Understanding Effective Citrus Spray Application through Computer Simulations

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UC Ag Experts Talk
Citrus Spray Training Webinar
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University *of* California
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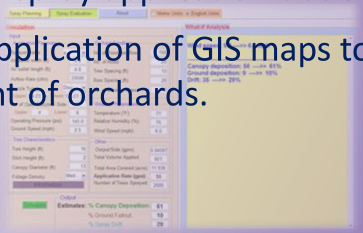
Program Overview





- Development and deployment of DSSs to assist growers and applicators with spray application decisions.
- Development and application of GIS maps to enable site-specific management of orchards.

- Effectiveness and efficiency assessment the of commercial equipment, sensor, and control systems for site-specific and precise spray application.

AGAPPE Lab Program Themes

- Deploying Spray Application Decision Support Systems
- Testing Commercial Spray Application Technologies
- Promoting Best Practices for Safe, Economical & Environmentally Sound Pesticide Spray Application
- Evaluating Spray Application Techniques
- Developing Novel Spray Application Technologies


- Needs assessment of grower and applicator spray application equipment and practices.
- Organizing and conducting timely and need-based training and technology transfer in pesticide spray application.
- Developing and disseminating science-based information for the clientele

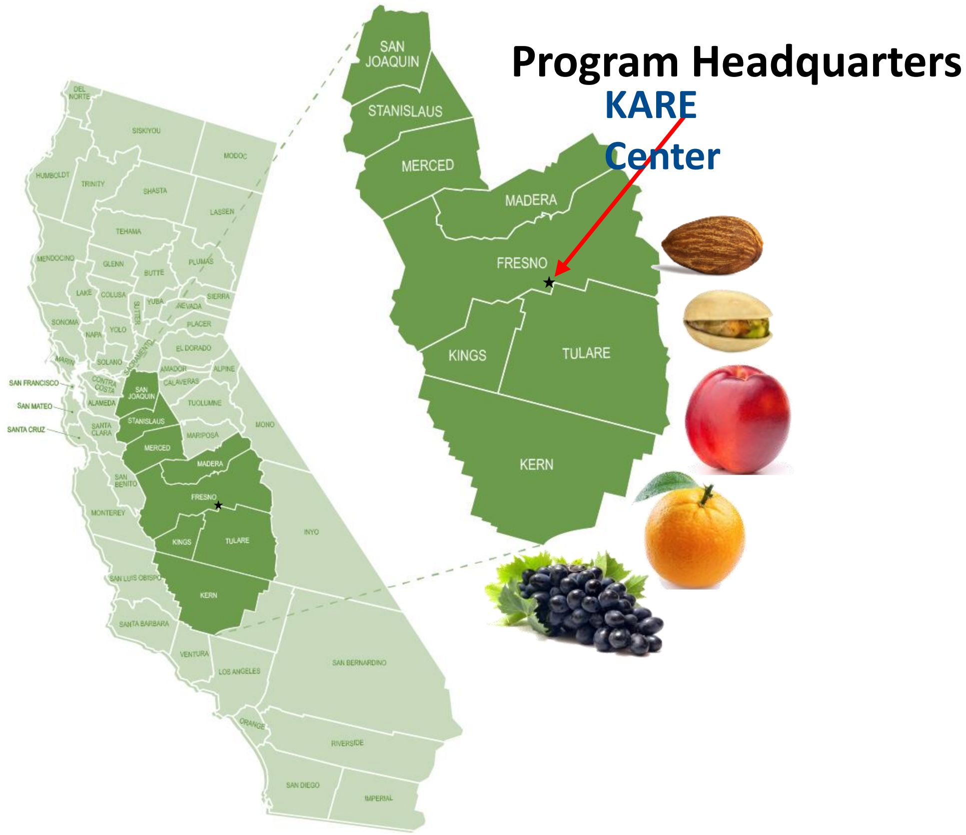
- Development of equipment and real-time sensing and control systems for precise & automated spray application.






- Evaluation of orchard spray application effectiveness based on different sprayers & different sprayer configurations.

Background



- Airblast sprayers are the main types of sprayers used for pesticide application.
- Critical need to achieve high on-target deposition and coverage with minimal losses for effective and economical pest and disease control.
- However, significant material loss can result due to drift and ground fallout because of variability in tree canopy profile and size.
- Such losses lead to increased production costs and reduced profits.

Airblast Spray Dispersion

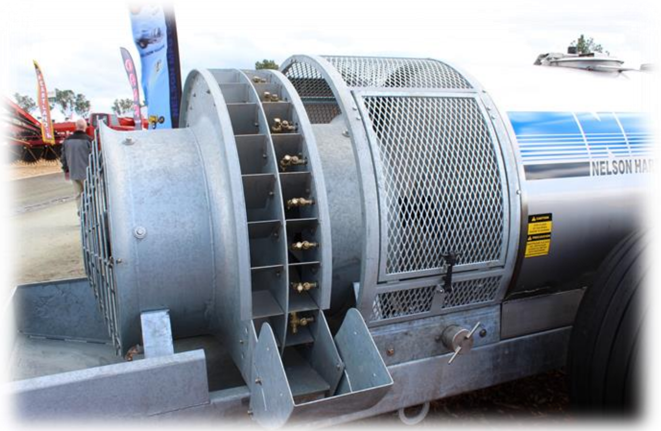


Photo: Conventional airblast sprayer with typical polar jet design.
Credit: **Peter Ako Larbi**

Photo taken 2009 in a citrus plot at University of Florida's Citrus Research and Education Center in Lake Alfred, Florida.
Credit: **Peter Ako Larbi**

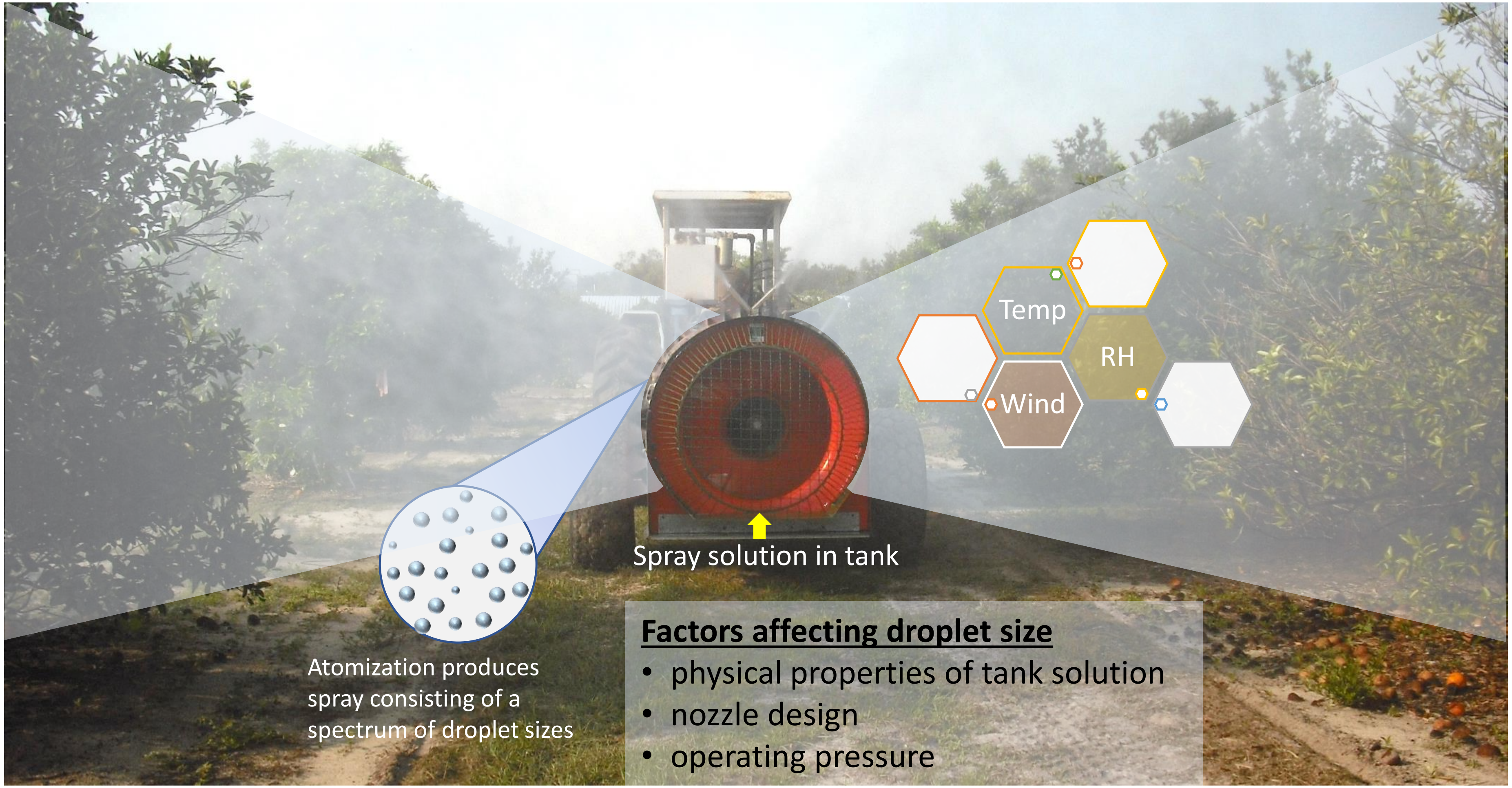
Airblast Spray Essentials

- Air-carrier/Air-blast Spraying

Atomization of tank mix liquid → **Transport** of spray droplets toward trees →

- **Drift** beyond canopy
- **Deposition** on intercepting canopy
- **Ground** deposit: directly/indirectly

Dynamics of Airblast Spray Application



Poll Questions

1. **Which of the following is true about airblast sprayers?**
   a) Airblast sprayers are mainly used to apply herbicides.
   b) Airblast sprayers have limited use in citrus pest control.
   c) Airblast sprayers use a high-volume high-velocity air to transport spray droplets.

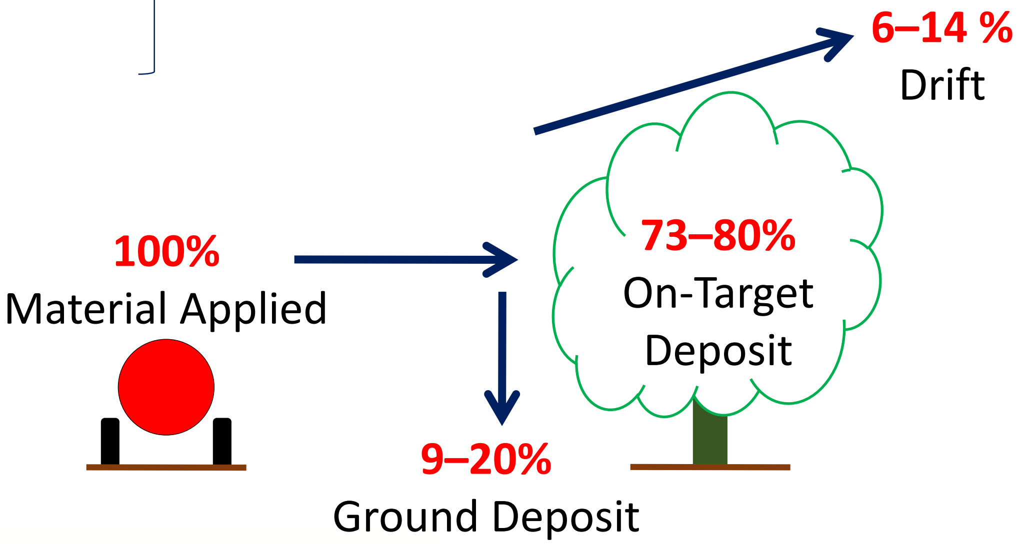
2. **At any instance during an airblast spray application, which of the following defines the target trees?**
   a) The target trees are all the trees in the orchard.
   b) The target trees are the trees adjacent to the sprayer in the immediate tree rows that are directly being sprayed.
   c) The target trees are all the trees that the sprayer has already sprayed.

3. **Which of the following is a desired outcome of airblast spray application?**
   a) Canopy deposition.
   b) Spray drift.
   c) Ground deposition.

Material Balance in Spray Application

- Lower than desired on-target spray deposition persistently occurs in citrus spray application due to several interacting factors
  - equipment design
  - application parameters
  - spray physical properties
  - tree characteristics
  - weather condition

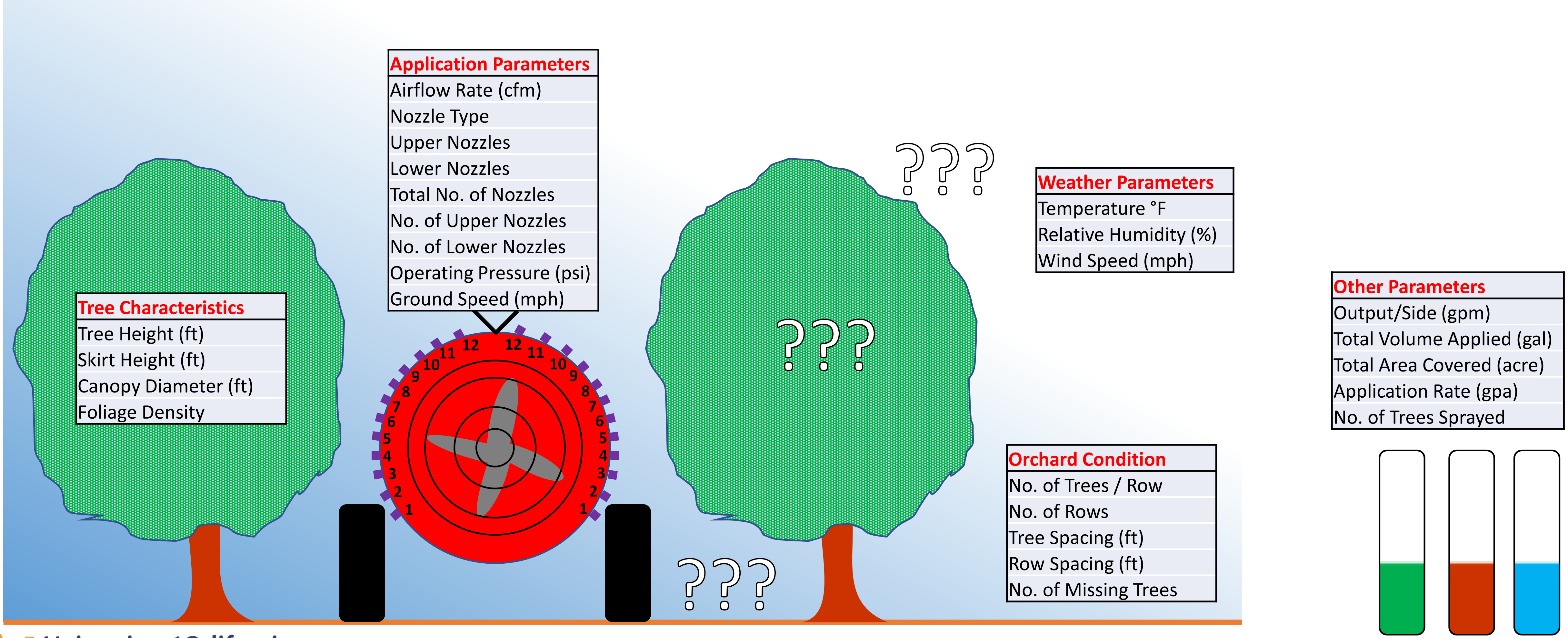
Complex interactions influence on-target spray deposition and off-target losses



18–26% Total Off-target Losses

(Salyani et al., 2007)

Computer Modeling Motivation



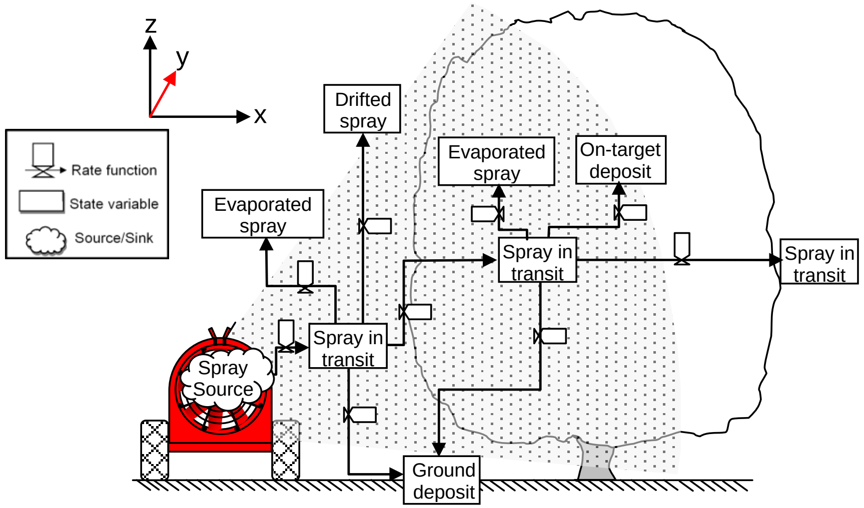
Not this model!!!

