

Roundup Ready Flex[®] cotton

Technical Manual



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1. About the Roundup Ready Flex cotton Stewardship Program

The Roundup Ready Flex cotton stewardship program is a part of the Monsanto Quality Assurance program supporting Roundup Ready Flex technology. In order to responsibly introduce and steward Roundup Ready Flex cotton, Monsanto is committed to ensuring that growers and their advisors are fully informed and supported with the appropriate tools.

The aims of the Roundup Ready Flex cotton stewardship strategy are to:

- Enable growers to **maximise the overall benefit** from the technology
- Ensure that all persons involved in the growing and management of Roundup Ready Flex cotton crops have a good understanding of the **agronomic considerations and application options** associated with the technology
- Protect the **sustainability of Roundup Ready Flex cotton** and to aid in minimising the risk of the evolution of glyphosate resistant weeds in the Australian cotton production system
- Ensure **compliance with the regulatory requirements** that accompany the technology.

All users will receive training and must exhibit competency before they will be accredited to service or use the technology.

2. Benefits of a Roundup Ready Flex cotton weed control system

Outstanding crop safety

- a. Built in vegetative and floral tolerance allows safe, in crop application of Roundup Ready herbicide with PLANTSHIELD
- b. Reduced potential for drift on neighboring crops with the opportunity to wait for the correct environmental conditions before spraying
- c. Reduced reliance on pre-plant residuals enhances plant establishment and seedling vigor, leading to fewer replants and fewer incidents of delayed crop development
- d. Reduced disease through less root damage

Management efficiencies

- a. Reduced residuals
 - less incorporation requirements and more flexible crop rotations
- b. Reduced chipping
 - minimizing time, people and OH&S concerns
- c. Reduced cultivation
 - less soil compaction, root pruning, spread of weeds and disease, improved moisture retention
- d. Reduced reliance on shielded spray equipment
- e. Reduced application time
- f. Reduced labour and equipment requirements with lower fuel, repairs and maintenance costs
- g. Reduced variability in weed control costs
 - improved budgeting
 - increased risk management

Superior and flexible weed control

- a. Wide herbicide application opportunity
 - OTT application – emergence to 22 nodes
 - OTT application 60% open to harvest
- b. Superior broad spectrum control of weeds using a herbicide you've had confidence in for over 30 years
 - manage hard to control weeds
 - less weed escapes
 - better weed control in wide row configurations
- c. Flexible in crop weed management
- d. Ability to control weeds when and where they appear
 - direct applications to target weeds **WHERE** they appear e.g. in furrow or in row
 - no restriction between sequential applications of Roundup Ready herbicide with PLANTSHIELD
 - superior weed control under the plant line

3. Getting the best from Roundup Ready Flex[®] cotton

3.1 Before planting

- Growers and advisors should consider Roundup Ready Flex cotton in the context of, and manage their fields within the context of, their existing **Integrated Weed Management** strategies. For more information, refer to section 10.
- Roundup Ready Flex cotton, non-Roundup Ready Flex cotton fields and other susceptible crops need to be clearly marked, and identified for all farm contractors and staff.
- Growers should integrate Roundup Ready Flex into their Pesticide Application Management Plan (PAMP) and make all applications of Roundup Ready herbicide with PLANTSHIELD according to the **AUSTRALIAN COTTON INDUSTRY'S BEST MANAGEMENT PRACTICES MANUAL**.
- Do not mix up Roundup Ready Flex and *non-Roundup Ready Flex* planting seed in the seed box.

3.2 Weed control

Know your field history

- Plan your weed control program to suit the weed spectrum and burden for each individual field.
- Use the **RIGHT TOOL**, using the **RIGHT RATE** at the **RIGHT TIME**.

Pre-plant knockdown

- Always start clean by planting into a weed-free field using either tillage or a herbicide application.
- Know your field history in order to identify whether any volunteer cotton present is Roundup Ready Flex.
- Consider using tank mixes with Roundup Ready herbicide with PLANTSHIELD or other registered products as part of an IWM strategy.

Residual herbicides

- Residual herbicides should be used where appropriate in a Roundup Ready Flex weed control system.
- Consider using residual herbicides where weeds not controlled by Roundup Ready herbicide with PLANTSHIELD are present.
- The residual herbicide can be applied as a pre-emergence application (either a pre-plant incorporated application, or at planting application).
- Use the recommended labelled rate and timing of the residual herbicide.

In-crop weed control

- Only apply Roundup Ready herbicide with PLANTSHIELD according to the registered application window
 - 0–22 nodes – 4 OTT applications (max 1.5 kg/ha per application)
 - 60% open to harvest – 1 OTT application (max 1.5 kg/ha per application)
- Use a maximum of 4 applications and no more than a total of 6.0 kg/ha of Roundup Ready herbicide with PLANTSHIELD per crop.
- Target the first application of Roundup Ready herbicide with PLANTSHIELD on young cotton with weeds less than 6cm in size.
- Sequential applications of Roundup Ready herbicide with PLANTSHIELD may be required to control new and subsequent germinations of weeds.
- Select the timing of sprays based on the most difficult to control weed species in each field.
- Post directed sprays should be used to achieve more thorough coverage on weeds.

- Refer to the “Weeds Controlled” table in the Roundup Ready herbicide with PLANTSHIELD for rate recommendations on specific weeds.
- Be aware of any potential contamination of spray application equipment (including mixing stations). Ensure all equipment is thoroughly cleaned and free of residues.
- Do not tank mix any product with Roundup Ready herbicide with PLANTSHIELD.
- Ensure all applications are made according to label guidelines on water volume, droplet size and environmental conditions.
- Be aware of off-target drift to susceptible crops and fields with both aerial and ground applications.

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 Roundup Ready herbicide with PLANTSHIELD.
- Use the recommended labelled rate and timing of the residual herbicide.

Pre-harvest application

- OTT application of 1.0 kg/ha is available if required before harvest and after cotton reaches 60% open bolls.
- This application can be used to control late season weeds and improve harvest efficiency.
- Compatible with commonly used defoliants (see Roundup Ready herbicide with PLANTSHIELD label). Do not use on crops intended for seed production.

3.3 Volunteer management

- Have plans in place to deal with any Roundup Ready Flex volunteers, monitor for their presence and plan to control them at an early growth stage.
- Remember, Volunteer Roundup Ready Flex cotton plants will not be controlled by Roundup Ready herbicide with PLANTSHIELD or any generic glyphosate product.

3.4 Crop management plan

- Read and adhere to the directives in the CMP and herbicide label.
- Practice Integrated Weed Management as a means of proactive resistance management as well as best weed management practice. For more information on Integrated Weed Management, refer to section 10.
- Stop seed set – control weeds that have “escaped” a Roundup Ready herbicide with PLANTSHIELD application with an effective alternative method.

4. Introduction to Roundup Ready Flex

In this Section

What is Roundup Ready Flex cotton?

How does Roundup Ready Flex cotton work?

How tolerant is Roundup Ready Flex to applications of Roundup Ready herbicide with PLANTSHIELD?

Summary Points

- Roundup Ready Flex cotton utilises the CP4 mechanism for glyphosate tolerance
Roundup Ready Flex cotton offers a very high margin of crop safety due to its tolerance to glyphosate during cotton fruiting.
- There is no restriction on number of days or cotton growth rate between sequential glyphosate applications.
- Australian trials have demonstrated that the fruiting dynamics, yield and fibre quality of Roundup Ready Flex cotton were not altered throughout the growing season with OTT applications of Roundup Ready herbicide with PLANTSHIELD.

4.1 What is Roundup Ready Flex cotton?

Roundup Ready Flex cotton has been modified using gene technology to tolerate applications of glyphosate, the active ingredient in the Roundup® family of herbicide.

Conventional cotton is susceptible to glyphosate damage and so with Roundup Ready Flex growers can apply Roundup Ready herbicide with PLANTSHIELD to control weeds that emerge in their crop without causing crop damage.

4.2 How does the technology work?

The primary effect of glyphosate is to interrupt the production of proteins essential for plant survival. Glyphosate acts on a specific biochemical process called the shikimate pathway, which converts sugars produced from photosynthesis into amino acids used to form plant proteins. Glyphosate inhibits the production of EPSPS (5-enolpyruvylshikimate-3-phosphate synthase) which is an enzyme critical in the process.

The amino acids (phenylalanine, tryptophan, and tyrosine) are important components of proteins and take part in a number of vital biochemical reactions in the plant. Essentially, the plant runs out of protein while growth-inhibiting processes also occur. This ultimately leads to senescence.

Monsanto was able to identify a soil bacterium which produced a modified form of the EPSPS enzyme, the CP4 strain, which was not affected by Roundup Ready herbicide with PLANTSHIELD. This modified form of EPSPS is functionally and chemically similar to naturally occurring EPSPS. The modified enzyme allows the production of amino acids and proteins in the presence of Roundup Ready herbicide with PLANTSHIELD and as a result, the modified plant is unaffected by applications of this herbicide. Roundup is **not metabolised** by the modified enzyme.

Therefore Roundup Ready herbicide with PLANTSHIELD can be used for weed control in Roundup Ready Flex crops. This is shown schematically below.

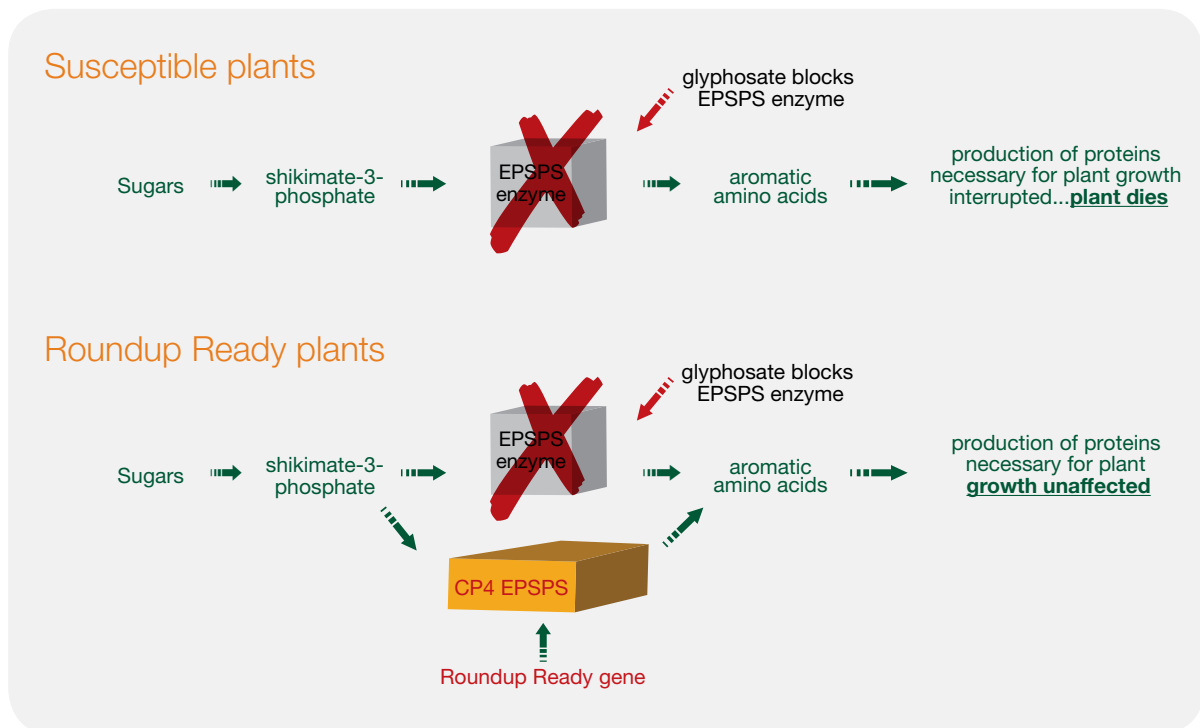


Figure 4.2.1 How Roundup and Roundup Ready crops work.

4.3 How tolerant is Roundup Ready Flex to Roundup Ready herbicide with PLANTSHIELD?

In Roundup Ready Flex cotton the two copies of the CP4 EPSPS gene present are expressed in **both** the vegetative parts and the floral parts of the plant. As such Roundup Ready Flex is able to tolerate applications of glyphosate when the cotton plant is in its reproductive phase (squaring, flowering, boll formation and maturation).

Additionally the full plant glyphosate tolerance of Roundup Ready Flex cotton means that sequential applications of glyphosate can be made to the plant without consideration of cotton growth rate or the number of days between applications.

Trial work has also been conducted in Australia to examine the growth, development, crop yield and fibre quality as part of the phenotypic evaluation of Roundup Ready Flex cotton. The purpose of the trials was to assess whether the presence of the novel proteins in Roundup Ready Flex cotton, or the application of Roundup herbicide to the plant, altered the agronomic characteristics of the plant when grown under Australian production conditions. Trials were conducted at 8 different locations throughout the cotton belt over 2 seasons.

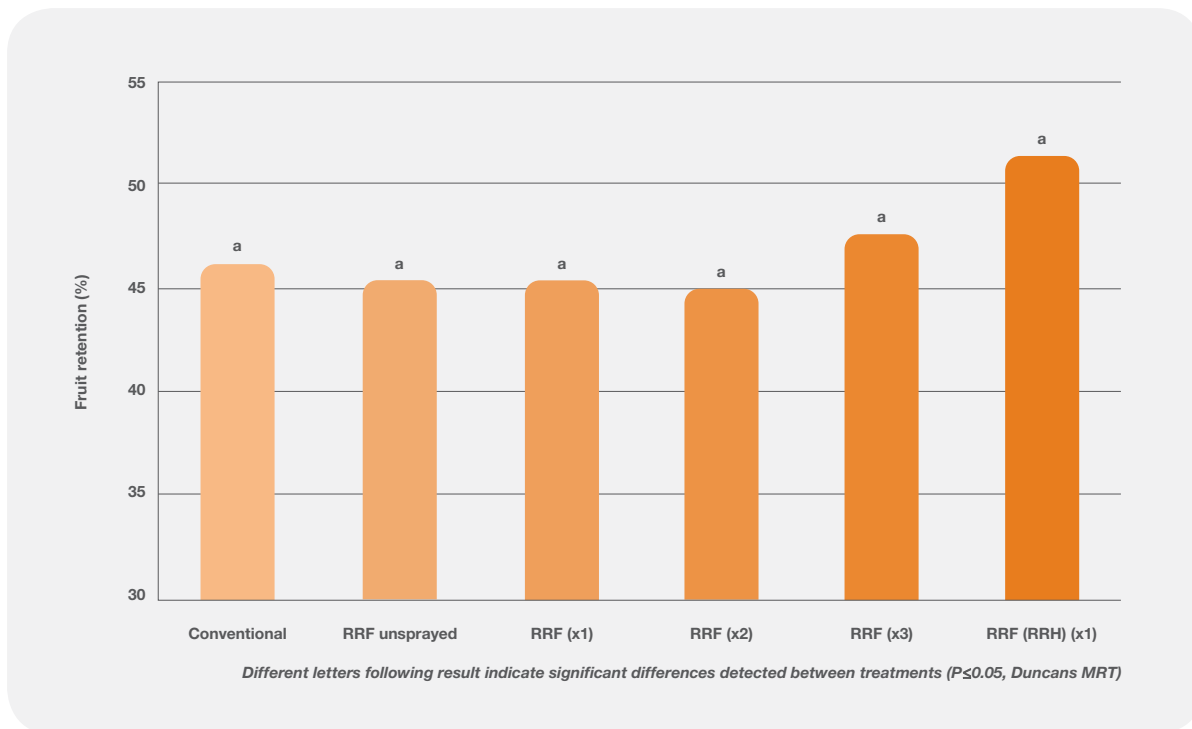
A range of rates of both Roundup Ready herbicide and Roundup PowerMAX were applied over the top of Roundup Ready Flex cotton at a number of different growth stages throughout the growing season.

