Post-Harvest Pest Management

December 10, 2015

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Speakers

Steve Lindsay, Diamond Foods (Moderator)

Randy Segawa, DPR

George Opit, Oklahoma State University

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Regulatory Update for Post-Harvest Fumigants

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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

Milestone	Timeframe
Registrant Data Call-In	August 2014
Data Submission	Summer 2016 – 2017
Risk Assessment	2018
Decision	2018 – 2019

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?

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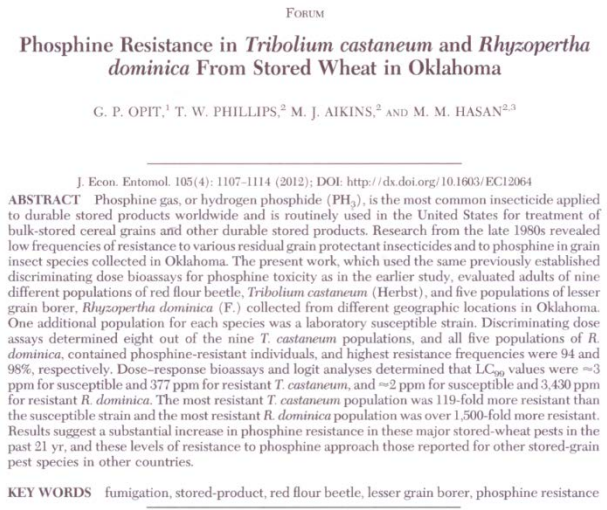
Phosphine Resistance in Stored-Product Insect Pests from Almond Storage and Processing Facilities in California

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.



FORUM

Phosphine Resistance in *Tribolium castaneum* and *Rhyzopertha dominica* From Stored Wheat in Oklahoma

G. P. OPIT,[1] T. W. PHILLIPS,[2] M. J. AIKINS,[2] AND M. M. HASAN[2,3]

J. Econ. Entomol. 105(4): 1107–1114 (2012); DOI: http://dx.doi.org/10.1603/EC12064

ABSTRACT Phosphine gas, or hydrogen phosphide (PH_3), is the most common insecticide applied to durable stored products worldwide and is routinely used in the United States for treatment of bulk-stored cereal grains and other durable stored products. Research from the late 1980s revealed low frequencies of resistance to various residual grain protectant insecticides and to phosphine in grain insect species collected in Oklahoma. The present work, which used the same previously established discriminating dose bioassays for phosphine toxicity as in the earlier study, evaluated adults of nine different populations of red flour beetle, *Tribolium castaneum* (Herbst), and five populations of lesser grain borer, *Rhyzopertha dominica* (F.) collected from different geographic locations in Oklahoma. One additional population for each species was a laboratory susceptible strain. Discriminating dose assays determined eight out of the nine *T. castaneum* populations, and all five populations of *R. dominica*, contained phosphine-resistant individuals, and highest resistance frequencies were 94 and 98%, respectively. Dose–response bioassays and logit analyses determined that LC_{50} values were ≈3 ppm for susceptible and 377 ppm for resistant *T. castaneum*, and ≈2 ppm for susceptible and 3,430 ppm for resistant *R. dominica*. The most resistant *T. castaneum* population was 119-fold more resistant than the susceptible strain and the most resistant *R. dominica* population was over 1,500-fold more resistant. Results suggest a substantial increase in phosphine resistance in these major stored-wheat pests in the past 21 yr, and these levels of resistance to phosphine approach those reported for other stored-grain pest species in other countries.

KEY WORDS fumigation, stored-product, red flour beetle, lesser grain borer, phosphine resistance

Concentrations of Phosphine Required to Kill 99% of **Lesser Grain Borer** Individuals

Lesser Grain Borer Population	LC_{99} (95% CI) (ppm)
Susceptible	**2.26 (1.70 – 2.90)**
Payne 1	**572.78 (485.32 – 790.58)**
Logan	**2054.40 (972.25 – 8002.30)**
Garfield	**3430.80 (1426.70 – 27142.0)**

