Weed management tactics for Australian cotton

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Formula to prevent manage/delay glyphosate resistance (2+2+0)

Extensive modeling of potential glyphosate resistant risks has found that irrespective of whether a farm is irrigated or dryland, weed species present, or the amount of glyphosate used, the most effective way to delay resistance is to use:

2 non-glyphosate tactics targeting both grasses and broadleaf weeds during the cotton crop
+
2 non-glyphosate tactics in fallow targeting both grasses and broadleaf weeds
+
0 glyphosate survivors allowed to set seed

If a tactic is selected that only targets grass weeds, than an additional tactic that targets broadleaf weeds will need to be included.

Develop a strategy

It is important to strategically plan how the different tactics will be utilised to give the best overall results for the existing weed spectrum. 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 where weed control has not been part of an integrated plan.

There are five principles in developing a successful long term approach to weed management:

- Know the weed spectrum and conduct monitoring.
- Use a diversity of in-crop and fallow management tactics to actively reduce seed bank, as well as prevent emerged weeds from surviving through to seed set (see 2+2+0 formula).
- Rotate herbicide mode of action.
- Monitor and follow up to ensure weeds that survive a herbicide are controlled by another tactic before they are able to set seed.
- Come Clean Go Clean to prevent movement of weeds seeds on, off or around the farm.

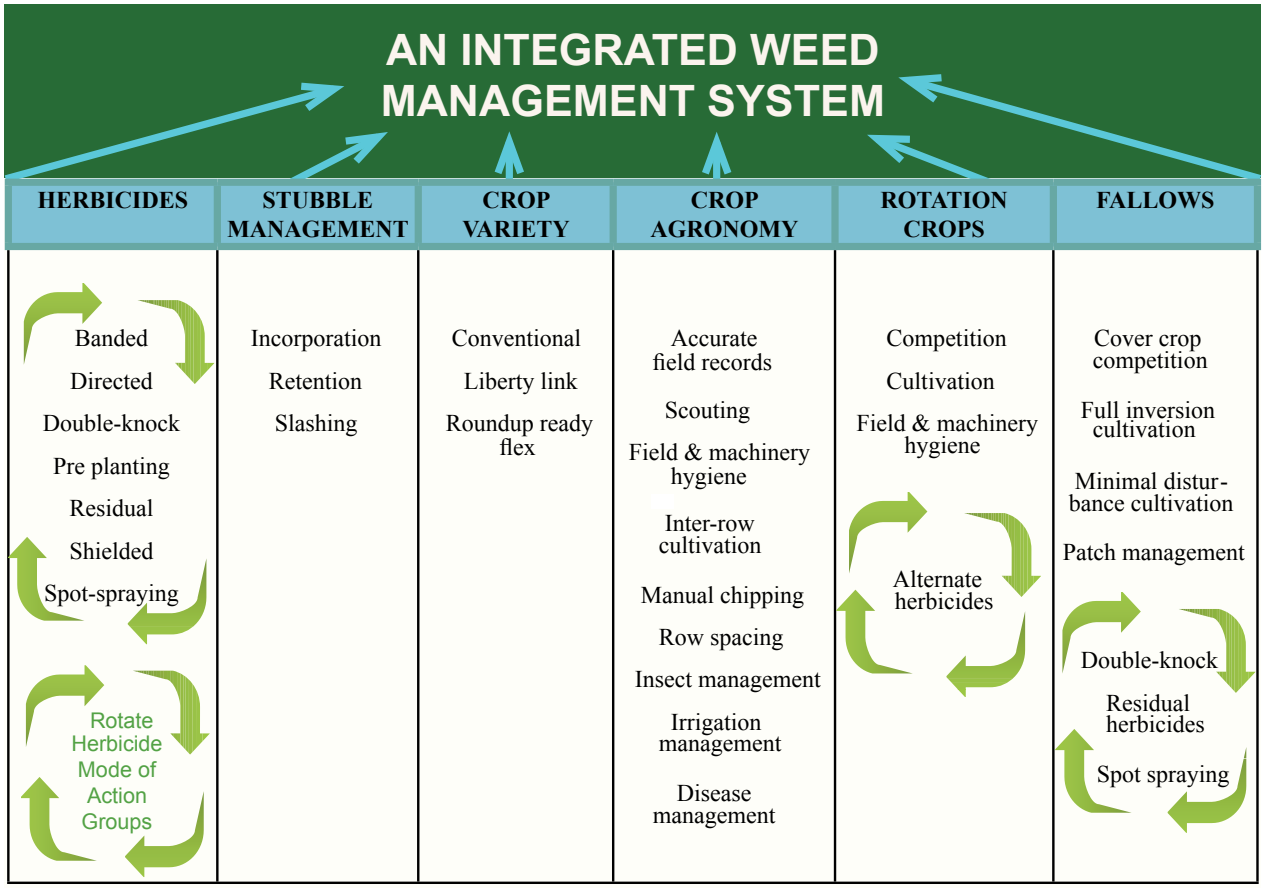
Deployment of tactics recognises the full range of farming system's inputs that impact on weeds and the interactions of these inputs, as shown diagrammatically in Figure 7.

