

THE BOLLGARD 3 RESISTANCE MANAGEMENT PLAN

The addition of the Vip3A protein in Bollgard 3 increases the durability of the technology, which allowed changes to be made to the Resistance Management Plan (RMP). A Bollgard 3 RMP was developed by Monsanto, endorsed by the cotton industry's Transgenic and Insect Management Strategies (TIMS) Committee. A submission has been made to the Australian Pesticides and Veterinary Medicines Authority (APVMA) to approve the Bollgard 3 product and also the proposed Resistance Management Plan. Monsanto anticipate receiving this approval in early 2016.

THE RESISTANCE MANAGEMENT PLAN IS BASED ON THREE BASIC PRINCIPLES:

1. Minimising the exposure of *Helicoverpa* spp. to the *Bacillus thuringiensis* (Bt) proteins Cry1Ac, Cry2Ab and Vip3A,
2. Providing a population of susceptible individuals that can mate with any resistant individuals, hence diluting any potential resistance, and
3. Removing resistant individuals at the end of the cotton season.

These principles are supported through the implementation of five elements that are the key components of the Resistance Management Plan. These elements are:



Planting restrictions



Refuge crops



Control of volunteers and ratoon cotton



Pupae destruction/trap crops



Spray limitations

Growers of Bollgard 3 cotton are required to practice preventative resistance management as set out below. Compliance with the Resistance Management Plan is required under the terms of the Bollgard 3 Technology User Agreement.



Planting restrictions

NEW SOUTH WALES AND SOUTHERN QUEENSLAND

All Bollgard 3 crops and refuges must be planted into moisture or watered-up between August 1 and before December 31 each year, unless otherwise specified in this Resistance Management Plan.

CENTRAL QUEENSLAND

All Bollgard 3 crops and refuges must be planted into moisture or watered-up between August 1 and before October 31 each year, unless otherwise specified in this Resistance Management Plan.

Any Bollgard 3 crops planted into moisture or watered-up after October 31 and up to December 31 must plant additional refuge as specified in Table 3 and 4.



Refuges

Growers planting Bollgard 3 cotton will be required to grow a refuge crop that is capable of producing large numbers of *Helicoverpa* spp. moths which have not been exposed to selection with the Bt proteins Cry1Ac, Cry2Ab and Vip3A. These unselected moths are expected to dominate matings with any survivors from Bollgard 3 crops and thus help to maintain resistant alleles to the Bt proteins Cry1Ac, Cry2Ab and Vip3A at low frequencies.

All refuge options are based on the requirement of a 5% unsprayed cotton refuge or its equivalent, as determined by the relative production of *Helicoverpa* spp. from each of the refuge types as described in Tables 1 and 2 for irrigated and dryland production scenarios, respectively.

For each area of irrigated Bollgard 3 cotton planted, a grower is required to plant one or more of the following:

Table 1: Irrigated Bollgard 3 cotton refuge options

CROP	CONDITIONS	% OF BOLLGARD 3
Cotton	Irrigated, sprayed conventional cotton	100
	Irrigated, unsprayed conventional cotton	5
Pigeon pea	Fully irrigated, unsprayed	2.5

Table 2: Dryland Bollgard 3 cotton refuge options

CROP	CONDITIONS	% OF BOLLGARD 3
Cotton	Dryland or irrigated, sprayed conventional cotton	100
	Dryland or irrigated, unsprayed conventional cotton	5
Pigeon pea	Dryland or fully irrigated, unsprayed. Dryland pigeon peas can only be planted with an approved plan from Monsanto Australia.	2.5

Table 3: Irrigated Bollgard 3 cotton refuge options for Central Queensland planted after October 31

CROP	CONDITIONS	% OF BOLLGARD 3
Cotton	Irrigated, sprayed conventional cotton	100
	Irrigated, unsprayed conventional cotton	10
Pigeon pea	Fully irrigated, unsprayed	5

Table 4: Dryland Bollgard 3 cotton refuge options for Central Queensland planted after October 31

CROP	CONDITIONS	% OF BOLLGARD 3
Cotton	Dryland or irrigated, sprayed conventional cotton	100
	Dryland or irrigated, unsprayed conventional cotton	10
Pigeon pea	Dryland or fully irrigated, unsprayed. Dryland pigeon peas can only be planted with an approved plan from Monsanto Australia.	5

Note: Unsprayed means not sprayed with any insecticide that targets any life stage of *Helicoverpa* spp.

Bt products must not be applied to any refuge (including sprayed cotton).

