

Refuges and their management

What is the purpose of a refuge?

The aim of a refuge is to generate significant numbers of *Helicoverpa* spp. moths which have not been exposed to selection pressure from either of the Bt proteins. Moths produced in the refuge crops will disperse to form part of the local mating population where they may mate with moths emerging from any Bollgard II crops. This reduces the chance that resistant moths will meet and mate. Provided susceptible moths from the refuges always predominate in the local area, they can effectively dilute resistance and slow down the rate at which it develops.

It is crucial that the timing of production of moths from refuges matches that of Bollgard II crops. For this reason, refuge crops which have a shorter period of production of moths than cotton may need to have several staggered plantings to extend the period over which moths are produced.

Refuge Location

For the refuge principle to be successful, refuge crop areas must be in close proximity to Bollgard II crop(s) and produce sufficient quantities of *Helicoverpa* spp. moths to ensure it is highly likely that moths emerging from the Bollgard II crops will mate with susceptible moths from the refuge crop.

Helicoverpa spp. moths are capable of migrating long distances, but during the summer cropping season a significant part of the population may remain quite localised and move only a few kilometres within a region. The level of movement will depend on the mix of crops and their attractiveness at the time of moth emergence. For this reason the best location for a refuge crop is as close as possible to the Bollgard II crop, at least within 2km. It is critical that refuges are managed for each farm unit growing Bollgard II and it is the responsibility of each Bollgard II grower to ensure that these refuges are effective.

Growers must take all reasonable steps to ensure that all refuges are planted:

- ▶ within the farm unit growing Bollgard II
- ▶ either on one side of, or next to, a Bollgard II field (special requirements exist for non-herbicide tolerant refuge crops planted near herbicide tolerant Bollgard II crops, refer to the Refuge Mixing section)
- ▶ so that no Bollgard II field is more than 2km from the nearest Bollgard II refuge
- ▶ and are managed using good agronomic practices.

Refuge Size

The relative numbers of adult moths that emerge per hectare from Bollgard II and the associated refuge crops determines the required size of the refuge areas. Different refuge crops will produce different numbers of moths per hectare.

The likely moth productivity of different refuge options has been determined from field experiments conducted by the Cotton CRC over several seasons. This knowledge is used to determine the areas of the different refuge crop options required for a specified area of Bollgard II. Only refuges which have been assessed in this way are currently approved by the APVMA as valid options for use with Bollgard II crops.

Where sprayed conventional cotton is grown on the farm unit, each refuge crop must be at least 48 metres wide and a minimum of 2 hectares. This is to minimise the risk of spray drift onto the refuge which will decrease the effectiveness of the refuge producing adult moths. If no sprayed conventional cotton is grown on farm, the minimum size of a refuge crop must be 24 metres wide and 24 metres long.

NB: For the purposes of the RMP conventional cotton includes any cotton varieties that do not have Bt proteins in the plant that control *Helicoverpa* spp. moths.

Extending the Period of Refuge Efficacy

While refuges must produce moths during the cotton season when Bollgard II is grown, if feasible, refuges can also be left in place until the following spring. In this way, any pupae produced in the autumn may be carried through to spring and provide additional genetic dilution of resistant survivors.

Refuge Mixing

It is possible to combine more than one type of refuge provided that the total requirements for area equivalence of refuges are met. Each refuge type must be managed so that it is productive and that restrictions on size, number of plantings and location are met (see Refuge requirements). However, a sprayed conventional cotton refuge must not be planted in the same field as any unsprayed refuge. To minimise the possibility of refuge attractiveness being affected by herbicide drift, non-herbicide tolerant refuges should be separated from herbicide tolerant Bollgard II cotton crops by a sufficient distance to minimise drift but be no more than 2km from the Bollgard II cotton.

Refuge Requirements

In order to ensure there are sufficient Bt susceptible *Helicoverpa* spp. moths to dominate any moths surviving from Bollgard II crops, growers must:

- ▶ plant a prescribed area of refuge crop
- ▶ manage the refuge crop appropriately to ensure healthy plants that are attractive to *Helicoverpa* spp.
- ▶ comply with specific requirements for the placement of refuges on the farm unit
- ▶ not cultivate the refuge once the corresponding Bollgard II crop begins to flower.