Critical success factors for using tactics

Correct weed identification

Ensure that weeds are correctly identified before deciding upon

FIGURE 7: An integrated weed management system relies on a large number of interrelated, complementary components. All inputs into the system are important.



USE ROUNDUP READY® HERBICIDE WITH PLANTSHIELD®

TO PROTECT AN OVER-THE-TOP COTTON YIELD.

Weed control in the first 8 weeks following emergence maximises the yield potential of a cotton crop. Roundup Ready® Herbicide with PLANTSHIELD® is the only product registered for over-the-top use in cotton that is covered by Monsanto's warranty as part of the Technology User Agreement (TUA).

Roundup Ready Herbicide with PLANTSHIELD is:

- **An easy to use 690g/kg dry glyphosate formulation**
- **Does not require additional surfactant**
- **Specially formulated to reduce spray drift and limit off target application**
- **Made in a dedicated glyphosate production facility which meets Monsanto's manufacturing specifications and quality assurance testing, avoiding the risk of contamination and reduced crop safety**

To ensure sustainable results and an over-the-top yield, Roundup Ready Herbicide with PLANTSHIELD should be used as part of an Integrated Weed Management (IWM) program.

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a response. Similar species may respond differently to control measures. For example, the strong seed dormancy mechanisms of cowvine (*Ipomoea lonchophylla*) make it less responsive to a tactic like the spring tickle than bellvine (Ipomoea plebeia) which has very little seed dormancy. Herbicide susceptibility can also differ between similar species.

The Weed Identification and Information Guide through the www.mybmp.com.au is a powerful tool to assist weed identification. Unknown weeds can be identified by scrolling through the collections of pictures and the supporting text. The picture collections include seedling, flowering and mature growth stages as well as close up images of seeds for over 100 of the weeds that commonly occur in cotton. Additional weeds and more detailed biology and ecology information are added to the collections as material becomes available.

Scouting

Scouting fields before weed control is implemented enables the weed control option to be matched to the species present. Soon after a control is implemented, scouting should be repeated to assess efficacy. Weed audits are a requirement of growing Liberty Link and Roundup Ready Flex cottons. See pages 102 and 105 for details. These auditing techniques can also be used to scout weeds in conventional cotton and rotation crops.

Timely scouting allows questions that affect the next weed control decision to be answered:

- Were the weeds damaged but have since recovered?
- Has control been better in some parts of the field than others?
- Has there been good control but a subsequent germination?

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. Weeds may need to be closely examined, as some are capable of setting seed while very small and many weeds respond to varying day-length, so a winter weed emerging in late winter or spring may rapidly enter the reproductive phase of growth in response to lengthening daylight hours. Information on the growth and development of some of the more common weeds is available in the Weed Growth & Development Guide in WEEDpak through www.myBMP.com.au

Identify and closely monitor areas where machinery such as pickers and headers breakdown. Weeds seeds are often inadvertently released when panels are removed from machines for repairs. There have been many instances where weeds such as parthenium weed have been spread this way. Long-term monitoring of breakdown sites is the best way to prevent these problems. Whenever possible, it is best practice to ensure that all machinery maintenance occurs in a centralized area, such as around the farm sheds, so that any new weed incursions will be readily observed and managed.

Weed scouting in non-crop areas of the farm is a valuable source of information for planning future weed management strategies. Non-cropping areas, such as roadways, channels, irrigation storages and degraded remnant vegetation can be a source of reinfestation and can provide opportunities for newly introduced weeds to build up significant seed banks. Some of these weeds will also host pests and diseases. These can be moved into fields via water, wind and animals. Weed managers should always be on the lookout for new weeds.

GUIDE TO THE CRITICAL PERIOD FOR WEED CONTROL TO PREVENT 2% YIELD LOSS

Weed Type	Weed Density/ 10 m row	Cotton Growth Stage (day degrees) To prevent yield loss, control weeds			
		From		To	
Large broadleaf weeds such as; noogoora burr, thornapple, volunteer sunflower, sesbania	1	1–2 leaf	(145)	3 leaf	(189)
	2	1–2 leaf	(144)	5–6 leaf	(275)
	5	1–2 leaf	(143)	first square	(447)
	10	1–2 leaf	(141)	squaring	(600)
	20	1–2 leaf	(139)	squaring	(738)
	50	1–2 leaf	(131)	early flowering	(862)
Medium broadleaf weeds such as; bladder ketmia, mintweed, Boggabri weed	1	1–2 leaf	(145)	2–3 leaf	(172)
	2	1–2 leaf	(144)	4–5 leaf	(244)
	5	1–2 leaf	(143)	pre-squaring	(387)
	10	1–2 leaf	(141)	early squaring	(514)
	20	1–2 leaf	(139)	squaring	(627)
	50	1–2 leaf	(131)	squaring	(729)
Grass weeds such as; awnless barnyard grass, liverseed grass, Johnson's grass	20	–	–	–	–
	30	1 leaf	(122)	1–2 leaf	(139)
	50	1 leaf	(122)	2–3 leaf	(174)
	100	1 leaf	(122)	4–5 leaf	(248)
	200	1 leaf	(122)	7–8 leaf	(357)
	500	1 leaf	(122)	early squaring	(531)

Good record keeping

Good record keeping will help to develop strategies. and are invaluable for mitigating problems if they occur. For all fields, maintain records of cropping history and weed control methods and their effectiveness after every operation. Consider the records from past years in this year's decisions, particularly in relation to rotating herbicide modes of action.