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

Insects

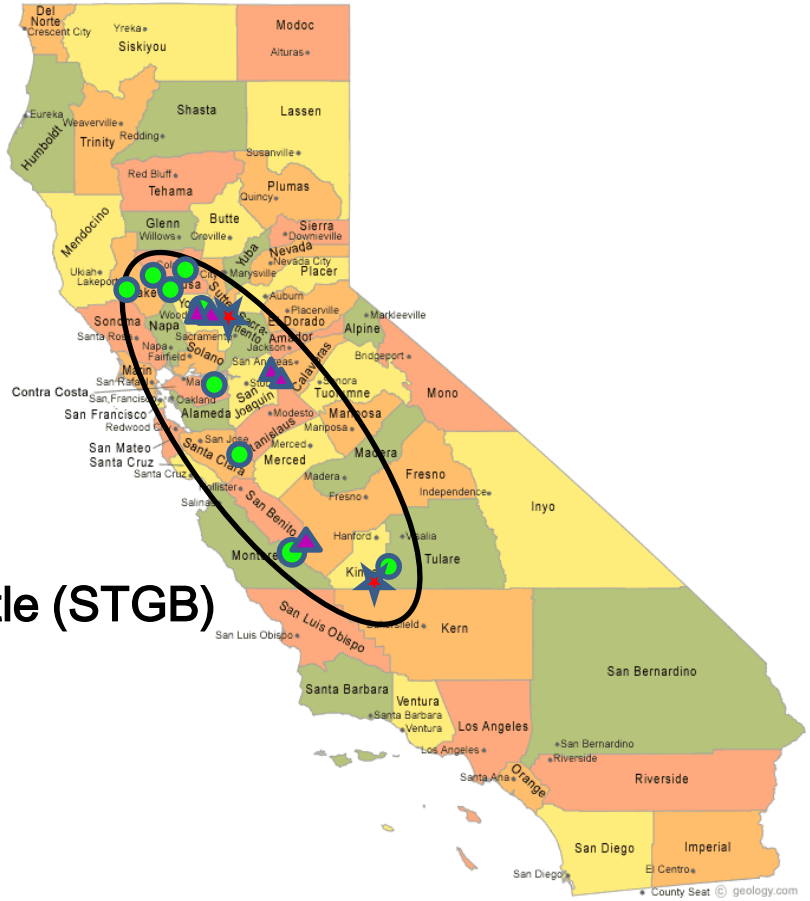
Oryzaephilus surinamenis (L.)
Sawtoothed Grain beetle (STGB)

Tribolium castaneum (Herbst)
Red flour beetle (RFB)

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).

RFB Population	Resistance Frequencies (%)
Box W	1
Box V	11
Box B	48
Box BR	54
Box BM	93
Box L	93
Box BN	97
Box E1, Box E3, Box F, Box I, Box N, Box S, Box T, Box Q, Box U3, Box R, and Box X (11)	0
Susceptible lab strain	0

Phosphine Resistance in STGB Adults

- 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).

STGB` Population	Resistance Frequencies (%)
Box A	1
Box BR	99
Box BF	91
Box Q, Box U3, Box S, Box X, and Box W (5)	0
Susceptible lab strain	0

Question 2

Is there phosphine resistance in RFB eggs and IMM eggs and larvae from insects in almond storage facilities in California?

Phosphine Resistance in RFB Eggs

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.

RFB Population	Resistance Frequencies (%)
Box B	56
Box BR	72
Box BN	100
Box BM	100
Box E1	0
Box E2	0
Box F	0
Box I	0
Box N	0
Box S	0
Box T	0
Susceptible lab strain	0

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.

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

IMM Population	Resistance Frequencies (%) — Larvae	Resistance Frequencies (%) — Eggs
Box E1	0	8
Box F	0	5
Box N	0	16
Susceptible lab strain	0	0

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.

RFB Adult Population	LC_{99} (95% CI) (ppm)
Susceptible lab strain	7.4 (6.8 – 8.0)
Box B	50.2 (41.5 – 63.4)
Box BR	54.3 (45.4 – 67.6)
Box BM	295.2 (226.0 – 421.3)
Box BN	356.9 (270.4 – 515.8)

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.

RFB Egg Population	LC_{99} (95% CI) (ppm)
Susceptible lab strain	**51.5 (44.6 – 62.4)**
Box B	220.4 (187.1 – 272.1)
Box BR	279.9 (236.6 – 346.7)
Box BM	605.5 (527.9 – 719.4)
Box BN	653.9 (580.3 – 755.1)

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

RFB Population	LC_{99} (95% CI) (ppm) — Adults	LC_{99} (95% CI) (ppm) — Eggs
Susceptible lab strain	7.4 (6.8 – 8.0)	51.5 (44.6 – 62.4)
Box B	50.2 (41.5 – 63.4)	220.4 (187.1 – 272.1)
Box BR	54.3 (45.4 – 67.6)	279.9 (236.6 – 346.7)
Box BM	295.2 (226.0 – 421.3)	605.5 (527.9 – 719.4)
Box BN	356.9 (270.4 – 515.8)	653.9 (580.3 – 755.1)

