Managing resistance collaboratively: the Australian experience

Sally Ceeney, Cotton Australia

78th ICAC Plenary Meeting, Brisbane, December 2019
History of resistance in the cotton industry – pre Bt

- Cotton first introduced 1960s in Eastern and Northern Australia
- 1970s – Nthn industry collapses due to widespread resistance
- 1980s – widespread resistance in Eastern Aus, SPs
- Mid 1990s: crisis point
  - Continuing resistance issues, increasing insecticide use
  - Increasing political and social pressures due to environmental concerns
  - Increasing insecticide costs for growers
  - Need to manage insecticide use was crucial
Managing insecticide resistance

- Combined with IPM principles
- Voluntary uptake ~95%
- Evolved - in use today, annual review
- Key principles of this strategy used in Bt resistance management
  - Grower led – precedent set
  - Grower knowledge
Industry representation

1993 – Bt Management Group
- growers + scientists
- pre emptive resistance management Bt
- identify research needs

1994 – Transgenic Insecticide Management Committee (TIMS)
- growers, consultants, research organisations
- develop and review stewardship strategies
- technical advisory panels (Bt, insecticides, herbicides)
The Australian Biotechnology Regulatory System

Office of the Gene Technology Regulator (OGTR)
Human health and environmental safety of biotech crops: ENVIRONMENTAL RELEASE

Food Standards Australia New Zealand (FSANZ)
Safety of food derived from biotech crops: FOOD / IMPORT

Australian Pesticides and Veterinary Medicines Authority (APVMA)
Safety and efficacy pesticides produced by biotech crops: ENVIRONMENTAL RELEASE

Department of Agriculture Biosecurity (ex AQIS)
Import, export and quarantine of plant material
The Australian Biotechnology Regulatory System

- Require RMP with industry endorsement for any insecticidal Bt product
The Australian Biotechnology Regulatory System – key roles

Tech Provider
Propose new trait and RMP

TIMS
Review tech provider proposals
Provide comment for APVMA
May not endorse

Technical Panels
Provide advice on proposed RMPs or amendments
Works with tech provider:
- Efficacy
- New knowledge
- Targeted research

APVMA
Requires RMP and evidence of industry support
Developing a Bollgard® 3 RMP

Aim: an RMP that is scientifically robust while achievable and practical for the grower.
RMP Annual Review System

Pre-emptive adaptive management

TIMS Bt Technical Panel & Tech Provider
- Review monitoring data post season
- Assess new risks/challenges
- Propose changes

Industry Consultation
- TIMS Committee
- Wider consultation

Industry Endorsement
- Proposed changes submitted to APVMA with industry endorsement

RMP changes approved by APVMA
What is the basis of the RMP?

**The Product**
- Number of modes of action
- Efficacy, expression
- Level of control of target pests (dose)

**The System: Pest Ecology**
- Host range (natural refuge)
- Generations per year

**Time to resistance**

**Resistance Genetics**
- Degree of dominance
- Resistant allele frequency
- Cross-resistance to other products

**Product Use**
- Likely product adoption
- Rate of compliance
Australian Bt RMP Key Principles

- **Plant in a defined window**
  - June
  - May

- **Mandatory refuge crops**
  - Bt-cotton
  - Refuge

- **Kill last generation moths**

- **Monitor for resistance**

---

<table>
<thead>
<tr>
<th>Control level</th>
<th>Operations</th>
<th>% Moth survival</th>
<th>Soil type</th>
<th>Trial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed</td>
<td>Chisel plough (on flat)</td>
<td>0.0</td>
<td>Dry</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Row blade plough (on flat)</td>
<td>1.5</td>
<td>Dry</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Centre-busting and cultivation with tillage</td>
<td>2.3</td>
<td>Wet</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Hydraulic stalk puller &amp; tillage</td>
<td>3.1</td>
<td>Mod. wet</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Disced and chiselled twice</td>
<td>3.4</td>
<td>Mod. wet</td>
<td>2</td>
</tr>
</tbody>
</table>
Current status of Bt resistance in Australia

