Pesticide Applications the Drone Way

Advanced Crop Advisers Workshop | Fargo, ND | Feb 12, 2025

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Devin Nohl, CEO - Customer Relations, Tenacity Ag

TENACITY AG

NDSU EXTENSION

Devin's experience: 2020–Present

Spray Drones in 2025

Ag drones currently are in their infancy in the USA

As of June last year, drones have treated over 1 billion acres of land worldwide.

There are currently over 300,000 agriculture drones working worldwide.

3.7 million acres sprayed by drone in 2023 across 41 states and 50 crops

A little bit about me

- Grew up on farm in WC MN
- Bought my first drone in 2020
- It had 2.5 gal tank and 10 mph
- Sprayed about 150 acres in 2021
- Sold the custom spray business in 2022 to go back to farming.
- Now have a business Tenacity Ag doing sales and service of ag drones.


1 day for 80 acres

Spraying Azera on Organic Carrots in 2021

Current Market Leaders in application drones in the USA

AGRICULTURE

What’s the ND context?

Spray drones have arrived in ND…


Unmanned aerial application owner-operators (with Part 137 certification)
30
20
10
0
2022
2023
2024


Unmanned aerial application owner-operators (with Part 137 certification)
30
20
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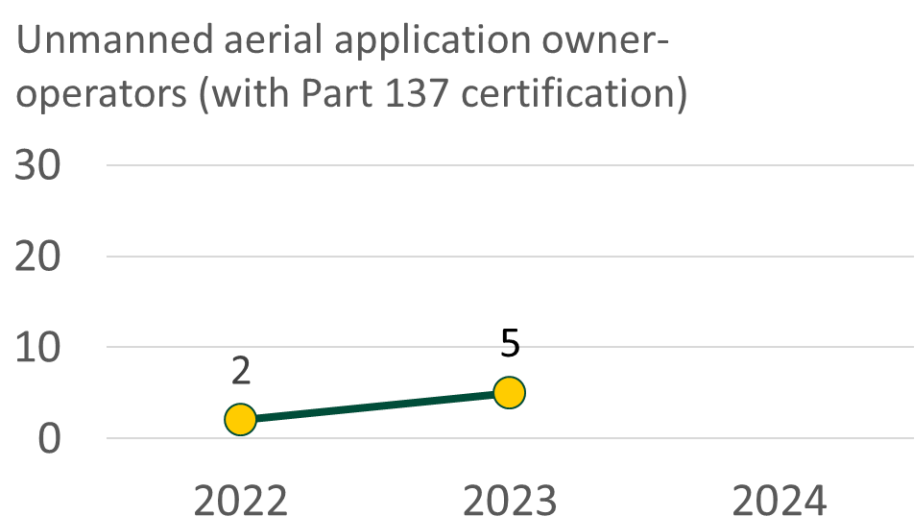
2022
2023
2024


Unmanned aerial application owner-operators (with Part 137 certification)
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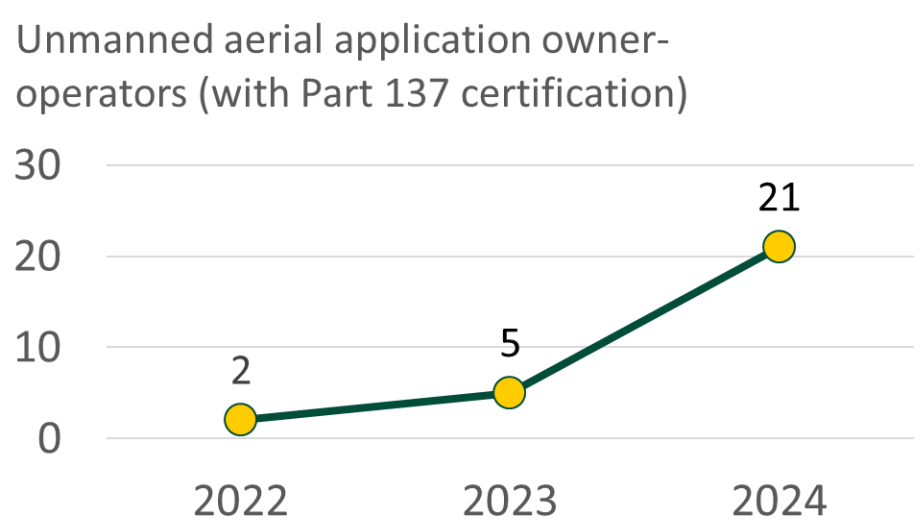
Unmanned aerial application owner-operators (with Part 137 certification)
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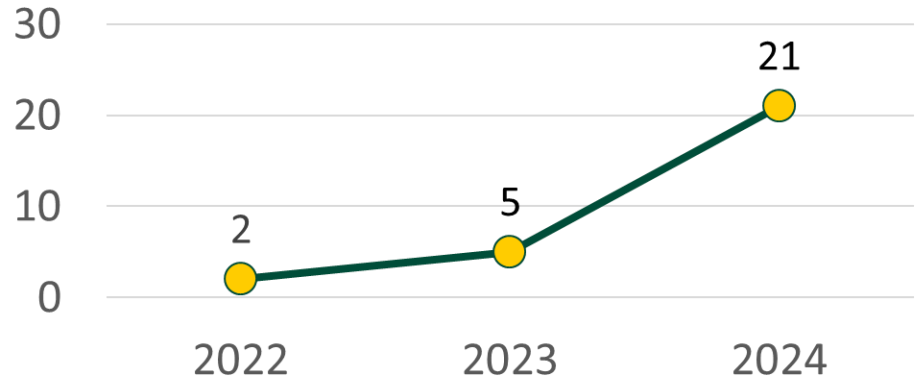
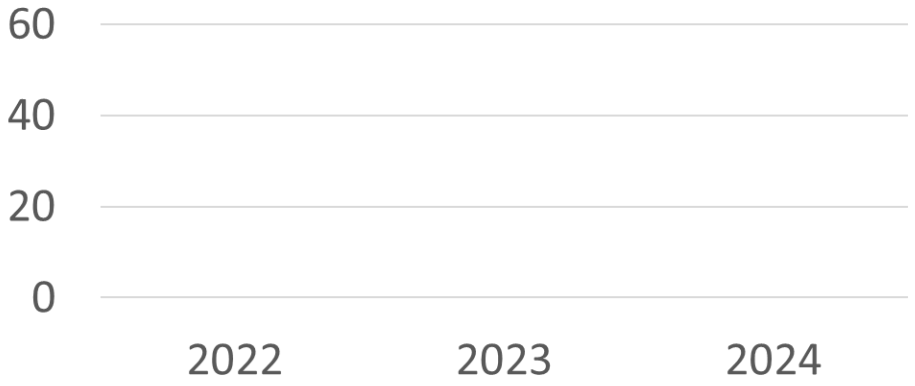


Licensed airmen (pilots) for unmanned aerial application



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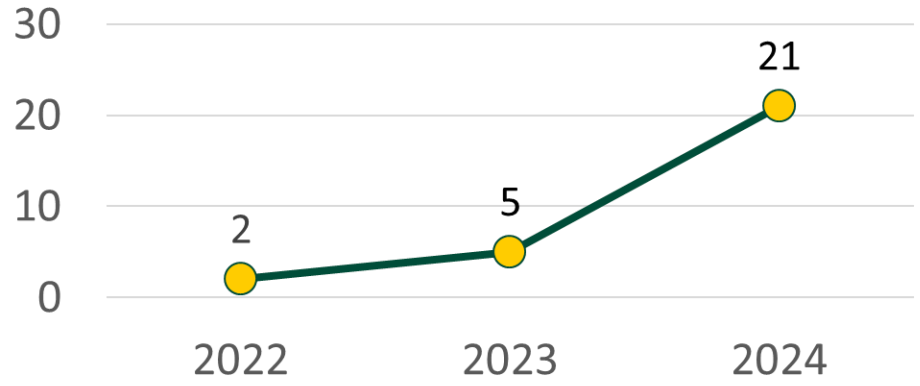

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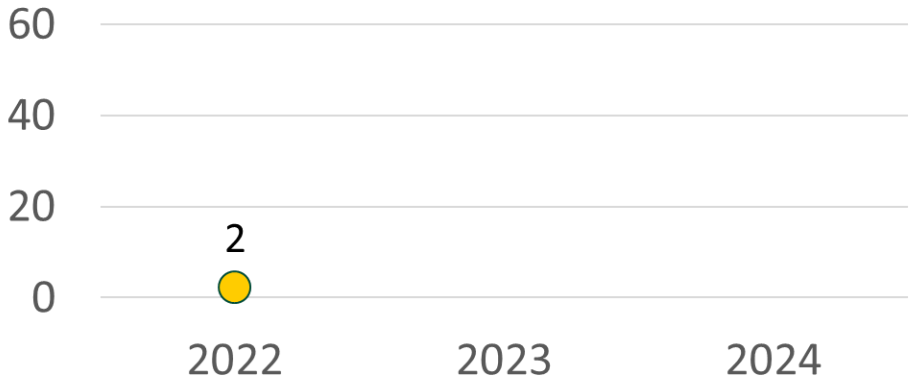

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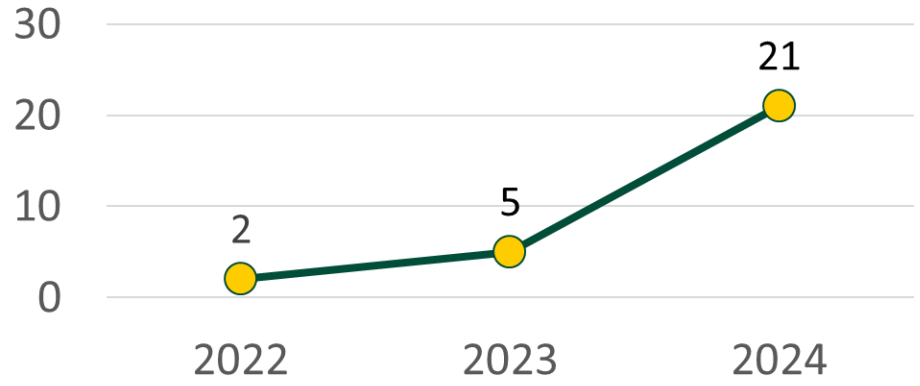

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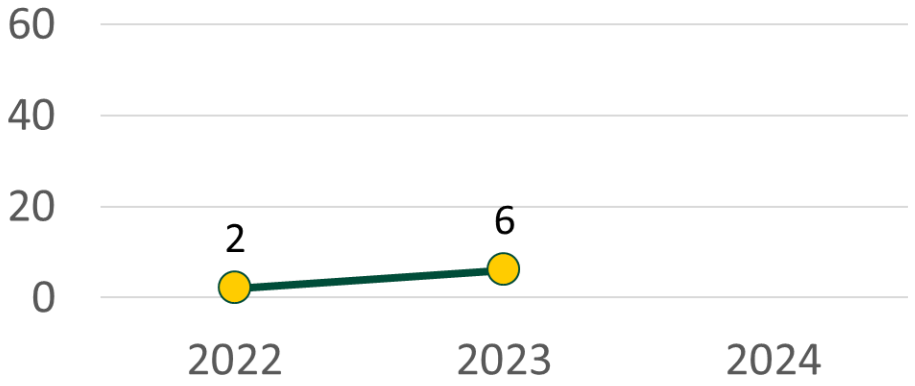

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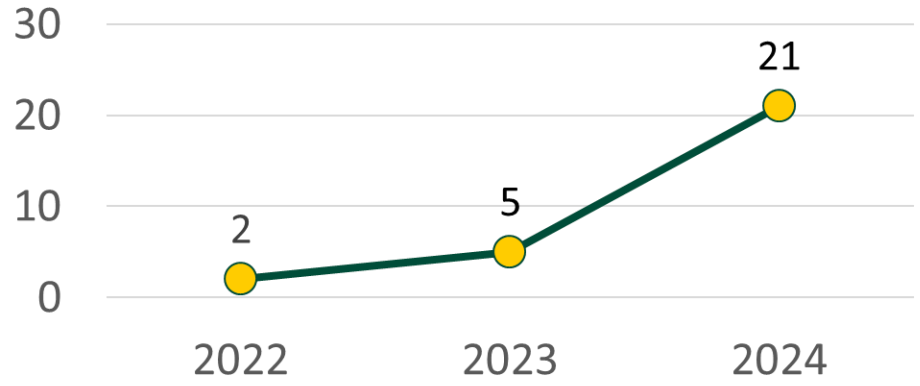

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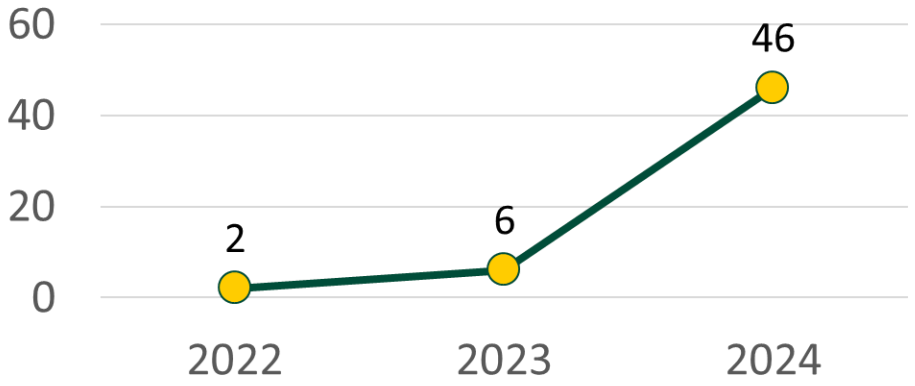

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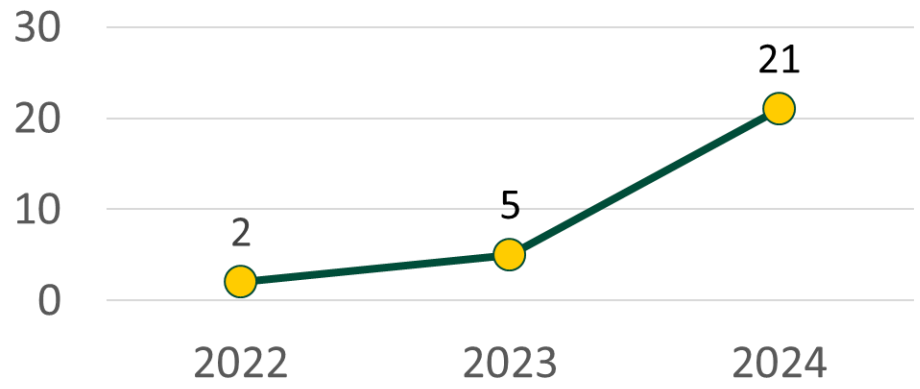

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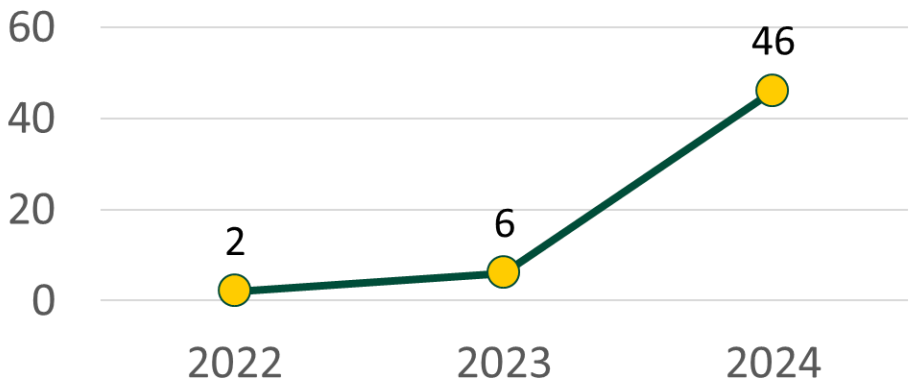
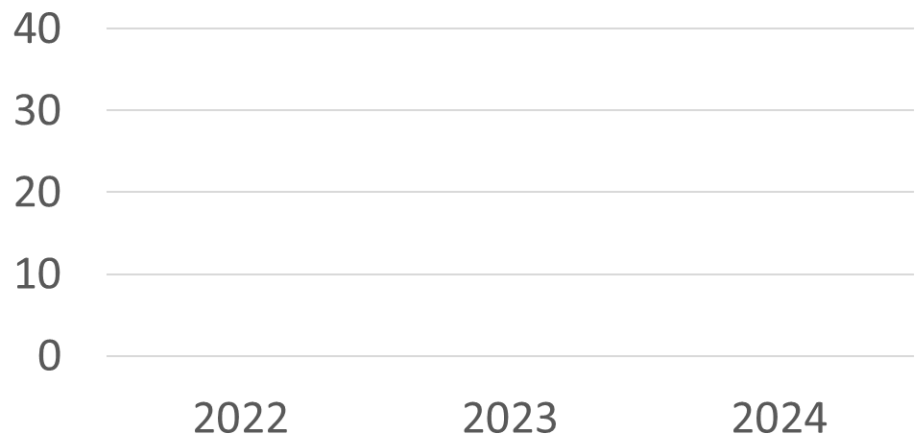


Registered unmanned aircraft



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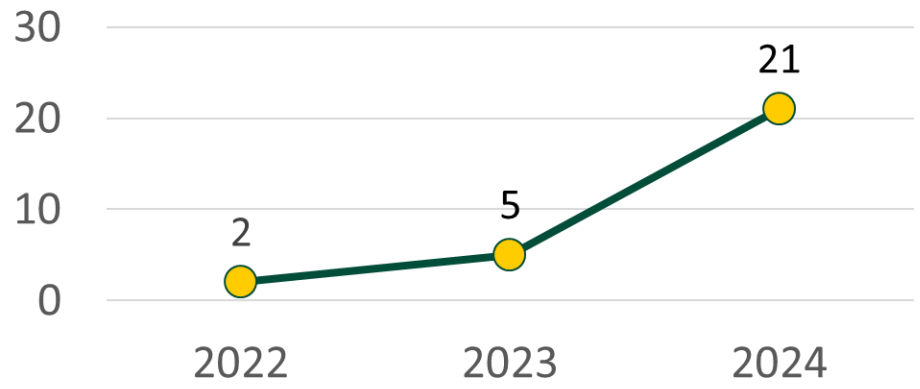

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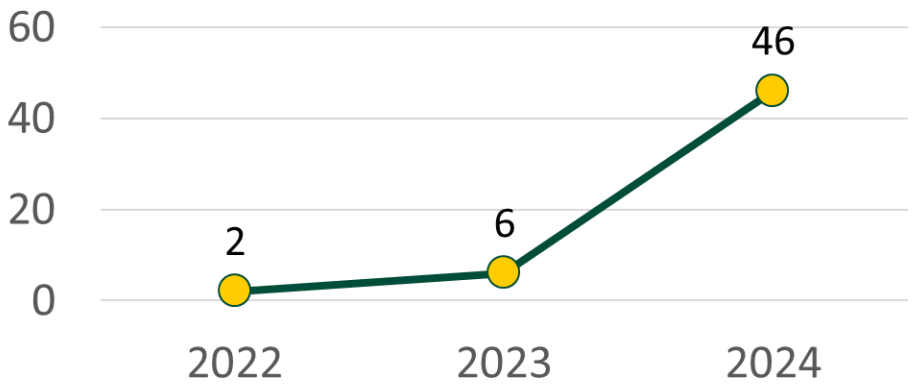

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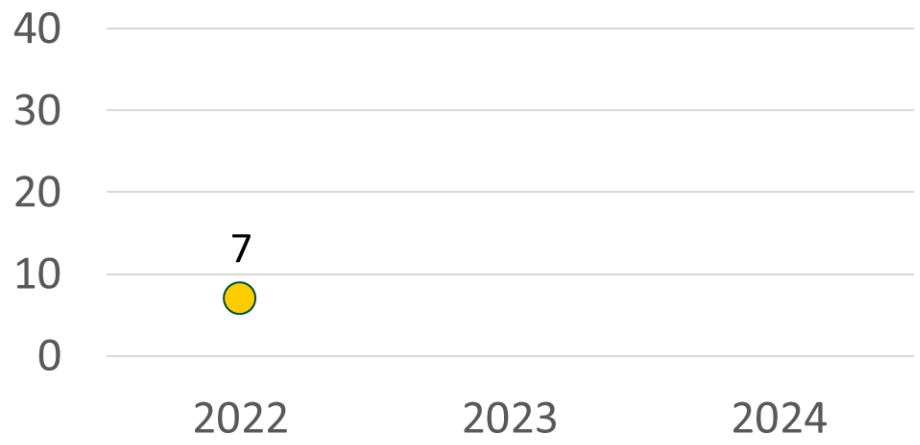

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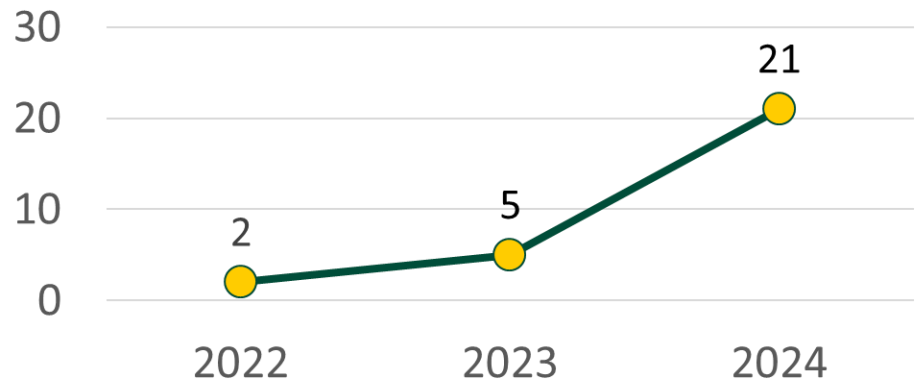

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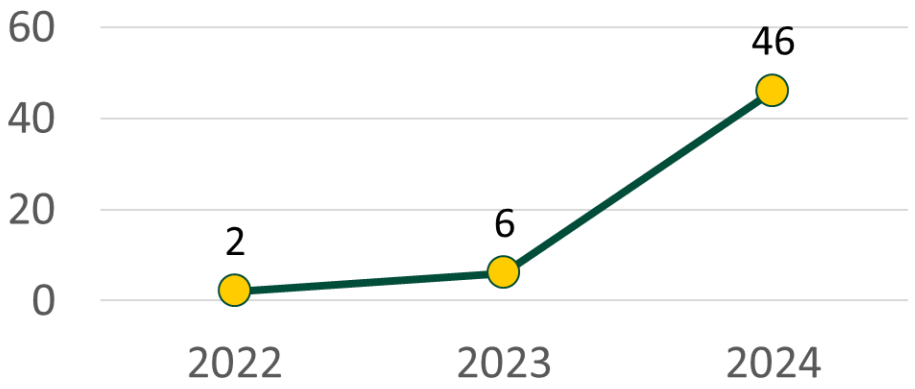

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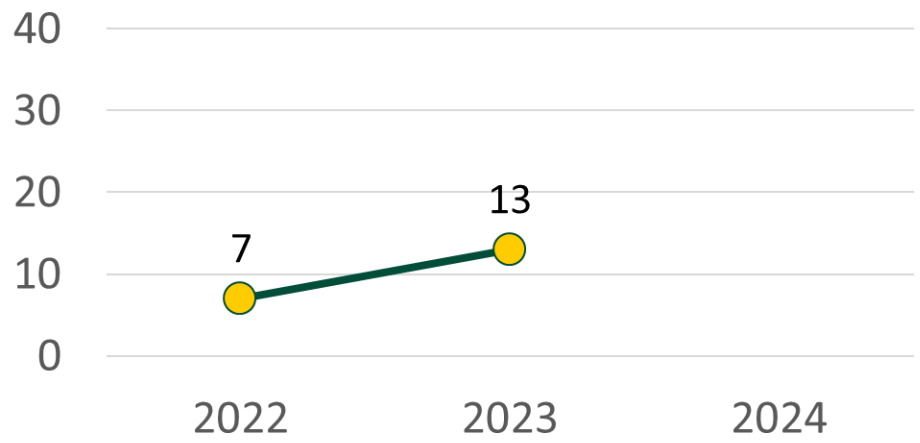

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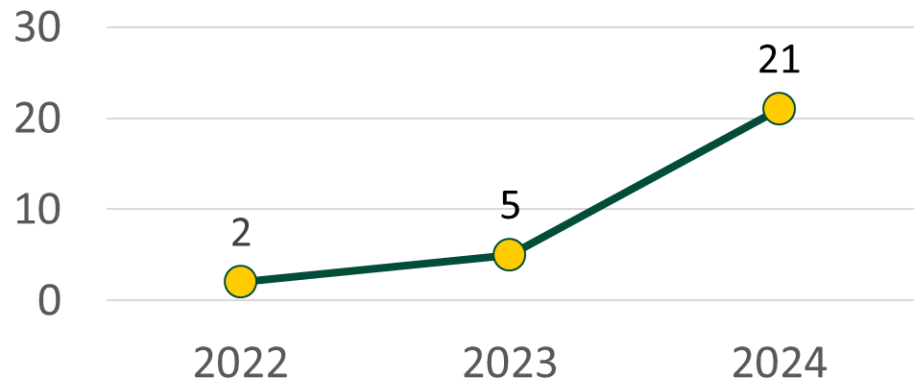

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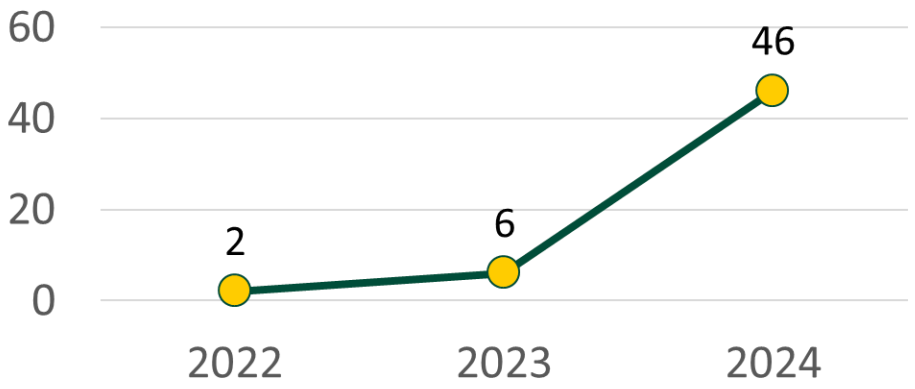

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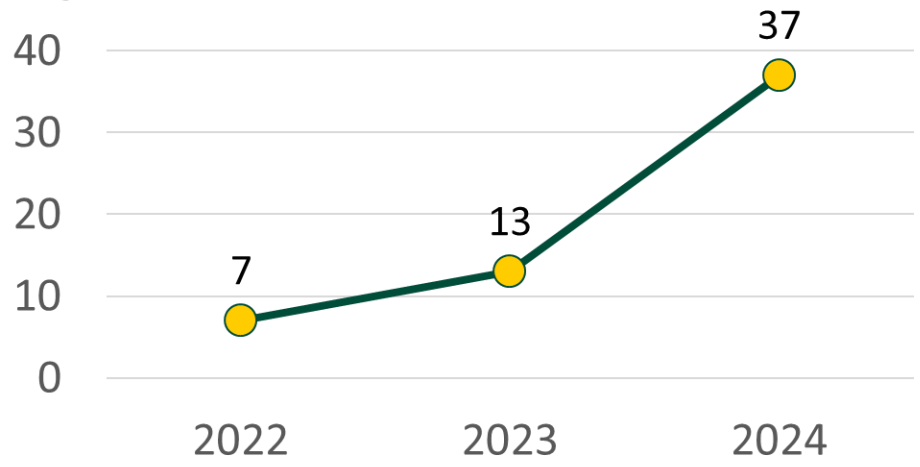

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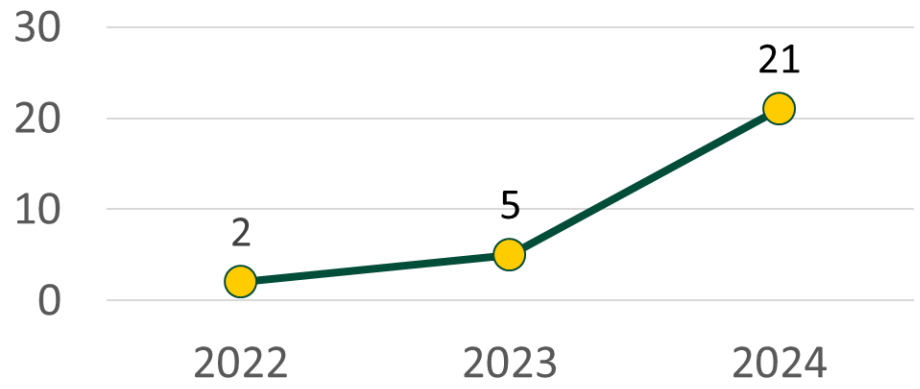

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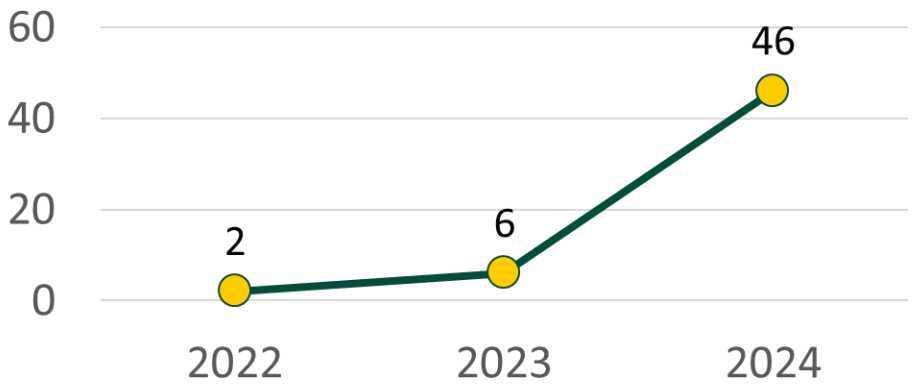

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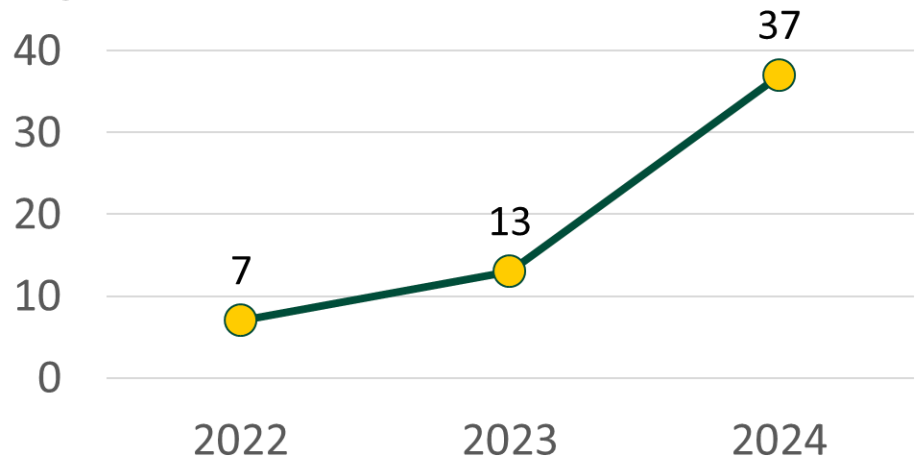
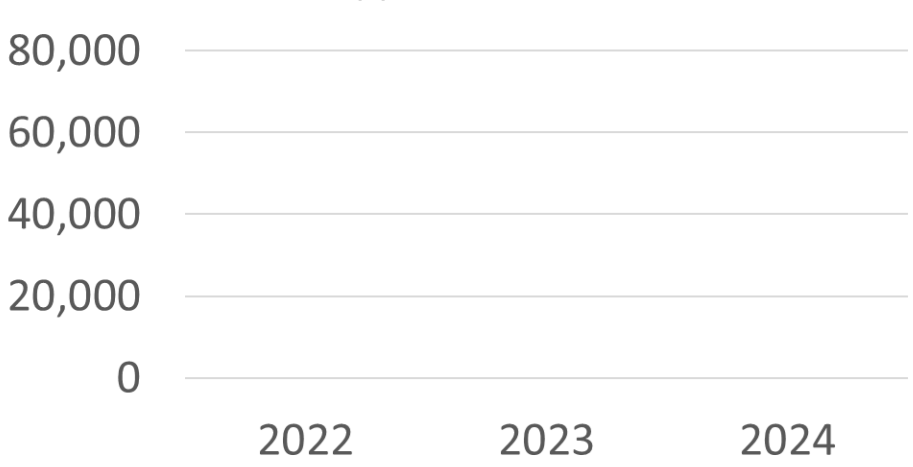
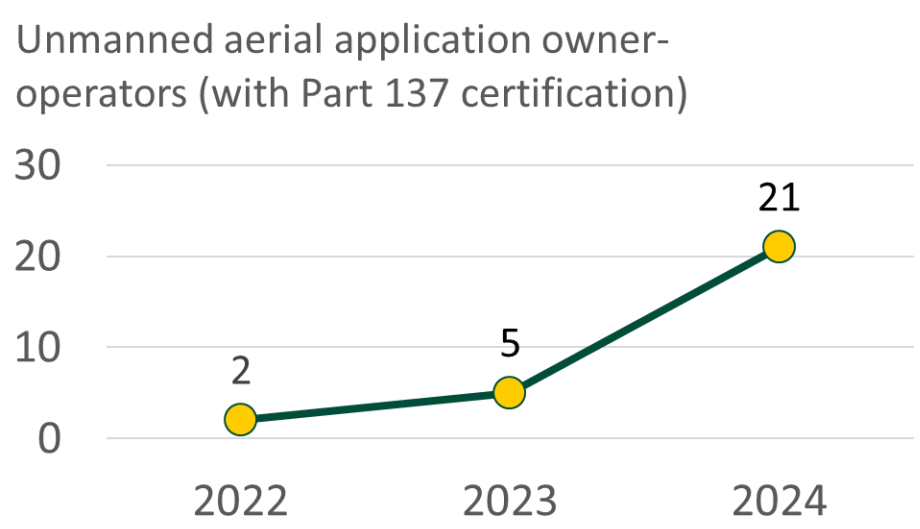


Unmanned aerial application acres

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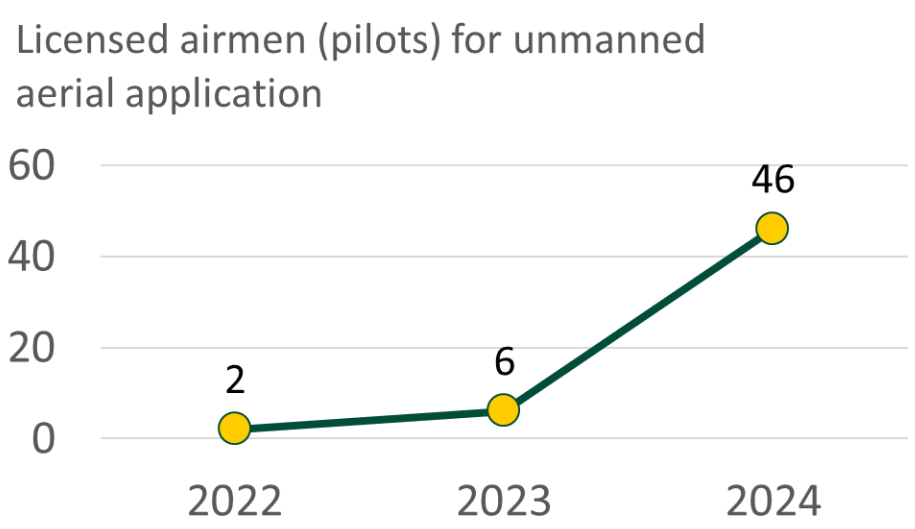
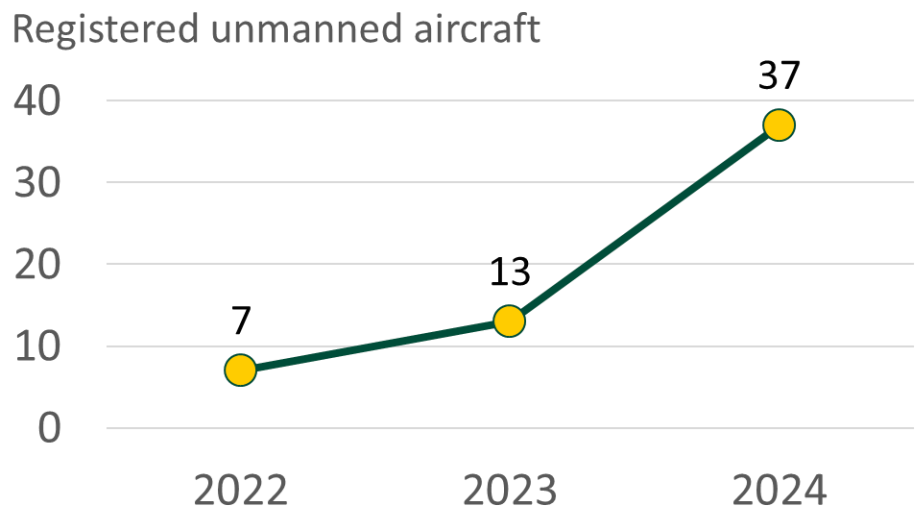
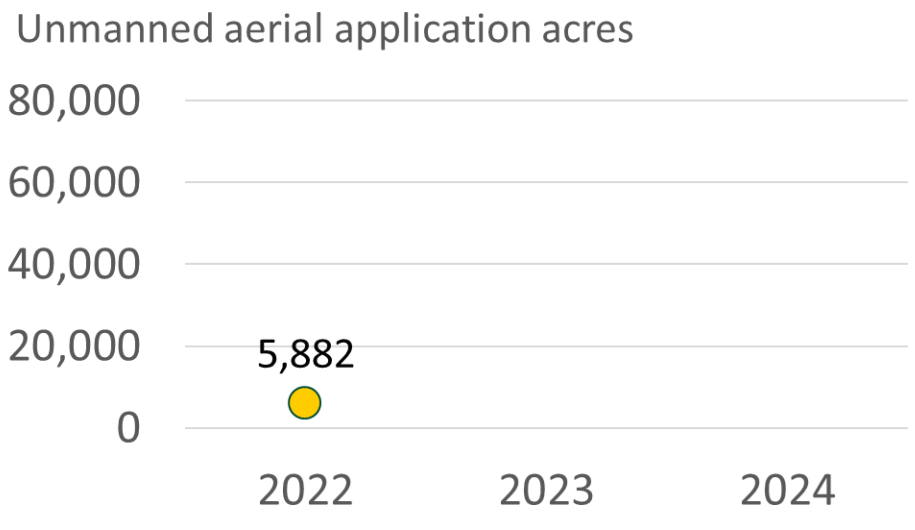
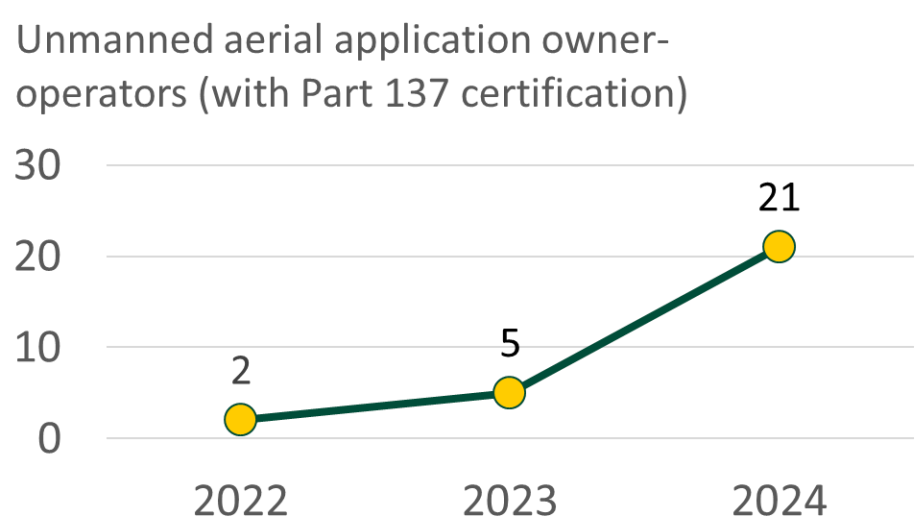

Licensed airmen (pilots) for unmanned aerial application
60
40
20
0
2
6
46
2022
2023
2024


Registered unmanned aircraft
40
30
20
10
0
7
13
37
2022
2023
2024


Unmanned aerial application acres
80,000
60,000
40,000
20,000
0
5,882
2022
2023
2024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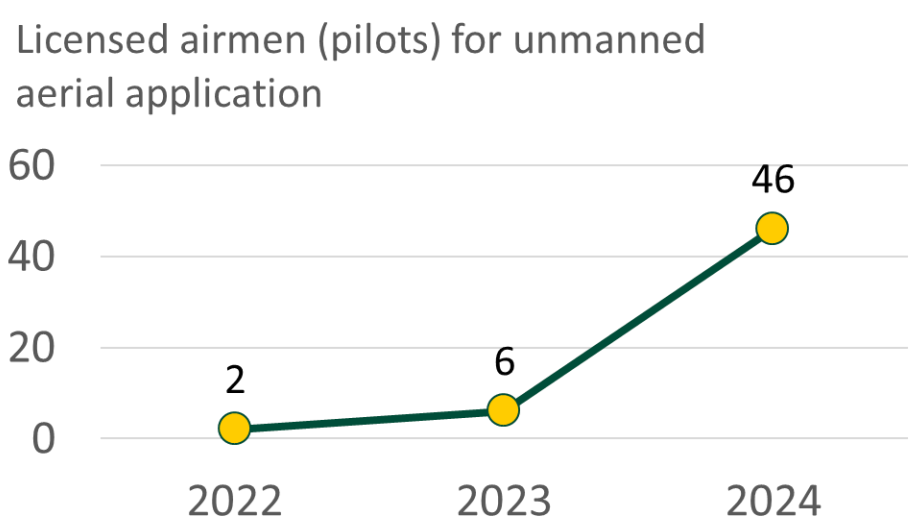
Licensed airmen (pilots) for unmanned aerial application
60
40
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2
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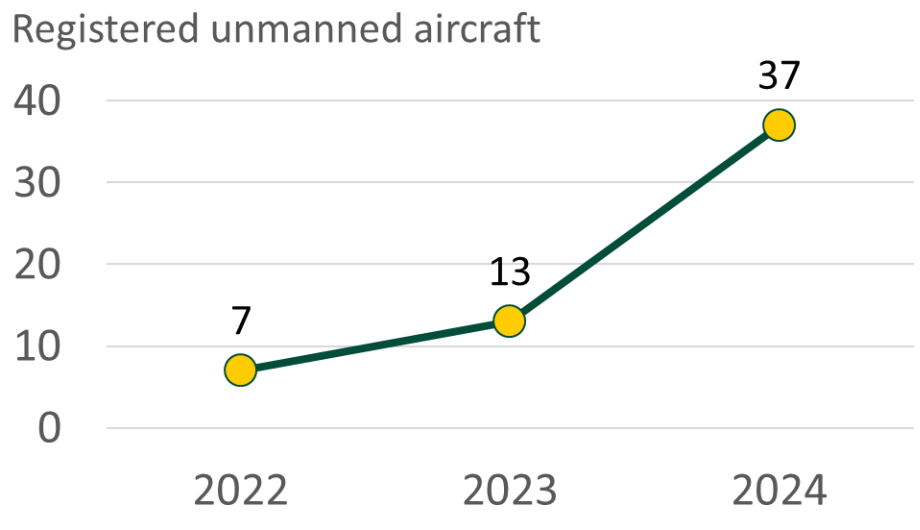
46
2022
2023
2024


Registered unmanned aircraft
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30
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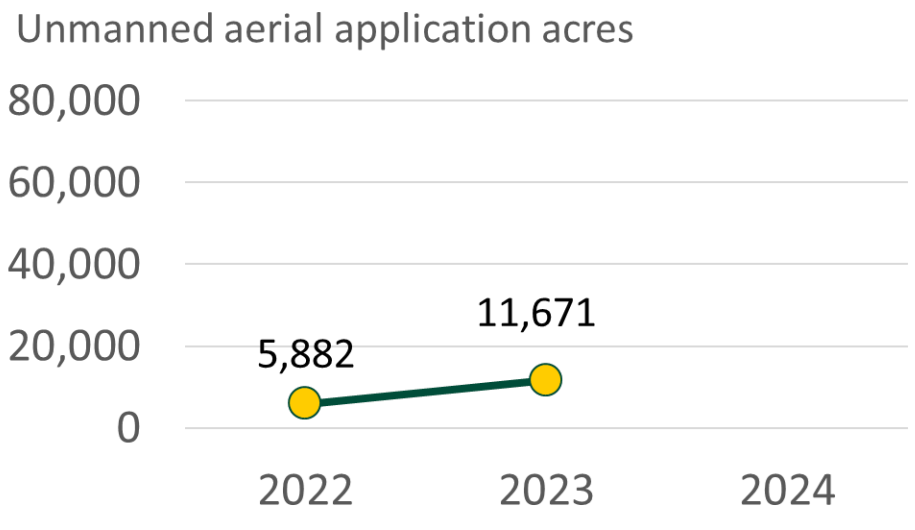
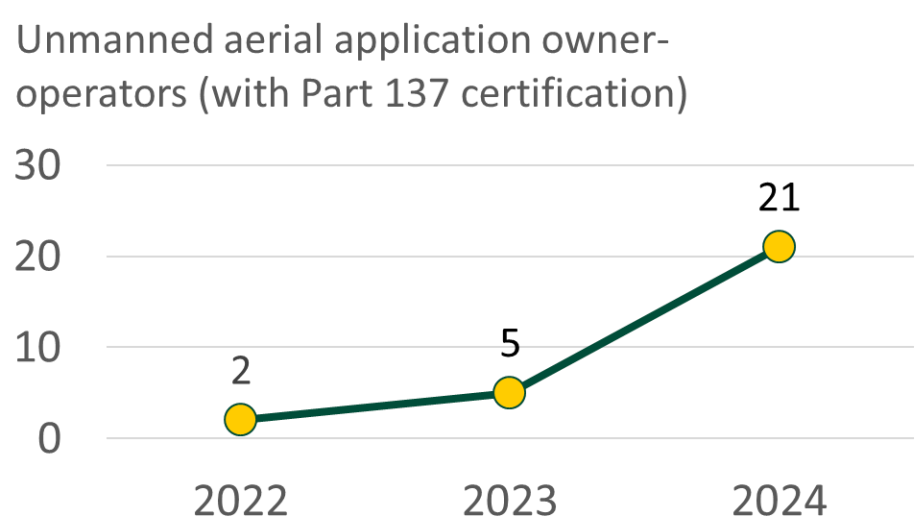
13
37
2022
2023
2024