Timely implementation of tactics

Often the timeliness of a weed control operation has the largest single impact on its effectiveness. Herbicides are far more effective on rapidly growing small weeds, and may be quite ineffective in controlling large or stressed weeds. Cultivation may be a more cost-effective option to control large or stressed weeds, but additional costs can be avoided through being prepared and implementing controls at the optimum time.

Timing to protect yield potential

In addition to targeting weeds in a timely manner, after planting, it is important to manage weeds to prevent yield loss, as young cotton is not a strong competitor with weeds. The critical times when weed competition can cause yield loss are provided in guide below for a range of weed densities and weed types. Irrespective of the type of weeds, early season control is critical to prevent yield loss. The higher the weed population, the longer into the season weed control is required. Preventing yield loss as well as preventing weed seed set ensures there is an economic return from weed control both today and in the future.

Rotate herbicide groups

All herbicides are classified into groups based on their mode of action in killing weeds. Rotate herbicide groups whenever possible to avoid using the same group on consecutive generations of weeds. When this is unavoidable, use other methods of weed control in combination with the herbicide and ensure no weeds survive to set seed. The cotton industry is very

fortunate to have registered herbicides in the majority of the mode of action groups.

Closely follow herbicide label recommendations

Herbicide efficacy is highly dependent on the use of correct application techniques. Always follow label directions, including ensuring that the rate you are about to use is right for the growth stage and condition of the target weeds, whether a wetter or crop oil is required to maximise herbicide performance and that the application set up you are about to use is consistent with the label – water volume, water quality, droplet spectrums and operating pressure. Always consider the suitability of weather conditions. Refer to pages 142–150 for additional information about herbicide application and weather conditions for spraying.

Stop seed set, and actively management the seedbank

Managing the weed seed bank is the most important component of weed management. This applies to resistance management as well as general weed management. Use a range of selective tactics – inter-row cultivation, lay-by herbicides, chipping and spot spraying – to prevent seed set in weeds that survived early-season tactics or have germinated late.

Consider other aspects of crop agronomy

Most agronomic decisions for cotton have some impact on weed management. Decisions such as cotton planting time, pre-irrigation versus watering-up, methods of fertiliser application, stubble retention and in-crop irrigation management all have an impact on weed emergence and growth. The influence of these decisions should be considered as part of any weed management program. For example, modify the timing and method of applying pre-plant N to achieve a 'spring tickle' in the same operation.

Cultural control

Cultural controls provide opportunities to incorporate different tactics and suppress weed populations.

Rotation crops

Rotation crops provide an opportunity to introduce a range of different tactics into the system including:

- Herbicide options not available in cotton.
- Producing stubble loads that reduce subsequent weed germinations.
- Varying the time of year non-selective measures can be used and the time of year that crop competition suppresses weed growth.
- Rotation between summer and winter cropping provides opportunities to use cultivation and knockdown herbicides in-fallow at all times of the year.

When summer crops, such as maize, are planted earlier than cotton, there is an opportunity to use crop competition and inter-row cultivation for cotton volunteer control rather than relying on herbicides, as can occur when cotton follows cotton.

Where cotton is grown in rotation with crops, such as winter cereals or maize, retaining the stubble cover from these rotation crops for as long as possible reduces weed establishment and encourages more rapid breakdown of weed seed on the soil surface.

Herbicide tolerant cotton traits

Incorporating this tactic into the strategy allows for more responsive, flexible weed management. Weeds need only be controlled if and when germinations occur, meaning herbicide application can be timed to have maximum impact on weed populations. Even where glyphosate resistant weed species are present, Roundup Ready® cotton is still likely to be a useful part of the farming system. However the use of other tactics, especially control of all weed survivors will be critical to the long-term value of the traits. Avoid using the same herbicide to control successive generations of weeds. Rotating to glufosinate tolerant cotton (Liberty Link), provides an opportunity to use a different mode of action in-crop, and can help to manage cotton volunteers. Refer to pages 97 and 102–106 for more information.

Crop competition

An evenly established, vigorously growing cotton crop can compete strongly with weeds, especially later in the season. Competition reduces the number of seeds each weed can produce. Factors such as uneven establishment (gappy stands) and seedling diseases reduce crop vigour, and increase the susceptibility of the crop to competition from weeds. Close attention to crop agronomy will increase crop yields and can help reduce weed problems. Delaying planting on weedy fields until last, gives more opportunity to control weeds that emerge prior to planting and better conditions for cotton emergence and early vigorous growth. Row closure in irrigated cotton is important to maximise light interception for optimum cotton yield but also provides a very important method of minimising light for weeds growing below the crop canopy. Many weeds will fail to germinate once row closure occurs, and many small weeds will not receive enough light to compete with cotton plants and produce few seeds.. Research has shown that in irrigated crops, weed-free periods of 8-9 weeks from planting cotton provide enough time for the crop to out-compete later emerging weeds and significantly reduced seed production

Irrigation

Weed emergence is often stimulated by rainfall and irrigation events. Irrigation should be planned to reduce the impact of weeds by coordinating irrigation with planting, cultivation

