Speakers

Steve Lindsay, Diamond Foods (Moderator)
Randy Segawa, DPR
George Opit, Oklahoma State University
Sean Glover, Cardinal Professional Products
Randy Segawa, DPR
Regulatory Update for Post-Harvest Fumigants
Overview

• Environmental Protection Agency (EPA) activities

• Department of Pesticide Regulation (DPR) activities

• Potential exposure issues and best practices
EPA methyl bromide label changes – distribution begins no later than 9/30/16

• Storage – can’t store methyl bromide within 100 feet of a residence

• Emergency preparedness measures
  – Trigger: residences or businesses within 50 feet of treatment or aeration buffer zone
  – If triggered: site monitoring or neighbor notification

• Fumigation management plans

• Buffer zones – refers to DPR and ag commissioner permit conditions
EPA proposed revisions to certification and training rules for restricted pesticide applicators

• Enhances applicator competency standards to ensure that restricted use pesticides are used safely, particularly for private applicators

• Requires additional specialized certifications for people using high-risk application methods (i.e. fumigation and aerial) and concurrent certification in appropriate categories (e.g. plant agriculture)

• Requires continuing education for each certification category

• EPA is accepting comments on the proposed revisions until Dec 23
EPA registration review schedule for all fumigants

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Timeframe</th>
</tr>
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<tbody>
<tr>
<td>Registrant Data Call-In</td>
<td>August 2014</td>
</tr>
<tr>
<td>Data Submission</td>
<td>Summer 2016 – 2017</td>
</tr>
<tr>
<td>Risk Assessment</td>
<td>2018</td>
</tr>
<tr>
<td>Decision</td>
<td>2018 – 2019</td>
</tr>
</tbody>
</table>
DPR sulfuryl fluoride mitigation of structural uses

• 2006 Risk Characterization Document
  – Bystander and resident exposure scenarios problematic

• 2007 Risk Management Directive
  – Mitigate exposure to bystanders and residents
  – Target concentration: ≤0.12 ppm
  – Label requirement: ≤1 ppm

• DPR is evaluating new toxicology data and may revise target concentration
DPR sulfuryl fluoride evaluation and mitigation of commodity uses

• DPR is evaluating risk of commodity fumigations, including new toxicology data

• DPR will likely need to address inconsistencies in the restrictions between commodity fumigations and non-residential building fumigations
DPR phosphine risk assessment, including aluminum and magnesium phosphide

• DPR completed its risk assessment in Dec 2014

• Mitigation is likely needed
  – Acute reference concentration (from risk assessment): ≤0.05 ppm
  – Label requirement: ≤0.3 ppm
DPR future work

• DPR will assess the risk from propylene oxide

• DPR is considering developing mitigation measures for all commodity fumigants simultaneously
  – Sulfuryl fluoride
  – Phosphine, including aluminum and magnesium phosphide
  – Propylene oxide
  – Methyl bromide revisions
Potential exposure issues

- Large fumigations, such as warehouse
- Multiple fumigations, such as side-by-side chambers
- Work areas, residences, sensitive sites near fumigations
- Aeration at ground level
- Enclosed areas
  - Indoor fumigations, such as chamber inside warehouse
  - Off-gassing from fumigated nuts
Best regulatory practices

- **Containment** – minimize leakage during fumigation
- **Dilution** – ventilate enclosed areas containing fumigations or fumigated nuts
- **Distance** – keep people away from fumigation sites and fumigated nuts
- **Time** – minimize time people are near fumigation sites and fumigated nuts
Post-harvest non-fumigant pesticides

• Foggers
  – DDVP (dichlorvos)
  – Pyrethroids and piperonyl butoxide (PBO)

• Bait stations
Questions and additional information

• www.cdpr.ca.gov
  – “QUICK LINKS” tab
  – “Air” link

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Questions?
George Opit,
Oklahoma State University
Phosphine Resistance in Stored-Product Insect Pests from Almond Storage and Processing Facilities in California