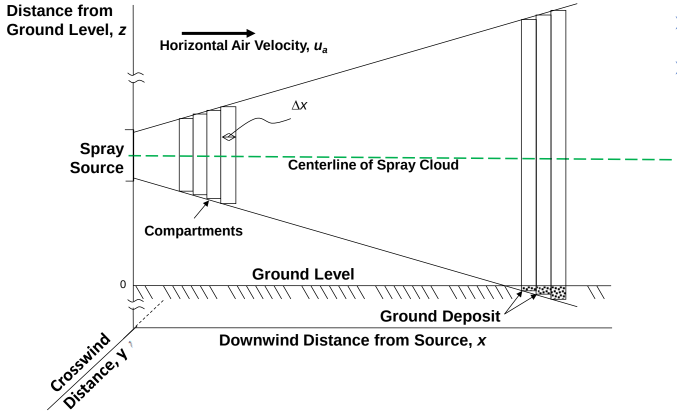
Not this!!!

Not this!!!

Not this!!!

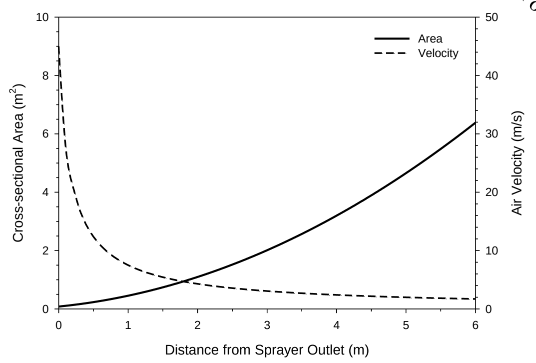
Spray Model

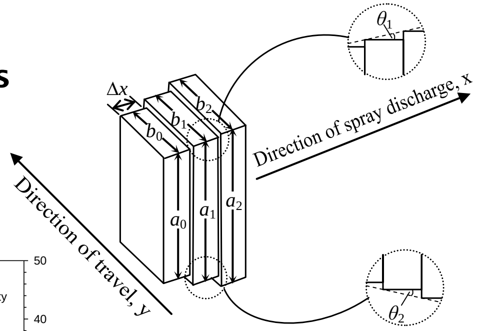


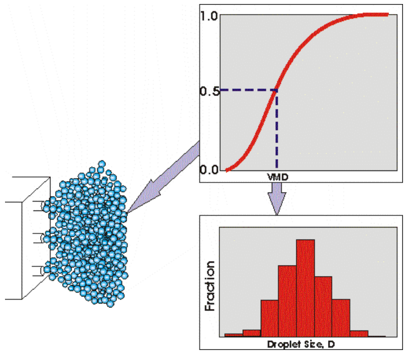


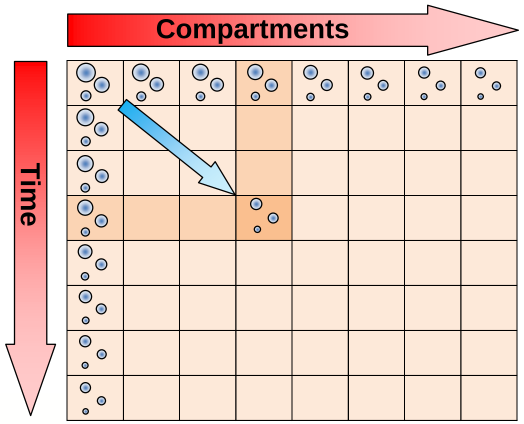
Compartment Characteristics

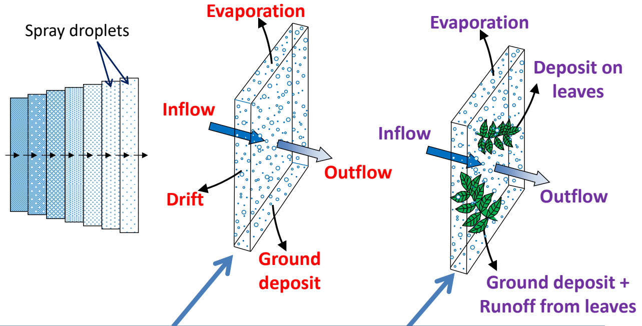
- Cross-sectional area
- Volume
- Air velocity







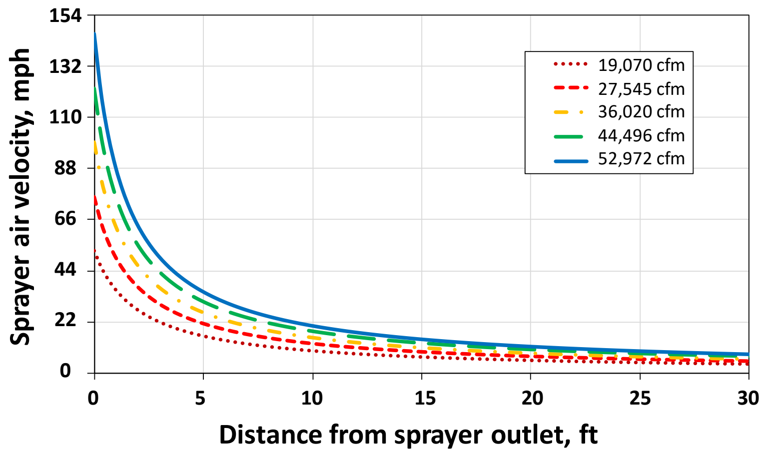


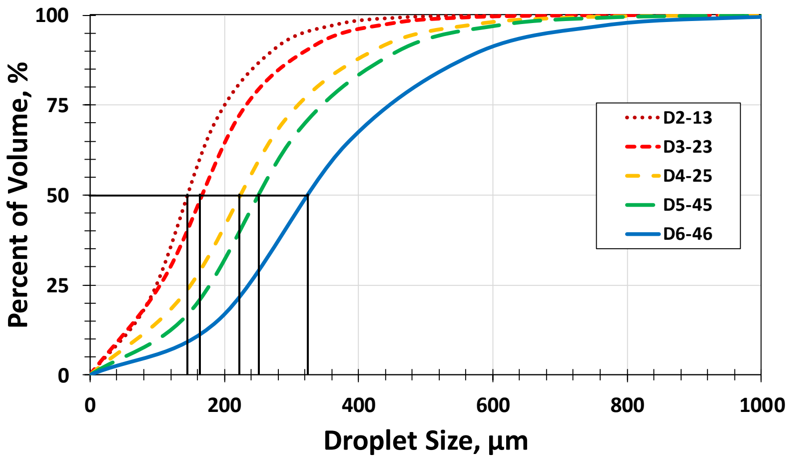


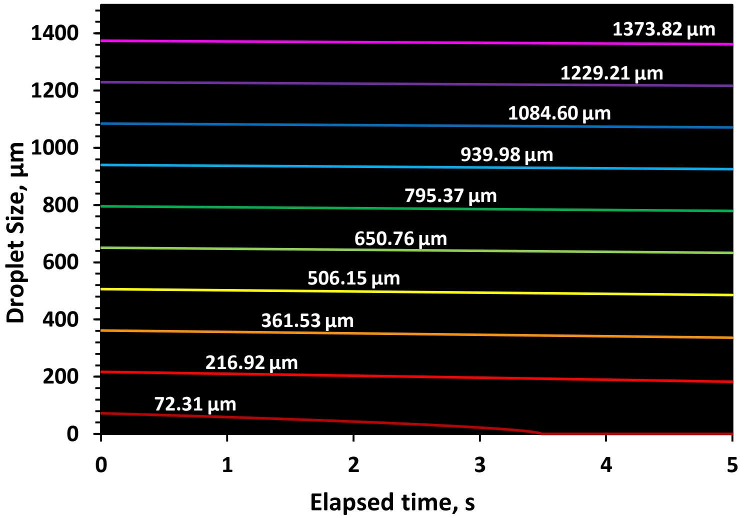
$$\frac{dm_x(t)}{dt} = f_{in,x}(t) - f_{out,x}(t) - f_{vap,x}(t) - f_{drift,x}(t) - f_{ground,x}(t)$$ Outside canopy

$$\frac{dm_{x'}(t)}{dt} = f_{in,x'}(t) - f_{out,x'}(t) - f_{vap,x'}(t) - f_{dep,x'}(t) - f_{runoff,x'}$$ Inside canopy

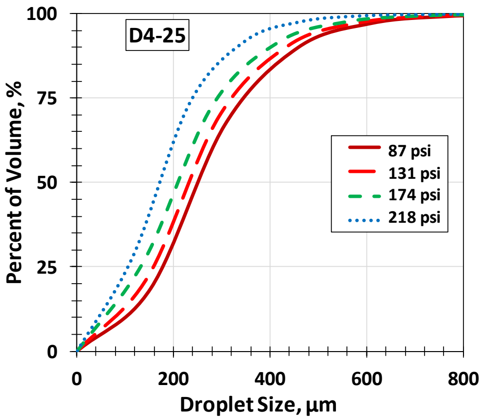
Spray Simulation



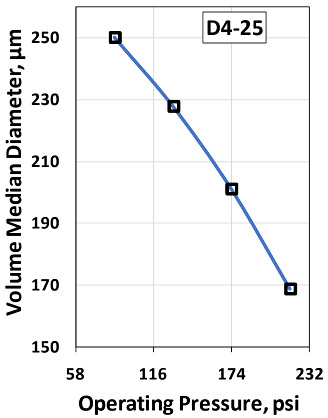




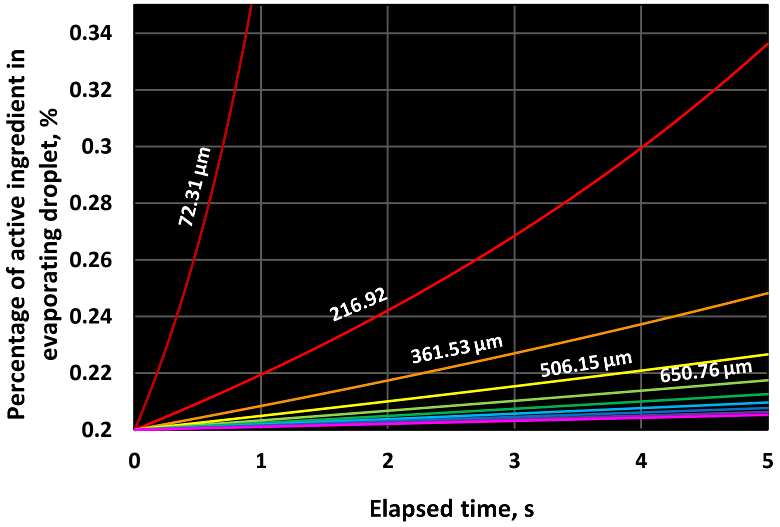
(a)



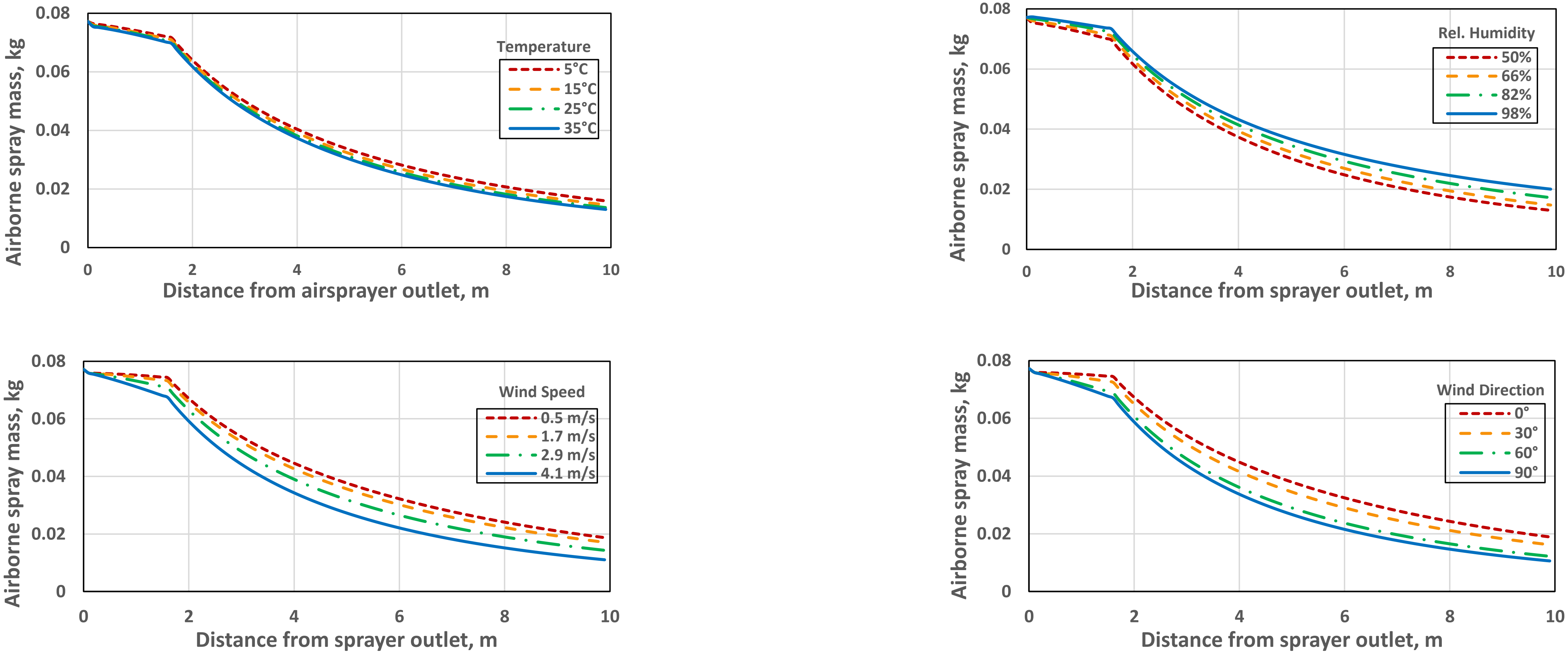
(b)



Nozzle	VMD (µm)	ASABE Droplet Category
D2-13	148.39	Very Fine to Fine
D3-23	166.33	Fine
D4-25	219.63	Fine to Medium
D5-45	252.32	Fine to Medium
D6-46	330.70	Medium to Coarse



Effect of Weather



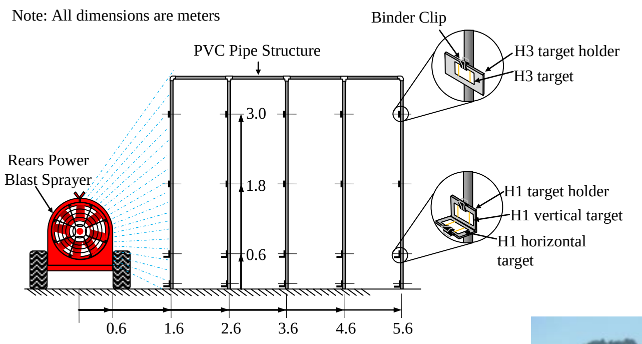
Poll Questions

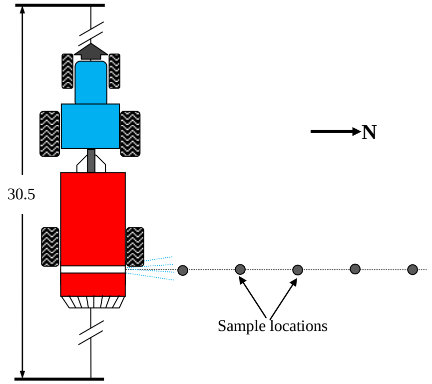
4. **Which of the following reasons incorrectly justifies the need for or use of model simulations?**
   a) It is very difficult to guestimate spray application outcome because of complex interactions among influential factors.
   b) Model simulations eliminate the limitations of actual field experiments in terms of time, labor, material, and other resources.
   c) Model simulations can create very cool graphs that cannot be created with actual field experiments.