Unmanned aerial application acres
80,000
60,000
40,000
20,000
0
5,882
11,671
2022
2023
2024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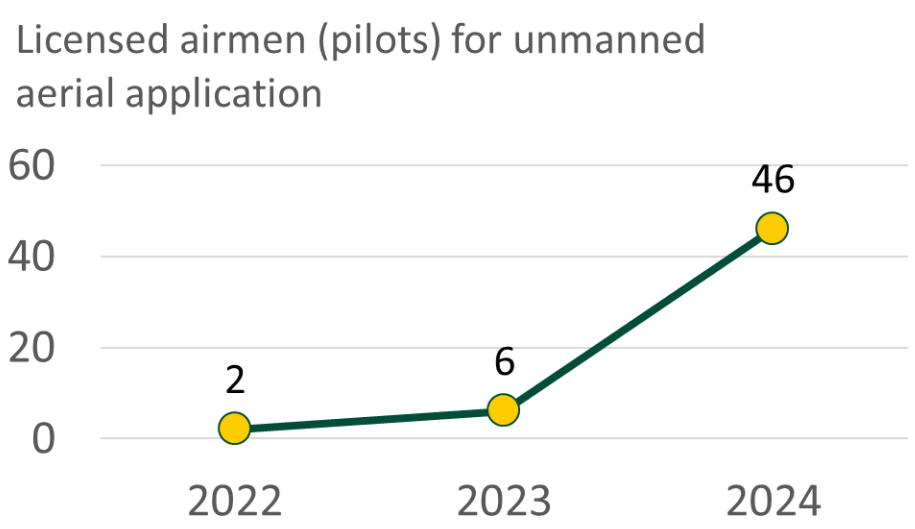
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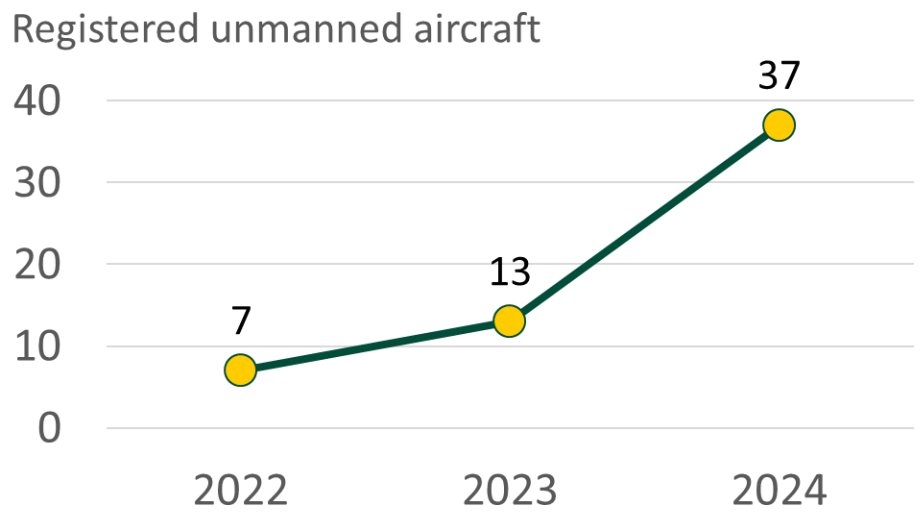
Registered unmanned aircraft
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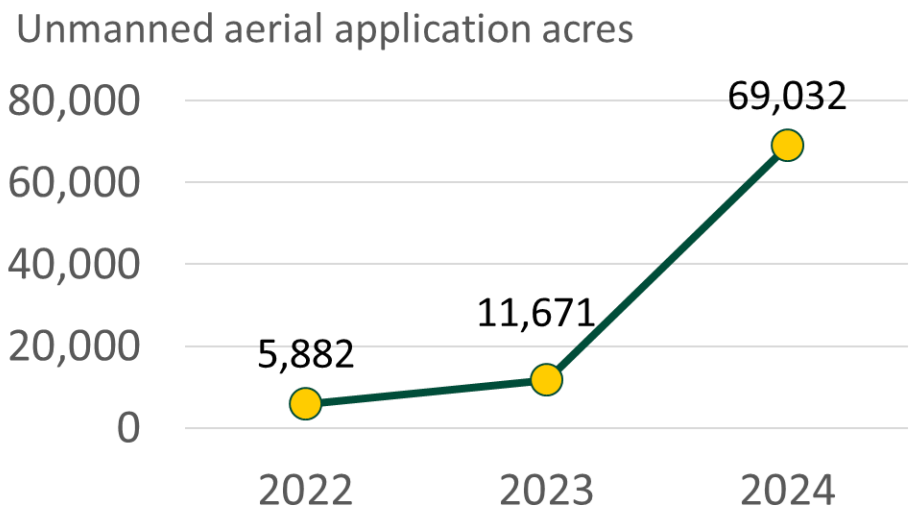
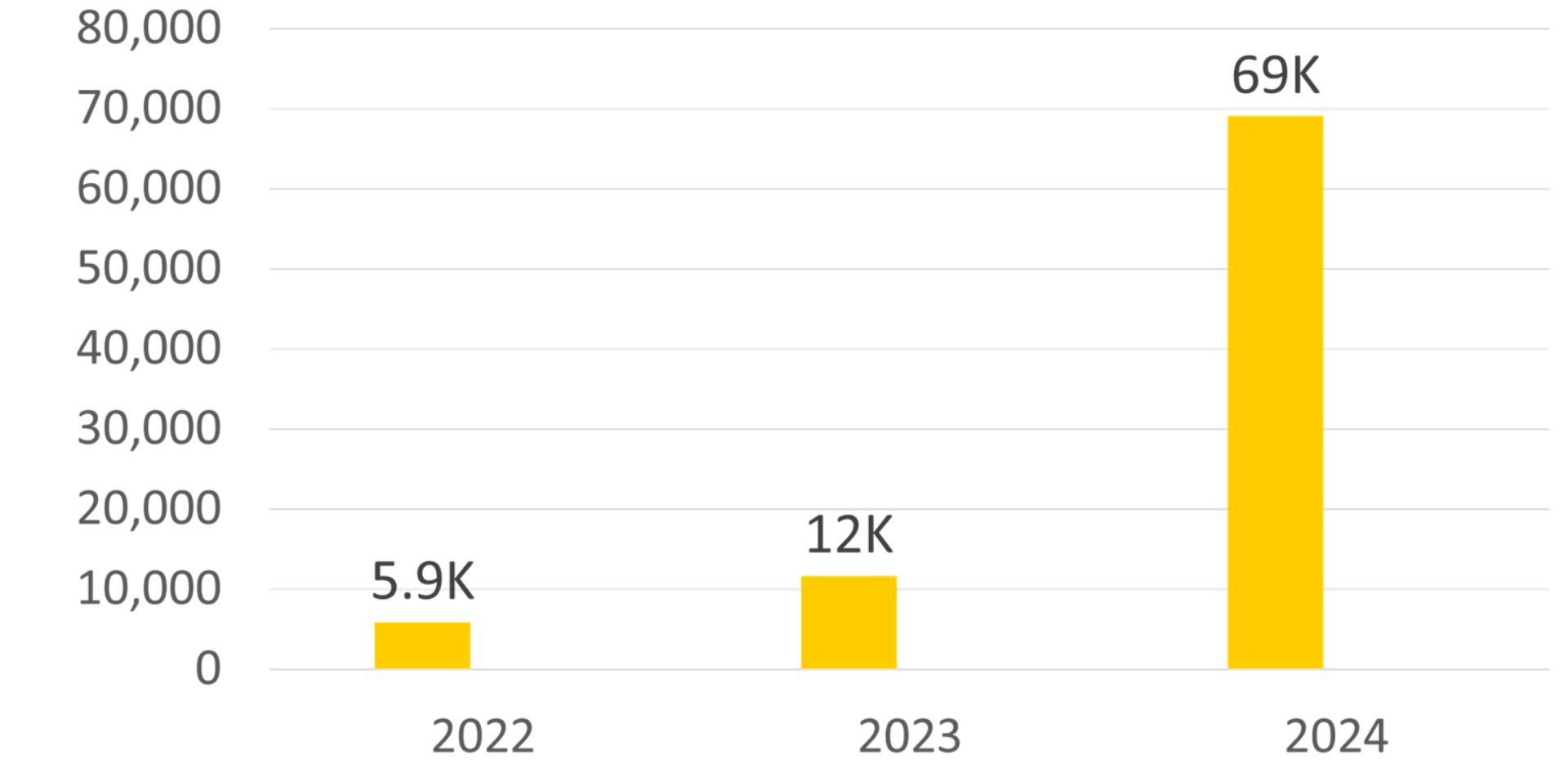
30
20
10
0
7
13
37
2022
2023
2024

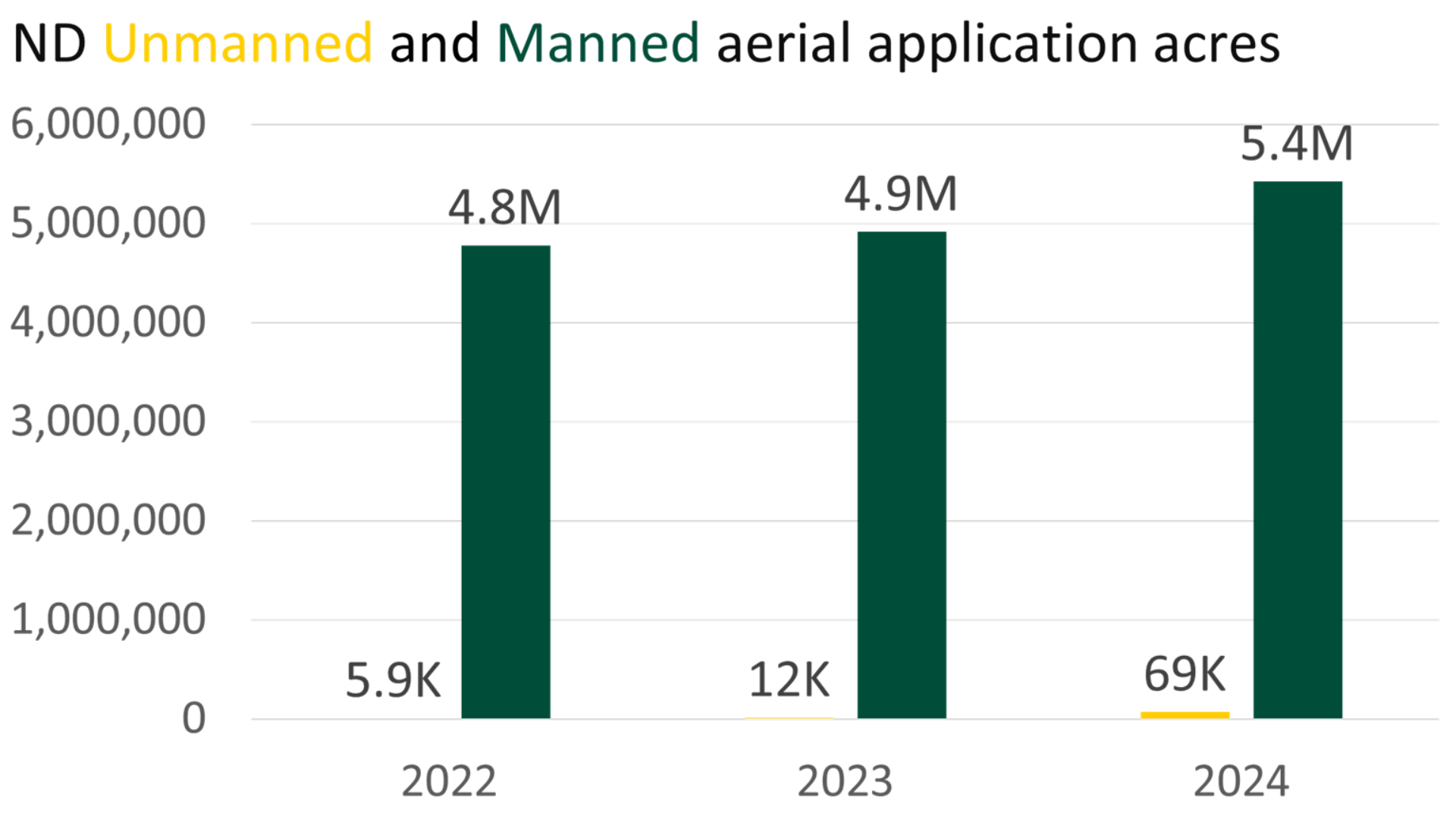

Unmanned aerial application acres
80,000
60,000
40,000
20,000
0
5,882
11,671
69,032
2022
2023
2024

Spray drones have arrived in ND…

Spray drones have arrived in ND…but they're not taking over…

ND Unmanned aerial application acres




ND Unmanned and Manned aerial application acres
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
0
4.8M
4.9M
5.4M
5.9K
12K
69K
2022
2023
2024

Spray drones have arrived in ND…but they're not taking over…

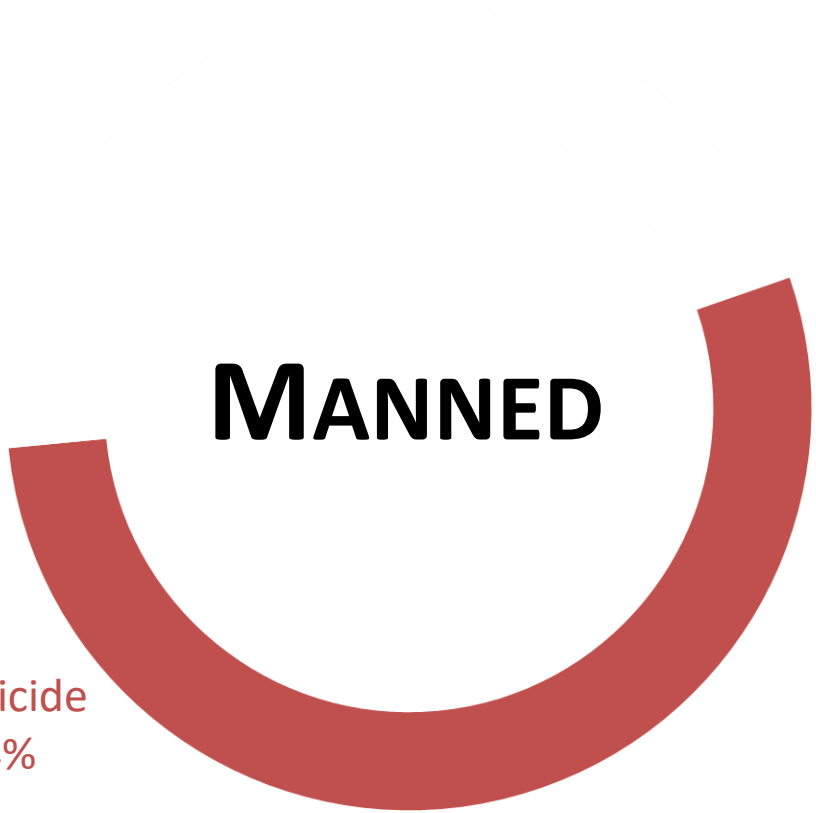
Spray drones have arrived in ND…but they're not taking over…but they seem to be filling a niche

2024 acreage

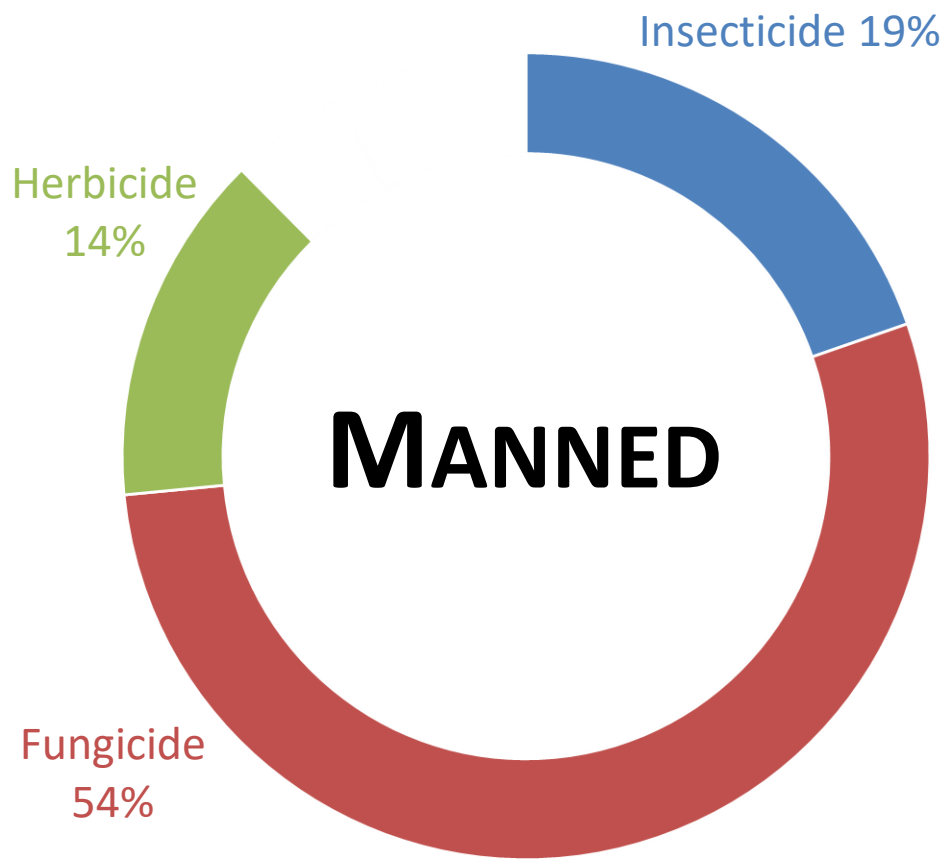
2024 acreage

MANNED

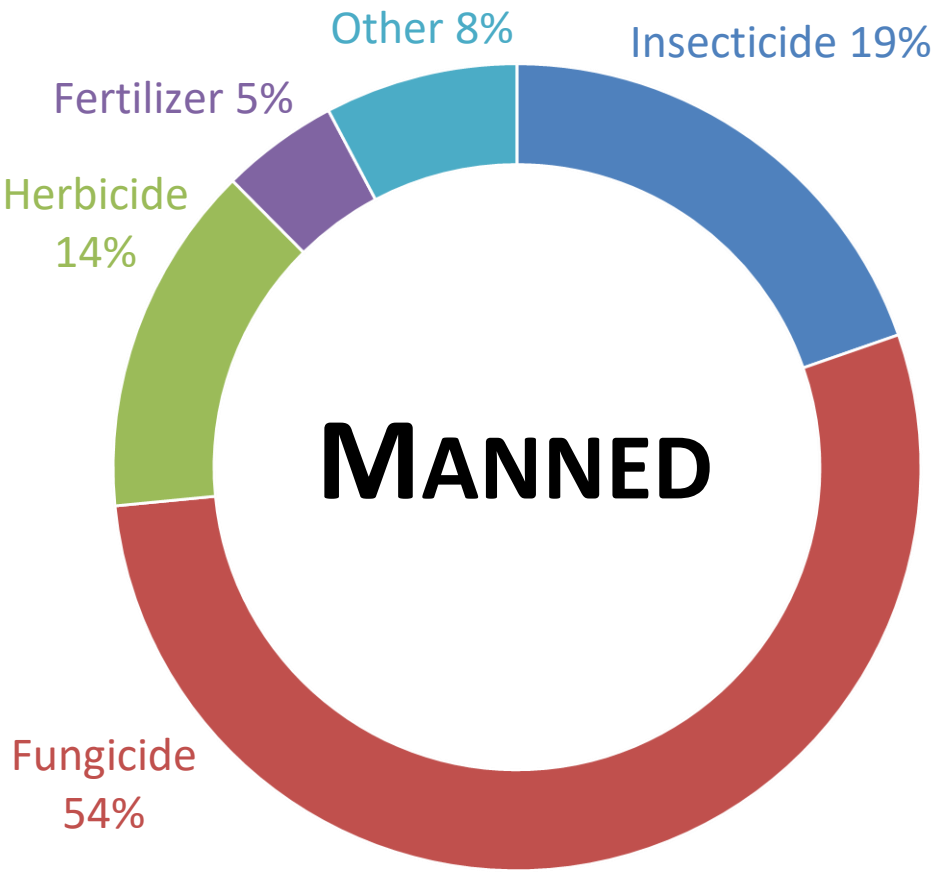
2024 acreage



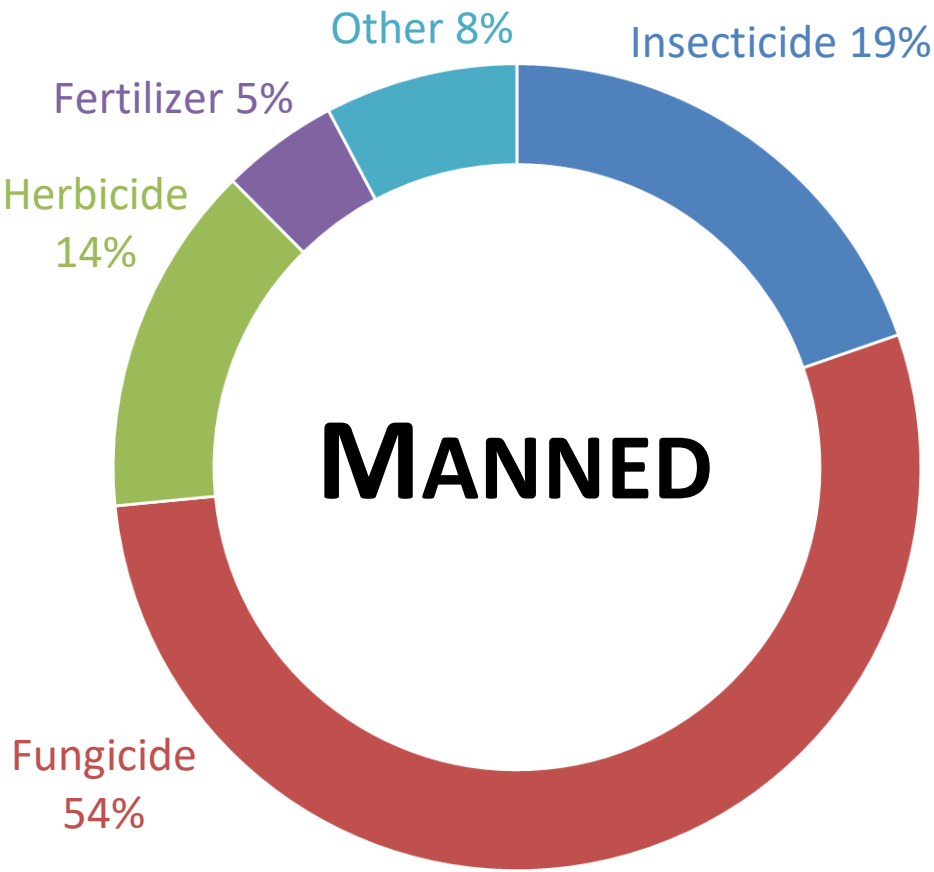
2024 acreage



2024 acreage



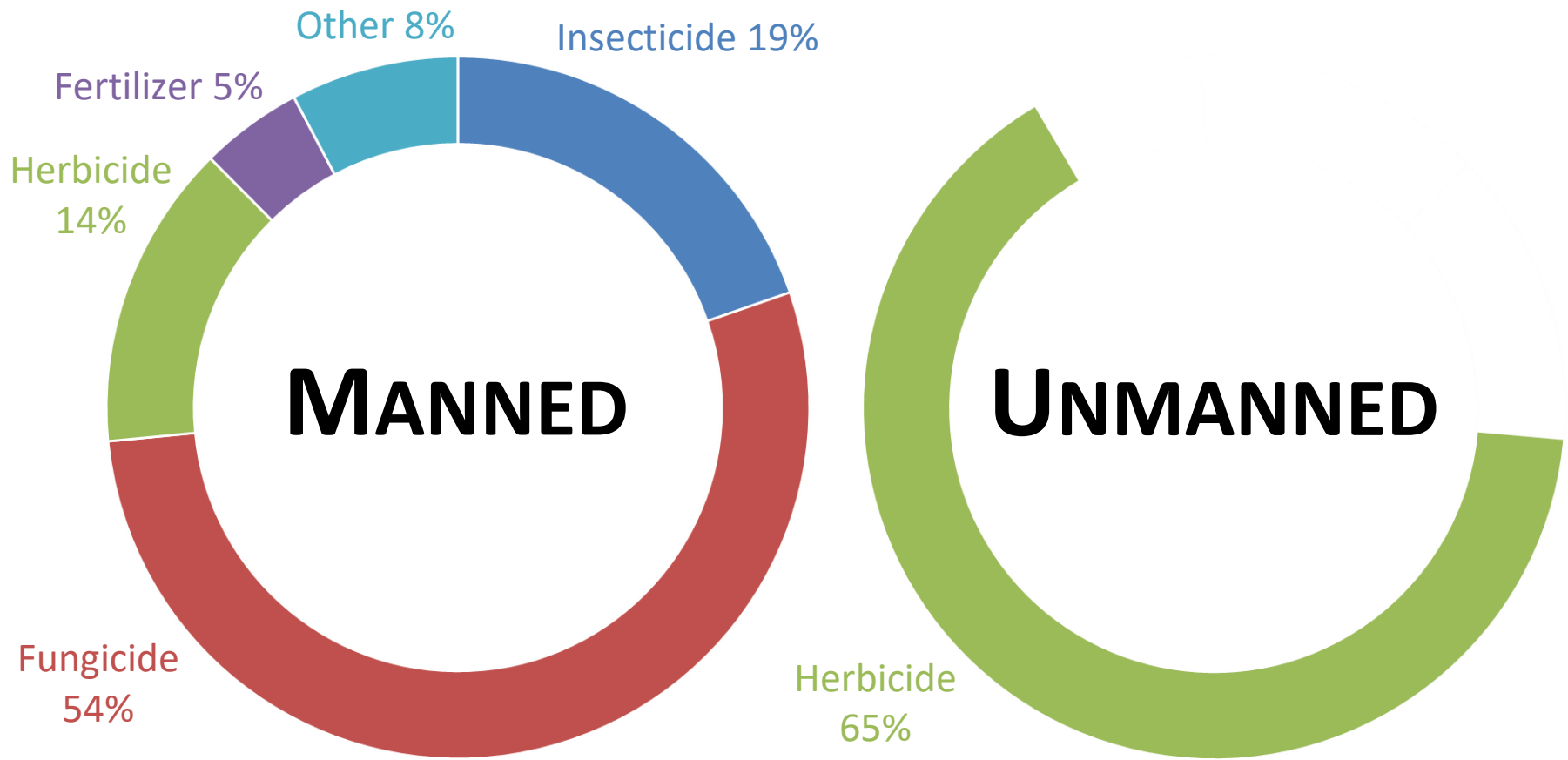
2024 acreage



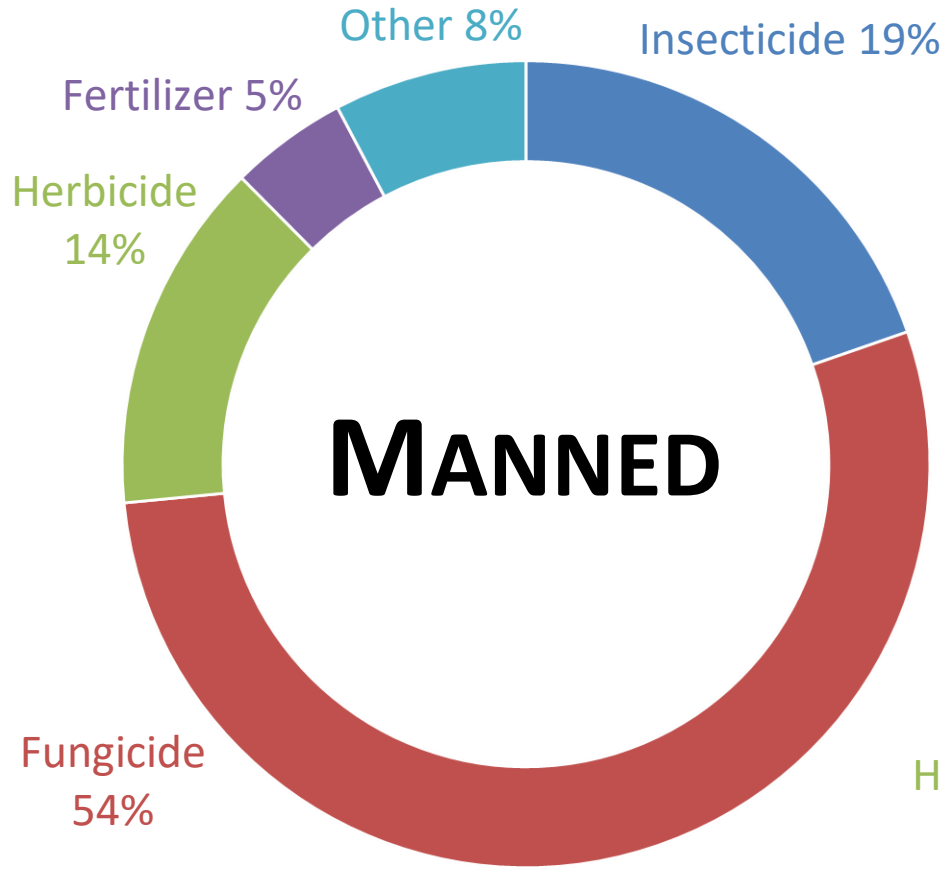
MANNED

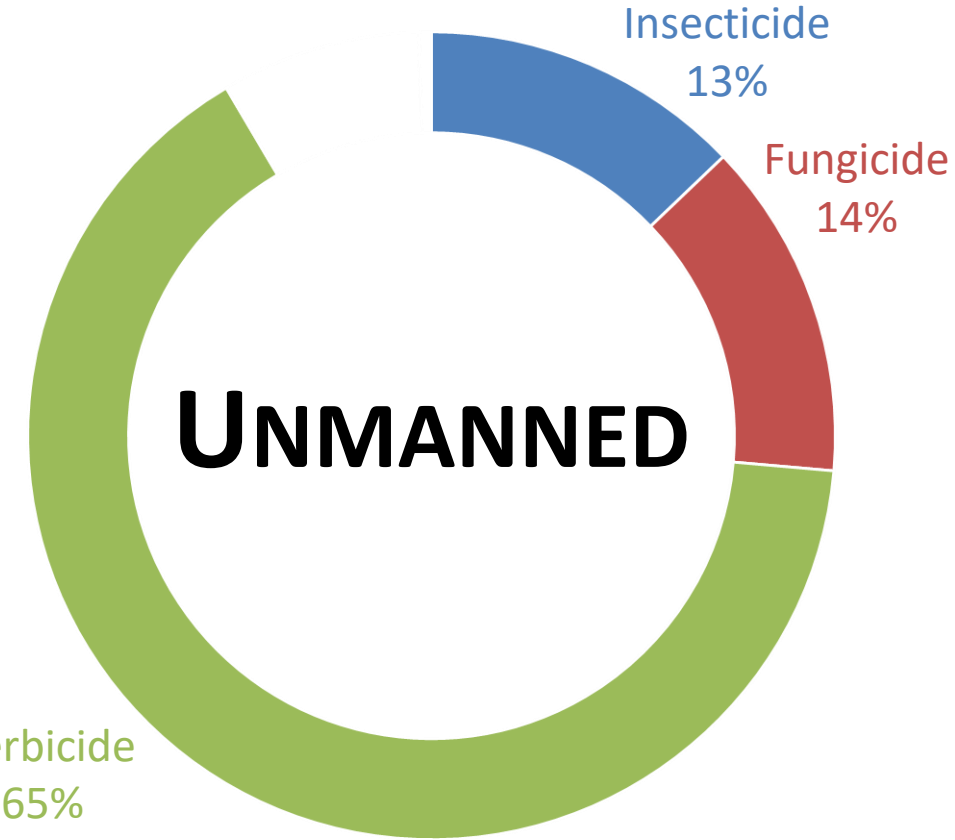
UNMANNED

2024 acreage



2024 acreage





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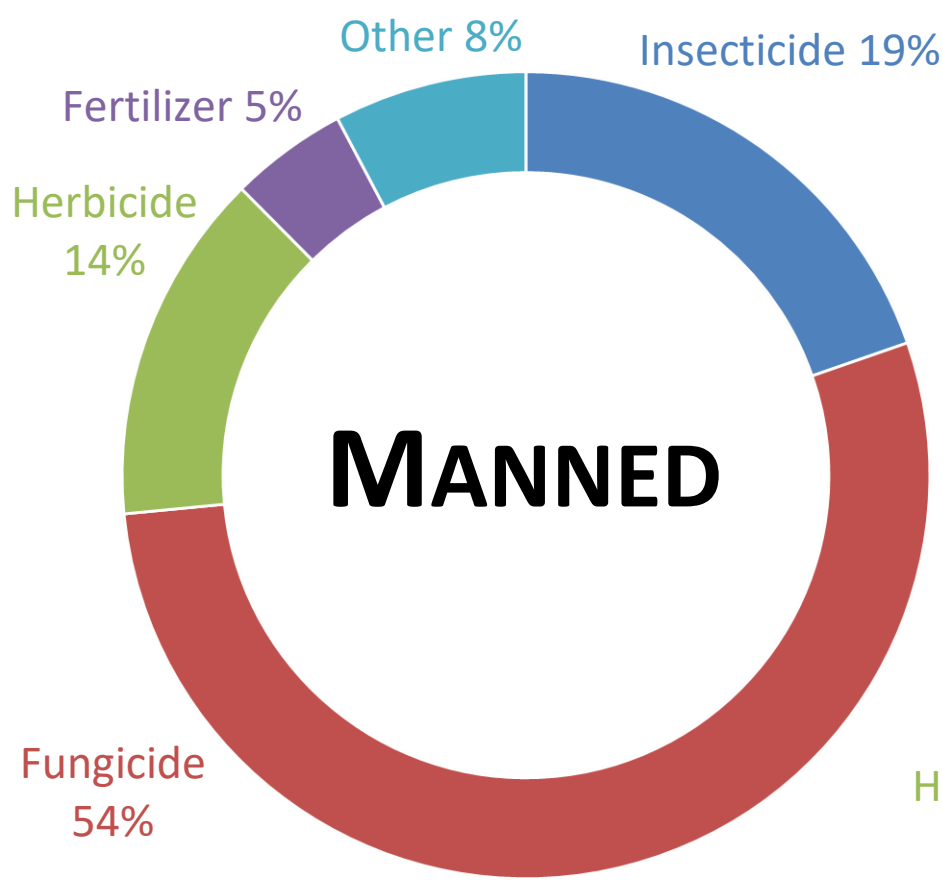

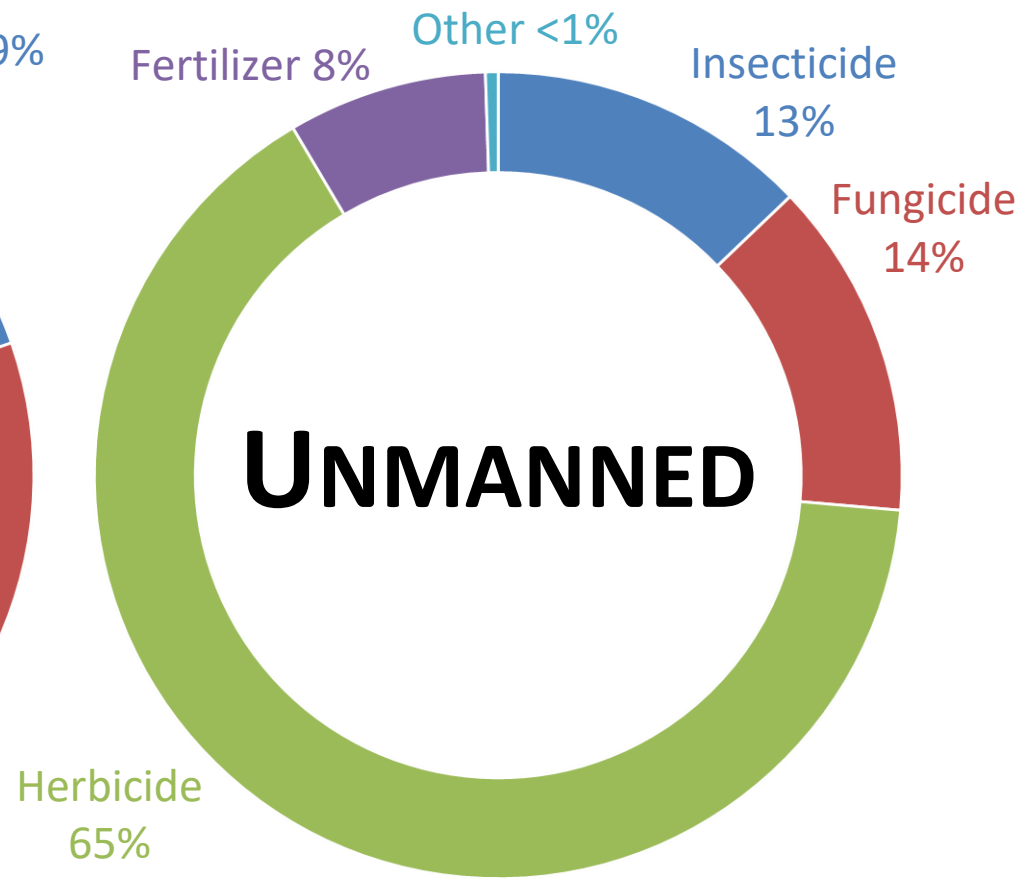

Most Recent Estimates, ND vs. MN

	ND	MN
Unmanned aerial applicators (with FAA Part 137)	21	11
Licensed airmen (pilots) for unmanned application	46	unknown
Registered unmanned aircraft for aerial application	37	14

Sources: ND Aeronautics Commission, MN Department of Transportation

Legalities and Licensing

What are the legalities of large ag drones?

We have a lawyer consultant for filing paperwork with the FAA, to help make it easier for our customers.

Encourage clients to get licensed or hire a licensed applicator. ND Aeronautics Commission is a key partner.

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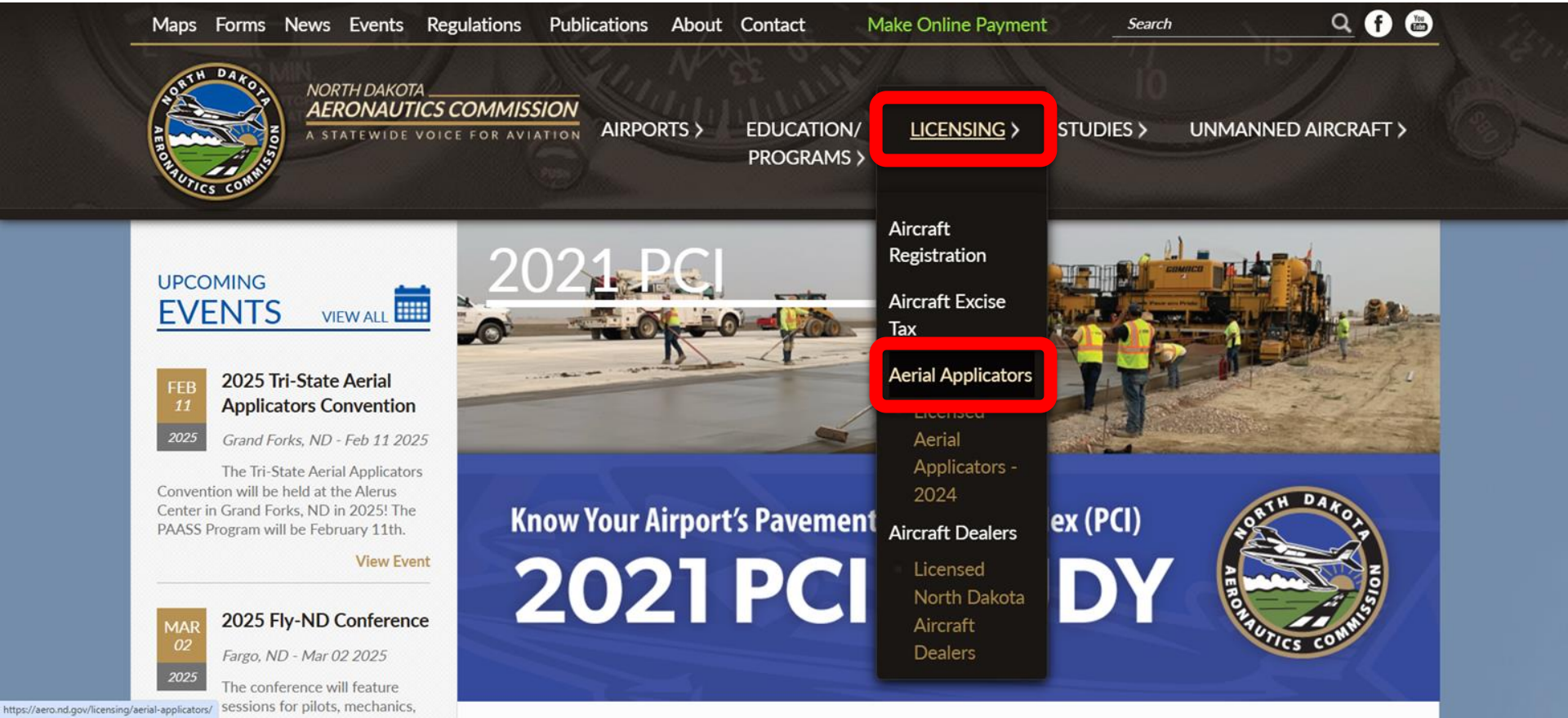
NORTH DAKOTA
AERONAUTICS COMMISSION
A STATEWIDE VOICE FOR AVIATION

“If it *flies* and *sprays*…

…it comes our way!”

– Janell Pederson, Licensing Specialist

https://aero.nd.gov/



Private Manned Aerial Applicators must complete SFN 2360. (Pilot's own land or land farmed by the pilot; not for hire)

The fee for an Aerial Applicator's license is $200.

- **UNMANNED** AERIAL APPLICATOR APPLICATION

Before you can even begin to apply chemicals with a drone in North Dakota, *even on your own farm*, operators need a Remote Pilot Certificate from the FAA (Part 107); an Agricultural Aircraft Operator certificate from the FAA (Part 137), a North Dakota Pesticide Certificate (NDSU); and finally, an Unmanned Aerial Applicator License from the North Dakota Aeronautics Commission. The fee for an Aerial Applicator's license is $200. There is no difference between commercial and private unmanned applicators.

NEED MORE INFORMATION?

Review the Unmanned Aerial Applicator CHECKLIST.

Visit the Game Board to see the steps you'll need to take to become an Unmanned Operator!

If you have any questions on this application, give us a call at (701) 328-9650 or email us.

What do you need *before* applying for an unmanned aerial applicator license in NORTH DAKOTA?

No person may engage in the activity or business of aerial application without first obtaining an aerial applicator's license from the North Dakota Aeronautics Commission [NDCC 6-02-02]. The following processes are not conducted *by* the office of the North Dakota Aeronautics Commission but each section in blue MUST be satisfied *before* applying for an aerial applicator license in ND. Use the check list below to assist you while you work your way toward a license to aerial applicate in North Dakota. Our office validates all certificates *before* granting a license.

There is preparation involved in collecting documentation and working with different agencies.

DO YOU HAVE

☐ FAA Part 107 Certification (Remote Pilot) | Unmanned Aircraft System (UAS):

In order to fly your drone under the FAA's Small UAS Rule (Part 107), you must obtain a Remote Pilot Certificate from the FAA. This certificate demonstrates that you understand the regulations, operating requirements, and procedures for safely flying drones.

- Find a Test Center: https://faa.psiexams.com/faa/login
- FAA Study Materials: Part 107 Study Materials
- FAA Drone Contact Info or call 844-FLY-MY-UA

DO YOU HAVE

☐ Aircraft Registration (Both State and Federal Require Registration):

Owners must register their UAS with the FAA via FAA Drone Zone if it weighs more than 0.55 pounds and **less than** 55 pounds. Unmanned aircraft weighing **more than** 55 pounds cannot use the FAA's online registration process and must

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The Game of LIFE of the UNMANNED AERIAL APPLICATOR

WHO CAN HELP ME?

- **FAA** Federal Aviation Administration (manages the nation's airspace and civil aviation systems)
- **FSDO** Flight Standards District Office (Fargo) (responsible for airmen certification)
- **NDSU** NDSU Extension Pesticide Program (certification to apply restricted-use pesticides)
- **NDAC** ND Aeronautics Commission (designated regulatory agency for the state)
- **NDDA** ND Department of Agriculture (requires the safety training administered by NDSU)

NDDA

CAUTION Everyone attends a safety meeting within the quarter of the application date. *Have you?*

ND Administrative Code 60-03-01-5.1(4) requires that all applicators seeking recertification must show proof of attendance at a PAASS Program at least one time every three years before recertification may be issued

WHAT IS PAASS? Professional Aerial Applicators' Support System is created and presented by ag pilots. New content on relevant topics each year covers key safety and drift mitigation issues important to flying, modern agriculture and crop protection.

If you were required to take PAASS in the 'current quarter' of this application, you have met the annual safety criteria.

Otherwise, you can attend NDAC's safety meeting at the Fly-ND Conference.

Contact NDAC for other options if attending is not possible.

Once approved, Pay $200 to NDAC

If already an approved manned operator, fee is waived

You must add any new pilots to the license (no fee, but pilot must be qualified) and any new drones ($15) throughout the year.

FINISH Congratulations! You are now a licensed aerial applicator in North Dakota. Expires December 31st of each year

NDAC

NDAC will verify:

- FAA Part 107
- FAA Part 137
- Chief Pilot experience
- All drones are registered
- All pilots have current ND Chemical from NDSU

LICENSED APPLICATOR DIRECTORY

Pilot vs. Chief Pilot: Before conducting solo flights, both must have (i) attended an approved training program or (ii) have received at least 10 hours of direct ground-supervised solo flight at operational loads while conducting aerial application, with supervision provided by a pilot who has conducted a minimum of twenty-five hours of solo flight at operational loads while conducting aerial application. **The Chief Pilot must provide evidence of training to NDAC.**

Apply for Unmanned Aerial Applicator License from NDAC

aero.nd.gov

Register your drone with the State

EACH DRONE IS $15 (cannot be over 500 lbs)

Are you from out of State? ND may issue a certificate on a reciprocal basis.

