Population dynamics of insect pests in mills and impact of aerosol treatments

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Integrated Pest Management Programs in Food Facilities

- Sanitation
- Structural Modification
- Exclusion
- Stock Rotation
- Temperature Management
- Insecticides
  - Crack and Crevice
  - Surface
  - Aerosol
  - Fumigant
Introduction

- Integrated pest management (IPM) programs can reduce need to perform a fumigation or heat treatment
  - Reducing population growth rates
  - Reducing carrying capacity of a facility
- Aerosol reduced risk insecticide use is increasing in food facilities
- What impact do aerosol insecticide applications have as part of an IPM program on pest populations in food facilities?
Why Aerosols Might Not Have an Impact

- Do not penetrate into hidden areas where populations are typically located
- Only a small proportion of the population, typically adults, is out and directly exposed to aerosol treatment
- Limited residual activity for many insecticides when applied as an aerosol
- Mortality of exposed adults can have a minimal impact on total population in hidden refugia
Why Aerosols Might Have an Impact

- Insect Growth Regulators (IGR) have good residual activity – increase exposure time
- Good coverage of all surfaces within a space – increase chance of contact
- Cumulative impact of repeated exposure to aerosols and build-up of residual IGR could cause greater impact on populations
- Combined impact with other IPM tactics such as sanitation and timing of fumigation
Approach

- Bioassays can be used, but don’t show impact on resident population
- Compare insect captures in facilities over time with and without the regular use of aerosol insecticide programs

Challenges
- Pest populations can change over time for reasons other than treatment
- Difficult to hold other factors constant and only change aerosol treatment
- No true replication
Examples of Aerosol Insecticides

- Insecticides commonly used in food industry
  - Synergized pyrethrins
  - Pyrethroids
  - Insect growth regulators (IGR)
  - Dichlorvos (DDVP)

- Different application systems and formulations

- Can mix compounds during application – typically IGR with another insecticide to get immediate knockdown and longer term residual control
Aerosol Insecticides Combination Evaluated in these Case Studies

- Synergized Pyrethrins
  - 1% and 3% formulations (Entech Fog-10 and Fog-30)
- Methoprene (Diacon II)
- Applied at labeled rates in combination using an aerosol application system
- Typically 2-4 week treatment intervals
Pheromone Trapping Program to Estimate Pest Populations

*Tribolium castaneum* – red flour beetle

**Case Study #1**
Flour Mill #1: 55 traps
Flour Mill #2: 32 traps

**Case Study #2**
Rice Mill: 36 traps
Case Study #1

Wheat Flour Mill
Mill #1

Mean number captured in traps: 4.5 ± 0.7 beetles/trap/monitoring period

Change in mean number captured between monitoring periods without fumigation: 45 ± 9% increase

Mean percent of traps with captures: 49 ± 3% of traps with one or more RFB

Change in percent of traps with captures between monitoring periods without fumigation: 18 ± 5% increase

Change in Mill Management Aerosol treatments - Synergized pyrethrin + IGR Applied 2-3 week intervals Enhanced sanitation and spot treatments in response to trapping
Mill #2

Mean number captured in traps: 2.6 ± 0.4 beetles/trap/monitoring period

Change in mean number captured between monitoring periods without fumigation: 62 ± 14% increase

Mean percent of traps with captures: 33 ± 2% of traps with one or more RFB

Change in percent of traps with captures between monitoring periods without fumigation: 32 ± 8% increase
Fumigation Efficacy – Initial Reduction in Beetle Captures

- Two mills did not differ from each other in reduction in trap capture after fumigation

- **84.6±4.6% reduction in beetles/trap/period (n=23 fumigations)**
  - 11.4±3.5 beetles/trap/period immediately before fumigation
  - 0.8±0.2 beetles/trap/period immediately after fumigation
  - Only 3 fumigations had no captures immediately after fumigation
Two mills did not differ from each other in reduction in proportion of traps with captures after fumigation

70.9±5.1% reduction in proportion of traps with captures (n=23 fumigations)

- 58±7% of traps had captures immediately before fumigation
- 20±5% of traps had captures immediately after fumigation
Difference Between Mills Before and After Changes at Mill #1

Mean Number of Beetles Captured

<table>
<thead>
<tr>
<th></th>
<th>Period Before</th>
<th>Period After</th>
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</thead>
<tbody>
<tr>
<td>Mill #1</td>
<td>12.7±2.1</td>
<td>1.2±0.2</td>
</tr>
<tr>
<td>Mill #2</td>
<td>1.4±0.8</td>
<td>3.1±0.4</td>
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</tbody>
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All combinations were significantly different: Mann-Whitney Ranked Sum Test (P<0.05)
Before and After Comparison: Mean Beetle Captures

Mean Trap Capture

GLM: $F_{1,166} = 64.91$, $P < 0.0001$

Proportion of Traps with Captures

GLM: $F_{1,166} = 111.27$, $P < 0.0001$
Before and After Comparison: Beetle Captures Before Fumigation

Mean Trap Capture at Time Fumigation Performed

GLM: $F_{1,9} = 9.71$, $P = 0.0124$

Proportion of Traps with Captures at Time Fumigation Performed

GLM: $F_{1,9} = 17.05$, $P = 0.0026$
Before and After Comparison: Percent Reduction After Fumigation