5. **Which of the following weather conditions should be avoided because of its effect on spray application?**
   a) High relative humidity because it favors spray drift.
   b) Low air temperature because it favors spray drift.
   c) High wind speed because it favors spray drift.

Model Validation

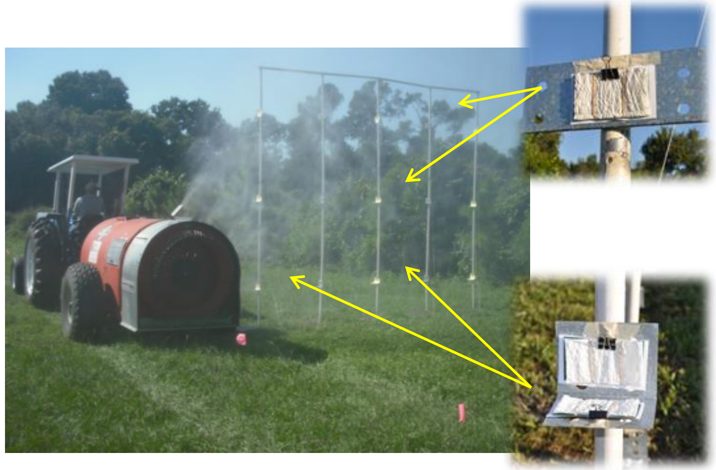
Dispersion Test





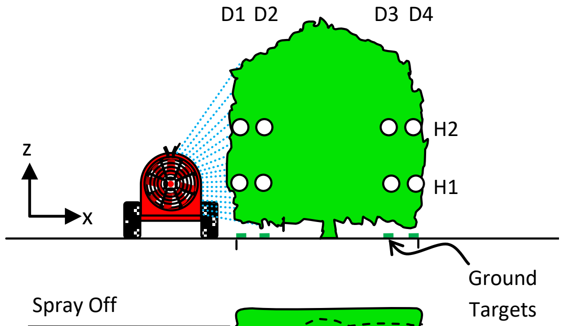
2 Nozzles – Albuz Lilac
– “ Blue

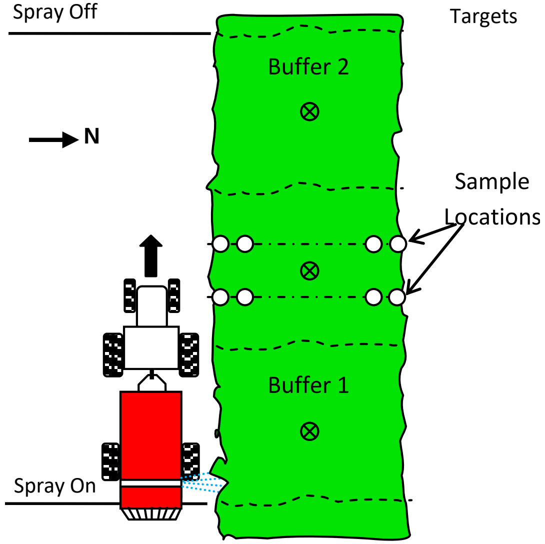
2 Speeds – Slow = 2.4 km/h
– Fast = 4.8 km/h



Deposition Test

Spray liquid consisted of pyranine dye solution and spray analysis was done by fluorometry.



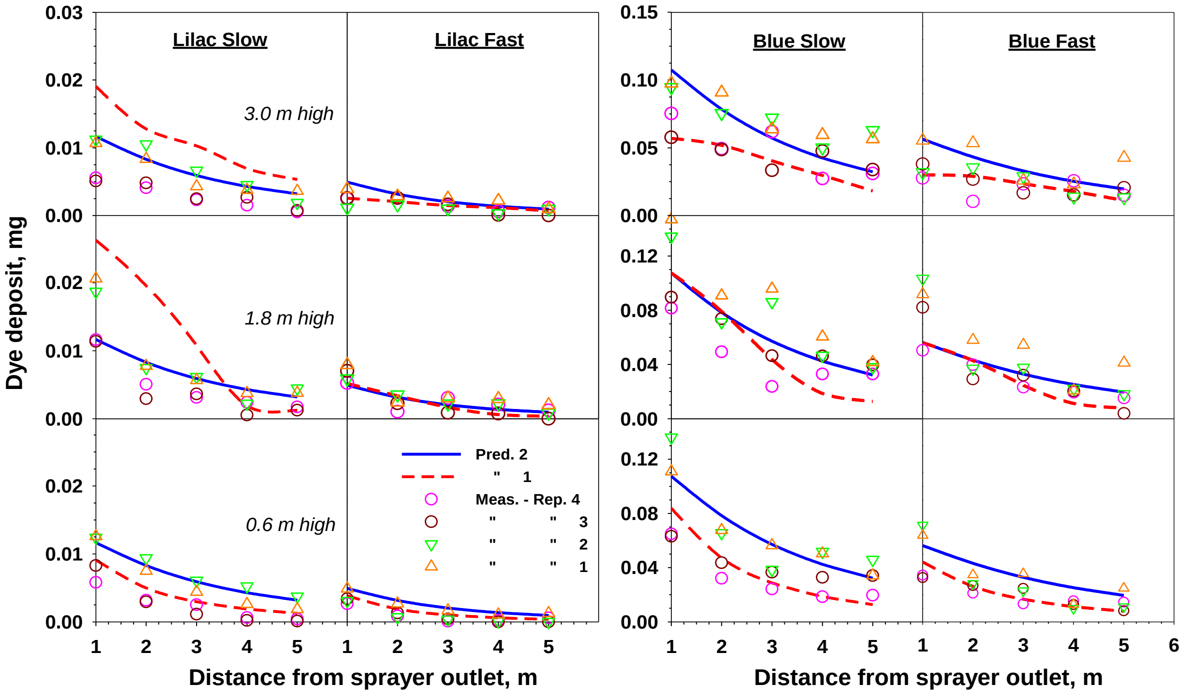


Model Validation

Dispersion Test

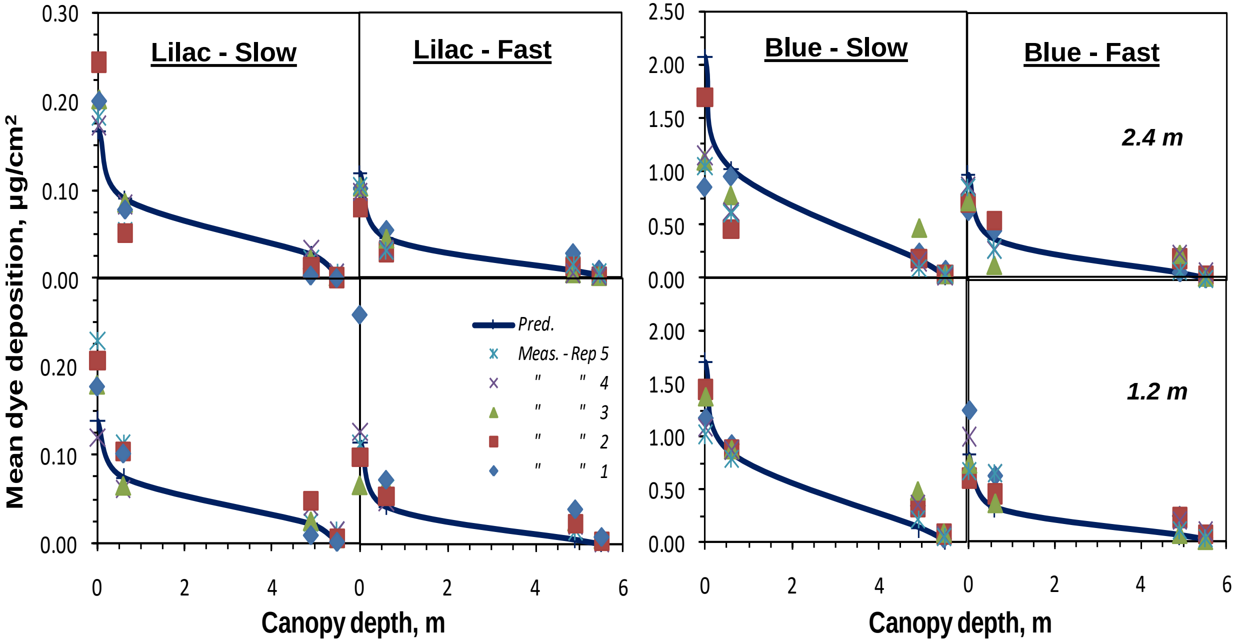
Airborne Spray

Ground deposit



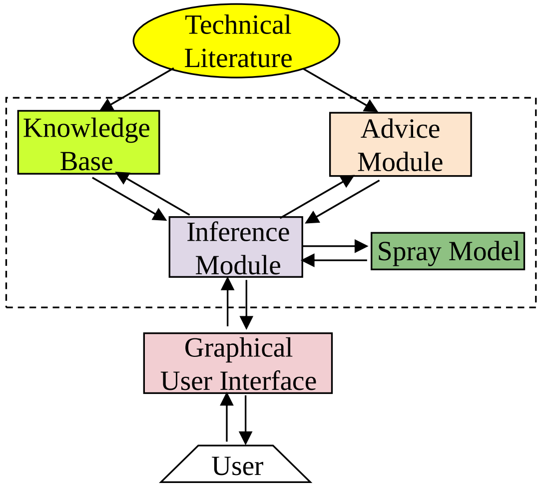
Modeling Efficiency, EF = 78%; Correlation Coef., r = 0.90

Deposition Test

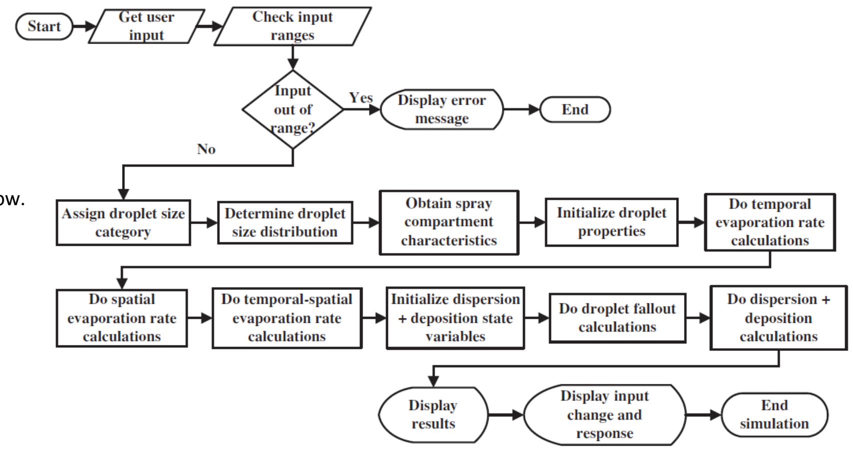


Modeling Efficiency, *EF* = 61%; Correlation Coef., *r* = 0.92

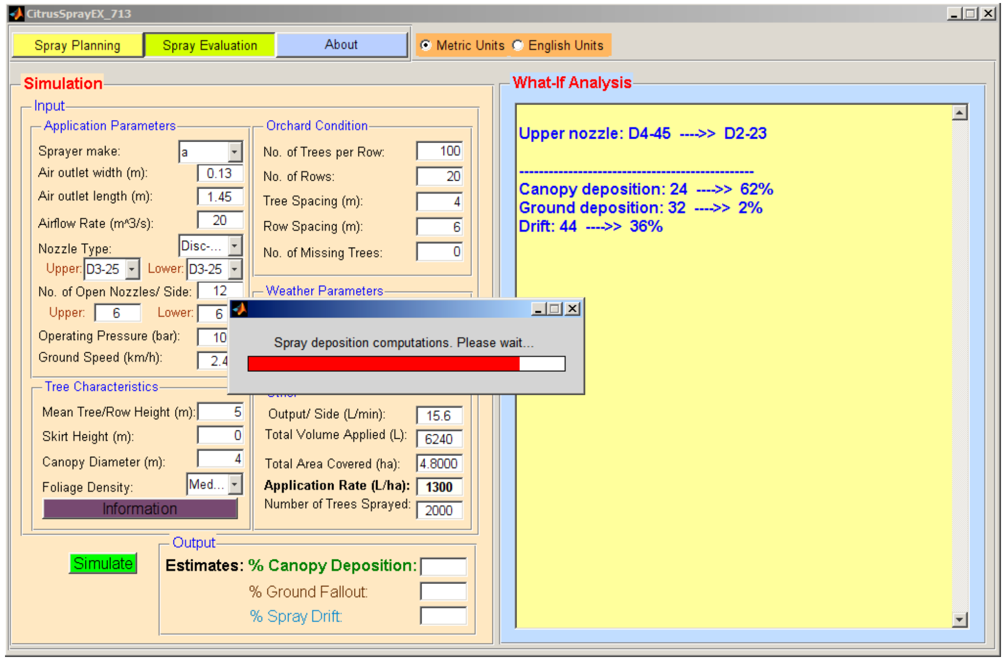
Model-based Expert System



Structure of ES with arrows showing the direction of information flow.



Simplified flowchart for spray evaluation simulation



GUI for spray evaluation showing an ongoing simulation.

Table 6
Percentage of evaluation response for different ratings.[a]

Category, %	Excellent, %	Very good, %	Good	Fair	Poor
ES content	80	20	0	0	0
Presentation	55	35	10	0	0
Effectiveness	30	70	0	0	0
User appeal & suitability	50	30	15	5	0
ES response	55	35	10	0	0
Ease of use	70	30	0	0	0
User interface and media quality	53	27	7	13	0

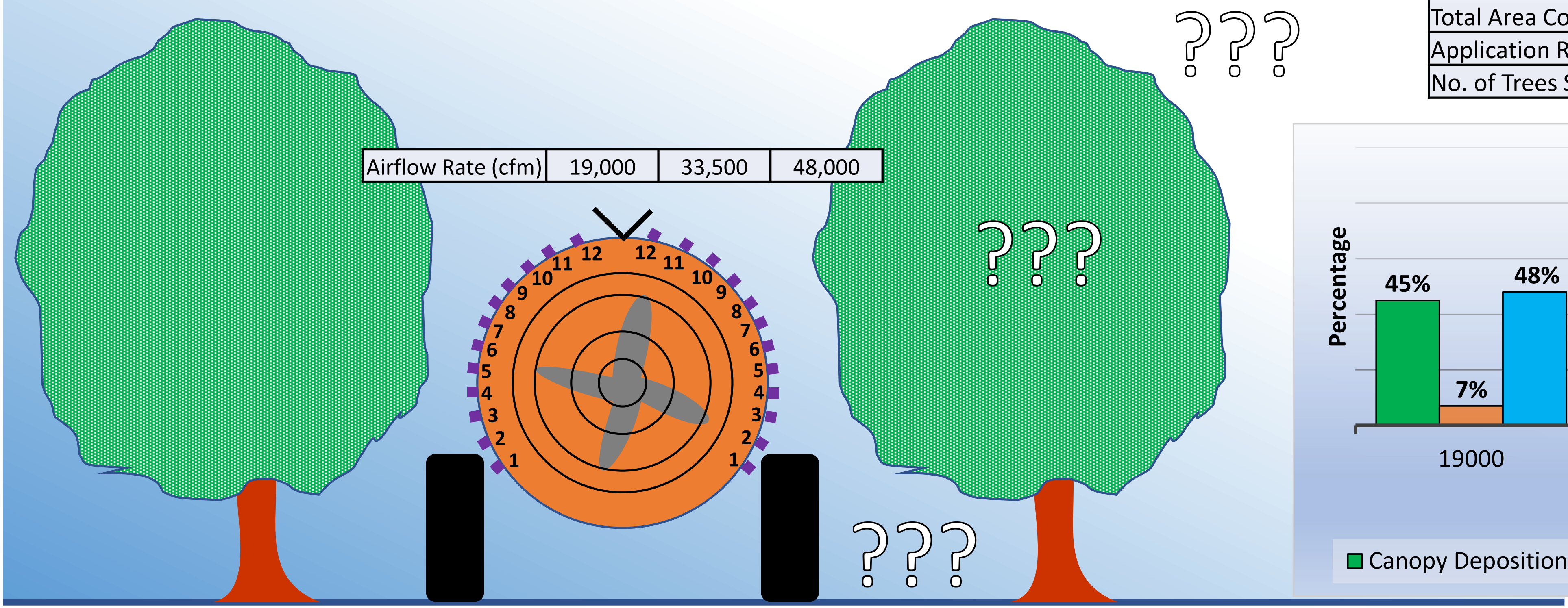
[a] Based on all questions under each category.

