Pesticide Application Technology

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Pesticide Application Technology
(More than Just the Machine & Its Nozzles)

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All About Allan

• Subject Matter Expert (SME) Liaison between the Entomological Society of America (ESA) and EPA OPP

• Professor at WSU (1993-present)
  ✓ Teaching, Extension, Research, Administration
  ✓ Pesticide technology A-Z

• University of Illinois (1978-1993)
  ✓ Research, some Extension & Teaching
  ✓ Environmental chemistry of pesticides; insect toxicology

• Education
  ✓ PhD (1978) Iowa State Univ. (Entomology)
  ✓ M.S. (1974) Univ of FL (Entomology)
  ✓ B.S. (1972) Tulane University (Biology)

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Agenda

• Premise: Pesticide application technology is more than the mechanical technology

• Deconstruction of spraying process
  ✓ Importance of adjuvants to spray delivery

• The “machines” (spray rigs, granular applicators, and fumigant delivery)

• Importance of how these “machines” are operated
  ✓ How can machines be operated to reduce “off-target” effects
From Active Ingredient to Residue

Pesticide Technology

Active Ingredient (AI)

- Water
- Solvents
- Surfactants

Formulation

- Anti-microbials
- Anti-foamers

- Water
- Crop Oil

Spray Tank Mixture

- Adjuvants (surfactants, buffers)

Delivery
Pesticide Application Technology Is More than the Mechanical Technology

- **The Machines**
  - ✓ Tractor or aircraft “pulling” the sprayer or granular applicator
    - ✴ Includes fumigation technology such as irrigation rigs
  - ✓ Pumps, booms, nozzles

- **Chemical Technology**
  - ✓ Adjuvants (mostly various types of surfactants)

- **Sociological component—the role of the operator**
  - ✓ How we choose the appropriate chemical technology and operate the machines in the context of efficacy needs and environmental conditions
The Fate of Pesticide Active Ingredients from Spray to Target & Beyond
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- Solutions are atomized when they flow across a small orifice (i.e., out of the nozzle tip) under high pressure.
- They are emitted from the nozzle orifice as a liquid sheet of varying lengths.
- The leading edge of the sheet is unstable and breaks apart (shears) into small droplets (atomization process).
- The surface tension and viscosity (resistance to flow) of the liquid can determine how the particles are formed.
Effect of Adjuvants on Break Up of Water Sprayed from a Pressurized Nozzle

0.5% Tallow amine Surfactant

Water Only

1% Vegetable Oil Adjuvant

Miller & Butler Ellis (2000)
Expressing Particle Sizes as a Unitary Parameter

- One half of the volume of spray is occupied by particles with spherical diameters larger than the VMD, and one-half of the volume has particles smaller than the VMD

**Volume Median Diameter (VMD)**
VMD: The particle size diameter at which half of the spray volume contains smaller particles and half of the spray volume contains larger particles. For example, if the VMD is 100 µm, than half the spray volume contains particles less than 100 µm.
Percentage of Spray Volume in Spray Particles Less Than 100 µm

Miller & Butler Ellis (2000)
The Fate of Pesticide Active Ingredients from Spray to Target & Beyond

Transport to Target

- Impaction on Target
- Retention
- Spreading
- Drying

Deposit Formation

Movement in/on Plant

Diffusion into Animal

Biological Effect

Drift Losses

Evaporation

Reflection (Bounce-Off)

Washoff

Photodegradation

Metabolism

Root Exudation

Volatilization

Runoff

Leaching

Soil
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Why We Need “Other Ingredients” to Achieve Efficacy in the Field

- If modify surface tension, water droplet will spread over the surface
Adjuvants Can **Enhance Retention** of Spray Droplets on Leaf Surfaces


Retention on Wheat Leaves

<table>
<thead>
<tr>
<th></th>
<th>1540 stems m⁻², flat-fan nozzle</th>
<th>1540 stems m⁻², air-induction nozzle</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>POEA</strong></td>
<td><img src="chart1.png" alt="POEA Bar Chart" /></td>
<td><img src="chart2.png" alt="POEA Bar Chart" /></td>
</tr>
<tr>
<td><strong>Water</strong></td>
<td><img src="chart3.png" alt="Water Bar Chart" /></td>
<td><img src="chart4.png" alt="Water Bar Chart" /></td>
</tr>
<tr>
<td><strong>EC</strong></td>
<td><img src="chart5.png" alt="EC Bar Chart" /></td>
<td><img src="chart6.png" alt="EC Bar Chart" /></td>
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</tbody>
</table>

retention (ml per 100 litre ha⁻¹ per g)
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Types of Application Techniques