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

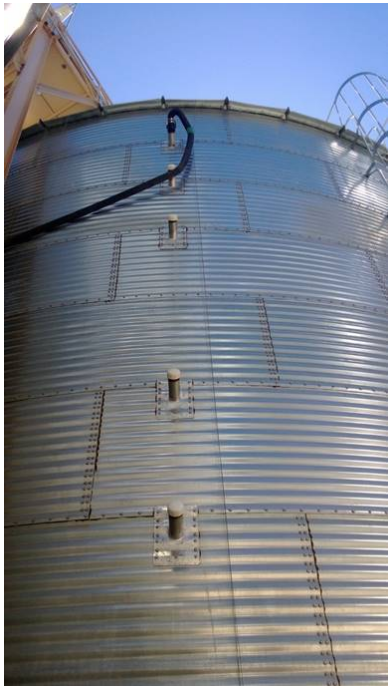
We must alter the perception that effective sealing cannot be achieved and require that fumigated storages be sealed to maintain lethal dosages of phosphine.

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

Resistance Monitoring

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

RFB Population	Resistance Frequencies (%)
Box B	56
Box BR	72
Box BN	100
Box BM	100
Box E1	0
Box E2	0
Box F	0
Box I	0
Box N	0
Box S	0
Box T	0
Susceptible lab strain	0

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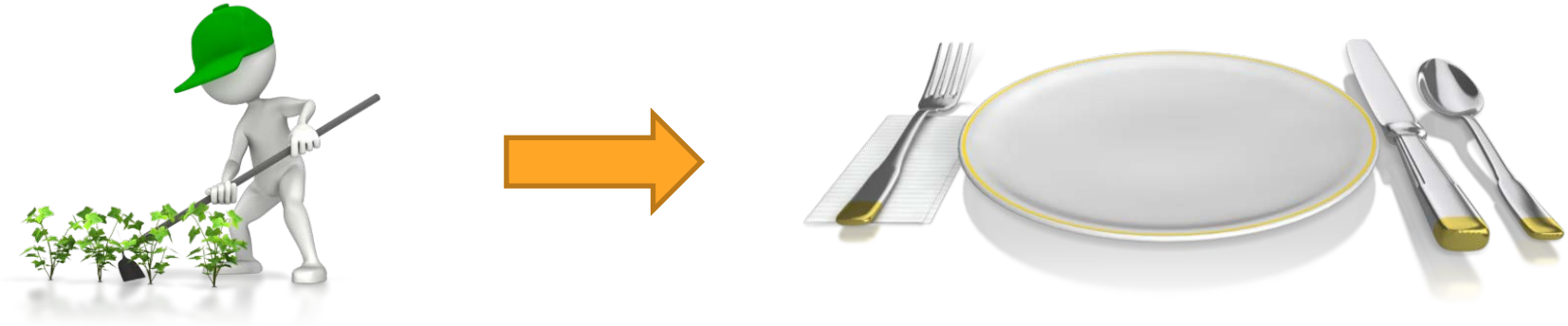
Pest Prevention – Entire Supply Chain; Farm to Fork



Farm → Huller / Sheller → Processor → Distribution → Client

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?