George Opit and Sandipa Gautam

Department of Entomology and Plant Pathology
Oklahoma State University
Stillwater, OK
Insect Resistance to Phosphine in US

• 2012 - George Opit (OSU), Tom Phillips, Jamie Aikins, and Mahbub Hassan (KSU) documented high levels of phosphine resistance (119-1519x) in red flour beetle (RFB) and lesser grain borer (LGB) in OK.
  – In 2013 there was no published research documenting phosphine resistance in stored-product insect pests from California almond storage and processing facilities.
Concentrations of Phosphine Required to Kill 99% of **Lesser Grain Borer** Individuals

<table>
<thead>
<tr>
<th>Lesser Grain Borer Population</th>
<th>LC$_{99}$ (95% CI) (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Susceptible</td>
<td>2.26 (1.70 – 2.90)</td>
</tr>
<tr>
<td>Payne 1</td>
<td>572.78 (485.32 – 790.58)</td>
</tr>
<tr>
<td>Logan</td>
<td>2054.40 (972.25 – 8002.30)</td>
</tr>
<tr>
<td>Garfield</td>
<td>3430.80 (1426.70 – 27142.0)</td>
</tr>
</tbody>
</table>

Based on 72-hour (3-day) exposure period
Insects

*Plodia interpunctella* (Hübner)
Indianmeal moth (IMM)

*Tribolium castaneum* (Herbst)
Red flour beetle (RFB)

*Oryzaephilus surinamenis* (L.)
Sawtoothed Grain beetle (STGB)

*Plodia interpunctella* (Hübner)
Indianmeal moth (IMM)
Source of Insects

- Red flour beetle (RFB)
- Indianmeal moth (IMM)
- Sawtoothed grain beetle (STGB)
Question 1

Is there phosphine resistance in RFB and STGB adults from almond storage facilities in California?
Phosphine Resistance in RFB Adults

- 3 out of 18 populations had high resistance frequencies (93-97%).
- 2 out of 18 populations had moderately high resistance frequencies.
- 2 out of 18 populations had low resistance frequencies.
- 11 out of 18 populations had resistance frequencies of 0% (no resistant insects!!).

What are these facilities doing correctly to result in RFB populations with no detectable resistance?

A discriminating dose of 30 ppm of phosphine used over a 20-hour exposure period at 25°C (FAO 1975).

<table>
<thead>
<tr>
<th>RFB Population</th>
<th>Resistance Frequencies (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Box W</td>
<td>1</td>
</tr>
<tr>
<td>Box V</td>
<td>11</td>
</tr>
<tr>
<td>Box B</td>
<td>48</td>
</tr>
<tr>
<td>Box BR</td>
<td>54</td>
</tr>
<tr>
<td>Box BM</td>
<td>93</td>
</tr>
<tr>
<td>Box L</td>
<td>93</td>
</tr>
<tr>
<td>Box BN</td>
<td>97</td>
</tr>
<tr>
<td>Box E1, Box E3, Box F, Box I, Box N, Box S, Box T, Box Q, Box U3, Box R, and Box X (11)</td>
<td>0</td>
</tr>
<tr>
<td>Susceptible lab strain</td>
<td>0</td>
</tr>
</tbody>
</table>
2 out of 8 populations had high resistance frequencies (91-99%).

1 out of 8 populations had low resistance frequencies.

5 out of 8 populations had resistance frequencies of 0% (no resistant insects!!).

What are these facilities doing correctly to result in STGB populations with no detectable resistance?

A discriminating dose of 37.5 ppm of phosphine used over a 20-hour exposure period at 25°C (FAO 1975).