Source: **Larbi, P.A.** and M. Salyani. 2012c.

Poll Questions

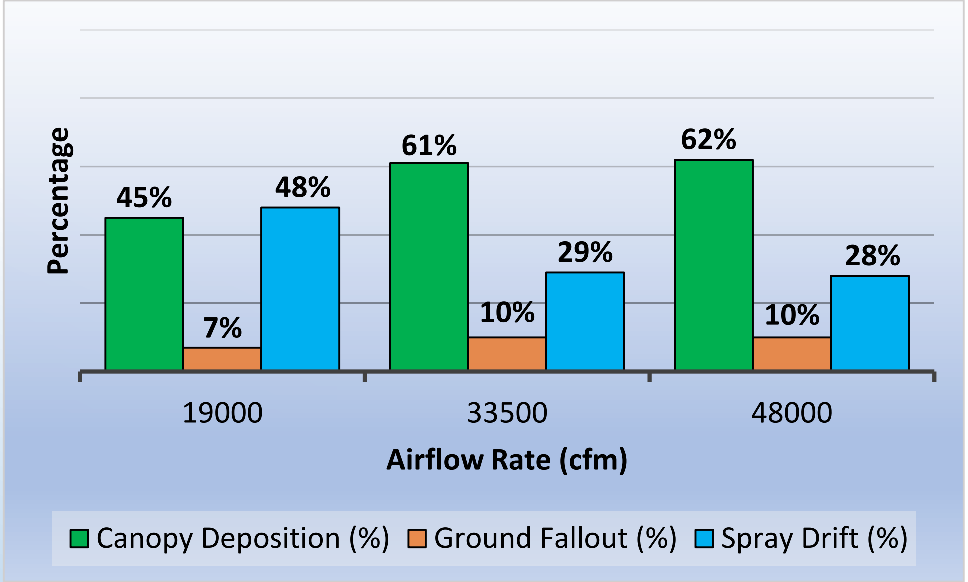
6. **Validating a model with data from an actual field experiment gives us some confidence to trust the model's predictions or make decisions based on it. True or false?**
   a) True.
   b) False.

Airflow Rate



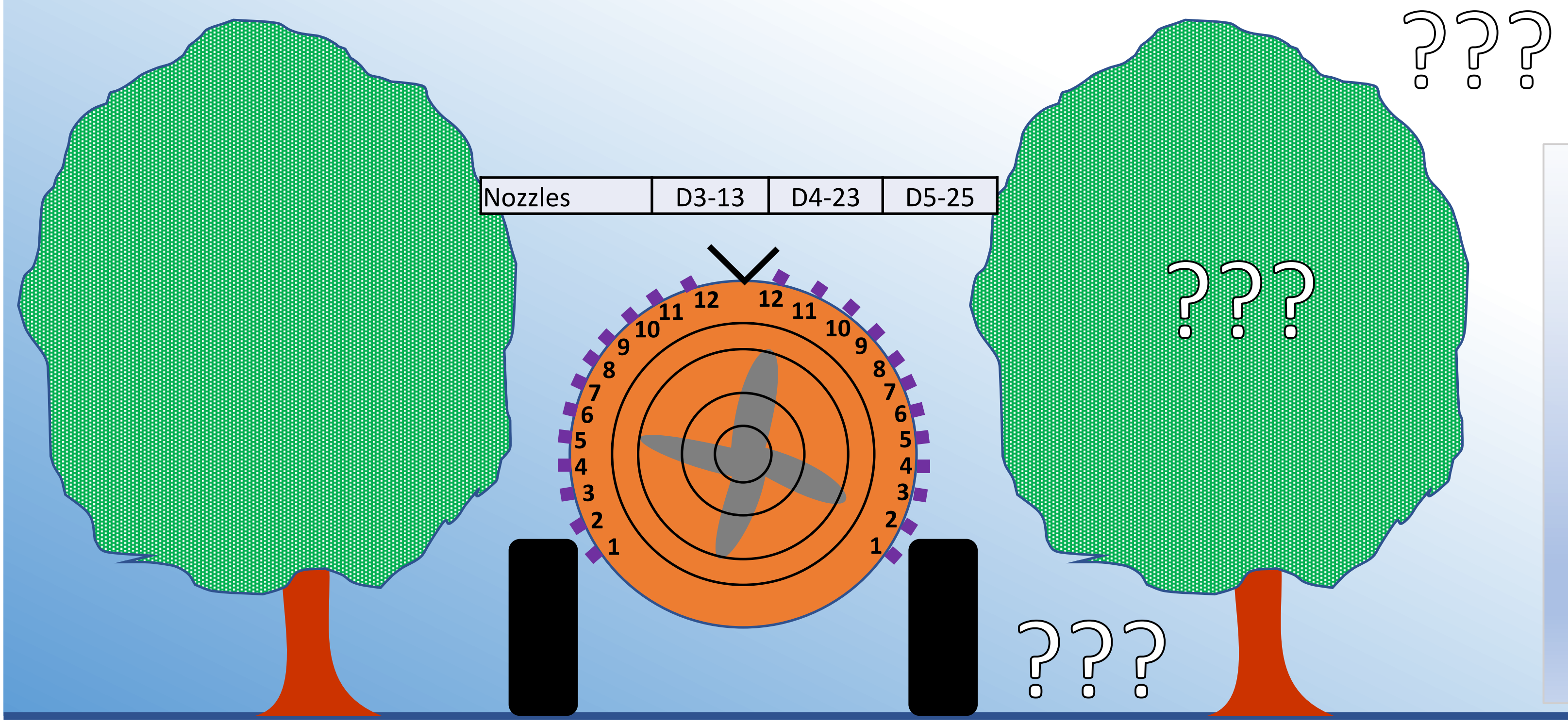
Airflow Rate (cfm)	19,000	33,500	48,000

Other Parameters			
Output/Side (gpm)	0.04587	0.04587	0.04587
Total Volume Applied (gal)	651	651	651
Total Area Covered (ac)	11.938	11.938	11.938
Application Rate (gpa)	55	55	55
No. of Trees Sprayed	2000	2000	2000

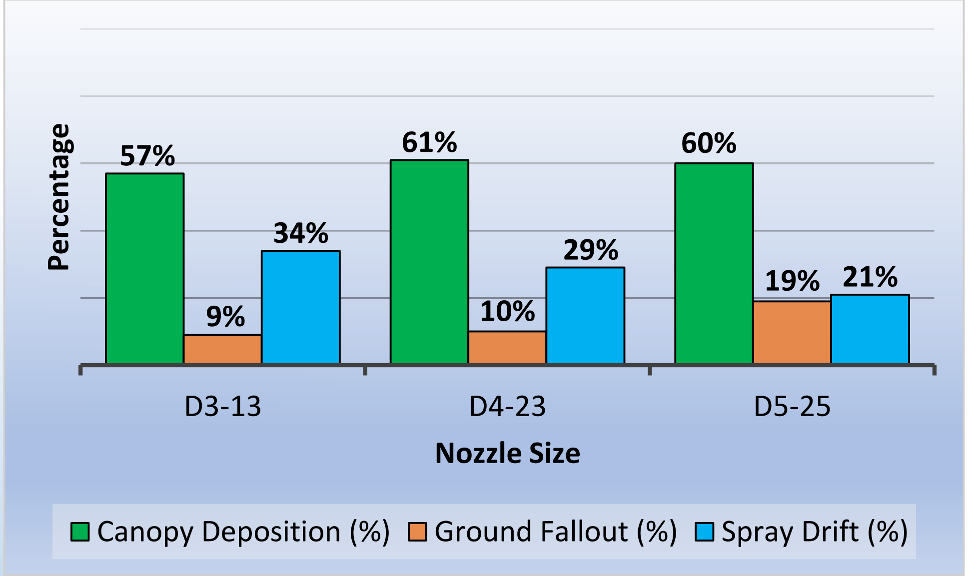


Nozzle Size

Nozzles	D3-13	D4-23	D5-25



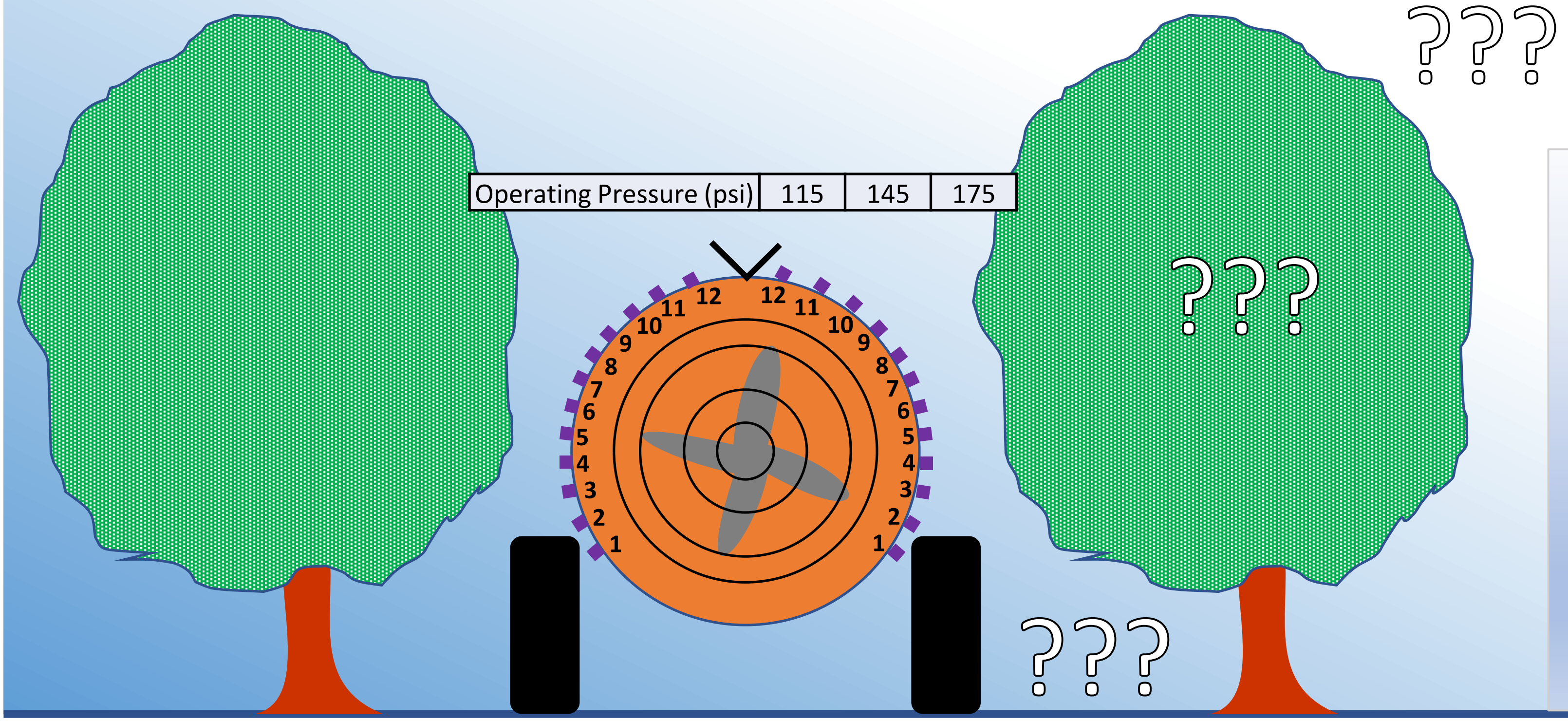
Other Parameters			
Output/Side (gpm)	0.02621	0.04587	0.1065
Total Volume Applied (gal)	372	651	1510
Total Area Covered (ac)	11.938	11.938	11.938
Application Rate (gpa)	31	55	127
No. of Trees Sprayed	2000	2000	2000

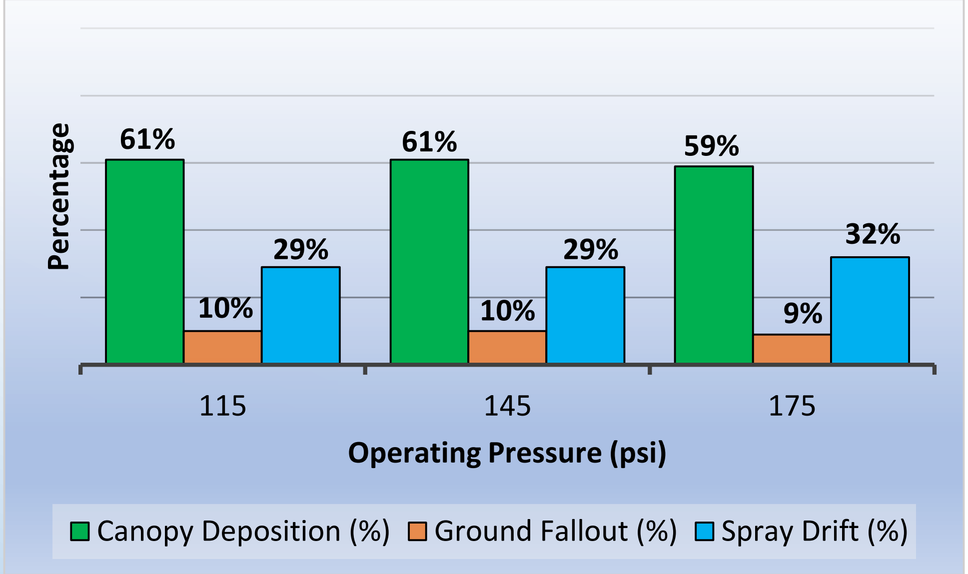


Operating Pressure

Other Parameters			
Output/Side (gpm)	0.0411	0.04587	0.05039
Total Volume Applied (gal)	583	651	715
Total Area Covered (ac)	11.938	11.938	11.938
Application Rate (gpa)	49	55	60
No. of Trees Sprayed	2000	2000	2000