Contact NDSU Extension

Any pilot that sprays by air must obtain a ND Pesticide Certification: Class Air/Ground Core

https://ndlegis.gov/cencode/t04-1c33.pdf

Obtain ND Pesticide Certification

NDSU Extension Service 701-231-7180

Apply for a FAA Part 137 License

Already a manned 137 holder? Contact FDSO to add UAS.

- The Owner/Operator holds the Part 137 (pertains specifically to the agricultural use of aircraft, including drones)
- There must be a qualified Chief Pilot. The Chief Pilot is responsible for any pilots beneath them and must **provide evidence of experience.** See ND Administrative Code 6-02-02-04.2 for all regulation regarding Chief Pilot criteria.
- There is no difference between Private and Commercial when aerial applicating with a drone
- The ND Aerial Applicator License is an annual process. All licenses and registrations expire December 31st

KEY INFORMATION

NDSU Extension Pesticide Program

FSDO

Contact FSDO to understand Part 137 requirements and obtain UAS Exemptions

FAA

START

Buying a Drone?

Will you aerial applicate with it?

Make sure you..

Become a Certified Remote-Pilot with the FAA

FAA Part 107

Register your drone with the FAA

The FAA requires all UAS spraying operations to obtain a Part 137 operating certificate

There is a new streamlined process for those applying for a Part 137 (UAS Certificate)

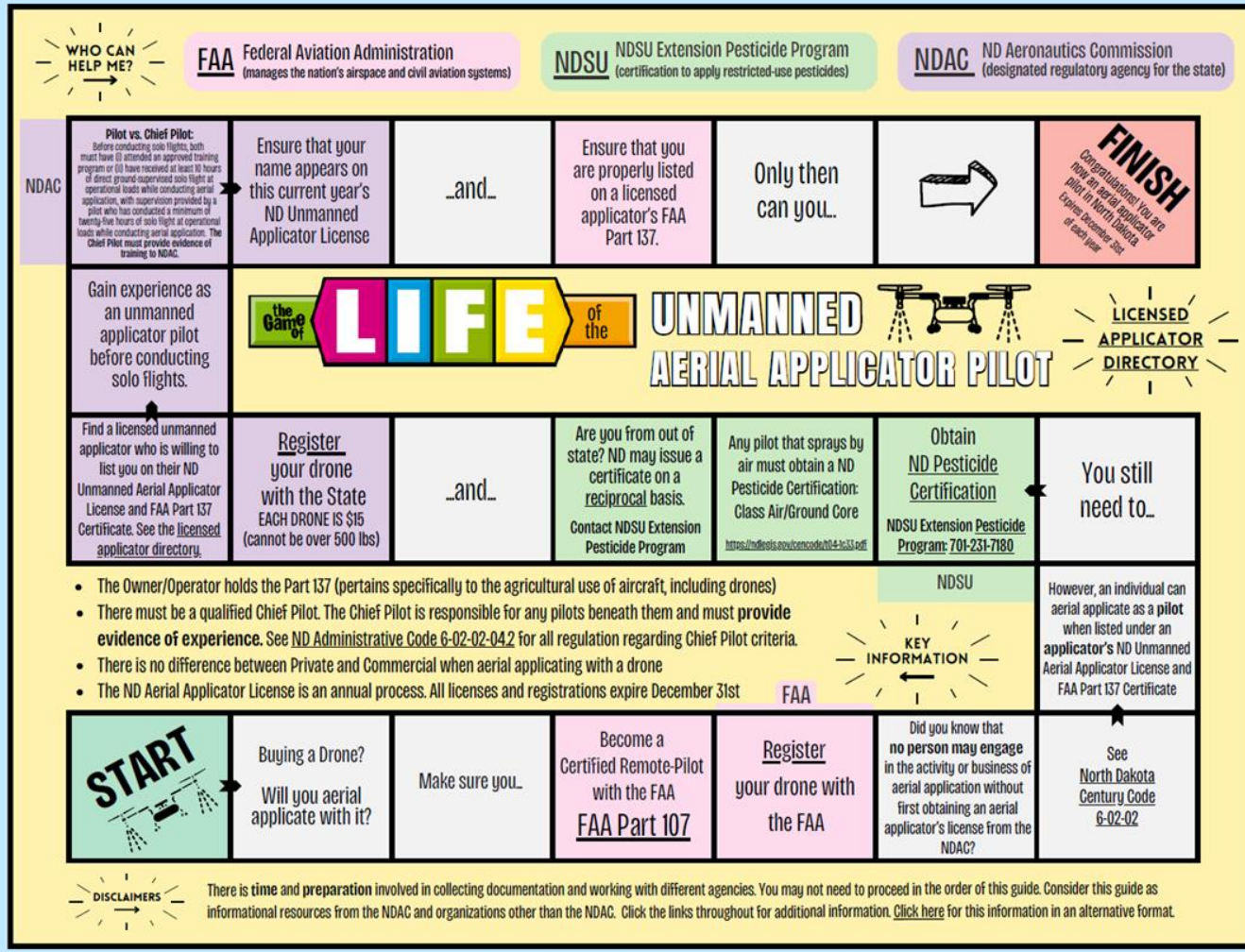
To begin the process, complete form FAA 8710-3 and email your assigned exemption number to the FAA:

UAS137certificates@faa.gov

DISCLAIMERS

There is **time** and **preparation** involved in collecting documentation and working with different agencies. You may not need to proceed in the order of this guide. Consider this guide as informational resources from the NDAC and organizations other than the NDAC. Click the links throughout for additional information. Click here for this information in an alternative format.

Authored by Rob Proulx, NDSU Extension (Conceptualization, Visualization, Writing – review & editing) and Janell Pederson, NDAC (Visualization, Writing – original draft)



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Encourage clients to get licensed or hire a licensed applicator. ND Aeronautics Commission is a key partner.

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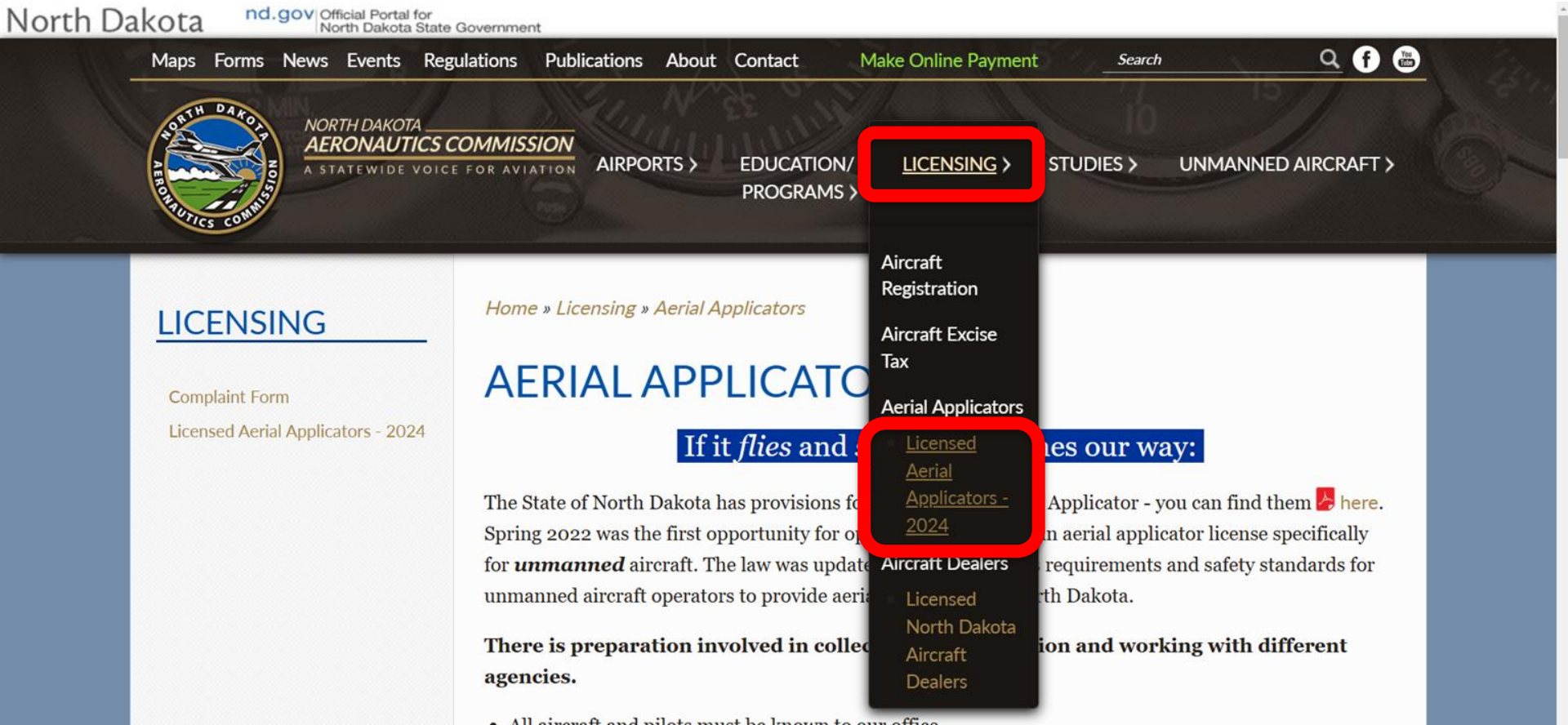


AERIAL APPLICATORS

Aerial Applicators licensed to spray in the State of North Dakota in 2024:

Any legally authorized person aerial applicating in this state will be able to produce a license from our office displaying each licensed aircraft and each licensed pilot.

Do you have questions or concerns about an applicator? You may email us to confirm the licensure of a manned or unmanned applicator, or you can Anonymously Report your concerns.

Download List

2024 Licensed Aerial Applicators.xlsx : as of 09-19-2024

BUSINESS NAME	CONTACT	EMAIL	TYPE OF LICENSE	PHONE	CITY | STATE	
3RD GEN AVIATION LLC	BEN HALSTENSON	bhalstenson@3rdgenaviation.com	MANNED	701-739-5463	LISBON	ND
AERIAL CROP CARE CO	KEITH & CHERYL CHA	aerialcrop@westriv.com	MANNED	701-878-4735	HEBRON	ND
AERO SPRAYING SERVICE INC	RICHARD MARBURGE	rckmrbrgr@gmail.com	MANNED	701-570-2342	WILLISTON	ND
AERO-TECH SOLUTIONS LLC	KELLY DOLLINGER	kellydollinger1@gmail.com	UNMANNED	701-426-6891	BISMARCK	ND
AG AIR LTD	DAVID GUST	dgust58039@aol.com	MANNED	701-261-6162	HARWOOD	ND
AG SPRAY INC	GARY JERGER	gary@agspray-inc.com	MANNED	218-233-0546	MOORHEAD	MN

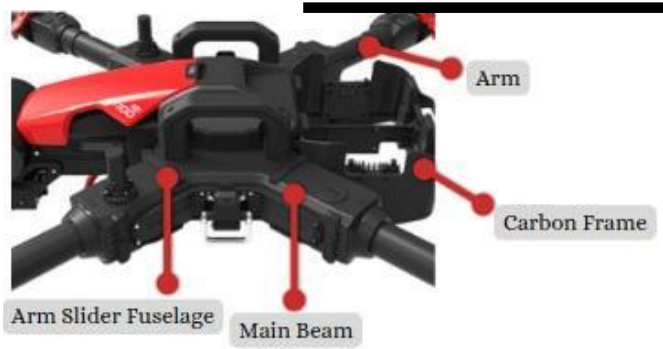
Hard lessons & Use cases

Cleaning

- Refill the Tank with soap water/tank cleaner
  - Engage all nozzles to drain and clean out remaining residues
- Refill the Tank with clean water and engage all nozzles to drain soap water within the spray system
- Can use power washer
  - don’t directly wash electrical components
- Use wet rag or brush to remove any stains and foreign objects
- Wipe and clean the propellers, motor housing, remote controller
- Use a damp microfiber cloth to clean the terrain module; ground radar & ground vision lens to ensure that the terrain module is clean and free of foreign debris
- Use a lens or microfiber cloth to wipe the perspective image camera and check whether it is functional through the XAG One App

Daily Post-Flight Clean must be conducted if the aircraft has been used for the application of agrichemicals

100 hours Maintenance

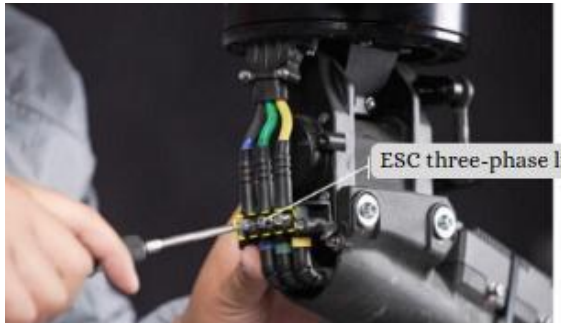


Check main body

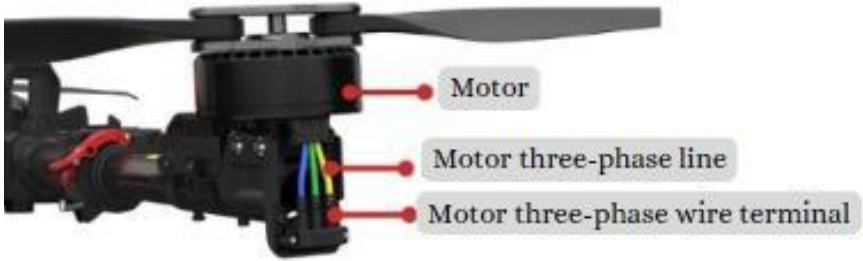
Deformation or breakage

Fixing screws are loose, slipped, rusted or broken

Wires at the flight control are worn or broken



Check the three-phase wires and terminals of the ESC

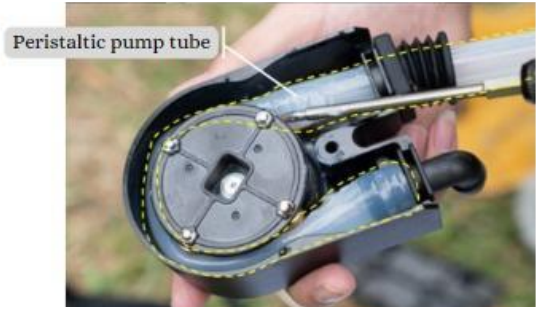


Check Power Systems

Abnormal noise or sticking

Three-phase wire wear and tear

Check the EV foam



Remove and observe the peristaltic pump tube blockage, aging, stiffness lubrication and damage

General Repairs

Replacement of propellers

Propeller repairs are most common

1.Don’t used imbalanced propellers

2.Replace a set at a time, never a single








Applied research on efficacy

Spray drones can achieve similar efficacy to ground spraying…

An Enlist, Roundup and Anthem Maxx tank mix applied to soybean in Missouri[1] achieved 68 to 75% waterhemp control with similar results between a drone sprayer (3 gpa AV) and a ground sprayer (15 to 20 gpa AV).

[1] Thompson, T., Barlow, H., Coe, G., Rogers, G., Knerr, D., & Bradley, K. W. (2024). *Field Evaluation of the DJI Agras T40 UAV for the Application of Herbicides in Soybean*. Mizzou Crop & Pest News. https://weedscience.missouri.edu/slideshows/uavs_2024.pdf

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[2] Virk, S., Byers, C., Meena, R., Kichler, J., & Kemerait, B. (2024, July 21). Spray Deposition and Efficacy of Pesticide Applications with Spray Drones in Row Crops in the Southeastern US. *Proceedings of the 16th International Conference on Precision Agriculture*. International Conference on Precision Agriculture, Manhattan, KS.

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[3] Deveau, J. (2024, March 19). Exploring spray drones in soybean. *Sprayers101*. https://sprayers101.com/drone-soybean/

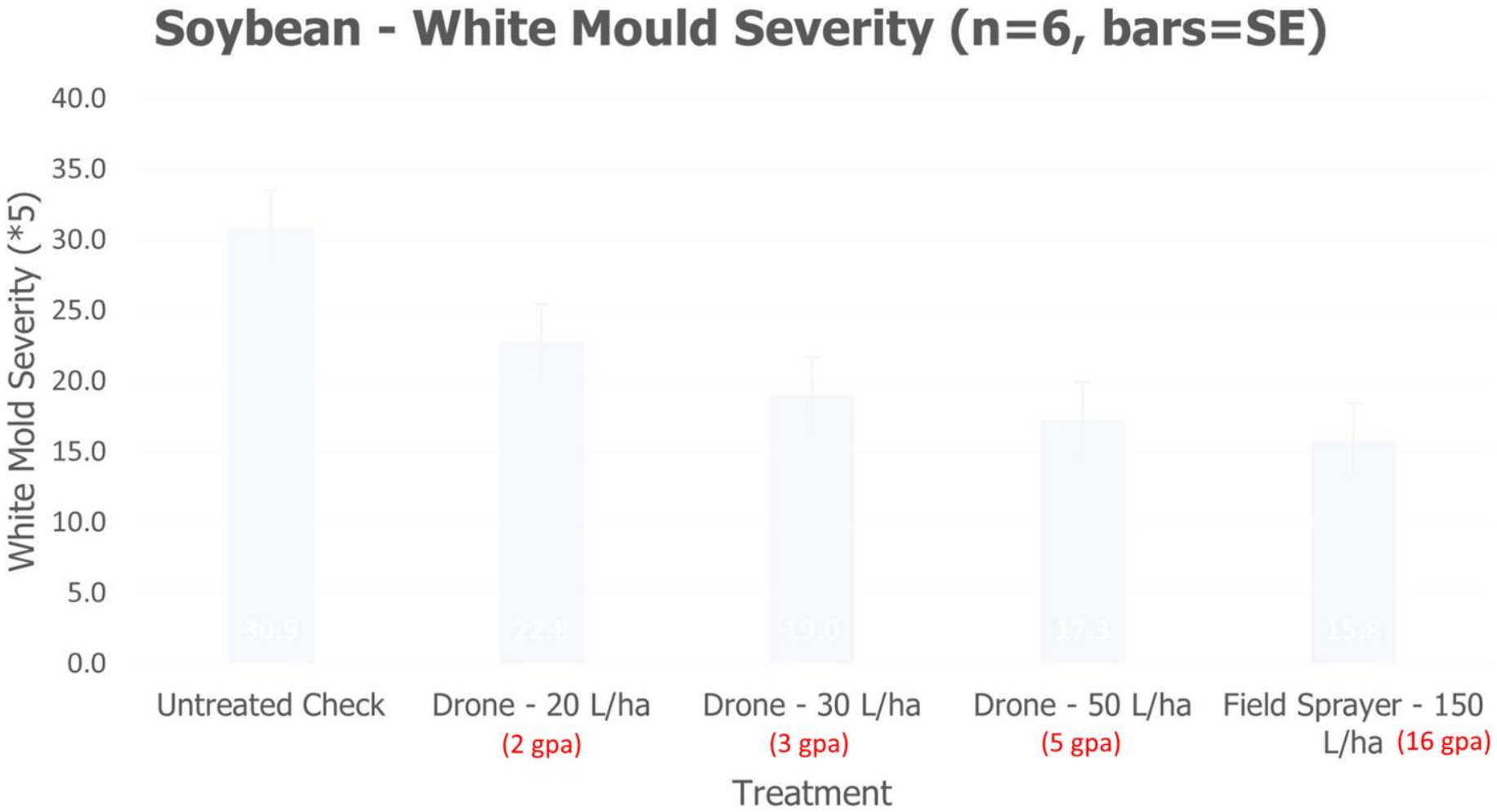
https://sprayers101.com/drone-soybean/

Exploring Spray Drones in Soybean

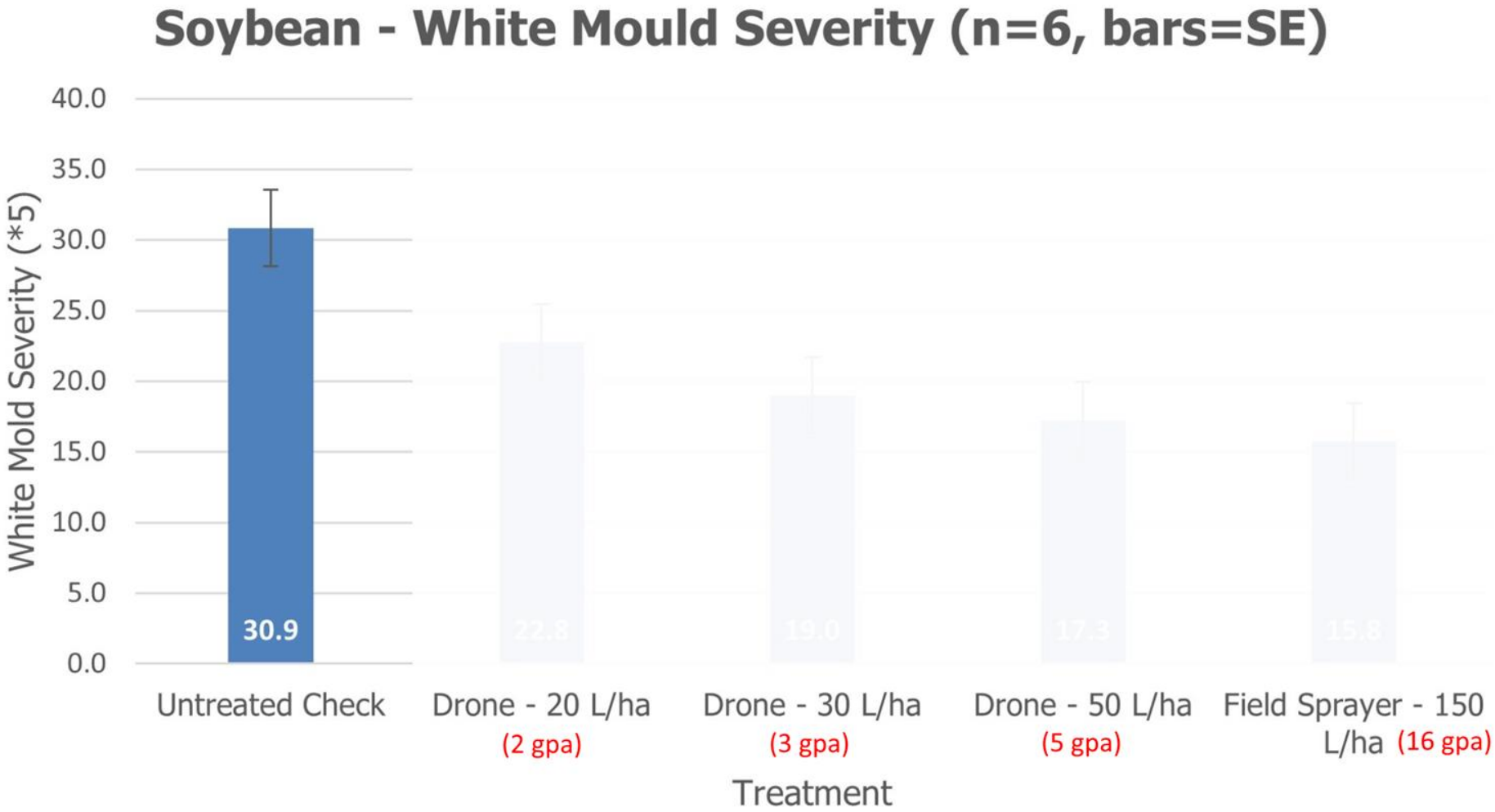
Posted on **March 19, 2024**

ABOUT JASON DEVEAU (SPRAY GUY)

Dr. Jason Deveau has been the OMAFA Application Technology Specialist since 2008. He researches and teaches methods to improve the safe, effective and efficient application of agricultural sprays in specialty crops, field crops and controlled environments. He is the co-administrator of Sprayers101, co-author of the Airblast101 Textbook, a slow cyclist and an even slower runner.



Source: Deveau, 2024 March 19



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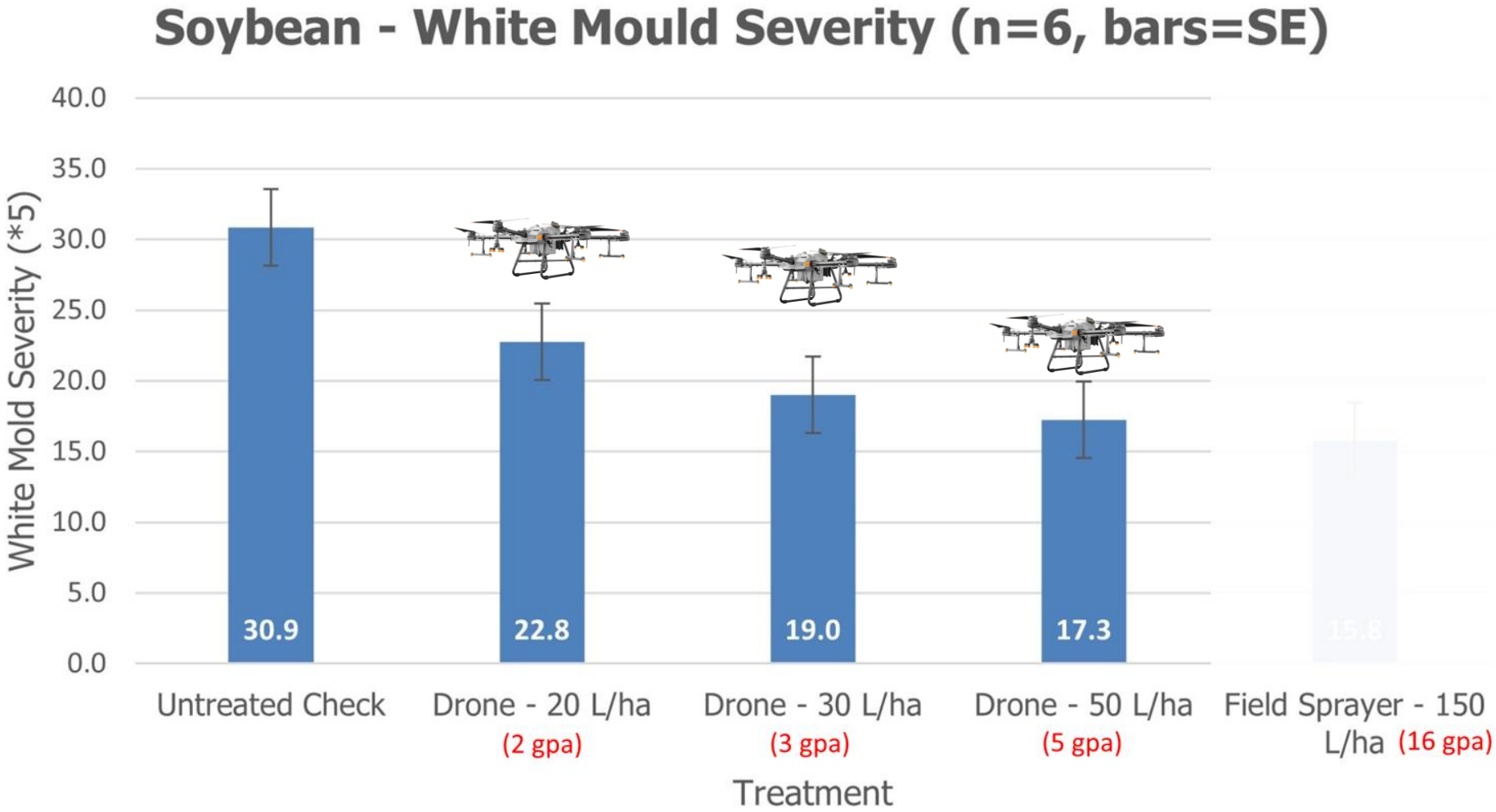
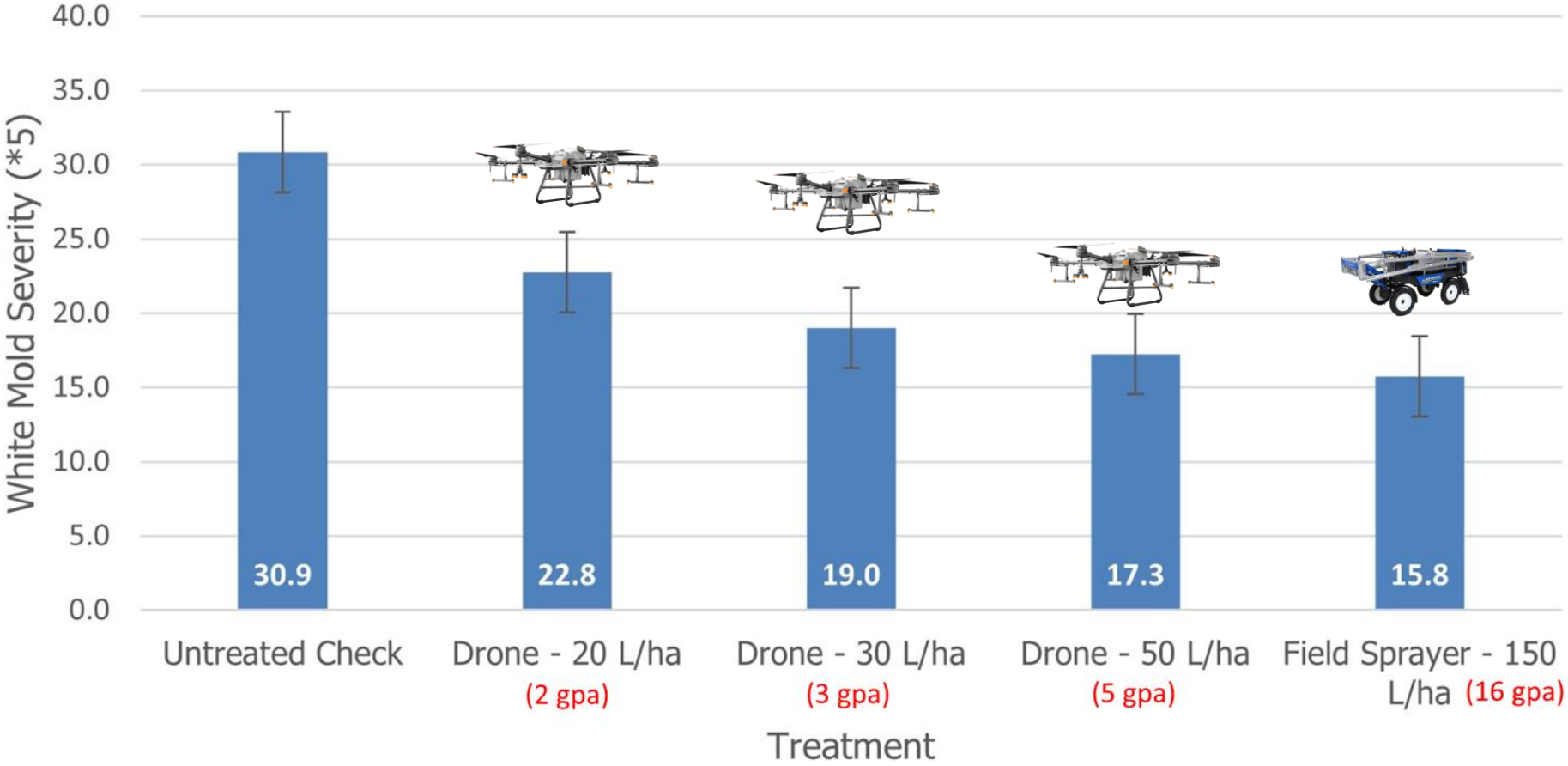


Source: Deveau, 2024 March 19

Soybean - White Mould Severity (n=6, bars=SE)



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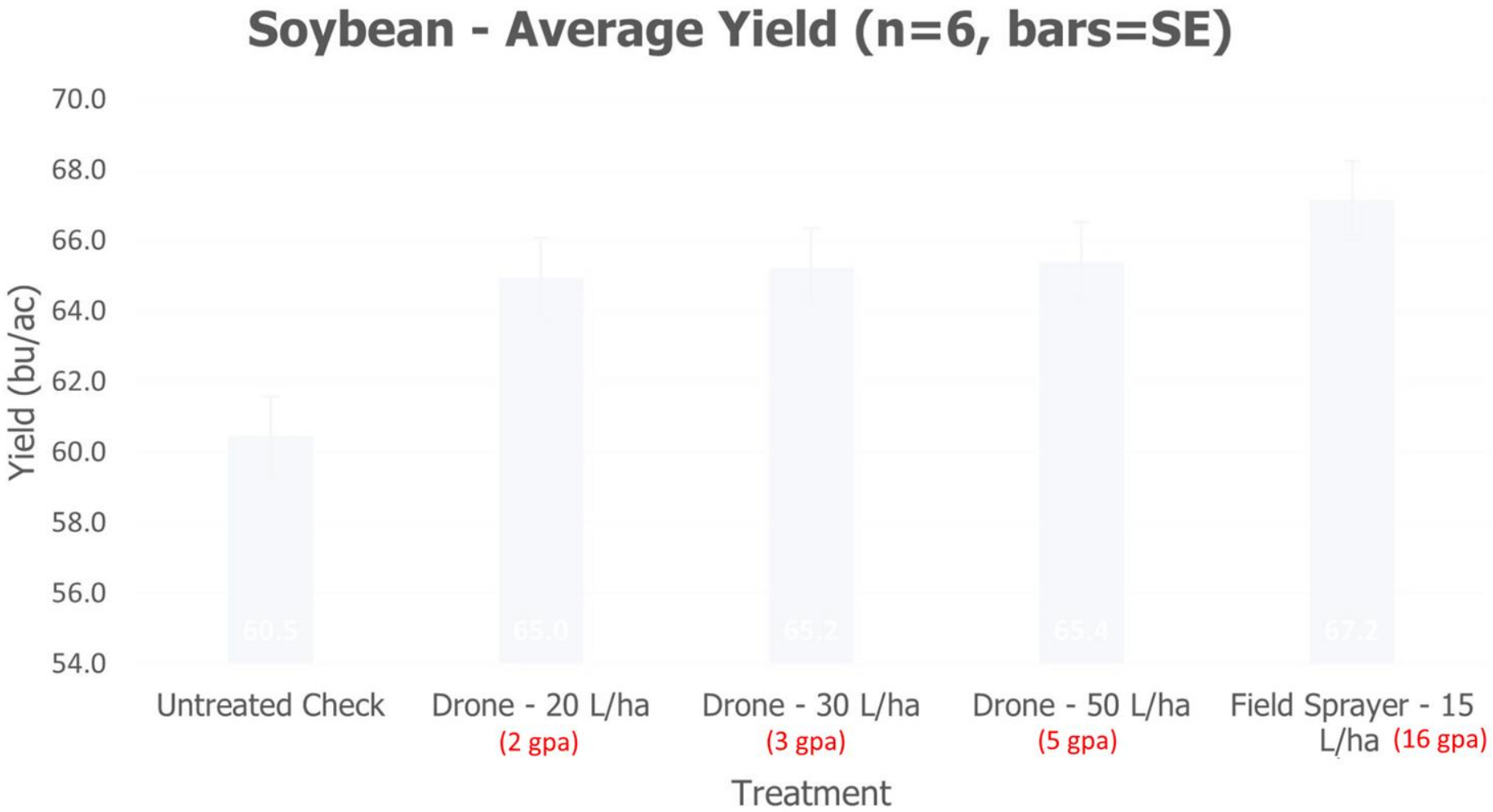

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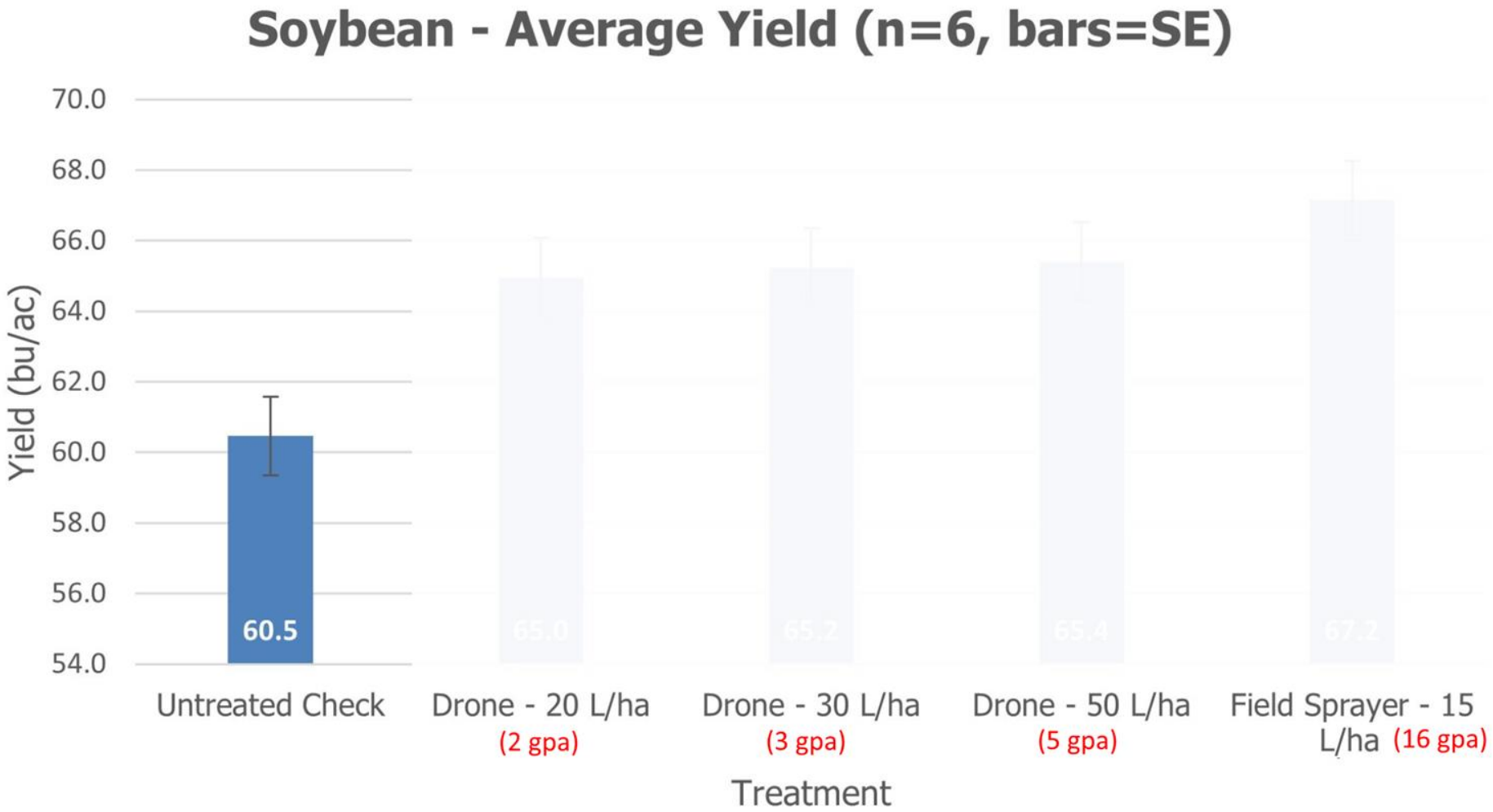

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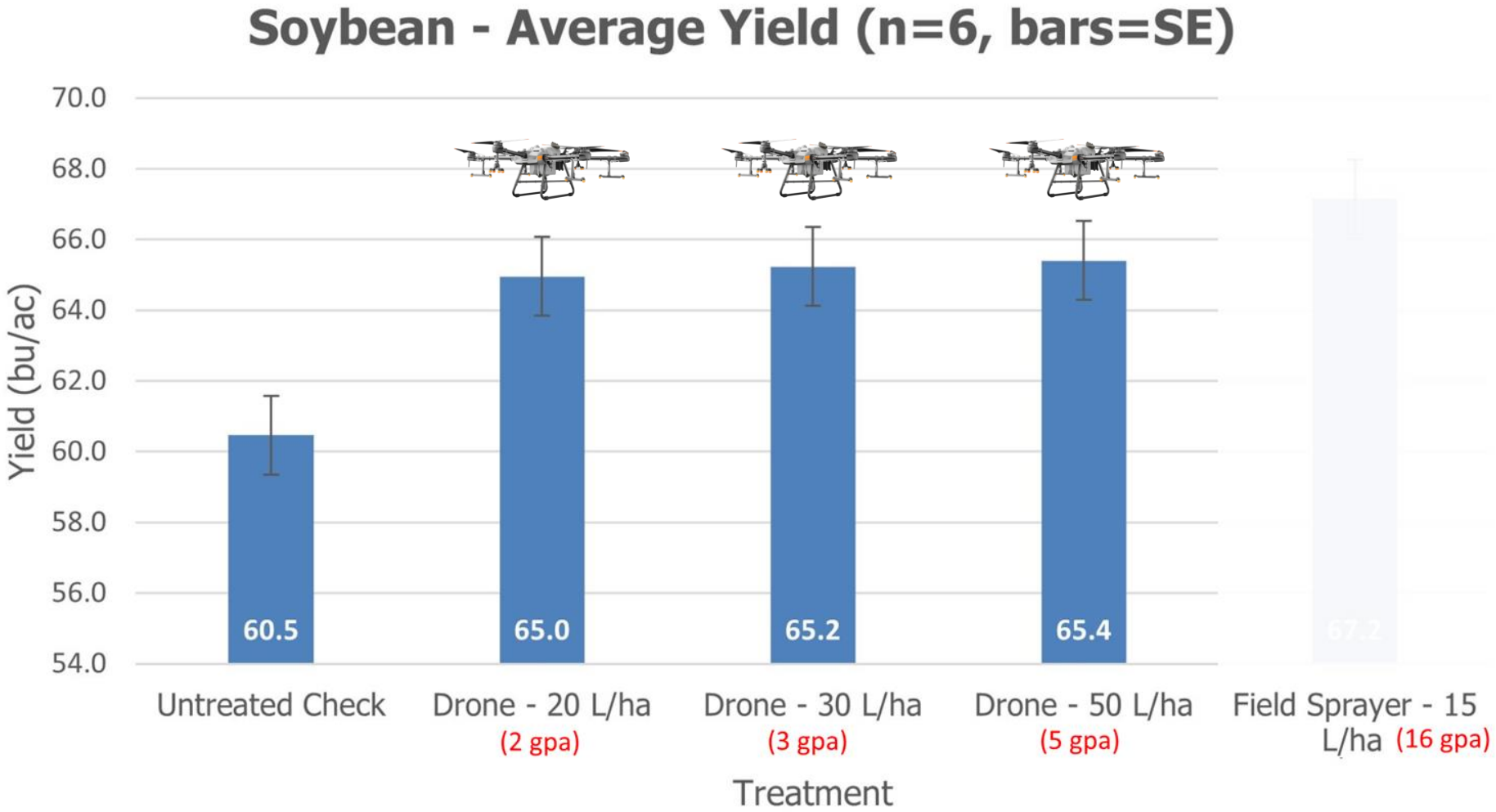

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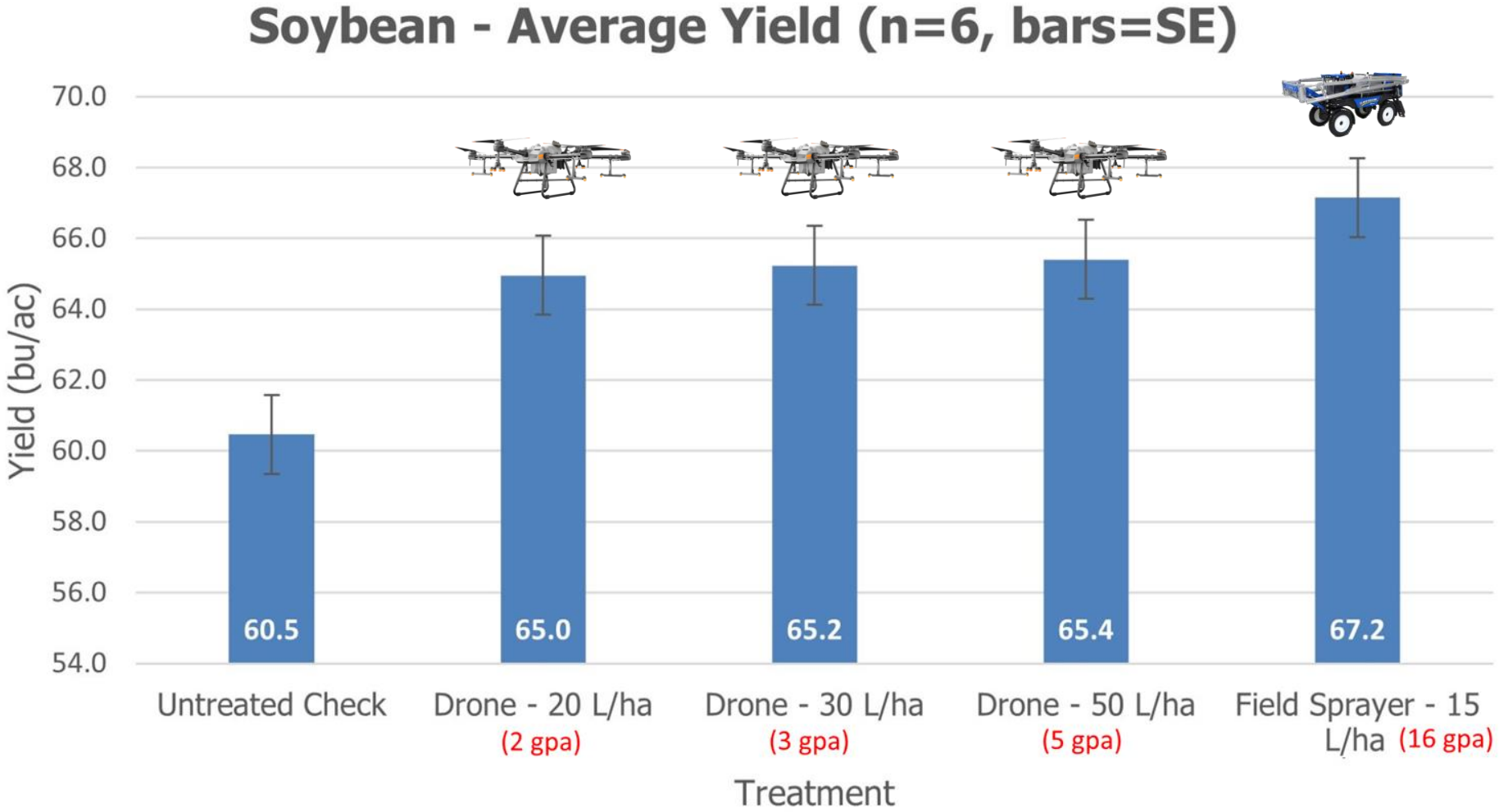

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Spray drones can achieve similar efficacy to ground spraying…

Spray drones can achieve similar efficacy to ground spraying…and efficacy trends higher at 5-6 GPA relative to 2-3 GPA

Georgia, fungicide application for corn leaf diseases

Table 2. Disease ratings and yield for fungicide applications with a spray drone at two different rates and an untreated control in maize.