<table>
<thead>
<tr>
<th>STGB Population</th>
<th>Resistance Frequencies (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Box A</td>
<td>1</td>
</tr>
<tr>
<td>Box BR</td>
<td>99</td>
</tr>
<tr>
<td>Box BF</td>
<td>91</td>
</tr>
<tr>
<td>Box Q, Box U3, Box S, Box X, and Box W (5)</td>
<td>0</td>
</tr>
<tr>
<td>Susceptible lab strain</td>
<td>0</td>
</tr>
</tbody>
</table>
Question 2

Is there phosphine resistance in RFB eggs and IMM eggs and larvae from insects in almond storage facilities in California?
Eggs from 11 field-collected populations of RFB were tested using a discriminating dose of 73.6 ppm of phosphine over a 72-hour (3-day) fumigation period at 25°C.

### Phosphine Resistance in RFB Eggs

<table>
<thead>
<tr>
<th>RFB Population</th>
<th>Resistance Frequencies (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Box B</td>
<td>56</td>
</tr>
<tr>
<td>Box BR</td>
<td>72</td>
</tr>
<tr>
<td>Box BN</td>
<td>100</td>
</tr>
<tr>
<td>Box BM</td>
<td>100</td>
</tr>
<tr>
<td>Box E1</td>
<td>0</td>
</tr>
<tr>
<td>Box E2</td>
<td>0</td>
</tr>
<tr>
<td>Box F</td>
<td>0</td>
</tr>
<tr>
<td>Box I</td>
<td>0</td>
</tr>
<tr>
<td>Box N</td>
<td>0</td>
</tr>
<tr>
<td>Box S</td>
<td>0</td>
</tr>
<tr>
<td>Box T</td>
<td>0</td>
</tr>
<tr>
<td>Susceptible lab strain</td>
<td>0</td>
</tr>
</tbody>
</table>
Phosphine Resistance in IMM Larvae and Eggs

Percentage survival of IMM larvae and eggs from a lab susceptible strain and three field-collected populations. Discriminating dose for larvae was 98.3 ppm over a 20-hour fumigation period; for eggs was 109.8 ppm over a 72-hour (3-day) fumigation period, respectively.

<table>
<thead>
<tr>
<th>IMM Population</th>
<th>Resistance Frequencies (%) — Larvae</th>
<th>Resistance Frequencies (%) — Eggs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Box E1</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>Box F</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Box N</td>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td>Susceptible lab strain</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

There were no resistance frequencies ≥ 40% for IMM eggs and larvae

Phosphine resistance was detected in only eggs and not larvae of IMM and RFs ranged from 8-16%.
Question 3

What dose of phosphine is required to kill 99% of resistant RFB eggs and adults?
Concentrations of phosphine required to kill 99% of adults of susceptible laboratory and resistant field populations over a 72-hour fumigation period at 25°C.

<table>
<thead>
<tr>
<th>RFB Adult Population</th>
<th>$\text{LC}_{99}$ (95% CI) (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Susceptible lab strain</td>
<td>7.4 (6.8 – 8.0)</td>
</tr>
<tr>
<td>Box B</td>
<td>50.2 (41.5 – 63.4)</td>
</tr>
<tr>
<td>Box BR</td>
<td>54.3 (45.4 – 67.6)</td>
</tr>
<tr>
<td>Box BM</td>
<td>295.2 (226.0 – 421.3)</td>
</tr>
<tr>
<td>Box BN</td>
<td>356.9 (270.4 – 515.8)</td>
</tr>
</tbody>
</table>

Probit analyses of dose-response data for the susceptible and four phosphine-resistant populations of RFB adults. LC values are lethal concentrations of phosphine over a 72-hour (3-day) fumigation period at 25°C.
Concentrations of phosphine required to kill 99% of eggs of susceptible laboratory and resistant field populations over a 72-hour fumigation period at 25°C.