Operating Pressure (psi)	115	145	175



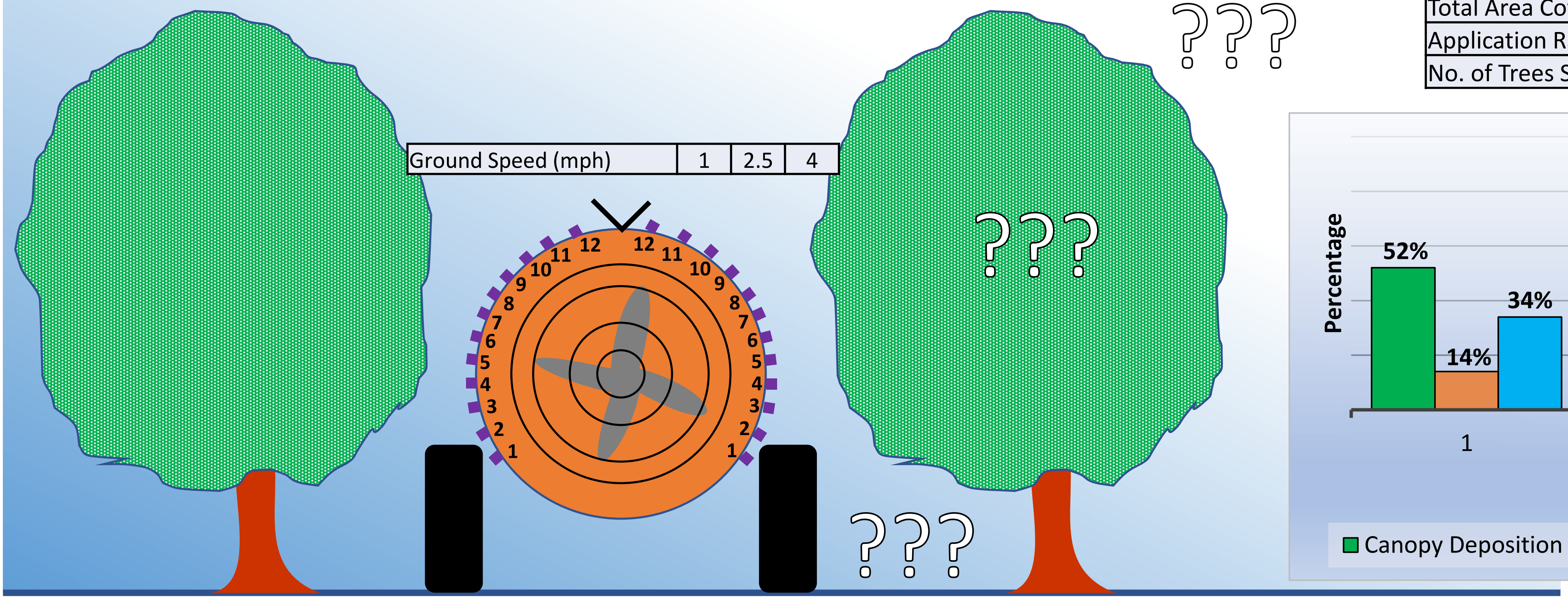


Poll Questions

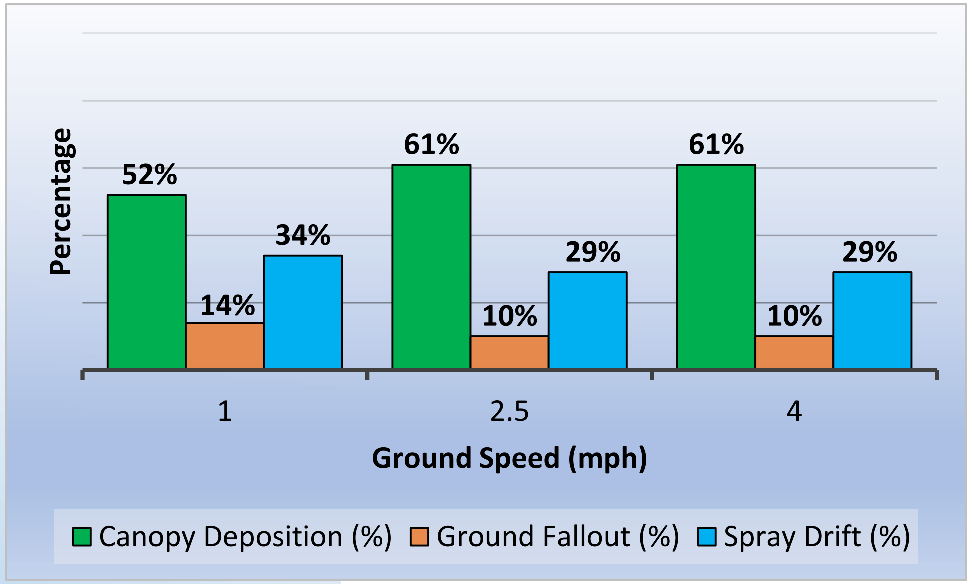
7. **According to model simulation results from preceding slides, which of the following general statements about citrus airblast spray applications is true?**
   a) Increasing airflow rate increases percentage canopy deposition.
   b) Increasing nozzle size increases percentage canopy deposition and percentage potential spray drift.
   c) Increasing operating pressure increases percentage canopy deposition.

Ground Speed

Ground Speed (mph)	1	2.5	4

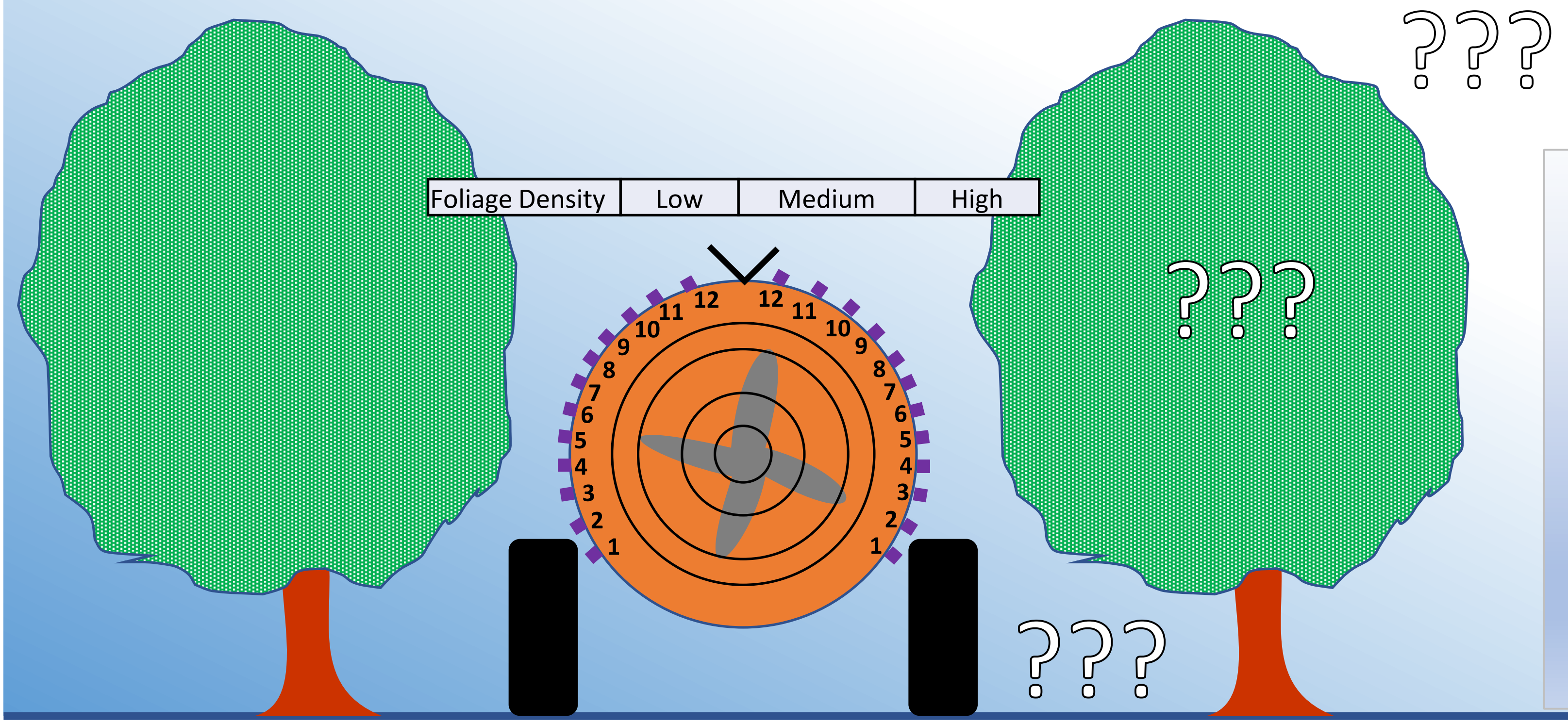


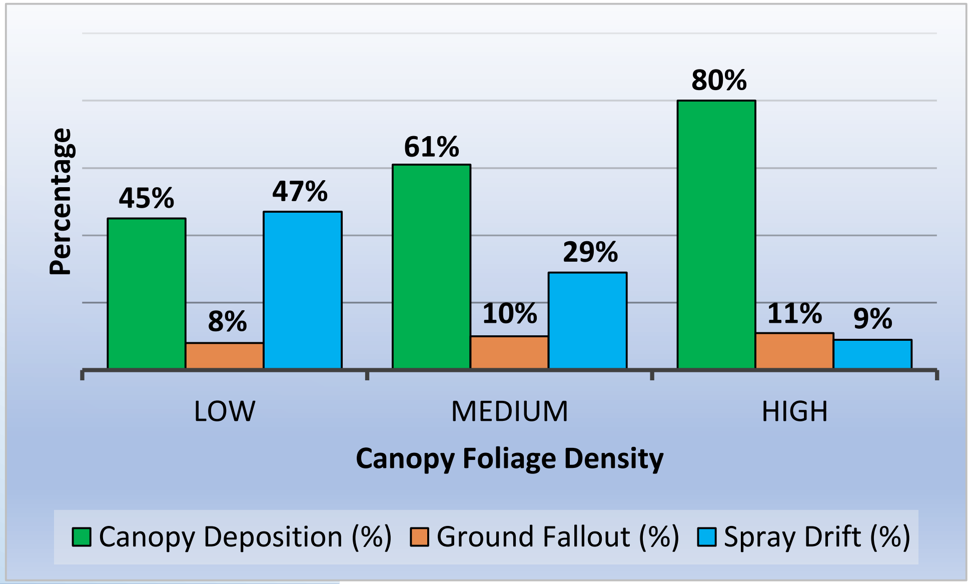
Other Parameters			
Output/Side (gpm)	0.04587	0.04587	0.04587
Total Volume Applied (gal)	1627	651	407
Total Area Covered (ac)	11.938	11.938	11.938
Application Rate (gpa)	136	55	34
No. of Trees Sprayed	2000	2000	2000



Canopy Foliage Density

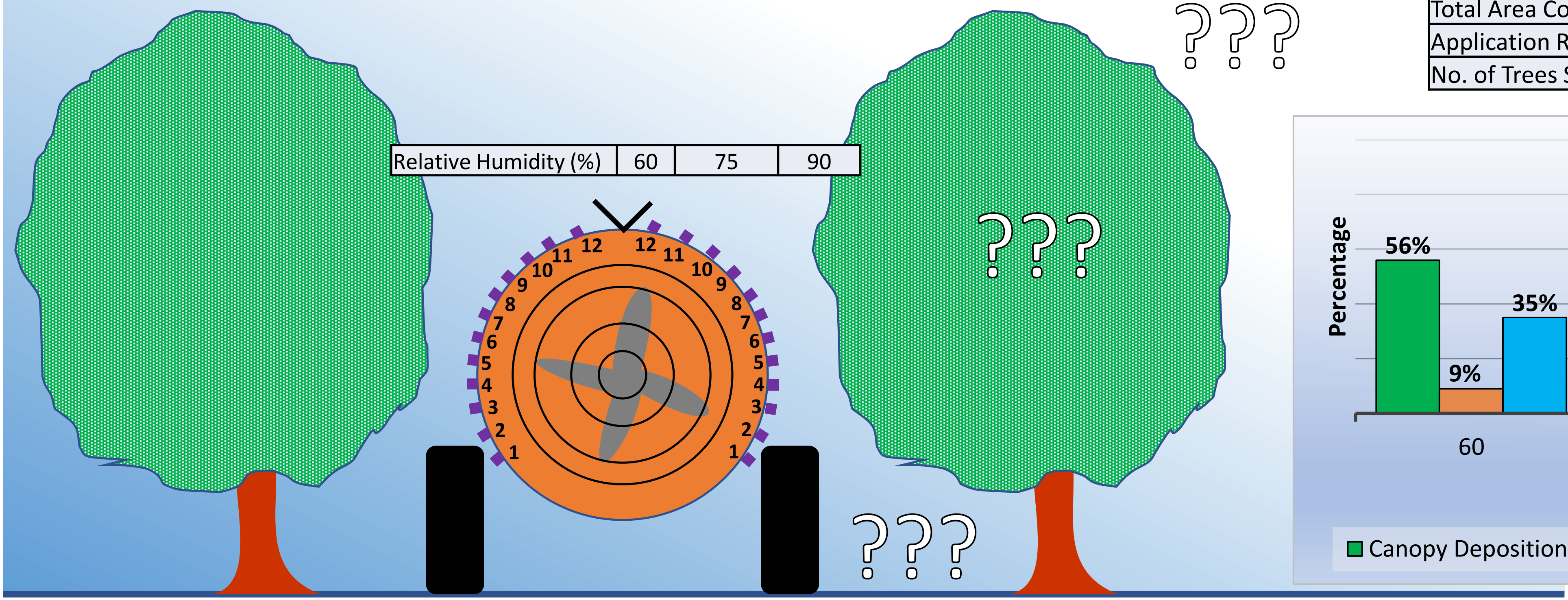
Other Parameters			
Output/Side (gpm)	0.04587	0.04587	0.04587
Total Volume Applied (gal)	651	651	651
Total Area Covered (ac)	11.938	11.938	11.938
Application Rate (gpa)	55	55	55
No. of Trees Sprayed	2000	2000	2000





Relative Humidity

Relative Humidity (%)	60	75	90



Other Parameters			
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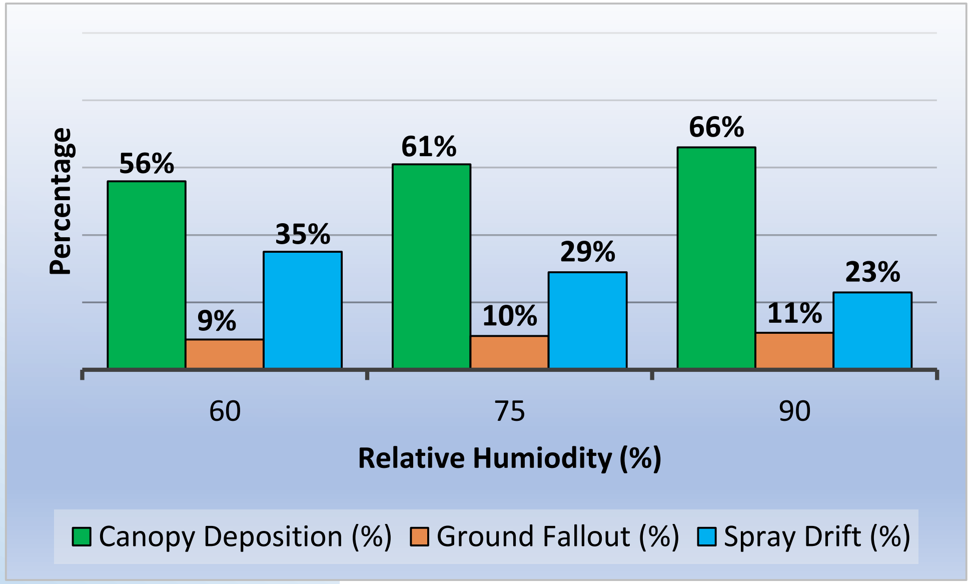
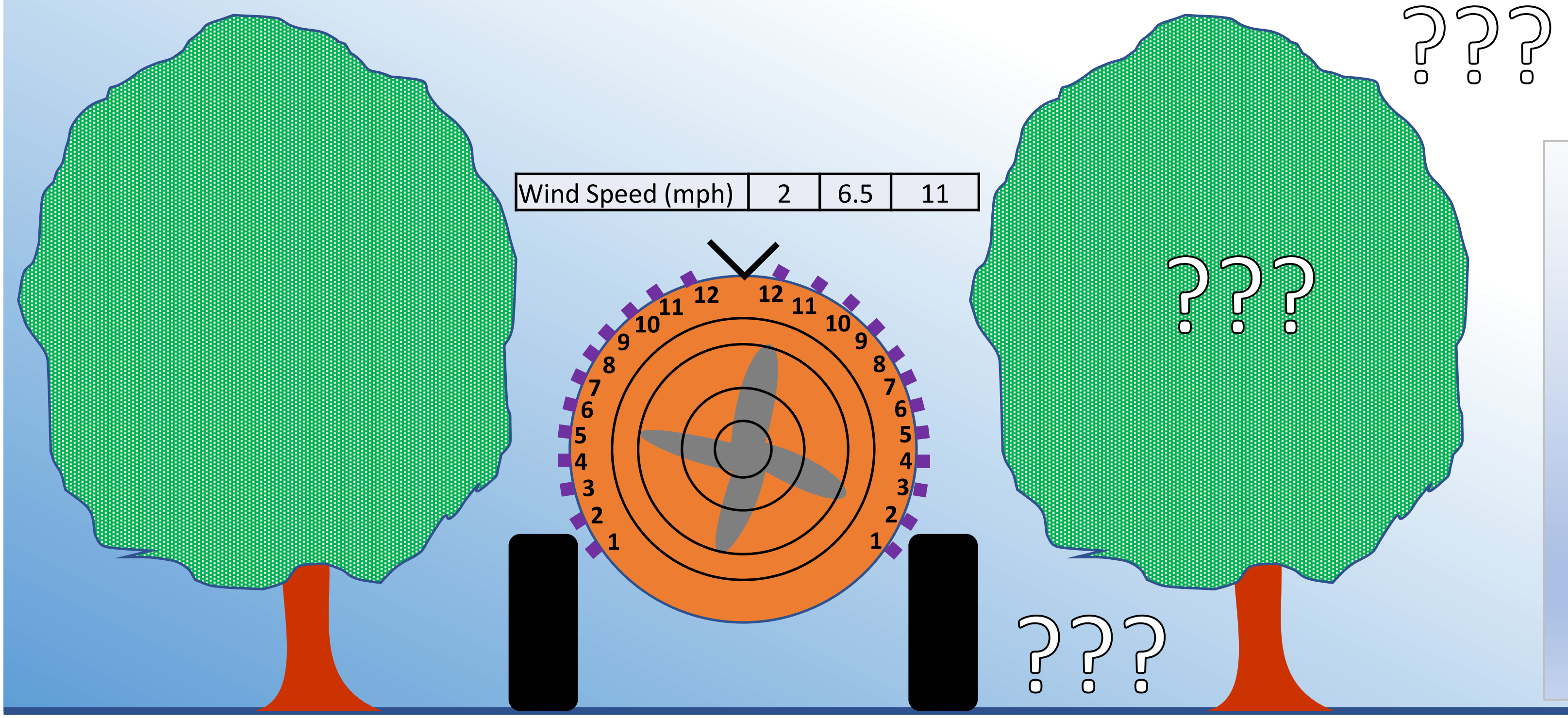
Application Rate (gpa)	55	55	55
No. of Trees Sprayed	2000	2000	2000