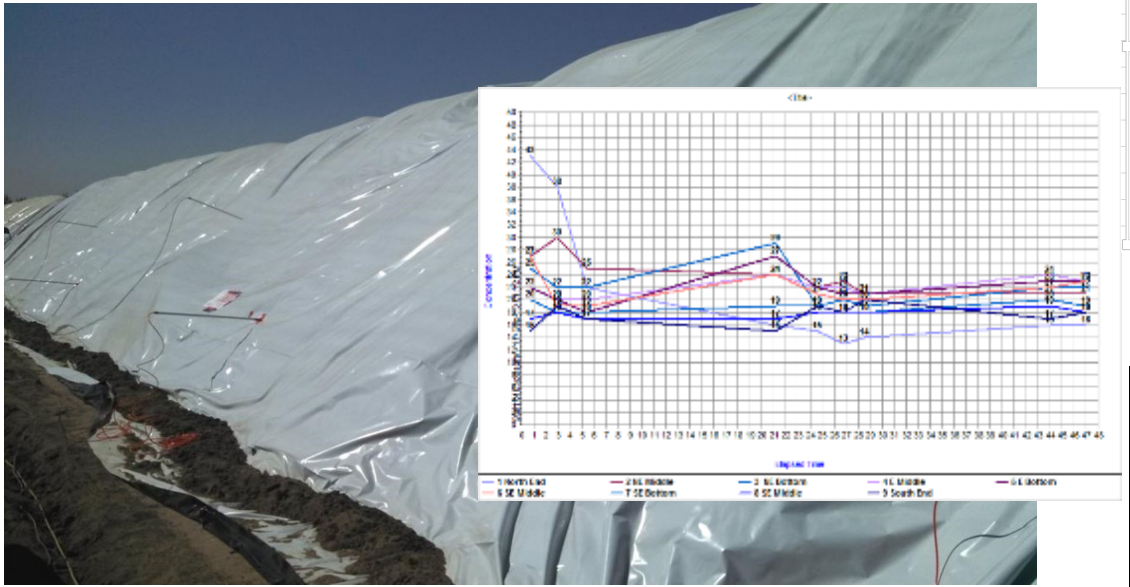
Biggest Opportunity for Improvement

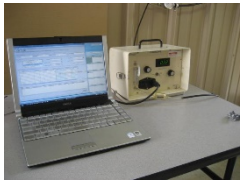
Stock Piles

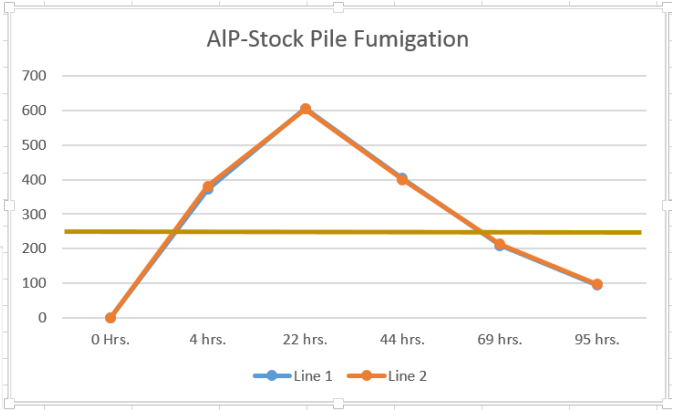
- Targeting only NOW
  - Promotes resistance in SPP populations
  - Infests the facility
- SPP control strategies
  - Manage the ground
    - Low concentration drench
    - Diacon IGR
  - Most PH_3 is gone after 2nd day!
  - Use best fumigation practices
    - Dose for SPP
    - Add gas & lengthen application PH_3
    - Use ProFume

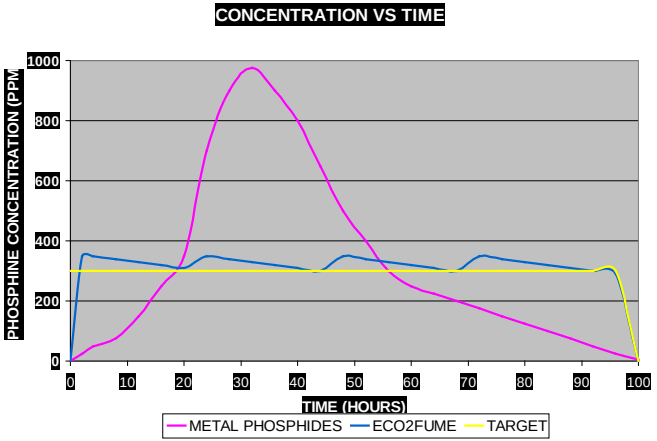
AlP		
8/29/2013		
Fum. Date	Reading North	Reading South
8/19/2013	0.09	not taken
8/25/2013	0.57	2.48
8/25/2013	52	55
8/25/2013	3	5
8/25/2013	10	10
8/27/2013	50	61
8/27/2013	142	**244**
8/27/2013	111	183
8/28/2013	114	165

Monitor and Manage CT Product









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

Hull and Shell Piles

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

Pest Prevention - Processor

Innovation Is Key – Embrace Change

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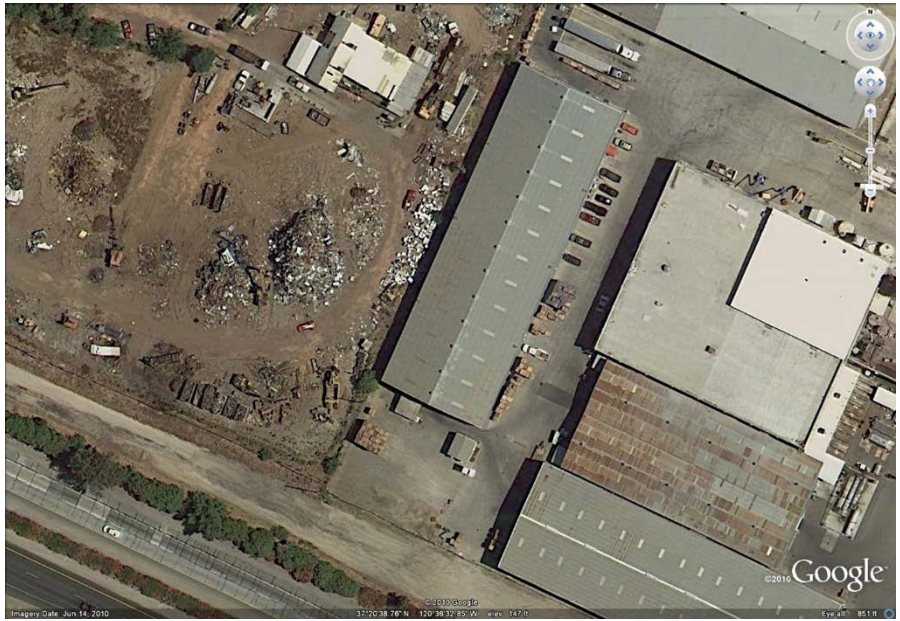
It’s All About Prevention