Percent Reduction in Mean Trap Capture Following Fumigation

Percent Reduction in Proportion of Traps with Captures at Time Fumigation Performed

GLM: $F_{1,9} = 0.04, P = 0.8438$

GLM: $F_{1,9} = 7.59, P = 0.0223$
Before and After Comparison: Beetle Captures After Fumigation

Mean Trap Capture After Fumigation Performed

Proportion of Traps with Captures After Fumigation

GLM: $F_{1,9} = 7.07, P = 0.0261$

GLM: $F_{1,9} = 17.07, P = 0.0026$
Fumigation Efficacy – Rebound in Beetle Captures

- Rebound in mean trap capture after fumigation was highly variable

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**Mill #1**

![Graph A (Mill #1)](#)

**Mill #2**

![Graph B (Mill #2)](#)
Fumigation Efficacy – Rebound in Beetle Captures

- Developed threshold value to compare rebound rates – 2.5 beetles/trap/2 wk period (= median trap capture prior to fumigation)
Fumigation Efficacy – Rebound in Trap Captures

Combined Mills and Seasons

174±33 days (n=21, 8 did not reach)
Fumigation Efficacy – Rebound in Beetle Captures

- Significant effect of season on rebound to mean beetle capture threshold

Sorted by Season

- **Spring**: $248 \pm 50$ days ($n=9$, 5 did not reach)
- **Fall**: $104 \pm 21$ days ($n=9$, 3 did not reach)
Fumigation Efficacy – Rebound in Beetle Captures

- Significant effect of change in management on rebound

Mean Threshold

Proportion That Have Not Reached Mean Trap Capture Threshold

Time after Fumigation (Days)

Proportion Threshold

Proportion That Have Not Reached Proportion Of Traps Threshold

Time after Fumigation (Days)

- 246±71 days (n=5, 2 did not reach)
- 246±71 days (n=5, 2 did not reach)
- 165±46 days (n=5, 0 did not reach)
- 165±46 days (n=5, 0 did not reach)

- 49±15 days (n=5, 0 did not reach)
- 49±15 days (n=5, 0 did not reach)
- 38±14 days (n=5, 0 did not reach)
- 38±14 days (n=5, 0 did not reach)
Change in Beetle Captures Between Sequential Monitoring Periods

- Overall model (GLM) for mean trap captures (season and before/after management change) was significant.
  - Season was a significant factor.
  - Change in management not significant.
  - Interaction not significant.
Air Temperature Differences Between Seasons

- Both inside and outside temperatures differed significantly between seasons.
- Impacts both population growth rate inside and immigration from outside sources.
Case Study #2

Rice Mill
Rice Mill

- Different zones at mill
- Range of stored-product species captured at the facility
- One year of monitoring before and one year afterward
Trends in Red Flour Beetle Captures: Whole Facility

Red Flour Beetle

Fumigations
Trends in Red Flour Beetle Captures: Aerosol Treated Zones

Use of Aerosol Insecticide Applications

Profume Fumigation
Trends in Red Flour Beetle Captures: Before and After
Aerosol Treated Areas

**Mill - Yearly Total**

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<thead>
<tr>
<th>Year</th>
<th>Total Number Captured (Adjusted to 2 week intervals)</th>
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**Clean Rice - Yearly Total**

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<tr>
<th>Year</th>
<th>Total Number Captured (Adjusted to 2 week intervals)</th>
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Non-Treated Areas

Rough Rice - Yearly Total

Outside - Yearly Total
Evaluation of Results to Date

- Decline in beetle captures during periods when aerosol system was used, but degree of impact is confounded by other factors
- Case Study #1 confounded with other management changes and potential seasonal impacts, but showed how combined IPM approach can impact populations
- Case Study #2 also had declines in non-treated areas and in other non-target species
- As add other locations and longer periods of time can better correlate impact with treatment
Questions

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Population Growth

Exponential Growth
- Population increases by a constant factor

Logistic Growth
- Factor decreases as approaches maximum number (K)

Difference between two due to competition

Management goal:
- Reduce carrying capacity (K) and growth rate

from Price (1984)
Fumigation Efficacy – Rebound in Trap Captures

- Significant effect of season on rebound to mean trap capture threshold

Combined Mills and Seasons

Sorted by Season

- 248 ± 50 days
- 174 ± 33 days (n=21, 8 did not reach)
- 104 ± 21 days
Fumigation Efficacy – Rebound in Beetle Captures

- Significant effect of change in management on rebound

**Mean Threshold**
- 246±71 days (n=5, 2 did not reach)
- 49±15 days (n=5, 0 did not reach)

**Proportion Threshold**
- 165±46 days (n=5, 0 did not reach)
- 38±14 days (n=5, 0 did not reach)
Trends in Almond Moth Captures: Whole Facility

Almond Moth

Number Captured (average +/- sem)

Fumigations
Trends in Almond Moth Captures: Aerosol Treated Zones

Almond Moth

Use of Aerosol Insecticide Applications

Profume Fumigation
Trends in Almond Moth Captures: Before and After