A very high level of crop safety was observed, with **no differences in growth, fruiting dynamics, yield, or fibre quality detected in either year of testing.**

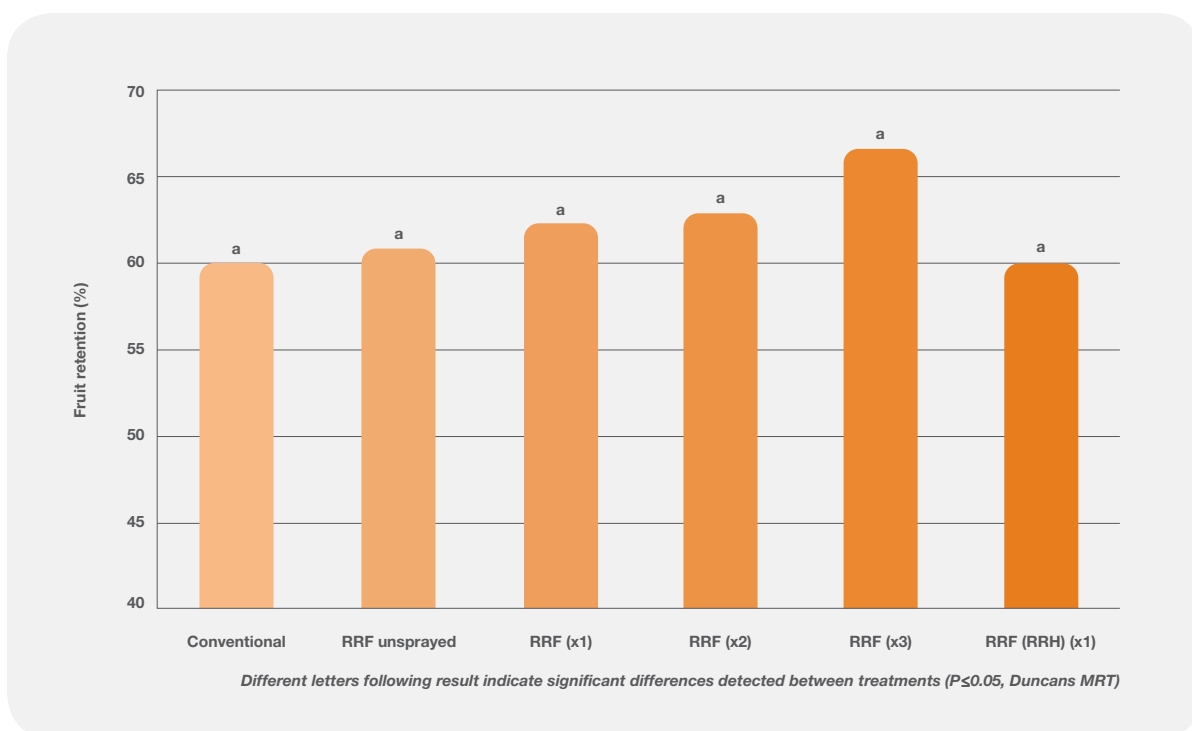
Table 4.3.1 Roundup Ready Flex Crop safety trials treatment schedule

	Product	Emergence to 8 nodes	8 nodes to 16 nodes	16 nodes to 22 nodes	60% open	Total
Conventional cotton	unsprayed	unsprayed	unsprayed	unsprayed	unsprayed	0
Roundup Ready Flex	unsprayed	unsprayed	unsprayed	unsprayed	unsprayed	0
Roundup Ready Flex (x1)	Roundup PowerMAX	3.8 L/ha	1.27 L/ha	1.27 L/ha	1.27 L/ha	7.6 L/ha
Roundup Ready Flex (RRH) (x1)	Roundup Ready herbicide	3.0 kg/ha	1.0 kg/ha	1.0 kg/ha	1.0 kg/ha	6.0 kg/ha
Roundup Ready Flex (x2)	Roundup PowerMAX	7.6 L/ha	2.54 L/ha	2.54 L/ha	2.54 L/ha	15.22 L/ha
Roundup Ready Flex (x3)	Roundup PowerMAX	11.4 L/ha	3.8 L/ha	3.8 L/ha	3.8 L/ha	22.83 L/ha

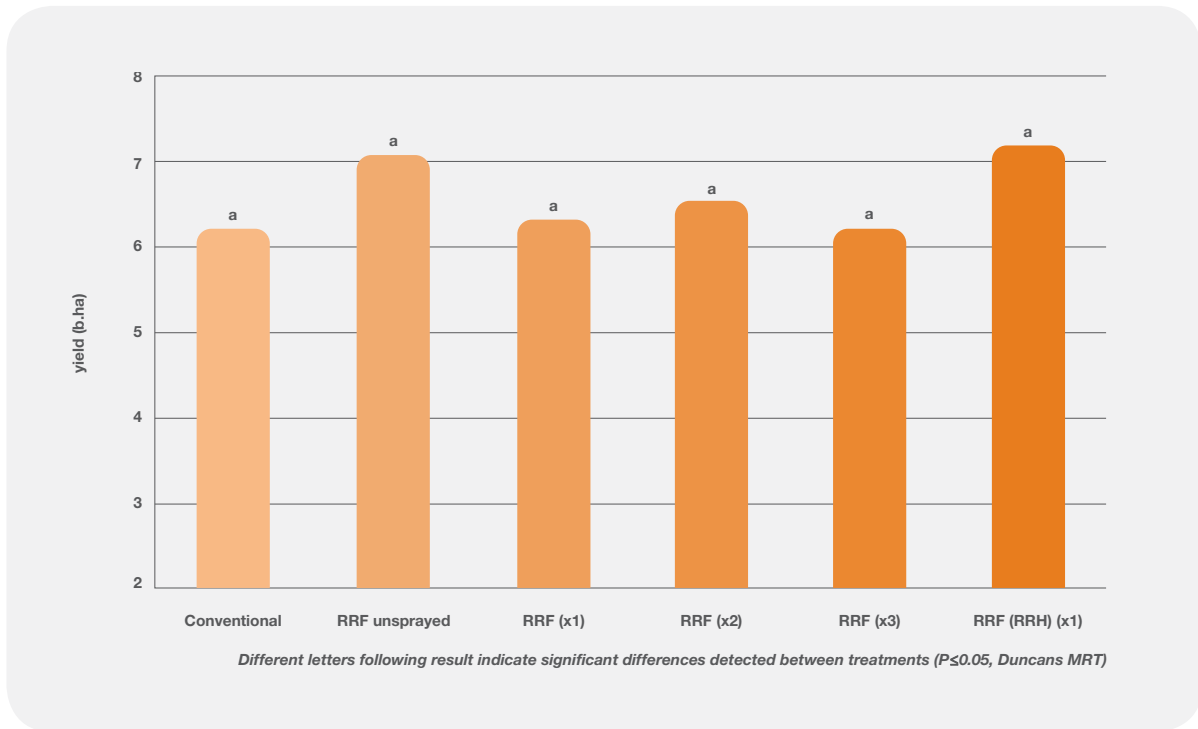
Graph 4.3.2 Total 1st Position Fruit Retention – 8 sites 2003/04 & 2004/05



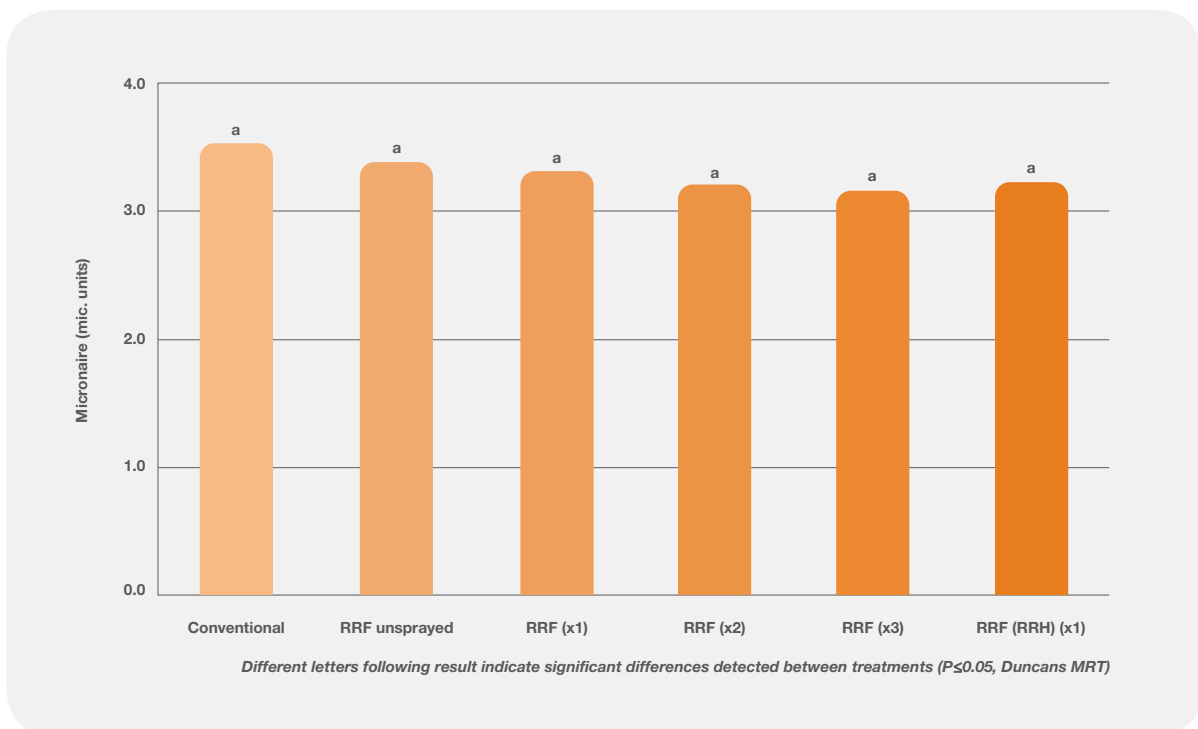
Graph 4.3.3 Total 1st Position Fruit Retention (bottom 5) – 8 sites 2003/04 & 2004/05



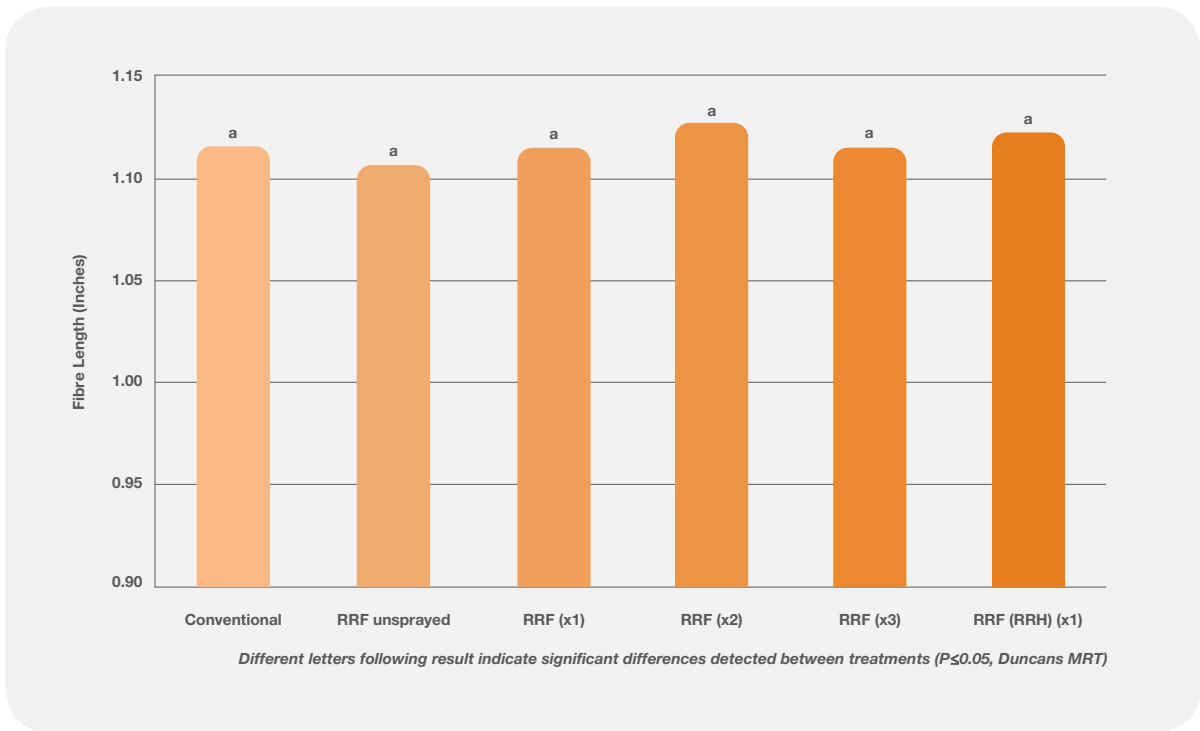
Graph 4.3.4 Total Yield – 8 sites 2003/04 & 2004/05



Graph 4.3.5 Fibre Quality (Micronaire) – 8 sites 2003/04 & 2004/05



Graph 4.3.6 Fibre Quality (Length) – 8 sites 2003/04 & 2004/05



5. Varietal development

In this Section

How is a Roundup Ready Flex variety developed?

Quality Assurance

Summary Points

- Conventional plant breeding is used to integrate Roundup Ready Flex from a donor cotton variety into elite varieties.
- Roundup Ready Flex cotton varieties are NOT identical to their recurrent parents.
- Monsanto requires seed companies to adhere to strict Quality Assurance guidelines in order to ensure only high quality Roundup Ready Flex cotton varieties are delivered to growers.

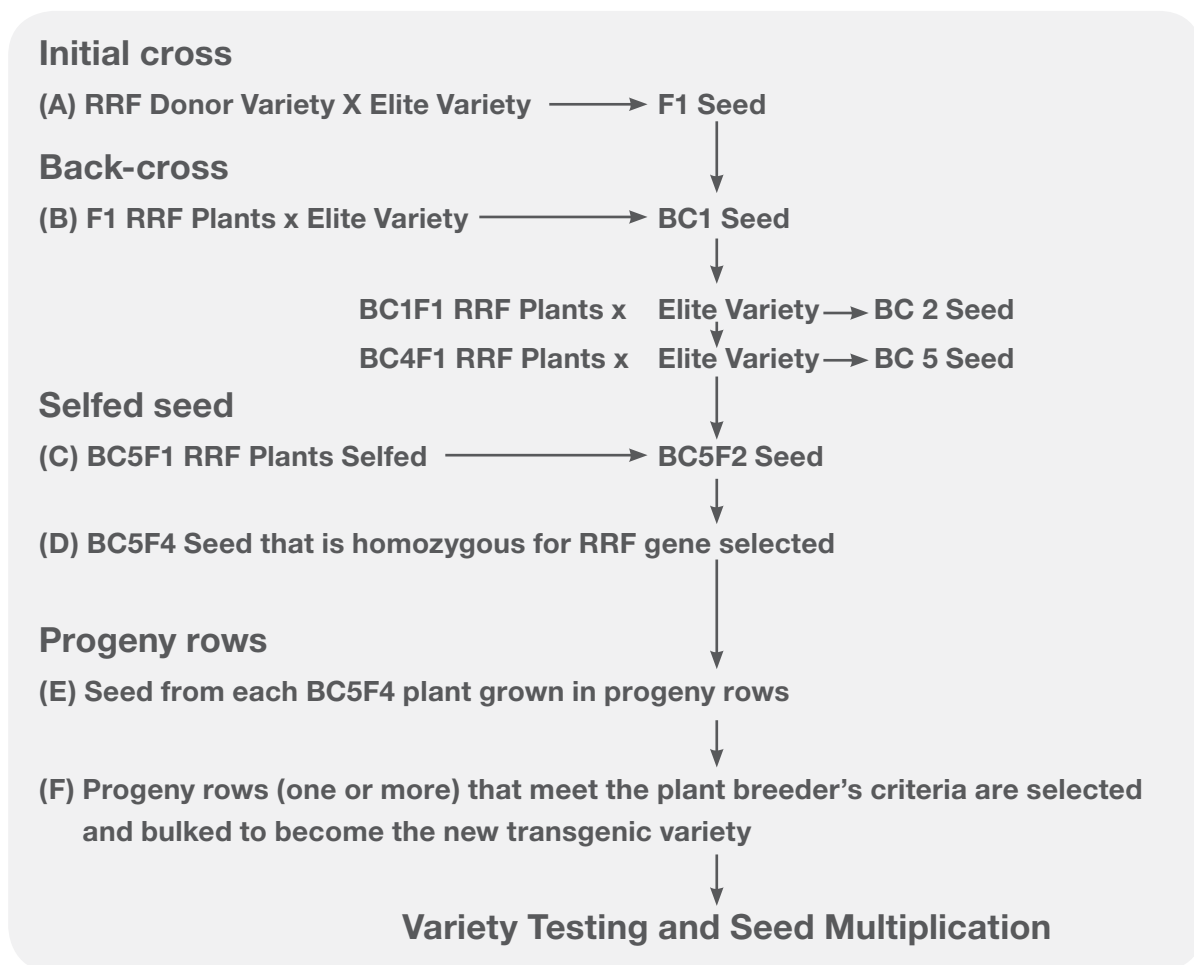
5.1 How is a Roundup Ready Flex variety developed?