- 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

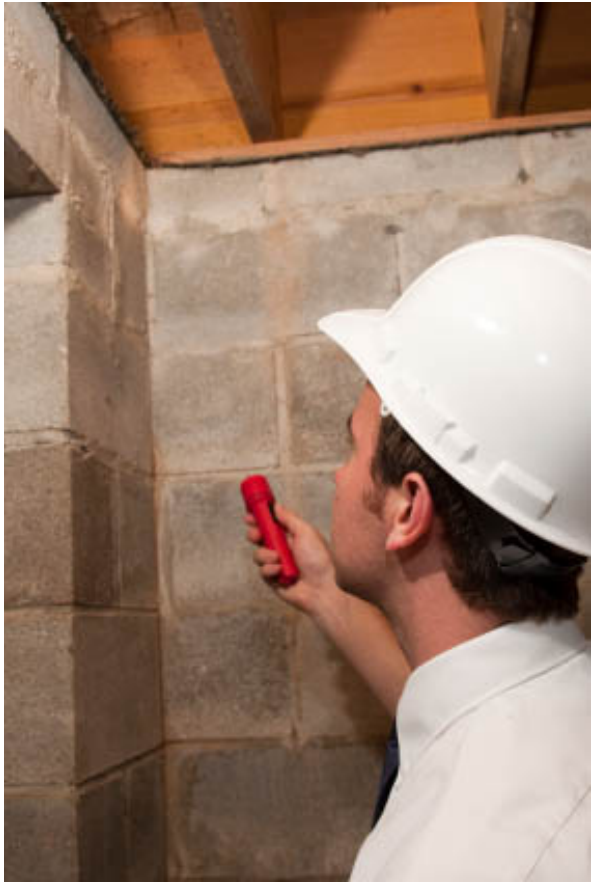
- Do
  - Sanitation in micro environments
  - Sanitary design
  - Environmental modification
  - Self inspections
  - CIDETRAK IMM Mating Disruption
  - IGR’s
  - Pheromone monitors
  - Fumigate all inbound including bins
    - Tarp stack, chamber or warehouse
  - Outbound fumigation if needed / required
  - The Strategic Pest Prevention System
- Don’t
  - Fumigate individual bins
  - Blindly fog / fumigate on schedule