Virk, S., Byers, C., Meena, R., Kichler, J., & Kemerait, B. (2024, July 21). Spray Deposition and Efficacy of Pesticide Applications with Spray Drones in Row Crops in the Southeastern US. *Proceedings of the 16th International Conference on Precision Agriculture*. International Conference on Precision Agriculture, Manhattan, KS.

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Application Rate ($L\ ha^{-1}$)								

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Application Rate (L ha^{-1})	
18.7	2 gpa
46.8	5 gpa
Untreated Control	

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Application Rate ($L\ ha^{-1}$)		Northern Leaf Blight (%)
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46.8 5 gpa	
Untreated Control	6.70 a

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Application Rate (L ha^{-1})		Northern Leaf Blight (%)
18.7	2 gpa	1.97 b
46.8	5 gpa	0.03 b
Untreated Control		6.70 a

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Georgia, fungicide application for corn leaf diseases

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Application Rate ($L\ ha^{-1}$)		Northern Leaf Blight (%)	Southern Corn Rust (%)
18.7	2 gpa	1.97 b	
46.8	5 gpa	0.03 b	
Untreated Control		6.70 a	

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Untreated Control		6.70 a	0.4345 a

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Application Rate (L ha^{-1})		Northern Leaf Blight (%)	Southern Corn Rust (%)
18.7	2 gpa	1.97 b	0.0351 b
46.8	5 gpa	0.03 b	0.0067 b
Untreated Control		6.70 a	0.4345 a

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46.8	5 gpa	0.03 b	0.0067 b	
Untreated Control		6.70 a	0.4345 a	

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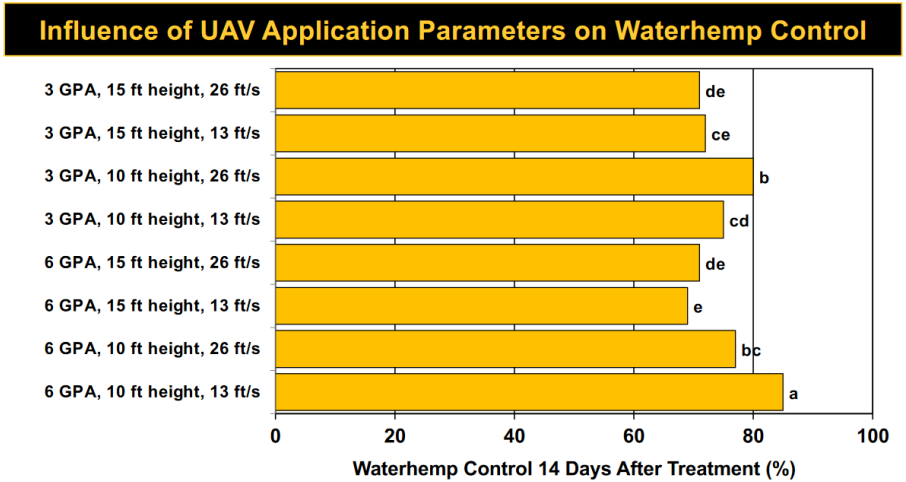
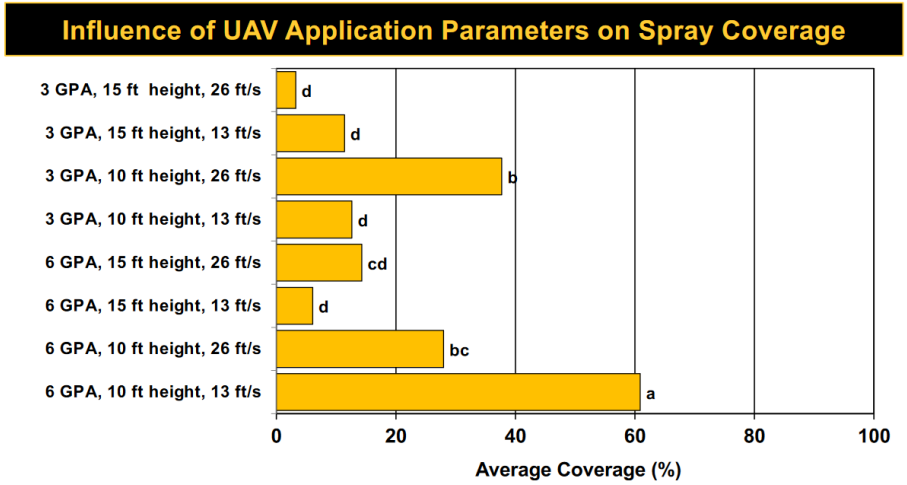
Application Rate (L ha^{-1})		Northern Leaf Blight (%)	Southern Corn Rust (%)	Yield (kg ha^{-1})
18.7	2 gpa	1.97 b	0.0351 b	12,679
46.8	5 gpa	0.03 b	0.0067 b	11,926
Untreated Control		6.70 a	0.4345 a	11,675

Virk, S., Byers, C., Meena, R., Kichler, J., & Kemerait, B. (2024, July 21). Spray Deposition and Efficacy of Pesticide Applications with Spray Drones in Row Crops in the Southeastern US. *Proceedings of the 16th International Conference on Precision Agriculture*. International Conference on Precision Agriculture, Manhattan, KS.

Missouri, herbicide application for waterhemp in soybean



*Bars followed by the same letter are not different, LSD=0.05.



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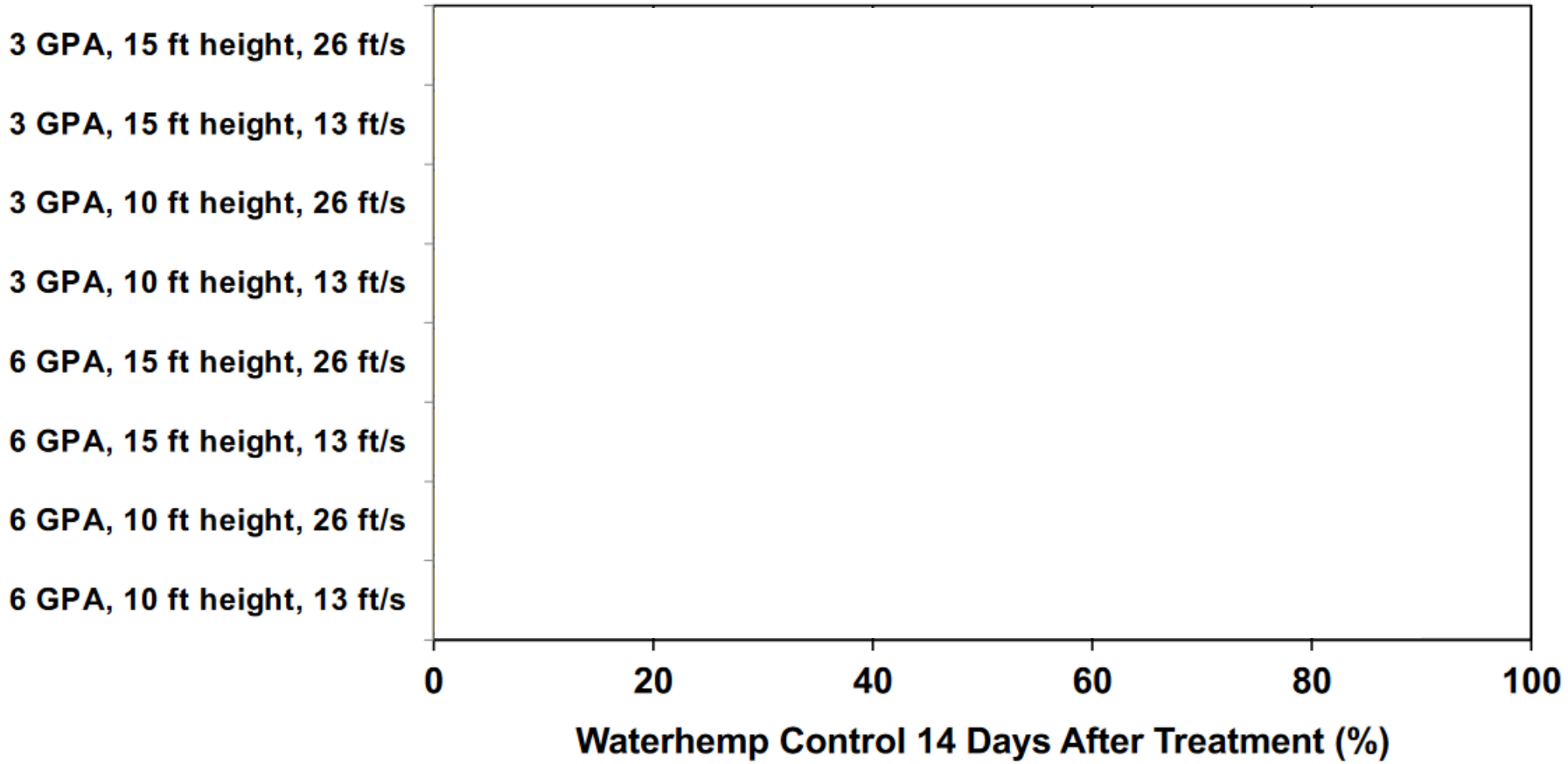
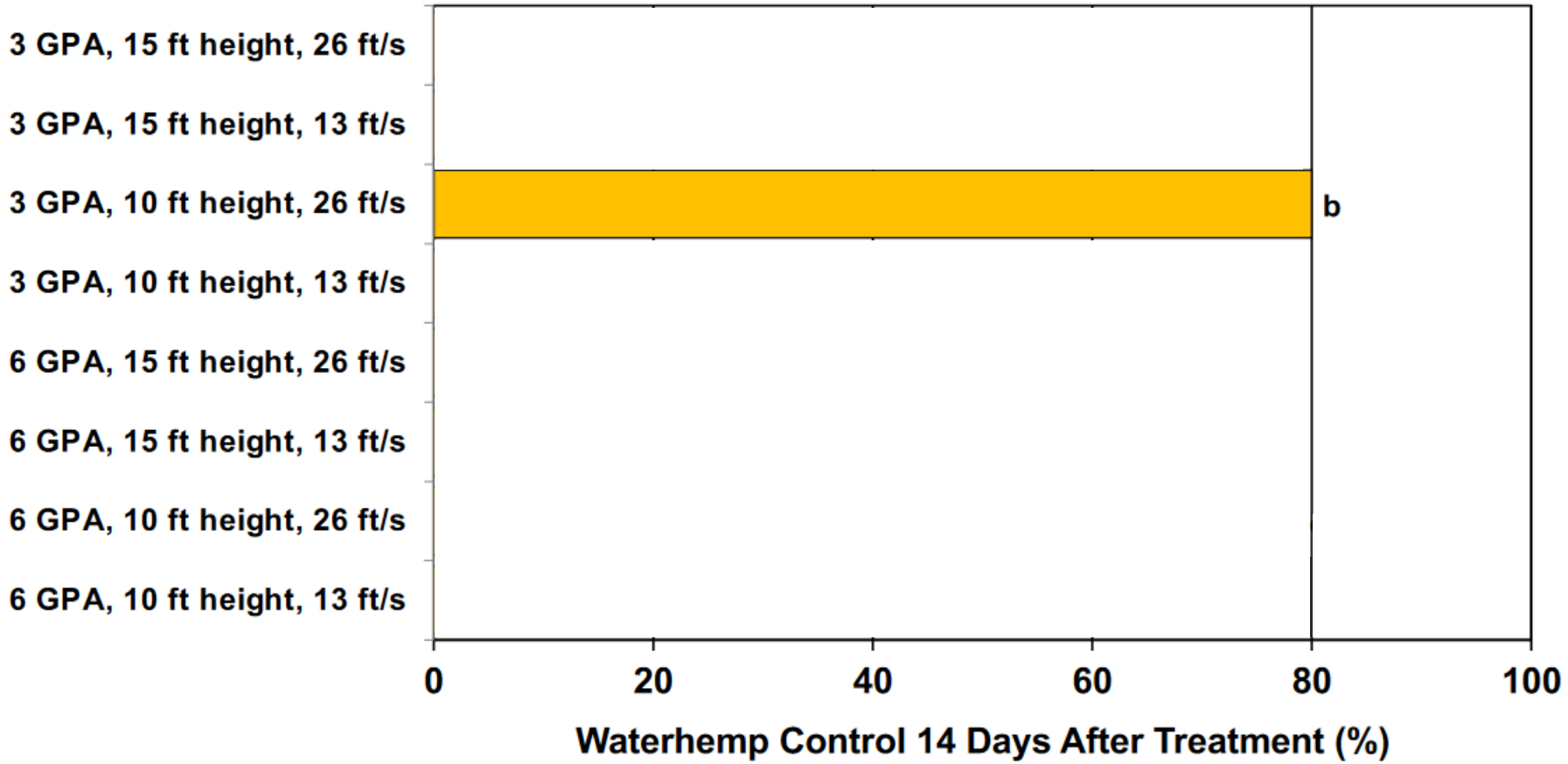
Thompson, T., Barlow, H., Coe, G., Rogers, G., Knerr, D., & Bradley, K. W. (2024). *Field Evaluation of the DJI Agras T40 UAV for the Application of Herbicides in Soybean*. Mizzou Crop & Pest News. https://weedscience.missouri.edu/slideshows/uavs_2024.pdf

Influence of UAV Application Parameters on Waterhemp Control



*Bars followed by the same letter are not different, LSD=0.05.

Influence of UAV Application Parameters on Waterhemp Control



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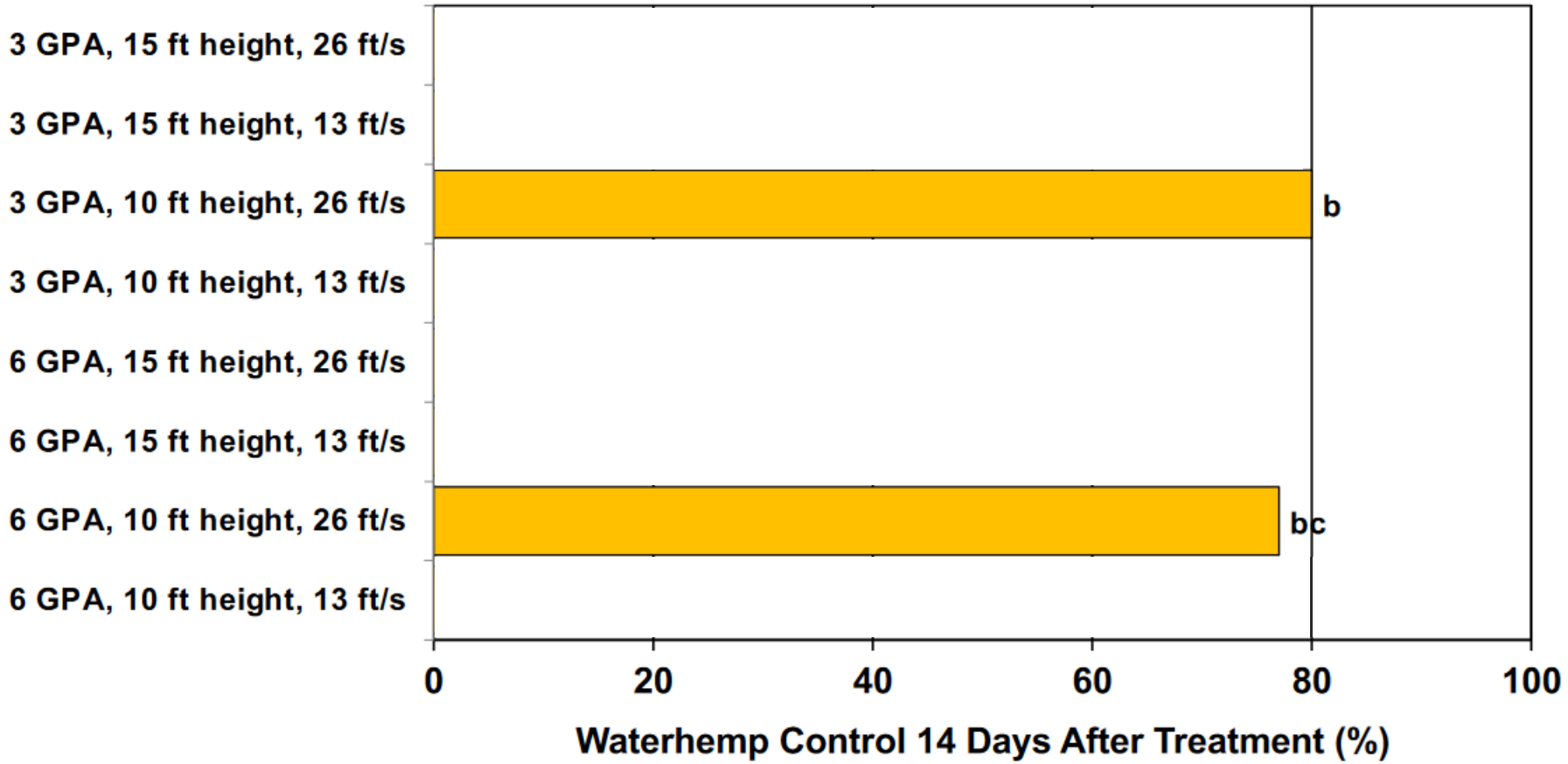

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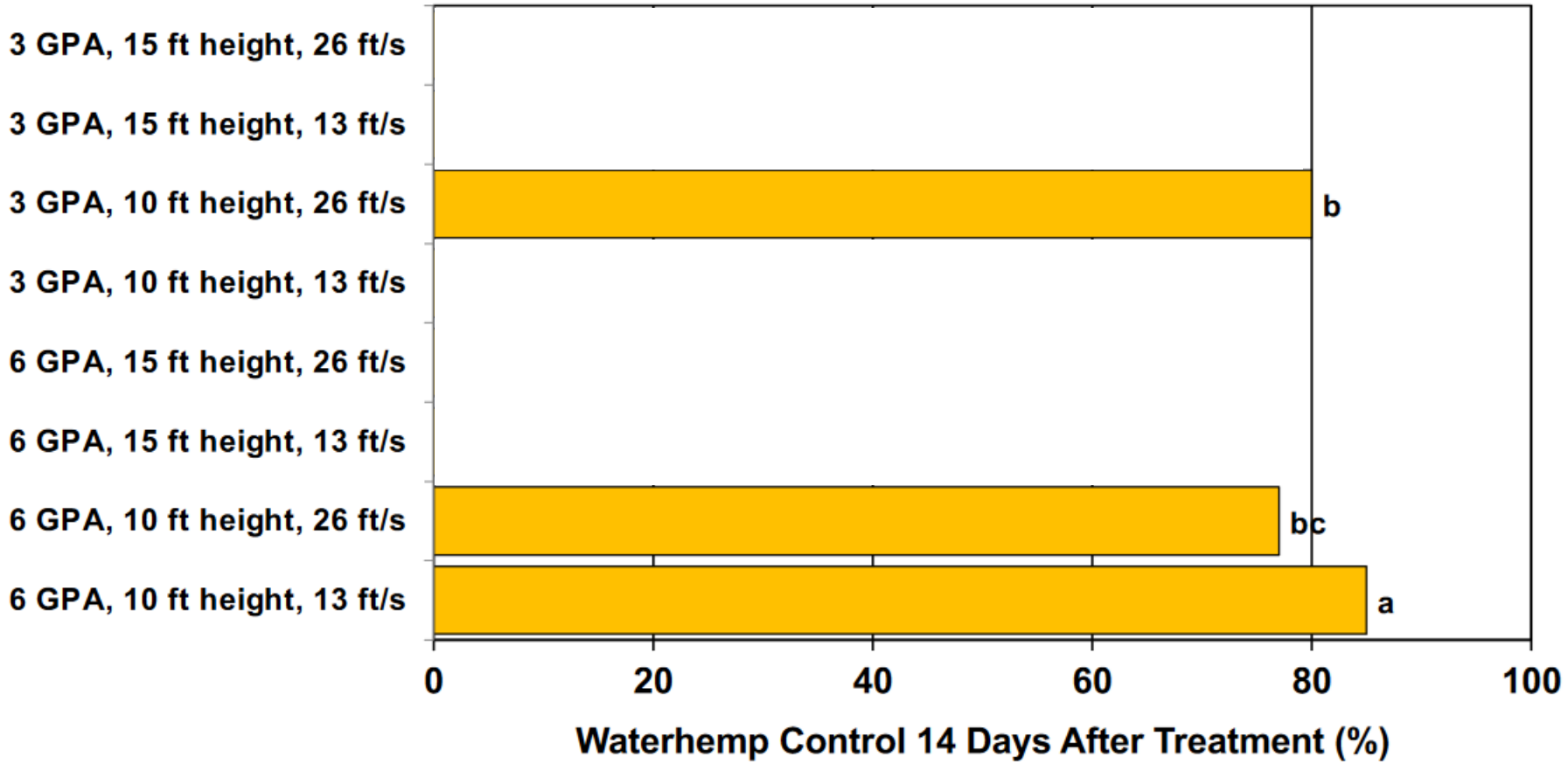

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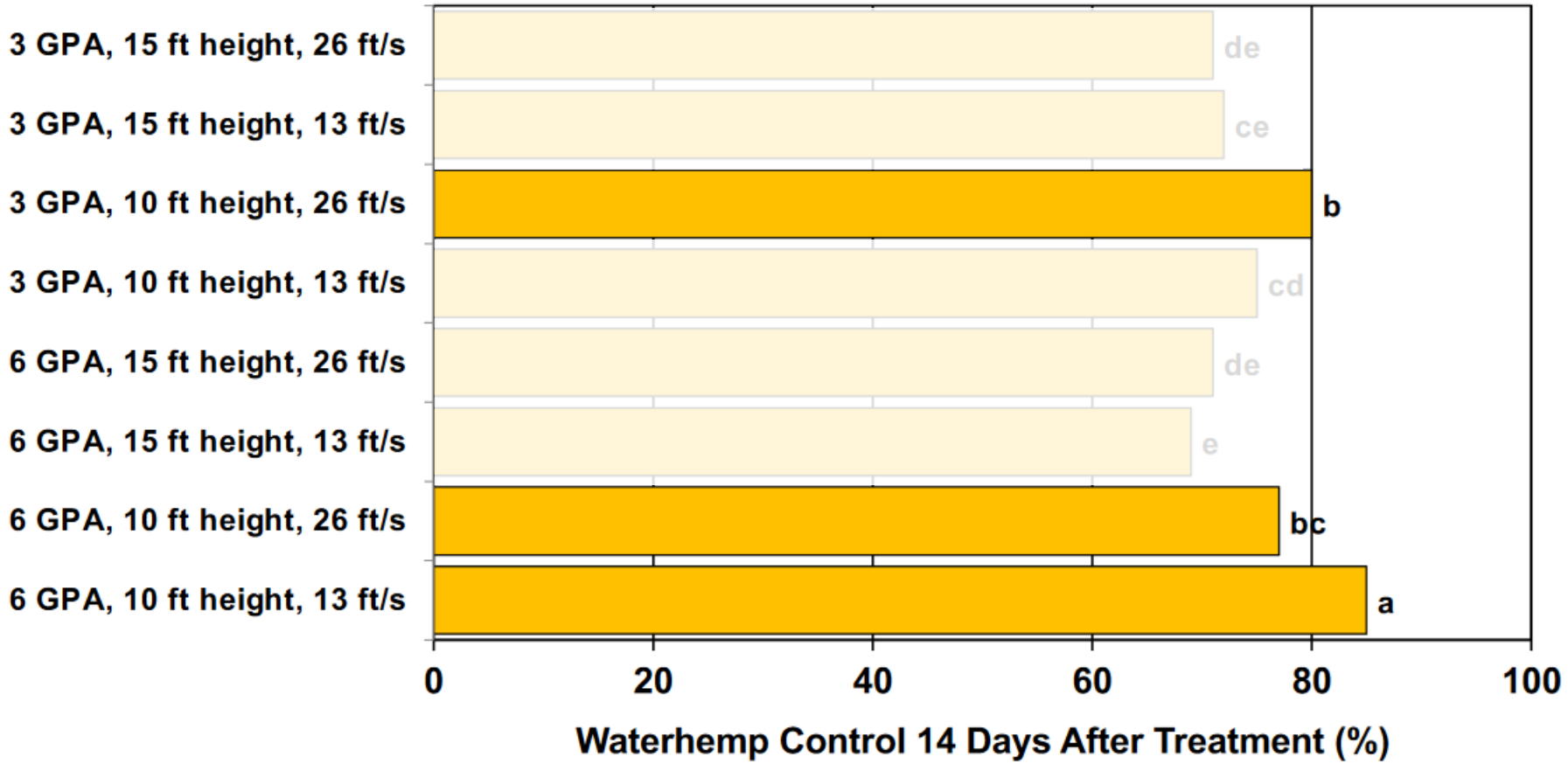

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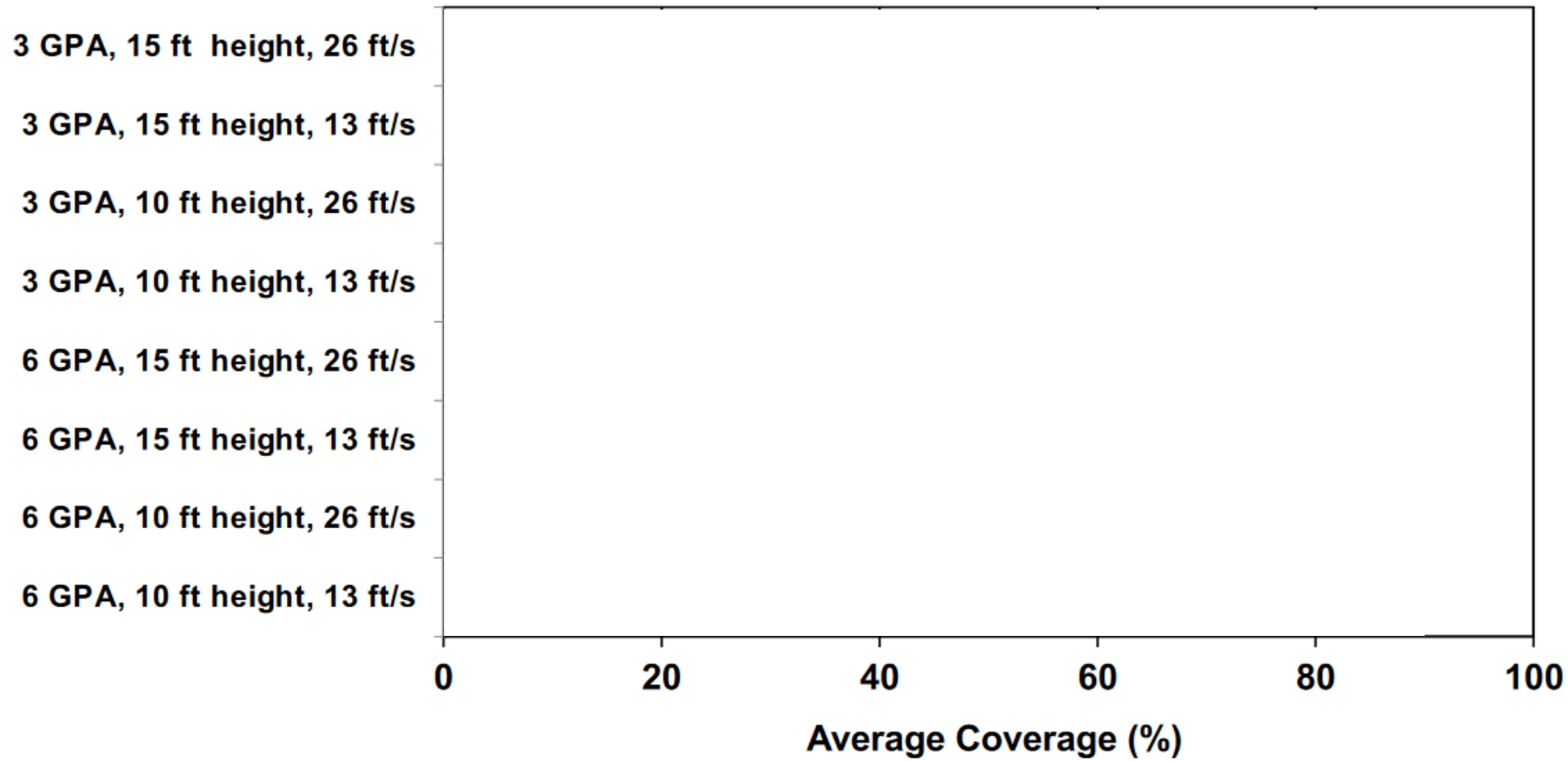
Influence of UAV Application Parameters on Spray Coverage



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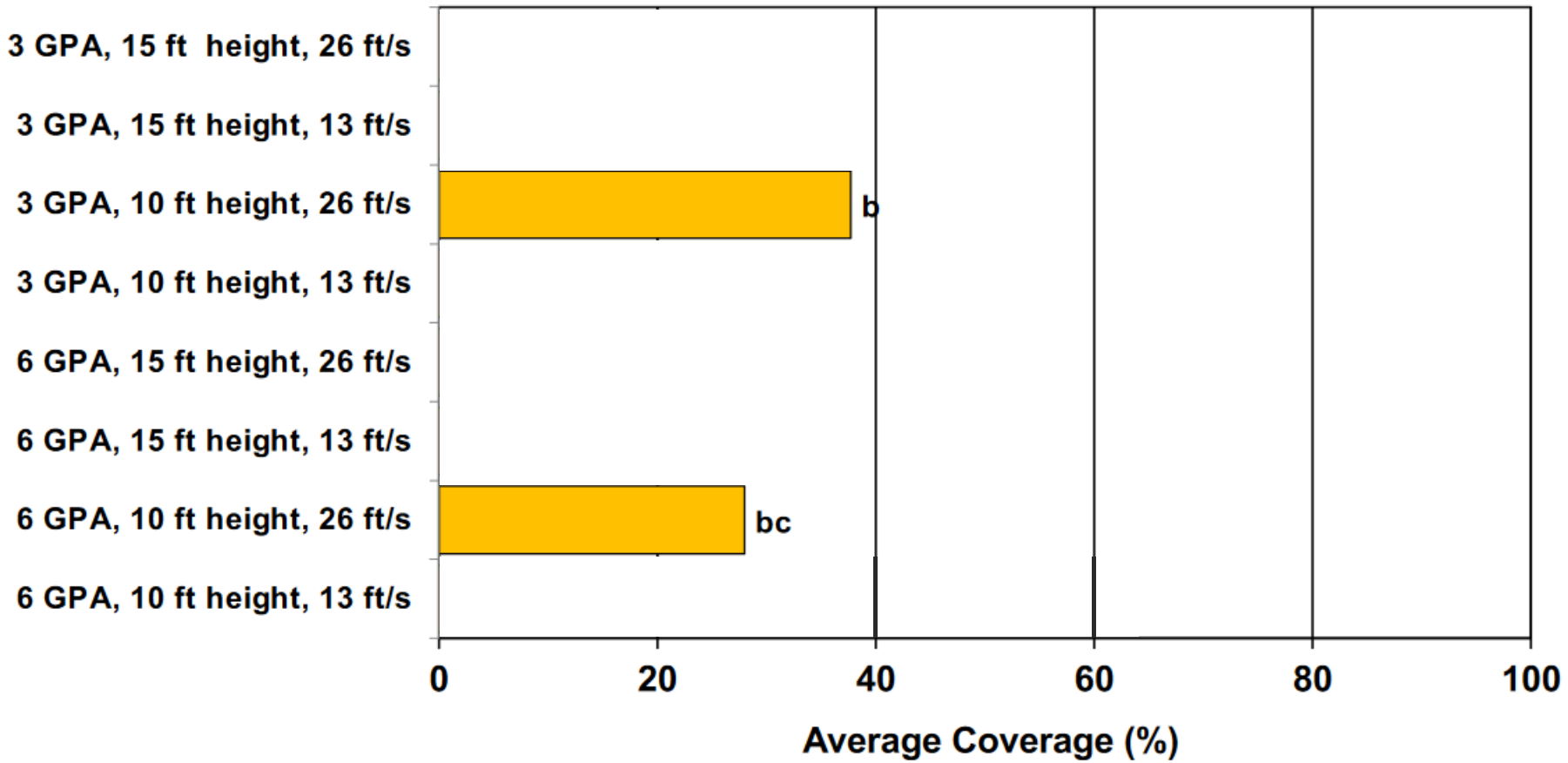

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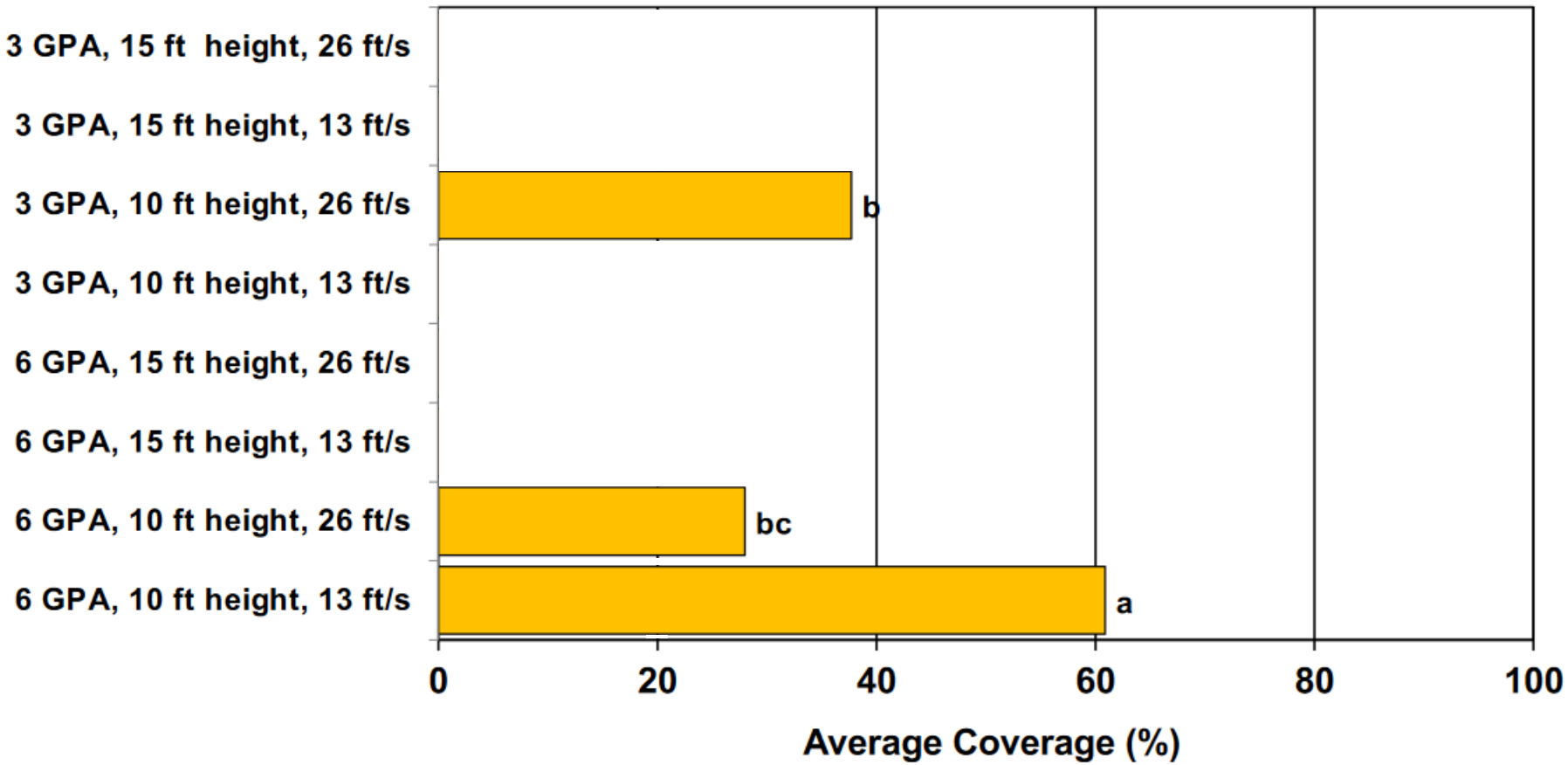

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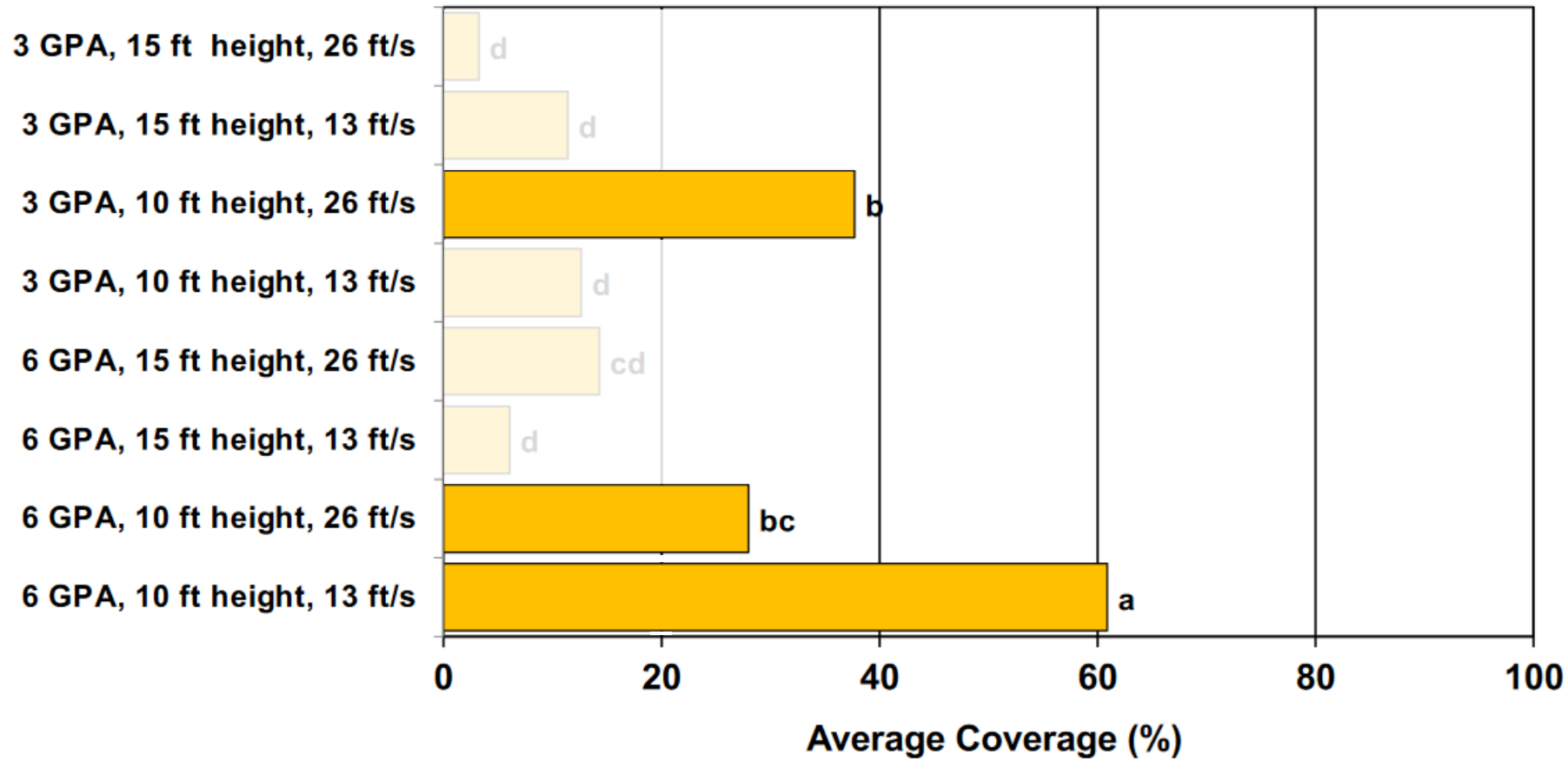
Influence of UAV Application Parameters on Spray Coverage

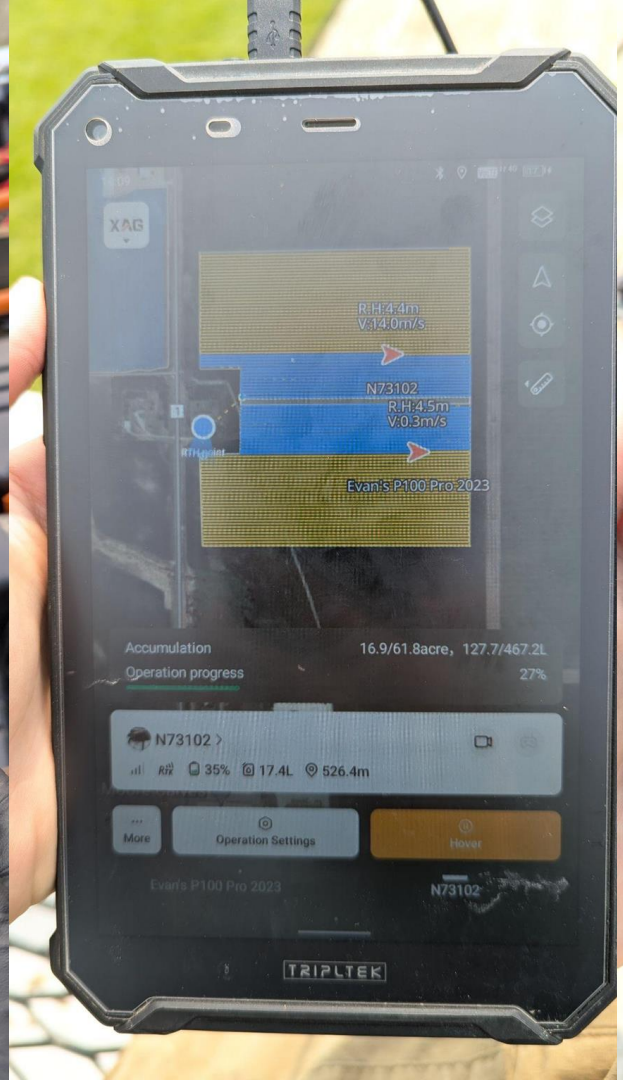


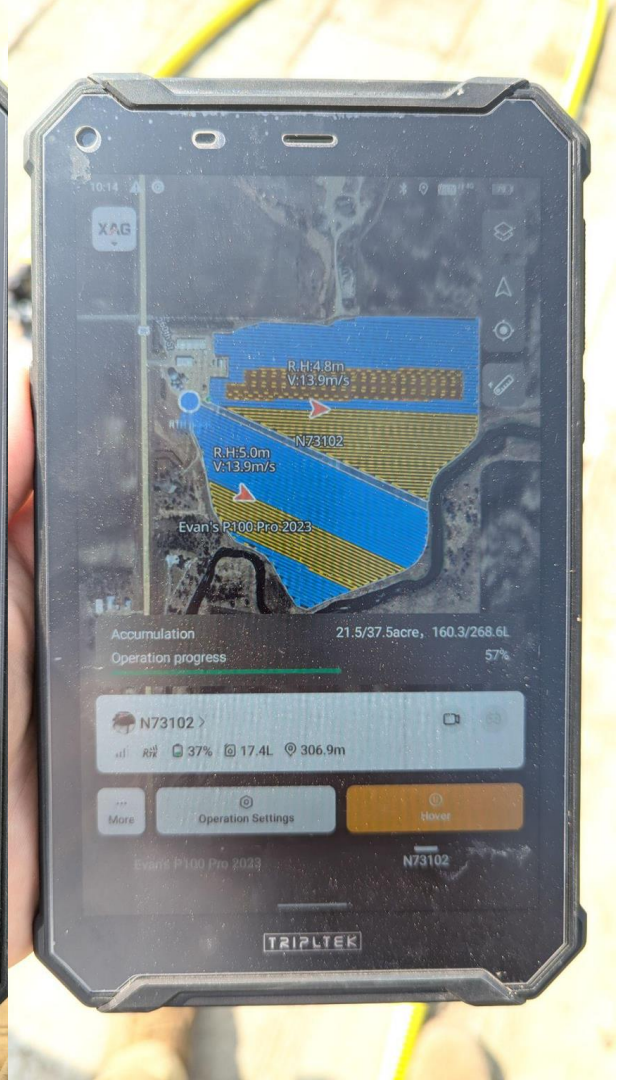
*Bars followed by the same letter are not different, LSD=0.05.

