

# Herbicide tolerant technology

## Liberty Link Technology

Developed by **Bayer CropScience** in association with the **Herbicide Tolerance Technical Panel of the Transgenic and Insect Management Strategies Committee of Cotton Australia**

### Liberty 200 Herbicide mode of action

In plants, the glutamine synthetase enzyme combines ammonium with glutamate to form glutamine which is then used by plants in photosynthetic processes. The active ingredient of Liberty 200 Herbicide, glufosinate-ammonium, inhibits the actions of the glutamine synthetase enzyme, stopping plants from utilising ammonium. Soon after application of Liberty 200 Herbicide, plant growth ceases and symptoms appear within a couple of days. Initially there is a general yellowing before damaged patches appear which enlarge as the plant wilts and collapses. Within 1–3 weeks the plant dies from the combined effects of ammonia building up to toxic levels within the cells and the breakdown of photosynthesis.

Liberty 200 Herbicide is a broad spectrum, post-emergent herbicide that is active against green plant tissue. It has no soil or residual activity. A range of broadleaf weed species are listed on the label. The label recommends that weeds should be targeted at the 2–6 leaf growth stage. As there is only very limited systemic movement of the product through the plant, high water volumes of at least 100 L/ha should be used to ensure thorough coverage. Liberty 200 Herbicide has shown activity on a number of other weeds including summer grasses, common thornapple, bathurst burr and common vetch. However further investigation is required before label claims could be made.

For resistance management purposes Liberty 200 Herbicide is a Group N herbicide. This is the first Group N herbicide to be made available for use in cotton. The use of Liberty Link technology in rotation with non-herbicide tolerant cotton and Roundup Ready technology can help to reduce the selection pressure on weeds from currently used herbicides.

### How does Liberty Link cotton work?

Liberty Link cotton contains the bar gene derived from the common soil bacterium, *Streptomyces hygroscopicus* which allows it to express a protein that blocks the action of Liberty 200 Herbicide. The protein, known as phosphinothricin acetyltransferase (PAT) attaches an acetyl group to the glufosinate ammonium molecules, rendering them ineffective. The expression of PAT allows Liberty Link cotton to continue producing glutamine when glufosinate-ammonium is present.

### How tolerant is Liberty Link cotton to Liberty 200 herbicide?

Liberty Link cotton is tolerant to repeated applications of Liberty 200 Herbicide when used in accordance with label recommendations. A maximum of three over-the-top applications can be made each season. Applications can be made up until 10 weeks prior to harvest.

### Weed management with Liberty Link

Before growing Liberty Link cotton, develop and document a weed control strategy for each field, including a rotation

### Sampling options when conducting weed audits in Liberty Link cotton.

#### Audit Method A

Divide the field into quarters. Within each quarter, select 2 x 50 m linear row ( $\geq 20$  m apart) that are representative of the weed burden prior to application. After application, assess these areas in at least three quarters of the field.

#### Audit Method B

Field Size	Sample size	Distance between each sampling site
<50 ha	4 x 100 m linear row	Minimum 100 rows
51–100 ha	6 x 100 m linear row	Minimum 100 rows
101–200 ha	8 x 100 m linear row	Minimum 100 rows
>200 ha	2 x 200 m linear row	Minimum 100 rows

program for crop and herbicide usage. For fields with heavy weed burdens, or where there is not the capacity to treat all Liberty Link cotton in a timely manner, Bayer CropScience recommends the use of residual herbicides prior to or at planting. Below are two example weed situations and suggested integration of Liberty Link technology into the weed management strategies.

Weed situation	IWM strategy
Light infestation of broadleaf	<ul style="list-style-type: none"> <li>– Glyphosate herbicide pre-plant</li> <li>– Liberty 200 Herbicide applied over-the-top of the established Liberty Link crop (1–3 applications)</li> <li>– Inter-row cultivation</li> <li>– Layby or selective herbicides if required</li> </ul>
Heavy infestation of broadleaf weeds, especially peach vine, bladder ketmia and dwarf amaranth	<ul style="list-style-type: none"> <li>– Residual herbicide incorporated pre or at planting of broadleaf weeds,</li> <li>– Liberty 200 Herbicide applied over-the-top of the established Liberty Link crop (1–3 applications)</li> <li>– Inter-row cultivation</li> <li>– Layby or selective herbicides if required</li> </ul>

### Managing Liberty Link volunteers

Control of cotton volunteers is an important component of rotational flexibility and an essential component of farm hygiene. Cultivation and herbicides are the two most common methods of controlling volunteer cotton. Cultivation is an effective and efficient method of managing all types of volunteer cotton. Seedling, established and ratoon growth stages of conventional, Roundup Ready Flex and Liberty Link varieties can be controlled with cultivation. Herbicides are only able to effectively control seedling volunteers. Liberty Link seedling volunteers are susceptible to Roundup Ready herbicide. Alternative herbicide options are Spray.Seed, Hammer and Pledge.

