, dicamba or glufosinate resistant weed species to a Bayer representative or Nufarm where Nufarm BIFFO® herbicide has been used.
- Implementing an integrated weed management (IWM) strategy.

- Completion of the XtendFlex® cotton spray applicator training when applying XtendiMax® 2 herbicide in XtendFlex® cotton.



XtendFlex® guides are downloadable from crop.bayer.com.au/products/biotechnology-traits/xtendflex-cotton



Reporting suspected resistance

Naturally occurring populations of some weeds may possess biotypes with resistance to glyphosate, dicamba or glufosinate. Growers should be aware of this prior to using any of the registered over the top (OTT) herbicides in XtendFlex® cotton and should aim to decrease the development and spread of resistant populations. If you suspect resistant biotypes are present, they should be sampled and tested. Contact your local Bayer Territory Business Manager for assistance with this process.

The weed resistance management plan (WRMP) aims to reduce the likelihood of weed resistance to glyphosate, dicamba or glufosinate herbicides developing, it does not guarantee that resistance will not occur.

Understanding your herbicide resistance risk

Each field planted to XtendFlex® cotton has its own unique risk of weed populations resistant to dicamba, glufosinate or glyphosate developing, based on herbicide usage history, the weeds present and their population density, and other historical rotations and agronomic management strategies employed.

As a part of any sound IWM plan, growers are encouraged to assess their resistance risk prior to planting XtendFlex® cotton when making decisions about weed management strategies.

 XTENDFLEX® COTTON   XTENDFLEX COTTON 			
XTENDFLEX COTTON HAS TOLERANCE TO THE FOLLOWING REGISTERED OVER-THE-TOP HERBICIDES 	GLYPHOSATE  ACTIVE CONSTITUENT 540 g/L glyphosate as potassium salt	LOW VOLATILITY DICAMBA + VOLATILITY REDUCTION AGENT   ACTIVE CONSTITUENT 480 g/L dicamba as monoethanolamine salt	GLUFOSINATE-AMMONIUM  ACTIVE CONSTITUENT 200 g/L glufosinate-ammonium

On-farm factors that change resistance risks

Factors that decrease resistance risk:

- Monitoring and preventing herbicide weed control escapes from setting seed.
- Planning and implementing an IWM strategy to reduce the weed seed-bank.
- Strategic use of alternative knockdown herbicides and tillage in fallows prior to sowing.
- Use of alternate herbicide modes of action including residual herbicides in crops and fallows.
- Use of a double-knock glyphosate followed by tillage or an appropriate double-knock product such as paraquat (Group 10) based products at effective rates.
- Applying stewardship plans when growing herbicide tolerant crops.
- Farm hygiene to prevent importing and moving herbicide resistant weed seeds.

Factors that increase resistance risk:

- Frequent glyphosate, glufosinate, or dicamba-based chemical fallow applications not followed by double-knocks to ensure no weed survivors.
- Continuous reliance on glyphosate, glufosinate, and mixtures with dicamba as a knockdown prior to sowing.
- Lack of tillage.
- Lack of use of alternative herbicide modes of action in fallows and crops.
- Allowing survivors of glyphosate, dicamba or glufosinate applications to set seed.
- High weed numbers.
- Lack of crop competition on weeds.
- Over-reliance on herbicide tolerant crops as a weed control mechanism.

Resistance management principles for XtendFlex® cotton

Incorporating a range of cultural and herbicide management practices will maximise the control of any potential herbicide resistant weed populations. The implementation of these practices should also result in a reduction in the weed population entering the XtendFlex® cotton cropping phase.

Key IWM principles for XtendFlex® cotton are:

1. Aim to enter the XtendFlex® cotton cropping phase of your rotation with a low weed burden.
2. Integrate as many different weed control options (chemical and cultural) as possible through all phases of the crop rotation.
3. Make every herbicide application count – use registered rates at the correct application growth stage and always assess its effectiveness.
4. Rotate herbicides with different modes of action throughout the fallow and crop rotation.
5. Regularly monitor the effectiveness of resistance management practices.
6. Test weed populations for herbicide resistance status as a part of ongoing IWM.
7. If planting into a paddock with suspected glyphosate, dicamba or glufosinate resistant weed populations growers must have a plan to manage such weeds.
8. Stop weed seed set by aiming for 100% control of any survivors.

Growers should aim to prevent seed set from any weeds surviving glyphosate, dicamba or glufosinate herbicide applications to prevent resistance development and

spread – never use the same herbicide/herbicide group twice on the same weed, or weeds growing from seed produced by a surviving weed.

Table 29 outlines some key principles for weed control at different stages through the cotton season.

Bayer strongly recommends that growers consult an agronomist when designing an IWM strategy for their property. For further resources and information see weedsmart.org.au.