EFFICACY OF KNOCKDOWNS IN FOUR WINTER FALLOW FIELD EXPERIMENTS, MEASURED AT 6 WEEKS AFTER TREATMENT, WHEN APPLIED TO 1- AND 3-MONTH-OLD WEEDS (THE RANGE OF EFFICACY ACROSS THE EXPERIMENTS IS IN BRACKETS)

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

fb = followed by 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 (Toowoomba, DAFF);

SUGGESTED INTERVALS FOR SOME COMMON DOUBLE KNOCK HERBICIDE COMBINATIONS IN THE NORTHERN GRAINS REGION

Weed	First application	Second application	Recommended timing*	Comments
BROADLEAF WEEDS				
Most broadleaf weeds	glyphosate	Group L (e.g. paraquat)	7 to 21 days. Optimal timing is generally 10 to 14 days	
Difficult to control broadleaf weeds such as fleabane (Conyza bonariensis)	Group I (e.g Amicide® Advance, Tordon®) with or without glyphosate	Group L (e.g. paraquat)	7 to 21 days. Optimal timing is generally 7 to 10 days	If interval is greater than 14 days, use maximum label rates of Group L herbicide
	glyphosate plus saflufenacil	Group L (e.g. paraquat)	7 to 21 days. Optimal timing is generally 10 to 14 days	Only target rosettes less than 6 leaf
Difficult to control broadleaf weeds such as sowthistle/ milkthistle (Sonchus oleraceus)	glyphosate	2,4-D	2 to 4 days	Recommended to split applications due to incompatibility within the plant. As both products are systemic, the interval needs to be short.
	glyphosate	Group L (e.g. paraquat)	7 to 10 days.	Only target small rosettes
	glyphosate plus saflufenacil	Group L (e.g. paraquat)	7 to 21 days. Optimal timing is generally 10 to 14 days	Only target small rosettes
GRASS WEEDS				
Most grass weeds including: Annual ryegrass (*Lolium rigidum*) Barnyard grass (Echin ochloa colona & E. crus-gali)	glyphosate	Group L (e.g. paraquat)	4 to 14 days. Optimal timing is generally 5 to 7 days	
Feathertop Rhodes grass (*Chloris virgata*)	haloxyfop	Group L (e.g. paraquat)	7 to 14 days. Optimal timing is generally 7 to 10 days	Refer to APVMA permit 12941 (QLD ONLY)
Windmill grass (*Chloris truncata*)	quizalofop	Group L (e.g. paraquat)	5 to 14 days. Optimal timing is generally 7 to 10 days	Refer to APVMA permit 13460 (NSW ONLY)

SOURCE: ICAN

and herbicide events. Pre-irrigation allows a flush of weeds to emerge and be controlled before cotton emergence. Irrigation during the season will cause another weed flush, providing another opportunity for a planned control tactic, as well as reducing moisture stress for existing weeds, making these more easily controlled by herbicide applications.

Post-harvest management

Some weeds will be present in the crop later in the season even in the cleanest crop. These weeds will produce few seeds in a competitive cotton crop but can take advantage of the open canopy created by defoliation and picking. Removing the crop residues and weeds as soon after picking as practical greatly reduces the opportunity for these weeds to set seed.

Herbicides

Herbicides continue to play a vital role in weed management. Understanding how the herbicide works can help to improve its impact and sustainability.

Mode of action (MOA) – Refers to how the herbicide acts against the weed to kill it. Avoid relying too heavily on herbicides with the same mode of action. Repetitive use of the same mode of action group over time is closely associated with the evolution of herbicide resistance within weed populations.

Contact herbicides – have limited movement within the plant. While results are usually quite rapid, coverage of the target weed is critical. Target small weeds, and optimise application technique and conditions.

Translocated herbicides – move within the plant using the xylem, where water and nutrients are transported from soil to growth sites, and/or the phloem, which moves products of photosynthesis to growth and storage sites. Response to the herbicide can appear quite slow. Understanding how the herbicide is translocated can help identify suitability for a situation. For example, atrazine is only translocated in an upwards direction, and so can be unsuitable to apply post-emergence, as very little herbicide gets to the roots.

Herbicide uptake – will vary with product (foliar, root absorption, coleoptile and young shoots absorption). Herbicides generally require the weed to be actively growing. It is important to refer to label for directions on the need for additives such as ammonium sulphate, wetters and oils.

Selective herbicides – have a limited range of target weed(s). This can help to target problem weeds under different scenarios. It is important to follow label recommendations about use or otherwise of adjuvants and avoid use in stressed crops. If only grass weeds are targeted by the use of a selective herbicide, consider how broadleaf weeds will be controlled.

Non selective herbicides – such as glyphosate or paraquat will damage most plants they contact with. However, these herbicides are not effective on all species and it is essential to check the label and not just assume a given species will be controlled.

Herbicide mixtures – refers to application of more than one herbicide in a single operation, which can reduce application costs. It is important that full label rate of each component is used. Refer to the label or manufacturer to determine suitable mix partners, as some products are antagonistic, reducing weed control, damaging the crop when mixed together or through physical incompatibility (form sludge).