Where Liberty Link seedling volunteers are present in a Liberty Link crop, the options for their control are the same as those for removing conventional cotton volunteers from conventional cotton. Refer to WEEDpak for strategies to control cotton volunteers or page 118.

### Audit requirements in the Liberty Link crop management plan

Growers holding a Liberty Link licence are required to conduct a weed audit in each field of Liberty Link cotton that has been treated with Liberty 200 Herbicide. The weed audit should take

place prior to crop canopy closure and from 14–18 days after an application of Liberty 200 Herbicide. The person conducting the audit is required to have undertaken the optional, additional module covering Weed Audits as part of successfully completing the Liberty Link Cotton and Liberty 200 Herbicide Accreditation Program with Bayer CropScience.

To sample the field, use Audit Method A where the distribution of weeds within the field prior to applying Liberty 200 Herbicide is known. Sample using Audit Method B where weed distribution prior to application is unknown. Methods A and B are shown on page 102. Within the sample areas, identify surviving weeds and volunteers. For each survivor, rate the infestation severity. Complete a Liberty Link Cotton Weed Management Audit form to capture the observations of the audit sampling, general comments on weed control and remedial action taken to control any surviving weeds prior to seed set. Return completed forms to Bayer CropScience by 31 December. Audit data will be collated and reported to the TIMS Weeds Subcommittee.

### Application guidelines

The Liberty 200 Herbicide is not significantly translocated as an active herbicide throughout the plant and therefore will only kill that part of the green plant that is contacted by the spray. Best results are achieved when applications are made to young weeds that are actively growing under warm, humid conditions. (eg. temperatures below 33°C and relative humidity above 50%.)

### Pre-plant paddock preparation

Control all existing weeds by cultivation or by using a knockdown herbicide such as glyphosate or paraquat.

### Over-the-top applications

Liberty 200 Herbicide can be applied over-the-top of Liberty Link cotton from emergence through to 10 weeks prior to harvest. Application can only be made using a ground boom sprayer. Application volumes of at least 100 L water/ha through flat fan nozzles with droplet size of 200–300 microns are recommended for most situations. Up to 3 over-the-top applications can be made each season.

### Tank mixes with Liberty 200 Herbicide

Liberty 200 Herbicide may be tank mixed with some other herbicides and insecticides. Check with your local Bayer CropScience representative for tank mixing compatibilities.

### Keeping good field records

It is essential that farmers keep records of the crops planted, the weeds present and the weed control methods each growing season. Such information is vital when planning crop and herbicide rotations to manage weeds, volunteers and herbicide resistance. Ensure good records are kept in relation to Liberty Link cotton and can be made available to Bayer CropScience or the regulatory authorities as required. Keep records for at least 2 years after harvest.

As a minimum, maintain records of:

- Paddock history – crop rotation, weeds present, herbicide applications, the use of non-herbicide weed controls, other management practices influencing weed control.
- A farm map with field reference numbers and varieties sown.
- Seed bag labels and accompanying information, especially seed lot numbers.

Further Information:

Website: [www.bayercropscience.com.au](http://www.bayercropscience.com.au)