- Foliar & soil spraying of liquid formulations in water or oil
- Soil application of granular formulations
- Seed treatments
- Fumigation of soil or a ‘space’
- Dispensers containing pheromones
- Barrier devices
Objectives of Application from an Efficacy Perspective

- Place the spray or granular formulation where the pest is or will be.
- Successful control will depend on good coverage of the surface intended to receive the spray.
- Some pesticides are mobile within the plant or across the leaf surface.

Visualization of Spray Deposition with Dayglo Paint Under UV Light
Using Liquid Spraying as the Model

- Pieces of equipment
  - ✔ Spray tank (reservoir)
  - ✔ Pump
  - ✔ Hose & boom
  - ✔ Nozzle
Basics of Pumping Systems

- Consider that the spray tank will be holding pesticide active ingredients in a formulation diluted in water

  ✓ Owing to the different properties and densities of the materials, it is important that the tank contents be well mixed prior to delivery to the boom

  ✴ Especially important when using wettable powder formulations

  ✓ The pump is key to both mixing and delivery

Bode & Butler (1981)
• The liquid spray is pumped under pressure through a network of hoses connecting to a boom that supports pipes terminated periodically with nozzles

✓ A nozzle is functionally the end of a pipe through which liquid emerges as a jet

✓ In other words, a nozzle is any device through which spray liquid is emitted, broken up into droplets and dispersed at least over a short distance

✴ Further distribution of spray droplets is influenced principally by natural air movements

✴ Some sprayers use an airstream to direct the spray toward its target

• Nozzles regulate spray flow rate (pressure also important), spray angle and coverage, and in part drift away from target

Note spray angle, nozzle spacing, and overlap of spray pattern

NOTES
Coverage is defined as the extent to which a pesticidal spray has been distributed on a target surface. The biological implication is that good coverage increases the probability that a pest will encounter a pesticide.

http://www.dropdata.org/DD/definitions.htm#size
Sprayer Equipment: Aerial Application

**Fixed Wing**

**Rotary Wing**

Typical Uses: Grain & Vegetable Crops; Forestry
Operation of Aerial Applications

Rule of Thumb: Boom length should be no more than 75% of the length of the fixed wing or rotary blades
How Aerial Spraying Is Supposed to Be
Operator Error?
So Far, So Good
Looks Like the Pilot Is Watching those Telephone Lines
Looks Like the Pilot Is Watching those Telephone Lines

Oops!!
What’s Wrong with this Picture?
The Drones Are Coming

3WDM8 - 20
20L payload,
43 kg take off weight
The Drones Are Coming

3WDM8 - 20
20L payload,
43 kg take off weight
Spray Equipment: Ground Application

Ground Booms:
Typical Applications on grain & vegetables
Effect of Boom Height on Downwind Drift Deposition

AgDRIFT Modeling
Ground Sprayer Technology to Manage Drift Out of Field

- Drift: Downwind movement of airborne spray droplets beyond the intended area of application originating from aerial or ground-based spraying operations
Granular soil insecticides are incorporated into an ~7-inch band over the seed row.
How the Planter with Soil Insecticide Delivery Works

- When the top of the hopper box is closed, the tank and the hoses become pressurized; just like if you capped a straw with your finger

  ✓ The pressure causes seeds to “blow” into individual row units. This is the piece of the planter that will put the seed in the ground.

- Each row unit has its own hose (#1) that links it to the main hopper tanks. Once seeds fill the smaller hopper boxes (#2), gravity forces them into the meter.

- Inside each meter (#3), a seed is sucked onto a plate that is pocked with individual holes. One seed to one hole. The vacuum effect is what holds the seed to the plate.

- As the planter moves through the field, the row cleaners (#4) push stalks, leaves and clods of dirt out of what will become the furrow.