Shielded spraying – the practice in which shields are used to protect the crop-rows while weeds in the inter-row area are sprayed with a non-selective herbicide.

Band spraying – the practice in which a given area (band) of selective herbicide is applied to weeds in either the crop-row or inter-row area.

Double knock tactic

A double knock is where two weed control tactics, with different modes of action, are used on a single flush of weeds to stop any survivors from the first application setting seed. The tactics do not need to be herbicides. Cultivation, heavy grazing or fire could also be used as the second knock.

When executed well (right products, right rates, right timing, right application) the double-knock tactic can provide excellent control of the target weeds (see Table above or below?). In cotton systems there are several ways the technique can be applied to improve control of weeds such as flaxleaf fleabane and simultaneously reduce the risk of resistance developing in other key weed species such as liverseed grass and awnless barnyard grass. It is important to remember that total control won't always be achieved, so fields will still need to be monitored and survivors dealt with an alternative method.

Originally the technique was developed to maximise weed control at planting by using Spray.Seed or Roundup CT followed by the sowing operation which included full soil disturbance. This has application at cotton planting time for effective management of volunteers, provided that full disturbance is achieved.

When using two herbicides, the basis of the double-knock is to apply a systemic herbicide, allow sufficient time for it to be fully translocated through the weeds, then return and apply a contact herbicide, **from a different mode of action group,** that will rapidly desiccate all of the above ground material, leaving the systemic product to completely kill the root system.

Most commonly, glyphosate is followed with a Group L product. The optimum time between the treatments is dependent on the weed targets. Small, rapidly growing grasses respond best when the second application occurs 3–5 days after the first. When slightly larger fleabane is the target, separate the applications by 7–10 days. Examples of double-knock treatments and their efficacy on flaxleaf fleabane compared to a standard fallow application of glyphosate are shown on the previous page.

Generally, glyphosate is relied on more in the fallows than in-crop. No-till is now adopted widely in both cotton and grains systems, putting severe pressure on glyphosate to keep weeds, particularly grasses, under control. Awnless barnyard grass can have five or more emergences over the summer fallow period. If glyphosate alone was used to control each of these flushes, the time frame for resistance development would be even lower than using glyphosate alone in Roundup Ready Flex.

The fallow creates an opportunity to use different herbicide groups. The double knock tactic has been proven to be effective on glyphosate-resistant awnless barnyard grass and can ensure that survivors of glyphosate applications are controlled.

Knockdown herbicides

A number of non-selective, knockdown herbicides can be used to control germinating weeds while they are young and actively growing. Glyphosate (Group M), Basta (Group N), Spray.Seed® and Gramoxone® (Group L), Pledge® and Hammer® (Group G), as well as some combinations of these herbicides can be used.

Where cotton with Roundup Ready® technology is to be planted this is an excellent opportunity to rotate herbicide mode of action by using the Group L or Group G products prior to planting. These alternate mode of action products can also be used to control herbicide tolerant cotton volunteers. Depending on the weed spectrum, more selective products from other modes of action may be used. Refer to Table 29 page 108. For additional information regarding the plant-back restrictions of these products for cotton, refer to Tables 24 and 25 on page 101.

Spot spraying

Spot sprayers may be used as a cheaper alternative to manual chipping for controlling low densities of weeds in-crop. Ideally, weeds should be sprayed with a relatively high rate of a herbicide from a different herbicide 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 of the field and difficult to get to, such as roadside culvets.

New weed detection technologies provide an opportunity to use spot spraying across large areas of fallow. This can provide opportunity to reduce herbicide costs, while still ensuring robust label rates are applied to problem weeds. Refer to label for plant-back limitations relevant to rate applied. Refer to Permit Per11163 and follow manufacturer recommendations for speed and nozzle type, as well as allowable products to ensure that application is effective.

Herbicide tolerant cotton traits

Herbicide tolerant cottons allow the use of non-selective herbicides for summer weed control in-crop. In relatively clean fields, the reliance on residual herbicides for in-crop management is reduced. In fields known to have heavy weed burdens, using non-selective together with residual herbicides can achieve very high levels of control. Avoid using the same herbicide to control successive generations of weeds.

Use field history records to match residual herbicides to the likely weed problems in the field. Applying residual herbicides in combination with other in-crop measures reduces the selection pressure for resistance on all herbicides.

Refer to pages 102–106 for more information.

Residual herbicides

Residual herbicides remain active in the soil for an extended period of time (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 complete. Residual herbicides must be absorbed through either the roots or shoots, or through both Residual herbicides can provide good control of difficult to control weeds, especially when used in conjunction with other tactics. For example when targeting feather top Rhodes grass in fallow, adding a residual to the second paraquat knock, 10-14 days after the first glyphosate knock, improves the paraquat knockdown and extends the period of control. Research has also found that where residuals such as pendimethalin and trifluralin are used for grass control, feather top Rhodes grass declines, especially if the grass escapes are then targeted and controlled in-crop with glyphosate or the Group A chemicals such as haloxyfop and fluazifop.