- The Roundup Ready Flex gene cassette was initially incorporated into the cotton plant by the transfer of the cassette into a gall-forming bacterium (an *agrobacterium* sp.), which was then allowed to naturally invade cotton plant tissue. The resultant tissue was then cultured and screened to produce a cotton plant with the Roundup Ready Flex gene cassette incorporated into the cotton plant's DNA.
- Once the initial gene transformation is completed, it is the task of plant breeders to incorporate the trait into a wide range of varieties. This is done using traditional plant breeding.
- Transgenic varieties are usually developed by crossing an elite conventional variety with a transgenic donor variety. The donor variety contains the desired trait or gene.
- Subsequent generations are backcrossed to the elite variety (recurrent parent). In this process, each generation is backcrossed with the elite variety for several generations to recapture the bulk of the genetics from the elite variety. Plant breeders may use a number of backcrosses to develop a new transgenic variety. Each generation is sprayed with Roundup Ready herbicide with PLANTSHIELD to eliminate progeny that do not carry the Roundup Ready Flex gene structure.
- At the end of the backcrossing process, the seeds are grown out and the plants are allowed to self-pollinate.
- The progeny seeds are grown out as individual plants and all plants that are not homozygous for the Roundup Ready Flex gene structure are eliminated.
- Seeds from each homozygous plant are planted in progeny rows for agronomic evaluations. Each progeny row contains the unique genetics of the individual cross that resulted in the parent seed. In general, a plant breeder will have from 12 to 50 progeny rows. The schematic chart (Chart 5.1.2) shows the backcrossing process.



Figure 5.1.1 Progeny rows of new Monsanto Roundup Ready Flex varieties

Chart 5.1.2 Backcrossing process in cotton variety development



- Using similar processes when new conventional varieties are developed, the plant breeder can evaluate each progeny row and choose those that meet the criteria established for the new transgenic variety. Plant breeders either select a single progeny row or bulk lines with similar characteristics together to form the new transgenic variety. The plant breeder may look for lines that are very similar to the parent variety or they may choose progeny lines that exhibit some improved characteristics – if they exist.
- The final result is that the new transgenic variety will not be identical to the recurrent parent and may have characteristics that are different enough, to necessitate changes in management practices. The new variety is **not an exact copy of the conventional (recurrent) parent**.

Since transgenic varieties are not identical to their recurrent parent, agronomic performance and management may vary. Any new variety whether conventional or transgenic, should be judged on its agronomic characteristics first. It is important to follow the seed company recommendations on agronomic management of the new variety. **It should not be assumed that the new transgenic variety would require the same management as the recurrent parent variety.**

***Maximising the agronomic performance of a specific cotton variety is more important than the particular trait.
Choose the variety first, and then the trait.***

5.2 Quality Assurance

Monsanto has licensed Australian cotton seed companies to make Roundup Ready Flex available in a range of elite varieties. These agreements include strict quality assurance requirements that each potential variety must pass before a new variety can be commercialised. The aim of the Monsanto Quality Assurance program is to ensure that only quality seed containing Roundup Ready Flex technology is delivered to growers. The Quality Assurance program has the following specific criteria:

a. Gene Purity

An assurance that the variety only contains Roundup Ready Flex technology. Testing is conducted at the early stages of varietal development to ensure that the intended event (gene insertion) is present. All tests must be conducted using a Monsanto – approved technique at an approved facility. Monsanto requires that each variety is 99% pure at the 99% confidence level. Tests are also conducted to confirm that other undesired gene technologies are not present in the variety.

b. Commercial Crop Tolerance

Ensuring that the over-the-top (OTT) application of Roundup Ready herbicide with PLANTSHIELD to the variety does not impact on the agronomic characteristics (fruit retention, yield, fibre quality etc.) Commercial crop tolerance trials are conducted in a minimum of 6 locations, comparing unsprayed and sprayed (at 4 different times) treatments replicated 4 times. In order for a variety to pass Crop Tolerance, there must be no difference (at a 95% confidence level) between sprayed and unsprayed plots under weed free conditions.

c. Seed Lot Verification

The objective of this test is to ensure that the final commercial seed contains the Roundup Ready Flex trait in the appropriate amounts. As with Gene Purity, high quality standards in the early stages of breeding, combined with good seed production techniques provide the best results to ensure only the desired transgenic trait(s) are present in the final product. Seed companies are required to confirm that any commercial seed lot sold as Roundup Ready Flex cotton has acceptable levels of trait purity.

d. Variety Performance

Seed companies must certify that any cotton variety containing Roundup Ready Flex technology is agronomically sound and commercially acceptable. Seed companies undertake at least 4 trials in the geography for which the variety has been developed to determine its commercial acceptability as to:

- Yield
- Fibre quality
- Disease tolerance
- Any aberrant morphological characteristics that may significantly reduce its market acceptability or performance.

e. Gene Equivalency (For Roundup Ready Flex varieties stacked with Bollgard II®)

In addition to Quality Assurance programs specific for Roundup Ready Flex varieties, any stacked variety (containing Bollgard II) must also pass the Gene Equivalency criteria particular to Bollgard II.

Gene Equivalency testing aims to ensure that the proposed new varieties containing Bollgard II express both of the Bt proteins in an equivalent manner to other acceptable Bollgard II or Bollgard II/Roundup Ready Flex varieties. The Gene Equivalency testing is not to determine efficacy, which is dependent on a number of factors such as plant health nutritional status.

f. Records

Accurate documentation of the breeding process must be kept by the seed company for 3 years after the final sale of pedigreed seed for the variety, including the origin of the various samples of all the QA tests mentioned.

For each seed lot, seed samples are to be retained under storage conditions adequate to ensure the viability of seed.

The seed company provides Monsanto with data for Gene Purity, Seed Lot Verification, Commercial Crop Tolerance and Variety Performance. Monsanto provides the Gene Equivalency data for varieties containing Bollgard II. Monsanto evaluates all results and based on this data Monsanto confirms to the seed company which varieties are approved for commercial sale.

6. Weed Management in Roundup Ready Flex crops

In this Section

Application Guidelines

Weed control in Roundup Ready Flex cotton

- Before planting
 1. *Know your field history*
 2. *Pre-plant knockdown*
- Pre-emergent residual herbicides
- In-crop Roundup Ready herbicide with PLANTSHIELD applications
 1. *1st OTT application*
 2. *Subsequent applications*
- Directed applications
- Lay-by residual applications
- In-crop cultivation
- Pre-harvest Roundup Ready herbicide with PLANTSHIELD applications
- Weed control examples
- Weed control guide.

Summary Points

- Only apply Roundup Ready herbicide with PLANTSHIELD according to the registered application window.
 - 0–22 nodes – 4 OTT applications (max 1.5 kg/ha per application)
 - 60% open to harvest – 1 OTT application (max 1.5 kg/ha per application)
- Use a maximum of 4 applications AND no more than a total of 6.0 kg/ha of Roundup Ready herbicide with PLANTSHIELD per crop.
- Use the RIGHT TOOL, using the RIGHT RATE at the RIGHT TIME.
- Always start clean by planting into a weed-free field.
- Use residual herbicides where appropriate.
- Target the 1st application of Roundup Ready herbicide with PLANTSHIELD on young cotton with weeds less than 6cm in size.
- Sequential applications of Roundup Ready herbicide with PLANTSHIELD may be required to control new and subsequent germinations of weeds.
- Select the timing of sprays based upon the most difficult to control weed species in each field.
- Post directed sprays should be used where applicable to achieve thorough coverage on weeds.
- Consider using a robust lay-by program where appropriate.

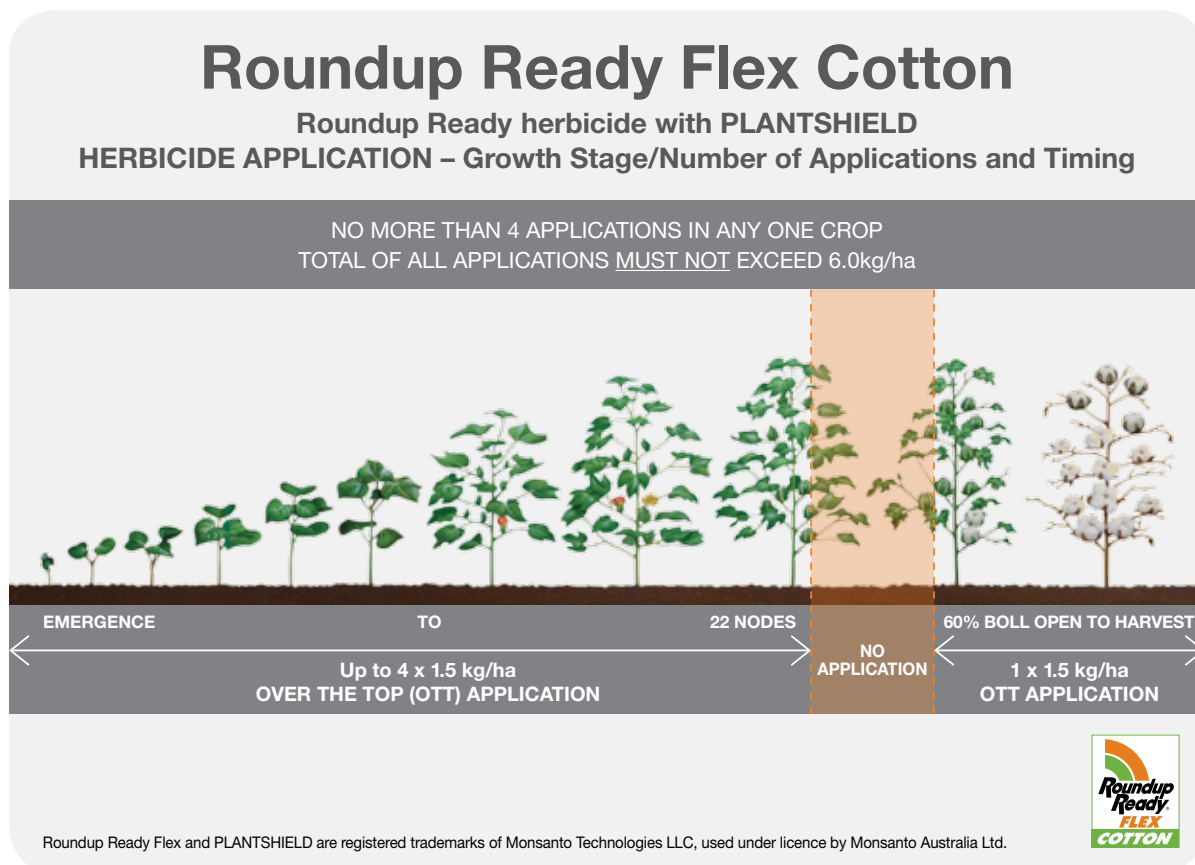
6.1 Application Guidelines

Roundup Ready herbicide with PLANTSHIELD may be applied to Roundup Ready Flex cotton as an over-the-top (OTT) application from emergence through to 22 nodes.

Note: spray contact with any part of the cotton plant at this stage will NOT affect crop development or fruit retention.

A pre-harvest application may be made once the crop has reached 60% boll open stage.

6.1.1 Herbicide Application – Growth Stage/Number of Applications and Timing diagram



Total amount available to be applied per season of 6.0 kg/ha Roundup Ready herbicide with PLANTSHIELD.

Note – No restrictions on timing of sequential applications.

6.2 Weed control in Roundup Ready Flex

Roundup Ready Flex cotton offers growers an increased margin of crop safety due to its tolerance of glyphosate during fruiting. This allows for a more flexible window for the safe OTT applications of Roundup Ready herbicide with PLANTSHIELD extending from crop emergence through to lay-by, the key timing for controlling economically damaging weeds.

Roundup Ready Flex cotton has the potential to increase the efficacy of weed control due to the ability to schedule in-crop glyphosate applications based on the weed growth stage/height instead of the crop growth stage. Growers can now more precisely treat weeds on a “needs basis”, reacting to weed flushes that may occur as a result of either rainfall or in-crop irrigation.

However, Roundup Ready Flex cotton should not be considered in isolation as a solution to all weed control scenarios. Instead it should be viewed as an extremely valuable component of an Integrated Weed Management (IWM) system. IWM is the use of a range of weed control options (chemical, cultural, mechanical and biological) incorporated together to achieve effective, economic and sustainable weed control. It is with an IWM approach to weed control that growers will realise the full benefits of Roundup Ready Flex technology, whilst simultaneously aiding in its sustainability. IWM is discussed in more detail in section 10.

6.2.1 Before Planting

Know your field history

Knowing your field history prior to planting Roundup Ready Flex will aid in maximising the weed control efficacy. Additionally, field history is also an important component of volunteer management (see section 7).

It is important to note that weed populations may often be affected by field history and the relative effectiveness of past herbicide programs. Variations in particular weed dominance may occur year to year depending on seasonal conditions which may also impact on the optimal weed control program.

In formulating a weed control program, growers and their advisors are strongly recommended to practice IWM.

Correct identification and understanding of the weeds present in a cotton crop is the essential first element in the design of a successful weed control program. It is critical that the correct herbicide and herbicide rate is chosen for the target weed species.

The Roundup Ready Flex weed control system is extremely effective in controlling most weeds that occur in cotton. However it should be understood that different weeds can require different rates of Roundup Ready herbicide with PLANTSHIELD for their control.

Refer to the “Weeds Controlled” table in the Roundup Ready herbicide with PLANTSHIELD label for rate recommendations on specific weeds.

By knowing field history, weed spectrum and weed burden, growers can then determine which weed control tools they should use, and at what time they should be employed to achieve the best results.

Use the RIGHT TOOL, using the RIGHT RATE at the RIGHT TIME

Pre-plant knockdown

Special care should be taken to plant Roundup Ready Flex cotton into a weed-free situation. Starting the crop “clean” gives the seedling cotton good conditions to emerge and develop unhindered by the competitive effects of weeds.

Pre-plant weed control can be achieved using tillage and/or appropriate registered herbicides. Using glyphosate tank mixes or herbicides with other modes of action is encouraged at this stage due to their compatibility in an IWM program, as well as their suitability as a method of controlling volunteer cotton.