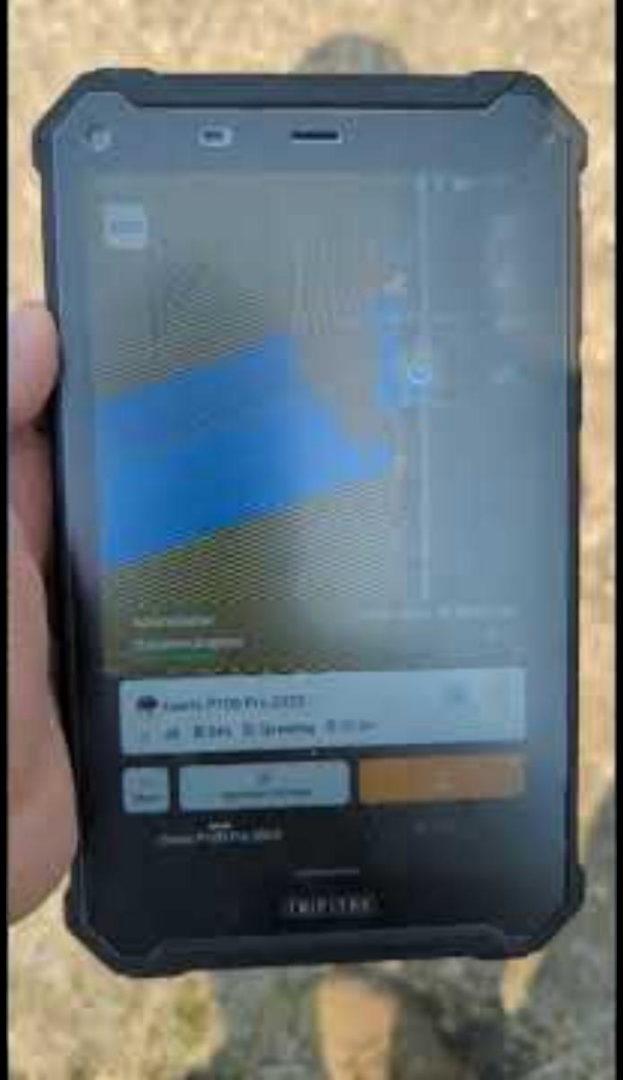
More use case examples


FX4
555 DZG


XAG
R.H:4.0m
V:13.9m/s
N73102
Deja Acres
R.H:4.4m
V:13.7m/s
Evan's P100 Pro 2023
Accumulation
39.2/65.7acre，296.4/496.7L
Operation progress
59%
N73102 >
69%
35.8L
700.9m
More
Operation Settings
Hover
Evan's P100 Pro 2023
N73102
TRIPLTEK


XAG
R.H:4.4m
V:14.0m/s
N73102
R.H:4.5m
V:0.3m/s
Evan's P100 Pro 2023
Accumulation
16.9/61.8acre，127.7/467.2L
Operation progress
27%
N73102 >
35%
17.4L
526.4m
More
Operation Settings
Hover
Evan's P100 Pro 2023
N73102
TRIPLTEK


XAG
R.H:4.8m
V:13.9m/s
N73102
R.H:5.0m
V:13.9m/s
Evan's P100 Pro 2023
Accumulation
21.5/37.5acre，160.3/268.6L
Operation progress
57%
N73102 >
37%
17.4L
306.9m
More
Operation Settings
Hover
N73102
TRIPLTEK



Seeding with drones

Calibrating for Success

NDSU | EXTENSION

Calibrate to determine effective swath width…

https://sprayers101.com/calibrate-drone/

How to Calibrate a Drone

Posted on **April 20, 2023**

ABOUT JASON AND TOM

With more than 40 years of experience in agricultural spraying, Tom and Jason have researched and presented on many aspects of safe, effective and efficient applications.

See all posts by **Jason and Tom**.

Source: Deveau & Wolf, 2023 Apr 20

Source: Deveau & Wolf, 2023 Apr 20

https://www.betterfieldstudies.com/swath-gobbler





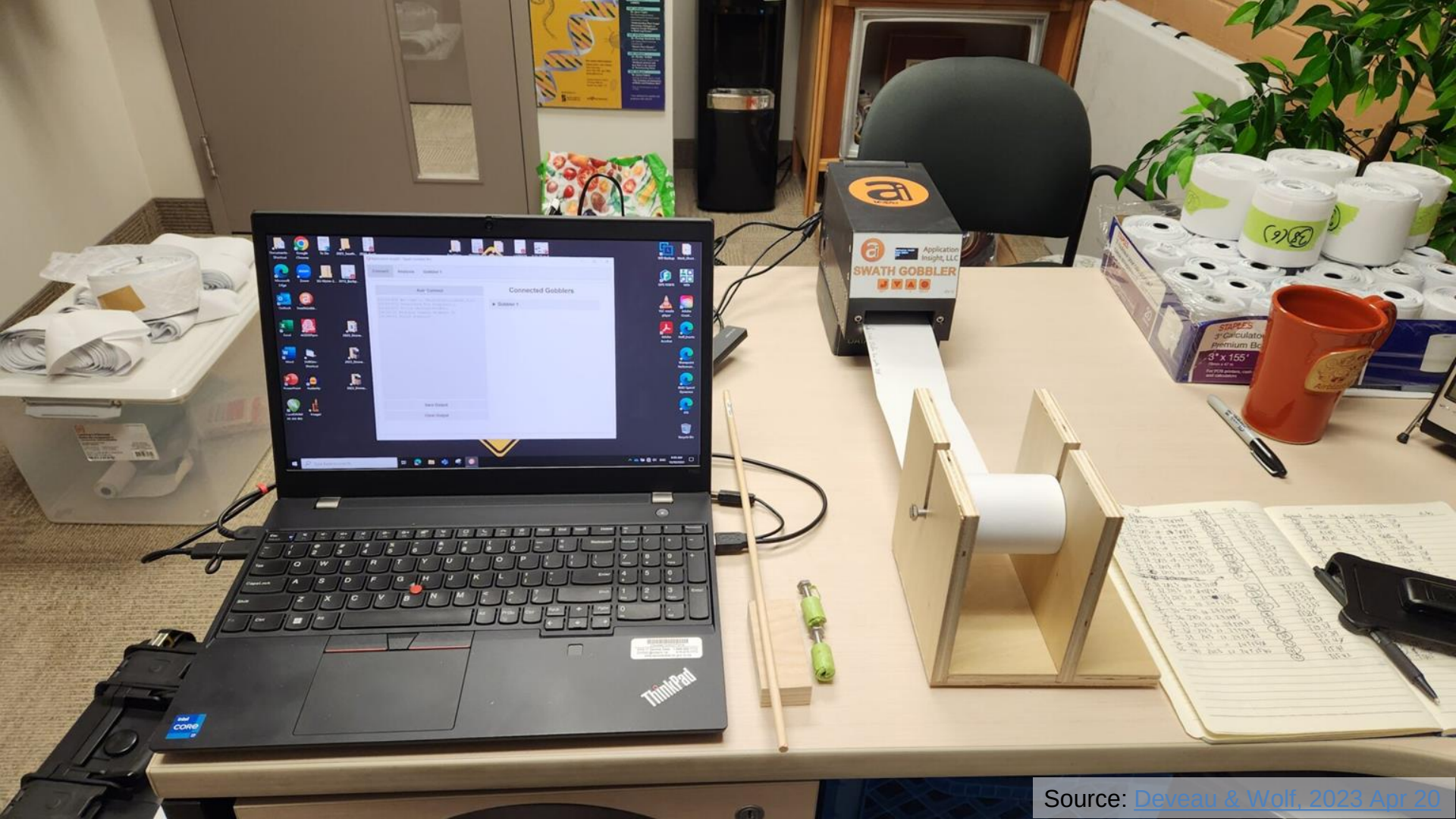
Swath Gobbler™

Order Form

IN STOCK NOW!
Ready to ship

Portable onsite swath sampling and processing system that analyzes the full spray swath, not just a few spray cards.
Using inexpensive calculator paper rolls and dye as a collector, The Swath Gobbler™ system quickly and precisely reads spray data and provides actionable outputs. Swath Gobbler™ gives you the research-quality data you need to be the best in your field.

Swathing Supplies | Swathing White Paper | Speed Track



Source: Deveau & Wolf, 2023 Apr 20

Calibrate to determine effective swath width…

Calibrate to determine effective swath width… because spray drones concentrate spray directly beneath the vehicle…

https://sprayers101.com/rpas-swathing-in-broad-acre-crop-canopies/

RPAS swathing in broad acre crop canopies

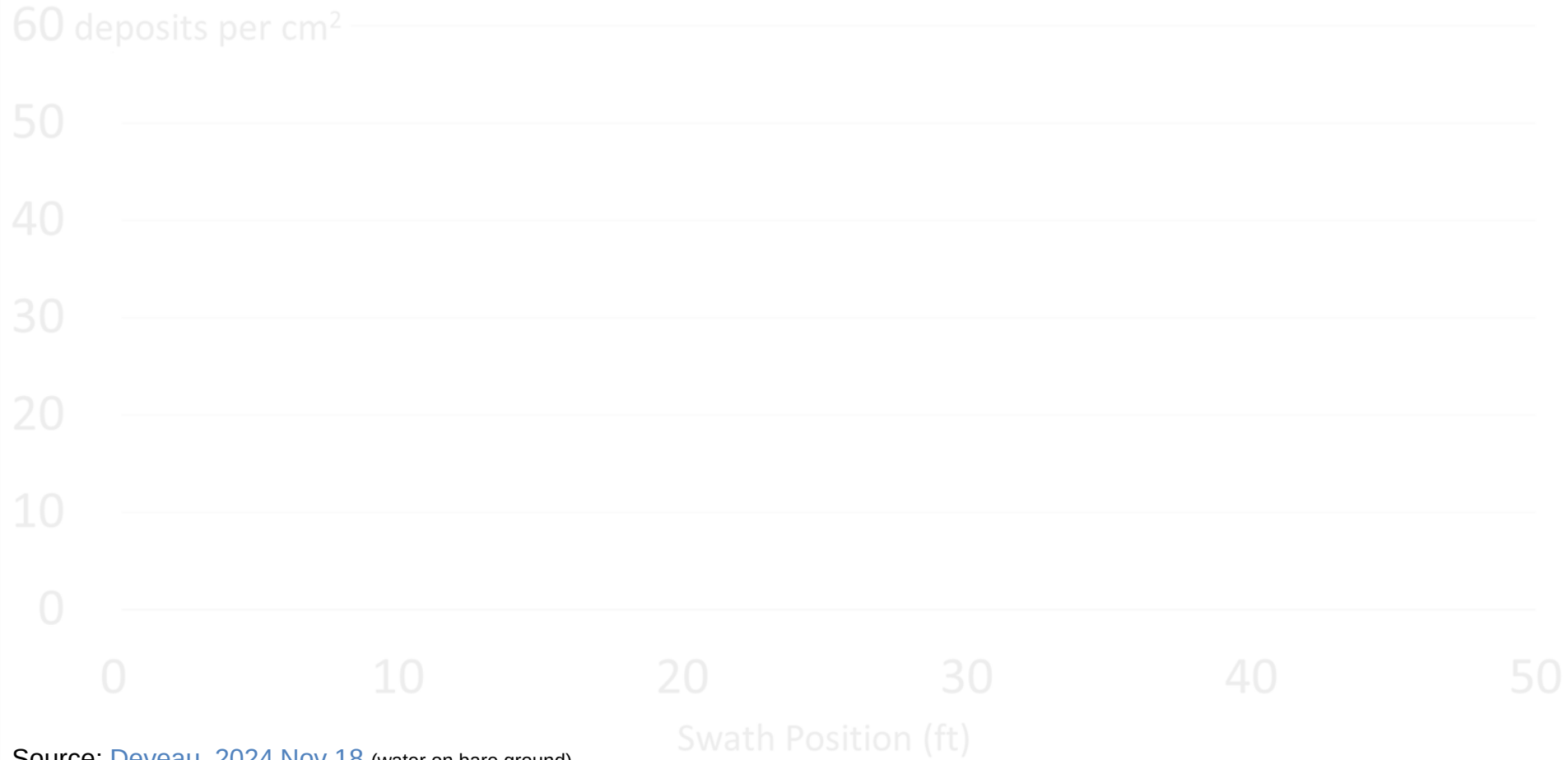
Posted on **November 18, 2024**

ABOUT JASON DEVEAU (SPRAY GUY)

Dr. Jason Deveau has been the OMAFA Application Technology Specialist since 2008. He researches and teaches methods to improve the safe, effective and efficient application of agricultural sprays in specialty crops, field crops and controlled environments. He is the co-administrator of Sprayers101, co-author of the Airblast101 Textbook, a slow cyclist and an even slower runner.

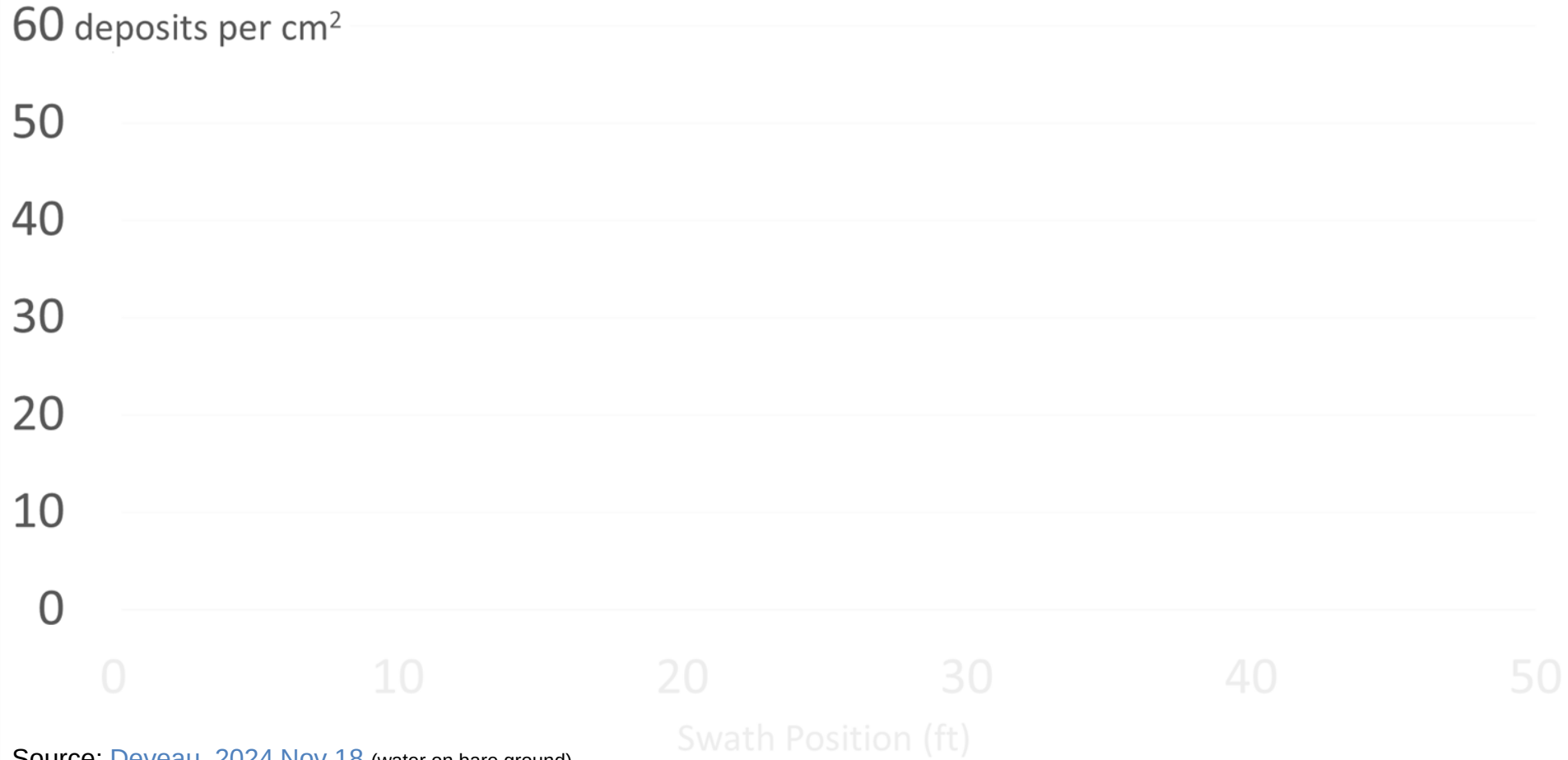
See all posts by **Jason Deveau (Spray Guy)**.

Spray deposit density is highly variable across the swath



Source: Deveau, 2024 Nov 18 (water on bare ground)

Spray deposit density is highly variable across the swath



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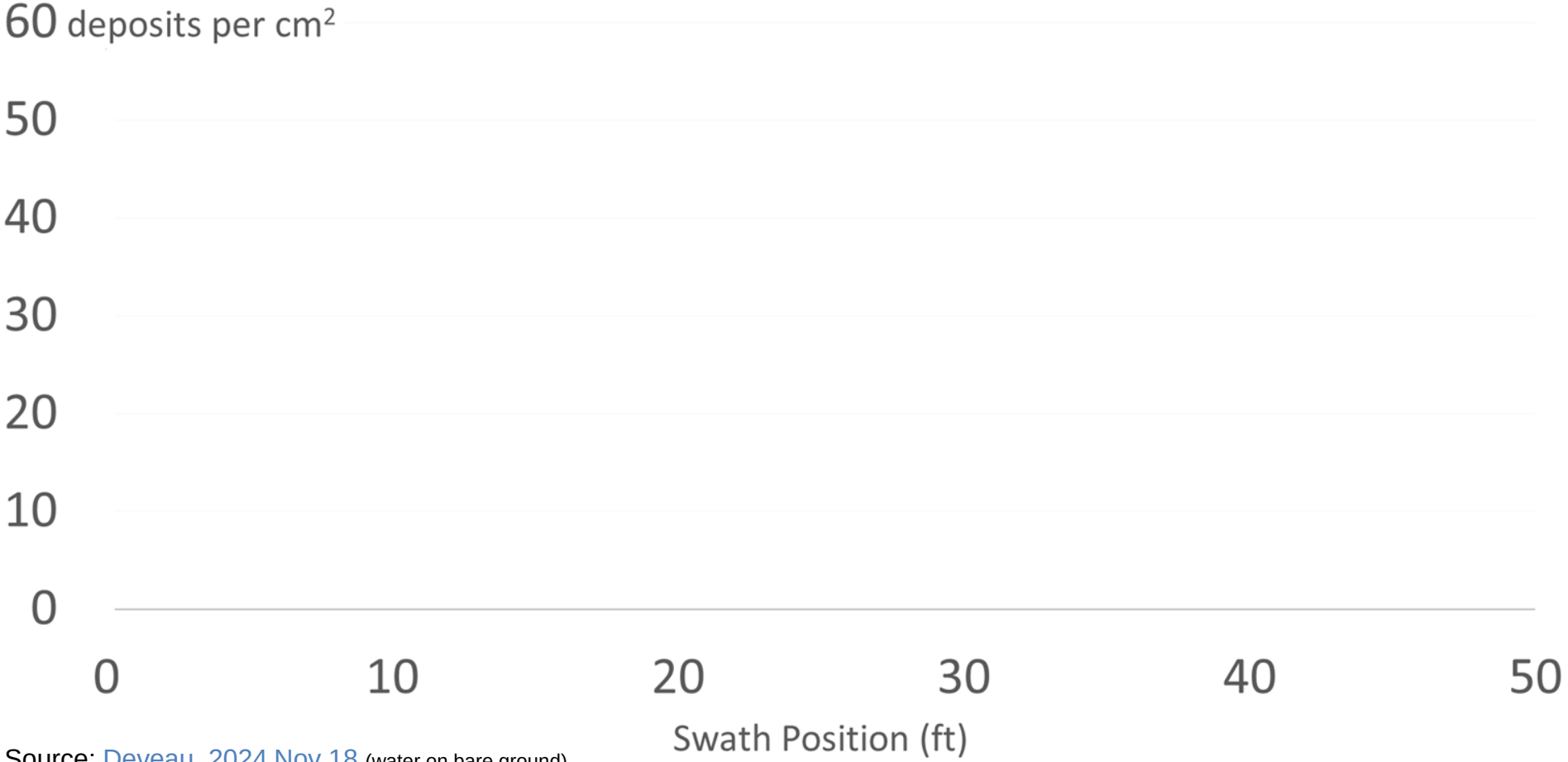

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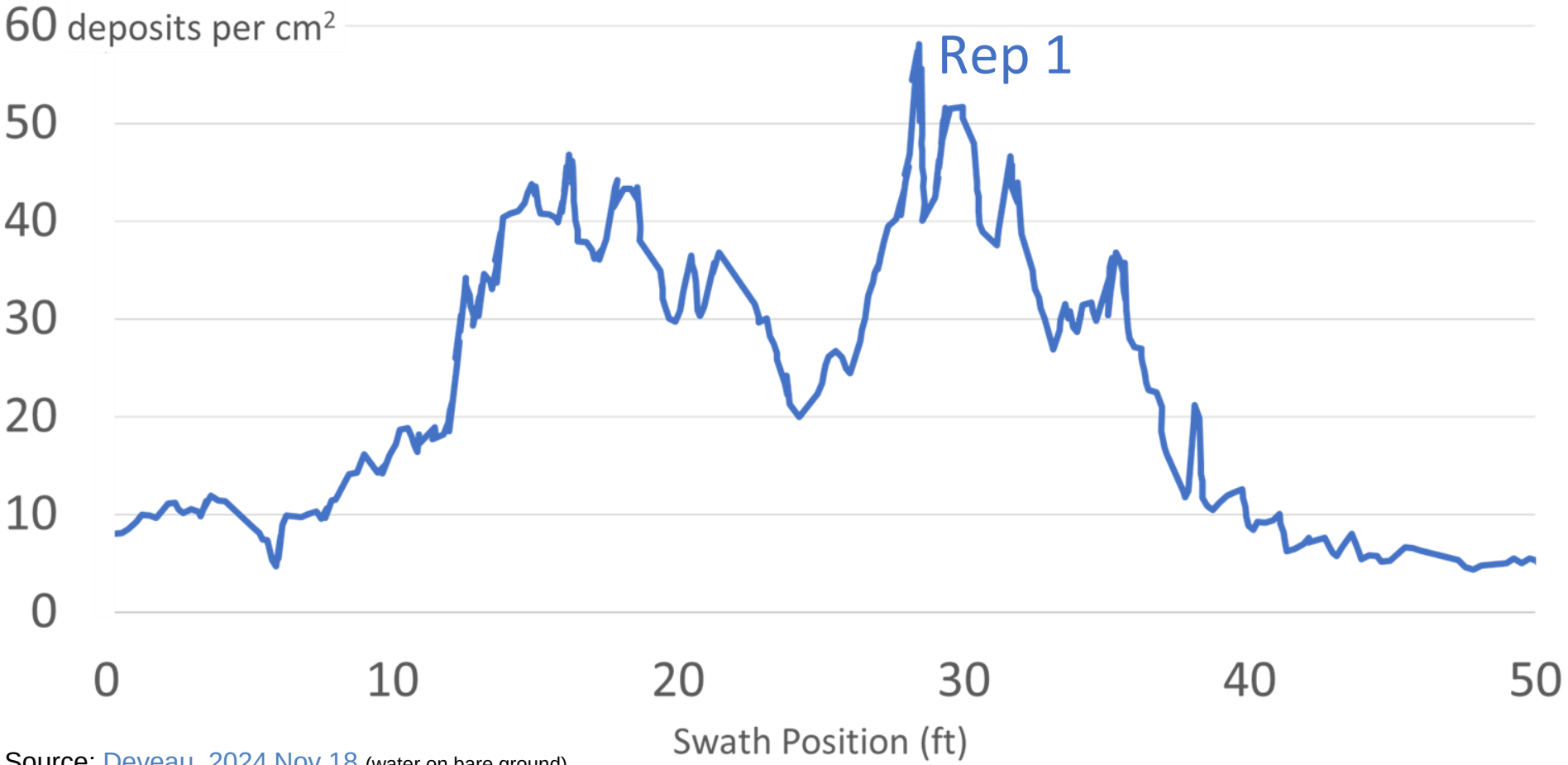

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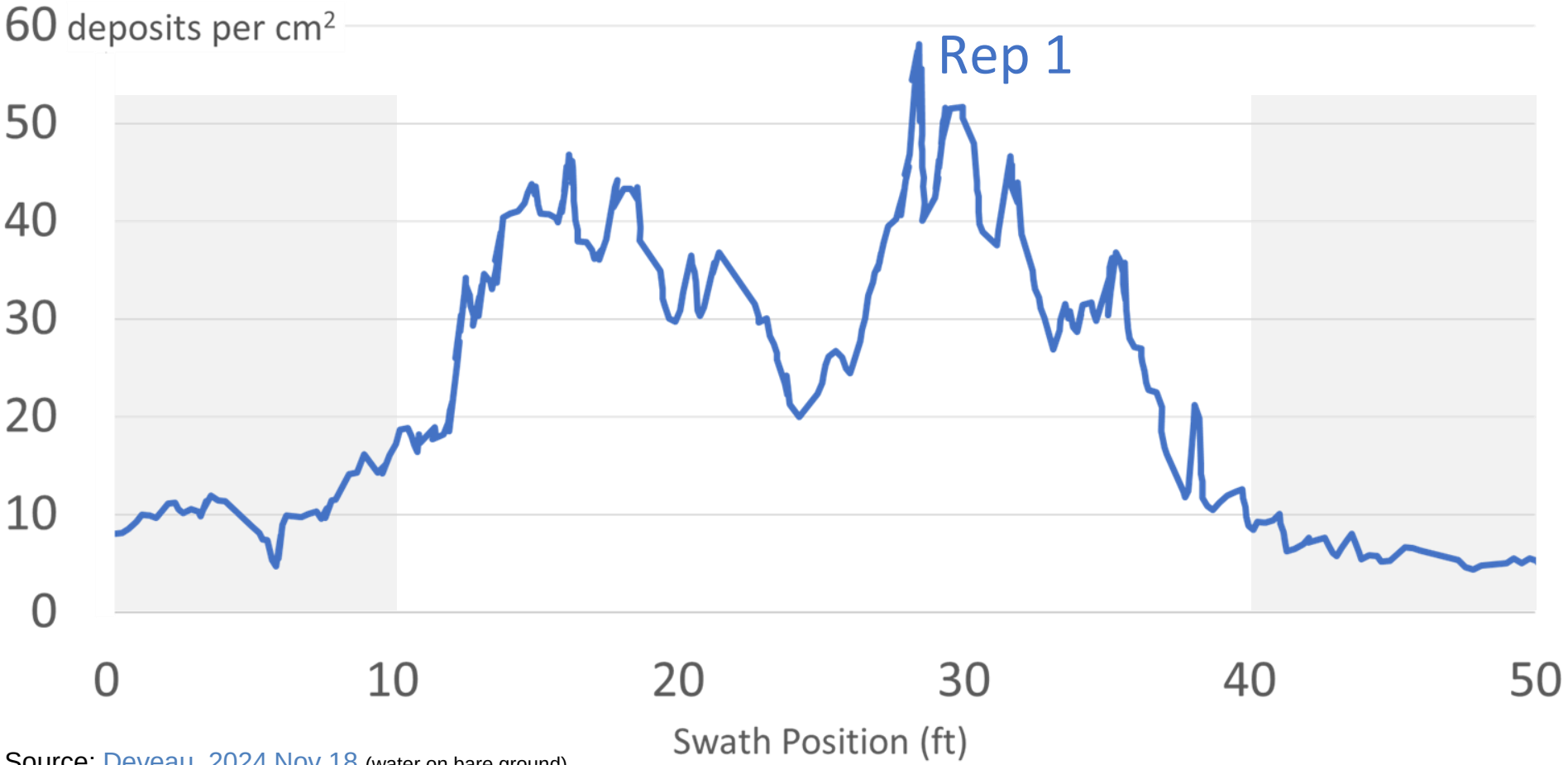

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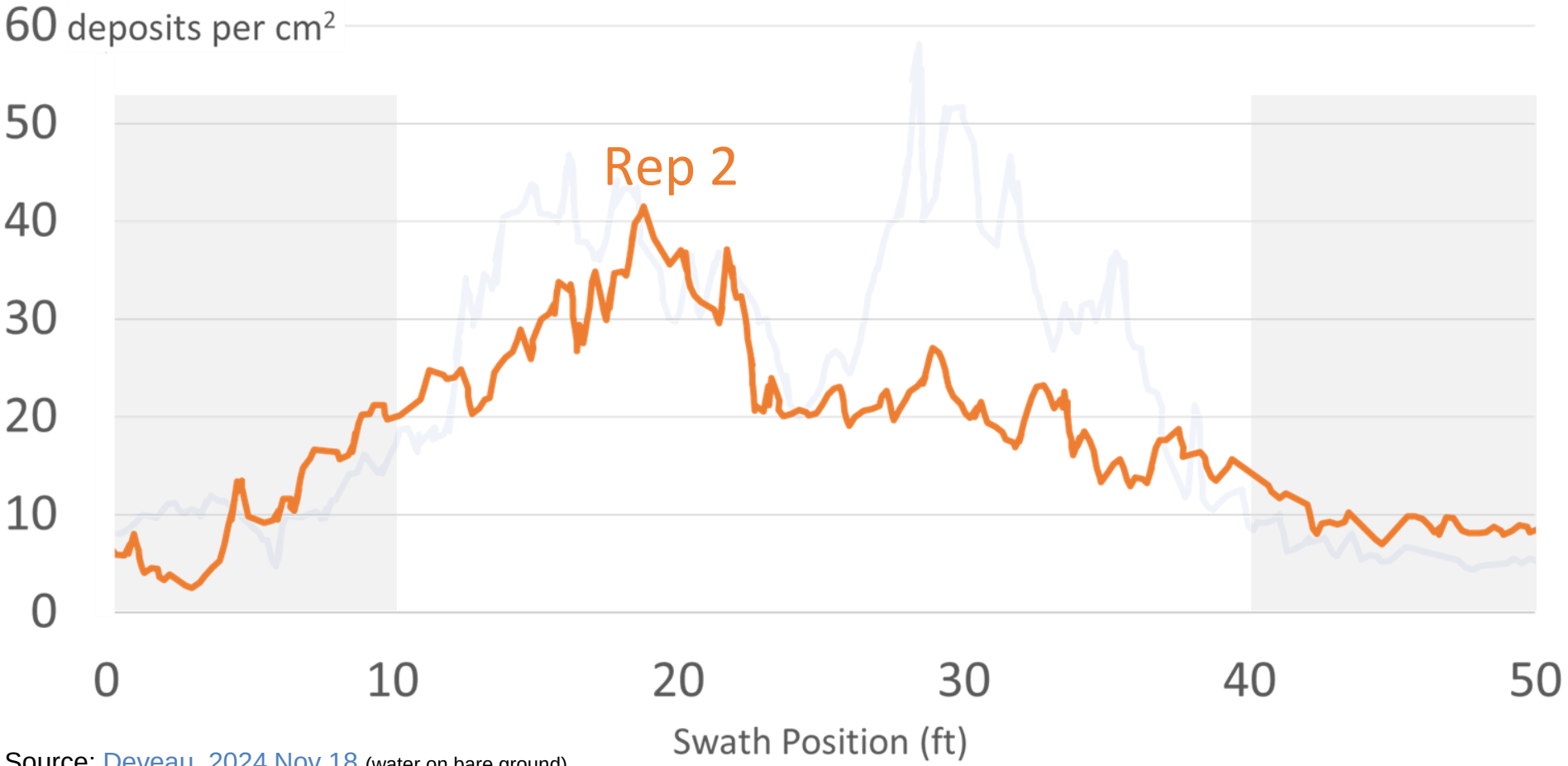

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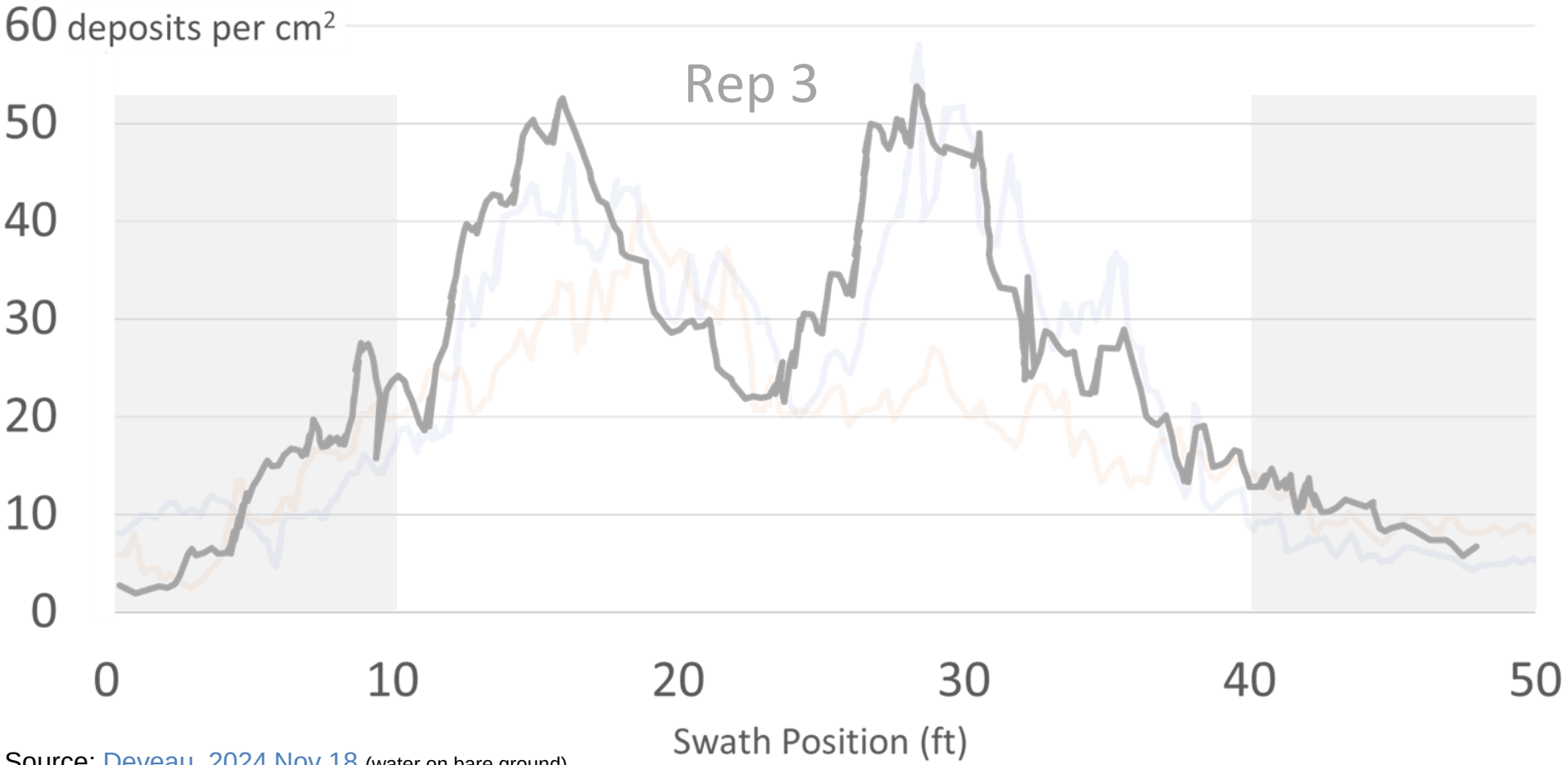

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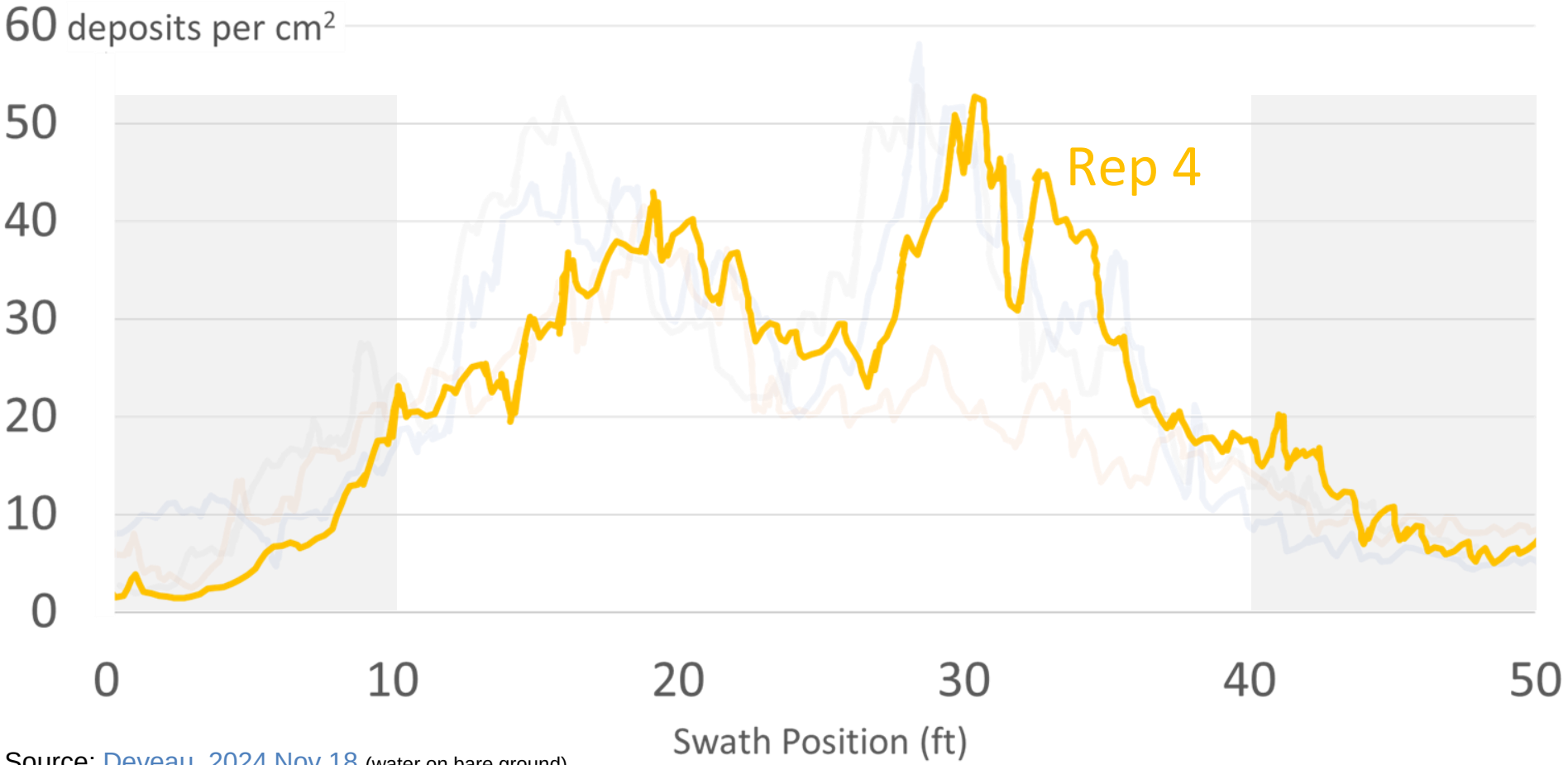

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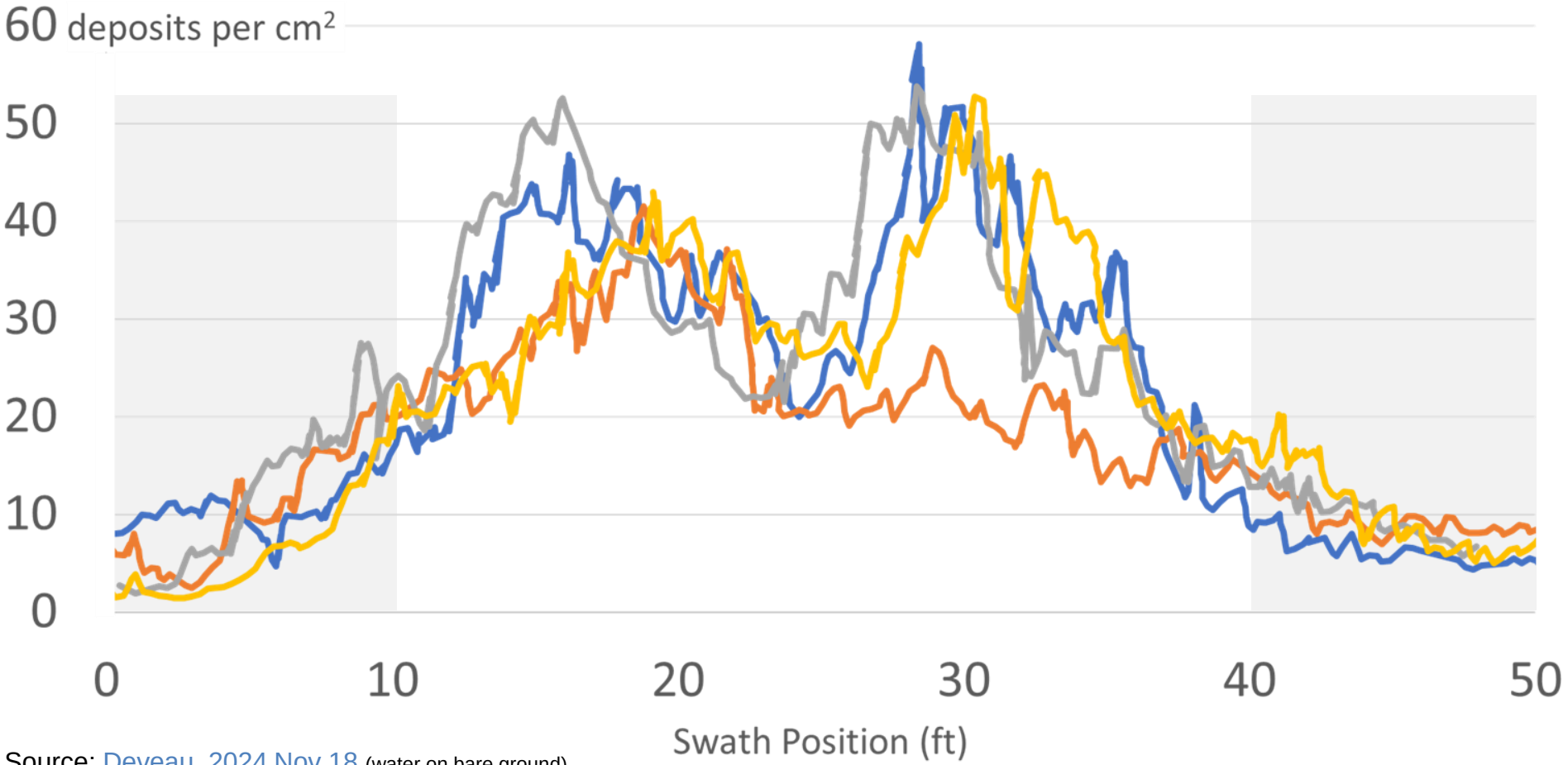

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Calibrate to determine effective swath width…because spray drones concentrate spray directly beneath the vehicle…

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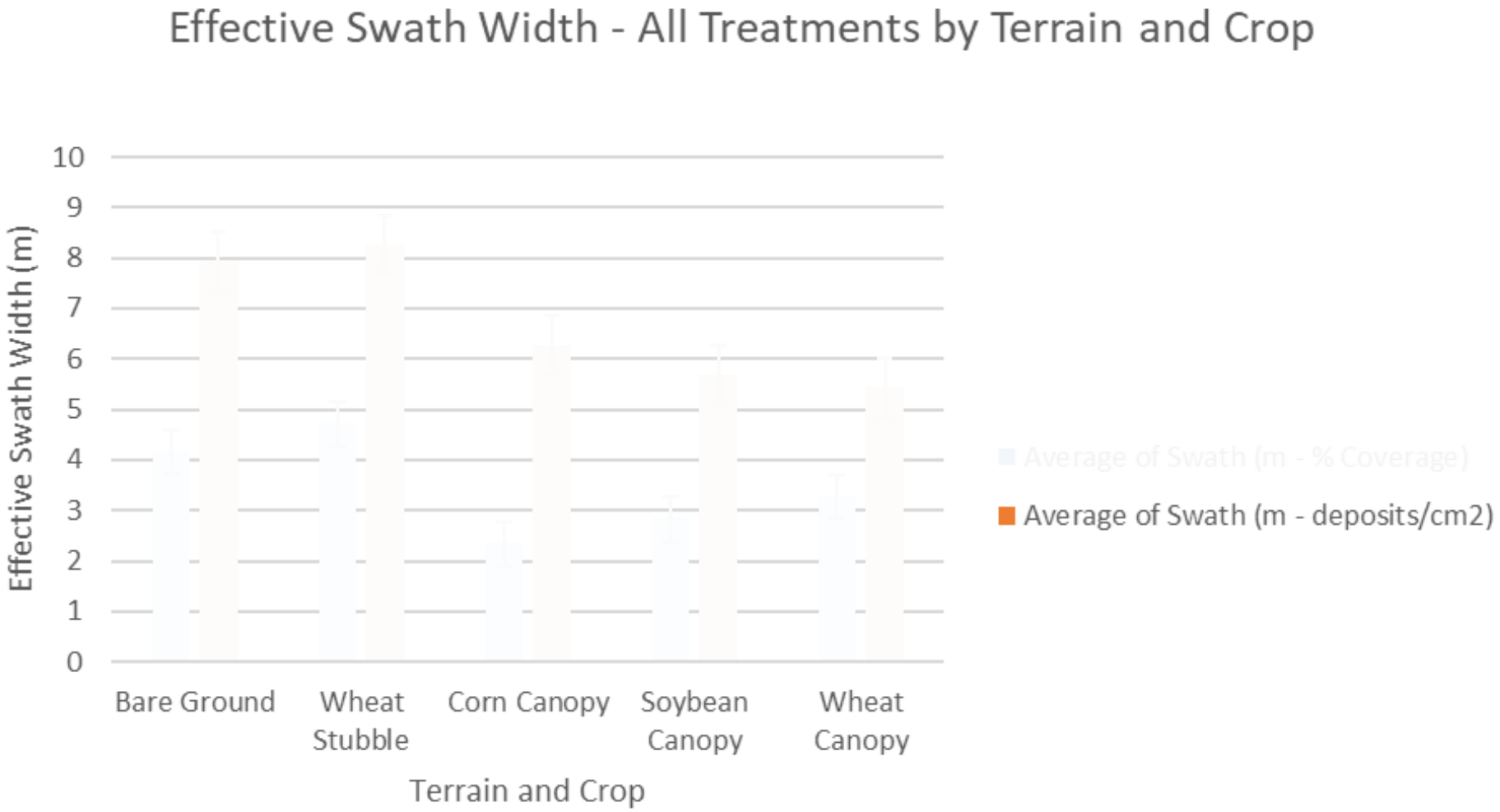