## Roundup Ready Flex technology

Monsanto Australia Limited,  
Graham Charles and Tracey Leven, CRDC

### How does Roundup Ready Flex cotton work?

The primary effect of glyphosate on plants is the inhibition of the production of EPSPS. EPSPS is an enzyme responsible for the production of amino acids essential for protein construction and plant growth. Monsanto identified a soil bacterium that produces a modified form of the EPSPS enzyme, the CP4 strain. The CP4 strain of EPSPS is not inhibited by Roundup Ready Herbicide with PLANTSHIELD by Monsanto. Roundup Ready Flex cotton plants produce the modified form of EPSPS, so are able to continue producing amino acids and proteins after Roundup Ready Herbicide with PLANTSHIELD by Monsanto has been applied. Roundup Ready Flex cotton contains two copies of the CP4 EPSPS gene and a promoter sequence resulting in expression in both the vegetative and reproductive parts of the plant. Roundup Ready Flex cotton is therefore able to tolerate applications of glyphosate in its vegetative (pre-squaring) and reproductive (squaring, flowering, boll development and maturation) stages. Roundup Ready Herbicide with PLANTSHIELD by Monsanto may be applied over the top (OTT) of Roundup Ready Flex cotton up to four times between emergence and 22 nodes, while one application is allowed between 60% bolls open and harvest. However, the total amount of herbicide applied to any one crop must not exceed 6 kg/ha in a total of 4 applications as illustrated in Figure 10. Crops that are intended for seed production must not have an application of Roundup Ready herbicide past the 60% bolls open stage.

The full-plant glyphosate tolerance of Roundup Ready Flex means that applications of glyphosate can be made irrespective of the rate of crop growth or the number of days between applications with no effect on fruit retention, fibre quality parameters or yield.

### Weed management in Roundup Ready Flex

Roundup Ready Flex cotton offers growers an increased margin of crop safety, a more flexible window for OTT applications of Roundup Ready Herbicide with PLANTSHIELD by Monsanto, and the potential to improve the efficacy of weed control. However Roundup Ready Flex cotton should be viewed as a component of an Integrated Weed Management (IWM) system, not as a solution to all weed management scenarios. Weeds species with natural tolerance to glyphosate will be selected for with repeated glyphosate applications, resulting in species shift. The most effective, economic and sustainable weed management system for growers will, therefore, be achieved using an integrated (IWM) approach. Refer to weed section pages 92–101 for detailed information on integrated weed management recommendations.

### Know your field history

A combination of the relative effectiveness of previous herbicide programs and other agronomic practices employed on a farm is likely influence the weed species present in any field. The correct identification and a basic understanding of the biology and ecology of the weeds present in a field

are essential elements in the design of a successful weed management program. It is critical that the appropriate herbicide and herbicide rate are chosen for the target weed species. By knowing field history, growers can determine which weed control tools they should use and when they should be employed to achieve the best results.

### Pre-plant knockdown

Starting with a 'clean' field provides seedling cotton with the best possible conditions to emerge and to develop, unhindered by the competitive effects of weeds. Pre-plant weed control can be achieved using tillage and/or the appropriate registered herbicides. The use of glyphosate tank mixes or herbicides with other modes of action is encouraged prior to planting to strengthen the IWM program. It is important that any cotton volunteers are controlled at this stage.

### The role of residual herbicides

Residual herbicides should be used where appropriate in the Roundup Ready Flex system. The nature of pre-emergence residual herbicides often requires that they be applied in anticipation of a weed problem. Consideration for the use of residual herbicides in a weed control program for any given field should be determined based on the knowledge of the field's history.

### The first OTT (over-the-top) application

Cotton is a very poor competitor and is sensitive to early season weed competition. The longer OTT window with Roundup Ready Flex may tempt growers to delay the first OTT application of Roundup Ready Herbicide with PLANTSHIELD by Monsanto in the hope that multiple weed germinations can be controlled with a single spray. Whilst competitive affects will vary according to weed species and weed density, it is commonly recognised that good weed control in the first 6-8 weeks following crop emergence maximises cotton yield potential. Delaying the initial OTT application may result in growers having to target weeds later in the season that are beyond the growth stage for optimum control.

### Subsequent OTT (over-the-top) applications

After the first OTT application, the use of subsequent OTT applications (up to a maximum of four), should be made according to the presence of new weed germinations. In any field, a mix of weed species will commonly exist. Correct

identification of weeds is very important as this will have a direct impact on the rate selection and application timing(s) chosen. Select the timing and application rate of Roundup Ready Herbicide with PLANTSHIELD by Monsanto based upon the most difficult to control weed species in each field.

### Inter-row cultivation

Inter-row cultivation is a relatively cheap and non-selective method of weed control. In irrigated cotton, it also assists in maintaining furrows to facilitate efficient irrigation. In a Roundup Ready Flex crop, inter-row cultivation contributes to the diversity of weed control methods being employed and, as such, is a valuable component of an IWM strategy.

