Increasing Pesticide Efficacy Through Proper Application Technique
## Author Profile

<table>
<thead>
<tr>
<th>Author Name:</th>
<th>Tyler Steinkamp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professional Title:</td>
<td>Regional Agronomist</td>
</tr>
<tr>
<td>Affiliation (Company / Department):</td>
<td>Winfield Solutions</td>
</tr>
<tr>
<td>Current professional work / research interests:</td>
<td>I currently work as a Regional Agronomist for Winfield Solutions in Eastern Iowa. My job is to educate farmers and agronomists about agronomic principals, and help them understand what is going on in their fields and how they can optimize their yields while still maintaining the quality of their fields.</td>
</tr>
</tbody>
</table>
## Module Contents

| Chapter 1: Introduction                      |
| Chapter 2: Sprayer Calibration               |
| Chapter 3: Maintaining a Good Spray Pattern  |
| Chapter 4: Selecting the Proper Nozzle Output|
| Chapter 5: Selecting the Proper Nozzle       |
| Chapter 6: Managing Drift                    |
| Chapter 7: Increasing Deposition/Coverage    |
| Chapter 8: Adjuvants and Surfactants         |
| Chapter 9: General Mixing Order              |
| Chapter 10: General Cleaning Procedures      |
| Chapter 11: Summary                          |
| Chapter 12: Test                             |
Chapter: 1 Introduction

- Pesticides being placed in a spray tank does a farmer no good if they do not reach the site of action in the pest that the pesticide is trying to control.
  - This learning module is designed to help agronomist understand how an application can be made to see the full benefit of the pesticides that are going into the spray tank.
  - This module is designed to help avoid problems like the one shown below.

Rickard, 2013
Chapter 2: Sprayer Calibration

Importance
- Even application of chemical across the whole boom
- Correct chemical dosage on the weeds
- Mix enough product to spray the entire field

Nozzle code
- First letters on a spray nozzle tell the type of spray nozzle
  Example: AIXR
- First set of 2 or 3 numbers is the width of the pattern
  Example: 110 Degrees
- Last 2 numbers are the gallons per minute at 40 PSI
  Example: 0.3 Gallons per minute
Chapter 2: Sprayer Calibration

Measuring cup method
1. Set sprayer to 40 PSI
2. Hold a measuring cup under nozzle for 15 seconds
3. Take measurement in ounces per 15 seconds
4. Multiply results by 4 to get ounces per minute
5. Divide results by 128 to get gallons per minute

Spot on spray calibrator method
1. Turn calibrator on
2. Switch to Gal/Min
3. Set sprayer to 40 PSI
4. Hold calibrator below the nozzle at slight angle
5. Wait till read out is displayed
Chapter 3: Maintaining a Good Spray Pattern

Maintain proper boom height

- Determined by nozzle spacing and degree of fan
- The chart below shows the relationship of boom height and nozzle angle to the amount of spray overlap.
- For ideal spray coverage, the nozzles should provide 100% overlap
- If a boom is set up on 20 inch nozzle spacing's with 110 degree nozzles, the lowest boom height that will provide 100% overlap would be 15 inches.

<table>
<thead>
<tr>
<th>Nozzle Angle</th>
<th>20” Nozzle Spacings</th>
<th>30” Nozzle Spacings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30-50% Overlap</td>
<td>100% Overlap</td>
</tr>
<tr>
<td>73 Degree</td>
<td>20</td>
<td>NR</td>
</tr>
<tr>
<td>80 Degree</td>
<td>17</td>
<td>24</td>
</tr>
<tr>
<td>110 Degree</td>
<td>10</td>
<td>15</td>
</tr>
</tbody>
</table>

Barnhart, 2013
Chapter 3: Maintaining a Good Spray Pattern

Maintain proper boom height

• Improper boom height can increase the amount of chemical being applied to a crop row.
• This picture shows that the target height was at 4 inches, but the canopy height was at 16 inches.
• This example would indicate that 175% of the desired rate is being put overtop of the corn plant because the boom height was too close to the canopy.

