

Herbicide Resistance Management Strategy

Explanatory notes: 2014-15

The Herbicide Resistance Management Strategy (HRMS) is designed as a tool for weed management in irrigated and dryland farming systems incorporating herbicide tolerant (HT) cotton, to delay glyphosate resistance.

This strategy predicts the increased number of years of sustainable glyphosate use that can be achieved using glyphosate plus other tactics both in crop and in summer fallow compared to a glyphosate alone system. It also predicts the effects these tactics will have on the weed seed bank.

The strategy has been developed in response to the escalating problem of group M herbicide resistance. This first version of the HRMS focuses on a glyphosate tolerant cotton system; however the current availability of other HT and future availability of multi-trait herbicide tolerant varieties have also been considered in the design of the strategy, and may require a more sophisticated strategy to follow into the future.

The formula to manage/delay glyphosate resistance:

Extensive modelling of potential glyphosate resistance development has found that irrespective of whether a farm is irrigated or dryland, or the 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 summer fallow targeting both grasses and broadleaf weeds

+

0 survivors, control survivors of glyphosate applications and do not allow them to set seed.

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

How to use the industry HRMS:

This strategy has been designed to help the Australian cotton industry manage the risk of herbicide resistance by indicating how different combinations of weed control tactics affect the timeframe to resistance development as well as their impact on the weed seed bank. Seed bank control is modelled on barnyard grass; however tactics are applicable to all weeds. The same practices apply to managing situations where resistant populations are already present.

Given the diversity of the Australian cotton farming system, 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.

Increased time to resistance:

Modelling has been used to predict the increased time to resistance as compared to a glyphosate only system, as the key determinant of risk. Identify where your cotton system already sits on the timeline to glyphosate resistance.

Research indicates glyphosate resistance develops in grass weeds in 13 years (dryland) and 19 years (irrigated) in a glyphosate only system. Resistance in broadleaf weeds is slower to develop and takes around 18 years in both irrigated and dryland systems with a summer fallow. Glyphosate resistance is delayed by 4-6 years if residual + double knock is already used in summer fallow.

Cropping System:

The HRMS models two systems:

- Continuous back to back irrigated glyphosate tolerant cotton with no summer fallow, and
- Dryland glyphosate tolerant cotton grown every second year, alternating with long summer fallows.

Determine the system that is most similar to your own. If you grow irrigated cotton but at a reduced frequency whether it is broken up by summer fallows or rotation cropping, it is more appropriate to use the dryland scenario. This will be somewhat conservative, as irrigated cotton is able to provide more crop competition.

In a dryland scenario, rotation cropping should be considered similar to a fallow, and using 2 non-glyphosate tactics should be applied. Dryland or irrigated rotation crops provide an important opportunity to incorporate other tactics, rotate herbicide groups, vary the time of year crop competition suppresses weeds and produce stubble loads that reduce subsequent weed germinations.

In Crop Tactics:

- Each model assumes that three over the top (OTT) glyphosate applications are made. Reducing the number of glyphosate applications in crop does not impact the time to resistance substantially. The control of survivors and use of non-glyphosate tactics is much more significant.
- The model assumes that the first weed flush of the season is the largest emergence. Start early in the season for weed seed bank control.

- A key principle of herbicide usage in an IWM system is to rotate herbicide groups.
- Residual herbicides need back up, such as tillage, chipping and non-glyphosate knockdowns. When using residuals, consider plant back periods.
- Aim for 100% control of glyphosate survivors after glyphosate application. In terms of survivor control, high efficacy with an alternative tactic is good, but high frequency control is better than reliance on efficacy. Cultivation after glyphosate application is predicted to achieve 80% survivor control, whereas cultivation plus chipping is predicted to achieve 99.9% survivor control. Other tactics for survivor control could be equally effective, such as shielded or spot-spraying with an effective knockdown herbicide.
- The *Monsanto Roundup Ready Flex Cotton Weed Management Guide* can be referenced for in crop tactic options.

Summer Fallow tactics:

- The dryland model compares glyphosate-only summer fallows with fallows that include 2 non-glyphosate tactics (residual herbicide followed by double knock).
- Summer fallows may include any two non-glyphosate tactics such as residual or knockdown herbicides or tillage that are effective on the weed species.
- See above for comments on rotation crops.