The presence of Bollgard II volunteers/ratoon cotton in any refuge will diminish the value of the refuge and may impose additional selection pressure to *Helicoverpa* spp. to develop resistance to

the Bt Cry 1Ac and Cry 2Ab proteins produced by Bollgard II. All refuges should preferably be planted into a fallow or rotation fields that have not been planted to cotton in the previous season so as to avoid the likelihood of ratoon or volunteer cotton in refuges. For more information, refer to the volunteer and ratoon control management topic.

Irrigated Bollgard II refuge options

Refuge crops for irrigated Bollgard II must also be irrigated to ensure that they maintain attractiveness and have a high likelihood of producing sufficient moths.

Crop	Conditions	% of Bollgard II
Irrigated Cotton	Sprayed Cotton Refuge – an area of irrigated conventional cotton that is equal to 100% of the area of Bollgard II on the farm (refer to refuge planting dates), which can be conventionally managed for <i>Helicoverpa</i> spp. and other pests. No Bt products may be included at any stage	100
	OR Unsprayed Cotton Refuge – an area of irrigated conventional cotton which will not be treated for any reason with any products that control <i>Helicoverpa</i> spp. that is equal to 10% of the Bollgard II area on the farm (refer to refuge planting dates).	10
Irrigated Pigeon Pea	An area of unsprayed irrigated pigeon pea which will not be treated for any reason with any products which control <i>Helicoverpa</i> spp. that is equal to 5% of the Bollgard II on the farm, (refer to refuge planting dates) and is managed to ensure several cycles of flowering throughout the cotton season.	5

Dryland Bollgard II refuge options

For dryland Bollgard II crops the only dryland refuge options available are sprayed or unsprayed cotton. The reason for this is that the other refuge option available in irrigated Bollgard II (irrigated unsprayed pigeon pea) may need to be planted after the cotton. This limitation reflects the uncertainties of establishing crops in dryland where planting opportunities from rainfall cannot be guaranteed. In dryland situations there will always be uncertainty about whether soil moisture will be adequate to successfully establish future crops therefore a dryland refuge crop must be planted within the 2 week period prior to the first day of Bollgard II cotton. While Bollgard II may be planted into soil moisture there is no guarantee that dryland refuge crops could be established some weeks later.

Irrigated refuge:

Sprayed or unsprayed irrigated cotton and unsprayed irrigated pigeon pea are the irrigated refuge options for dryland cotton. The establishment of irrigated refuges is generally not subject to soil moisture and cotton and pigeon pea are the most effective refuges currently available. No other refuge options are approved for dryland Bollgard II.

Refuges for dryland Bollgard II crops must be planted in the same row configuration as the Bollgard II crop.

Crop	Conditions	% of Bollgard II
Irrigated Cotton	Sprayed Cotton Refuge – an area of dryland or irrigated conventional cotton, equal to 100% of the area of dryland Bollgard II planted on the farm, planted within the 2 week period prior to the first day of planting Bollgard II, which can be conventionally managed for <i>Helicoverpa</i> spp. and other pests. No Bt products may be included at any stage	100
	OR Unsprayed Cotton Refuge – an area of dryland or irrigated conventional cotton equal to 10% of the dryland Bollgard II area planted on the farm, planted within the 2 week period prior to the first day of planting Bollgard II cotton, which will not be treated for any reason with any products that control <i>Helicoverpa</i> spp.	10
Irrigated Pigeon Pea	An area of irrigated pigeon pea, equal to 5% of the Bollgard II planted on the farm, (refer to refuge planting dates) and managed to ensure several cycles of flowering throughout the cotton season, which will not be treated for any reason with any products which control <i>Helicoverpa</i> spp.	5

For dryland Bollgard II crops, all refuge areas should have a similar field history to the associated Bollgard II fields (i.e. the same previous cropping pattern). This is to prevent the situation where, for example, the Bollgard II field had just returned from fallow and the refuge immediately followed a cotton crop, or vice-versa, as this will affect the relative growth and development of the plants and their attractiveness to *Helicoverpa* spp.