Resources on weed management and minimising the risk of resistance can be found at weedsmart.org.au



Monitoring herbicide efficacy

All growers or agronomists should inspect fields between 14 and 28 days after spraying with glyphosate, dicamba or glufosinate to monitor the effectiveness of the herbicide application. During an inspection, any surviving weeds that are normally susceptible to the herbicide/s used should be identified. The outcomes of any inspection and any remedial application used should be recorded. Any case of suspected resistance should be reported immediately to Bayer (Nufarm for glufosinate) for further investigation.

Growing Roundup Ready Flex® cotton?

If you are planning to grow Roundup Ready Flex® cotton in the 2025/26 cotton season, please refer to the Roundup Ready Flex® Weed Resistance Management Plan (see link below) or refer to the 2025/26 Bayer Technology User Agreement document.

Roundup Ready Flex® Weed RMP:

crop.bayer.com.au/-/media/bcs-inter/ws_australia/use-our-products/product-resources/cotton-traits/rrflex-cotton-weed-rmp-m0181.pdf



XtendFlex®, Roundup Ready®, XtendiMax®, PLANTSHIELD® and VapourGrip® are Registered Trademarks of the Bayer Group; BIFFO® is a Registered Trademark of Nufarm Australia Ltd. III

USEFUL RESOURCE:

For stewardship and resistance management information regarding these technology traits and related products visit crop.bayer.com.au



TABLE 29: Key principles for weed control in XtendFlex® cotton crops

PRE-PLANT KNOCKDOWN	• Always start clean by planting into a weed-free field using either tillage or an effective herbicide application. • Know your field history in order to identify whether any volunteer cotton present is XtendFlex® cotton. • Consider using approved tank mixes when applying any of the OTT registered products in XtendFlex® cotton (do not mix any ammonium containing products e.g. ammonium sulfate, glufosinate-ammonium or glyphosate ammonium salts).
RESIDUAL HERBICIDES	• Residual herbicides should be used where appropriate in an XtendFlex® cotton system. • Consider using residual herbicides where weed pressure is high, or weeds will not be adequately controlled by the OTT products registered for use in XtendFlex® cotton. • The residual herbicide can be applied as a pre-emergence application (either a pre-plant incorporated application, or at planting application). • Use the recommended label rate and timing of the residual herbicide.
IN-CROP WEED CONTROL	• Refer to the XtendiMax® 2 product label for use patterns and application timing restrictions for use in XtendFlex® cotton. • Select the timing and application rate of sprays based on the most difficult to control weed species in each field in accordance with the label. • Post-directed sprays should be used to achieve more thorough coverage on weeds. • Refer to the 'Weeds Controlled' table on the label for the rate recommendations on specific weeds for products registered for OTT use in XtendFlex® cotton. • Aim for 100% control of weeds. Monitor and where required implement additional tactics such as inter row cultivation, and/or alternative modes of action to control survivors. • Be aware of any potential contamination of spray application equipment (including mixing stations). • Ensure all equipment is thoroughly cleaned and free of residues. • Only tank mix with products that are approved according to the label. • Do not mix products containing ammonium ions with dicamba, including ammonium sulfate (AMS), glufosinate-ammonium and ammonium salts of glyphosate. • Ensure all applications are made according to label guidelines on water volume, droplet size and environmental conditions and appropriate boom heights and application speeds are maintained. • Be aware of off-target drift to susceptible crops and fields with both aerial and ground applications. Do not apply herbicides by aircraft unless approved on label. • Monitor predicted conditions to manage the possibility of dicamba volatility and drift up to 72 hours post application (refer label). • Growers should use registered herbicides other than glyphosate, glufosinate or dicamba where required to increase diversity of weed control tactics.
LAY-BY APPLICATIONS	• If you currently use lay-by herbicides, then consider maintaining this program. • A robust lay-by program can provide residual control of weeds not controlled by glyphosate, dicamba or glufosinate. • Use the recommended label rate and timing of the residual herbicide.
PRE- HARVEST APPLICATION	• An over-the-top application of a Roundup Ready® Herbicide is possible, if required, before harvest and after cotton reaches 60% open bolls, as one of the 4 glyphosate applications. Rate: 1.5 kg/ha for Roundup Ready® Herbicide with PLANTSHIELD® or 1.9 L/ha for Roundup Ready® PL Herbicide with PLANTSHIELD® Technology. • This application can be used to control late season weeds and improve harvest efficiency. • Compatible with commonly used defoliant (see Roundup Ready® Herbicide with PLANTSHIELD® and Roundup Ready® PL with PLANTSHIELD® Technology labels). • Do not use on crops intended for planting seed production.

