Fungicides play an essential role in protecting against disease. However, there are increasing concerns regarding over-reliance, increased resistance, and impacts on environmental and human health.

Restrictions in the use of fungicides in Australia have caused a situation where there are now fourteen fungicidal active ingredients registered for use in almonds, and two of them (iprodione and chlorothalonil) may be on their way out.

**With pollen and nectar, bees collect fungicides**

During pollination, bees collect fungicides that remain on pollen and nectar after spraying, and store them in the hive for later consumption. To better understand the impact of this on bee health, we have reviewed more than 100 publications from across the world that assess the effect of fungicidal active ingredients (a.i.) on honey bees, either on their own, or in combination with other fungicides, herbicides or insecticides. Here we summarise the outcome of this review for the fungicidal a.i. registered for use in almonds. Our summary includes only those studies that were published in peer reviewed scientific journals, and present experiments with classifiable outcomes.

The experiments were classified into field sprays and laboratory experiments. The latter involved contact, feeding or spray trials with fungicidal a.i. The outcomes were classified as non-harmful or harmful (i.e. significantly affecting survival, general health or behaviour).

**When used on their own, most fungicides do not harm bees**

The table shows there is still an enormous lack of information about the effects of fungicides used in almonds (see table). But there are some general conclusions. No fungicides were harmful in field trials. Six fungicides and fungicide combinations were harmless in feeding trials. For three active ingredients, some studies showed harm while others did not. These variable outcomes may be due to differences in concentrations or in condition of the hives involved in the experiments. They do not necessarily indicate harmful effects when spraying. While this seems good news, some feeding trials indicated that a number of active ingredients (chlorothalonil, pyraclostrobin) cause reduced immune function in bees. In addition, feeding trials with mixes of insecticides and fungicides often show synergistic effects, making the insecticides toxic at lower concentrations. However, the importance of these effects has not been assessed in field trials.

**Advice**

Careful and judicious use of chemicals is in everyone's best interest, to limit the development of fungicide resistance, reduce costs, and maintain healthy bees in the orchard. Best practice advice is:

- Discuss the pesticide program with your bee keeper and agronomist before the start of the season to select chemicals that are friendly to bees while still achieving effective results.
- Always read the label and follow directions for use.
- Avoid applying insecticides with extended residual toxicity or systemic insecticides (such as neonicotinoids) may be expressed in pollen and nectar that may affect the brood if taken back to hives.
- Avoid all insecticide use during flowering
- Only spray fungicides if essential and only at night, when the bees aren't active allowing time for the chemical application to dry.
- Thoroughly clean spray tanks to avoid remnant insecticide contaminating fungicide sprays.
- Ensure bees have access to clean water and cover or remove water sources before spraying
- Do not spray hives directly with any pesticide.
- Ensure that the spray-rig driver turns off nozzles when near hives.
- Ensure bees are not foraging in the area to be sprayed and do not hit flying bees with spray applications as the weight of spray droplets on their wings will mean they can’t fly.
- Notify neighbours when bees will be in the orchard and provide your contact details so they can provide notice before intended sprays.
- During the year, notify beekeepers with hives on nearby properties before applying pesticides to the orchard using appropriate communication method (e.g. Bee Keeper contact details on the hive, BeeConnected app or via state government bee biosecurity officers).

And if unsure about a new product or combination, ask the distributor or agronomist about safety for bees, and specifically about interactive effects. But don't take their word – ask for the evidence!
### Fungicidal active ingredients registered for use in almonds

<table>
<thead>
<tr>
<th>Impact of single fungicidal active ingredients</th>
<th>Field spray</th>
<th>Contact</th>
<th>Laboratory Oral</th>
<th>Spray</th>
</tr>
</thead>
<tbody>
<tr>
<td>AZOXYSTROBIN</td>
<td>0/2</td>
<td></td>
<td></td>
<td>1/2</td>
</tr>
<tr>
<td>CAPTAN</td>
<td>0/5</td>
<td>2/4</td>
<td></td>
<td>0/1</td>
</tr>
<tr>
<td>CHLOROTHALONIL</td>
<td>0/1</td>
<td>4/6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>COPPER OXYCHLORIDE</td>
<td>0/2</td>
<td>0/1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CYPRODINIL</td>
<td>0/2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FLUOPYRAM (only registered in mix)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FLUXAPYROXAD (only registered in mix)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IPRODIONE</td>
<td>0/1</td>
<td>1/3</td>
<td>1/1</td>
<td></td>
</tr>
<tr>
<td>MANCOZEB</td>
<td>0/1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PENTHIOPYRAD</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PYRACLOSTROBIN</td>
<td></td>
<td>2/2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SULFUR (S) PRESENT AS POLYSULFIDE SULFUR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TEBUCONAZOLE (only registered in mix)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TRIFLOXYSTROBIN (only registered in mix)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Impact of mixes fungicidal active ingredients

- AZOXYSTROBIN - TEBUCONAZOLE: 0/1*
- FLUOPYRAM - TRIFLOXYSTROBIN: 0/1*
- PYRACLOSTROBIN - FLUXAPYROXAD: 0/1*

* Fung et al. in preparation

**Key**
- **Relatively safe**
- **Potentially harmful**

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The University of Adelaide, School of Agriculture, Food and Wine, July 2020

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