The use of residuals in the farming system requires good planning as:

- They must be applied in anticipation of a weed problem, and so usage should consider potential weed species and density for at least the previous 12 months.
- 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 incorporation through cultivation which may conflict with other farming practices such as minimum tillage and stubble retention. 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 therefore must be dissipated with a light cultivation or rainfall prior to herbicide application. The risk to crop needs to be minimised. Always refer to the label for instructions on how to apply each residual herbicide.
- While advantageous to weed management, the persistence of residual herbicides needs to be considered within the farming system in terms of rotation cropping sequence. Persistence is determined by a range of factors including application rate, soil texture, organic matter levels, soil pH, rainfall/irrigation, temperature and the herbicide's characteristics. It can be quite complex, for example, moisture can be a big factor, however it is not the volume of rain, but the length of time the soil is moist that is the critical factor. A couple of storms, where the soil dries out quickly won't contribute as much to the breakdown of residuals, compared with soil staying moist for a few days. Table 23 to 26 provides information on some plant-back limitations. Refer to product label for more information. If growers are concerned in the lead up to planting, look for the presence of susceptible weeds in the treated paddock or pot up soil from the treated and an untreated area, sow the susceptible crop and compare emergence. Where there is a concern, plant the paddock last and pre-irrigate if it is to be irrigated.
- Persistence in the environment can also be a concern for industry, and it is important to ensure that best practice is followed in terms of capture and management of runoff water.

Tillage and cultivation

Inter-row cultivation

Inter-row cultivation can be used mid-summer to prevent successive cohorts of weeds from being targeted by post-emergent herbicides. Cultivating when the soil is drying out is the most successful strategy for killing weeds and will reduce the soil damage caused by tractor compaction and soil smearing from tillage implements. However, letting the soil dry down too much will result in poor implement penetration, bringing up clods, require excessive horsepower and be hard on equipment.

EFFECT OF TILLAGE TYPE ON EMERGENCE OF FLEABANE

Tillage type	% Untreated
Zero tillage	100.0
Harrows	9.0
Tynes	8.1
Off set discs	2.6
One-way disc	1.3

Source Widderick/Mclean, DAFF Queensland, 2011.

'Spring tickle' (flush & cultivate)

The spring tickle uses shallow cultivation in combination with a non-selective, knockdown herbicide. The aim of the spring tickle is to promote early and uniform germination of weeds prior to sowing to ease weed pressure in-crop. Some weed species are more responsive to the spring tickle than others. Highly responsive weeds include bellvine and annual grasses – liverseed grass and the barnyard grasses. Weeds that are less responsive include; cowvine, thornapple, noogoora burr and bathurst burr. No till specialist weeds such as Fleabane and feather top Rhodes grass are discouraged from germination by these types of operation.

The shallow cultivation (1–3 cm) can be performed using implements such as, lillistons or go-devils.

Best results are achieved when the cultivation follows a rainfall event of ≥ 20 mm. Adequate soil moisture is needed to ensure that weed germination immediately follows the cultivation. Where moisture is marginal, staggered germination may result in greater weed competition during crop establishment.

Bury seed of surface–germinating species

Use strategic cultivation to bury weed seeds and prevent their germination. Some weed species, such as common sowthistle (milk thistle), flaxleaf fleabane, and feathertop Rhodes grass are only able to germinate from on or near the soil surface (top 20 mm). Tillage operations such as pupae busting, where full disturbance of the soil is required, can be timed to assist in situations where these species have set seed. Burying the seed more than 20 mm below the surface will prevent its germination. This tactic is most successful when used infrequently as seed longevity of common sowthistle and flaxleaf fleabane will be extended from ~12 months to ~30 months by seed burial, meaning that a cultivation pass burying seed which is on the surface could at the same time expose older but still viable seed buried in a previous operation.

Manual chipping

Manual chipping is ideally suited to dealing with low densities of weeds, especially those that occur within the crop row. It is normally used to supplement inter-row cultivation or spraying. Historically chipping has been an important part of the cotton farming system, however this has dramatically reduced in recent years. As a tool to prevent survivors setting seed, chipping has been shown to be a cost effective means of preventing survivor seed set.

Control survivors before they set seed.

For a range of reasons, situations will occur when some weeds escape control by herbicides. Missed strips due to blocked nozzles, inadequate tank mixing, poor operation of equipment, insufficient coverage due to high weed numbers, applying the incorrect rate and interruptions by rainfall are just a few reasons why weeds escape control. If herbicide resistant individuals are present, they will be amongst the survivors. It is critical to the longer term success of the IWM strategy that survivors not be allowed to set seed.

Come Clean Go Clean

To minimise the entry of new weeds into fields, clean down boots, vehicles, and equipment between fields and between properties. Pickers and headers require special attention. Eradicate any new weeds that appear while they are still in small patches. Monitor patches frequently for new emergences.

Irrigation water can be a source of weed infestation with weed seeds being carried in the water. While it is not practical to filter seeds from the water, growers should be on the look out for weeds that gain entry to fields via irrigation. Give special consideration to water pumped during floods, as this has the greatest potential to carry new seeds. If possible, flood water should be first pumped into a storage to allow weed seeds to settle out before being applied to fields. Control weeds that establish on irrigation storages, supply channels and head ditches.