Always start clean by planting into weed-free field

6.2.2 Pre-emergent Residual Herbicides

Residual herbicides can be a valuable component of a Roundup Ready Flex cotton weed control system. Residual pre-emergent herbicides (either applied as pre-plant incorporated or at-planting) may offer growers the following benefits:

- Control of weeds that are not controlled by Roundup Ready herbicide with PLANTSHIELD
- Residual control of some perennial weed targets (e.g. Couch grass)
- Residual control in situations of high weed burden and/or shallow germinating weeds (e.g. Mintweed, Blackberry nightshade, some grasses)
- May aid in reducing early season weed competition.

A residual herbicide program provides diversity in methods of weed control and is broadly compatible with IWM principles.

However, residual herbicides can impact seedling emergence and early crop vigour. Pre-emergence residual herbicides are also often applied in anticipation of a weed problem, whether or not a problem actually occurs.

Growers need to consider the applicability of a pre-emergence residual herbicide program according to the weed population status of each individual field and in view of the overall IWM program.

Residual herbicides should be used where appropriate in a Roundup Ready Flex weed control system.

6.2.3 In-crop Roundup Ready herbicide with PLANTSHIELD Applications

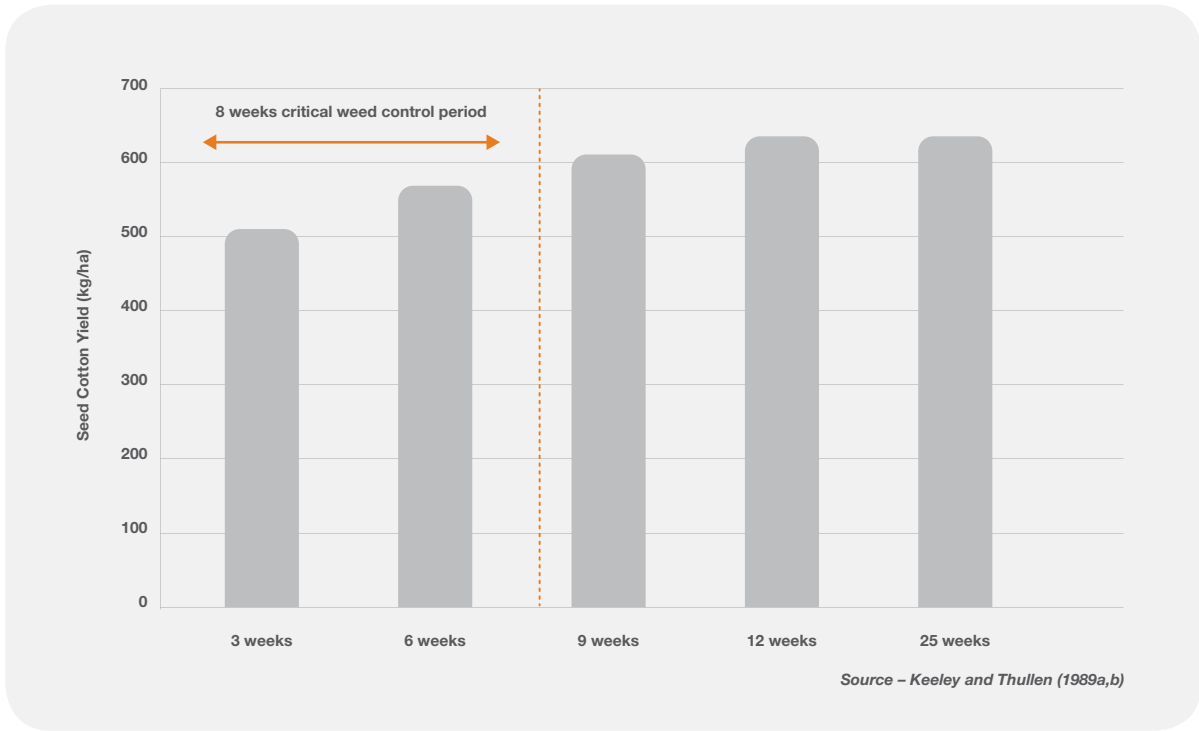
1st OTT application

The application flexibility afforded by Roundup Ready Flex cotton might tempt some growers to delay the 1st application of Roundup Ready herbicide with PLANTSHIELD with a hope that they may control multiple germinations of weeds.

However cotton is a very poor competitor, and is quite sensitive to early season weed competition. Most weeds that emerge with cotton grow more quickly than the crop and, as such, better exploit available water and nutrients.

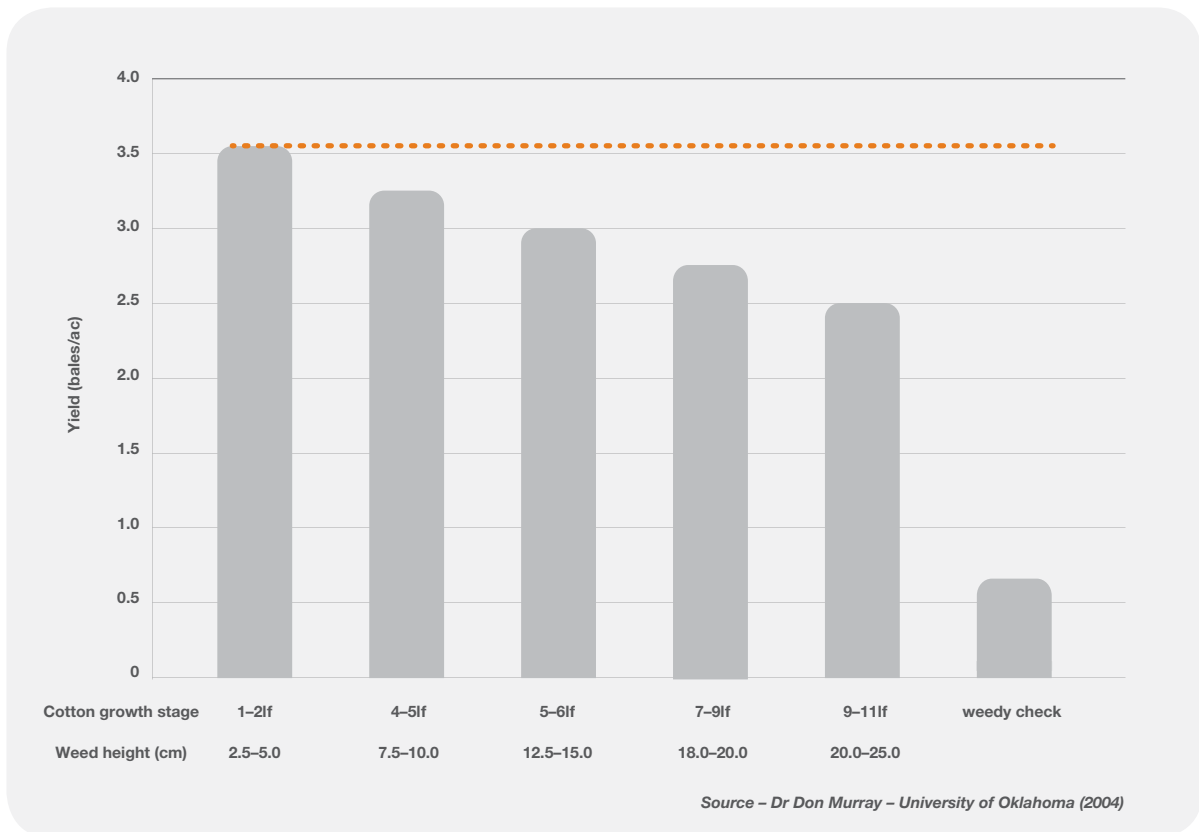
Numerous studies have indicated that **competition from weeds can severely reduce lint yields**. Whilst competitive affects can vary according to weed species and weed density, it is commonly recognised that good weed control in the first 8 weeks following emergence maximises the yield potential of a cotton crop (graph 6.2.3.1).

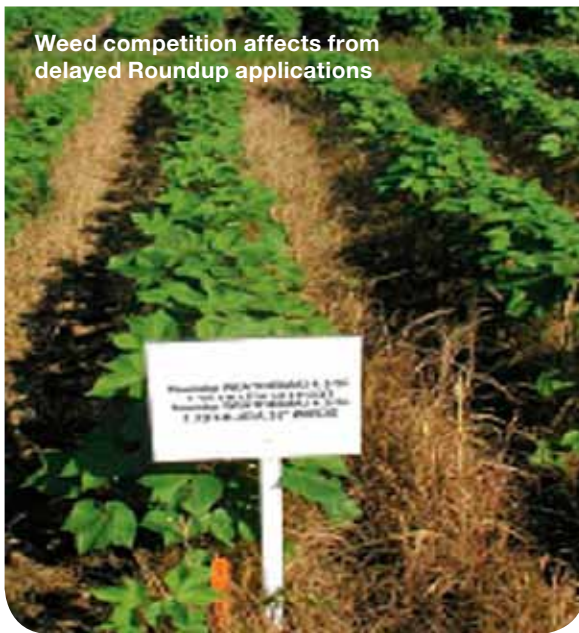
Graph 6.2.3.1 The influence of weed competition on cotton yield



By delaying the initial OTT application in Roundup Ready Flex, growers may risk the yield potential of their crop. The graph below illustrates the influence the 1st OTT application and weed size can have on cotton lint yield.

Graph 6.2.3.2 Early season weed competition affects in Roundup Ready Flex cotton





Source – Dr Robert Hayes University of Tennessee (2003)

Figure 6.2.3.1 Timely applications of Roundup minimise weed competition effects on crop growth

Delaying the initial OTT application may also result in growers targeting weeds that are beyond the growth stage for optimum control. For instance, Climbing buckwheat (*Fallopia convolvulus*) is best controlled prior to the 12 leaf stage. Control from applications of Roundup Ready herbicide with PLANTSHIELD to larger *Fallopia* sp. can often be unpredictable.

Refer to the “Weeds Controlled” table in the Roundup Ready herbicide with PLANTSHIELD label for rate recommendations on specific weeds.

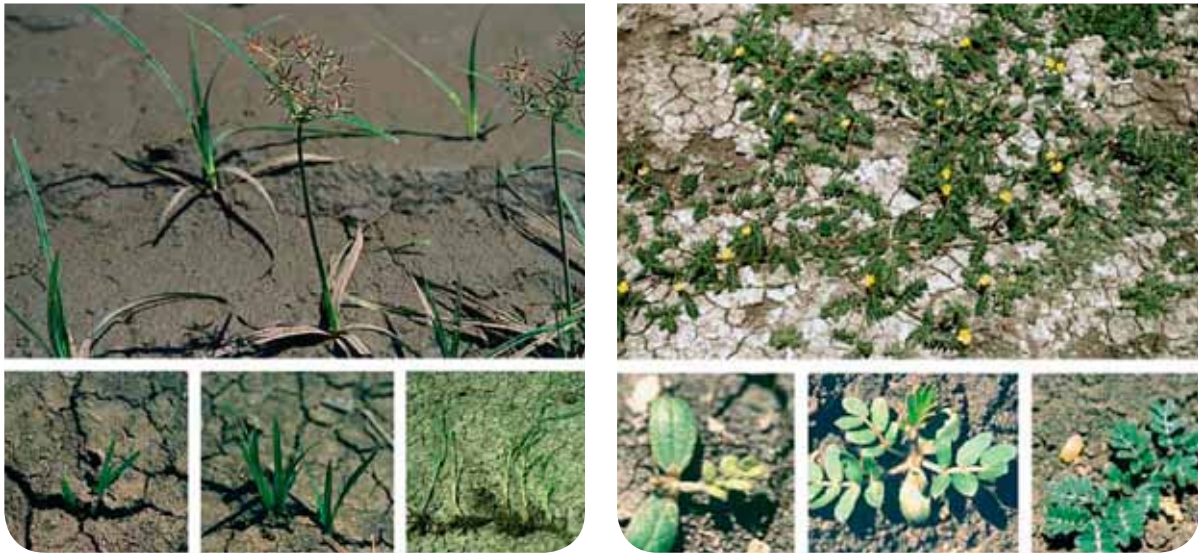
The presence of larger weeds in-crop may also harbour disease (e.g. Verticillium wilt) and insect pests such as *Helicoverpa* sp., Armyworm (*Spodoptera* sp.), Whitefly and Rough bollworm (*Earias huegeliana*). Once these weeds senesce as a result of applications of Roundup Ready herbicide with PLANTSHIELD, insect pests can migrate onto nearby cotton plants. Controlling these insects can be an unnecessary cost burden, and in the case of Bollgard II can substantially increase the risk of insect damage and resistance development.

Target the first in-crop application of Roundup Ready herbicide with PLANTSHIELD on young cotton with weeds less than 6cm in size.

Subsequent applications

Further in-crop applications of Roundup Ready herbicide with PLANTSHIELD may be required to achieve good weed control. These applications should be made according to the presence of new and subsequent germinations of weeds.

In any field, a mix of weed species will commonly exist. Some of these weeds may be inherently “easier” to control with glyphosate than others. Correct identification of weeds is very important, as this will have a direct impact on the rate selection and application timing of the herbicide options chosen (fig 6.2.3.2).



Source – WeedPAK

Figure 6.2.3.2 Cyperus rotundus (Nutgrass) left, and Tribulus micrococcus (Yellowvine) right, require different Roundup Ready herbicide rates and timings to achieve good control

In order to maximise the effectiveness of in-crop applications of Roundup Ready herbicide with PLANTSHIELD, growers should base the timing of these applications on the growth stage of the most difficult to control weed species present in each field.

Refer to the “Weeds Controlled” table in the Roundup Ready herbicide with PLANTSHIELD label for rate recommendations on specific weeds.

All Roundup Ready herbicide with PLANTSHIELD applications should be made to weeds that are small and are actively growing. Applications should not be made when weeds are stressed, when rain is expected soon after application, or when high temperatures or strong winds make spraying conditions unsuitable.

Select the timing and application rate of Roundup Ready herbicide with PLANTSHIELD based upon the most difficult to control weed species in each field.

6.2.4 Directed Applications

As the crop canopy develops, weeds may germinate in the plant line which are unable to be controlled with cultivation or may be shaded when applying Roundup Ready herbicide with PLANTSHIELD in a broad acre fashion (Fig 6.2.4.1). Applications made in-crop at later growth stages may require directed sprays in order to achieve more thorough coverage on target weeds (Fig 6.2.4.3).