Influence of canopy height on herbicide interception

% of desired rate intercepted

16” 175%
12” 140%
8” 117%
4” 100%

Barnhart, 2013
Chapter 4: Selecting a Proper Nozzle Output

• Desired gallons per acre must be determined to decide nozzle output
  • This will depend on what type of chemical is being sprayed
    • Contact pesticides once in the plant do not move from where the droplet landed
      • Examples
        • Strobilurin fungicides
        • Fomesafen
        • Glufosinate
      • Use high volumes of water and a small droplet size
    • Systemic pesticides once in the plant move throughout the entire plant.
      • Examples
        • Dicamba
        • 2-4D
        • Glyphosate
      • Larger droplet sizes with lower volumes of water can be used
Chapter 4: Selecting a Proper Nozzle Output

**Contact**
- Coverage is extremely important
  - High carrier volumes
  - Small droplets

**Systemic**
- Coverage not as important
  - Lower carrier volumes
  - Larger droplets

Herbicide Example
Chapter 4: Selecting a Proper Nozzle Output

- Here are a few examples of pesticides showing activity as contact or systemic:

<table>
<thead>
<tr>
<th>Contact (non-translocated)</th>
<th>Intermediate*</th>
<th>Systemic (translocated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aim</td>
<td>Atrazine</td>
<td>Glyphosate</td>
</tr>
<tr>
<td>Authority/Spartan</td>
<td>Princep/</td>
<td>Balance</td>
</tr>
<tr>
<td>Basagran</td>
<td>Simazine</td>
<td>Beacon</td>
</tr>
<tr>
<td>Blazer</td>
<td>Sencor</td>
<td>Exceed, Spirit</td>
</tr>
<tr>
<td>Buctril/Moxy</td>
<td>Command</td>
<td>Glean</td>
</tr>
<tr>
<td>Cobra</td>
<td>Liberty</td>
<td>Permit</td>
</tr>
<tr>
<td>Gramoxone</td>
<td>Ignite</td>
<td>Harmony</td>
</tr>
<tr>
<td>Flexstar</td>
<td></td>
<td>Peak</td>
</tr>
<tr>
<td>Reflex</td>
<td></td>
<td>Stinger</td>
</tr>
<tr>
<td>Resource</td>
<td></td>
<td>Basis</td>
</tr>
<tr>
<td>Ultra Blazer</td>
<td></td>
<td>Tordon</td>
</tr>
</tbody>
</table>

* Command & triazine herbicides move upward from roots to leaves when soil applied, but not down from foliage to the roots if post applied. Liquid fertilizer can provide contact action. Simazine is not as effective post as other triazines. Barnhart, 2013
Chapter 4: Selecting a Proper Nozzle Output

- Nozzle output selection is based on
  - Gallons per acre desired
  - Speed
  - Nozzle orifice size
  - Nozzle pressure

- Once nozzle output conditions are determined, nozzle manufacturer charts can be used to figure out which nozzle size is needed.
  - 1\(^{st}\) select the pressure the nozzle should be run at
  - 2\(^{nd}\) select the speed that the sprayer will be running at
  - 3\(^{rd}\) move down the chart to find the desired gallons per acre
  - 4\(^{th}\) select the proper nozzle size based on the above information

- The next few slides give some samples of how to use the manufacture’s charts to come up with the correct nozzle orifice size.
**Goal**

- Volume: 15 GPA
- Pressure: 40 PSI
- Speed: Fast as Possible

**TeeJet**, 2014
Chapter 5: Selecting the Proper Nozzle

• Micron size comparisons

- 615 µm: period at end of sentence, light rain
- 300 µm: toothbrush bristle, fine misty rain
- 2000 µm: #2 pencil lead, heavy thunderstorm rain
- 40 µm: limit of visibility to naked eye
- 17 µm: fog
- 105 µm: human hair mist
- 210 µm: 2 sheets of paper
Chapter 5 Video: Selecting the Proper Nozzle, spray patterns

Nozzle Spray Patterns

https://www.youtube.com/watch?v=dmuqKQrVNZ8&feature=player_detailpage
Chapter 6: Managing Drift

• Why manage drift?
  • Drift can cause off target injury
  • Drift reduces the amount of chemical being applied

• Ways to decrease drift
  • Decrease spray pressure
    • Slow down
    • Increase the size of the nozzle orifice
    • Use of Pulse Width Technology
  • Change spray tips to tips with larger droplet sizes
  • Use a drift control agent

• What are different factors that effect drift
  • Droplet size
  • Wind speed
  • Boom height
  • Pesticide being sprayed
Chapter 6: Managing Drift

Pressure Comparison

https://www.youtube.com/watch?v=Ykkm5uhwSKk&feature=player_detailpage
Chapter 6: Managing Drift