### Lay-by residual application

Growers and their advisors are encouraged to scout fields prior to row closure and to combine these observations with their historical knowledge of individual fields to ascertain the need for a lay-by herbicide application. A lay-by application should be used on fields where there is an expectation of a significant emergence of weeds later in the season.

### Pre-harvest application

One application of Roundup Ready Herbicide with PLANTSHIELD by Monsanto may be made OTT between 60% boll open and harvest. In most circumstances, good weed control earlier in the crop should render the pre-harvest application redundant. However, if late season weeds are present, a pre-harvest application can be used to reduce seed set and improve harvest efficiency. Pre-harvest applications of glyphosate will not provide regrowth control in Roundup Ready Flex cotton.

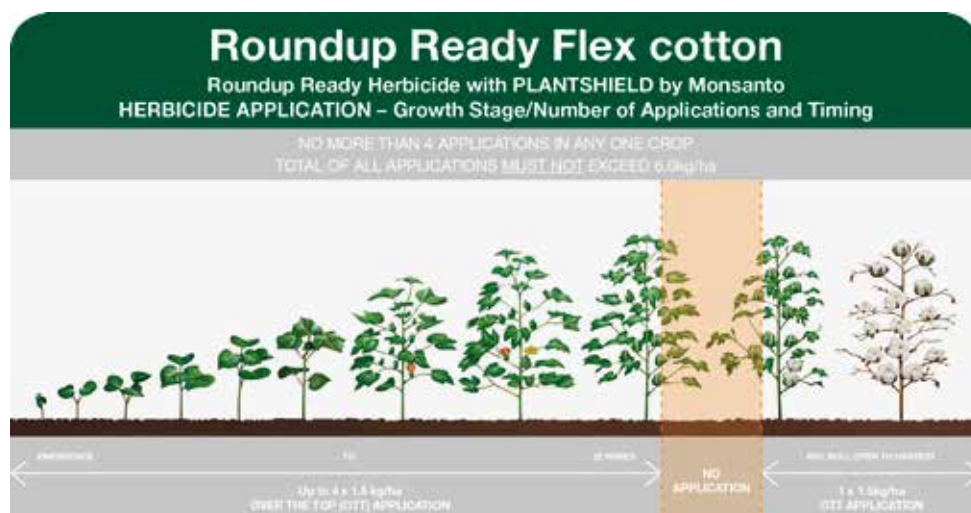
### Audit requirements in the Roundup Ready Flex crop management plan

It is a requirement of the Technology User Agreement (TUA) that growers sign annually that all persons growing and managing Roundup Ready Flex cotton crops comply with the Crop Management Plan (CMP). Within the CMP, there are the requirements for a Planting Audit and a Weed Management Post Spray Survey.

### Planting audit

The Technology Service Provider (TSP) is responsible for completion of the planting audit by no later than 5th December,

**FIGURE 10: Roundup Ready Flex cotton allows you to spray Roundup Ready® herbicide with PLANTSHIELD by Monsanto over the top (OTT) of your cotton from emergence through to 22 nodes.**



as set out in the Technology User Agreement (TUA). The information required includes:

- Number of hectares sown;
- Location of Roundup Ready Flex cotton on the farm unit;
- Date/s of sowing; and,
- A record of compliance with the Bollgard II Resistance Management Plan (RMP) and the CMP

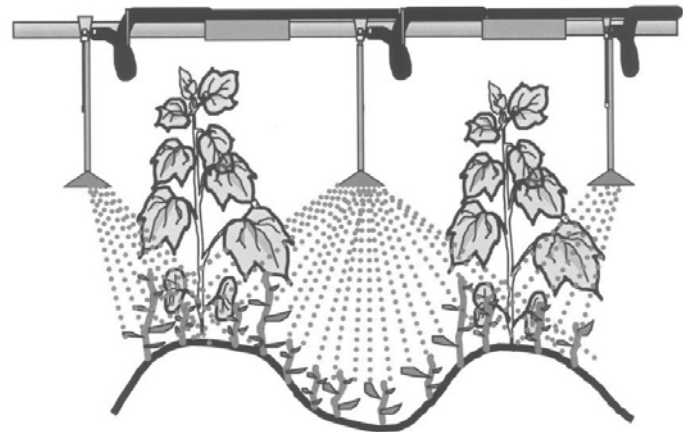
### Weed management Post Spray Survey

Only accredited TSPs will be able to conduct the Weed Management Post Spray Survey.