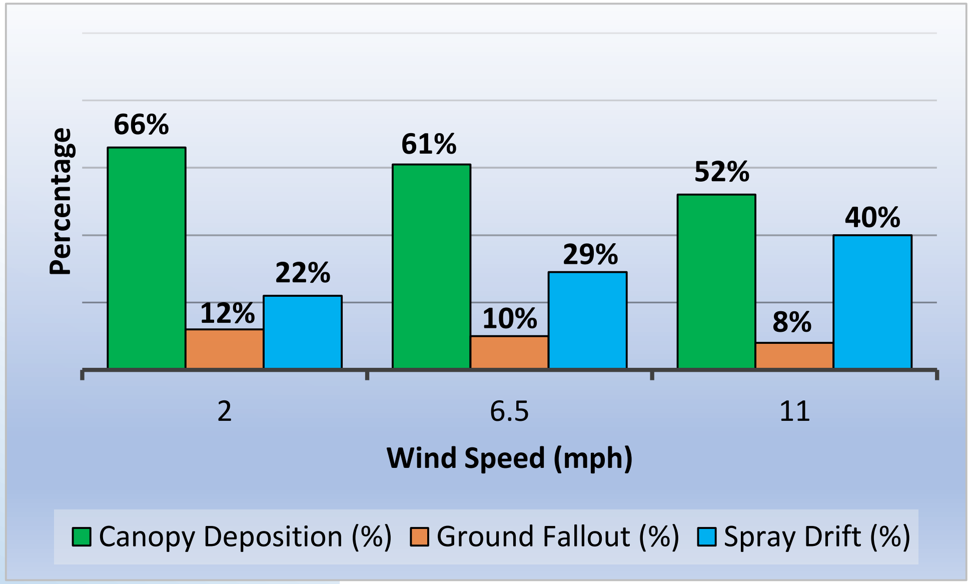


Wind Speed

Wind Speed (mph)	2	6.5	11



Other Parameters			
Output/Side (gpm)	0.04587	0.04587	0.04587
Total Volume Applied (gal)	651	651	651
Total Area Covered (ac)	11.938	11.938	11.938
Application Rate (gpa)	55	55	55
No. of Trees Sprayed	2000	2000	2000



Poll Questions

8. **According to model simulation results from preceding slides, which of the following general statements about citrus airblast spray applications is true?**
   a) Increasing sprayer ground speed increases percentage canopy deposition.
   b) Increasing canopy foliage density increases percentage potential spray drift.
   c) Increasing relative humidity increases percentage potential spray drift.

Analysis of Advanced Airblast Systems

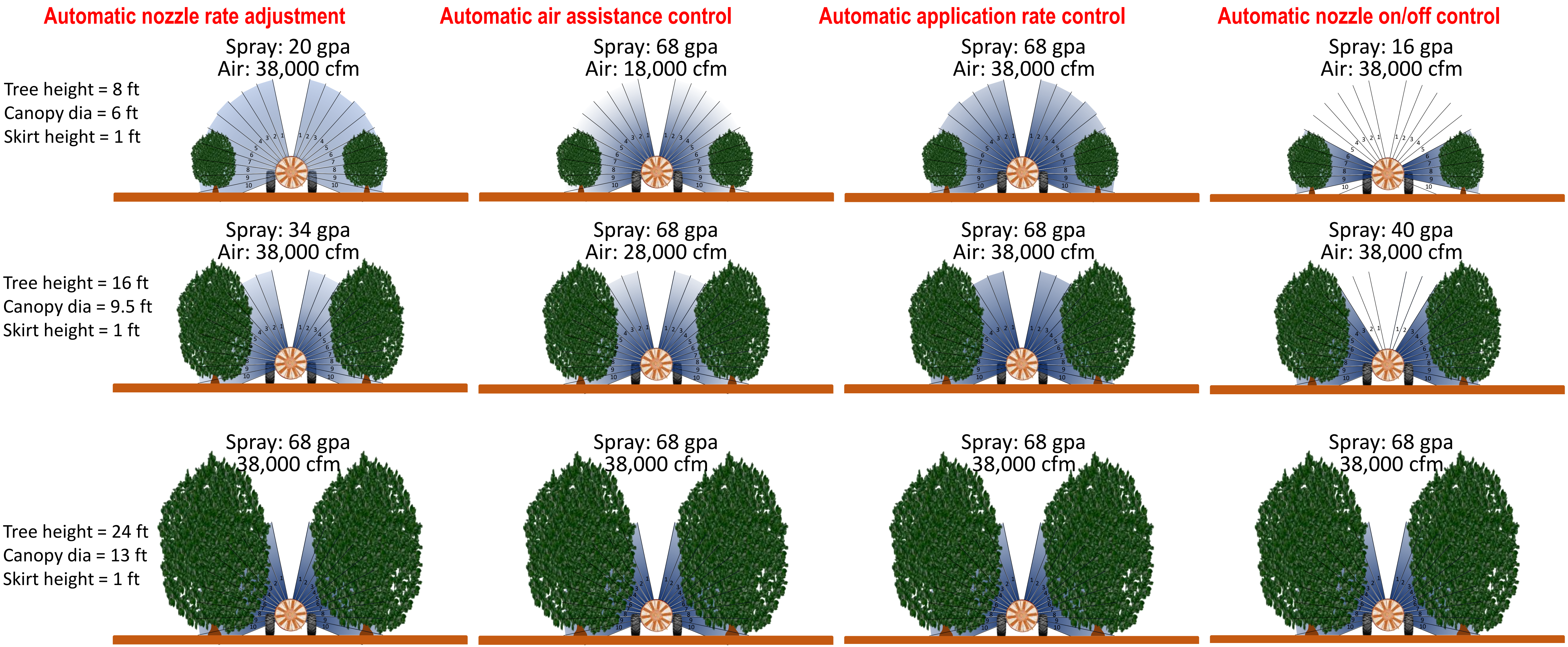
Systems Tested

Trt	System	Remarks
1	Conventional	No variable rate
2	Automatic nozzle rate adjustment only	Could be based on aerial map
3	Automatic air assistance control only	Could be based on aerial map
4	Automatic application rate control only	Based on real-time speed sensing
5	Automatic nozzle on/off control only	Based on real-time tree canopy sensing

Systems Setup

- Orchard & Tree Characteristics
  - ✓ 20 ft row spacing x 13 ft tree spacing
  - ✓ 100 rows x 100 trees/row = 10,000 trees
  - ✓ 0% missing-tree (0% MT) situation
  - ✓ 3 tree sizes: small = 8 ft high x 6 ft dia
    medium = 16 ft high x 9.5 ft dia
    large = 24-ft x 13 ft
  - ✓ 3 foliage densities: low (LD), medium (MD), and high (HD)

- Weather Conditions
  - Temp = 77ºF, RH = 75%, and wind speed = 5 mph
- Standard Sprayer Setup
  - Type: Conventional airblast
  - Air outlet width (horizontal) = 0.4 ft
  - Air outlet length (vertical) = 4.8 ft
  - Nozzle type = D4-23 disc-core
  - # nozzles = 10 /side



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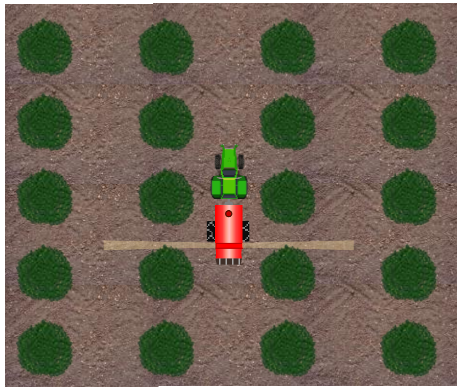
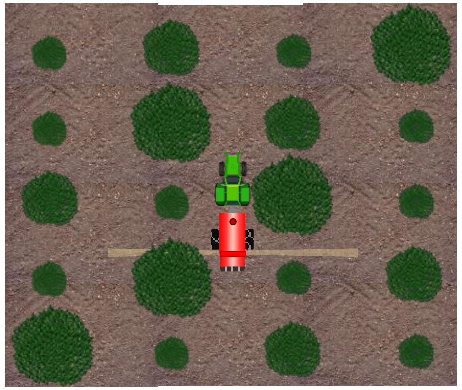
Overall, 207 non-replicated simulation runs

Orchard Tree Configuration (%Small-%Medium-%Large)

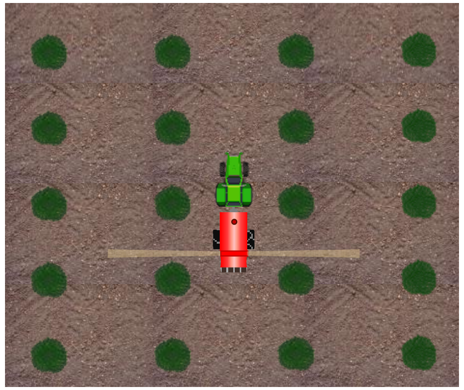
0-100-0



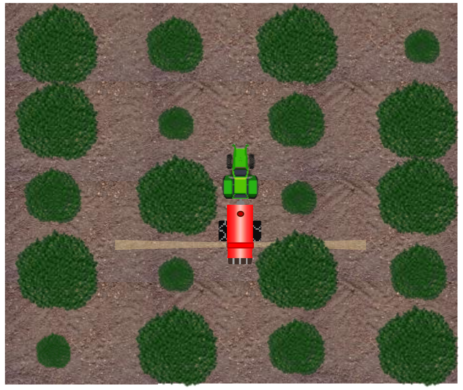
50-25-25



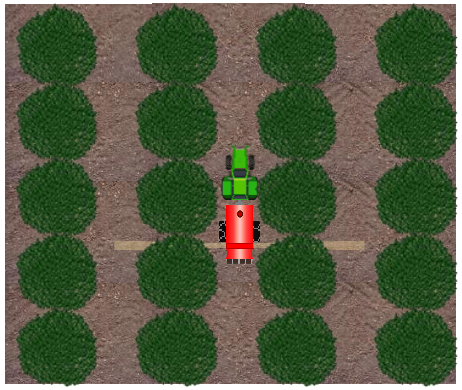
100-0-0



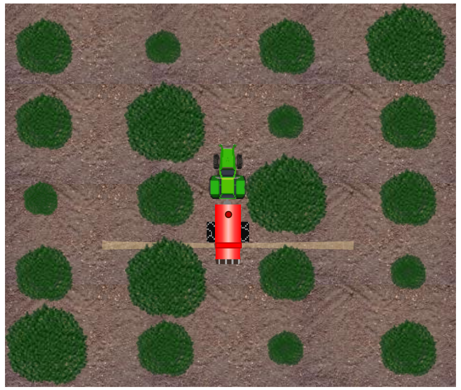
25-25-50



0-0-100



25-50-25



Tree Configuration

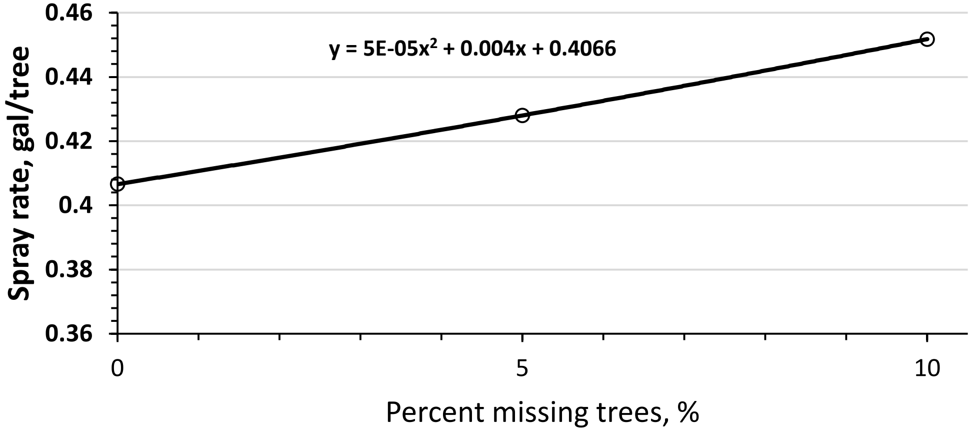
Uniform	Non-uniform
100-0-0	50-25-25
0-100-0	25-50-25
0-0-100	25-25-50

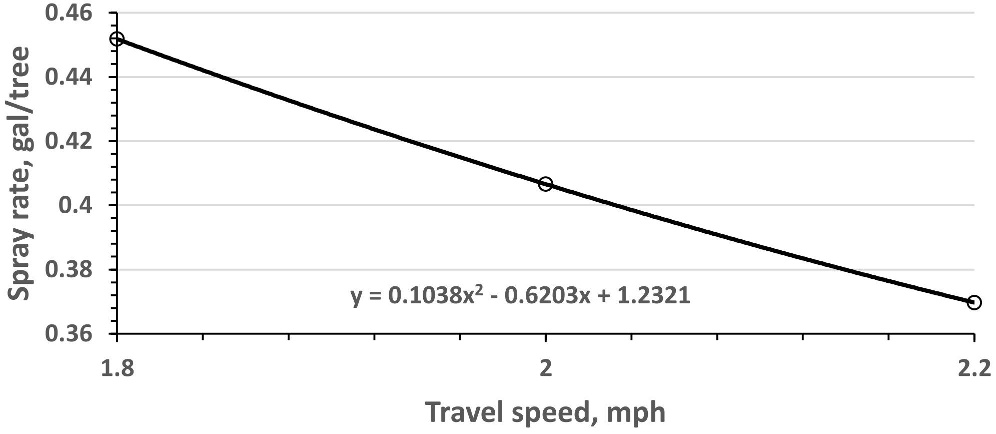
Foliage Density	Leaf Area Density (m^2/m^3)
Low	3.0
Medium	3.8
High	5.4