- Effect of herbicide on percentage of driftable fines
  - Notice that every herbicide to the right of this bar increases driftable fines

XR 11003 @ 43.5 PSI

Cumulative % Fines < 141 um

2,4-D ester
Clethodim 2
Saflufenacil mix 2
2,4-D acid 1
Isoxaflutole
Saflufenacil + glyph mix
2,4-D amine (qt)
Water
Glyphosate K-salt 2
R-11 XR1102
2,4-D amine (pt)
Dicamba DGA (8 oz)
Tembotrione mix
Fomesafen mix
Cloransulam-methyl mix
Dicamba K-salt 1 (1.7%)
Glyphosate K-salt 1 (2.5)

Barnhart, 2013
Chapter 6: Managing Drift

- **Types of Drift Control Agents**
  - **Thickeners or viscosity modifiers**
    - These products thicken up the solutions by changing the viscosity of the solution
    - They work by lumping the fine droplets together
    - These products will also increase the size of larger droplets
    - Viscosity modifiers may decrease the efficacy of certain pesticides
    - These should not be used with Air Induction Nozzles
  - **Encapsulators**
    - These products suspend the pesticide in capsules which are too large to fit in a small droplet
    - They work by greatly decreasing the amount of herbicide in the driftable fines
    - These products do not change the look of the spray
  - **Spray droplet modifiers**
    - Reduces drift by reducing the number of fine droplets
    - This product works differently than the viscosity modifiers because it does not effect the viscosity of the solution
    - This product works by narrowing the range of different sized droplets coming out of a spray nozzle.
    - These products do not decrease pesticide efficacy
    - Droplet modifiers can be used with any spray nozzle
Increasing the viscosity of a spray solution can reduce the fan width on air induction nozzles.

Rickard, 2013

Rickard, 2013

Rickard, 2013

Rickard, 2013
## Chapter 6: Managing Drift

- Use a drift control agent

### Interlock- Spray Droplet Modifier
- Polymer- Viscosity Modifier

### Spray Comparison Wind - Al TeeJet®

<table>
<thead>
<tr>
<th>Water Alone</th>
<th>Herbicide Alone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herbicide + InterLock®</td>
<td>Herbicide + Polymer</td>
</tr>
</tbody>
</table>
Chapter 6: Managing Drift

- **Pulse width technology**
  - Decouples flow rate from application pressure
  - Solenoids are used to rapidly shut the spray pattern on and off at a rate of 10 times per second
  - The flow rate is controlled by varying the width of the pulse.
  - The longer the pulse width, the more chemical is put through the spray tip
    - This change in the width of the pulse is referred to as the duty cycle
  - As the sprayer speeds up, the duty cycle is increased to increase the flow rate through the nozzle. All of this is done without increasing the pressure at the nozzle tip which decreases the drift potential.

### Duty Cycle

<table>
<thead>
<tr>
<th>VALVE</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPEN</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CLOSED</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TIME</th>
<th>10%</th>
<th>50%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPEN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CLOSED</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Wolf, 2013
Chapter 6: Managing Drift

- Pulse width technology
  - When one nozzle is on, its neighboring nozzle is off. This offset pattern provides an even application as long as proper boom height is maintained.

Wolf, 2013
Increasing pressure can decrease droplet size and canopy penetration

Wolf, 2013
Chapter 7: Increasing Deposition/Coverage

- Small droplets decrease terminal velocity which decrease the amount of time for evaporation and the amount of pesticide that penetrates the canopy

<table>
<thead>
<tr>
<th>Droplet Diameter (microns)</th>
<th>Terminal Velocity (ft/sec)</th>
<th>Final Drop Diameter (microns)</th>
<th>Time to Evaporate (sec)</th>
<th>Deceleration Distance (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>.04</td>
<td>7</td>
<td>0.3</td>
<td>&lt;1</td>
</tr>
<tr>
<td>50</td>
<td>.25</td>
<td>17</td>
<td>1.8</td>
<td>3</td>
</tr>
<tr>
<td>100</td>
<td>.91</td>
<td>33</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>150</td>
<td>1.7</td>
<td>50</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>200</td>
<td>2.4</td>
<td>67</td>
<td>29</td>
<td>25</td>
</tr>
</tbody>
</table>