Surrounding Properties

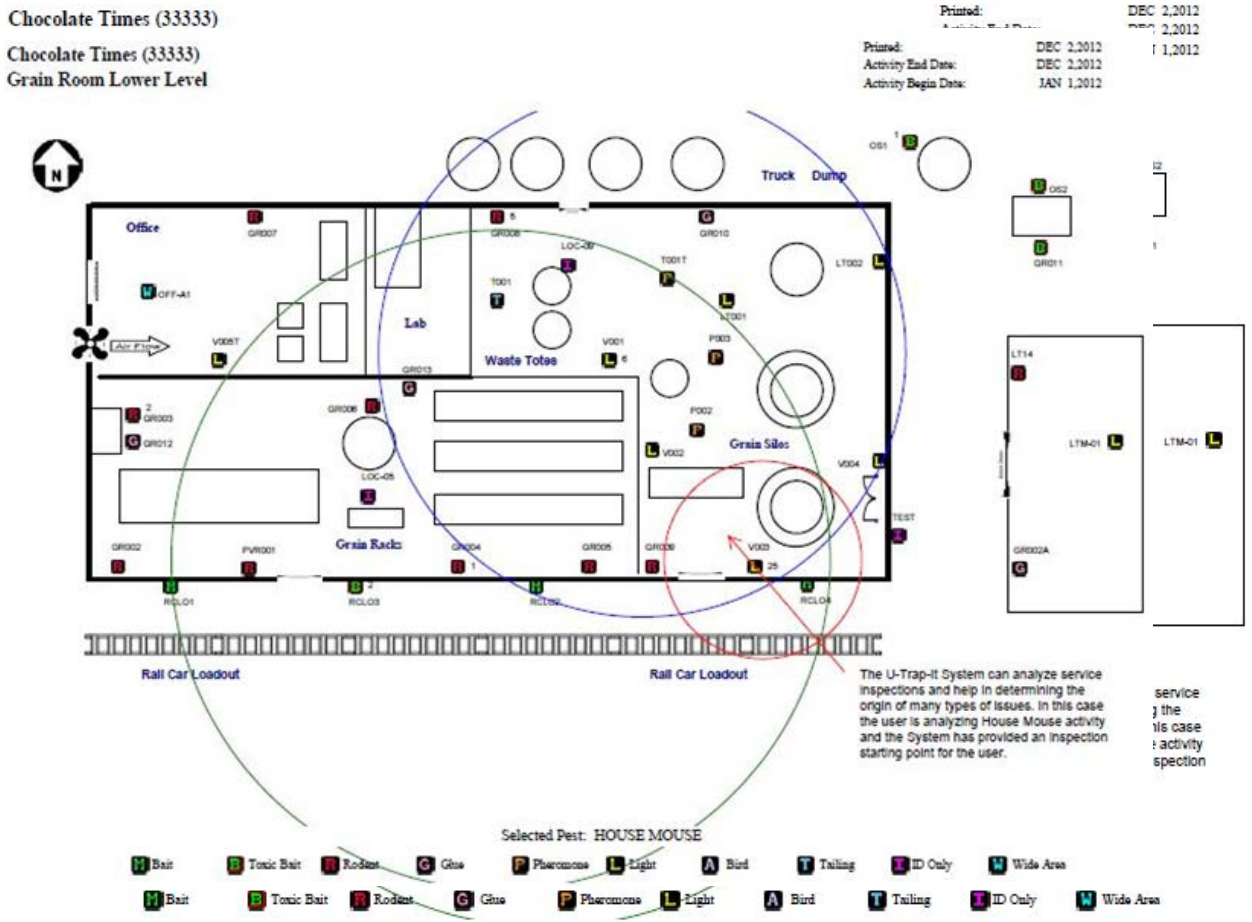


Conducive Conditions and Access

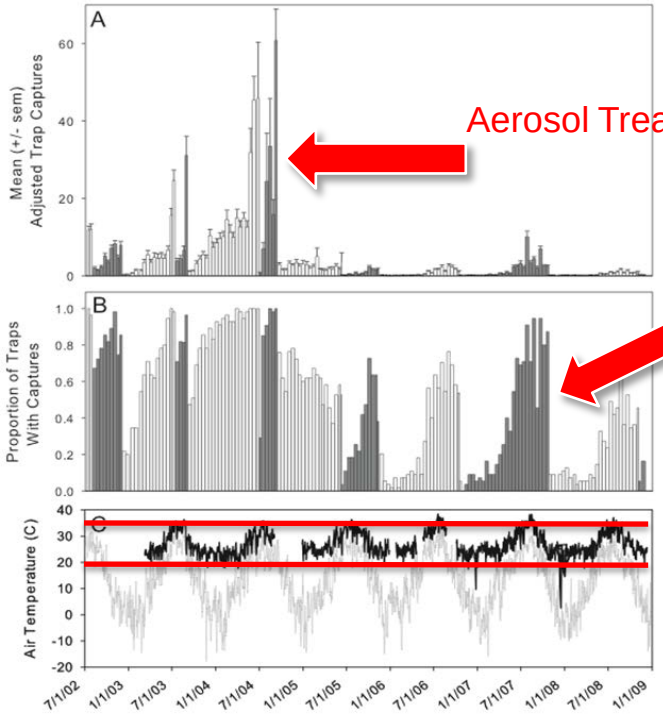
Inspection and Monitoring



Software Tools



Track Results. Adjust Strategy

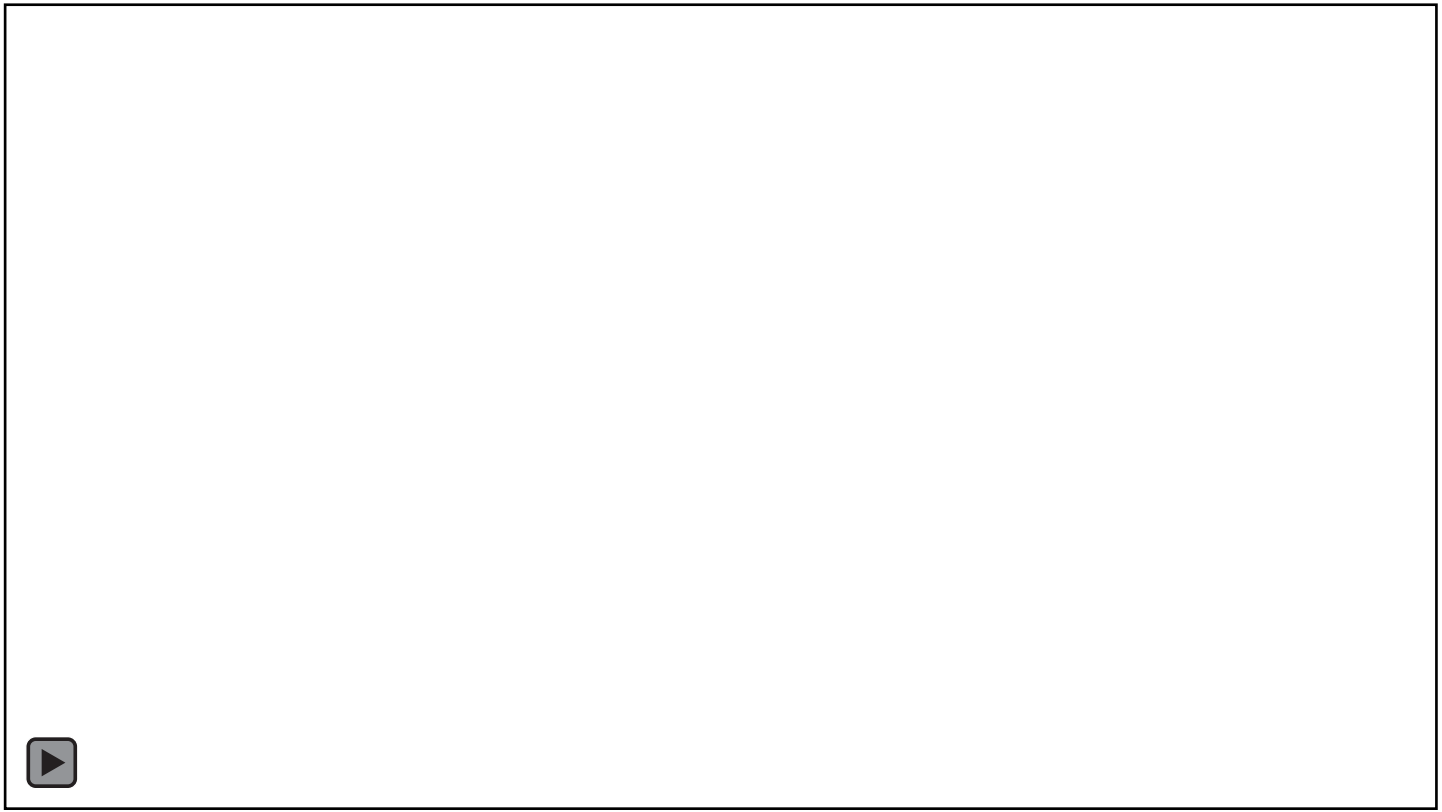


Aerosol Treatments & Enhanced Sanitation

Targeting Hot Spots

Effects of Temperature