Putting it all together

When preparing a weed management plan it is important to consider the following points:

- What are the key weed species in each field, and how dense are they? Different species may require specific management.
- What is the history of herbicide use in the field? Although glyphosate-tolerant cotton may have only been used in a field for a couple of years, it is important to know what herbicides have been used in other crops and fallows prior. Glyphosate may have been heavily relied upon in fallows long before the introduction of glyphosate-tolerant cotton.
- What herbicides are effective on the key weeds in each field, and when is the best time to use them? In the case of awnless barnyard grass, it is controlled well by glyphosate, paraquat, group A herbicides such as Verdict and some residual herbicides. In a rotation containing glyphosate-tolerant cotton, glyphosate will be used in-crop. However to minimise the glyphosate selection pressure, residual or post-emergent herbicides can also be used. It should also be noted that glyphosate should not be solely relied upon in fallow: this is an opportune time to use paraquat (group L) or perhaps even a residual (keeping in mind they have a medium resistance risk). The table on page 84 shows that Verdict (group A) has a high risk of developing resistance, so its use should be limited to in-crop applications rather than in fallow.
- Any extraneous factors. The presence of a glyphosate resistant weed such as flaxleaf fleabane on a neighboring field or property, for example, would mean there is a high likelihood of the resistant weed being present even if there have been no past indications of resistance. Strategies to deal with resistance need to be implemented before a full-blown problem occurs.
- Last but not least, when can tillage be used? There are a number of opportunities, particularly in irrigated cotton, where tillage can be used. These include pupae busting, incorporation of fertilisers, seed bed preparation and maintaining irrigation furrows. It is possible that these operations can be timed to combine with weed control measures.
- The weed management requirement of the Roundup Ready Flex and Liberty Link Crop Management Plans (CMP's) are designed to ensure that the technology is used as part of an integrated strategy. It is essential that industry follows the CMPs and is proactive in managing the risk of herbicide resistance.

TABLE 23: Herbicide plant backs from rotation crops to cotton

Trade name	Herbicide active ingredient	Registered for use in	Plant back to cotton	Notes
Hotshot	aminopyralid + fluroxypyr	Cereal Crops: wheat, barley, oats, triticale fallows	9 months	Plant back interval on black cracking clay soils. When rainfall is less than 100mm for a period of 4 months or greater the plant back period may be significantly longer.
atrazine	atrazine	Cereal Crops: broom millet, maize, sorghum Legume Crops: lupins Other Field Crops: forage sorghum, potatoes, TT canola, sugarcane Pastures: lucerne, grass pastures	6 months	Following treatments of up to 1.4kg/ha
			18 months	Following treatments of 1.4kg/ha to 3.3kg/ha
Primextra Gold	atrazine + s-metolachlor	Cereal Crops: sorghum, maize. Other Field Crops: sugarcane	6 months	When rates up to 3.2 L/ha are used.
			18 months	When rates up to 3.2 L/ha are used. On alkaline soils, a bioassay or analytical test should be undertaken.
Glean	chlorsulfuron	Cereal Crops: wheat, barley, triticale, oats, cereal rye	18 months	Where soil pH is 6.6–7.5 and 700 mm of rain has fallen. For soil pH >7.5 only grow cotton after growing a test strip.
Lontrel750SG	clopyralid	Cereal Crops: wheat, barley, oats, triticale. Other Field Crops: canola. Pastures and Fallows	3 months	When rates up to 30g/ha are used.
			6 months	When rates of 30–120g/ha are used.
			24 months	When rates above 120 g/ha are used. For all rates at least 100mm rain required during plant back period.

TABLE 23: Herbicide plant backs from rotation crops to cotton (continued)