TSPs will undertake the Post Spray Survey on a percentage of fields growing Roundup Ready Flex cotton in accordance with Table A. TSPs will assess all weeds remaining ten to fourteen days after an OTT) application of Roundup Ready Herbicide or Roundup Ready Herbicide with PLANTSHIELD by Monsanto at a minimum of 6 nodes crop growth, and not exceeding 16 nodes.)

TABLE A: Post Spray Survey requirements in field	
Field size	Assessment of surviving weeds
< 50 ha	4 x 100 metres linear row
51–100 ha	6 x 100 metres linear row
101–151 ha	8 x 100 metres linear row
> 150 ha	8 x 200 metres linear row

Table A outlines how to assess the field for the presence of surviving weeds. The minimum distance between each assessment (ie each 100 metres linear row) must be 100 rows. In addition to the assessment of surviving weeds, the TSP is required to record:



Directed application between 16 and 22 nodes targets weeds along the plant line.

- Reasons as to why survival of weeds has occurred. For example, this may be due to shading, environmental conditions, subsequent germinations, off label weeds or suspected resistance
- Any remedial action taken to stop seed set of surviving weeds. Weeds identified to have survived Roundup Ready Herbicide applications must be controlled by an alternative management strategy in order to prevent those weeds from setting seed. Details on this strategy must be provided
- Adverse event reporting. Growers and TSPs are required to report any adverse event, such as suspected weed resistance, to Monsanto as soon as it is identified. Monsanto must report any cases of confirmed resistance to the APVMA.

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Monsanto will discuss the data collected with relevant industry weed scientists and any findings will be reported to the TIMS Herbicide Tolerant Crop Technical Panel and the APVMA.

### Managing Roundup Ready Flex volunteers

A major consideration in the development of an IWM plan for Roundup Ready Flex is the management of herbicide tolerant cotton volunteers. Plans need to be made to use cultural control options and herbicides with alternate modes of action in fallows and subsequent crops to control volunteers. Refer to pages 118–119 for more information

### Application guidelines

#### Timing options

The Roundup Ready Herbicide with PLANTSHIELD by Monsanto label permits:

- Applications in fallow, prior to sowing the Roundup Ready Flex crop, with the maximum rate applied dependent on the targeted weed/s. Application may be made by ground rig sprayer or by aircraft.
- Up to four applications of Roundup Ready Herbicide between crop emergence and 22 nodes of crop growth, with a maximum of 1.5 kg/ha being applied in any single spray event.
- An option for a pre-harvest application, alone or in tank mix with Dropp, once the crop is 60% open and immature bolls cannot be cut with a sharp knife. The maximum herbicide rate for pre-harvest use is 1.5 kg/ha. Application may be made by ground rig sprayer or by aircraft.

- Not more than four applications and 6.0kg of Roundup Ready Herbicide with PLANTSHIELD by Monsanto may be applied through all growth stages of Roundup Ready Flex cotton in any one growing season.

Tank-mixtures with other herbicides or insecticides are not recommended for over-the-top applications of Roundup Ready Herbicide with PLANTSHIELD by Monsanto due to the potential for reduced weed control or crop injury to result. (Refer to Label for Directions for use – Roundup Ready Flex cotton).

#### Over-the-top applications

Before an over-the-top application, it is absolutely essential to thoroughly decontaminate the sprayer of any products which might damage the crop, particularly sulfonylurea and phenoxy herbicides. For ground rig sprayers, a spray volume of 50–80 litres per sprayed hectare is recommended for optimum performance. Nozzles and pressure settings must be selected to deliver a minimum of a COARSE spray quality (American Society of Agricultural Engineers (ASAE) S572) at the target. For aerial application, nozzles and pressure settings must be selected to deliver a minimum of a COARSE spray quality (ASAE SS572) at the target. A minimum total application volume of 40L per hectare needs to be used. Do not apply Roundup Ready Herbicide with PLANTSHIELD by Monsanto by aircraft at temperatures above 30°C or if relative humidity falls below 35%.

#### Other Sources of Information:

Roundup Ready Flex Cotton Technical Manual, Monsanto Australia Ltd.  
Technical enquiries: 1800 804 479

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