<table>
<thead>
<tr>
<th>RFB Egg Population</th>
<th>LC$_{99}$ (95% CI) (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Susceptible lab strain</td>
<td>51.5 (44.6 – 62.4)</td>
</tr>
<tr>
<td>Box B</td>
<td>220.4 (187.1 – 272.1)</td>
</tr>
<tr>
<td>Box BR</td>
<td>279.9 (236.6 – 346.7)</td>
</tr>
<tr>
<td>Box BM</td>
<td>605.5 (527.9 – 719.4)</td>
</tr>
<tr>
<td>Box BN</td>
<td>653.9 (580.3 – 755.1)</td>
</tr>
</tbody>
</table>

Concentration of phosphine required to kill 99% eggs of the most resistant RFB population, Box BN, was 653.9 ppm over a 72-hour (3-day) fumigation period.
### RFB Eggs Compared to Adults

<table>
<thead>
<tr>
<th>RFB Population</th>
<th>LC$_{99}$ (95% CI) (ppm)</th>
<th>LC$_{99}$ (95% CI) (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Adults</td>
<td>Eggs</td>
</tr>
<tr>
<td>Susceptible lab strain</td>
<td>7.4 (6.8 – 8.0)</td>
<td>51.5 (44.6 – 62.4)</td>
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Lethal concentrations (ppm) required to kill 99% adults and eggs of the laboratory susceptible and the phosphine-resistant RFB populations.
Questions and Answers

Question 1: Is there phosphine resistance in RFB and STGB adults? **YES.**

Question 2: Is there phosphine resistance in RFB eggs and IMM eggs and larvae? **YES.**

Question 3: What dose of phosphine is required to kill 99% of resistant RFB eggs and adults? **654 ppm over a 72-hour (3-day) fumigation period.**
Factors Causing Resistance

- Lack of effective sealing of structures being fumigated.
- Lack of monitoring to ensure effective phosphine gas levels during fumigations.
- Not allowing for proper length of fumigation treatment times.
- Frequent phosphine fumigation of the same parcel of the commodity.
Generic Fumigation Recommendations

• 500-1000 ppm concentration of phosphine.
• Exposure period minimum of 3 days recommended, but 5 to 7 days would be highly recommended (label minimum is 24-36 hours dependent upon the commodity temperature, but it is probably better not to fumigate for less than 48 hours regardless of the temperature and dose).
• Pay extra care to sealing all areas.
• Monitor gas concentrations and re-add gas as necessary. Almonds sorb phosphine very readily, especially in-shell, in-hull almonds.
• In storage silos and warehouses, it is recommended to install either permanent or temporary recirculation systems to get phosphine into good distribution throughout the structure.
Proper Sealing

We must alter the perception that effective sealing cannot be achieved and require that fumigated storages be sealed to maintain lethal dosages of phosphine.
Proper Sealing
Monitoring Phosphine Concentrations

Monitoring is essential in order to ensure success of any fumigation. It is federal law under current EPA approved labels that **efficacy** (high levels required to achieve a kill) **monitoring** is conducted during fumigation.
Phosphine Recirculation

Temporary recirculation tubing  Permanent recirculation tubing
Know whether or not you have resistant insects and the concentrations of phosphine required to control these insects.

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<tr>
<td>Box BN</td>
<td>100</td>
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<td>Box BM</td>
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</tr>
<tr>
<td>Box E1</td>
<td>0</td>
</tr>
<tr>
<td>Box E2</td>
<td>0</td>
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<tr>
<td>Box F</td>
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<tr>
<td>Box N</td>
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<td>Box S</td>
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<tr>
<td>Box T</td>
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</tr>
<tr>
<td>Susceptible lab strain</td>
<td>0</td>
</tr>
</tbody>
</table>
Acknowledgements

- Mr. Ed Hosoda
- Mr. Charlie Konemann
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- Ms. Sulochana Paudyal
- Ms. Friendly Yang
Thank you

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Fax: 405-744-6039
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Post Harvest Pest Prevention

Sean Glover, A.C.E.
Associate Certified Entomologist
Cardinal Professional Products
Cardinal Consulting Company
Pest Prevention – Entire Supply Chain; Farm to Fork
Pre-Harvest Pest Prevention
Post Harvest Pest Management Starts Before Harvest
Farm

• Minimize NOW
  – Best practices
  – Pheromone mating disruption
  – Monitoring, treatment, etc.