Figure 6.2.4.1 Surviving grass weeds in the plant line as a result of incorrect spray coverage

There are a number of different configurations to consider for such applications. The use of droppers and extra nozzles may enable effective targeting of the soil and weeds under the crop canopy. A “branch lifter” may also be useful to deflect the lower branches of the crop as the rig moves through the field, enabling more precise targeting of the plant line area. (Fig 6.2.4.2)

Refer to the Roundup Ready herbicide with PLANTSHIELD label for specific spray and nozzle guidelines



Figure 6.2.4.2 “Branch lifters” may help in targeting weeds in the plant line

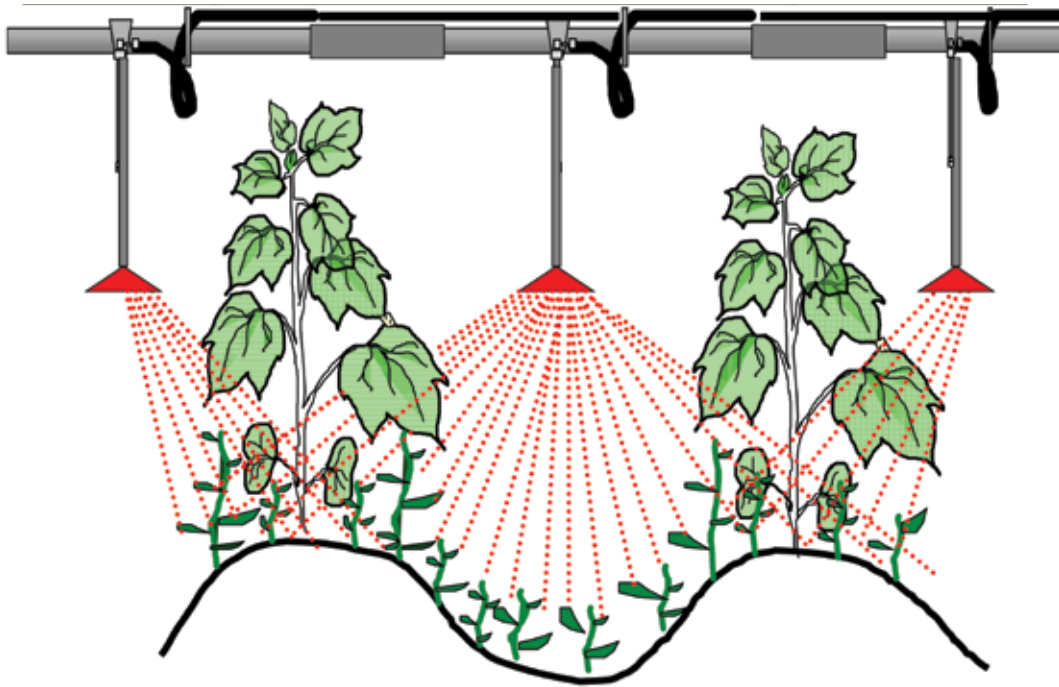


Figure 6.2.4.3 Directed spray rig set up for Roundup Ready Flex to achieve maximum weed coverage

Post directed sprays should be used where applicable to achieve thorough coverage on weeds

6.2.5 Lay-by Residual Applications

Lay-by residual herbicides can complement a Roundup Ready Flex weed control system. Incorporating a lay-by residual application may have the following benefits:

- Lay-by residuals can provide control of weeds not controlled by Roundup Ready herbicide with PLANTSHIELD as glyphosate provides no residual control, incorporating a lay-by prior to row closure may allow for extended weed control through to harvest.
- A robust lay-by program provides diversity in methods of weed control and is broadly compatible with IWM principles.
- Lay-by applications may be beneficial in limiting any “weed escapes” and, as such, contribute to effective weed resistance management

Growers and their advisors are encouraged to scout fields prior to row closure, and combine these observations with their historical knowledge of the individual fields weed burden to formulate the need for, and/or the herbicide components of, a lay-by program.

Consider using a robust lay-by program where appropriate

6.2.6 In-crop cultivation

Inter-row cultivation is a relatively cheap and non selective method of weed control. In irrigated cotton production it also assists in maintaining an adequate furrow, facilitating efficient irrigation.



Figure 6.2.6.1 Efficient irrigation as facilitated by in-crop cultivation

In Roundup Ready Flex crops, in-crop cultivation may contribute to the diversity of weed control methods and as such is a valuable component of an IWM system.

6.2.7 Pre-Harvest Roundup Ready herbicide with PLANTSHIELD Application

A single OTT application of Roundup Ready herbicide with PLANTSHIELD is available for use as a pre-harvest treatment.



Figure 6.2.7.1 Pre-harvest application of Roundup Ready herbicide with PLANTSHIELD

In most circumstances, good weed control earlier in the crop should replace the requirement for a pre-harvest application. If the field history indicates that late season weeds may be a problem, then a robust residual lay-by is recommended.

However, if late season weeds are present, a pre-harvest application of Roundup Ready herbicide with PLANTSHIELD can be used to reduce seed set and improve harvest efficiency.

The pre-harvest application is available once the crop has reached 60% open boll stage through to harvest. Applications made at this time are also broadly compatible with several commonly used defoliant.

Pre-harvest applications of glyphosate will not provide regrowth control in Roundup Ready Flex cotton.

Refer to the Roundup Ready herbicide with PLANTSHIELD label for specific directions.

7. Post-crop and volunteer management

In this Section

Cotton Volunteer Overview

Herbicide Control Options

Planning for In-crop Volunteer Management

Ratoon control

Fallow management

Non-cropping areas

Summary Points

- Volunteer and ratoon Roundup Ready Flex cotton plants will not be controlled by Roundup Ready herbicide with PLANTSHIELD or any generic glyphosate product.
- Roundup Ready Flex cotton volunteers can be controlled in EXACTLY the same way.
- Paraquat/Diquat, Carfentrazone and Bromoxynil are all registered herbicide options for volunteer cotton control.
- Target small volunteer plants, using the appropriate herbicide option applied in a sufficient spray volume to achieve good coverage.
- Be aware of the potential for volunteer cotton, and plan appropriate control measures.
- The quality of post-picking crop residue programs is extremely important in the prevention of ratooning (stub) cotton.

7.1 Cotton Volunteer Overview

On any farm, cotton volunteers from the previous season may compete for valuable resources such as water and nutrients. In addition cotton volunteers can also:

1. Act as a host for pests such as mites and aphids
2. Increase the risks associated with Bollgard II resistance management
3. Reduce seed purity
4. Have the ability to interfere with disease management strategies

The control of cotton volunteers is an important component of cropping rotational flexibility and general farm hygiene. As with conventional cotton, volunteer and ratoon Roundup Ready Flex plants may occur in-crop, in fallows, and in non-cropping areas of a farm such as irrigation ditches, module pads and water storages.

Cultivation and herbicides are the two most common forms of volunteer cotton control. However as Roundup Ready Flex cotton is vegetatively tolerant to applications of glyphosate, the use of Roundup Ready herbicide (or any generic glyphosate) will not control volunteers from either of these plants.

Volunteer and ratoon Roundup Ready Flex cotton plants will not be controlled by Roundup Ready herbicide with PLANTSHIELD or any generic glyphosate product.

Therefore alternative herbicides that control Roundup Ready Flex cotton volunteers or cultivation will need to be utilised. This does provide an opportunity to introduce another herbicide group or cultivation into the weed management system, both of which are important components of Integrated Weed Management (IWM).

7.2 Herbicide Control Options

For in-crop or fallow situations, herbicides that control volunteer cotton should ideally have good efficacy at a range of cotton growth stages as well as possess no residual affects on any subsequent crops.

Roundup Ready Flex cotton volunteers can be controlled in EXACTLY the same way.

As part of the introduction of Roundup Ready cotton, the following herbicides were screened by both Monsanto and the Cotton CRC for their effectiveness in controlling cotton volunteers.

Graph 7.2.1 Monsanto Cotton Volunteer Control comparison 2000/01, 2001/02, 2002/03

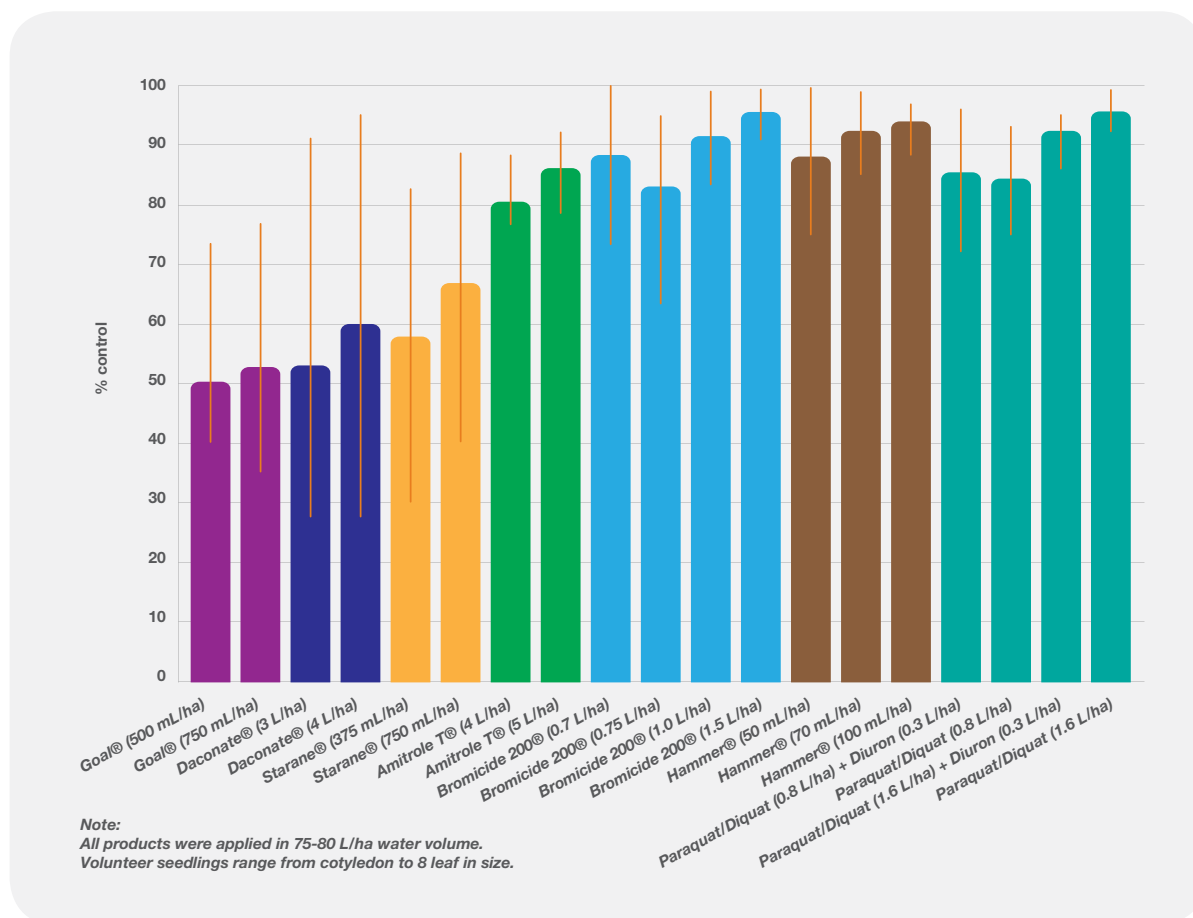


Table 7.2.2 Effect of various herbicides on seedling cotton at St George and Narrabri 2001/02

Herbicide	Trade Name	Group	Rate (kg or L/ha)	Percentage control	
				4 leaf (St George)	8 leaf (Narrabri)
Unsprayed	-	-	-	0	0
Effective control					
Paraquat/Diquat***	Revolver* etc.	L	2.0	100	100
Bromoxynil***	Bromicide* 200	C	4.0	100	100
Carfentrazone***	Hammer* 240 EC	G	0.15	100	100
Incomplete control					
2,4-D amine	Surpass* etc.	I	2	0	95
Glufosinate ammonium	Basta*	N	3	92	96
Fluroxypyr	Starane*	I	1	25	95
MCPA Amine	various	I	2	30	88
No control					
Chlorpyralid	Lontrel*	I	0.15	0	0
Dicamba	Banvel* etc.	I	1.4	2	0
Diuron	various	C	1.9	0	0
Fluometuron	various	C	1.9	0	0
Oxyfluorfen	Goal*	G	0.25	15	0
Prometryn	various	C	3	19	10
Triclopyr	Garlon*	I	0.15	0	0

***Denotes registered option for cotton volunteer control

Source - WEEDPak

Currently there are four registered herbicide options for the control of volunteer cotton

1. Paraquat/Diquat (Spray.Seed[®], Revolver[®])
2. Bromoxynil (Bromicide[®] 200)
3. Carfentrazone ethyl (Hammer[®] 240 EC)
4. Paraquat/Amitrole – (Alliance[®])

These options are very effective in controlling volunteer cotton, however the following points should be considered

- The size of the volunteer plants needs to be assessed before removal with herbicides, as the effectiveness of these herbicides on conventional, and Roundup Ready Flex cotton is generally limited to plants no more than 4–6 leaf, or about 25cm in height.
- Larger plants will generally be more difficult to control with a single pass.
- It is important to read all labels before use to confirm the correct timing and rates. **The respective label directions must be followed.**
- Using the correct water volumes in herbicide application is imperative for effective control. All herbicide options require sufficient coverage of the leaves, stems and growing point of volunteer cotton seedlings to achieve maximum control.
- Other weeds within the field should be taken into consideration when determining the herbicide control choice.
- Bromoxynil and Carfentrazone can be mixed with Roundup which may provide supplementary control of certain weed species.
- Correct herbicide choice is important to provide the best possible control.

Target small volunteer plants, using the appropriate herbicide option applied in a sufficient spray volume to achieve good coverage

7.3 Planning for In-crop Volunteer Management

A major factor in any crop and herbicide rotation decision is the management of volunteers. Each year, irrespective of the previous crop, self sown volunteers have the capacity to emerge. Growers commonly recognise this, and plan for its occurrence. For the volunteers from herbicide tolerant crops, plans need to be made to use cultural options and herbicides from groups other than those to which the volunteers have a specific tolerance.

Cultivation and herbicide options for controlling volunteer cotton both require cotton to have germinated and emerged before effective control can take place. As such, rainfall or irrigation timing relative to crop emergence can have a large impact on the most efficient control method.

Environmental conditions can also impact on the occurrence of volunteer cotton. Frosts for instance, may help to manage volunteer cotton. Generally, seedlings that germinate in late summer or autumn will not survive the first frost, making control less critical than volunteers that germinate at planting time. Dry winters on the other hand can limit the germination and/or degradation of cotton seed, which may serve to increase the amount of volunteers present when establishing a crop in the following spring.

Residual herbicides applied at or before planting can under certain circumstances, impact on the amount of volunteers present. As volunteer cotton originates from left over seed on or slightly below the surface, soil residual herbicides can cause injury and mortality as a consequence of their mode of action. For instance dinitroaniline herbicides such as trifluralin or pendimethalin cause damage to the cotton seedling root. Therefore shallow germinating seedlings such as those from surface lint can be more predisposed to injury and death from these types of herbicides.

**Be aware of the potential for volunteer cotton,
and plan appropriate control measures**

For effective in-crop cotton volunteer control planning, three main factors need to be considered:

1. Type of potential volunteers present
2. Type of crop to be established
3. Irrigation method to be used for crop establishment

Regardless of the type of potential cotton volunteer, growers can assist in volunteer management prior to crop emergence by minimising any lint/seed on the plant line. Operations such as moisture seeking, bed renovation and fertiliser application can all serve to redistribute any cotton lint (and hence potential volunteer plants) from the plant line to the furrow where cultivation and/or shielded spraying can be used for control in-crop.

Pre-watering is an effective cultural method for volunteer control. Stimulation of volunteer germination and emergence prior to crop establishment gives growers the opportunity to target volunteers with broad spectrum herbicides. Rainfall prior to planting may also stimulate volunteer emergence and present growers with subsequent control options.

After crop emergence growers have the option of in-crop cultivation or the use of a number of different herbicide options in shielded sprays to control volunteers.