Seed Bank Control:

A high weed burden contributes to herbicide resistance risk, as the more weeds that are present, the more likely that a resistant individual will be present and hence multiplies. Strategies are best aimed at driving down the seed bank and preventing seed bank replenishment.

Seed bank Control Key:

Very high = <10 seeds/m²
 High = 10-100 seeds/m²
 Med =100-500 seeds/m²
 Low = 500-1500 seeds/m²
 Very low =>1500 seeds/m²

Other management recommendations:

- 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 on glyphosate to manage weeds in non-crop areas. Manage adjacent areas as fallows and rotate non-glyphosate tactics including residual herbicide and chipping of weeds.
- Be aware of weed seed contamination sources (eg waterways, vehicle/machinery, and farm inputs). Establish and maintain COME CLEAN. GO CLEAN to prevent introduction and transport of resistant seeds. Monitor high risk areas around machinery sheds and where vehicles enter and exit the farm.
- Monitor and follow up to ensure weeds that survive glyphosate applications are controlled using a non-glyphosate tactic before they are able to set seed
- Get suspect weed survivors tested for resistance – refer to the *Cotton Pest Management Guide* for more
- Patch control - control weeds in isolated patches
- Use IWM best practice when employing tactics

- Regular scouting and correct weed identification
- Good record keeping
- Timely implementation of tactics
- Rotate herbicide mode of action groups
- Always follow label recommendations
- Consider other aspects of crop agronomy.

Assessing your own risk:

For a more detailed assessment of the resistance risks for individual paddocks, use QLD DAFF's *Online Glyphosate Resistance Toolkit*, available via www.mybmp.com.au.

Australia glyphosate sustainability working group findings so far:

All of the glyphosate resistant weed populations (confirmed) have occurred in situations where there has been intense use of glyphosate, often over 15 years or more, few or no other effective herbicides used and few other weed control practices used.

This suggests the following are the main risk factors for the evolution of glyphosate resistance:

- Intensive use of glyphosate - every year or multiple times a year for 15 years or more
- Heavy reliance on glyphosate for weed control
- No other weed control measures

Preston, C. *The Australian Glyphosate Sustainability Working Group*.
www.glyphosateresistance.org.au.

Key findings for delaying resistance development:

Using specific, well-timed, non-glyphosate tactics to control glyphosate survivors after every glyphosate application is the best-performing option & should be the first action.

- Actions taken to control glyphosate survivors should be made to every weed flush in a given year, where possible. Modelling shows that inter-row cultivation is a useful tactic for survivor control, and is further enhanced when followed up with chipping.
- Irrigated systems present greater opportunity to delay glyphosate resistance through more timely herbicide applications to even weed flushes and through enhanced crop competition compared to dryland systems.
- Summer fallows where glyphosate only is used pose the greatest risk of glyphosate resistance development; taking two non-glyphosate actions in every summer fallow is predicted to be of substantial benefit for seed bank control and in many cases to extend the lifespan of glyphosate (especially on barnyard grass) if even a single non-glyphosate action is also taken in crop.
- Using two non-glyphosate actions in every summer fallow is predicted in many cases to extend the lifespan of glyphosate (especially on barnyard grass) in conjunction with a single non-glyphosate action in crop.
- In almost all cases, strategies that work best to slow or prevent resistance are the same as the best strategies for controlling resistant seed banks in the long term.
- Resistance can be imported through machinery or other methods regardless of glyphosate use history.

Cotton HRMS:

Irrigated back to back cotton

Increased time to 100% resistance	In crop tactics 3 x OTT glyphosate applications PLUS	Seed bank control	Comments
>20 years	Very high survivor control after each OTT glyphosate	Very high	Aim to avoid controlling last in crop flush with glyphosate alone
	Moderate survivor control after each OTT glyphosate	Very high	Control survivors of OTT applications
	2 x strategic in crop cultivations	Very high	Time the second cultivation to control last weed flush and escapes prior to row closure
10-20 years	Pre-plant residual plus residual layby	Very high	Consider plantback period restrictions
5-10 years	Very high survivor control after first OTT glyphosate	Very high	Control survivors from first flush which has highest weed germination
	Cultivation + grass selective herbicide (note: repeated use of Group A grass selective herbicide can lead to development of Group A resistance)	Effects on seed bank not yet modelled	
<5 years	Moderate survivor control after first OTT	Low	Control survivors from the first flush which has the highest weed germination
nil	Glyphosate only	Very low	Test survivors for glyphosate resistance