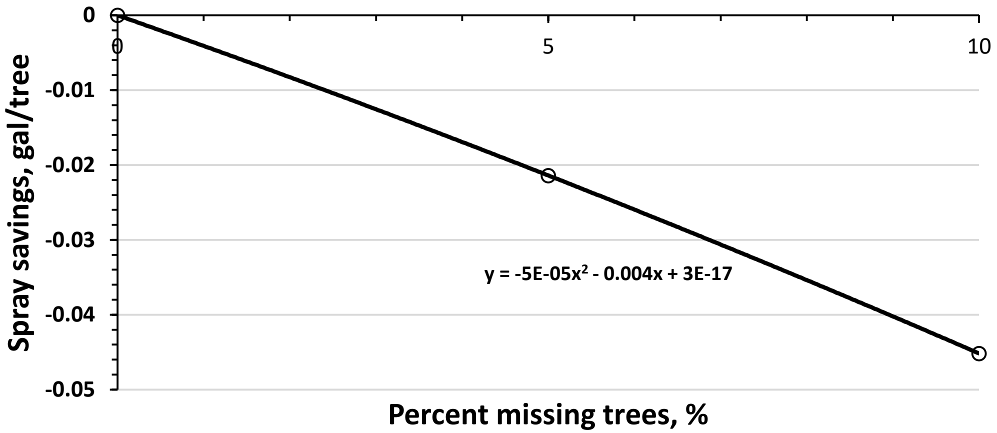
Data Analysis

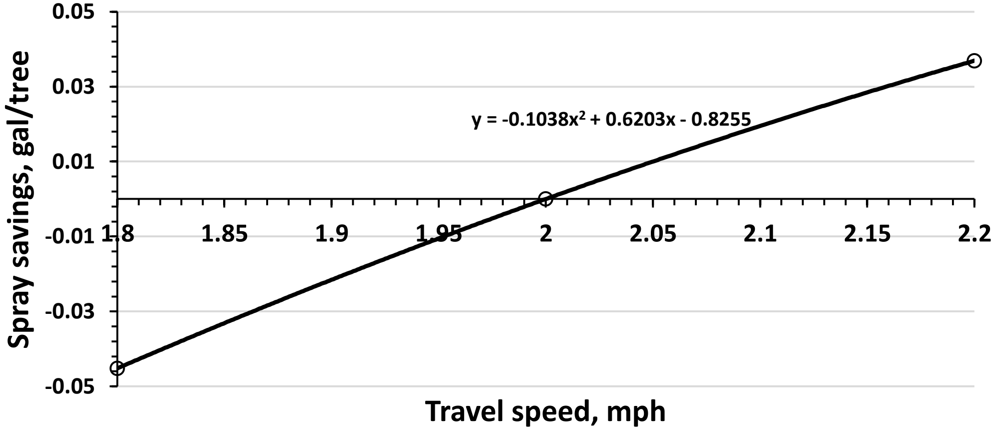
- Focused on canopy deposition, ignoring ground fallout and spray drift.
- $\boldsymbol{Spray\ rate} = \frac{volume\ applied}{number\ of\ trees\ sprayed}$
- $\boldsymbol{Deposition\ rate} = \frac{volume\ depositied}{number\ of\ trees\ sprayed}$
- ***Spray savings*** = deficit volume sprayed compared to a corresponding conventional airblast application
- ***Deposition savings*** = supplementary deposition compared to a corresponding conventional airblast application.
- $\boldsymbol{Total\ savings} = Spray\ savings + deposition\ savings$