**Current status of Bt resistance**

*How many moths in the field carry a gene for resistance to the Bt toxins?*

<table>
<thead>
<tr>
<th></th>
<th>1 in 100</th>
<th>1 in 25</th>
<th>1 in 50</th>
<th>1 in 33</th>
<th>1 in 100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cry1Ac</td>
<td><em>(H. punctigera)</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cry2Ab</td>
<td><em>(H. armigera)</em></td>
<td><em>(H. punctigera)</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VIP3A</td>
<td><em>(H. armigera)</em></td>
<td><em>(H. punctigera)</em></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Source: Helicoverpa resistance monitoring end of season 2015/16 report, Sharon Downes, CSIRO.*

*All based on F1 data.*

- existing levels of resistance: successfully managed for over 20 years
- pre-emptive RMP
- High level of RMP compliance
Bt cotton: the success story

- Reduced pesticide use 95%
- Industry expansion
- Environmental benefits
- Health and safety
- Social/community benefits

![Historical Insecticide Usage on Cotton](image)

Does not include seed treatment

Source: CCA Market Audit, conducted in partnership with CRDC

[My BMP]

[BCI Better Cotton Initiative]
Collaboration in managing herbicide resistance

When initial system was established, there was
• 1 trait provider + 1 herbicide registrant for use in RR cotton
• No glyphosate resistance in landscape
• **Crop Management plan** focussed on post spray audit to DETECT AND REPORT resistance

• Multiple herbicide registrant for use in cotton
• Herbicide resistance wide spread in low levels across farming system
• Herbicides are used in fallow and rotation phases of system
• DETECTING and REPORTING not resulting in change in management.
Herbicide RMP = 2+2 AND 0

- Voluntary management strategy based on research & modelling.
- Work with herbicide registrants and trait provider to monitor herbicide resistance and identify emerging issues

2 non-glyphosate tactics targeting both grasses and broadleaf weeds during the cotton crop
+
2 non-glyphosate tactics in summer fallow/rotation targeting both grasses and broad leaf weeds

And

NO Survivors, control survivors of glyphosate applications and do not allow them to set seed
Australian RMP: Keys to Success

Collaborative approach supported by science

- CRDC Industry funded monitoring program involving partnerships with key research organisations
- Separate but complimentary monitoring program run annually by Bayer
- Potential resistance issues can be identified and monitored
- CRDC Industry funded research into other aspects of resistance science: pest and weed ecology, resistance mechanism etc.
- Grower input into research priorities
Australian RMP: Keys to Success

Stewardship supported by an industry extension and communication program

TABLE 3: Impact of insecticides and miticides on predators, parasitoids and bees in cotton

<table>
<thead>
<tr>
<th>Insecticide</th>
<th>Rank</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>4th</th>
<th>5th</th>
<th>6th</th>
<th>7th</th>
<th>8th</th>
<th>9th</th>
<th>10th</th>
<th>Overall Ranking</th>
<th>Persistence</th>
<th>Red &amp; Blue</th>
<th>Predatory beetles</th>
<th>Predatory bugs</th>
<th>Other</th>
<th>Insectivorans</th>
<th>Bees</th>
<th>Arachnids</th>
<th>Apids</th>
<th>Spiders</th>
<th>Hymenoptera</th>
<th>Mites</th>
<th>Thrips</th>
<th>Pred. res.</th>
<th>Pest</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acephate</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>Very Short</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
</tr>
<tr>
<td>Pyraclostrobin</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>Short</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
</tr>
<tr>
<td>Imidacloprid</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>Very Short</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
</tr>
<tr>
<td>Methoxyfenozide</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>Medium Long</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
</tr>
<tr>
<td>Pyridostrobin</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>Very Short</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
</tr>
<tr>
<td>Pyridaben</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>Short</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
</tr>
<tr>
<td>Methidathion</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>Medium</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
</tr>
<tr>
<td>Deltamethrin</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>Very Short</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
</tr>
<tr>
<td>Cypermethrin</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>Very Short</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
</tr>
<tr>
<td>Spinosad</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>Short</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
</tr>
</tbody>
</table>

Notes: 1. Includes feeding deterrents; 2. Includes disease control; 3. Includes abiotic factors; 4. Includes predation; 5. Includes parasitism; 6. Includes consumption; 7. Includes other.
Thankyou

Acknowledgement to the many representatives of Cotton Australia, CRDC, CSIRO, NSW DPI, QDAF and Bayer who all contribute to this work.