The Effects of Pesticide-Contaminated Pollen on Larval Development of the Honey Bee, *Apis mellifera*

by Rusty Burlew
The Problem

Honey bees pollinate a large portion of the world food supply

Honey bee colonies are dying at an unprecedented rate

Why? Many theories, no concrete answers
Loss of Managed Hives in U.S.

Year

1900 1950 2000 2050

Millions of Colonies

<table>
<thead>
<tr>
<th>Year</th>
<th>Millions of Colonies</th>
</tr>
</thead>
<tbody>
<tr>
<td>1900</td>
<td>5.9</td>
</tr>
<tr>
<td>1950</td>
<td>4.3</td>
</tr>
<tr>
<td>2000</td>
<td>2.7</td>
</tr>
<tr>
<td>2050</td>
<td>1.53</td>
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</tbody>
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Could Pesticides be Part of the Problem?

By 2000, world pesticide use exceeded 5 billion pounds of active ingredient per year.

- US EPA
Pesticides Have Changed

• Two new classes
  – Neonicotinoids
  – Phenylpyrazoles
• Developed in late 1980s
• Affect insect central nervous system
• Relatively non-toxic to other species, including humans
Pesticides are Now More Toxic in Smaller Doses
Pesticide Painted on Seeds

Maize treated with Clothianidin
Systemic pesticides move through the plant from seed to pollen.
EPA Requires Testing on Adult Honey Bees

- A median lethal dose (LD50) is determined and used to establish safe application rates

However, no testing is required on larvae (immature bees)
Three Questions:

1. Are honey bee larvae affected by smaller doses—ones that are not lethal to adults?

2. How often is pollen contaminated?

3. Are EPA regulations keeping up with changes in the pesticide industry?
How Larvae are Exposed to Pesticides

This requires an understanding of how larvae are fed.
Foraging Bees Collect Four Things

- Nectar
- Pollen
- Propolis
- Water
Bees use propolis the way humans use duct tape.

Nectar is regurgitated and dehydrated to make honey.

Water is used for rehydrating honey and to cool the hive.
Pollen is the Key to Colony Health

- Protein
- Lipids
- Vitamins
- Minerals
An Average Colony Collects 100 lbs. per Year

Pollen baskets on bee’s legs

Pollen adhering to bee’s body
Pollen Brought to Hive
Cells Filled with “Bee Bread”
Egg: 3 days
Larva: 6 days
Adult
Pupa: 12 days
Larvae Fed by Nurse Bees

- Nurse bees eat large amounts of pollen
- They digest the pollen and secrete royal jelly
- Royal jelly is fed to the larvae
Larval Weight Increases 1700-Fold in 6 Days
Pesticides Accumulate in Pollen Because of Its Fat Content

- 25% protein
- 10% free amino acids
- 30% carbohydrate
- 15% lipids, fats, enzymes, vitamins, sterols, & minerals
- 20% water
Honey is Nearly Free of Pesticides

- Most pesticides are fat soluble or are dissolved in oil-based carriers.
- Honey is almost pure carbohydrate and is usually free of pesticides.
Six Different Categories of Pesticides

- Insecticides
- Acaricides
- Herbicides
- Fungicides
- Insect growth regulators
- Transgenic plants
All Categories, except transgenic plants, have Harmful Effects on Larvae

- Structural deformities
- Wing malformations
- Reproductive failure
- Learning disabilities
- Glandular disruption
- Immune system suppression
Sublethal Effects

- Amount required to produce harmful effects in larvae was far below $LD_{50}$ for adult bees

  Example: Imidacloprid
  Oral $LD_{50}$ for adult bees: 40.9 ng/bee
  Sublethal effects in larvae: 0.1 ng/bee

EPA requires no testing for sublethal effects
Synergistic Effects

• Some combinations are 6000 times more toxic than either chemical used alone

EPA routinely allows the combining of pesticides
Pesticide metabolites may be 100s or 1000s of time more toxic than the original product.

Important for larvae because nurses metabolize pollen (and its contaminants) before producing royal jelly.

The EPA does not regulate metabolites, it only requires them to be reported.
Fungicides & Herbicides are Toxic to Larvae

- Although not considered toxic to adult bees, these products are extremely toxic to larvae.
- Example: Captan

EPA allows spraying of these products even when crops are in bloom.
How Much? How Often?

How frequently is contaminated pollen found in agricultural areas?
A Penn State Study of 108 Pollen Samples Found that:

All 108 samples tested positive for pesticides.

46 different pesticides were identified.

As many as 17 pesticides were found in 1 sample of pollen.
A USDA-ARS Study of 350 Pollen Samples Found that:

- All 347 samples tested positive for pesticides
- 98 different pesticides were identified
- As many as 31 pesticides were found in 1 sample of pollen
Conclusions

• Larvae are particularly sensitive to pesticides
• Contaminated pollen is ubiquitous in agricultural environments
• Current EPA regulations are not addressing the problems
Recommendations for EPA

• Use of systemic pesticides should be restricted
• Levels at which sublethal effects occur should be determined
• Metabolites should be regulated as if they were pesticides
• Fungicides should not be used during crop flowering
• Combining of pesticides should be prohibited when synergistic effects may occur
EPA Update
December 2009

• EPA will now “review” the registration of all pesticides once every 15 years.

• The first round of reviews will be completed by the end of 2022.
Questions?
Part 2: Process & Problems
Recent Paper on CCD

A virus and a microsporidian were found in all collapsing colonies.

- Cause or a consequence?
- Are external stressors weakening immune system?
How paper changed from prospectus to completion

Prospectus: Does pollen in agricultural areas contain enough pesticide to affect larval development?

Thesis: Are current EPA regulations sufficient to protect honey bee larvae from contaminated pollen? If not, how should they be changed?
Problem: Information on Honey Bee Larvae was Scarce

Many papers had only a paragraph or two on the larval stage.
Problem: Legal Information Confusing

• Difference between statutes, regulations, state laws, federal laws

• EPA “guidelines”

• For current status had to call the EPA in Washington, D.C.
Problem: Papers in Foreign Languages

Problem: Interdisciplinary Communication

Entomologist

Botanist

Pollen Grains
Problem: New Information Constantly Published

I wanted to include all the latest research, but I had to make a cut-off point.
Problem: Writing

“To help your reader along this section has to go in the beginning. And this one. And this one. And this one. And this one. And this one. And this one . . .”
Problem: Writing

Introduction

Bibliography

And you’re done!
Problem: Lack of Time

Bee on thyme
Tip: Contact Authors

- Questions
- Clarifications
- Permissions
- Challenges
Thank you and Good Luck!