What does pupae busting achieve and why is it important?

As autumn progresses in New South Wales and Southern Queensland, an increasing proportion of the *Helicoverpa* spp. larvae that pupate under cotton crops will enter diapause. These diapausing pupae will remain dormant in soil during the winter months. The triggers for larvae to enter diapause as pupae, are a combination of reduced day length and cooler temperatures.

From mid May until early September, few adult moths will emerge. Fully developed large larvae leave the plant and become pupae in the soil. The pupae can be found up to 10cm below the soil surface. The larvae burrow into the soil and leave a tunnel connecting the pupa to the surface to allow the moth to emerge. These pupae will have originated from *Helicoverpa* spp. populations that have been selected with the proteins in Bollgard II cotton during the second half of the cotton season and, therefore, potentially carry resistance genes from one season to the next.

‘Pupae busting’ by cultivation destroys the exit tunnels of the pupae and directly kills some pupae. This reduces any population that may emerge the following spring, thereby also reducing the carry-over of resistance genes. The largest benefit of this strategy comes with leaving refuges uncultivated until the following spring to contribute susceptible moths to the population while at the same time killing potentially resistant pupae from under Bollgard II. Otherwise the strategy is effectively reducing the overall population, but not increasing dilution or selectively killing resistant individuals.

Pupae can be effectively destroyed through a number of field operations listed (see in section (iii)). More detail on the requirements for effective pupae busting can be obtained in publications available from the Cotton CRC’s website. These include a research review on ‘Management of Overwintering Pupae’, an information sheet on ‘Heliothis Pupae Control – A key resistance management tactic’ and in ‘Machine Pak’ (Chapter 3) which describes appropriate tillage equipment for different situations.
Pupae busting requirements for Bollgard II crops

All Bollgard II crops in New South Wales and Southern Queensland must be cultivated after harvest at a level adequate to stop regrowth and to destroy *Helicoverpa* spp. pupae in the soil. Late season *Helicoverpa* spp. are managed by trap crops in Central Queensland (refer to the section on Central Queensland Late Summer Trap Crop below).

We acknowledge the incompatibility of using tillage for pupae busting with the desire to optimise soil moisture management in dryland. However, at present there are no alternatives. All fields that are to be sown to cereals following a Bollgard II crop must be inspected by the Technology Service Provider before sowing commences. When following Bollgard II with a winter crop it is important to ensure that pupae destruction has been rigorous. Full soil disturbance across the entire field to a depth of at least 10 centimetres is required.

All reasonable efforts must be made to complete pupae busting within four weeks of harvest to ensure the Bollgard II crops do not continue to act as a host for *Helicoverpa* spp.

Pupae busting requirements for dryland crops

Machinery designed to cultivate double skip dryland crops along the plant line only, have recently been developed.

While such machinery is helpful, it isn’t a substitution for full pupae busting to a depth of at least 10cm, across the full profile including in the skip row, furrow and wheel tracks.

In a previous single skip trial, larvae were placed in the plant line and found, as pupae, between the rows.

Failed crops

Bollgard II crops that will not be grown through to harvest for various reasons and are declared to, and verified by Monsanto as, failed before February 28 must be slashed and mulched and cultivated within two weeks to prevent regrowth. These crops do not require pupae busting.
Pupae busting requirements for refuges

In New South Wales and Southern Queensland, to ensure maximum emergence of late pupae from associated refuges, soil disturbance of refuge crops should not be undertaken until after the pupae busting in Bollgard II cotton crops on the farm unit is complete.

In Central Queensland soil disturbance of refuge crops can only occur two weeks after final defoliation of the Bollgard II cotton.

(i) **Unsprayed refuges (cotton or alternatives)**

If possible leave these refuges uncultivated until the following spring, when it can be slashed or harvested and the soil cultivated. This will allow the emergence of moths that have not been selected by the Bt proteins. These moths can then mate with any resistant moths that have survived under Bollgard II crops, further helping to dilute resistance.

Unsprayed cotton and pigeon pea refuge crops may also produce diapausing *Helicoverpa* spp. pupae in the autumn and it would be beneficial for them to be left undisturbed until the following spring. This would provide an additional supply of susceptible moths for the first generation of the next season. Moreover, pupae busting only under Bollgard II will selectively kill potentially resistant individuals.

(ii) **Sprayed or unsprayed cotton refuges in Central Queensland**

In Central Queensland temperatures are too high and day lengths too long to trigger larvae to enter diapause as pupae. Consequently many pupae under cotton crops at the end of the season will have completed development as adults and emerged before crops are harvested. Pupae busting after harvesting in Central Queensland is therefore not effective. Instead a summer trap crop is used to concentrate moths emerging from cotton crops late in the season (see below). It is, however, still important to destroy Bollgard II crops as soon as possible after-harvest, by cultivation or herbicide, to prevent larvae developing and being selected for resistance on regrowth and possible increases in disease.

(iii) **Options and effectiveness of different implements for pupae busting**

<table>
<thead>
<tr>
<th>Good</th>
<th>Inadequate alone</th>
<th>Unacceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chisel, disc or blade plough</td>
<td>Centre busting</td>
<td>Stalk pulling when wet</td>
</tr>
<tr>
<td>Stalk pulling + go-devils or lillistons + alabamas</td>
<td>Stalk pull dry, rake and burn</td>
<td>Phoenix harrows</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Drag harrows</td>
</tr>
<tr>
<td>Cultivation with wide sweeps</td>
<td>Go-devils</td>
<td>Direct drill planters</td>
</tr>
<tr>
<td>Planters with cultivating tynes</td>
<td>Stubble mulchers</td>
<td>Cultivation along the plant line only</td>
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