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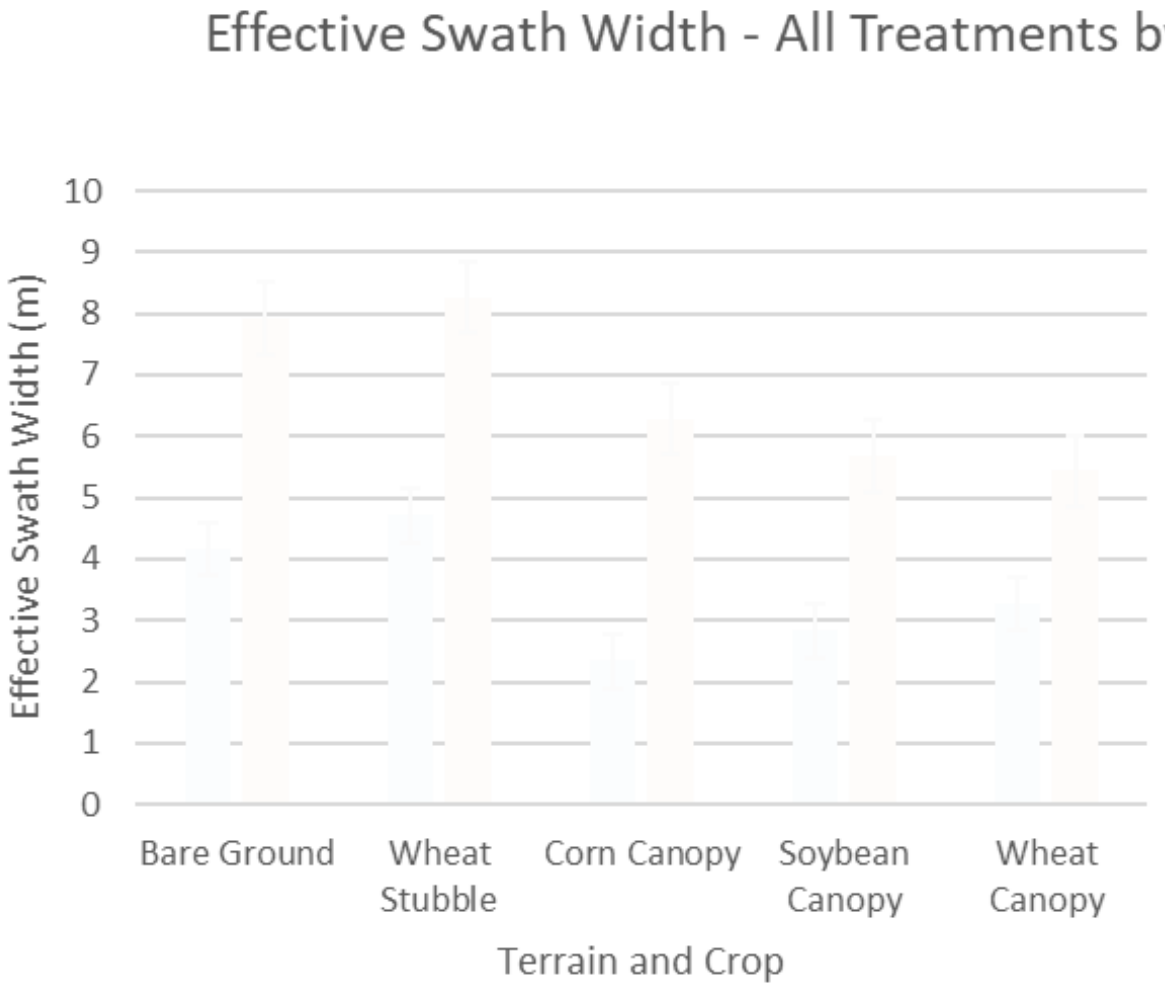
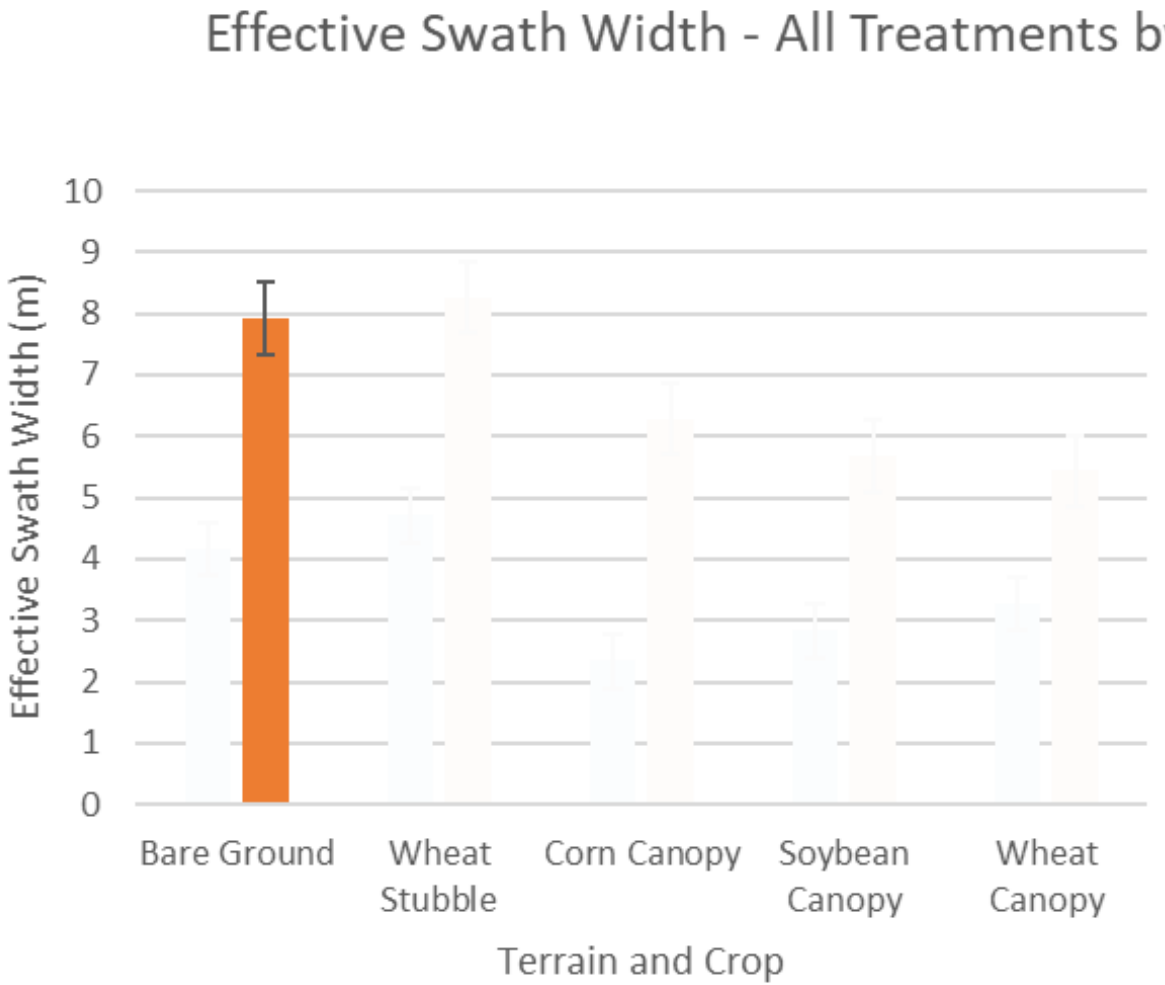


- DJI Agras T40
- 9.8 ft. above ground/canopy
- avg. across multiple appl. volumes and speeds

Source: Deveau, 2024 Nov 18



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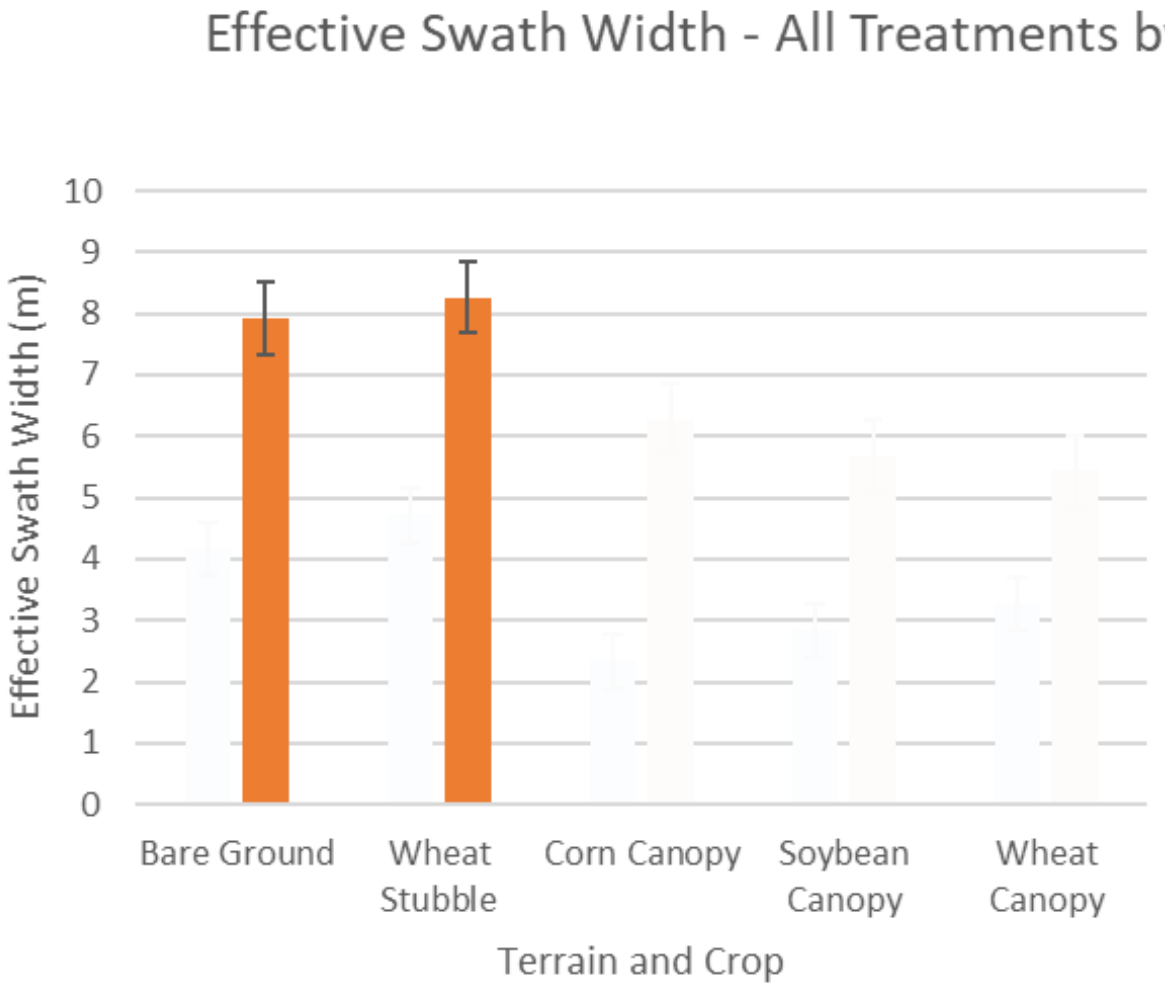

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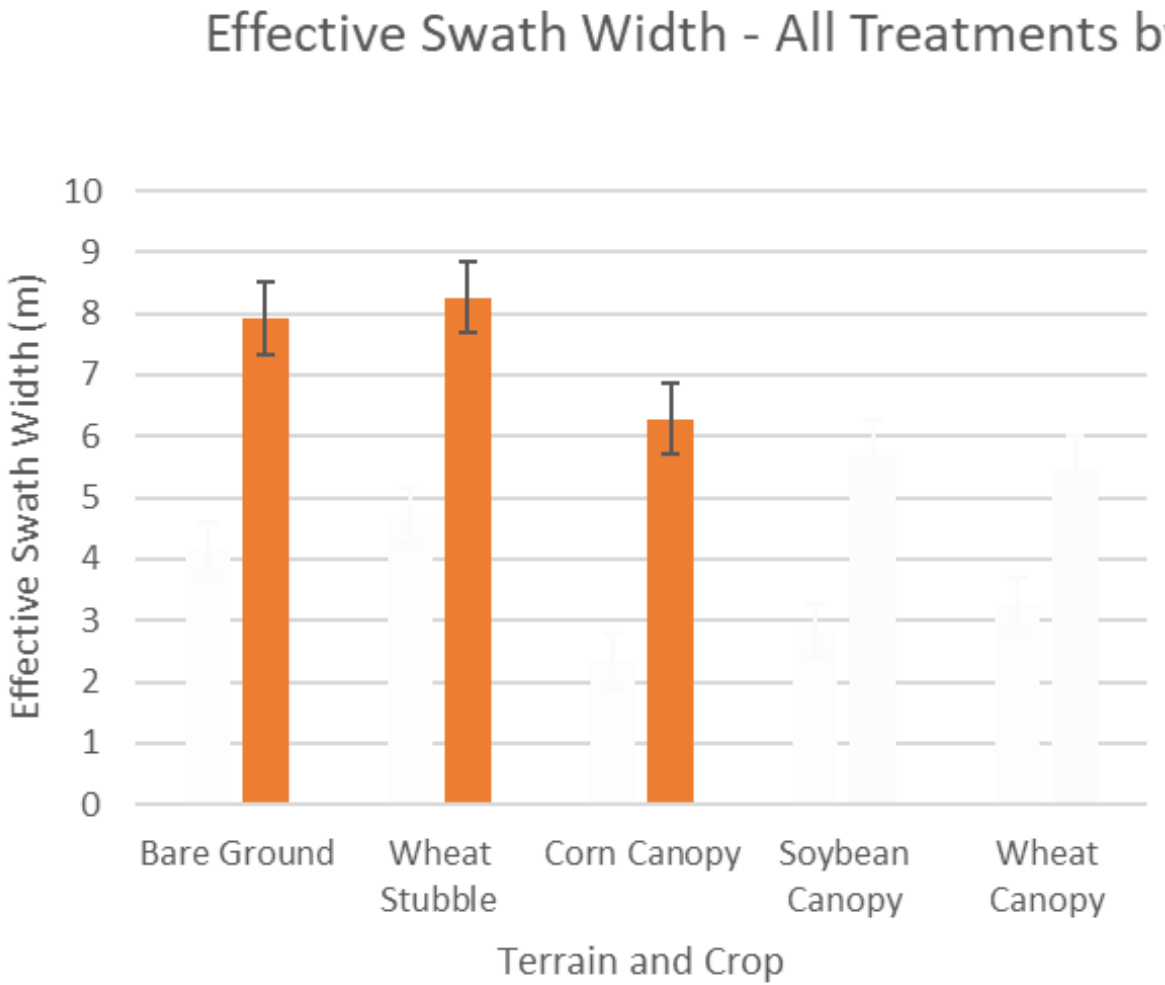

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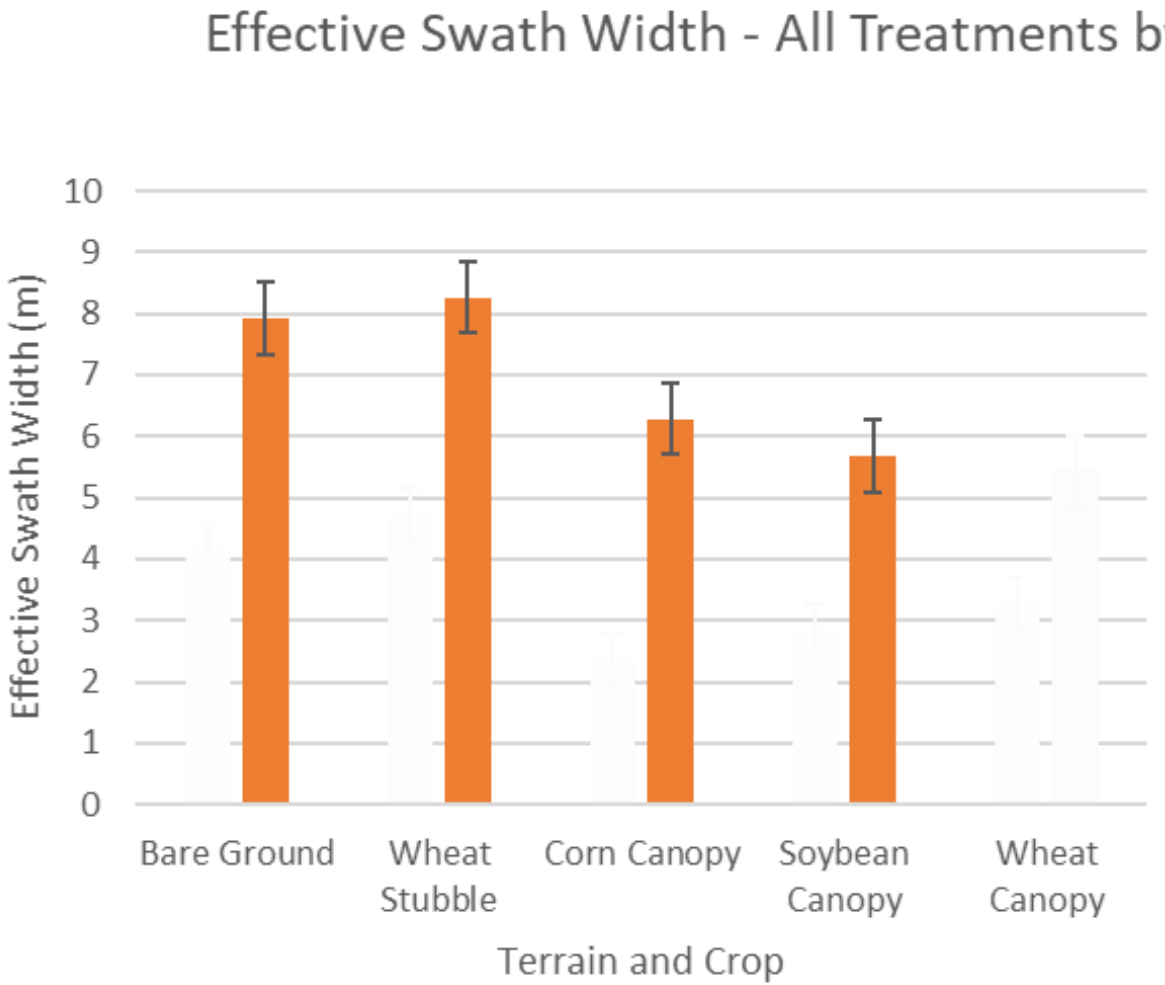

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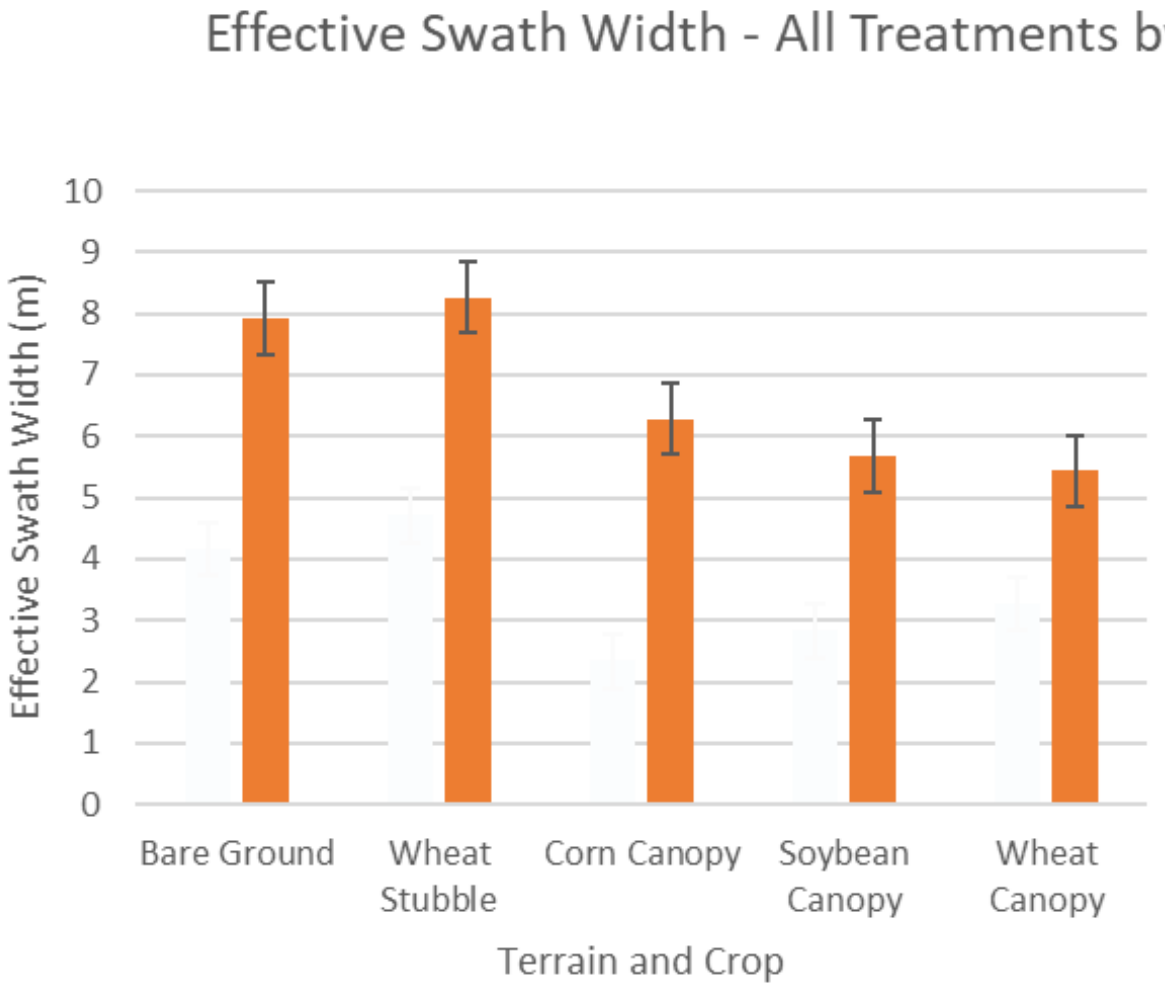

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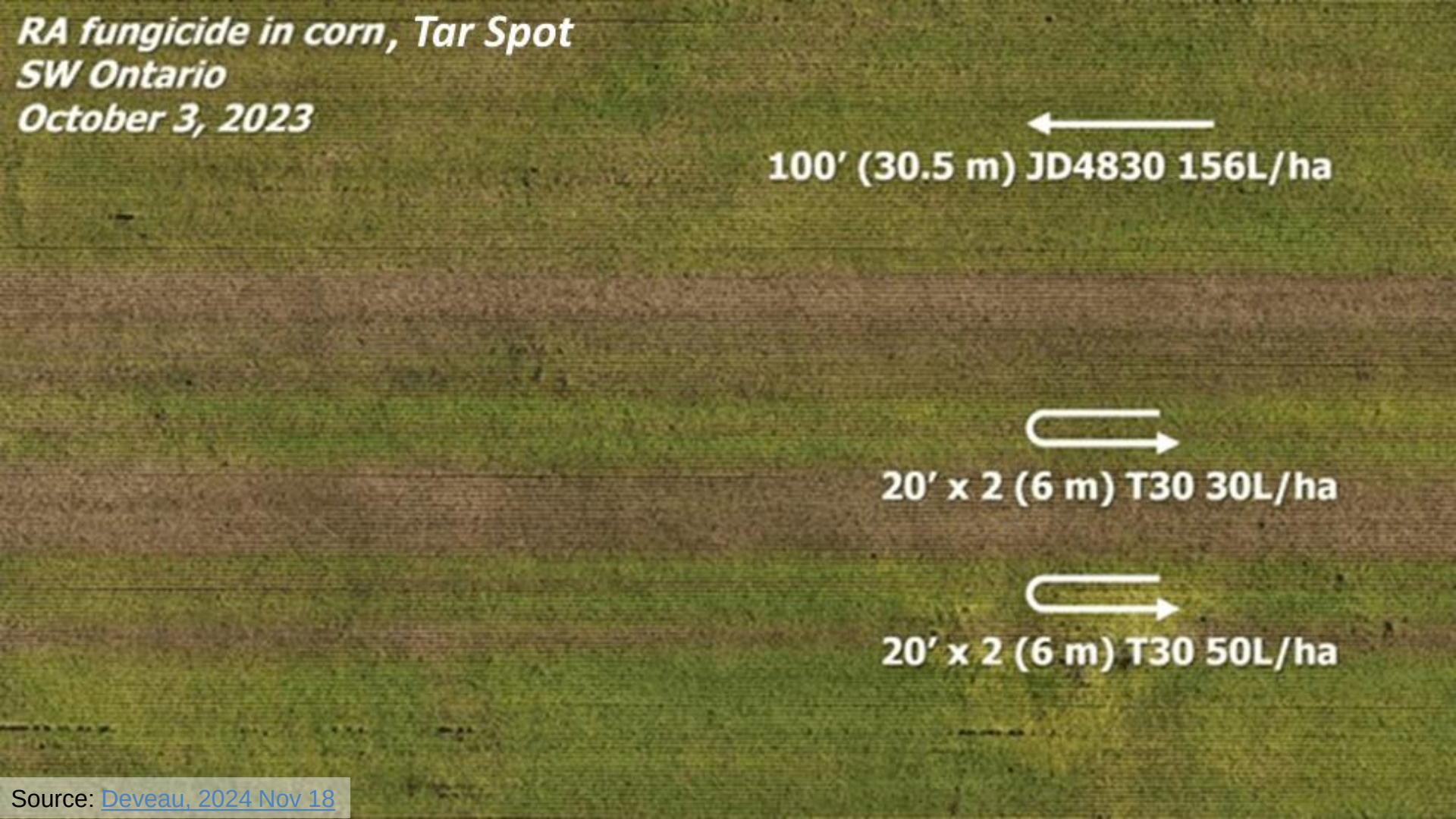
Source: Deveau, 2024 Nov 18

Calibrate to determine effective swath width…because spray drones concentrate spray directly beneath the vehicle…and patterns narrow considerably in-crop…

Calibrate to determine effective swath width…because spray drones concentrate spray directly beneath the vehicle…and patterns narrow considerably in-crop…which causes skips if passes are too far apart



Source: Deveau, 2024 Nov 18

RA fungicide in corn, Tar Spot
SW Ontario
October 3, 2023

100’ (30.5 m) JD4830 156L/ha

20’ x 2 (6 m) T30 30L/ha

20’ x 2 (6 m) T30 50L/ha

Source: Deveau, 2024 Nov 18

Source: Deveau, 2024 Nov 18

Tendering and Loading for Success

TENACITY AG


LYP8-13241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POWER


DRONE
TRAILER


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XAG P150
Agricultural Drone

What's included:

- **A.** XAG P150 Agricultural Drone
- **B.** XAG Smart Remote Controller
- **C.** XAG Pro Ground Module
- **D.** 8x XAG Smart Supercharge Battery
- **E.** 3x P150 Non-Stop kit
- **F.** 3x XAG Super Charger

XAG P150
Agricultural Drone

Exciting specs:

8 gal/min	18.5 gal	155 lbs	8 min
Max. Flow Rate	Smart Liquid Tank	Rated Payload	Fast Charge

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Being Productive vs. Being Productive & Successful

At parameters necessary to optimize efficacy, productivity may be much lower than advertised

AGRAS T40

One for All

per hour **21.3** hectare [4]

(farmland)

per hour **4** hectare [5]

(orchards)

per hour **1.5** tonnes of fertilizer [6]

(spreading)

AGRAS T40

One for All

52.6 acre per hour

21.3 hectare [4] (farmland)

Consumption rate: 15 L/ha

Spray width: 11 m

Flight speed: 7 m/s

Flight altitude: 3 m

AGRAS T40

One for All

52.6 acre per hour 21.3 hectare [4] (farmland)

~~1.6 gal/ac~~

Consumption rate: ~~15 L/ha~~ 3 to 5 gal/ac?

Spray width: 11 m

per hour 4 hectare [5]

Flight speed: 7 m/s

Flight altitude: 3 m

per hour 1.5 tonnes of fertilizer [6] (spreading)

AGRAS T40

One for All

52.6 acre per hour 21.3 hectare [4] (farmland)

~~1.6 gal/ac~~

Consumption rate: ~~15 L/ha~~ 3 to 5 gal/ac?

Spray width: ~~11 m~~ 5.5 to 8 m?

per hour 4 hectare [5] (sprinkling)

Flight speed: 7 m/s

Flight altitude: 3 m

per hour 1.5 tonnes of fertilizer [6] (spreading)

Contact herbicide successes

TENACITY AG


Liberty, Glyphosate, AMS

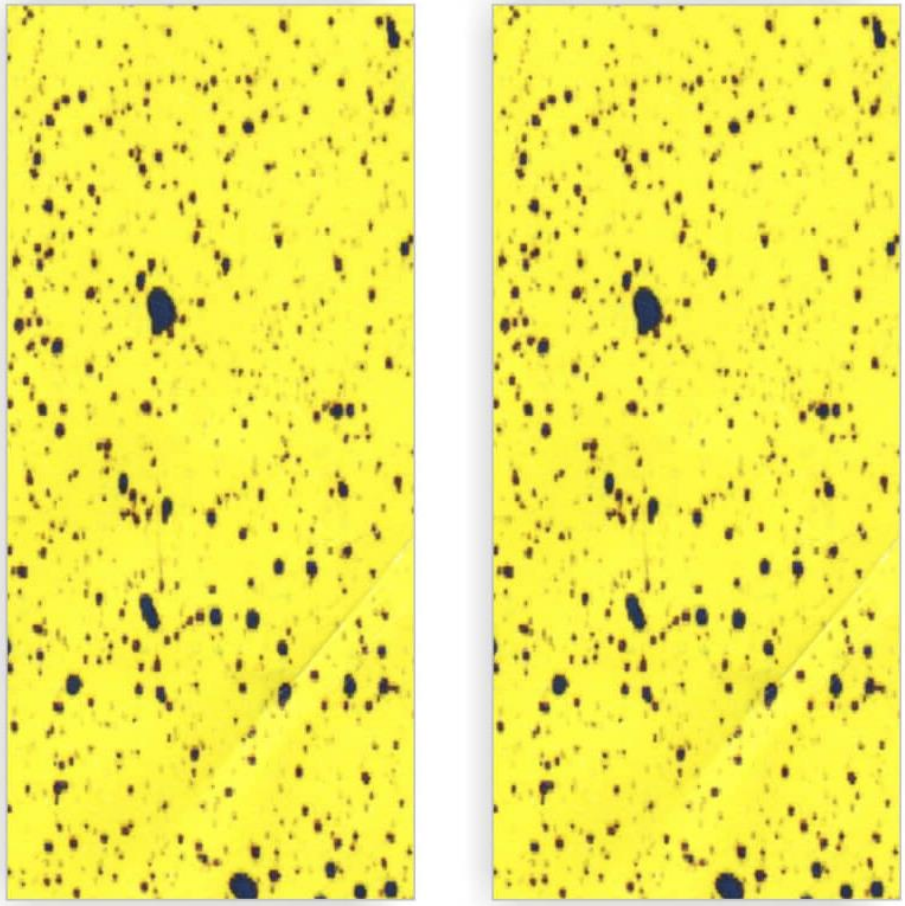
HOW CAN THIS WORK???

Rethink coverage.

Rethink coverage. When applying low volumes of highly concentrated pesticide…

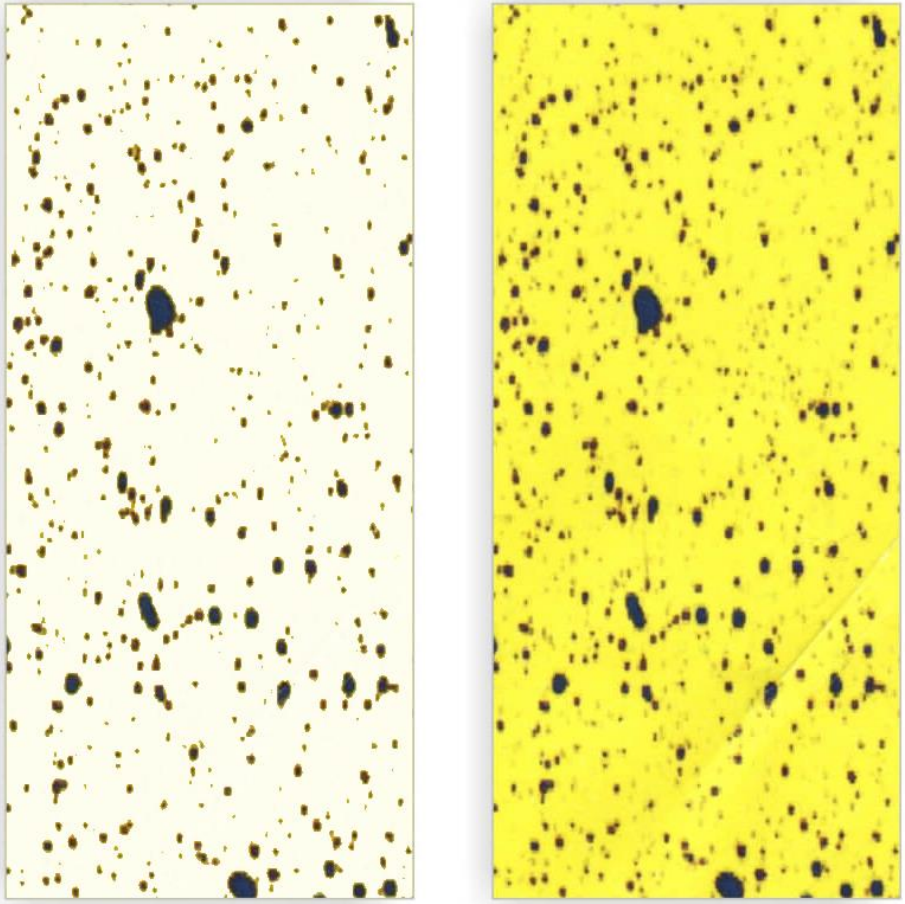
Rethink coverage. When applying low volumes of highly concentrated pesticide…deposit density seems to be the best measure of coverage

Percent Coverage



Deposit Density

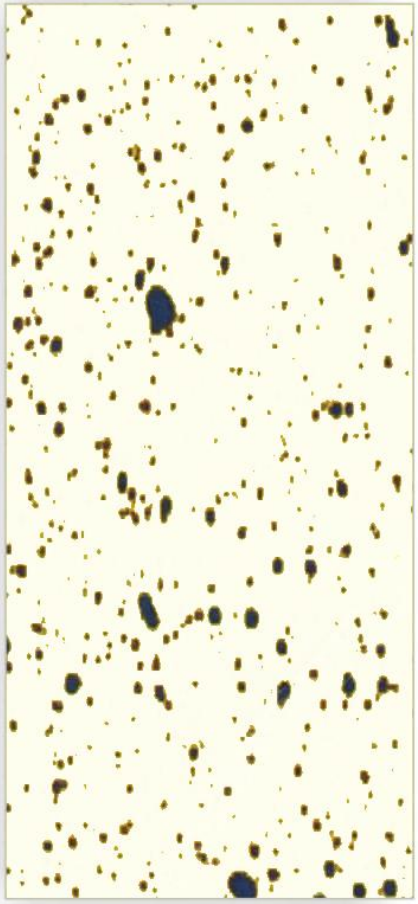
Percent Coverage

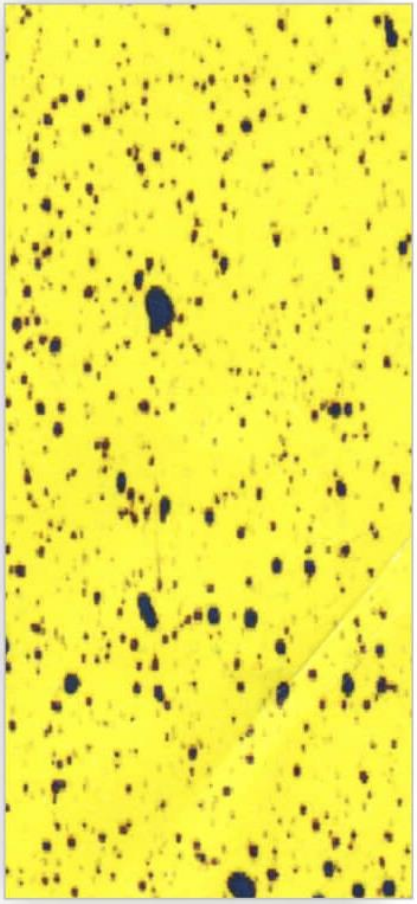


Deposit Density

6.7%

Percent Coverage





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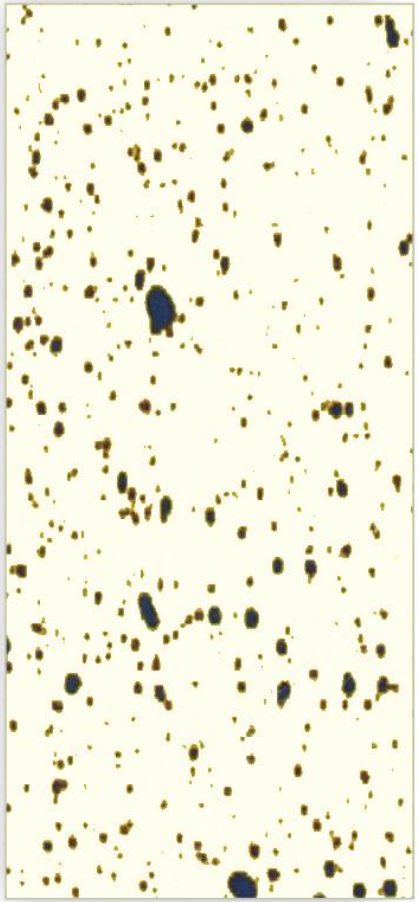
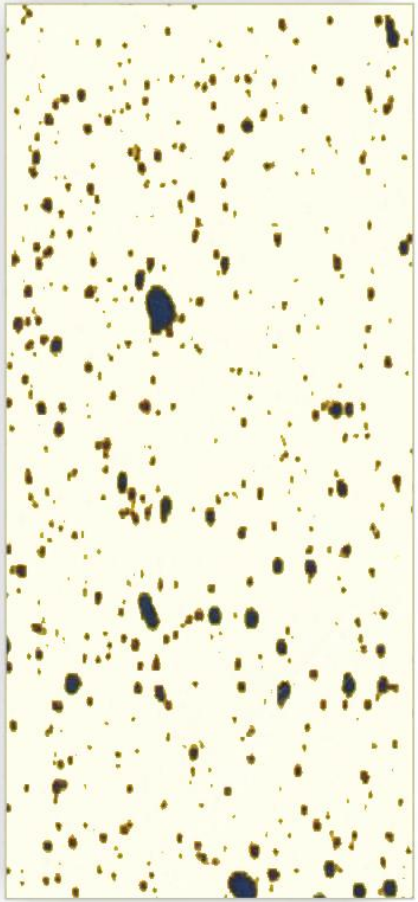


Deposit Density

Percent Coverage

6.7%



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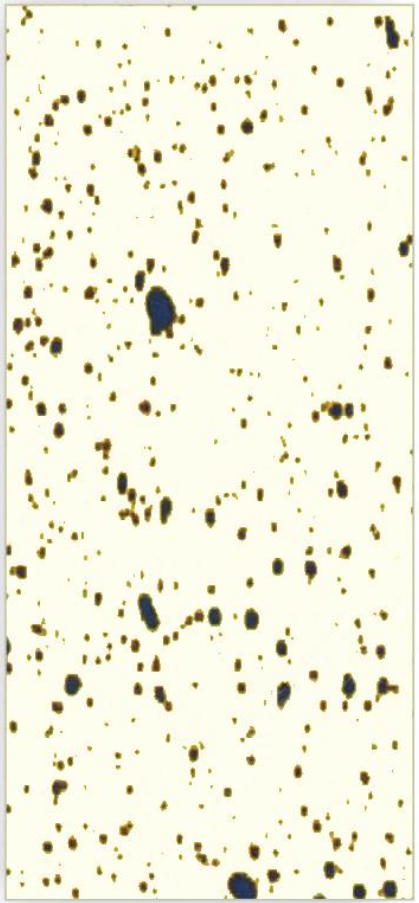

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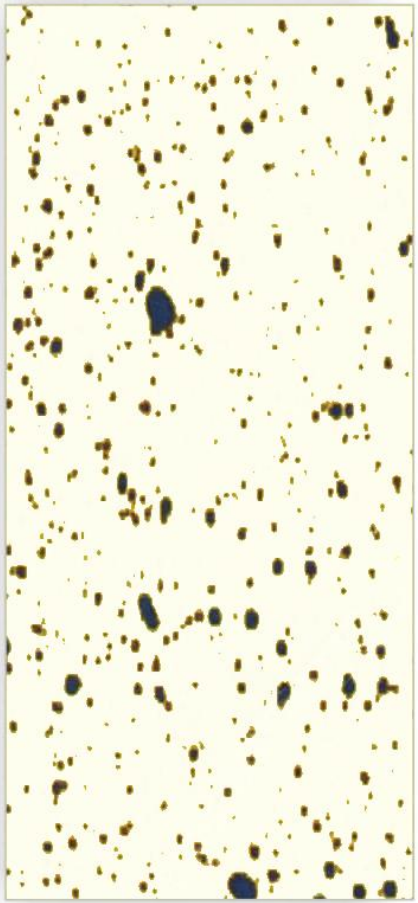

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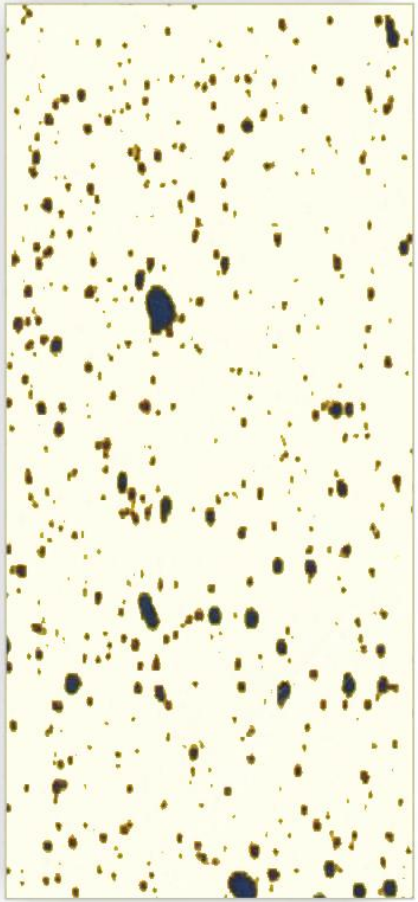
Percent Coverage

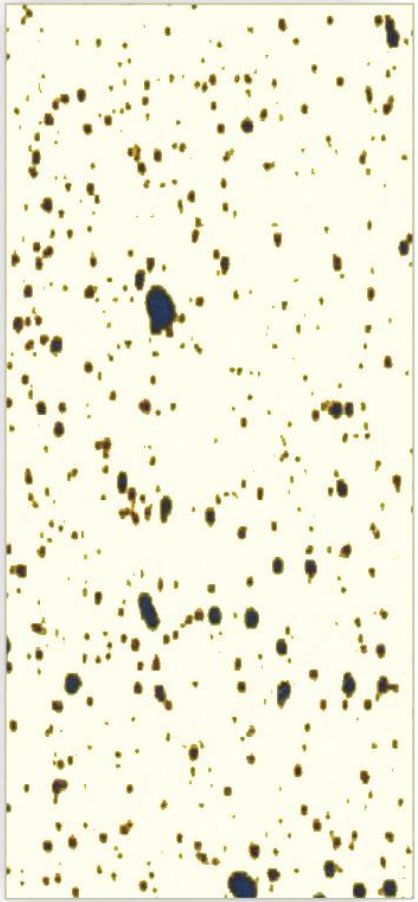
6.7%



Deposit Density

Percent Coverage

6.7%



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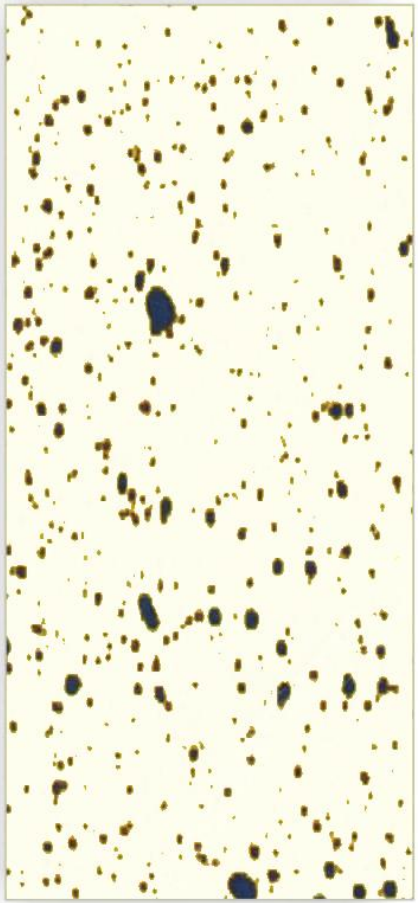

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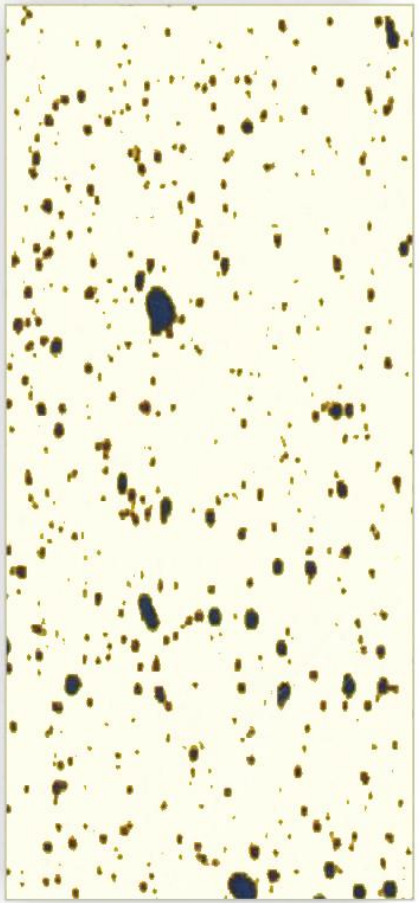

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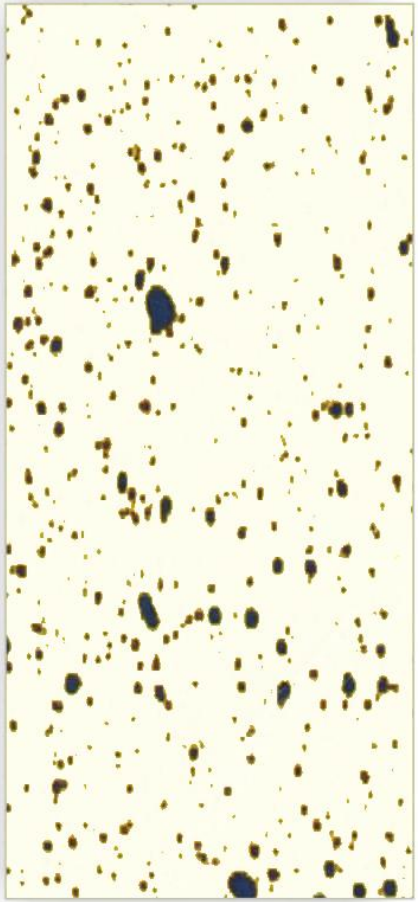
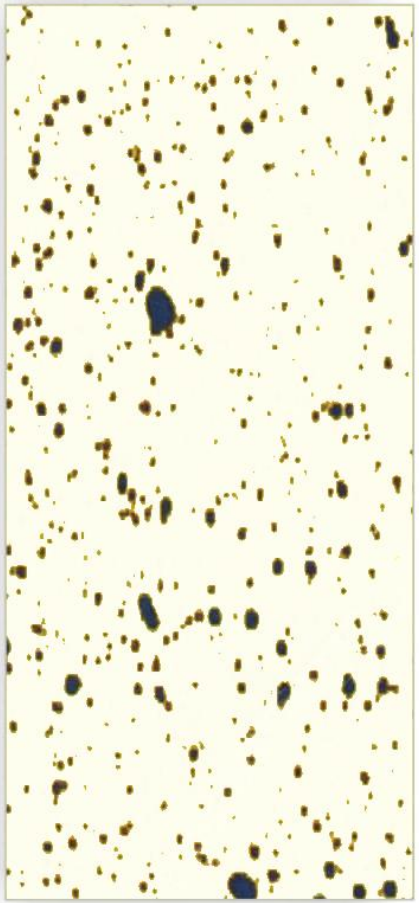