Conventional Airblast

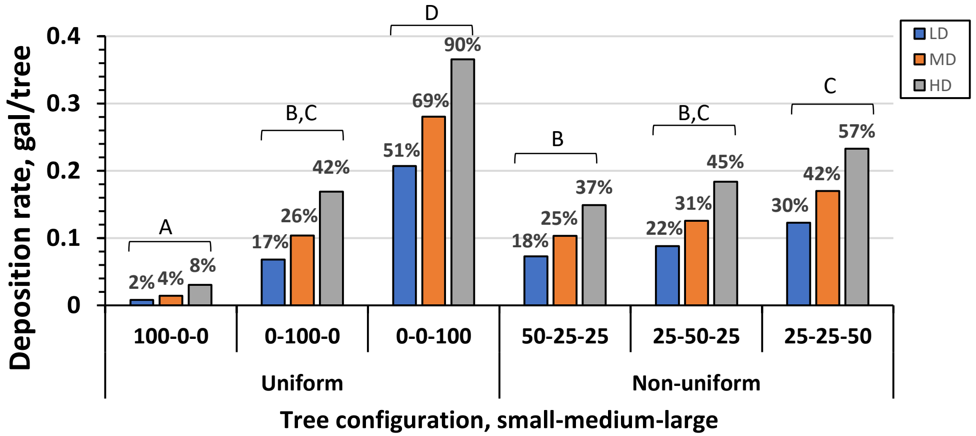


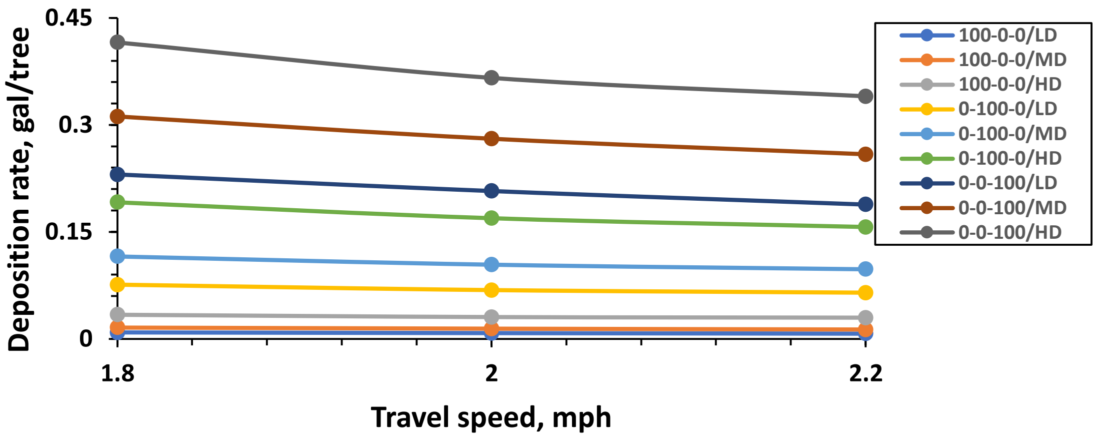


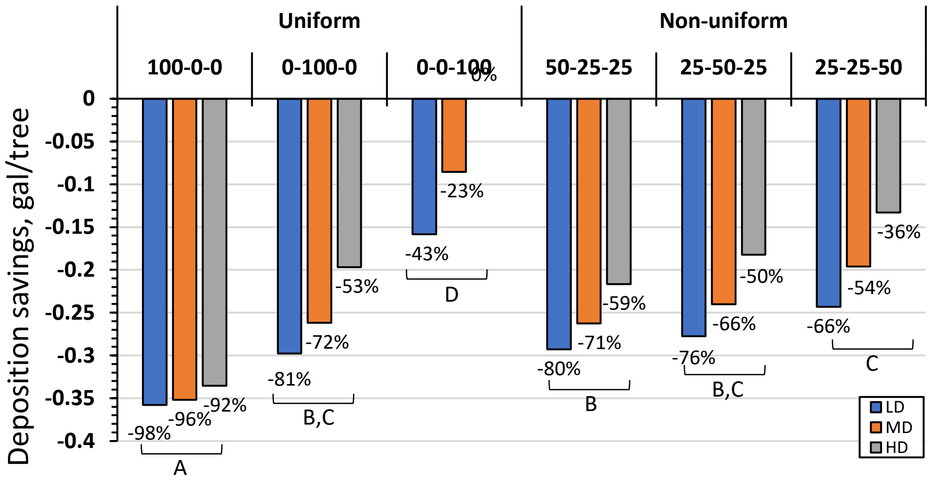


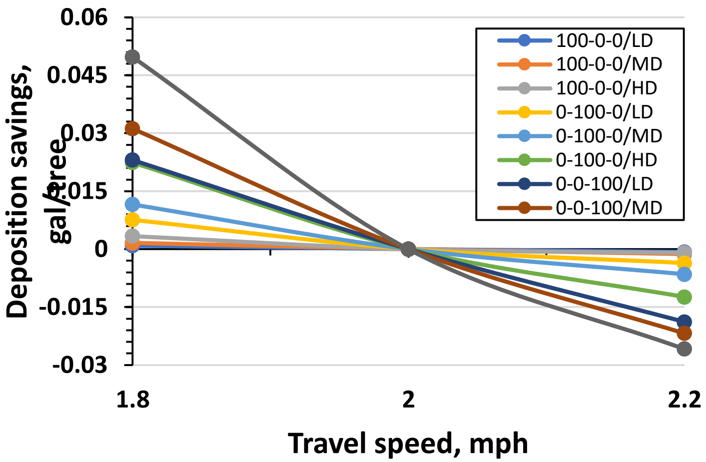


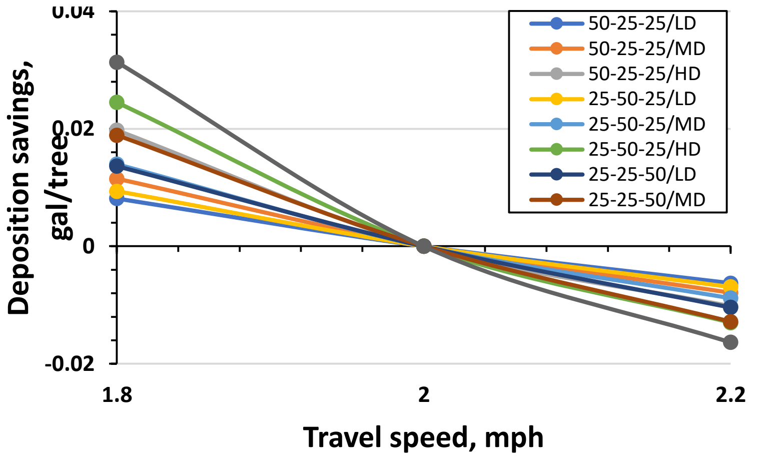
Conventional Airblast



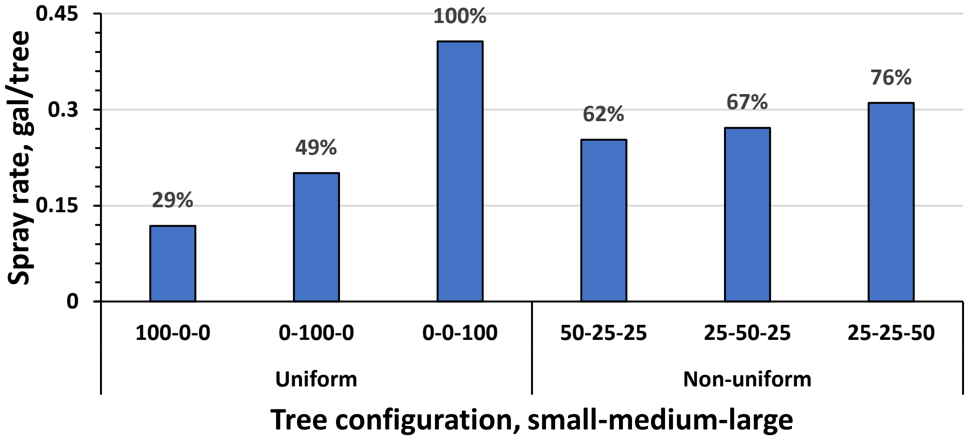


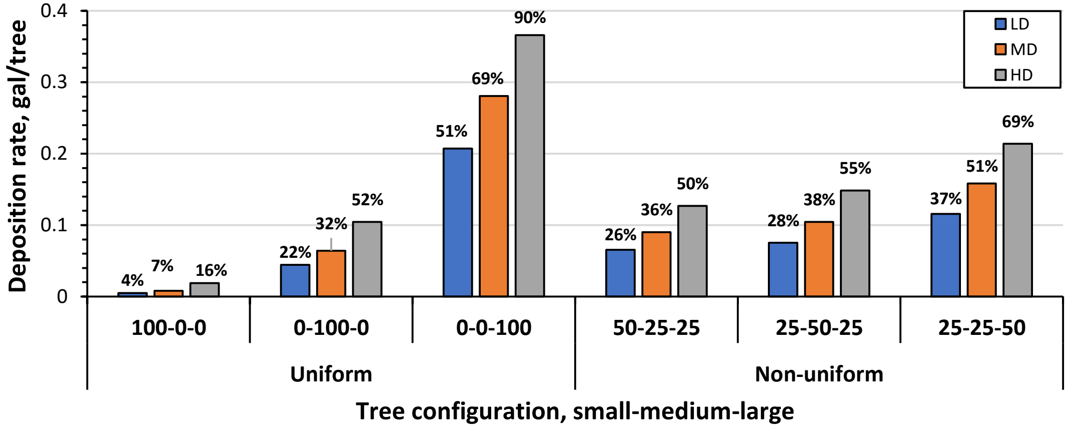


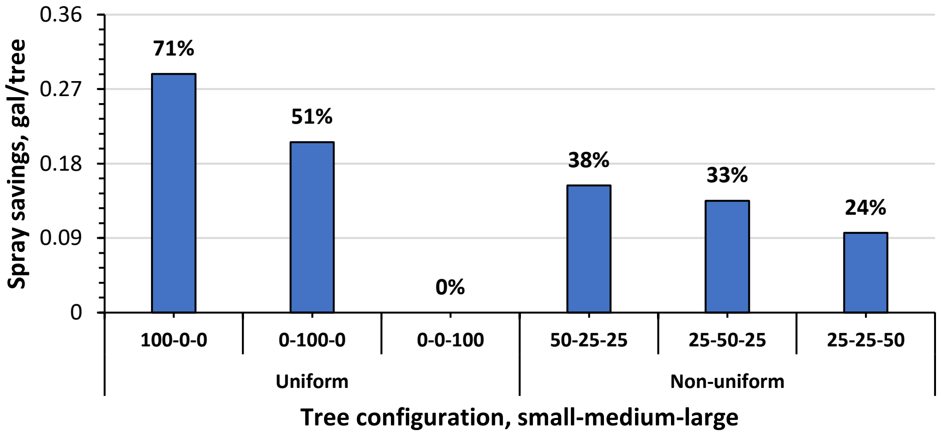


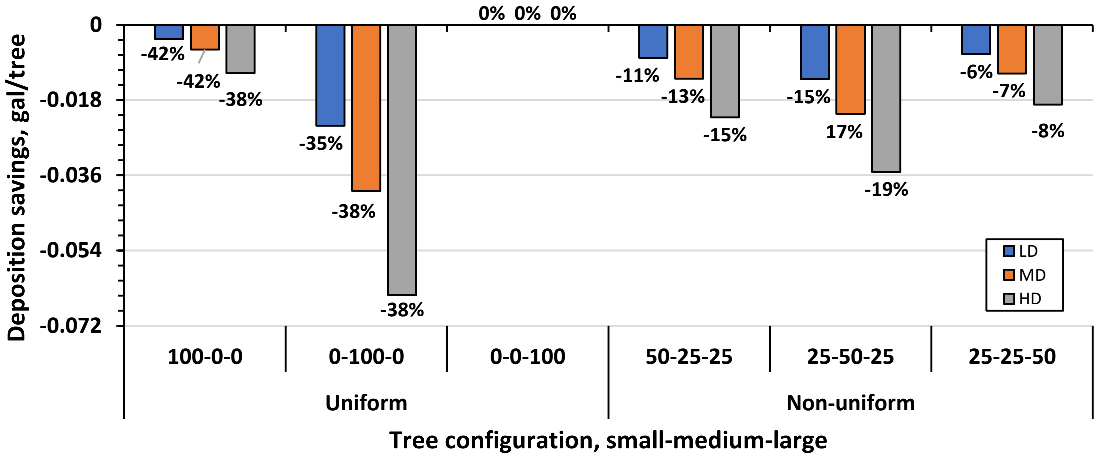


Automatic Nozzle Rate Adjustment



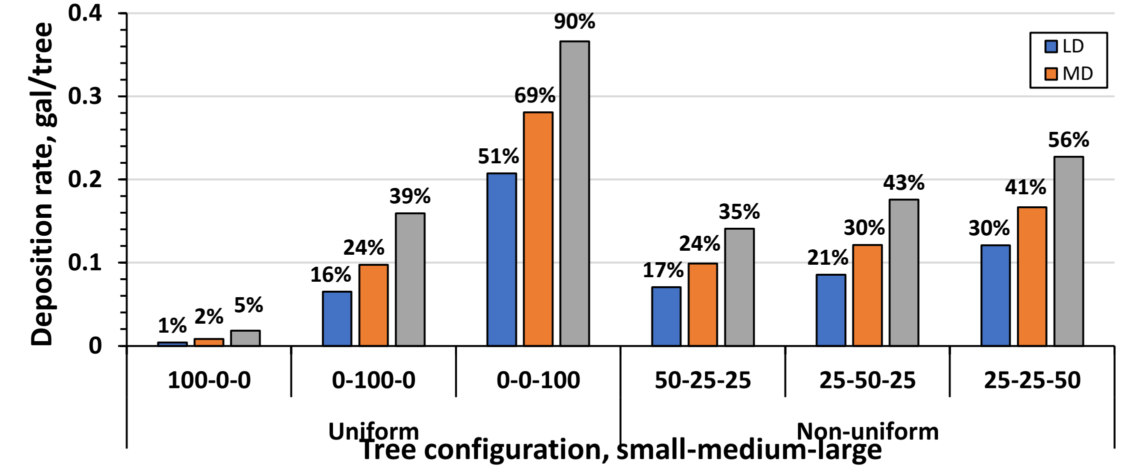


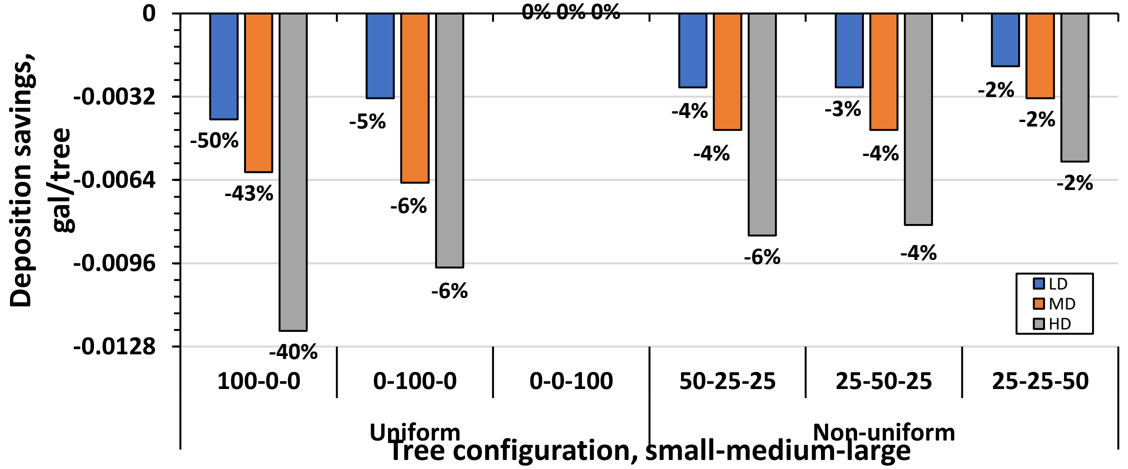




Automatic Air Assistance Control

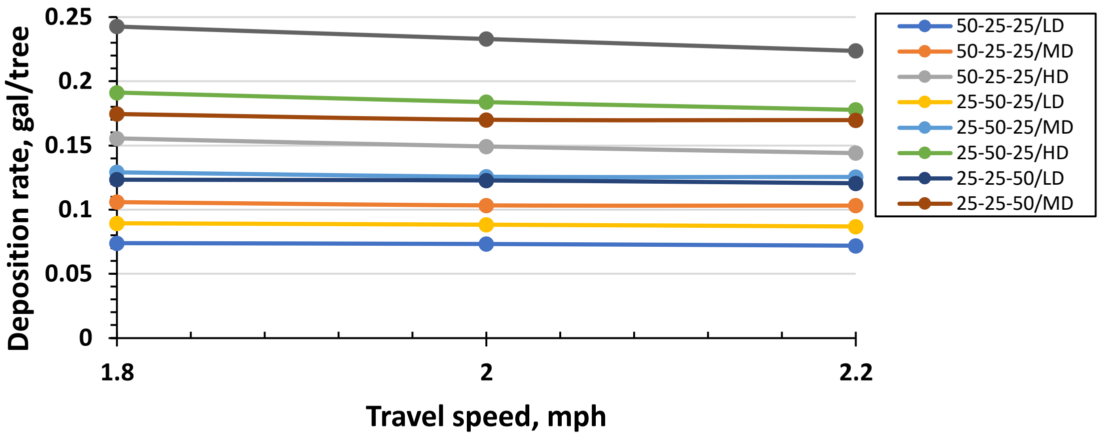
Application rate same as conventional application
No spray savings

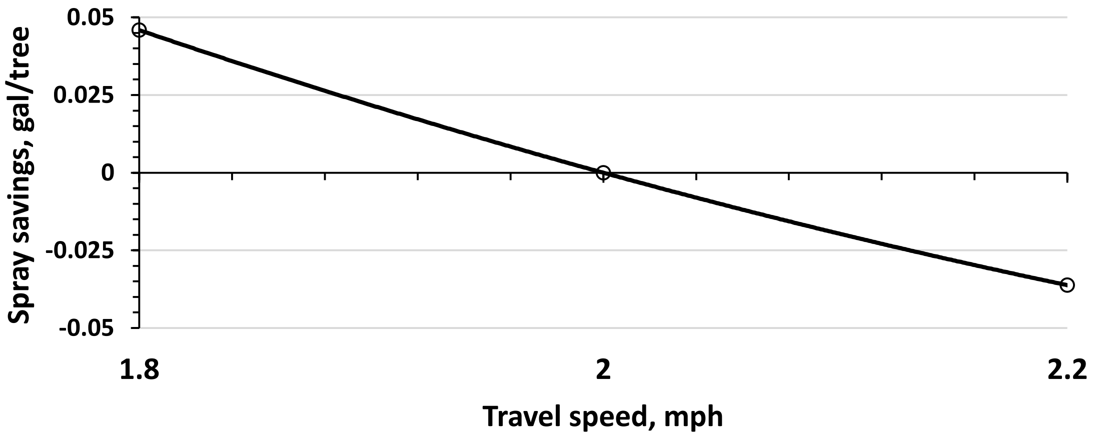


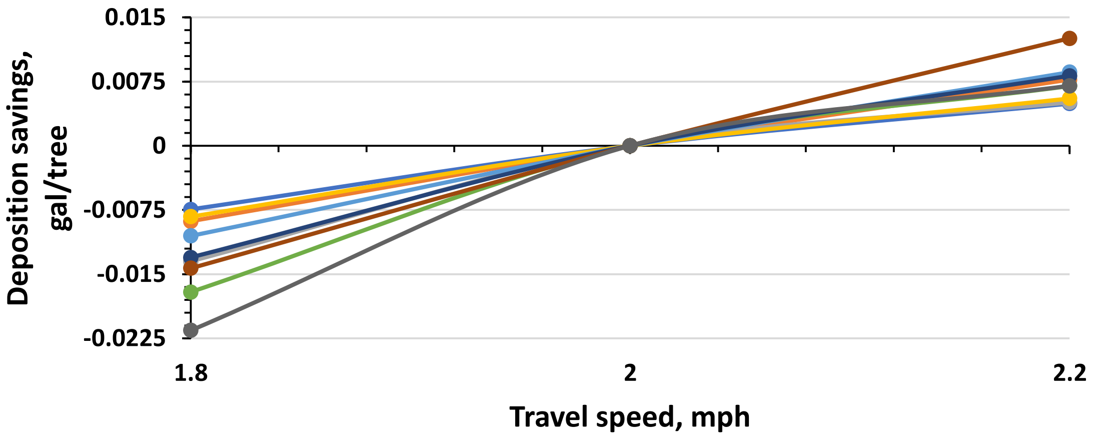


Automatic Application Rate Control

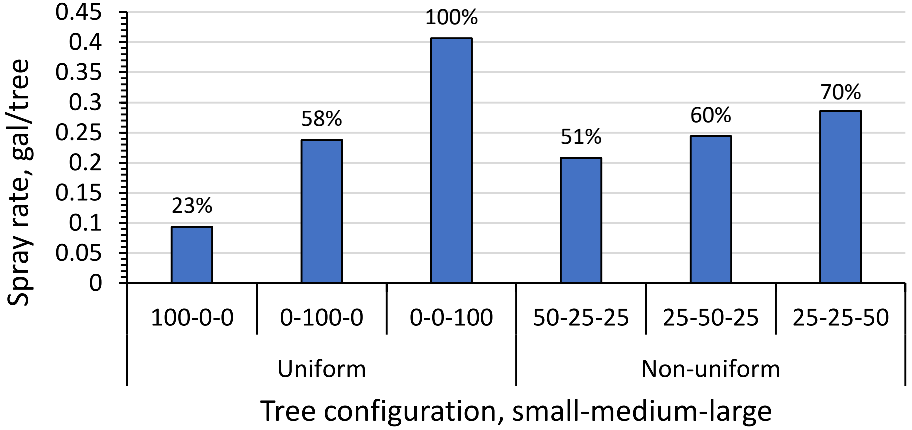
Application rate maintained at conventional rate

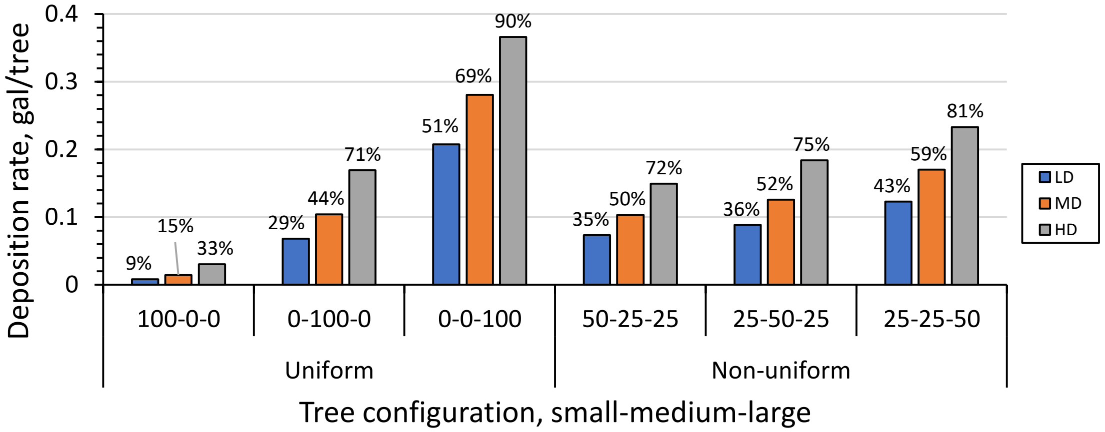


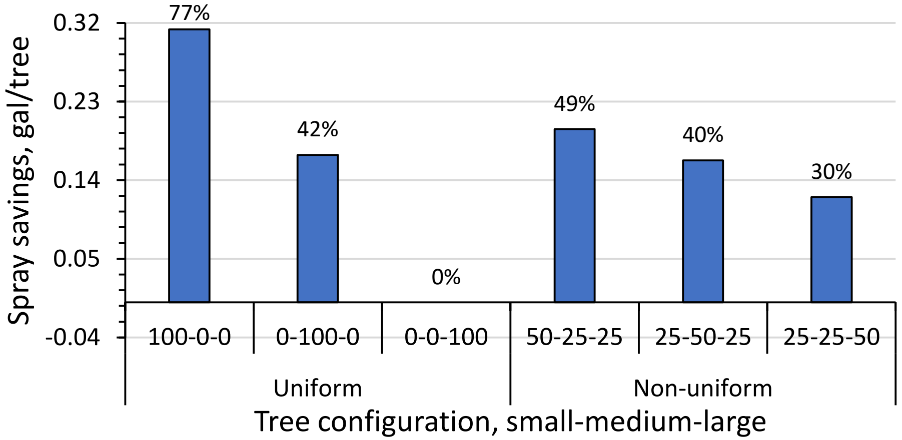




Automatic Nozzle On/off Control

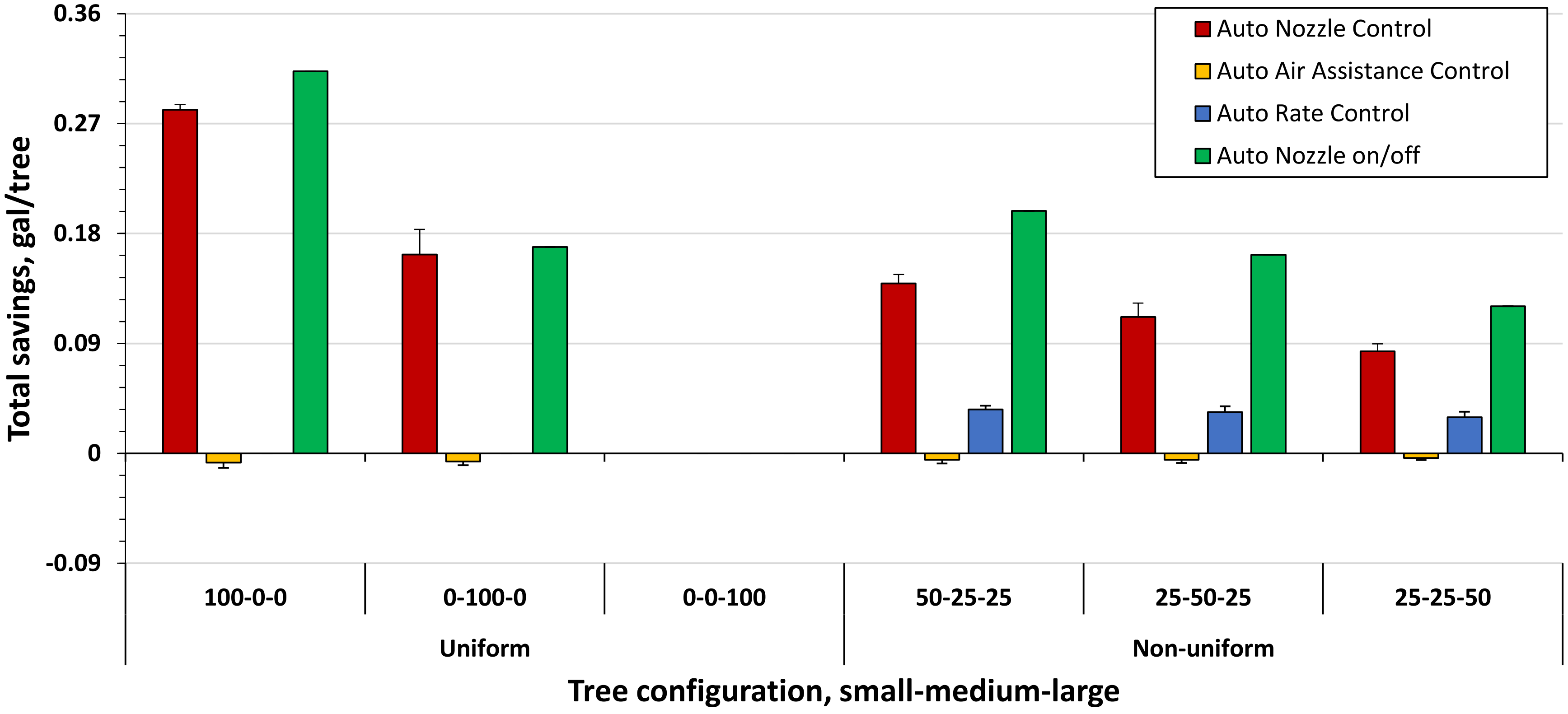






No deposition savings

Total Application Savings



Poll Questions

9. **From simulation results in earlier slides, which of the following advanced systems may benefit (in terms of material savings) spraying an orchard having uniform foliage density hedgerows (i.e. tree canopies touching) trimmed at the top and sides?**
   a) An airblast sprayer with automatic nozzle flow adjustment, based on foliage density.
   b) An airblast sprayer with automatic application rate control, based on ground speed.
   c) An airblast sprayer with automatic nozzle on/off control, based on presence/absence of tree.

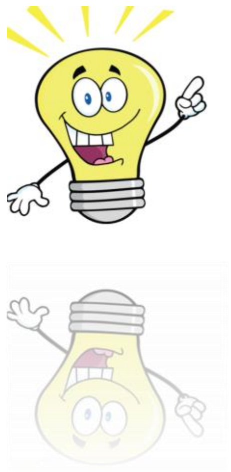
10. **In an orchard with variable tree sizes, canopy gaps, and possible missing trees, which of the following advanced systems may provide the greatest benefit in terms of material savings?**
    a) An airblast sprayer with automatic nozzle flow adjustment, based on foliage density.
    b) An airblast sprayer with automatic application rate control, based on ground speed.
    c) An airblast sprayer with automatic nozzle on/off control, based on presence/absence of tree.

Take-home Messages

1. Guesstimating the outcome of an airblast spray application (as in canopy deposition, drift, and ground fallout) is almost impossible.

2. Using modeling and simulation tools for predictions can improve decision making for better planning.

3. **CitrusSprayEx** ES or similar tools can help.



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Thank You!

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