*Conditions assumed: 90 F, 36% R.H., 25 psi., 3.75% pesticide solution

Schoper, 2010
Chapter 8: Adjuvants and Surfactants

• **Adjuvants** are materials added to a spray tank to aid or modify the action of a chemical
  • Some adjuvants are made to increase the efficacy of the spray solution
  • Some adjuvants are made to increase ease of handling for a particular chemical

• **Surfactants are Surface Acting Agents**
  • These products change the surface tension of the water usually reducing it to increase droplet spread on a leaf
  • All surfactants are adjuvants, but not all adjuvants are considered surfactants
    • Those adjuvants that do not effect the surface tension of water are not considered surfactants

• **Adjuvant usage**
  • Certain adjuvants will increase the activity of some pesticides while decreasing the effectiveness of other pesticides, so it is important to know which adjuvant to use with which type of application.
  • Pesticide labels will often tell a user which type of adjuvant should be used with a particular product.
Chapter 8: Adjuvants and Surfactants

**Surfactants**

Mode of action: decrease surface tension of water
Preference is a non ionic surfactant
Interlock is a spray droplet modifier

https://www.youtube.com/watch?v=SqxV5RnvRm4&feature=player_detailpage
**Chapter 8: Adjuvants and Surfactants**

- **Crop Oil Concentrates (COC)**
  - Increases efficacy of certain herbicides by increasing the amount of herbicide that moves through the waxy layers of the leaf surface
  - Oils can also help with droplet spreading across the leaf surface
  - Certain formulations of this product can decrease the efficacy of glyphosate
  - Only use High surfactant oil Concentrates (HC) formulations with glyphosate
  - The example below shows the increase efficacy with a COC on an ACCase group 1 herbicide

<table>
<thead>
<tr>
<th>Without Crop Oil Concentrate</th>
<th>With Crop Oil Concentrate</th>
</tr>
</thead>
</table>

Barnhart, 2013
Chapter 8: Adjuvants and Surfactants

- Adjuvant recommendations may change depending on
  - Weather conditions
  - Weed height
  - Crop stage and height

Oils and Fertilizers
- Methylated Seed Oils
- Crop Oil Concentrates
- Surfactants and Fertilizers
- Nitrogen Fertilizers
- Silicone Surfactants
- Non-Ionic Surfactants

Spray Conditions
- Good
- Adverse

Weed Control and/or Crop Injury
- High
- Low

Barnhart, 2013
Chapter 8: Adjuvants and Surfactants

Glyphosate Molecule

\[ \text{HO - C - CH}_2\text{-N - CH}_2\text{-P - O}^- \]
Chapter 8: Adjuvants and Surfactants

Ammonium Monosulfate Molecule (AMS)

Glyphosate Molecule

\[
\text{Ca}^{2+} \quad \text{CH}_3 \quad \text{O} \quad \text{CH}_3 \\
\text{H}_3\text{N} - \text{CH} + \text{O} - \text{S} - \text{O} \quad \text{Ca}^{2+} \quad \text{CH}_3 - \text{NH}_3 \\
\text{Ca}^{2+} \quad \text{CH}_2 \quad \text{O} \quad \text{CH}_3
\]
Here are two different water analysis reports, notice that both of them require a different amount of AMS to counteract the Cations in the solution.

### Spray Water Analysis Report

<table>
<thead>
<tr>
<th>Agrivite B.D.M.</th>
<th>Winfield Solutions AM =</th>
<th>Coefficient</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company Name:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mailing Address</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>City</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>State</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zip</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phone</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Water Source** = WELL

**Sample ID.** = 1 GRAFTON, IA SAMPLE

**Date Received** = 10-18-04

**Date Reported** = 10-20-04

**AGVISE Lab No** = 10788

<table>
<thead>
<tr>
<th>pH</th>
<th>Antagonism</th>
<th>Coefficient</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.7</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Sodium | 248 ppm | 0.005* | 1.23918 |
| Calcium | 320 ppm | 0.009* | 2.88056 |
| Magnesium | 140 ppm | 0.014* | 1.96266 |
| Potassium | 14.0 ppm | 0.002** | 0.028 |
| Iron | 0.301 ppm | 0.014* | 0.00421 |
| Hardness (mg equivalent CaCO3/L) | 1386 ppm |  |
| SAR (Sodium Adsorption Ratio) | 2.91 |  |

Recommended AMS required for 100 gallons of water = 0.72 lbs AMS

Note: The amount of AMS given above is an estimate of the amount required to overcome the antagonistic effect of the cations in your water. This estimate is based on the cations listed above and the coefficients provided by North Dakota State University* and Agrivite **.