Deposit Density

6.7%

85/cm²

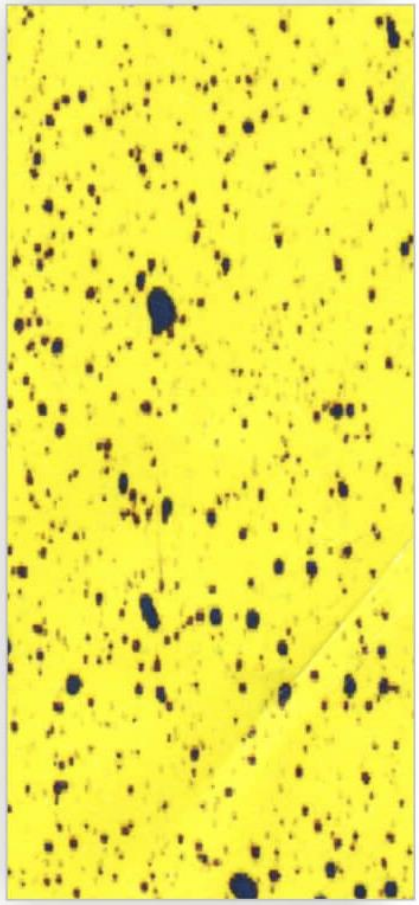
Percent Coverage



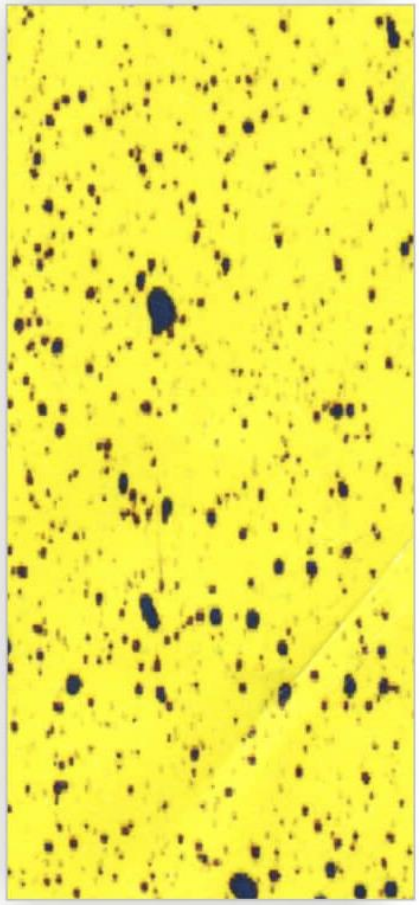
Deposit Density

Percent Coverage

6.7%



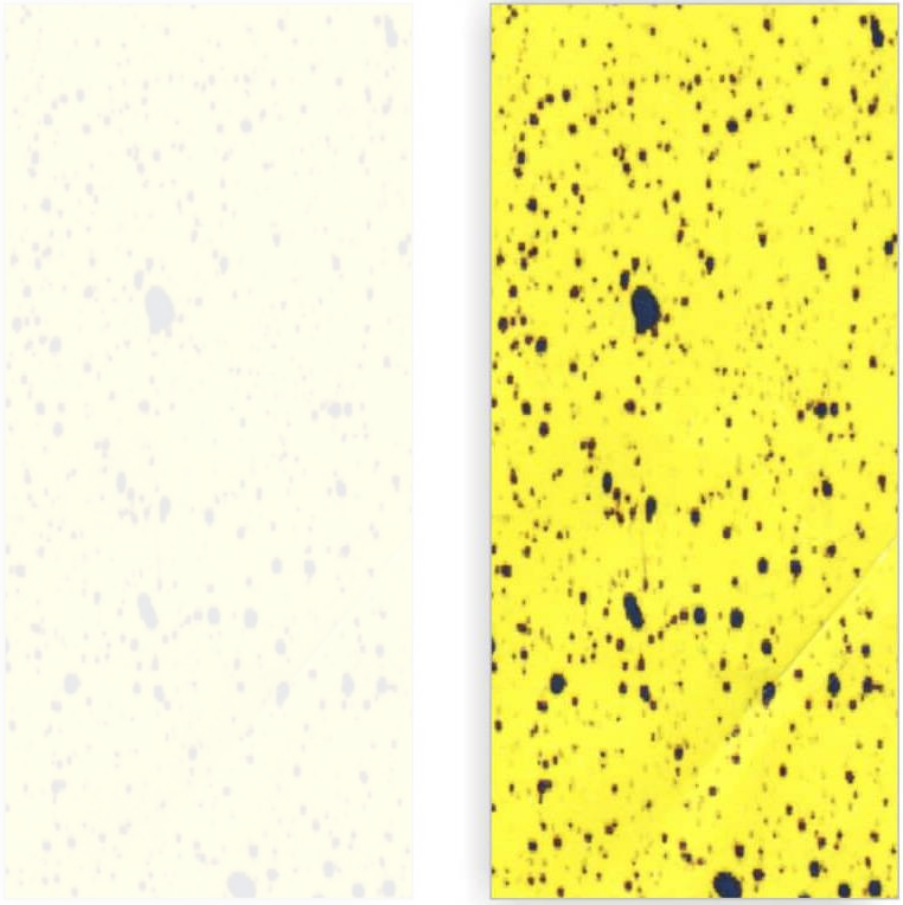
85/cm²



Deposit Density

6.7%

85/cm²



Percent Coverage

Deposit Density

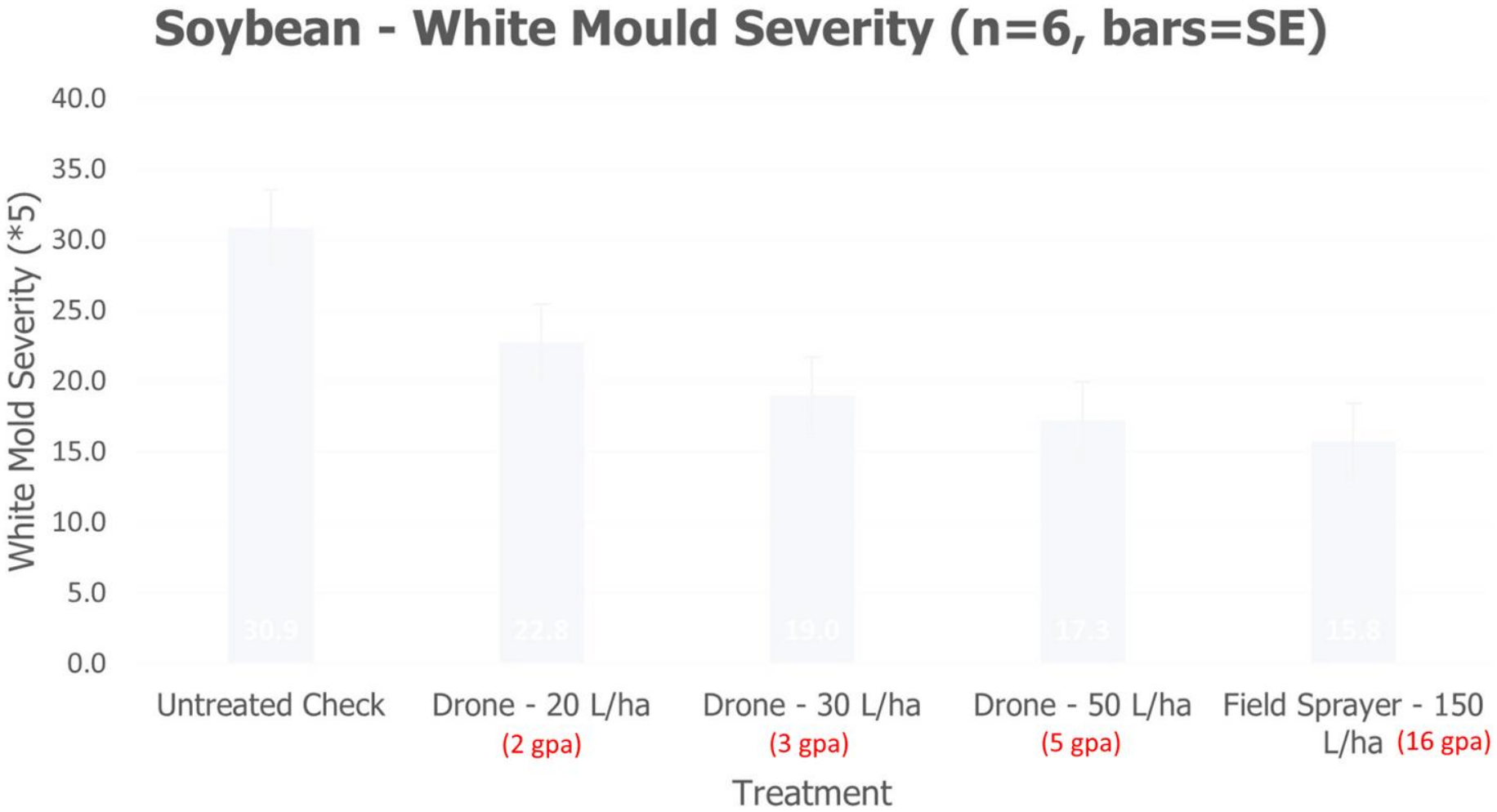
https://sprayers101.com/drone-soybean/

Exploring Spray Drones in Soybean

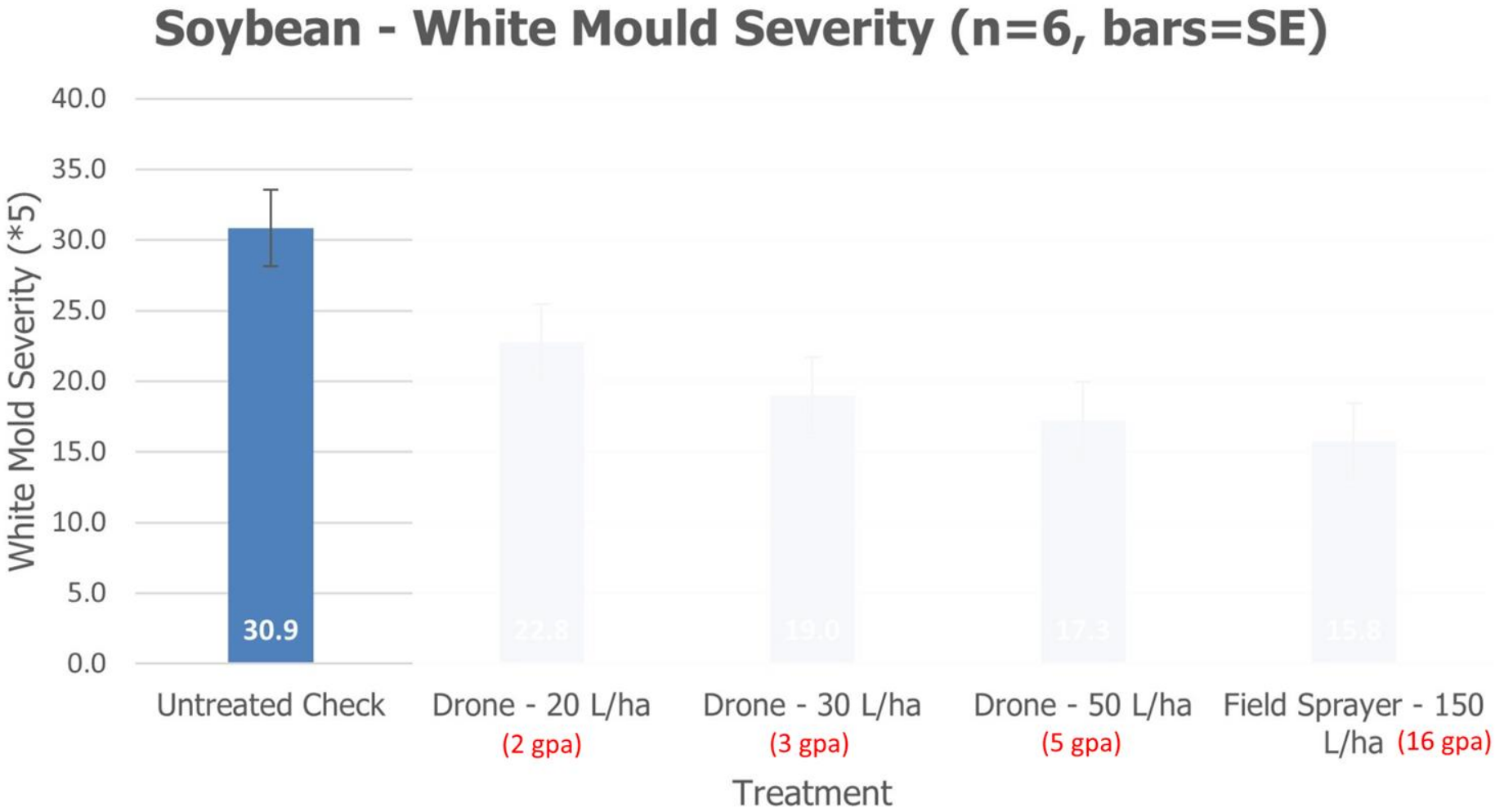
Posted on **March 19, 2024**

ABOUT JASON DEVEAU (SPRAY GUY)

Dr. Jason Deveau has been the OMAFA Application Technology Specialist since 2008. He researches and teaches methods to improve the safe, effective and efficient application of agricultural sprays in specialty crops, field crops and controlled environments. He is the co-administrator of Sprayers101, co-author of the Airblast101 Textbook, a slow cyclist and an even slower runner.

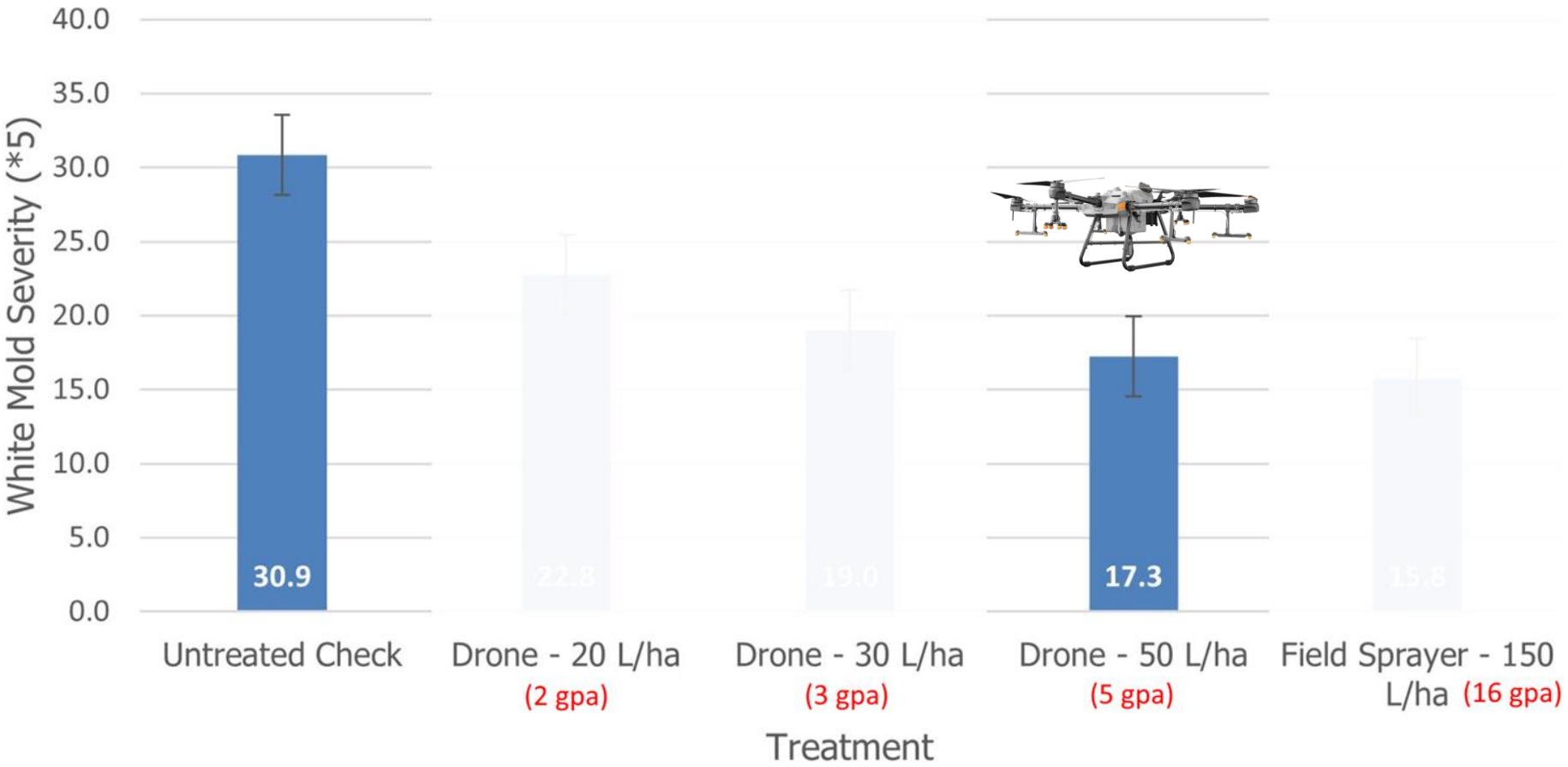


Source: Deveau, 2024 March 19



Source: Deveau, 2024 March 19

Soybean - White Mould Severity (n=6, bars=SE)



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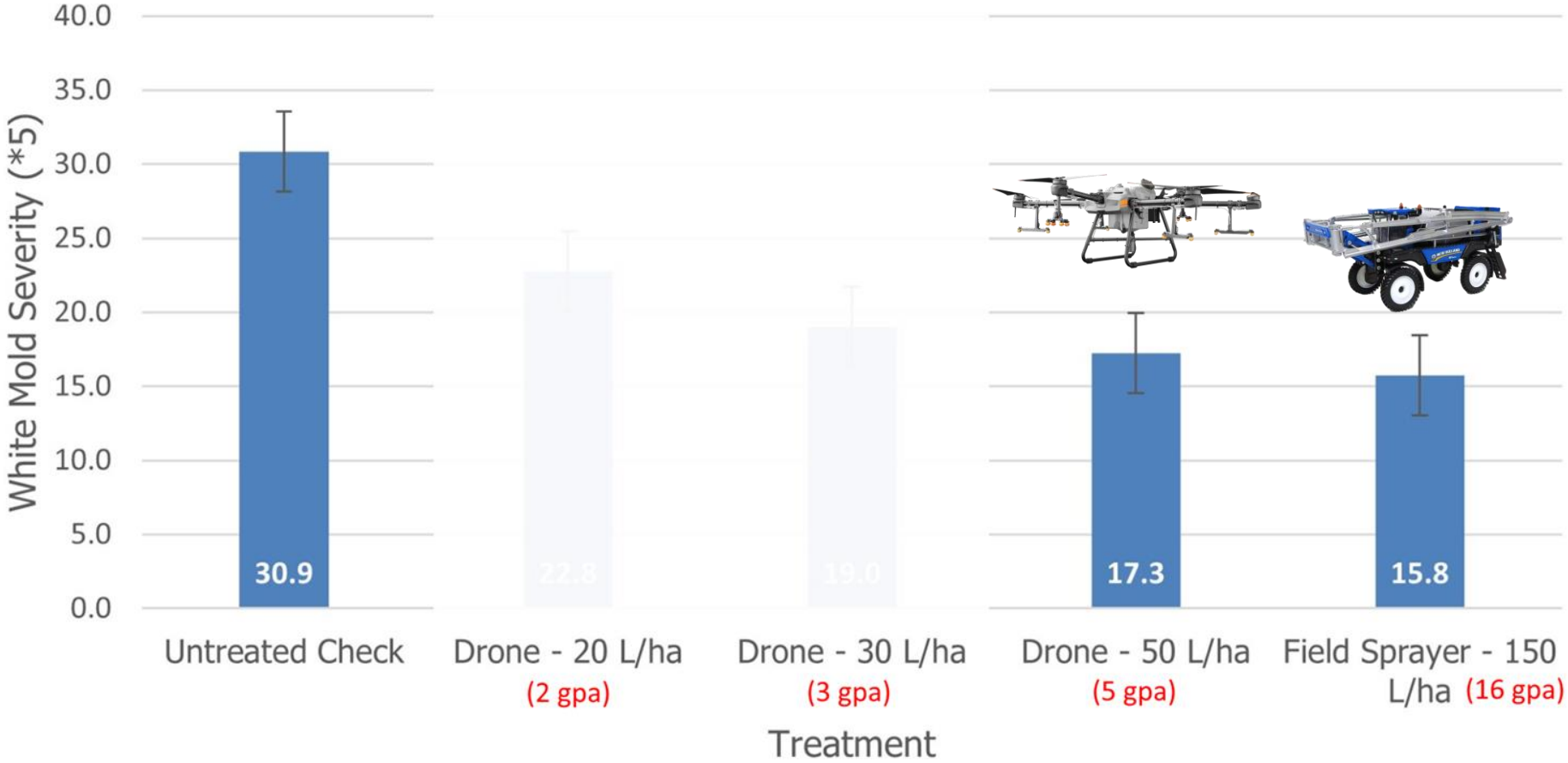
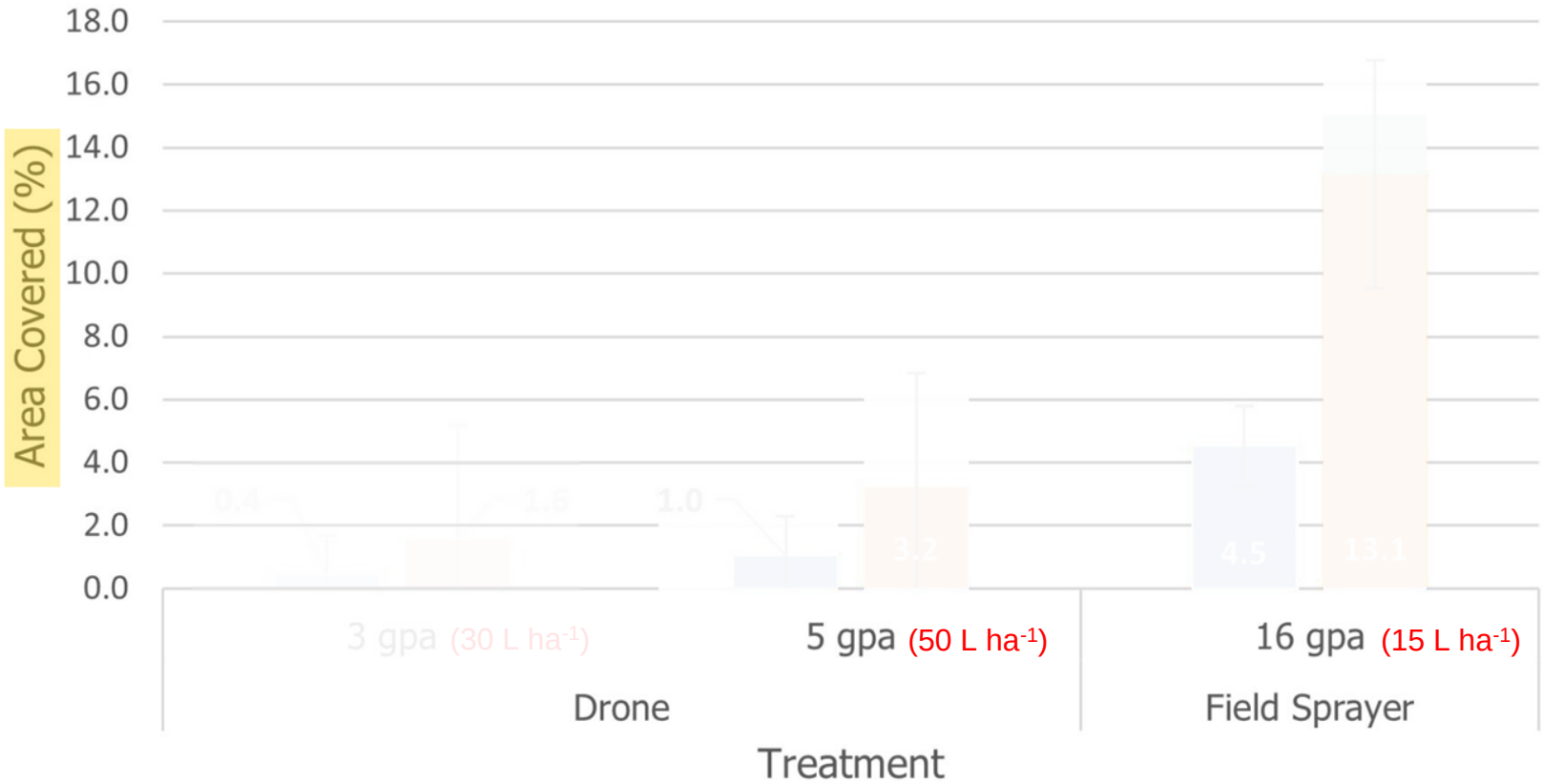


Source: Deveau, 2024 March 19

Average Soybean Canopy Coverage (n=4, bars=S.E.)



Source: Deveau, 2024 March 19

Average Soybean Canopy Coverage (n=4, bars=S.E.)

Area Covered (%)

18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0

0.4
1.6
1.0
3.2
4.5
13.1

Bottom
Top

3 gpa (30 L ha^{-1})
5 gpa (50 L ha^{-1})
16 gpa (15 L ha^{-1})

Drone
Field Sprayer

Treatment

Source: Deveau, 2024 March 19

Average Soybean Canopy Coverage (n=4, bars=S.E.)

-76%

Area Covered (%)

18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0

3.2
13.1

Bottom
Top

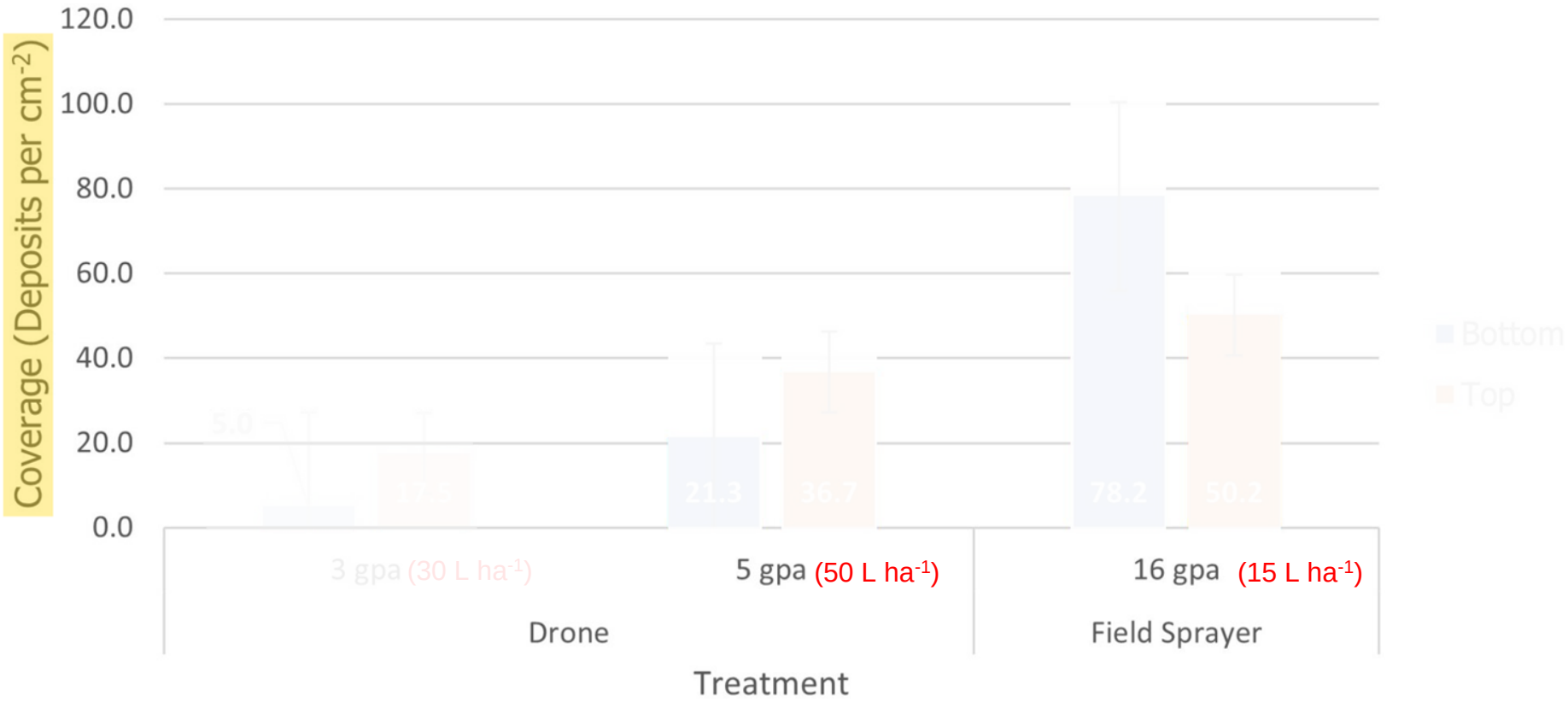
3 gpa (30 L ha^{-1})
5 gpa (50 L ha^{-1})
16 gpa (15 L ha^{-1})

Drone
Field Sprayer

Treatment

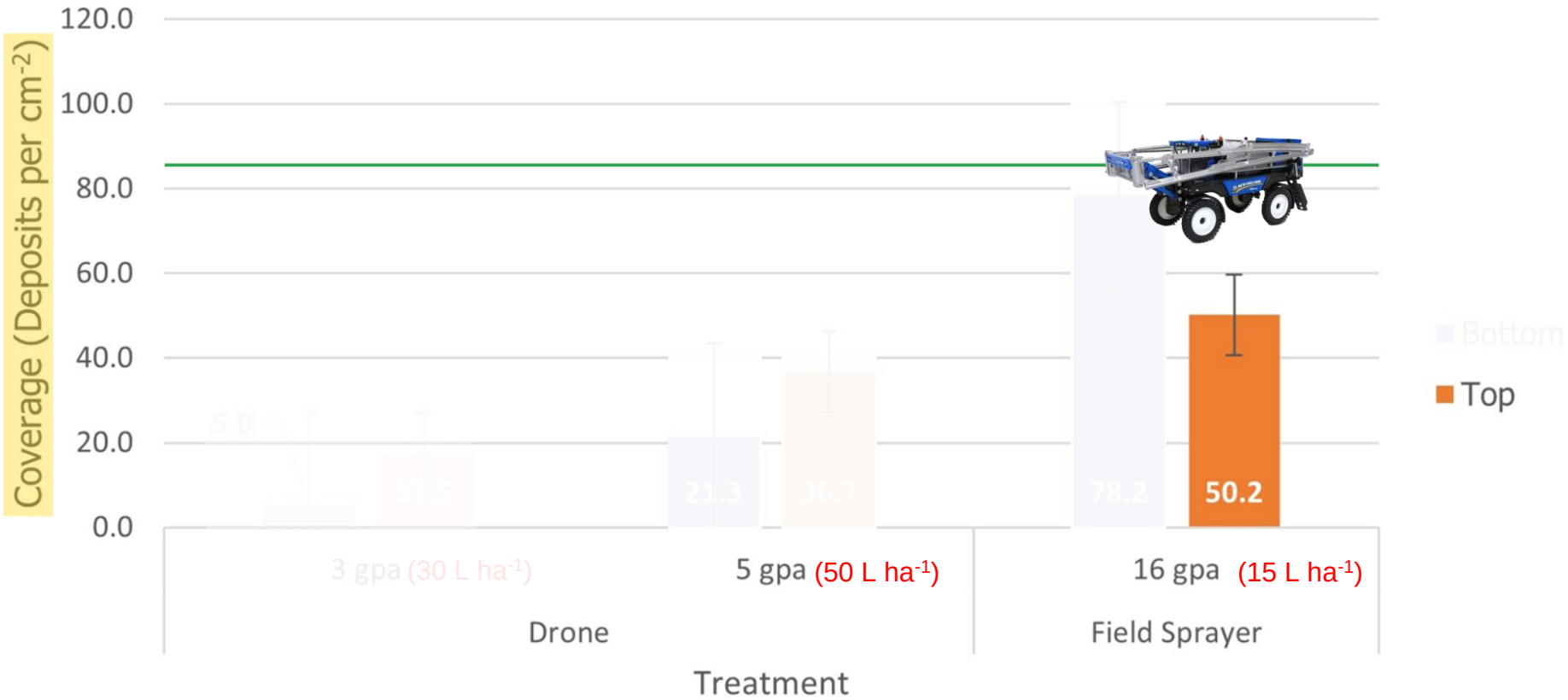
Source: Deveau, 2024 March 19

Average Soybean Canopy Coverage (n=4, bars=S.E.)



Source: Deveau, 2024 March 19

Average Soybean Canopy Coverage (n=4, bars=S.E.)



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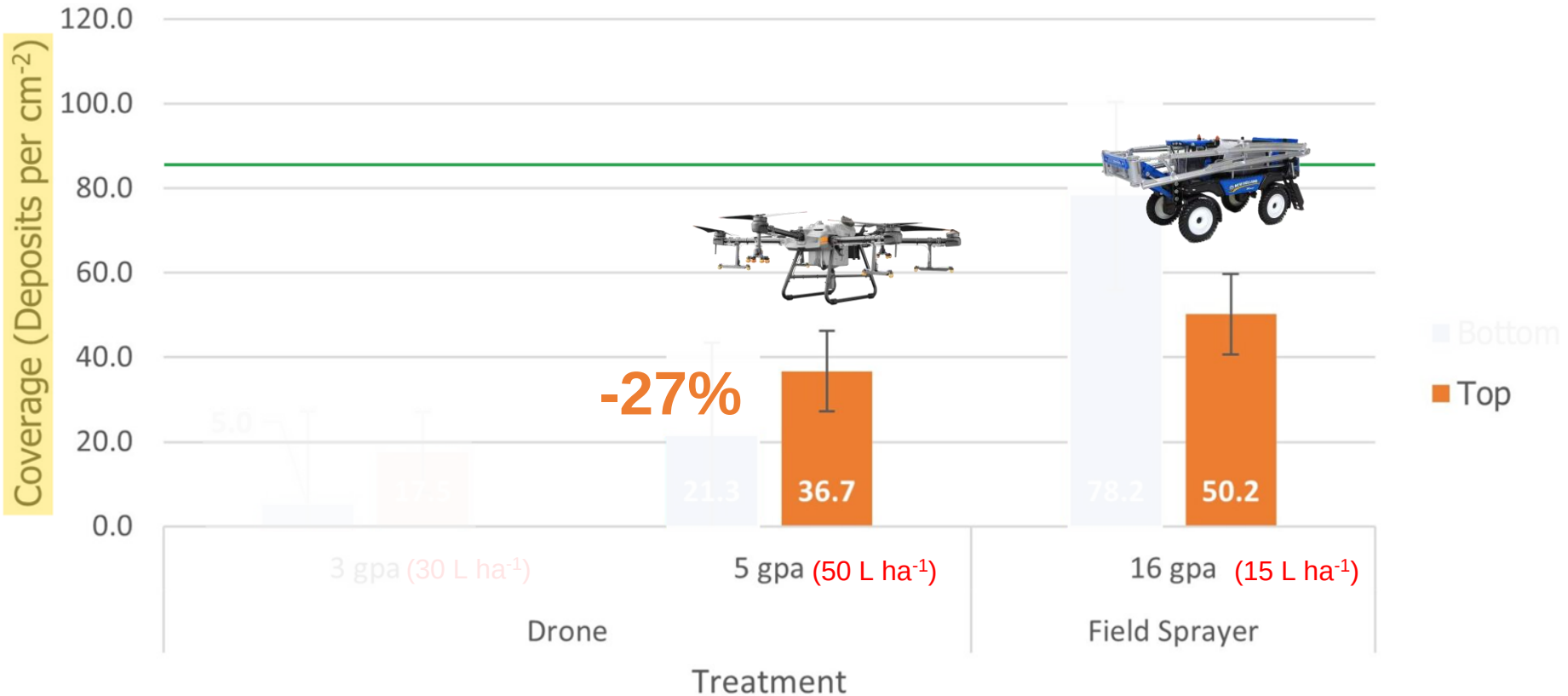


Source: Deveau, 2024 March 19

Deposit density, combined with a more highly concentrated active ingredient (3x), were sufficient in this case to provide suitable fungicide efficacy.

Rethink formulations.

Rethink formulations. When applying low volumes of highly concentrated pesticide…

Rethink formulations. When applying low volumes of highly concentrated pesticide…formulations may perform differently

Application of Crop Protection Products Using UAV: Considerations for a Successful Application from a Formulation Perspective

(ASABE Abstract Submission ID: 2401514)

Rajeev Sinha, Gagandeep Kaur, John Atkinson, Leandro Cordova, Minija Praveen, Krista Scharnak, MaryRose Foley

Corteva Agriscience, 9330 Zionsville Road, Indianapolis, IN- 46268 (rajeev.sinha@corteva.com)

Introduction

- Drones (aka Unmanned aerial vehicles [UAV], unmanned aerial pesticide application systems [UAPAS]) have gained momentum for pesticide application.
- UAVs may be perceived as a more viable option for pesticide application compared to conventional techniques, especially backpack/knapsack applicators.
- The spray volume for drone-based spraying is in the range of 10-20 L ha^{-1}.

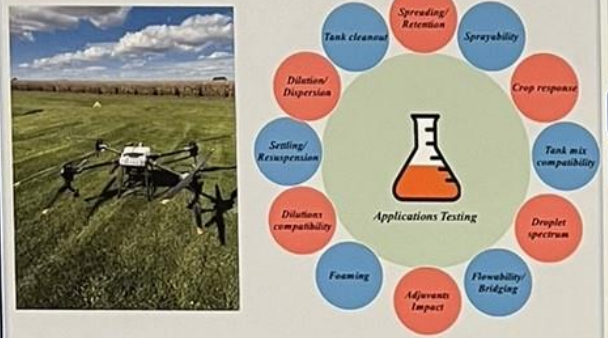


Fig. 1. A typical UAAS to apply CP products and application quality assessment parameters.

Problem Statement

- Carrier volume in UAV spraying can be about 5, 10 and 50 times lesser compared to manned aircrafts, ground sprayers and orchard sprayers, respectively.
- Low water volume can cause issues with application quality, efficacy of pesticide application, and physical-chemical characteristics of the tank mix.
- For example, a highly concentrated tank mix may negatively impact properties like dispersibility, sprayability, surface tension & compatibility of a tank mix.

Materials and Methods *(continues)*

Experimental protocol

- Tank mixes were prepared using 342 ppm water (5 C) prepared in lab using Ca and Mg salts.
- Formulation use rate:
  - ❑ Maximum product use rate as specified by approved label
- Application volume:
  - ❑ Ground Rate - 100 Lha^{-1}; UAV Rate – 10 Lha^{-1}
- Droplet Size Characterization – XR8002 nozzle at 40 psi operating pressure

Results

Tank mix compatibility assessment

Tank Mix Details		Compatibility Result	
Product 1	Product 2	Ground Rate	UAV Rate
Insecticide- I4 (WDG)	Fungicide- F2 (SE)		
Insecticide- I1 (SC)	Fungicide- F2 (SE)		
Insecticide- I5 (SC)	Fungicide- F2 (SE)		
Fungicide- F4 (EC)	Fungicide- F2 (SE)		
Herbicide- H2 (WDG)	Herbicide- H4 (SL)		
Herbicide- H8 (WDG)	Herbicide- H4 (SL)		
Herbicide- H7 (OD)	Herbicide- H4 (SL)		
Insecticide- I3 (WDG)	Insecticide- I5 (SC)		
Insecticide- I3 (WDG)	Insecticide- I4 (WDG)		
Herbicide- H2 (WDG)	Fungicide- F3 (EC)		
Herbicide- H8 (WDG)	Fungicide- F5 (SE)		

(a) (b)

Results *(continues)*

Droplet size characterization

S. No.	Formulation Details		Use rate			Ground Rate			UAV Rate			Δ Fines,
			Ground	UAV	Unit	Fines	RS	DV50	Fines	RS	DV50	%
1	Herbicide H1	OD	1.0	20.0	%v/v	39	1.1	170	47	1.2	156	19.7
2	Herbicide H2	WDG	0.1	0.7	%w/v	44	1.3	162	48	1.5	155	8.4
3	Herbicide H3	EC	2.5	20.0	%v/v	52	1.2	146	52	1.4	147	-1.2
4	Herbicide H4	SL	2.4	23.4	%v/v	41	1.2	167	48	1.5	154	16.1
5	Herbicide H5	OD	0.2	15.0	%v/v	38	1.1	172	48	1.3	154	25.5
6	Herbicide H6	SE	1.0	10.0	%v/v	33	1.1	185	43	1.2	165	29.8
7	Herbicide H7	OD	0.6	6.0	%v/v	32	1.1	187	35	1.1	180	10.6
8	Herbicide H8	WDG	0.2	1.0	%w/v	47	1.4	157	48	1.4	155	2.9
9	Herbicide H9	EC	0.1	12.5	%v/v	32	1.1	187	43	1.1	162	36.6
10	Insecticide I1	SC	5.0	9.0	%v/v	38	1.4	177	38	1.8	208	0.8
11	Insecticide I2	SC	0.6	6.0	%v/v	43	1.3	163	46	1.3	159	5.2
12	Insecticide I3	WDG	0.4	1.9	%w/v	46	1.4	171	47	1.3	157	2.3
13	Insecticide I4	WDG	2.6	4.9	%w/v	40	1.4	171	45	1.4	161	11.3
14	Insecticide I5	SC	0.2	8.0	%v/v	41	1.2	168	42	1.3	166	2.4
15	Fungicide F1	EC	3.8	14.2	%v/v	46	1.2	157	48	1.2	153	4.8
16	Fungicide F2	SE	0.2	6.0	%v/v	40	1.2	170	42	1.2	165	5.2
17	Fungicide F3	EC	1.0	10.0	%v/v	42	1.1	166	49	1.3	151	19.1
18	Fungicide F4	EC	0.2	5.0	%v/v	33	1.1	184	41	1.1	167	25.1
19	Fungicide F5	SE	0.2	20.0	%v/v	43	1.3	164	48	1.4	154	10.8

% Fines - % of total sample volume formed by droplets of diameter ≤ 150 µm.

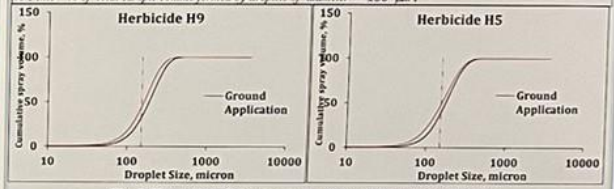
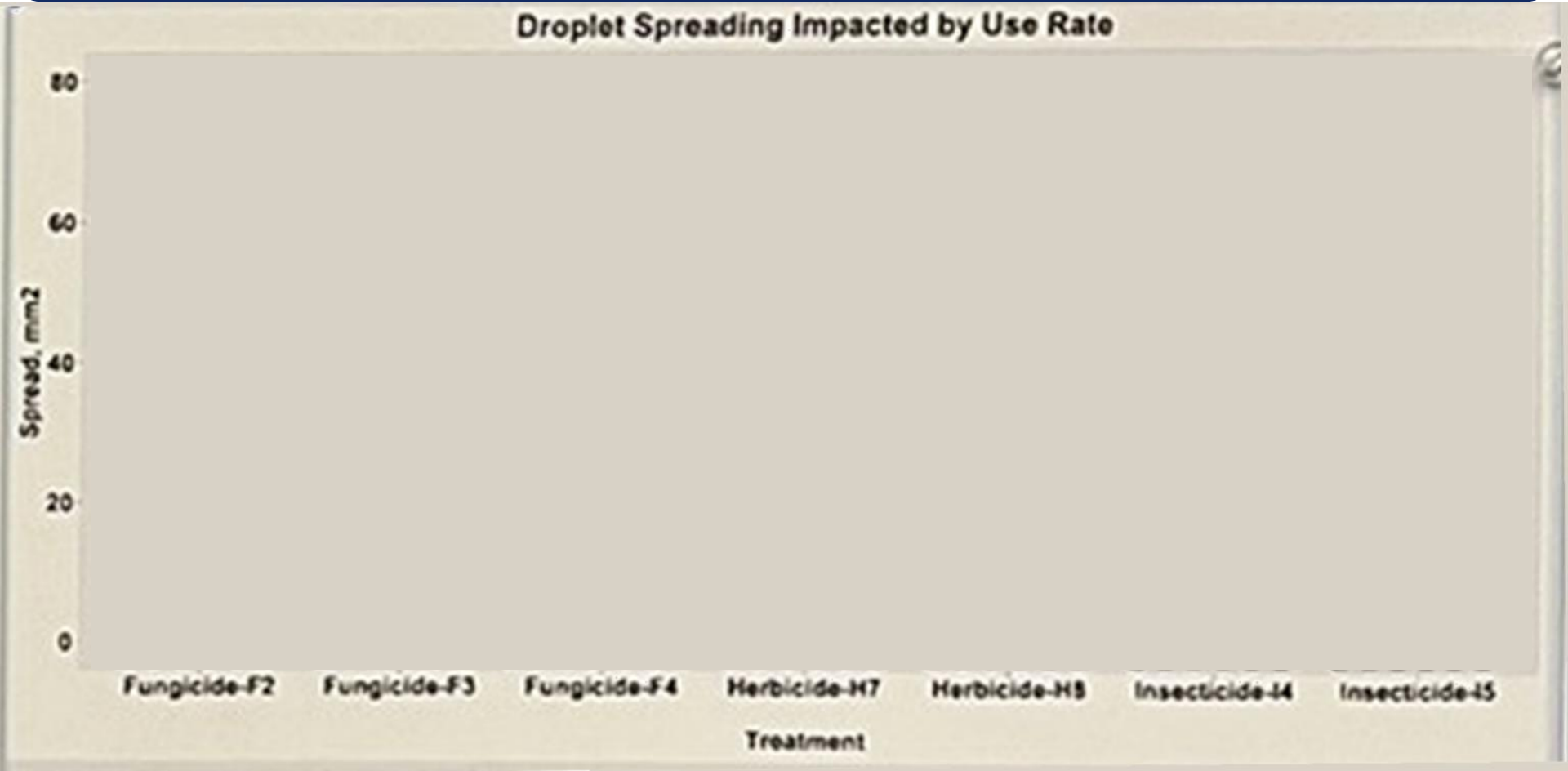


Fig. 5. Examples of droplet size spectrum of herbicide products

Conclusions

- Using a low water volume (i.e. at drone rate) can increase the risk of incompatibility between pesticide partners
- Complex formulations like OD, SC, and SE may result in considerable residue buildup along nozzle screens, while simpler formulations like EC and SL showed acceptable sprayability at drone rates
- Droplet spreading was not different for most of the formulations evaluated, especially herbicides and insecticides. However, some of the fungicides showed higher spreading at drone use rate.