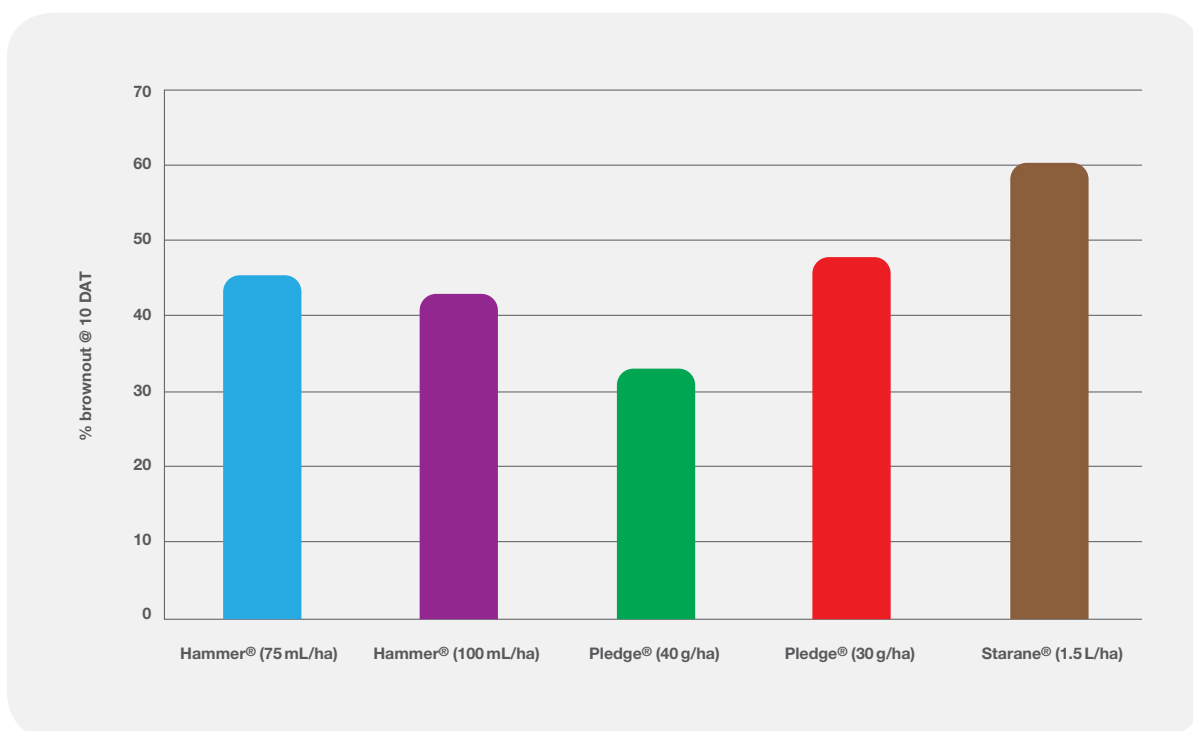
7.4 Ratoon Control

Ratoon or “stub” cotton is cotton that has “re-grown” from root stock left over from the previous season. Ratoon cotton is normally a product of minimum tillage where either conventional cotton is double cropped back to a winter cereal, or cotton is grown consecutively, summer to summer. Ratoon cotton is generally undesirable as it can act as hosts for pests such as mites, aphids and whitefly, as well as harbour diseases such as Verticillium wilt, Black root rot, Fusarium wilt and Alternaria leaf spot.

Ratoon cotton plants are inherently difficult to control chemically due to the large root mass they have accumulated in the previous crop and the lack of potential non-persistent herbicide options. Ratoon conventional, *Roundup Ready* or Roundup Ready Flex cotton is not controlled by glyphosate (Table 7.4.1).

Trial work conducted by Monsanto in 2002/03 highlights the difficulty in getting long term ratoon control using several common herbicides (Graph 7.4.1 and 7.4.2). Quite often, initial results may be encouraging; however complete control is often unachievable (Table 7.4.1)

Graph 7.4.1 Monsanto Ratoon Roundup Ready cotton control screen 2002/03 – % brownout 10 DAT



Graph 7.4.2 Monsanto Ratoon Roundup Ready cotton control screen 2002/03 – % control 21 DAT

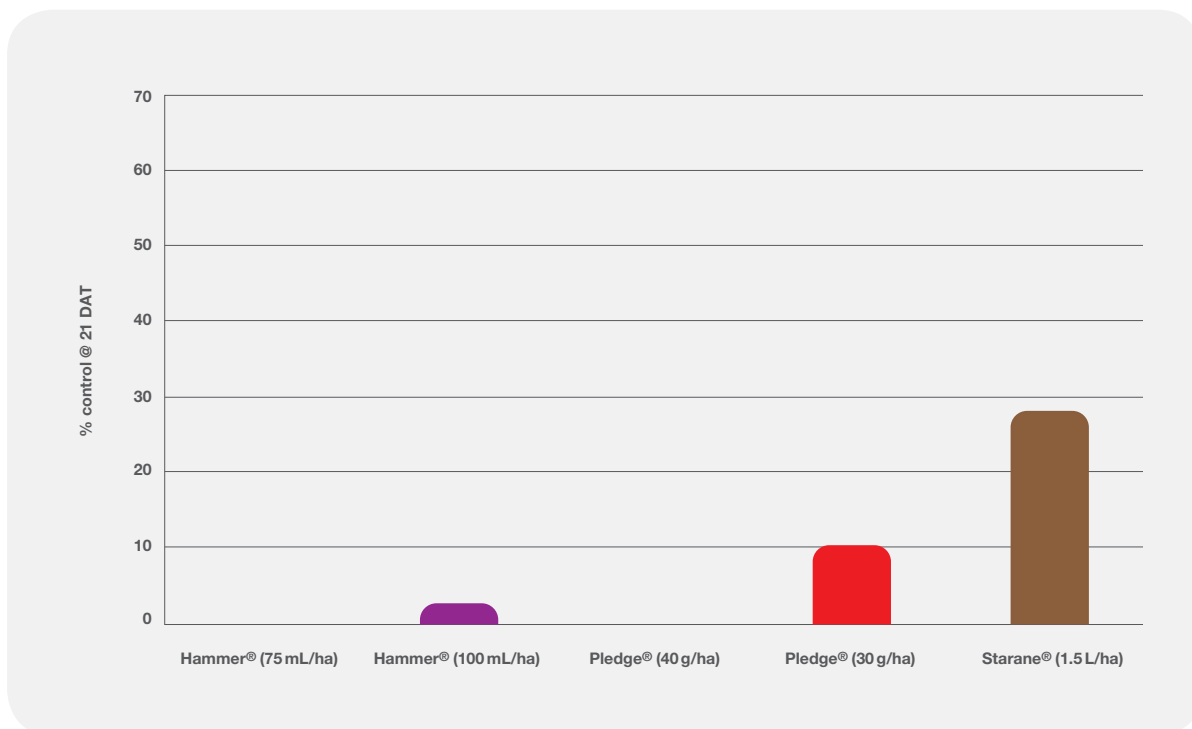


Table 7.4.1 The effect of selected herbicides on ratoon cotton regrowth

Herbicide Treatments	Trade name	Rate	% regrowth 10 DAT	% regrowth 20 DAT
<i>Unsprayed</i>		-	80%	95%
Glyphosate	Roundup	4.6 L/ha	47%	93%
Glufosinate ammonium	Basta*	5 L/ha	53%	92%
Fluroxypyr	Starane*	2 L/ha	7%	91%
Fluroxypyr	Starane*	4 L/ha	5%	92%
Bromoxynil	Bromicide* 200	3 L/ha	37%	93%
Prometryne	various	6 L/ha	47%	94%

Source – WEEDPak

The most effective means of controlling ratoon cotton is achieved by effective root cutting/elimination of cotton stalks, followed by “centre busting” tooling. Care needs to be taken so that the centre tooling does not run slightly “off bed centre” and leave residual stalks to regrow in the following spring. These “ratoon escapes” will not be controlled by Roundup Ready herbicide with PLANTSHIELD in a Roundup Ready Flex crop.

The quality of post-picking crop residue programs is extremely important in the prevention of ratooning (stub) cotton.

7.5 Fallow Management

Seeding volunteer cotton plants may also occur in fallow fields. Often there will be a range of other weeds that should also be considered when making control decisions.

In the first instance where control of volunteer cotton and regrowth (ratoon) cotton is required, cultivation represents an effective option where appropriate.

Control of fallow weeds including Roundup Ready Flex cotton volunteers may be achieved by tank mixing registered herbicides with Roundup Ready herbicide with PLANTSHIELD as another effective alternative to cultivation. **Growers should consider the overall weed spectrum, plant back period and any susceptible crops when choosing fallow herbicide options.**

As with conventional cotton, effectiveness is generally limited to plants up to 6 to 8 leaf or about 25 cm height. Larger plants will be less consistently controlled with a single pass. **The respective labels and plant back periods of these products must be read and adhered to.**

Rotation crops such as wheat and sorghum also present an opportunity to control volunteers. The use of herbicides such as atrazine, metsulfuron, chlorsulfuron 2,4-D in these rotation crops may provide a level of “incidental” control of any cotton volunteers present.

7.6 Non-Cropping areas

Head ditches and channels can be a challenging area in which to control cotton volunteers. Ideal growing conditions and the difficulty with mechanical removal methods such as cultivation means these areas need particular attention.

Residual herbicides have been used to control weeds in head ditches and channels for a number of years and many of these products will suppress the growth of cotton seedlings.

Established cotton is difficult to control with herbicides alone. Options for control are limited, particularly as cotton or other sensitive crops are often planted nearby. For best results non-residual herbicides should be targeted at small (less than 6 leaf) cotton volunteers. Only registered products should be used and it is recommended that all label directions are followed.

Typically, volunteer plants germinate in spring once the soil temperatures have warmed up and after rainfall or irrigation has occurred. The other key time is after harvest when fresh seed has fallen to the ground and the weather conditions are still warm enough for the seeds to germinate.

Identifying these key times and using mechanical removal such as cultivation or registered knockdown herbicides such as Hammer* or Revolver* will help prevent the volunteers from becoming a problem.

Grader blades and/or appropriate herbicides are effective in module building or storage areas. Physical collection of spilled cotton during picking/module building is good farm hygiene and will also aid in reducing the seed burden in these areas.

8. Roundup Ready herbicide with PLANTSHIELD

In this Section

About Roundup Ready herbicide with PLANTSHIELD

How the herbicide works

- Entry into the plant
- Inside the plant
- Activity in the plant
- Factors affecting performance.

Using Roundup Ready herbicide with PLANTSHIELD

- Compatibility
- Mixing
- Handling, Storage and Container Disposal.

Summary Points

- Roundup Ready herbicide with PLANTSHIELD is an easy to use dry formulation that does not require additional surfactant
- Do not tank mix with any other chemical
- Avoid spraying stressed weeds
- Do not apply to grass weeds at the one leaf stage
- Handle, store and dispose of containers properly.

8.1 About Roundup Ready herbicide with PLANTSHIELD

Many formulations of Roundup (and glyphosate) have been tested over the top of Roundup Ready crops in Australia and overseas. As each formulation is unique in its “chemical fingerprint” and/or manufacturing process, a range of weed control and crop safety effects are observed. Roundup Ready herbicide with PLANTSHIELD offers excellent weed control and the highest level of crop safety when applied in Roundup Ready Flex cotton crops.

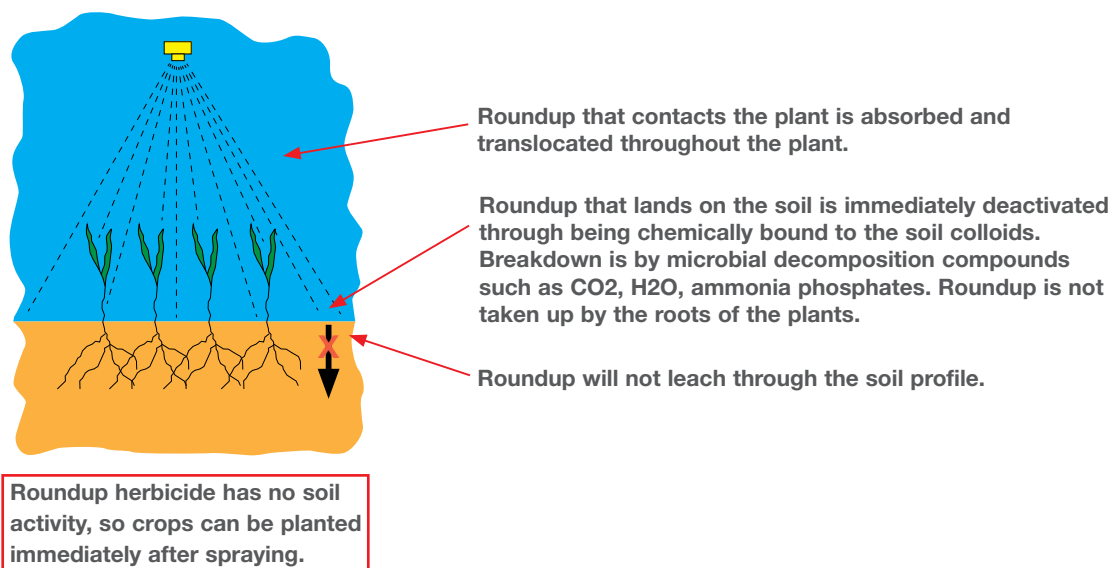
This section outlines the herbicide related management decisions and supporting data to ensure growers maximise the performance of Roundup Ready herbicide with PLANTSHIELD.

The key points when using Roundup Ready herbicide with PLANTSHIELD are:

- Follow label stipulations for the timing of herbicide application
- **DO NOT** add surfactant to Roundup Ready herbicide with PLANTSHIELD
- **DO NOT** use tank mixes with other chemicals
- Always apply in accordance to the Australian Cotton Industry’s Best Management Practices (BMP) manual
- To achieve the best results, applications should be made to weeds when they are small and are actively growing
- Applications should not be made when weeds are stressed, when rain is expected soon after application, or when high temperatures or strong winds make spraying conditions unsuitable.

8.2 How Roundup Works

Roundup Ready herbicide with PLANTSHIELD is a member of the Roundup family of herbicides. This family is well known within the Australian agricultural industry, where it has been extensively used for many years. Roundup is a post-emergent, systemic herbicide with no soil residual activity. It is non-selective and gives broad spectrum control of many annual and perennial weeds. Roundup is also non-volatile, stable in sunlight, completely water soluble and easy to apply. Roundup herbicide has excellent environmental features such as rapid soil binding (resistance to leaching), biodegradation (decreased persistence) and extremely low toxicity to mammals, birds and fish.



The primary effect of glyphosate (the active ingredient in Roundup herbicides) is the interruption of the shikimic acid pathway. This pathway is only found in plants and bacteria. The production of EPSPS (5 enolpyruvylshikimate-3-phosphate synthase) is inhibited by glyphosate. This ensures that plants can not manufacture essential amino acids, which ultimately leads to their death.

As the effectiveness of Roundup comes from activity upon an enzyme within the plant, its performance is dependent upon:

- Entry into the plant
- Movement in the plant
- Activity in the plant.

Environmental conditions affect all of these functions and the final expression of the observed result. Application under good environmental conditions is critical to ensuring the success of any Roundup application.

How does Roundup work?



- Sprayed onto the leaves of growing
- Absorbed through the leaf into the plant
- Translocates throughout the entire plant, including the roots
- Moves through the plant with the sugars
- Kills all parts of the plant, including the roots

Figure 8.2.2 Roundup is translocated throughout the plant, and controls the plant by disrupting the growth at the leaf and root tips. Any factor that causes plant stress may result in a decrease in the effectiveness of Roundup.

8.2.1 Entry into the plant

The entry of chemicals, including Roundup, into plant foliage (leaves and stems) is restricted by cuticle layers and membranes at the surface of the foliage. These layers and membranes are composed of complex arrangements of fatty and waxy materials that particularly restrict the entry of water soluble materials such as Roundup.

The Roundup formulation contains a surfactant (or “surface active” agent) which assists in uptake by reducing droplet surface tension to increase area of contact, and assisting diffusion of glyphosate across the plant cuticle.

Roundup Ready herbicide with PLANTSHIELD is a dry formulation fully loaded with surfactant. This formulation offers new technology with a surfactant type and concentration sufficient to provide good crop safety and effective weed control when used in accordance with label directions.

Adding additional surfactant to Roundup Ready herbicide with PLANTSHIELD can have detrimental effects on crop safety. Leaves can be damaged and burnt, which will reduce the growth rate of the crop.

DO NOT add surfactant to Roundup Ready herbicide with PLANTSHIELD

8.2.2 Inside the plant

Roundup is a translocated herbicide that moves throughout the plant in its natural sap flow. Typically Roundup follows the movement of sugars manufactured by photosynthesis in the plant’s foliage. These reserves move from the foliage to sites of new or active growth, or to areas of storage.

By following such paths in the plant Roundup can interfere with the basic growth and survival functions of the plant to give both broad spectrum and very reliable weed control. Translocation in plants is related to growing conditions and seasonal patterns of growth.