Management of volunteer and ratoon cotton

Controlling unwanted cotton is an essential part of good integrated pest and disease management and general farm hygiene. Volunteer (established unintentionally) and ratoon (regrown from surviving root stock) plants can:

- create problems for Bt resistance management
- physically block row access
- act as a 'green bridge' or as early hosts for pests such as spider mites, aphids and cotton bunchy top (mealybug hotspots are often associated with ratoon cotton plants)
- interfere with disease management strategies
- reduce seed purity.

Unwanted cotton can occur in fields that have previously grown cotton, elsewhere on the farm, or even further afield (e.g. along irrigation channel or road corridors). Questions to ask when planning your IWM strategy include:

1. Are the volunteers/ratoons likely to be varieties that possess herbicide tolerance genes?
2. If a rotation or cover crop is planned, will there be problems managing unwanted cotton within it?

Do not allow established volunteers or ratoons to set seed as this will potentially create additional volunteers.

Volunteers

The majority of volunteers come from seed cotton that falls out of the boll early or is lost during picking or module assembly/transport, although plastic-wrapped round modules tend to have lower losses than tarped rectangular modules. Plants can also establish directly from fuzzy seed escapes while being transported to crushing plants or stock feed areas, or from planting seed accidentally spilled on route to or within fields.

Volunteers that emerge pre-planting may allow the early establishment of in-field pests populations and promote disease incidence. Volunteers are also more likely to be impacted by seedling diseases and cool conditions, and rarely contribute to crop yield.

Reduce the amount of viable cotton seed left in fields (via clean pick and stubble management) and around the farm (cleaning up after module removal and spillages) to minimise the volunteers germinating next season.

Best practice...

- Control volunteer and ratoon cotton plants in crop and non-cropping areas as part of an integrated weed management strategy.
- Target plants when small, using physical methods or an appropriate herbicide.
- Read and follow all label directions before use to confirm timing and rates and use sufficient spray volume to achieve good coverage.
- Undertake crop destruction operations as soon as practical after picking to prevent ratoon cotton.
- Ensure implements are set up to cultivate both hill and furrow; avoid leaving uncultivated strips.
- Manual removal (i.e. chipping) may be necessary where isolated plants remain in non-field areas.



Cultivation and herbicides are the most common methods of volunteer cotton control. Both require the plants to have germinated and emerged (following pre-irrigation or sufficient rainfall). Cultivating is a good IWM fit, as it readily controls seedlings (and also manages other weeds). However, it is only fully effective when applied across the entire field (both furrow and hill). It is also relatively slow, can lead to soil damage (if conducted at an inappropriate time) or erosion, and increases soil moisture losses (a problem in rain-grown farming systems).

Seedling volunteers can also be controlled reasonably well with less invasive physical removal such as Kelly chains, which break the young stems and can be used relatively close to planting. In-crop cultivation with sweeps is also effective on small volunteer cotton plants.

Most herbicides work best on young cotton seedlings (up to 4 nodes). Larger plants are usually much harder to kill, even when using double knocks.

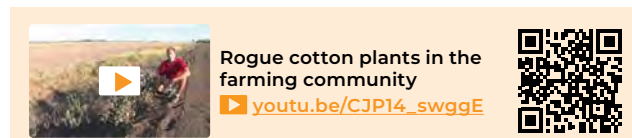
Tables 30 and 31 provide a list of herbicide actives registered for volunteer control, including established plants. Note that glufosinate will not be effective in controlling XtendFlex® cotton volunteers.

Refer to product labels for specific use information as not all products containing these actives have volunteer cotton on the label. Use different modes of action than utilised in-crop where possible, to help prevent resistance in other weed species that may be present, ensure any plant-back intervals fit with your proposed planting schedule, and take precautions to minimise drift.

Excellent spray coverage of contact herbicides is essential. Use sufficient volumes and appropriate speeds and note that shadowing from nearby stubble, lint or other weeds can adversely affect spray outcomes.

Crop rotation enables the use of alternate modes of action and residual herbicides. Ensure good control is achieved as cotton plants hidden within subsequent crops can continue to host pests and diseases.

Occasionally, cotton plants become well established before there is opportunity to control them due to unforeseen circumstances (often weather-related). Fluroxypyr (Comet®) can be used on larger (15-30 nodes) plants (see Table 31). Where isolated plants establish in fallows or non-field areas such as along roadsides and fences, physical removal by chipping can be very effective.



Ratoon cotton

Ratoon cotton (also called regrowth or stub cotton) usually results from ineffective crop destruction – either the stems have not been fully severed or have not been cut below the cotyledons. Ratoons are more likely to occur from volunteer plants or if planted seed grew outside the row line targeted by root cutting.

In theory, ratoons should not occur after Bt crops as harvested plants are required to be controlled as soon as practical after picking (usually by mulching and/or root cutting followed by cultivation to destroy the root system) in the Technology User Agreement.