- Gauge wheels (#5) regulate how deep a seed will be planted. The silver discs (#6) are “openers” that open the soil to create the furrow. The seed meter continually spins dropping one seed into the ground at a time.
The Soil Insecticide Smart Box as an Example of Closed Application System Equipment
Boom Sprayers for Cultivating and Spraying

Hagie™ Self-Propelled Sprayer
Sprayer Equipment: Orchards & Vineyards

- For insect and disease management in orchards and vineyards, basically two types of sprayers are used

  ✓ Air-blast
    - Spray emitted from nozzles located several feet off the ground
    - Spray emitted from towers that run parallel to the tree height

  ✓ Proptec
    - Spray delivered is delivered through a hose that is broken up by a fan pushing air over the hose end nozzle
    - Consists of series of fans situated parallel to the length of the tree
Airblast Sprayers: The Most Used Machines for Orchards & Vineyards
Sprayer Equipment: Orchards & Vineyards

Axial Fan Air-blast Sprayers; Typical Use in Orchards

Airblast Sprayers Used in Vineyards
Note how the fan cowling is divided into two independent sectors on this axial fan airblast sprayer.
Sonic Anemometer Measurements of Windfield Around a Pak-Blast Sprayer
Kriged Windfield Around an Axial Fan Air Blast Sprayer (contour lines = meters/sec)
How Far is the “Boom” on an Air Blast Sprayer from the Target?
Turbomist Tower Sprayer
Proptec Spray Head Nozzle & Fan

Blueline 6 Head Telescoping Vertical Boom Proptec Sprayer
Atomized Spray from Proptec Head
Proptec Mounted on a T-Boom
Blueline 8 Head Wrap-Around Proptec Sprayer
Proptec Sprayers for Orchard Use (The Tower)
The Quantum Mist Sprayer (note that pressurized nozzles surround the fan cowling)
The Quantum Mist Sprayer
(note that pressurized nozzles surround the fan cowling)
How Not to Operate a Proptec Sprayer
Horizontal Boom on Proptec Orchard Sprayer
Advantages of Tower Sprayers

- One consideration when preparing a spray tank mix is the volume rate of spray
  - For example, typical orchard sprays are applied at the rate of 150 - 200 gallons per acre

- Tower sprayers are typically reduced volume sprayers
  - Volume rates as low as 20 gallons per acre are possible
  - Tower sprayers also move faster than air-blast sprayers (~4 mph vs. 1-2 mph)

- Thus, tower sprayers can save time from repeated tank fill ups as well as cut labor costs and worker exposure to hazardous materials

- Tower sprayers also place the spray closer to the foliage than do airblast sprayers, reducing wastage
Spraying Outside Rows with One Set of Nozzles Open
The Backwash Effect
The Backwash Effect
How Much Does the Air Backwash Effect Contribute to Out of Orchard Drift??
FEQL 2005 Spray Drift Study: Documenting the Air Backwash Effect

Silica Gel Drift Deposition Plates

Sprayer Pass 1

Sprayer Pass 2

Spraying Direction
Ground deposits of Guthion due to drift

Distance (feet) from First Tree Row

Guthion
µg/cm²

Outside Row Sprayed
Outside + Row 1 & 2

Outside Orchard
Inside Orchard
Within Canopy Movement & Deposition of Orchard Sprays

In-Row Deposition

Blow-Through to Next Row

Fluorescent Tracer Deposition

No Deposit

Blow Through Two Rows Over
Guthion (azinphos-methyl) Residues on Field Treated Foliage

- Every Row
- Alternate Row
- Skip Row

1 Day After Application

Crop Year 2003
Conclusion: Significantly less ground deposition in orchard when a row is skipped.
Conclusion: Under the conditions of the experiment, no effect of alternative spraying practices on drift.
Conclusion: Leaves from the untreated side of the tree have less residues but mortality of codling moth neonates is about the same as on leaves from the treated side of the tree.
Conclusion: Residues on apples are less effective than on leaves in controlling CM larvae; residues on apples from untreated side of the tree are insufficient for adequate control of larval penetration.
Hand & Backpack Sprayers
Greenhouse Spraying: Backpack Sprayers & Foggers
Greenhouse Spraying: Robotic Boom & Stationary Thermal Pulse Foggers
Efficient spraying starts with accurate calibration

http://berrygrape.org/airblast-sprayer-calibrator/
Questions??