If the viability of an unsprayed refuge is at risk due to early or late season pressure by *Helicoverpa* spp., or any other caterpillar species, contact Monsanto Australia immediately. With prior approval from Monsanto Australia, a non-Bt heliocide can be applied.

For the purposes of this Resistance Management Plan, conventional cotton includes any cotton varieties that do not have Bt proteins in the plant that control *Helicoverpa* spp. larvae.

GENERAL CONDITIONS FOR ALL REFUGES

- (a) Refuge crops are to be planted and managed so that they are attractive to *Helicoverpa* spp. during the growing period of the Bollgard 3 cotton varieties.

Irrigated: It is preferable that all refuge is planted within the 2 week period prior to planting Bollgard 3. If this is not possible, refuge planting must be completed within 3 weeks of the first day of sowing of Bollgard 3. At this time, sufficient refuge must have been planted to cover all of the Bollgard 3 cotton proposed to be planted for the season (including Bollgard 3 already planted and any that remains unplanted). If additional Bollgard 3 is planted after this date which is not already covered by refuge, additional refuge must be planted as soon as possible and no more than 2 weeks after sowing of the additional Bollgard 3.

Dryland: A dryland refuge must be planted within the 2 week period prior to the first day of planting Bollgard 3 cotton.

- (b) Pigeon pea refuges should not be planted until the soil temperature reaches 17°C, which is a requirement for germination, and should also be planted into moisture to ensure successful germination. If soil temperatures are not suitable to allow germination of pigeon peas in line with condition (a), an alternative refuge must be planted in its place within the prescribed period (under (a) above).
- (c) All refuges should preferably be planted into a fallow or rotation field that has not been planted to Bt cotton in the previous season to avoid volunteer and ratoon cotton. See Refuge Management Guide for all unsprayed refuges.

- (d) Once Bollgard 3 cotton begins to flower, the corresponding refuge must not be cultivated.
- (e) All refuges are to be planted within the farm unit growing Bollgard 3 cotton no more than 2 km from the associated Bollgard 3 cotton field. For any cases where it may not be possible to plant the refuge within 2 km from the associated Bollgard 3, approval must be sought from Monsanto Australia.
- (f) To minimise the possibility of refuge attractiveness being affected by herbicide drift, non-herbicide tolerant refuges should be separated from herbicide tolerant Bollgard 3 cotton crops by a sufficient distance to minimise such drift, but no more than 2 km from the Bollgard 3 cotton.
- (g) To account for possible insecticide drift, the options for the width of refuge crops vary according to spray regime. If any sprayed conventional cotton is grown on the same farm unit, Bollgard 3 refuge crops must be at least 48 metres wide and each refuge area must be a minimum of 2 hectares. If sprayed conventional cotton is not grown on the same farm unit, Bollgard 3 refuge crops must be at least 24 metres wide and each refuge area must be a minimum of 0.5 hectares. Different unsprayed refuge options may be planted in the same field as a single unit; however a sprayed conventional cotton refuge must not be planted in a field that is also planted to an unsprayed refuge type unless a sufficient buffer is in place to prevent insecticide drift.
- (h) In all regions, destruction of refuges must only be carried out after Bollgard 3 has been harvested. In Central Queensland, soil disturbance of refuge crops must only occur when the trap crop is being destroyed (refer to section on Pupae Destruction).
- (i) Refuges for dryland Bollgard 3 cotton crops must be planted in the same row configuration as the Bollgard 3 crop unless the refuge is irrigated. If an irrigated option is utilised for a dryland Bollgard 3 crop, then that refuge may be planted in a solid configuration. Dryland cotton is measured as green hectares (calculated as defined in the Technology User Agreement).

Control of volunteer and ratoon cotton

Volunteer and ratoon cotton may impose additional selection pressure on *Helicoverpa* spp. to develop resistance to the Bt proteins Cry1Ac, Cry2Ab and Vip3A produced by Bollgard 3 cotton.

As soon as practical after harvest, Bollgard 3 cotton crops must be destroyed by cultivation, root cutting or herbicide so that they do not continue to act as hosts for *Helicoverpa* spp.

Growers must ensure that volunteer and ratoon plants are removed as soon as possible from all fields, including fallow areas, Bollgard 3 crops, conventional cotton crops and all refuges. *The presence of Bollgard 3 volunteers/ratoon cotton in any refuge will diminish the value of the refuge and must be removed as soon as possible.*

Note: The refuge should preferably be planted into fallow or rotation fields that have not been planted to cotton in the previous season.