• Minimize SPP
  – Sanitation – eliminate food sources
  – Understand it affects valley insect populations
Pest Prevention – Huller/Sheller

Post Harvest Processor or Farm Operation?
Biggest Opportunity for Improvement
Stock Piles

• Targeting only NOW
  – Promotes resistance in SPP populations
  – Infests the facility

• SPP control strategies
  – Manage the ground
    • Low concentration drench
    • Diacon IGR
  – Most PH₃ is gone after 2nd day!
  – Use best fumigation practices
    • Dose for SPP
    • Add gas & lengthen application PH₃
    • Use ProFume

<table>
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<tbody>
<tr>
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<table>
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<tbody>
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<tr>
<td>8/28/2013</td>
<td>114</td>
<td>165</td>
</tr>
</tbody>
</table>
Monitor and Manage CT Product

CONCENTRATION VS TIME

0  200  400  600  800  1000

0  10  20  30  40  50  60  70  80  90  100

TIME (HOURS)

PHOSPHINE CONCENTRATION (PPM)

CONCENTRATION VS TIME

1000  800  600  400  200

TIME (HOURS)

METAL PHOSPHIDES  ECO2FUME  TARGET
Huller / Sheller Facility

• Challenges
  – Farm operations or processing?
  – Dirty process
  – Open and exposed
  – Little to no sanitation
  – Lack of treatment strategies
  – Proximity to processors
  – Hull & shell piles infested
  – Significant source of SPP

• Solutions
  – In a nutshell - treat more like a processor than a farm operation
  – Industry best practices
  – Seal up the facilities
  – Locate away from processors
  – Control dust & other fine materials
  – Sanitation and sanitary design
  – End of season deep clean / treatment
  – Treatment strategies
    • Monitoring
    • IGR's
    • CIDETRAK IMM mating disruption
    • Fogging/fumigation as needed

• Monitoring
  • IGR's
  • CIDETRAK IMM mating disruption
  • Fogging/fumigation as needed
Hull and Shell Piles

- Treatment strategies
  - Diacon IGR through automated system as piled
  - Fumigation as needed
Pest Prevention - Processor

Innovation Is Key – Embrace Change
It’s All About Prevention

• Risk assessment
• Eliminate conducive conditions
• Mitigate remaining risks through program design
• Monitor and inspect
• Data collection and analysis electronically
• Science based control strategies
  – Integrated approach
  – Low risk methods first
• Use data to verify effectiveness

• Do
  – Sanitation in micro environments
  – Sanitary design
  – Environmental modification
  – Self inspections
  – CIDETRAK IMM Mating Disruption
  – IGR’s
  – Pheromone monitors
  – Fumigate all inbound including bins
    • Tarp stack, chamber or warehouse
  – Outbound fumigation if needed / required
  – The Strategic Pest Prevention System

• Don’t
  – Fumigate individual bins
  – Blindly fog / fumigate on schedule
Surrounding Properties
Conducive Conditions and Access
Inspection and Monitoring
Software Tools
Track Results. Adjust Strategy

Aerosol Treatments & Enhanced Sanitation

Targeting Hot Spots

Effects of Temperature
New Fogging Technology
Fumigation Best Practices

- Fumigant selection; right tool for the job
- Planning; FMP & ERP
- Dose appropriate for conditions and target pest
- Sealing
- Efficacy monitoring
- Achieve appropriate concentration and time (CT Product)
- Safety monitoring and PPE
- Documentation
Distribution And Beyond
Just Because It Leaves Your Facility Doesn’t Mean It’s Not Your Problem Anymore
Evaluate Downline Risks

• How does product move from you to the consumer?
  – Trucking
  – Warehouses
  – Retail
  – Food service
  – Further processing

• Minimize or eliminate risks you discover in the downline supply chain

• Education

• It should be your concern until the consumer enjoys it
The Future of Grocery Shopping

Paper or Plastic?
Bugs or Pesticides?