Trade name	Herbicide active ingredient	Registered for use in	Plant back to cotton	Notes
diuron	diuron	Cereal Crops: wheat, barley, oats, triticale, cereal rye. Legumes: lupins. Pastures: perennial grass seed crops, lucerne	DO NOT replant treated areas within 2 years of application of diuron except when otherwise stated on label	
Broadstrike	flumetsulam	Cereal Crops: winter cereals, maize. Legume Crops: chickpeas, field peas, lentils, soybeans. Other Field Crops: peanuts, fenugreek, lathyrus. Pastures: lucerne, serredella, clover, medic, Popany vetch	6 months(NNSW, QLD) Not stated SNSW	When rates up to 25g/ha are used. Dependent on rainfall (Soil wetness for at least 1 week) and soil type.
			9 months (NNSW, QLD) Not stated SNSW	When rates of up to 50g/ha are used Dependent on rainfall (Soil wetness for at least 1 week) and soil type.
			2 years	On shallow duplex, low organic matter soils with impermeable sub-horizon within root zone (30cm deep or less) and alkaline
Balance	isoxaflutole	Legume Crops: chickpeas. Other Field Crops: sugarcane, fallow	7 months	350 mm rainfall (do not include flood/furrow irrigation) between application and planting the subsequent crop.
Sakura	Pyroxasulfone	wheat (not Durum), triticale	5 months + 150mm of rainfall	Less total rainfall between application and planting of the following crop than 150 mm may require extended plant back period.
Spinnaker	imazethapyr	Legume Crops: chickpeas, faba beans, field peas, mungbeans, soybeans. Other Field Crops: peanuts. Pastures: lucerne, serradella, sub clovers	22 months.	Dryland cotton.,
			18 months.	Irrigated only. (Providing rainfall and irrigation exceeds 2000mm)
Tordon 75D	picloram + 2,4-D	Cereal Crops: wheat, barley, oats, triticale, sorghum, maize. Other Field Crops: sugarcane. Pastures: Pastures	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.
Tordon 242	picloram + MCPA		12 months (Nth NSW & Qld) 20 months (Sth NSW)	Based on normal rainfall.
simazine	simazine	Legume Crops: chickpeas, faba beans, lupins. Fruit & vegetable crops, Forestry & Ornamental. Other Field Crops: TT canola. Pastures: lucerne, sub clover, perennial grasses	9 months	When up to 2.5kg/ha are used.
Logran	triasulfuron	Cereal Crops: wheat, barley, oats	15 months Soil pH Less than 7.5	700 mm rainfall between application and sowing the plant back crop.
			18 months Soil pH 7.6–8.5	
Grazon* Extra	triclopyr + picloram + aminopyralid	Fallow	4 months (0.2L/ha) 6 months (0.4L/ha)	During drought conditions (<100mm rainfall in a 4 month period) the plant back is significantly longer
Hussar	mefenpyr-diethyl + iodosulfuron-methyl sodium	Cereal Crops: wheat.	12 months	Rainfall of less than 500mm following Hussar use may result in extended re-cropping intervals for summer crops sown in the following season.
Sencor 700 Sencor 480	metribuzin	Cereal Crops: wheat, barley, oats Legume Crops: chickpeas, faba beans, lentils, vetch, lupins, field peas, soybeans (irrigated) Other Field Crops: potatoes	12 months 6 months for rates <1.5L/ha; 12 months for rates > 1.5L/ha	This could be longer if there have been long dry periods between crops.
Atlantis	metsulfuron methyl + mefenpyr-diethyl	Cereal Crops: wheat	12 months.	Rainfall of less than 500mm following Atlantis use may result in extended re-cropping intervals for summer crops sown in the following year.

TABLE 24: Plant backs to cotton for herbicides used in seedbed preparation

Herbicide active ingredient	2,4-D amine 700 g/L (2,4-D amine 300 g/L)			dicamba 700 g/kg (dicamba 500 g/L)			fluroxypyr 200 g/L (fluroxypyr 333g/L)			triclopyr 600 g/L
Rate L or g/ha	0.5 (1.1)	0.5–.98 (1.1–2.3)	0.98–1.5 (2.3–3.4)	140 (200)	200 (280)	400 (560)	0.375 (0.225)	0.75 (0.45)	1.5 0.9)	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.

TABLE 25: Herbicides with unknown plant back periods to cotton

Trade name	Active ingredient	Registered for use in
Raptor	imazamox	Legume Field Crops: field peas, soybeans Other Field Crops: peanuts Pastures: lucerne, legume-based pastures
Intervix	Imazamox + imazapyr	Clearfield crops 34 months
Ally	metsulfuron methyl	Cereal Crops: wheat, barley, triticale Legume Crops: chickpeas (desiccant)
Harmony M	metsulfuron methyl + thifensulfuron	Cereal Crops: wheat, barley, triticale
Monza	sulfosulfuron	Cereal Crops: wheat, triticale
Express	tribenuron methyl	Fallows

Where fields have been treated with herbicides with no plant back recommendations to cotton, firstly determine the tolerance of cotton grown through to maturity on a smaller scale before sowing larger areas.

TABLE 26: Cotton herbicide plant backs to rotation crops

Herbicide 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	Cow pea	Fab bean	Field pea	Lab Lab	Lupin	Lucerne	Mungbean	Pigeon pea	Soybean	Canola	Safflower	Linseed	Sunflower
chlorthal dimethyl	8	8	8	8	8	8	8	8	8	8	8	8	8	8	FH	FH	8	FH	8	8	8	8
diuron	24	24	24	24	24	24	24	24	24	24	24	24	24	24	12	24	24	24	24	24	24	24
fluometuron	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
fluometuron + prometryn	6	6	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	24	24
metolachlor	6	0	6	6	0[1]	6	6	6	6	6	6	6	6	6	6	6	6	0	6	6	6	0
norflurazon[2]	24	21	NI	24	21	24	24	NI	3	NI	24	NI	NI	NI	NI	21	NI	3	NI	18	18	27
pendimethalin	6	0[3]	12	12	12	NI	NI	NI	NI	NI	NI	NI	NI	NI	6	NI	NI	NI	6	NI	NI	NI
prometryn	6	6	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	6	0
trifloxysulfuron sodium	6	22	22	6	22	22	6	22	18	22	7	22	22	22	22	9	15	15	22	22	22	22
trifluralin	12	12	12	12	12	12	12	FH	FH	FH	FH	FH	FH	FH	FH	FH	FH	FH	FH	FH	FH	FH

1 Concep II treated seed only.
2 For rates up to 3.5 kg/ha. Where higher rates, up to 4.2 kg/ha are used, increase plant back period by 6 months.
3 Maize can be resown immediately after use in a failed crop provided the seed is sown below the treated band of soil.
Further information in Weed control in Summer and Winter Crop Publications from NSW DPI

FH = following cotton harvest
NR = not recommended
NI = no information
S= in the spring following application