Pupae destruction / trap crops

NEW SOUTH WALES AND SOUTHERN QUEENSLAND

To further mitigate the risk of resistance, each grower of Bollgard 3 must undertake *Helicoverpa* spp. pupae destruction in fields with a higher probability of carrying over wintering pupae according to the following key guidelines:

- If first defoliation of a Bollgard 3 field occurs on or before March 31, the Bollgard 3 field must be slashed or mulched and controlled to prevent regrowth within 4 weeks of harvesting.
- If first defoliation of a Bollgard 3 field occurs after March 31, the Bollgard 3 field must be slashed or mulched and controlled to prevent regrowth within 4 weeks of harvesting and pupae busting must be complete by July 31 for all valleys except for all regions including the Lachlan, Murrumbidgee, Menindee and Murray Valleys where pupae busting must be complete by August 31.
- Ensure disturbance of the soil surface to a depth of 10 cm to a distance of 30 cm both sides of the plant line.

CENTRAL QUEENSLAND

Crop destruction

All Bollgard 3 crops must be slashed or mulched and controlled to prevent regrowth within 4 weeks of harvesting.

End of season management of refuges/trap crops

End of season pupae busting practices are not effective in the Central Queensland region as *Helicoverpa* spp. are less likely to diapause. A late summer trap crop (pigeon pea) must be planted for all Bollgard 3 cotton grown in Central Queensland. The planting configuration of the trap crop should be the same as that of the Bollgard 3 crop. Irrigated Bollgard 3 must have an irrigated trap crop. Table 5 shows the requirements for the late summer pigeon pea trap crop. *Dryland Bollgard 3 growers who do not have any irrigated cotton on their farm should contact Monsanto Australia for alternative options.*

Refuge and late summer trap crops have different purposes. Where a pigeon pea refuge is utilised, the full pigeon pea refuge area must be managed to become the late summer trap crop. If unsprayed cotton is used as the refuge, an additional area of 1% pigeon pea must be planted as the late summer trap crop. Requirements for late summer trap crops are detailed in Table 5 (right).

FAILED CROPS – ALL REGIONS

Bollgard 3 crops that will not be grown through to harvest for various reasons and are declared to, and verified by, Monsanto as failed must be destroyed within two weeks after verification, in such a way that prevents regrowth. Crops that are abandoned before February 28 should be slashed and mulched within 4 weeks.

Table 5: Late summer pigeon pea trap crop requirements in Central Queensland

CRITERION	TRAP CROP*
Minimum area & dimension (Requirement)	<p>A minimum trap crop of 1% of planted Bollgard 3 cotton crop is required.</p> <p><i>If sprayed conventional cotton is grown on that farm unit:</i> the trap crop must be at least 48m x 48m.</p> <p><i>If no sprayed conventional cotton is grown on that farm unit:</i> the trap crop must be at least 24m x 24m.</p>
Planting time	<p>The trap crop should preferably be planted 4 weeks after the associated Bollgard 3.</p> <p>Note: if growers choose to plant their trap crop to coincide with the planting of pigeon pea refuges, they must manage the trap crop in such a way that it remains attractive to <i>Helicoverpa</i> spp. 2–4 weeks after final defoliation.</p>
Planting rate **	35kg/ha (recommended establishment greater than 4 plants per metre)
Insect control	<p>The trap crop can be sprayed with virus after flowering, while avoiding insecticide spray drift, except where a pigeon pea refuge is converted to a trap crop. In this case the full 5% pigeon pea refuge area managed to become the late summer trap crop can only be sprayed with virus after the first defoliation of Bollgard 3 cotton.</p>
Irrigation	<p>The refuge/trap crop must be planted into an area where it can receive the additional irrigation required to keep the trap crop attractive to <i>Helicoverpa</i> spp. until after the cotton is defoliated.</p>
Weed control	<p>The trap crop should be kept free of weeds and particularly volunteer Bollgard 3 cotton. When using the full pigeon pea refuge area as the trap crop, weed control must not be carried out by cultivation once flowering of the associated Bollgard 3 cotton crop has commenced.</p>
Crop destruction	<p>The trap crop must be destroyed 2–4 weeks (but not before 2 weeks) after final defoliation of the Bollgard 3 cotton crop, (slash and pupae bust – full soil disturbance to a depth of 10 cm across the entire trap crop area). All Bollgard 3 and associated trap crops must be destroyed by July 31.</p>

* A pigeon pea trap crop is to be planted so that it is attractive (flowering) to *Helicoverpa* spp. after the cotton crop has cut out, and as any survivors from the Bollgard 3 crop emerge. Planting pigeon pea too early (e.g. before November) or too late (e.g. mid December) is not adequate for cotton crops planted during September through to October.