In minimum-till situations, thorough crop destruction can be particularly challenging and care must be taken to ensure regrowth is prevented.



Effective end of season crop destruction

youtu.be/rO-JAX7s7jg



Crop destruction also provides an opportunity to destroy overwintering helicoverpa pupae (a mandatory strategy for Bollgard 3 crops where the first defoliation occurs after March 31) to manage insecticide resistance.

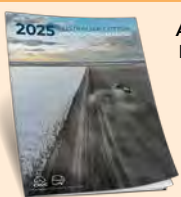
Ratoon cotton plants that have survived crop destruction can be difficult to control, having developed a large root system and small leaf surface area. Three herbicide options, registered for both optical booms and broadcast application, are available for the control of large volunteer cotton or ratoon cotton amongst stubble or in fallow (see Table 31). **ALWAYS FOLLOW LABEL DIRECTIONS.**

USEFUL RESOURCES:



WEEDpak

cottoninfo.com.au/publications/weedpak



Australian Cotton Production Manual: Chapter 23, Post-harvest pest and stubble management

cottoninfo.com.au/publications/australian-cotton-production-manual



TABLE 30: Herbicides for control of volunteer cotton

Active ingredient	MoA group	Comments (always refer to product labels)
Amitrole + paraquat*	34(Q) + 22(L)	Can be applied after glyphosate (as a double knock). See label for spot spray rates.
Bromoxynil	5(C)	Apply in minimum of 80 L/ha water for Roundup Ready cotton. See label for rain-fastness and restrictions on spray quality & condition.
Carfentrazone-ethyl	14(G)	Apply minimum spray volume of 80 L/ha to ensure effective coverage. To broaden weed spectrum may be tank mixed with the recommended rate of a knockdown herbicide. See label for adjuvant recommendation.
Paraquat + diquat*	22(L)	Apply in 50-100 L water/ha. Avoid spraying under hot dry conditions. For best results, spray in the evenings or in humid conditions.
Flumetsulam	2(B)	May be banded (>40%) over the row or broadcast. Minimum spray volume 150 L/ha for optimum results.
Flumioxazin	14(G)	Do not apply post-sowing pre-emergent. Do not sow crops for at least one hour after application. Can be tank mixed with glyphosate to control other weeds that may be present. See label for adjuvant details.
Glufosinate-ammonium**	10(N)	Good coverage is essential. Do not apply more than three applications per season. Best results are achieved when applied under warm humid conditions.
Metribuzin	5(C)	Registered for control of volunteer cotton in pigeon pea. See label for critical comments.
Fluroxypyr	4(I)	Summer fallow.
Saflufenacil	14(G)	Do not apply post-sowing pre-emergent. Always apply with adjuvant or high quality methylated seed oil. See label for mandatory no-spray zone and spraying rates.
Pyraflufen-ethyl	14(G)	Prior to sowing summer crop or starting a summer fallow. Apply by ground rig only. Good spray coverage is essential. Do not sow crops for at least 1 hour after application.

*paraquat and diquat are currently under APVMA review, with a final decision expected late in 2025. If reduced rates are recommended, this control option may be less effective.

**Note that volunteers with XtendFlex® traits will be tolerant to glufosinate-ammonium; adjust your IWM plan accordingly.

For the latest registration details, refer to portal.apvma.gov.au/pubcris

TABLE 31: Herbicides for control of large (15 to 30 node) volunteer cotton and ratoon cotton in fallow

Active ingredient	Rates	Comments
Fluroxypyr 4(I)	1 L/ha followed by 1 L/ha	OR
	1 L/ha followed by Shirquat® (22/L) 2 L/ha	OR
	1 L/ha + 1 L/ha Amicide Advance® (4/I) 700/ha	
		For control of large cotton plants or ratoon cotton a sequential application of Comet followed by Comet is required for maximum control. Ensure sufficient leaf regrowth has occurred on the ratoon cotton to maximise chemical uptake.
		For control of large cotton plants or ratoon cotton a sequential application of Comet followed by Shirquat is required for maximum control. The sequential application interval should be 7-14 days. Ensure sufficient leaf regrowth has occurred on the ratoon cotton to maximise chemical uptake.
		For a single pass operation apply Comet + Amicide Advance 700. Ensure sufficient leaf regrowth has occurred on the ratoon cotton to maximise chemical uptake.

Refer to the Comet® 400 registration label for further details on control rates for optical spot spray technologies. Note that paraquat is currently under review by the APVMA, and if reduced rates are recommended, a double knock with this product may not be as effective. Note that control rates are based on L/ha for broadcast application and L/100L (spot spraying rate) for optical sprayers.

For the latest registration details, refer to portal.apvma.gov.au/pubcris