DO NOT apply Roundup Ready herbicide with PLANTSHIELD to grasses at the one leaf stage

This is because the majority of translocation in single leaf grasses is towards the leaf tip, and not fully throughout the plant. As a result, leaf tip “burning” or necrosis is often observed, and the rest of the plant can remain unaffected.

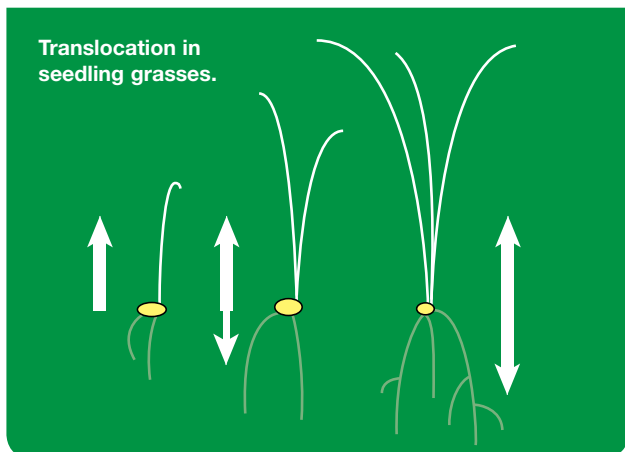


Figure 8.2.2.1 The translocation of plant sugars, and hence also Roundup, is determined by the growth stage of the plant. Roundup does not control one leaf grasses as it is translocated to the leaf tip, but not throughout the rest of the plant.

8.2.3 Activity in the plant

Very often herbicides affect a number of processes in plants, some of which are related. This is the case with Roundup where there are both rapid effects and longer-term changes in the plants.

Rapid effects occur in the treated plant within hours as the use of an essential element, potassium, is interrupted. The effects are evident as a quick reduction in water uptake by the weeds and a halting of foliage growth.

Following this, other essential processes are affected. The primary effect is that the production of three essential amino acids is inhibited in the meristematic (growing point) regions of the plant. A number of vital biochemical reactions in the plant are disrupted and the plant runs out of protein and growth. Eventually the whole plant system begins to collapse with symptoms of accelerated old age and finally death.

The time for visual effects to become obvious depends on plant size and growing conditions (as this influences the level of plant reserves and how quickly they are run down). This explains the earlier development of visual symptoms and plant collapse on young, actively growing annual weeds, for example, compared with more advanced growth or perennial weeds.

8.2.4 Factors Affecting Performance of Roundup Herbicide

The performance of Roundup Ready herbicide with PLANTSHIELD is dependent upon the following broadly grouped factors:

Growing conditions affect the activity of weed growth and the response to Roundup treatment.

Good growing conditions favour the best product performance. Where weed growth is slowed or reduced due to environmental conditions, the speed of the result and possibly the overall effectiveness is reduced.

Weeds can be stressed by periods of drought or water logging, heat or cold and respond by reducing growth activity until the period of stress has passed. Application of most herbicides, including Roundup, to weeds under stress conditions will not give optimal results.

Weather conditions may also affect the uptake of Roundup by the weed foliage, as well as affecting weed growth. It is particularly favoured under higher humidity conditions.

Rainfall immediately after spraying may reduce results, and heavy rainfall may wash Roundup off the foliage.

Dew and Relative Humidity may also affect Roundup uptake, separate to the effect of rainfall. Roundup herbicide may be applied to dew covered weeds provided that water droplets are not "rolling off" the foliage. Where there is some doubt about chemical being removed from the foliage, wait until droplets are not rolling off the foliage before commencing spraying.

Target weed type is important in determining the rate of Roundup required to control a weed. For example, within the grass family a lower rate is required to control barley grass than ryegrass. Within the broadleaf family, a lower rate is required to control capeweed than wild radish. The rate selected for use in Roundup Ready Flex cotton is adequate to control most types and stages of weeds expected to occur throughout the Australian cotton belt.

Target weed size and stage of growth affect the rate of Roundup required and the timing of application.

Soil type, paddock history and field fertility can also influence the growth patterns of weeds, and thus indirectly affect Roundup performance.

Any other stress factor like insect damage or disease can also influence the effectiveness of a Roundup application.

For further information on how to get the best results from an application of Roundup, please contact your local Nufarm representative.

8.3 Using Roundup Ready herbicide with PLANTSHIELD

Roundup Ready herbicide with PLANTSHIELD is produced as a fine (0.8mm diameter) high quality, extruded granule. This provides excellent mixing with minimal operator exposure and rapid dissolution of material in the spray tank. Roundup Ready herbicide with PLANTSHIELD completely dissolves even at concentrations as high as 1 kg in 6 L of water, and once dissolved will not 'fall out' of solution.

Roundup Ready herbicide with PLANTSHIELD has a concentrated formulation, which provides substantial benefits in handling, transport and storage. It is supplied in lined 15kg cardboard boxes.

8.3.1 Compatibility

There are no label recommendations for any tank mixtures with Roundup Ready herbicide with PLANTSHIELD over the top of Roundup Ready Flex cotton. Compatibility studies are planned for the future to determine the crop safety of applying Roundup Ready herbicide with PLANTSHIELD in combination with current chemical options in cotton. Until these studies are finalised, Roundup Ready herbicide with PLANTSHIELD should not be applied over the top of Roundup Ready Flex cotton in a tank mix with ANY herbicide, insecticide, fungicide, adjuvant, fertiliser/nutrient or other agent. Incompatibility should be assumed until proven otherwise.

DO NOT use tank mixes with other chemicals

Roundup Ready herbicide with PLANTSHIELD mixes readily with water and is completely soluble when agitated as per label. Reduced results may occur if not agitated correctly, or if water is used that contains suspended clay or organic matter (e.g. from dams, streams and irrigation channels), or high levels of calcium, magnesium or bicarbonate ions.

Do not mix, store or apply this product in galvanised steel or unlined steel containers or spray tanks, since a highly flammable gas mixture may be formed. Use stainless steel, aluminium, brass, copper, fibreglass, plastic or plastic-lined containers or spray tanks. Spray tanks, pumps, lines and nozzles should be thoroughly cleaned with clean water following application. Ensure that the spray tank is free of any residue of other spray solutions prior to mixing. Good agitation is required, particularly under cold conditions, to ensure all of the Roundup Ready herbicide with PLANTSHIELD dissolves when first added to the tank. Use spray solution promptly as a gradual loss of activity may occur over a period of days following spray preparation.

Mixing instructions:

- Fill the tank with one-half the required amount of clean water and set the pump on full agitation.
- Add the required amount of Roundup Ready herbicide with PLANTSHIELD slowly to ensure that it is well dispersed throughout the tank and none collects on the bottom. Suggested rate is 10 kg in 2–3 minutes.
- Continue water addition and fully agitate until all the Roundup Ready herbicide with PLANTSHIELD is completely dissolved.

8.3.2 Handling, Storage and Container Disposal

Roundup Ready herbicide with PLANTSHIELD is packed in a robust outer carton with a convenient opening, which reduces the likelihood of spills and eliminates the potential for splashing. Containers should be stored in a dry area. The outer package can be recycled or disposed of in an approved landfill. Spills may be swept up, re-used or disposed of in an approved landfill.

9. Applying Roundup Ready herbicide with PLANTSHIELD

In this Section

Pesticide Application Management Plans

Cleaning and decontamination of spray equipment

Field Identification

Avoiding Off-target drift

Aerial application

Ground rig application

Formulation and Volume Median Diameter (VMD)

Summary Points

- All users of Roundup Ready Flex cotton are strongly encouraged to integrate its use into a Pesticide Application Management Plan (PAMP) as outlined by the Australian Cotton Industry's Best Management Practices (BMP).
- Ensure all spray equipment is thoroughly clean before applying Roundup Ready herbicide with PLANTSHIELD
- Clearly identify all Roundup Ready Flex fields on farm maps and at field boundaries
- Drift can be influenced by droplet sizing, spray tip height, operating speed, wind velocity, air temperature and humidity
- Always ensure both crop and environmental conditions are suitable before applying Roundup Ready herbicide with PLANTSHIELD to a Roundup Ready Flex cotton crop. Conditions should be monitored throughout the operation, and spraying must cease whenever unsuitable conditions occur.
- All nozzles produce a wide range of droplet sizes at any given pressure
- All applications must comply with the application guidelines on the Roundup Ready herbicide with PLANTSHIELD label.

9.1 Pesticide Application Management Plans (PAMP)

When applying any pesticide, the safety of people and the environment is the primary consideration. The safe and responsible use of pesticides in the Australian cotton industry is an essential element of Best Management Practices (BMP) demonstrated in the development of a Pesticide Application Management Plan (PAMP).

A PAMP provides a framework to help ensure that all people involved in a pesticide application have a clear understanding of their responsibilities. It also assists in identifying potential risks with pesticide applications so that appropriate measures can be instigated to minimise those risks.

A PAMP has two essential aims:

- 1. Establishing good communication with all persons involved in the application of pesticides**
- 2. Using appropriate application techniques and procedures**

All users of Roundup Ready Flex cotton are strongly encouraged to integrate its use into a Pesticide Application Management Plan (PAMP) as outlined by the Australian cotton industry's Best Management Practices (BMP).

9.2 Cleaning and decontamination of spray equipment

Properly calibrated, clean equipment is necessary for effective spray coverage and ensuring no off-target effects (in the form of drift) to the crop being sprayed or to surrounding susceptible crops or pastures.

Failure to thoroughly clean out and decontaminate spray equipment before spraying Roundup Ready herbicide 'over the top' of Roundup Ready Flex cotton could result in severe crop injury. Refer to individual product labels to source details of what products and rates can be used to clean and decontaminate spraying equipment.

- Small amounts of Sulfonyl Urea and Phenoxy herbicides can cause significant crop damage
- Traces of suspension concentrates in screens can cause crop damage

Ensure all spray Roundup Ready herbicide with PLANTSHIELD



Figure 9.2.1 Effects on cotton from a boom contaminated with 2,4-D (left) and a SU herbicide (right)

9.3 Field Identification

Fields sown to Roundup Ready Flex cotton should be clearly identified on farm maps and at the boundaries of these fields to prevent accidental product application to a field not planted to Roundup Ready Flex cotton.

The location of the different types of cotton present on the farm should be communicated to all farm workers, spray contractors and neighbours prior to the commencement of the season.

**Clearly identify all Roundup Ready Flex fields
on farm maps and at field boundaries**

Care also needs to be taken to ensure that the correct seed is planted into the appropriately designated field. Roundup Ready herbicide with PLANTSHIELD will kill conventional cotton. Always check the seed bags and seek advice from the respective seed companies regarding their seed colours, if in any doubt. Remember once it goes into the ground it is too late!



Figure 9.3.1 Double skip cotton where both conventional planting seed and Roundup Ready seed went into the same planter (in different boxes) and were sprayed OTT with Roundup Ready herbicide with PLANTSHIELD.

9.4 Avoiding off-target drift

Correct selection of spray nozzle tips that are designed for the intended application is the first step in reducing off target drift during spray applications of all herbicides and pesticides, not only Roundup Ready herbicide with PLANTSHIELD. Drift can be successfully managed with correct knowledge of the spray equipment and factors influencing drift.

Drift can be influenced by droplet sizing, spray tip height, operating speed, wind velocity, air temperature and humidity.

It is vital to ensure adequate buffer zones, or safe distances, from susceptible crops are in place prior to application.

When making applications in low relative humidity conditions, the potential for droplet evaporation increases dramatically. Ensure the droplets produced are able to compensate for this evaporation.

“Temperature inversion” is a term used to describe conditions that restrict vertical air mixing, causing small suspended droplets to remain in a concentrated cloud. This cloud can move in any direction directed by the light and variable winds common during inversion conditions. Smoke is a commonly used method to indicate these conditions. Smoke that layers and moves laterally in a concentrated cloud indicates inversion conditions, while smoke that moves upwards and rapidly dissipates indicates good vertical air mixing.

Every application is a balance between managing drift and maintaining efficacious weed control. After having taken into account all the potential causes of drift, it is prudent to consider the use of a range of drift control nozzles commercially available. **Remember that all nozzles produce a wide range of droplet sizes at any given pressure, whether they are marketed as drift retardant or not. This spectrum varies with each nozzle configuration, spray liquid and operating pressure.**

All applications must comply with the application guidelines on the Roundup Ready herbicide with PLANTSHIELD label.

Always ensure both crop and environmental conditions are suitable before applying Roundup Ready herbicide with PLANTSHIELD to a Roundup Ready Flex cotton crop. Conditions should be monitored throughout the operation, and spraying must cease whenever unsuitable conditions occur.

9.5 Aerial Application

Roundup Ready herbicide with PLANTSHIELD may be applied over the top by aircraft through to the end of the sixteenth (16th) node stage, and again as a pre-harvest spray at the 60% boll open stage, in a total spray volume of not less than 40 L of water per hectare. These applications must comply with the application guidelines on the Roundup Ready herbicide with PLANTSHIELD label.

Extreme care must be used when applying this product to prevent injury to desirable plants and crops.

9.6 Ground Rig Applications

Before any in-crop application it is absolutely essential to thoroughly decontaminate the sprayer (including tank, lines and filters) of any products (particularly sulfonyleurea or phenoxy herbicides) which might damage the crop.

These applications must comply with the application guidelines on the Roundup Ready herbicide with PLANTSHIELD label.

Growers should consider using droppers and directed sprays in order to achieve adequate weed coverage.

10. Resistance Management Strategy for Roundup Ready Flex cotton

In this Section

Herbicide Resistance Overview

Herbicide Resistance and glyphosate

Herbicide Resistance in the Australian cotton industry

Principles of Integrated Weed Management

Resistance Management Strategy for Roundup Ready Flex cotton

Summary Points

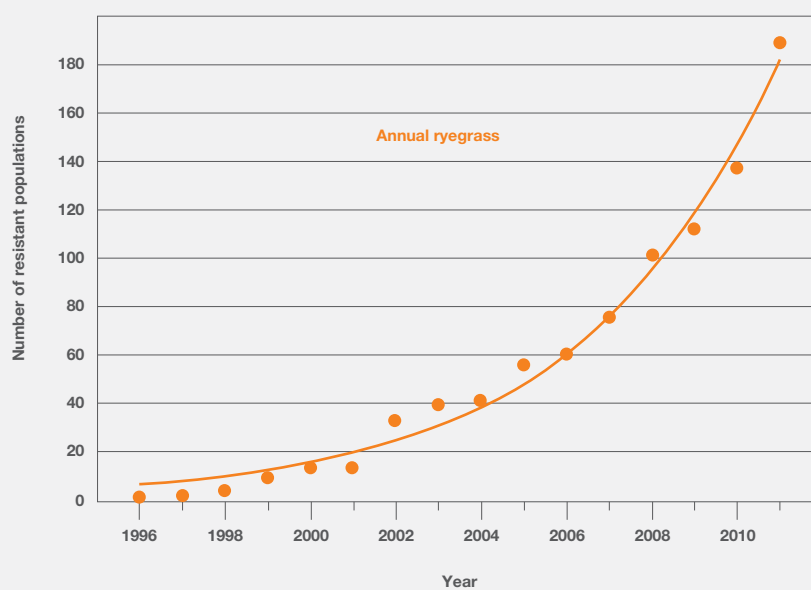
- Glyphosate resistance can occur, however it is relatively rare and slow to develop.
- The risk of resistance to any herbicide increases when that particular herbicide is used in isolation with no other effective forms of weed control.
- Integrated Weed Management IS best practice in weed management.
- The primary aim of the Roundup Ready Flex cotton Crop Management Plan (CMP) is to aid in minimising the risk of the evolution of glyphosate resistant weeds in the Australian cotton production system.
- The Roundup Ready Flex cotton CMP has been developed by Monsanto in consultation with leading Australian weed scientists and researchers.