** The planting rate is a recommendation based on a minimum of 85% seed germination.

▲ Spray Limitations

Insecticide preparations containing Bt may be used on Bollgard 3 cotton throughout the season BUT NOT on any refuge crops.

An unsprayed refuge should not be planted in the same field as any crop sprayed with a rate of insecticide that is registered for *Helicoverpa* spp., with the exception of Bollgard 3. Sprayed crops and unsprayed refuges that are planted in adjacent fields must be separated by sufficient distance to minimise the likelihood of insecticide drift onto the unsprayed refuge.

If the viability of an unsprayed refuge is at risk due to early or late season pressure by *Helicoverpa* spp., or any other caterpillar species, contact Monsanto Australia immediately. With prior approval from Monsanto Australia, a non-Bt heliocide can be applied.

NB: If any grower encounters problems in complying with the Resistance Management Plan please contact Monsanto Australia.

For further background information on the various components of this plan see the "Preamble to the Resistance Management Plan for Bollgard 3" in the current Cotton Pest Management Guide.

The RMP helps support long term viability of Bt technologies, by providing farm and crop management techniques to aid in managing the risk of resistance occurring. It is also a regulatory requirement that forms part of Monsanto's product registration with the APVMA and must be complied with for all planting of Bollgard 3.

Note. Any planting of Bollgard II cotton must comply with the Bollgard II RMP

ADDITIONAL STEWARDSHIP CONSIDERATIONS

Refuge Management

Refuges must be managed using good agronomic practices to ensure healthy plants that are attractive to *Helicoverpa* spp. In order to be effective, the refuge must be as attractive, if not more so, than the Bollgard 3 crop. To ensure this refuge planning should be part of your pre-season management:

- Plant the prescribed area of refuge crop
- Consider the placement of the refuge
 - » To avoid insecticide and herbicide drift
 - » To avoid the presence of Bollgard II/3 volunteers and other weeds in the refuge. Preferably plant refuges in fallow or rotation fields that have not been planted to cotton in the previous season.

- Manage the refuge crop appropriately to ensure healthy plants that are attractive to *Helicoverpa* spp. This may be different for cotton and pigeon pea refuges

PIGEON PEA REFUGES:

- Consider sourcing QA pigeon pea seed – this variety has been assessed for its agronomic qualities i.e. germination, time to flowering as well as its attractiveness to *Helicoverpa* spp.
- Inoculate pigeon pea seed – use Group J.
- Avoid water stress – pigeon peas become easily waterlogged which will decrease the attractiveness of the refuge and can cause the pigeon peas to die. Aim to select fields with good surface and internal drainage. Try to avoid areas where water tends to back up after irrigation and/or heavy rainfall.
- If in doubt, refer to the Pigeon Pea Agronomy guide in the Cotton Pest Management Guide.

End of season volunteer/ratoon management

Volunteers or ratoon cotton in Bollgard 3 fields reduce the value of the refuge and put the Bollgard 3 technology at risk. As soon as practical after harvest, Bollgard 3 cotton crops must be destroyed by cultivation or herbicide so that they do not continue to act as hosts for *Helicoverpa* spp. In particular, fields that have been defoliated on or before March 31 must not be allowed to regrow as *Helicoverpa* spp. will still be active and this will increase selection pressure to develop resistance to the Bt proteins in Bollgard 3 cotton.

Once the crop has been harvested is the ideal time for volunteer control and 'pupae busting' if required. This is generally achieved with cultivation:

- Effective cultivation incorporates any remaining seed cotton into the soil, where over winter it will break down, resulting in a reduction of volunteers in the following season.
- Slashing used in combination with an effective root-cutting operation will greatly reduce regrowth.
- Mechanical disturbance (e.g. centre buster with blades) and/or herbicide application may be required to further eliminate ratoon cotton.
- The choice of herbicides is important and should include rotation of modes of action, consideration of plant back periods for rotation crops, what other weeds are to be controlled and the size of weeds to be controlled.
- It is important to remember that any Roundup Ready Flex® volunteers will not be controlled by glyphosate.
- If cultivation doesn't occur, any seed cotton that remains on the surface may germinate under the right conditions leading to increased numbers of volunteers and non compliance with the RMP.