Simulation data provided by D. Thornby

Model Assumptions:

- Glyphosate tolerant cotton grown every summer with a short winter fallow. 3 in crop glyphosate applications are made + 1 in fallow.
- Cultivation occurs in winter for crop destruction, pupae busting, stubble management and seedbed preparation but not specifically for weed control.
- The first weed flush of the season is the largest emergence.
- Pre-plant residual + layby assumes a maximum of 90% efficacy and an average of 70% to 85% efficacy over 30 years.
- Seed bank control is modelled on barnyard grass
- Survivor control:
Very high survivor control = 99.9%. This can be achieved through cultivation then chipping or spot spraying with an alternative mode of action.
Moderate survivor control = 80%. This can be achieved through cultivation.

Notes:

- Do NOT rely on glyphosate to manage weeds in non-crop areas (channels, tail drains, head ditches). Manage adjacent areas as fallows and rotate with non-glyphosate tactics to control weeds and cotton volunteers.
- COME CLEAN. GO CLEAN to prevent introduction and transport of resistant seeds. Monitor high risk entry areas and patch manage introduced weed seeds.
- Monitor and follow up to ensure survivors are controlled by another tactic before they are able to set seed. Have suspect weed survivors tested for resistance
- Conduct regular scouting and correct weed identification.
- Keep good records.
- Ensure timely implementation of tactics
- Rotate herbicide mode of action groups.
- Always follow label recommendations.
- Refer to the *Cotton Pest Management Guide* for additional tips on IWM and use of tactics.

Cotton HRMS:

Dryland cotton every second summer

Increased time to 100% resistance	Summer fallow tactics	In crop tactics 3 x OTT glyphosate applications PLUS	Seed bank control	Comments
>20 years	2 non-glyphosate tactics	Very high survivor control after each OTT glyphosate	Very high	The most effective scenario for delaying glyphosate resistance
10-20 years	Glyphosate only fallow	Very high survivor control after each OTT glyphosate	Very high	Very high frequency & efficacy of survivor control is required if in-crop only tactics are used.
	2 non-glyphosate tactics	Moderate survivor control after each OTT glyphosate	High	Lower intensity in-crop tactics can give excellent results if backed up in summer fallows. Specific, frequent, well-timed control of glyphosate survivors provides long-term resistance delay/management
5-10 years	Glyphosate only fallow	Two strategic cultivations	Low	Time last cultivation to control late flushes and escapes
<5 years	Glyphosate only fallow	Pre-plant residual + layby	Very Low	These tactics give limited increased time to resistance and poor seed bank control
	Glyphosate only fallow	Moderate survivor control after each OTT	Very Low	
	2 non-glyphosate tactics	Glyphosate only	Very Low	
nil	Glyphosate only fallow	Glyphosate only	Very Low	

Decreasing - Non-glyphosate tactics and survivor control - increasing

Simulation data provided by D. Thornby

Model Assumptions:

- Glyphosate tolerant cotton grown every second summer, alternating with long summer fallows.
- 2 non-glyphosate tactics in summer fallow – model uses residual herbicide followed by double knock.
- Model assumes pre-plant residual + layby has a maximum of 90% efficacy, averages 70% to 85% efficacy.
- Seed bank control modelled on barnyard grass
- Survivor control:
Very high survivor control = 99.9%. This can be achieved through cultivation then chipping or spot spraying with an alternative mode of action.
Moderate survivor control = 80%. This can be achieved through cultivation.

Notes:

- Do NOT rely on glyphosate to manage weeds in adjacent non-crop areas (roadways, fencelines). Manage adjacent areas as fallows and rotate with non-glyphosate tactics to control weeds and cotton volunteers.
- COME CLEAN. GO CLEAN to prevent introduction and transport of resistant seeds. Monitor high risk entry areas control weeds in isolated patches
- Monitor and follow up to ensure that survivors of glyphosate applications are controlled using another tactic before they set seed. Have suspect weed survivors tested for resistance
- Conduct regular scouting and correct weed identification.
- Keep good records.
- Ensure timely implementation of tactics
- Rotate herbicide mode of action groups
- Always follow label recommendations
- Refer to the *Cotton Pest Management Guide* for additional tips on IWM and use of tactics.