---

**Spray Water Analysis Report**

<table>
<thead>
<tr>
<th>Water Source</th>
<th>CITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample ID.</td>
<td>NA</td>
</tr>
<tr>
<td>Date Received</td>
<td>12-20-12</td>
</tr>
<tr>
<td>Date Reported</td>
<td>12-21-12</td>
</tr>
</tbody>
</table>

**AGVISE Lab No** = 12-10846

<table>
<thead>
<tr>
<th>Antagonism</th>
<th>Coefficient</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.7</td>
<td></td>
</tr>
<tr>
<td>Sodium</td>
<td>248 ppm</td>
<td>0.005*</td>
</tr>
<tr>
<td>Calcium</td>
<td>320 ppm</td>
<td>0.009*</td>
</tr>
<tr>
<td>Magnesium</td>
<td>140 ppm</td>
<td>0.014*</td>
</tr>
<tr>
<td>Potassium</td>
<td>14.0 ppm</td>
<td>0.002**</td>
</tr>
<tr>
<td>Iron</td>
<td>0.301 ppm</td>
<td>0.014*</td>
</tr>
<tr>
<td>Hardness (mg equivalent CaCO3/L)</td>
<td>1386 ppm</td>
<td></td>
</tr>
<tr>
<td>SAR (Sodium Adsorption Ratio)</td>
<td>2.91</td>
<td></td>
</tr>
</tbody>
</table>

Recommended AMS required for 100 gallons of water = 6.11 lbs AMS

Note: The amount of AMS given above is an estimate of the amount required to overcome the antagonistic effect of the cations in your water. This estimate is based on the cations listed above and the coefficients provided by North Dakota State University* and Winfield Solutions **.

---

*Schoper, 2010

*Barnhart, 2013
High fructose corn syrup and alkyl polygulcoside (CornSorb Technology)
  • Increases leaf uptake of herbicides and micronutrients
    • Increases humectancy of solution
      • Keeps the droplet wetter longer
    • Increase uptake through the waxy layers on the leaf
Chapter 9: General Mixing Order

- General pesticide mixing order
- Wales or dales method
  - Fill the sprayer half way full of water
  - (D/W) Add Wettable powders, Water dispersible granules, and/or Dry flowables
    - If formulations are having trouble dissolving, consider pre-slurrying them in a bucket of water and then adding them to the tank especially when mixing with liquid fertilizer
  - (A) Agitate
  - (L) add Liquid formulations
  - (E) add Emulsified concentrates
- Other considerations
  - Surfactants, oils, and drift control agents should be added last
  - If a compatibility agent is required, it should be the first thing in the tank
  - AMS and adjuvants containing AMS should be added before herbicides requiring water conditioning agents (glyphosate, Liberty, etc.)
  - Suspension Concentrates (SC) formulations should be added to the tank first because of the reduction in solubility at lower pH’s
Chapter 10: General Cleaning Procedures

- General cleaning guidelines
  - Most sprayer contamination occurs in the lines and tips rather than the tank
  - Make sure to look for dead spots in the sprayer
    - Dead spots are any areas on the sprayer that do not have flowing water through them during operation
      - This could be a line off the manifold that is not in use such as a fence row sprayer
      - The more common area where this occurs is in a wet boom where the line extends past the last nozzle and is capped at the end
  - These dead spots can have chemical hang up in them, every time the sprayer is stopped, some of that chemical dissolves back into the line
    - Example: It takes as little as 0.0005 ounces/acre to see visual damage to soybeans with Dicamba and only 0.04 ounces/acre to have yield loss
  - To help avoid contamination in the lines, flush with water and tank cleaner after every day of spraying
Chapter 11: Conclusion

- Adding pesticides into a spray tank does not guarantee that the pesticide will make it to the site of action to kill the pests.
- Applicators can increase the chances of controlling pests by
  - Calibrating the sprayer
  - Maintaining even applications across the entire boom
  - Choosing the right nozzles, droplet sizes, and gallons per acre
  - Controlling drift and managing deposition into the canopy
  - Using adjuvants
  - Mixing in the correct order
  - Cleaning the sprayer correctly after an application is finished
References


Wolf, R. (Director) (2013, March 15). Management and Behavioral Changes for Controlling Weeds, Insects, and Diseases. Lecture conducted at River Falls, WI.