New Fogging Technology

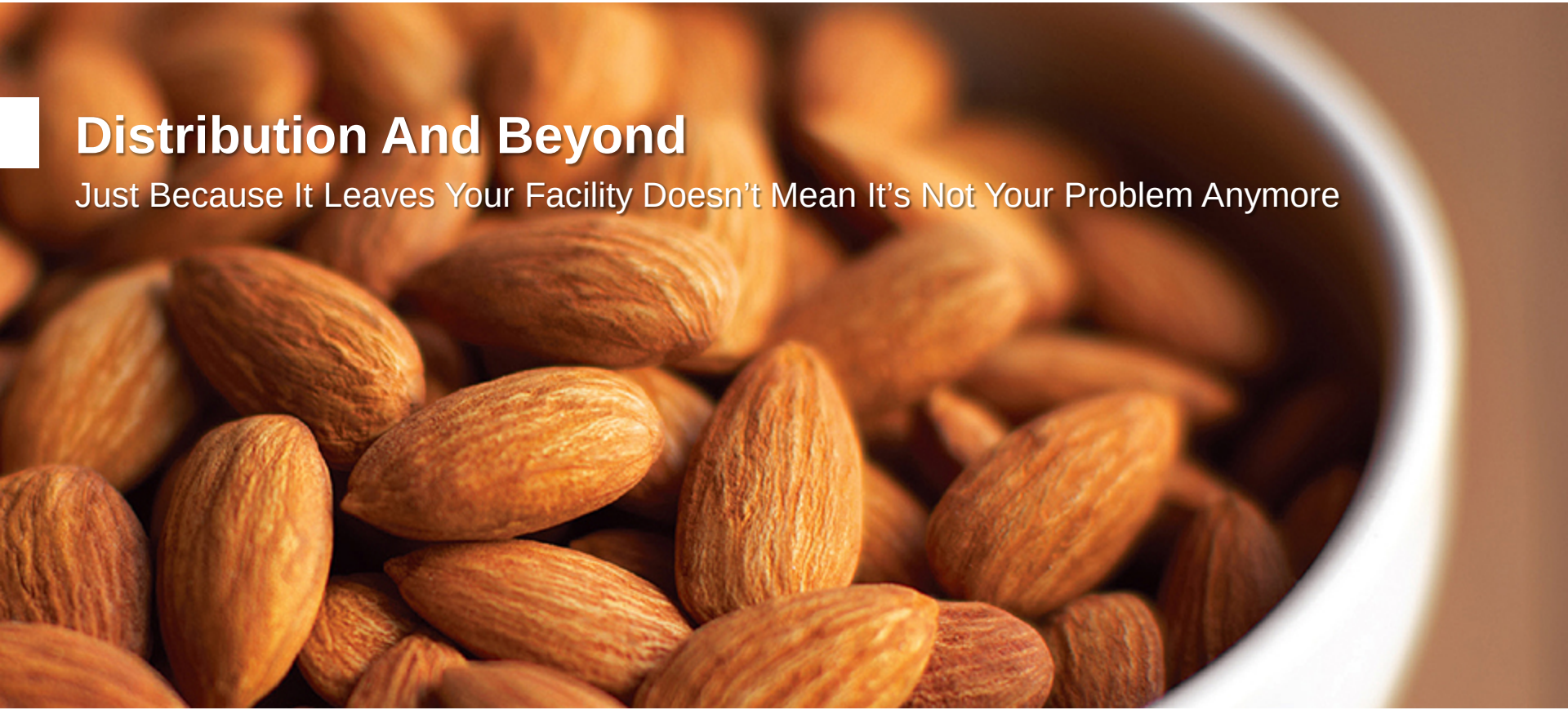


Fumigation Best Practices

- 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



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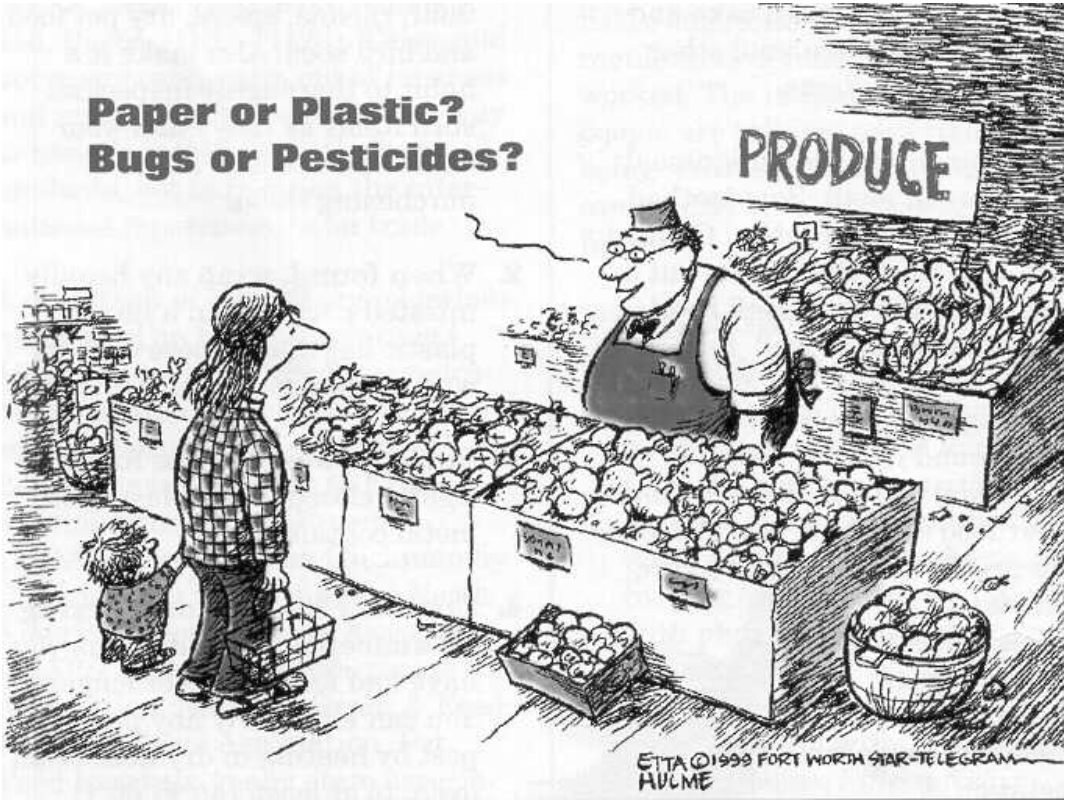
Evaluate Downline Risks

- 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



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Questions? Comments?

We are happy to help you!

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CARDINAL PROFESSIONAL PRODUCTS

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SPP THE Strategic Pest Prevention System

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