The current status of glyphosate resistance in Australia

Table 1. Glyphosate resistant annual ryegrass has occurred in the following situations:

Situation		Number of sites	States
Broadacre cropping	Chemical fallow	29	NSW
	Winter grains	59	NSW, SA, VIC, WA
	Irrigated crops	1	SA
Horticulture	Tree crops	5	NSW, SA
	Vine crops	21	SA, WA
	Vegetables	2	VIC
Other	Driveway	4	NSW, SA, VIC, WA
	Fence line/Firebreak	53	NSW, SA, VIC, WA
	Irrigation channel/Drain	12	NSW, SA, VIC
	Airstrip	1	SA
	Railway	1	WA
	Roadside	1	SA

The glyphosate-resistant awnless barnyard grass, fleabane, liverseed grass and windmill grass populations all occur in summer chemical fallow situations.



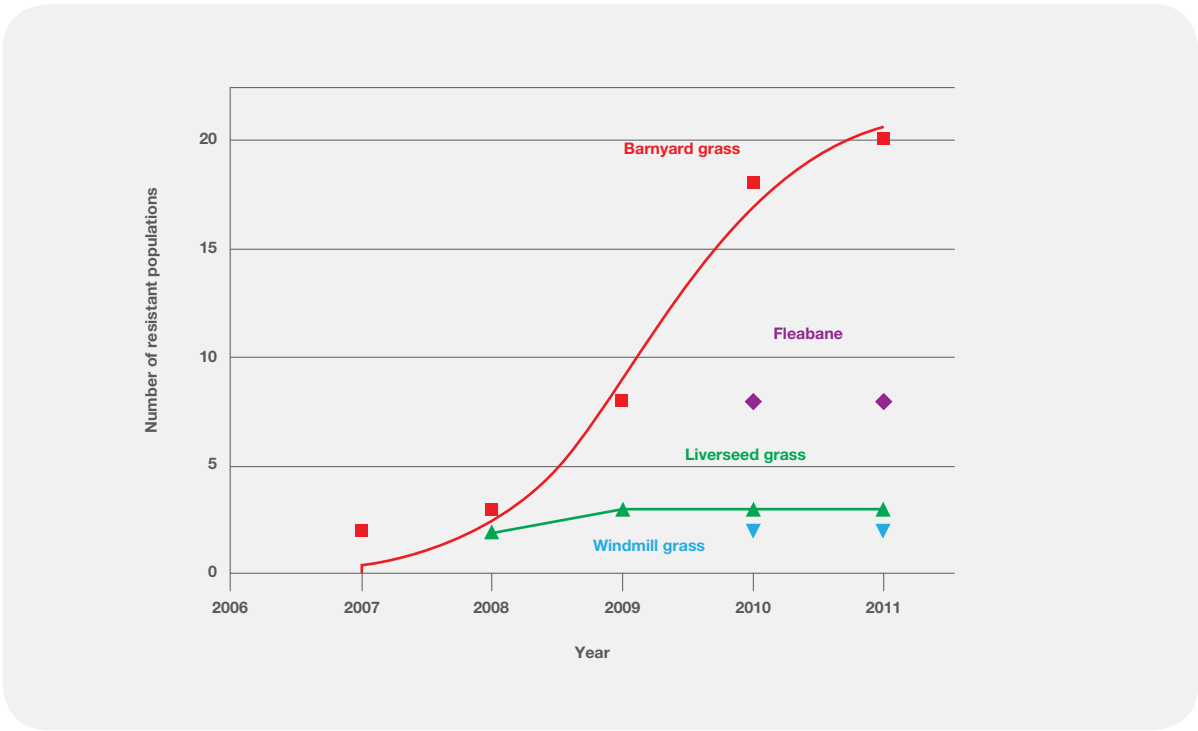


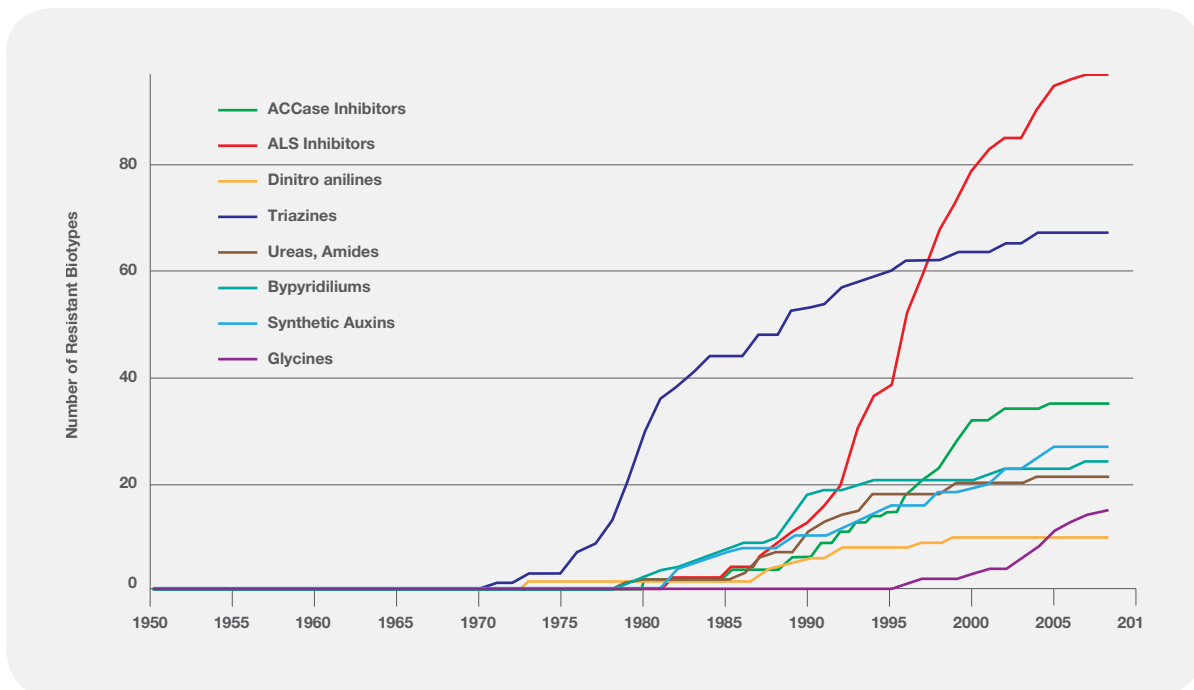
Figure 1 a and b Number of confirmed cases of glyphosate resistance in Australia

The predisposing factors for the development of glyphosate resistance are intensive use of glyphosate, lack of other herbicide options due to existing resistance, and little or no tillage. Source: Dr Chris Preston (2011) Australian Glyphosate Resistance Register, Australian Glyphosate Sustainability Working Group, online: <http://www.glyphosateresistance.org.au/>

Further reading:
International Survey of Herbicide Resistant Weeds – www.weedscience.org

10.1 Herbicide Resistance and glyphosate

Glyphosate resistance is rare, and has been slow to develop in comparison to other herbicides.



Source: Ian Heap <http://WeedScience.com>

Figure 10.1.1 Overview of the development of resistance to each of the major herbicide groups (amended for Australian herbicide groups from Dr Ian Heap, May 2010). Glyphosate (Group M/Glycines) resistance is rare and has been slow to develop.

Glyphosate can be considered to be at a low risk for the development of resistance for the following reasons:

- **Lack of soil residual activity** – Herbicides with soil residual activity dissipate over time in the soil, which may lead to sublethal exposure and, in effect, low dose selection pressure. Glyphosate adsorption to the soil is rapid (usually less than 1 hour). Soil bound glyphosate is unavailable to plant roots, and as such any sublethal dose over time affect is eliminated.
- **Target site specificity** – A herbicide’s mode of action is classified by the interference of a critical metabolic process in the plant by binding to a target protein and disrupting the required function. The “specificity” of this interaction is critical for the opportunity to develop target site resistance. Because the herbicide contacts discrete amino acids during protein binding, changing one of these contact point amino acids can interrupt binding. Specificity of inhibitor binding is dependant on the number and type of amino acids serving as contact points.

On one extreme is glyphosate, the only herbicide compound which can bind to EPSPS. Single amino acid substitutions near the active site have been observed for EPSPS, and whilst glyphosate binding is slightly weaker, these enzymes are also less fit.

The other extreme is target enzymes that are efficiently inhibited by a wide array of compounds, eg acetolactate synthase (ALS) is inhibited by 53 and acetyl CoA carboxylase (ACCCase) is inhibited by 21 separate herbicide compounds that bind within and outside the active site. These cases demonstrate that numerous non-critical amino acids are involved outside of the active site, offering a relatively large range of permissible mutations. In these two herbicide classes, a single amino acid change can result in virtual immunity to the herbicides and has directly led to the high prevalence of resistant weed species for these modes-of-actions.

As a transition state inhibitor, glyphosate binds only to the key catalytic residues in the active site. Catalytic residues are critical for plant function, and cannot be altered without a lethal or serious fitness penalty. Furthermore, very few selective changes can occur near the active site of the enzyme to alter the competitiveness of glyphosate without interfering with normal catalytic function.

Therefore target site resistance is highly unlikely with glyphosate.

- **Limited Metabolism in Plants** – Glyphosate has been demonstrated to have no or significantly low metabolism across several species. Therefore this mechanism is unlikely to confer resistance to glyphosate in plants.

Glyphosate resistance can occur, however it is rare and slow to develop

10.2 Herbicide Resistance in the Australian Cotton industry

Historically, weed control in Australian cotton production has involved the use of a diverse range of management and control options. Land preparation, chipping, inter row cultivation, selective herbicides (both pre plant and in crop), and non-selective herbicides in crop have characterised weed management systems over the last 30 years.

The potential development of herbicide resistance in the Australian cotton industry can be, and has been, managed to date through the use of this range of weed management practices.

While the adoption of Roundup Ready Flex cotton may reduce the requirement for some growers to apply pre-plant residual herbicides and use hand weeding methods, it is highly unlikely that all methods of weed control will be abandoned in favour of a glyphosate-alone system.

Maintaining diversity of weed control measures is the key to the long term sustainability of the cotton weed control system.

10.3 Principles of Integrated Weed Management

Repeated exposure of a weed population to any herbicide in isolation may have two effects. The weed species that are not controlled by the herbicide will dominate the population (species shift) and pressure will be exerted on the population to select any resistant individuals that may be present (herbicide resistance).

The development of both species shift and herbicide resistance can be effectively managed by the practice of Integrated Weed Management (IWM). The principles of IWM are that weed management should not rely on one single form of control. In practical terms IWM means the development of a weed management program that uses a combination of preventative, cultural, mechanical and chemical control practices.

IWM provides a framework for effective and sustainable weed management that ultimately prevents weeds from propagating (from setting seed or vegetatively reproducing). This will lead to a reduction in the weed population over time, resulting in reduced crop competition and an improvement in crop productivity.

Integrated Weed Management is best practice weed control

10.4 Resistance Management Strategy for Roundup Ready Flex cotton

The sustainable use of Roundup Ready herbicide with PLANTSHIELD is critical for Australian cotton farming systems. Furthermore, the longevity of Roundup Ready Flex technology relies on minimising the development of weed resistance to glyphosate-based herbicides. As such, the Roundup Ready Flex cotton Crop Management Plan (CMP) is a critical component for the use of Roundup Ready technology in Australia.

The purpose of the Roundup Ready Flex CMP is to protect the sustainability of Roundup Ready Flex cotton and to aid in minimising the risk of the evolution of glyphosate resistant weeds in the Australian cotton production system.

The CMP has been developed by Monsanto in consultation with leading Australian weed scientists and researchers, and has been ratified by the Transgenic and Insect Management Strategy (TIMS) committee.

10.4.1 Weed Management Post Spray Survey

The Weed Management Post Spray Survey is used to monitor the status of weeds present in a Roundup Ready Flex crop following applications of Roundup Ready herbicide with PLANTSHIELD.

Details required include:

- Assessment of all weeds remaining ten (10) to fourteen (14) days after an “over the top” (OTT) application of Roundup Ready herbicide with PLANTSHIELD at a minimum of 6 nodes of crop growth, and not exceeding 16 nodes.
- Any remedial action taken to stop seed set
- Comments about the level of weed control achieved in Roundup Ready Flex cotton, including the efficacy of remedial actions undertaken
- Adverse event reporting.

Monsanto collates this data and discusses the findings with relevant industry weed scientists who will report these findings back to the TIMS Herbicide technical panel.

One of the keys of any resistance management strategy is to minimise and limit the number of weed “escapes”. If any weed escapes are prevented from setting seed, then essentially no potential resistant population can develop.

In Roundup Ready Flex cotton, weeds that have been identified as surviving Roundup Ready herbicide with PLANTSHIELD applications must be controlled by an alternative management strategy in order to prevent those weeds from setting seed.

10.4.2 Integrated Weed Management Strategy (IWMS)

The use of a range of weed control options, rather than reliance on any one single weed control option, is the basis behind the Roundup Ready Flex Integrated Weed Management Strategy (IWMS). The purpose of the IWMS is to provide a framework for aiding in the prevention of the development of herbicide resistant weeds. Prevention is best achieved by following integrated weed management guidelines:

1. Scouting – Regularly check fields **before and after** herbicide applications. Ensure that weeds not controlled by a herbicide application are controlled by some other method.
2. Field Records – Maintain records of crops, weed control methods and the effectiveness of each management operation. This will allow the field rotation and the effectiveness of weed control methods to be compared. It will also aid in maximising the efficiency of the weed control and volunteer plans.
3. Accurate weed identification – Ensure that weeds are correctly identified, and that the appropriate herbicide choices and rates are made to suit the weed population present. Always be on the look out for new weeds.
4. Use as many different weed control options (chemical and non-chemical) as applicable in both crop and fallow phases (including rotation crops).

For example

- Re – hilling
- Bed formation and bed renovation
- In-crop cultivation
- Hand weeding / spot chipping
- Herbicides with differing modes of action
- Rotation crops.

5. Use the appropriate registered product for the target weed species and make every herbicide application count – **use the registered rate that kills**. Pay particular attention to the size of the weed targeted, and always adhere to the conditions of use of the appropriate product label.
6. Utilise crop rotations to help manage the potential for resistance development :
 - Crop rotation allows the use of different weed control methods on the same field in different years.
 - Crops with differing sowing times and different seedbed preparation can lead to a variety of cultural techniques being employed to manage a particular weed problem.
 - The growth season of a particular weed can be avoided or disrupted
 - Crops also differ in their inherent competitiveness against weeds. A strongly competitive crop will have a better chance to restrict weed seed production.
 - Introducing rotation crops such as sorghum or wheat into the cropping system, for example, has the potential to introduce a range of different weed control methods (cultivation, sowing, herbicides with different modes of action etc).
 - Fallows also provide opportunities to use non-selective methods of weed control (cultivation etc.) as well as herbicides from different groups.
7. Enter a cropping phase with low weed numbers.
8. Farm hygiene – minimise new weeds entering fields. Clean down vehicles and equipment between fields. Monitor frequently for weeds, and control any new weeds that appear when they are in small patches.

Further reading:
www.weedresistancemanagement.com

11. Appendix 1 – Herbicide groups

Herbicide Mode of Action Groups

Current classification of herbicide mode of action groups are accessible at:

<http://www.croplifeaustralia.org.au/files/resistancemanagemen/herbicides/2009%20Herbicide%20MOA%20Table.pdf>

12. Appendix 2 – Roundup Ready herbicide with PLANTSHIELD Label

To see the current Roundup Ready herbicide with PLANTSHIELD by Monsanto label visit:

<http://services.apvma.gov.au/PubcrisWebClient/details.do?view=general&pcode=63268>

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Head Office: 12/600 St Kilda Road, Melbourne, VIC 3004
Post: PO Box 6051, St Kilda Road Central, VIC 8008
Phone: 1800 069 569 Fax: 03 9522 6122
www.monsanto.com.au

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