Droplet Spreading



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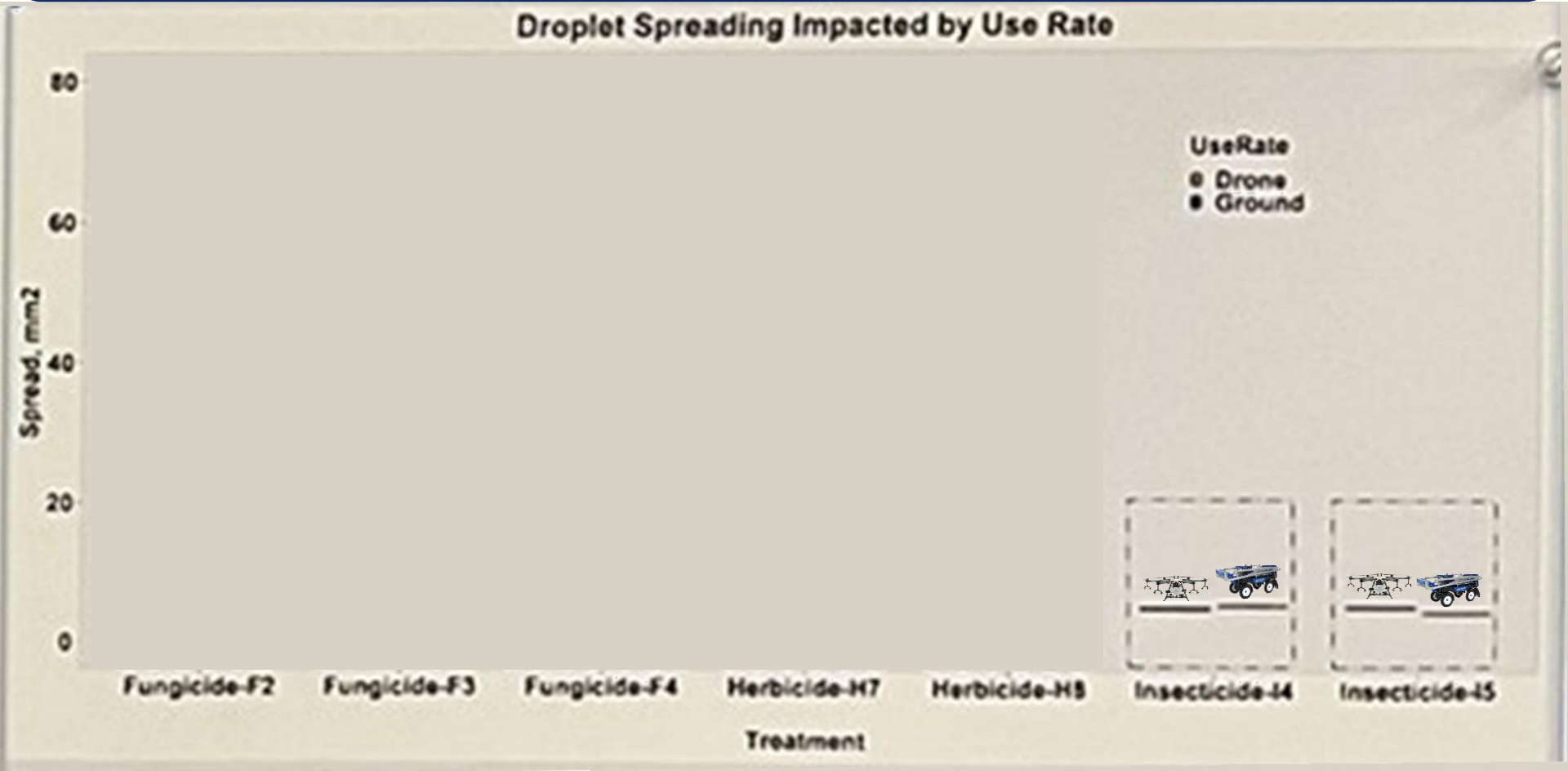

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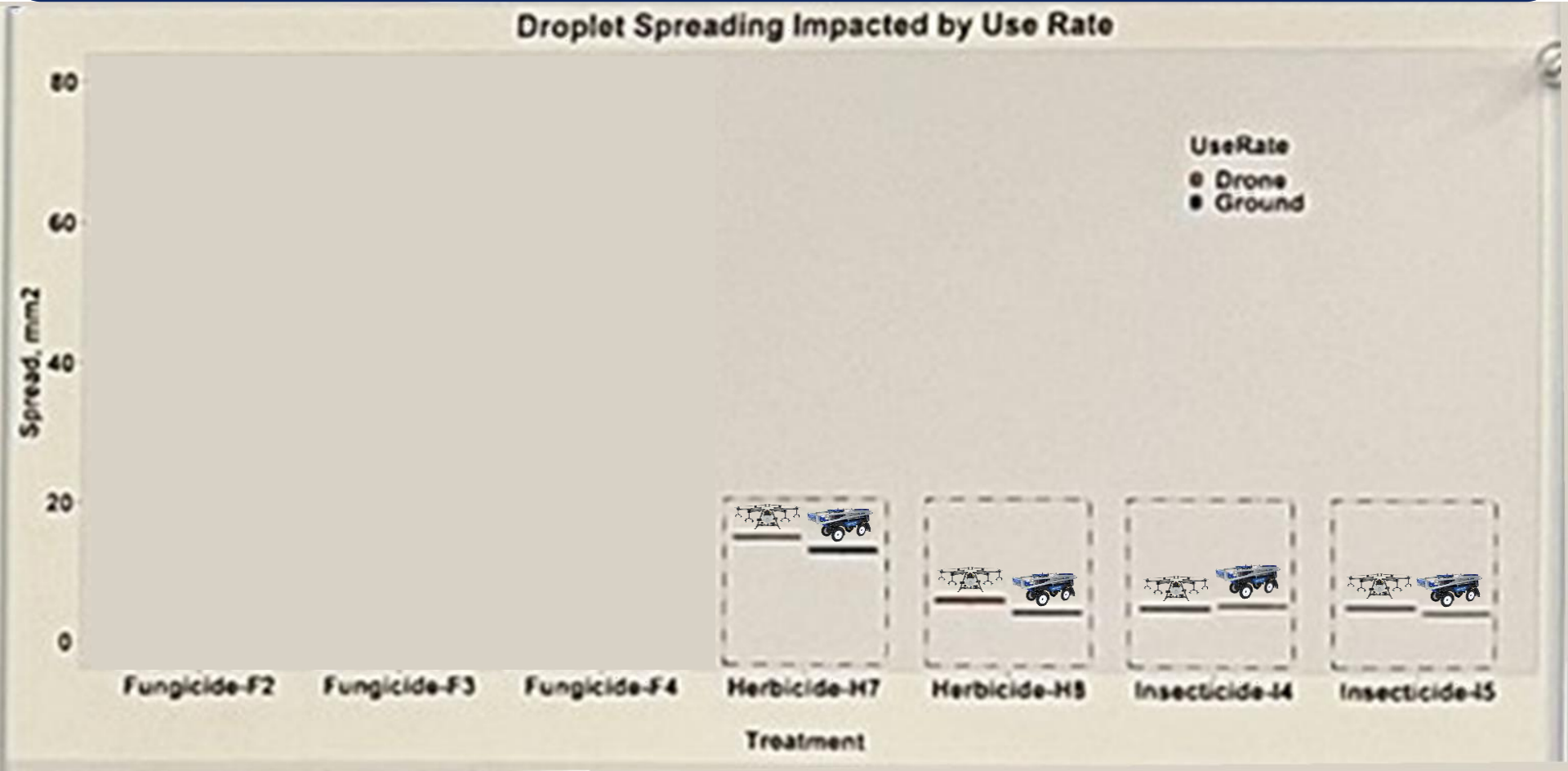

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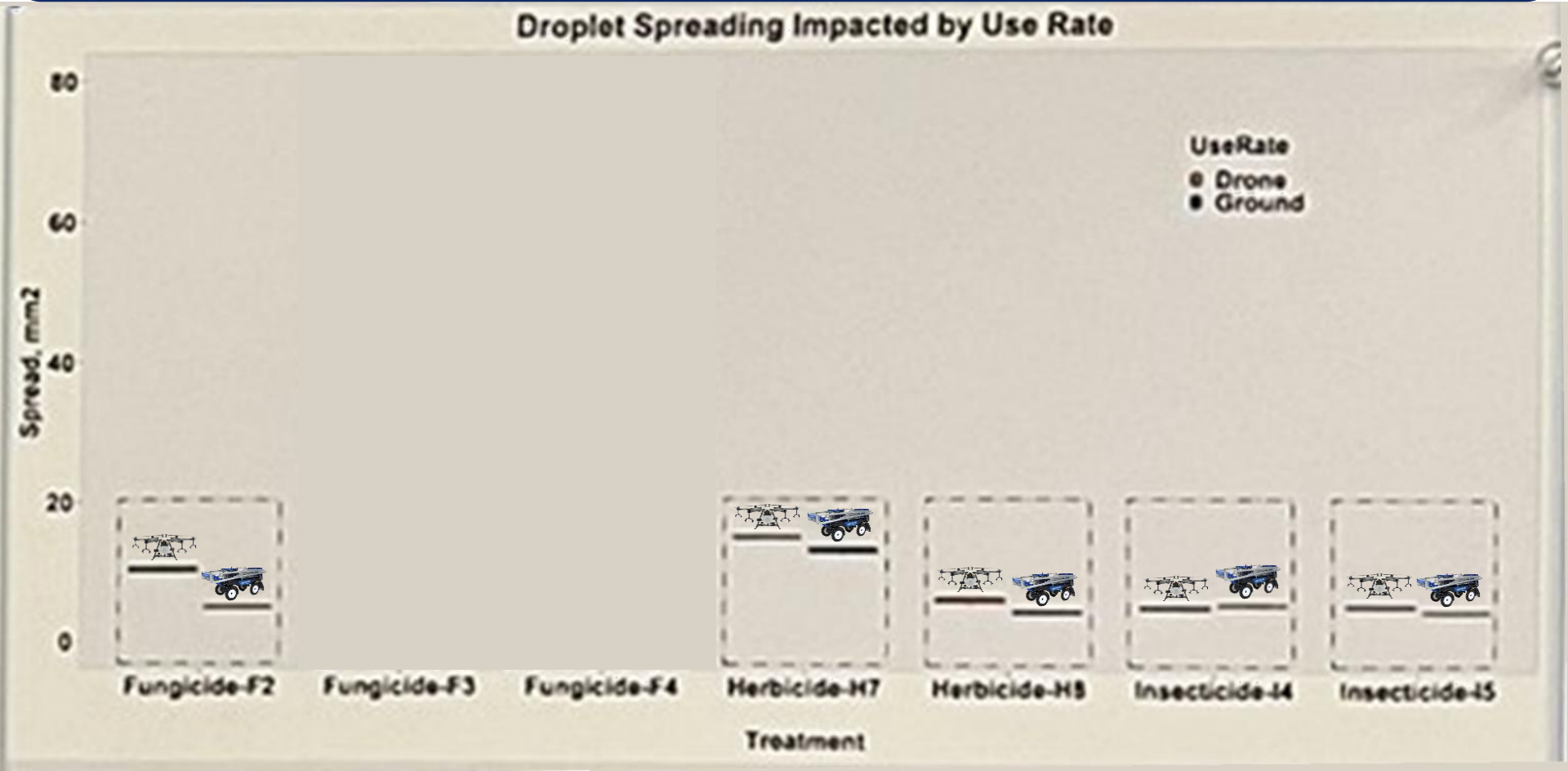
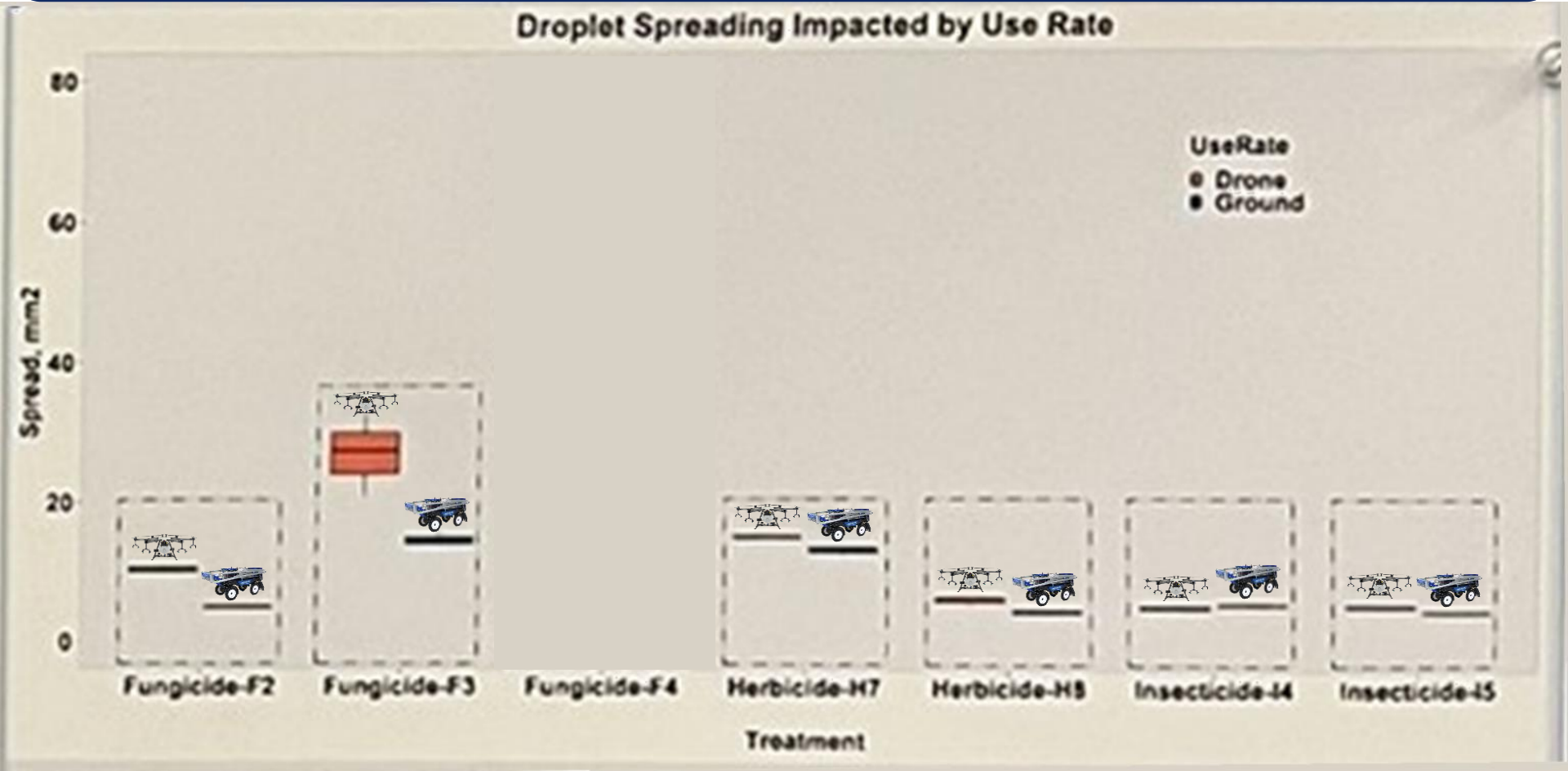


Droplet Spreading



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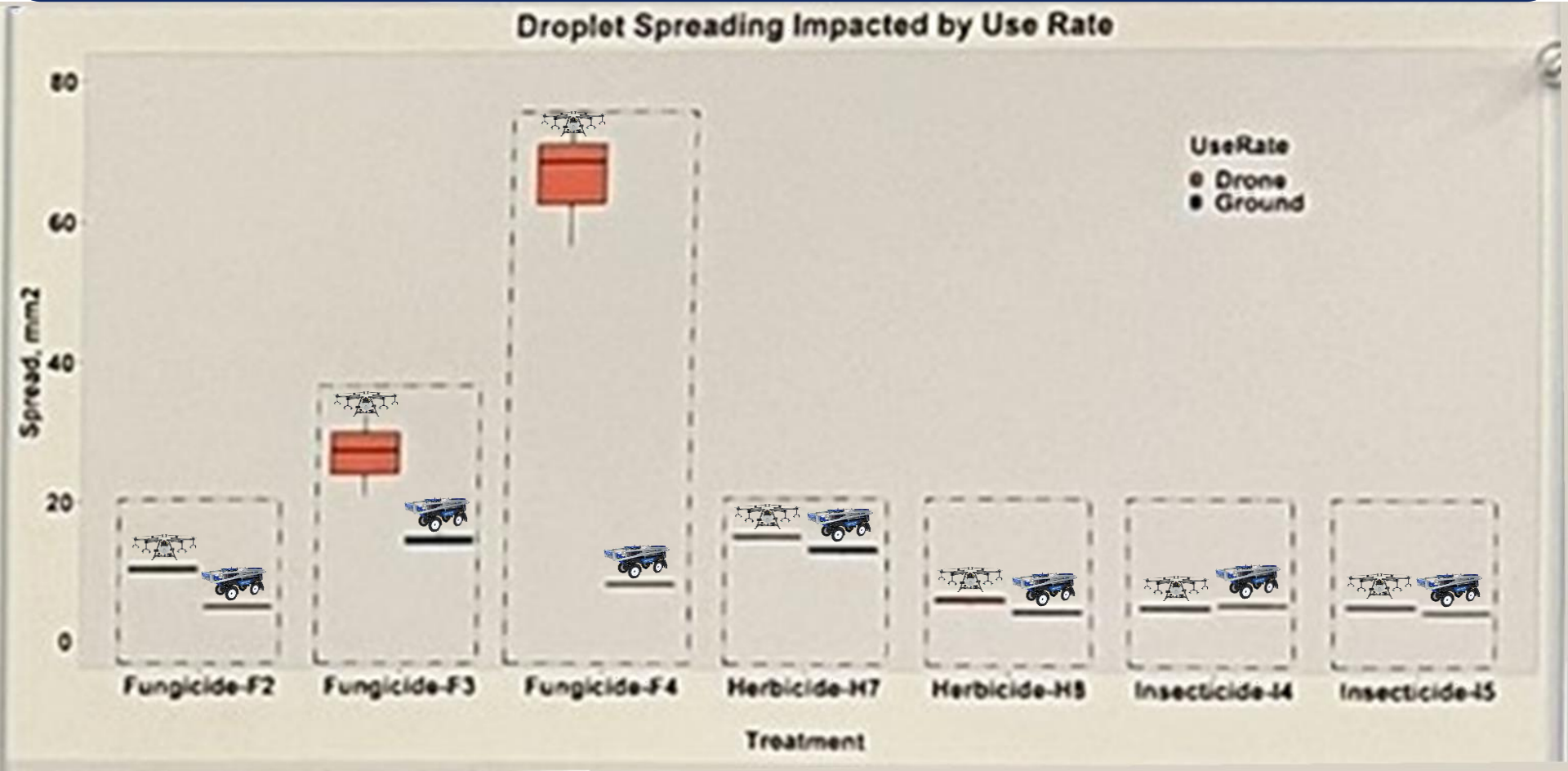
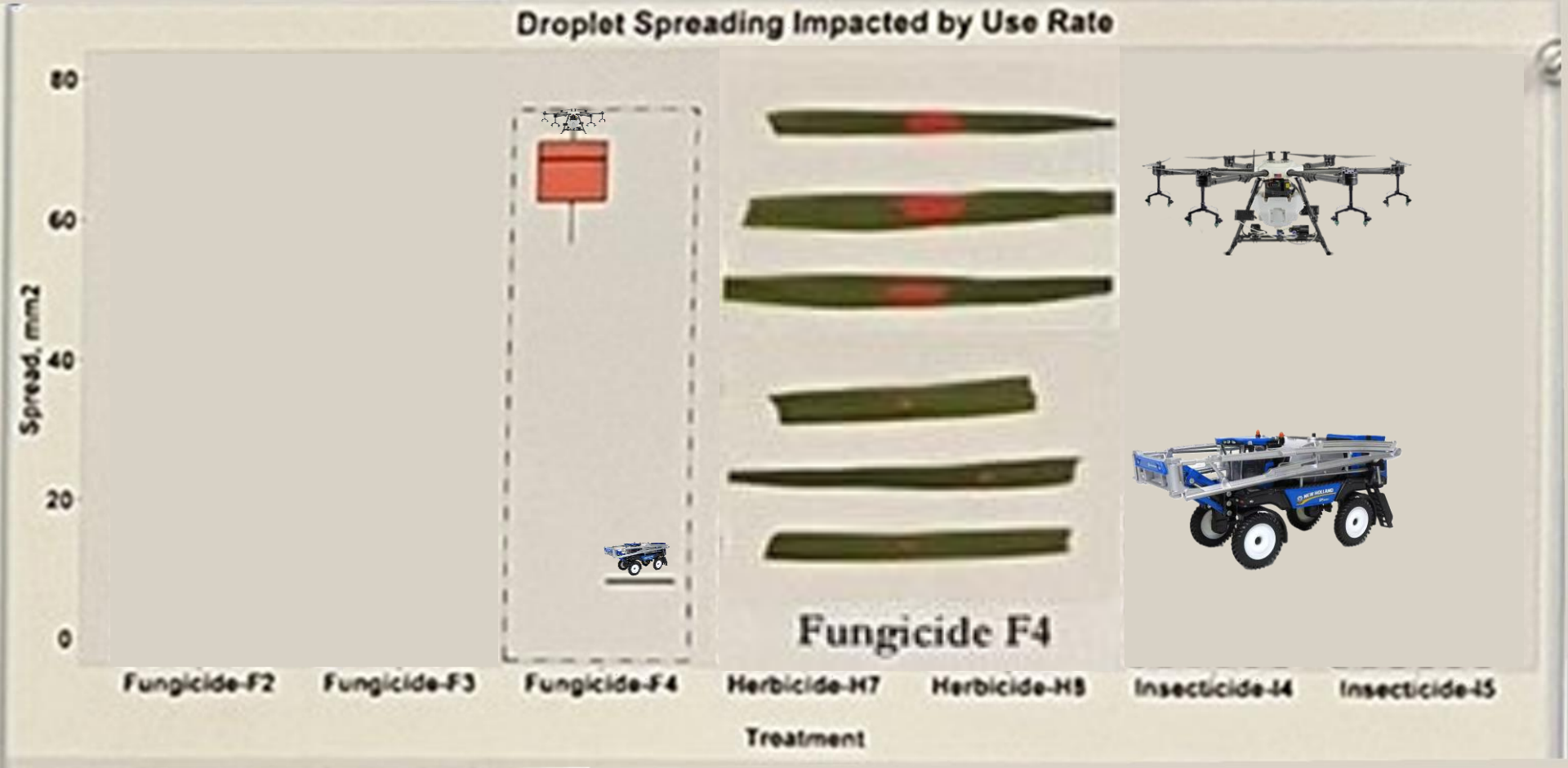


Droplet Spreading



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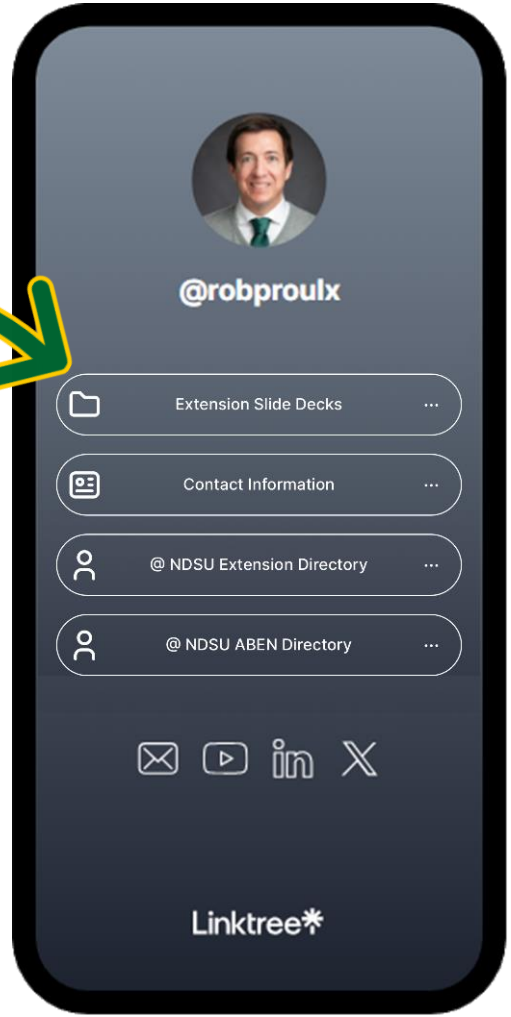
Thank you!

Access my public presentations here

linktr.ee/robproulx



Extra Slides

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NDSU | EXTENSION

Operational Details

We will now walk through a typical spraying operation with an XAG drone

Operation Preparation

There's more to it than just the drone...

Steps

1. Evaluate/plan mission
2. Prepare equipment & products
3. Transport & setup
4. Pre-flight checklist
5. Execute mission
6. Pack & transport
7. Records/logs

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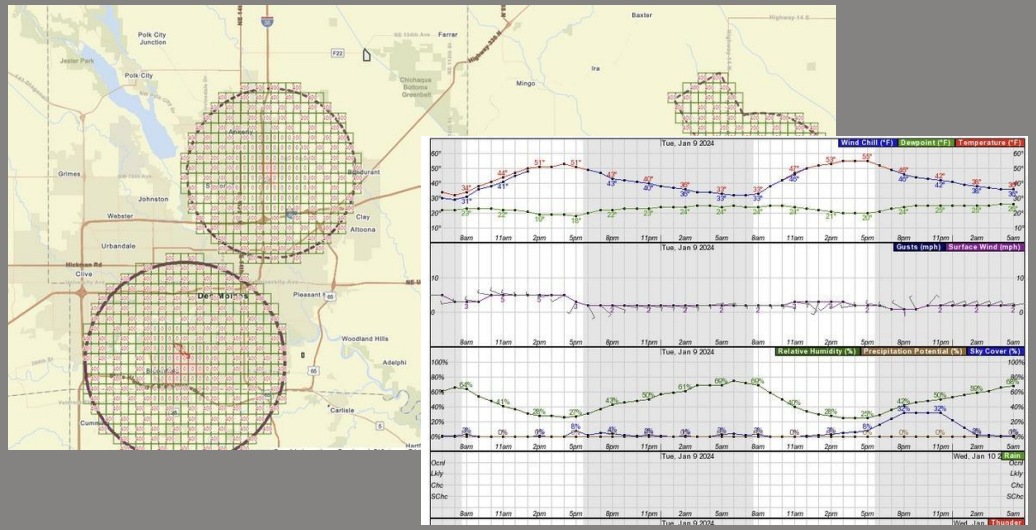
Evaluate/plan mission



https://faa.maps.arcgis.com/apps/webappviewer/index.html?id=9c2e4406710048e19806ebf6a06754ad

- Site evaluation
  - Map ahead?
  - Obstacles / Power / roads
  - Topography
- Weather
  - Check NOAA/weather.gov
- Product evaluation
  - Logistics
  - Label considerations
  - Special requirements
- FAA/Legal considerations
  - Airspace
  - Events
  - NOTAMS

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Route Operation / Planning

Mission Prep

- Always scout the field
- Never rely on the sensors
- Know your environmental & operational limitations
- Request flight authorization if necessary
- Scout a safe spot for the drone to land & and take off (stay away from road, ditches, powerlines, and trees if possible)

Setting up a Mission

Method 1: Field Mapping using XAG One app

Method 2: Field Mapping by adding boundary points from drone or controller

Method 3: Field Mapping using mapping drone & software

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Prepare equipment & products

- Charge
  - Remote(s)
  - Smart device(s)
  - Drone batteries
- Inspect/calibrate/update equipment
- Transport vehicle/trailer
- Power system
- Load
  - Drones & batteries
  - Mapping drone/SD cards/laptop/cords
  - Product/water/etc
  - Fuel
  - Tools & spare parts
  - Drinking water/fan/first aid/PPE

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Transport & setup

1. Travel to site
2. Set up in safe area, consider field size/shape
3. Map boundary/obstacles (if needed)
4. Inspect/verify site
5. Deploy P100 Pro:
    a. Take out aircraft, place in open area
    b. Unbuckle remove foam top
    c. Open arm latches/unbuckle straps
    d. Fold out arms & secure latches
    e. Fold out propellers
    f. Deploy spray arms (if needed)
    g. Insert batteries
6. Prepare product & load P100 Pro
7. Power on devices & setup misison

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Pre-flight checklist

1. Propellers (free from cracks/breakage)
2. Propeller bushings (secure flap hinge/wiggle blade)
3. Motors (turn, listen)
4. Arm clamps fully engaged
5. Arms (wiggle, check for lose clamps)
6. Ensure RevoSpray/RevoCast latched & plugged
7. Spray arms/discs or Spreader system
8. Batteries fully latched
9. GNSS antennas & GPS/VRTK/RTK enabled
10. Final check approach route & mission settings
11. Clear the area

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Execute mission

1. Communicate with team!
    a. Deviations of plan
    b. Aircraft issues
    c. Take off/landing callouts
2. Maintain line of sight
3. Charge batteries / product mixing
4. Watch for manned aircraft
5. Keep spectators/visitors in safe area

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Pack & transport

- Record keeping
- Clean & discharge spray/spreading tank
- Shut down P100 Pro / ARC3 Pro
- Rinse aircraft (if chemical)
- Fold up P100 Pro
- Manage remaining products
- Load trailer/vehicle
- Secure batteries/P100 Pro/products
- Travel home or next mission

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Applied research on efficacy

An Enlist, Roundup and Anthem Maxx tank mix applied to soybean in Missouri[1] achieved 68 to 75% waterhemp control with similar results between a drone sprayer (3 gpa AV) and a ground sprayer (15 to 20 gpa AV). In Georgia[2], fungicide applied by spray drone at 5 gpa AV and ground sprayer at 15 gpa AV achieved equivalent leaf spot suppression in peanut, with no detectable difference in yield.

[2] Virk, S., Byers, C., Meena, R., Kichler, J., & Kemerait, B. (2024, July 21). Spray Deposition and Efficacy of Pesticide Applications with Spray Drones in Row Crops in the Southeastern US. *Proceedings of the 16th International Conference on Precision Agriculture*. International Conference on Precision Agriculture, Manhattan, KS.

Table 4. Disease ratings and yield for fungicide applications performed with a ground sprayer and a spray drone versus an untreated control in peanut.

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Application Method
Ground Sprayer
Drone Sprayer
Untreated Control

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Application Method	Application Rate (L ha^{-1})
Ground Sprayer	
Drone Sprayer	
Untreated Control	

[2] Virk, S., Byers, C., Meena, R., Kichler, J., & Kemerait, B. (2024, July 21). Spray Deposition and Efficacy of Pesticide Applications with Spray Drones in Row Crops in the Southeastern US. *Proceedings of the 16th International Conference on Precision Agriculture*. International Conference on Precision Agriculture, Manhattan, KS.

Table 4. Disease ratings and yield for fungicide applications performed with a ground sprayer and a spray drone versus an untreated control in peanut.

Application Method	Application Rate (L ha^{-1})	
Ground Sprayer	140.3	15 gpa
Drone Sprayer	46.8	5 gpa
Untreated Control	-	

[2] Virk, S., Byers, C., Meena, R., Kichler, J., & Kemerait, B. (2024, July 21). Spray Deposition and Efficacy of Pesticide Applications with Spray Drones in Row Crops in the Southeastern US. *Proceedings of the 16th International Conference on Precision Agriculture*. International Conference on Precision Agriculture, Manhattan, KS.

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Application Method	Application Rate (L ha^{-1})	Leaf Spot (1-10)
Ground Sprayer	140.3 15 gpa	
Drone Sprayer	46.8 5 gpa	
Untreated Control	-	

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Drone Sprayer	46.8 5 gpa	
Untreated Control	-	6.4 a

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Application Method	Application Rate (L ha^{-1})	Leaf Spot (1-10)
Ground Sprayer	140.3 15 gpa	3.4 b
Drone Sprayer	46.8 5 gpa	3.3 b
Untreated Control	-	6.4 a

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Ground Sprayer	140.3 15 gpa	3.4 b	
Drone Sprayer	46.8 5 gpa	3.3 b	
Untreated Control	-	6.4 a	

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Table 4. Disease ratings and yield for fungicide applications performed with a ground sprayer and a spray drone versus an untreated control in peanut.

Application Method	Application Rate (L ha^{-1})	Leaf Spot (1-10)	Yield (kg ha^{-1})
Ground Sprayer	140.3 15 gpa	3.4 b	12,679
Drone Sprayer	46.8 5 gpa	3.3 b	11,926
Untreated Control	-	6.4 a	11,675

[2] Virk, S., Byers, C., Meena, R., Kichler, J., & Kemerait, B. (2024, July 21). Spray Deposition and Efficacy of Pesticide Applications with Spray Drones in Row Crops in the Southeastern US. *Proceedings of the 16th International Conference on Precision Agriculture*. International Conference on Precision Agriculture, Manhattan, KS.

ASABE Formulations Poster

NDSU | EXTENSION

Application of Crop Protection Products Using UAV: Considerations for a Successful Application from a Formulation Perspective

(ASABE Abstract Submission ID: 2401514)

Rajeev Sinha, Gagandeep Kaur, John Atkinson, Leandro Cordova, Minija Praveen, Krista Scharnak, MaryRose Foley

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Introduction

- Drones (aka Unmanned aerial vehicles [UAV], unmanned aerial pesticide application systems [UAPAS]) have gained momentum for pesticide application.
- UAVs may be perceived as a more viable option for pesticide application compared to conventional techniques, especially backpack/knapsack applicators.
- The spray volume for drone-based spraying is in the range of 10-20 L ha^{-1}.

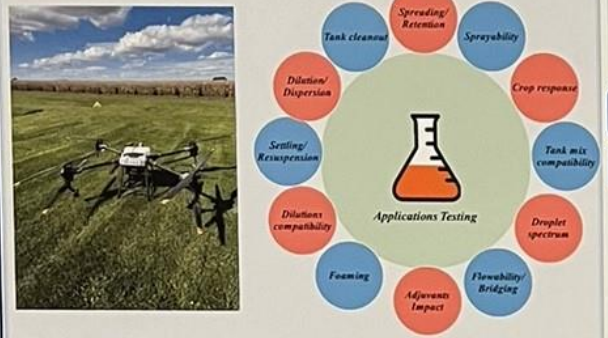

Fig. 1. A typical UAAS to apply CP products and application quality assessment parameters.

Problem Statement

- Carrier volume in UAV spraying can be about 5, 10 and 50 times lesser compared to manned aircrafts, ground sprayers and orchard sprayers, respectively.
- Low water volume can cause issues with application quality, efficacy of pesticide application, and physical-chemical characteristics of the tank mix.
- For example, a highly concentrated tank mix may negatively impact properties like dispersibility, sprayability, surface tension & compatibility of a tank mix.

Materials and Methods *(continues)*

Experimental protocol

- Tank mixes were prepared using 342 ppm water (5 C) prepared in lab using Ca and Mg salts.
- Formulation use rate:
  - ❑ Maximum product use rate as specified by approved label
- Application volume:
  - ❑ Ground Rate - 100 Lha^{-1}; UAV Rate – 10 Lha^{-1}
- Droplet Size Characterization – XR8002 nozzle at 40 psi operating pressure

Results

Tank mix compatibility assessment

Tank Mix Details		Compatibility Result	
Product 1	Product 2	Ground Rate	UAV Rate
Insecticide- I4 (WDG)	Fungicide- F2 (SE)		
Insecticide- I1 (SC)	Fungicide- F2 (SE)		
Insecticide- I5 (SC)	Fungicide- F2 (SE)		
Fungicide- F4 (EC)	Fungicide- F2 (SE)		
Herbicide- H2 (WDG)	Herbicide- H4 (SL)		
Herbicide- H8 (WDG)	Herbicide- H4 (SL)		
Herbicide- H7 (OD)	Herbicide- H4 (SL)		
Insecticide- I3 (WDG)	Insecticide- I5 (SC)		
Insecticide- I3 (WDG)	Insecticide- I4 (WDG)		
Herbicide- H2 (WDG)	Fungicide- F3 (EC)		
Herbicide- H8 (WDG)	Fungicide- F5 (SE)		

(a) (b)

Results *(continues)*

Droplet size characterization

S. No.	Formulation Details		Use rate			Ground Rate			UAV Rate			Δ Fines,
			Ground	UAV	Unit	Fines	RS	DV50	Fines	RS	DV50	%
1	Herbicide H1	OD	1.0	20.0	%v/v	39	1.1	170	47	1.2	156	19.7
2	Herbicide H2	WDG	0.1	0.7	%w/v	44	1.3	162	48	1.5	155	8.4
3	Herbicide H3	EC	2.5	20.0	%v/v	52	1.2	146	52	1.4	147	-1.2
4	Herbicide H4	SL	2.4	23.4	%v/v	41	1.2	167	48	1.5	154	16.1
5	Herbicide H5	OD	0.2	15.0	%v/v	38	1.1	172	48	1.3	154	25.5
6	Herbicide H6	SE	1.0	10.0	%v/v	33	1.1	185	43	1.2	165	29.8
7	Herbicide H7	OD	0.6	6.0	%v/v	32	1.1	187	35	1.1	180	10.6
8	Herbicide H8	WDG	0.2	1.0	%w/v	47	1.4	157	48	1.4	155	2.9
9	Herbicide H9	EC	0.1	12.5	%v/v	32	1.1	187	43	1.1	162	36.6
10	Insecticide I1	SC	5.0	9.0	%v/v	38	1.4	177	38	1.8	208	0.8
11	Insecticide I2	SC	0.6	6.0	%v/v	43	1.3	163	46	1.3	159	5.2
12	Insecticide I3	WDG	0.4	1.9	%w/v	46	1.4	171	47	1.3	157	2.3
13	Insecticide I4	WDG	2.6	4.9	%w/v	40	1.4	171	45	1.4	161	11.3
14	Insecticide I5	SC	0.2	8.0	%v/v	41	1.2	168	42	1.3	166	2.4
15	Fungicide F1	EC	3.8	14.2	%v/v	46	1.2	157	48	1.2	153	4.8
16	Fungicide F2	SE	0.2	6.0	%v/v	40	1.2	170	42	1.2	165	5.2
17	Fungicide F3	EC	1.0	10.0	%v/v	42	1.1	166	49	1.3	151	19.1
18	Fungicide F4	EC	0.2	5.0	%v/v	33	1.1	184	41	1.1	167	25.1
19	Fungicide F5	SE	0.2	20.0	%v/v	43	1.3	164	48	1.4	154	10.8

% Fines - % of total sample volume formed by droplets of diameter ≤ 150 µm.

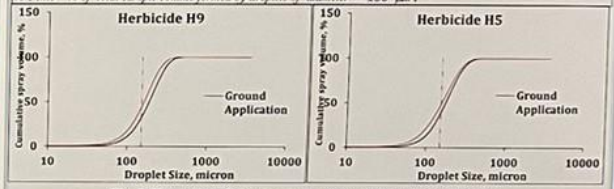

Fig. 5. Examples of droplet size spectrum of herbicide products

Conclusions

- Using a low water volume (i.e. at drone rate) can increase the risk of incompatibility between pesticide partners

Tank Mix Compatibility Assessment

Tank Mix Details		Compatibility Result	
Product 1	Product 2	Ground Rate	UAV Rate
Insecticide-I4 (WDG)	Fungicide-F2 (SB)		
Insecticide-I1 (SC)	Fungicide-F2 (SB)		
Insecticide-I5 (SC)	Fungicide-F2 (SB)		
Fungicide-F4 (EC)	Fungicide-F2 (SB)		
Herbicide-H2 (WDG)	Herbicide-H4 (SL)		
Herbicide-H8 (WDG)	Herbicide-H4 (SL)		
Herbicide-H7 (OD)	Herbicide-H4 (SL)		
Insecticide-I3 (WDG)	Insecticide-I5 (SC)		
Insecticide-I3 (WDG)	Insecticide-I4 (WDG)		
Herbicide-H2 (WDG)	Fungicide-F3 (EC)		
Herbicide-H8 (WDG)	Fungicide-F5 (SB)		

Tank Mix Compatibility Assessment

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Product 1	Product 2	Ground Rate	UAV Rate
Insecticide-I4 (WDG)	Fungicide-F2 (SB)		
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Insecticide-I5 (SC)	Fungicide-F2 (SB)		
Fungicide-F4 (EC)	Fungicide-F2 (SB)		
Herbicide-H2 (WDG)	Herbicide-H4 (SL)		
Herbicide-H8 (WDG)	Herbicide-H4 (SL)		
Herbicide-H7 (OD)	Herbicide-H4 (SL)		
Insecticide-I3 (WDG)	Insecticide-I5 (SC)		
Insecticide-I3 (WDG)	Insecticide-I4 (WDG)		
Herbicide-H2 (WDG)	Fungicide-F3 (EC)		
Herbicide-H8 (WDG)	Fungicide-F5 (SB)		

Tank Mix Compatibility Assessment

Tank Mix Details		Compatibility Result	
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Insecticide- I4 (WDG)	Fungicide- F2 (SE)		
Insecticide- I1 (SC)	Fungicide- F2 (SE)		
Insecticide- I5 (SC)	Fungicide- F2 (SE)		
Fungicide- F4 (EC)	Fungicide- F2 (SE)		
Herbicide- H2 (WDG)	Herbicide- H4 (SL)		
Herbicide- H8 (WDG)	Herbicide- H4 (SL)		
Herbicide- H7 (OD)	Herbicide- H4 (SL)		
Insecticide- I3 (WDG)	Insecticide- I5 (SC)		
Insecticide- I3 (WDG)	Insecticide- I4 (WDG)		
Herbicide- H2 (WDG)	Fungicide- F3 (EC)		
Herbicide- H8 (WDG)	Fungicide- F5 (SE)		

11 mixtures

Tank Mix Compatibility Assessment

Tank Mix Details		Compatibility Result	
Product 1	Product 2	Ground Rate	UAV Rate
Insecticide- I4 (WDG)	Fungicide- F2 (SE)		
Insecticide- I1 (SC)	Fungicide- F2 (SE)		
Insecticide- I5 (SC)	Fungicide- F2 (SE)		
Fungicide- F4 (EC)	Fungicide- F2 (SE)		
Herbicide- H2 (WDG)	Herbicide- H4 (SL)		
Herbicide- H8 (WDG)	Herbicide- H4 (SL)		
Herbicide- H7 (OD)	Herbicide- H4 (SL)		
Insecticide- I3 (WDG)	Insecticide- I5 (SC)		
Insecticide- I3 (WDG)	Insecticide- I4 (WDG)		
Herbicide- H2 (WDG)	Fungicide- F3 (EC)		
Herbicide- H8 (WDG)	Fungicide- F5 (SE)		

10
compatible

1
incompatible

Tank Mix Compatibility Assessment

Tank Mix Details		Compatibility Result	
Product 1	Product 2	Ground Rate	UAV Rate
Insecticide- I4 (WDG)	Fungicide- F2 (SE)		
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Fungicide- F4 (EC)	Fungicide- F2 (SE)		
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Herbicide- H8 (WDG)	Herbicide- H4 (SL)		
Herbicide- H7 (OD)	Herbicide- H4 (SL)		
Insecticide- I3 (WDG)	Insecticide- I5 (SC)		
Insecticide- I3 (WDG)	Insecticide- I4 (WDG)		
Herbicide- H2 (WDG)	Fungicide- F3 (EC)		
Herbicide- H8 (WDG)	Fungicide- F5 (SE)		

6
compatible

1
marginal

4
incompatible

Tank Mix Compatibility Assessment

Tank Mix Details		Compatibility Result	
Product 1	Product 2	Ground Rate	UAV Rate
Insecticide- I4 (WDG)	Fungicide- F2 (SE)		
Insecticide- I1 (SC)	Fungicide- F2 (SE)		
Insecticide- I5 (SC)	Fungicide- F2 (SE)		
Fungicide- F4 (EC)	Fungicide- F2 (SE)		
Herbicide- H2 (WDG)	Herbicide- H4 (SL)		
Herbicide- H8 (WDG)	Herbicide- H4 (SL)		
Herbicide- H7 (OD)	Herbicide- H4 (SL)		
Insecticide- I3 (WDG)	Insecticide- I5 (SC)		
Insecticide- I3 (WDG)	Insecticide- I4 (WDG)		
Herbicide- H2 (WDG)	Fungicide- F3 (EC)		
Herbicide- H8 (WDG)	Fungicide- F5 (SE)		

Tank Mix Compatibility Assessment

Tank Mix Details		Compatibility Result	
Product 1	Product 2	Ground Rate	UAV Rate
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Insecticide- I5 (SC)	Fungicide- F2 (SE)		
Fungicide- F4 (EC)	Fungicide- F2 (SE)		
Herbicide- H2 (WDG)	Herbicide- H4 (SL)		
Herbicide- H8 (WDG)	Herbicide- H4 (SL)		
Herbicide- H7 (OD)	Herbicide- H4 (SL)		
Insecticide- I3 (WDG)	Insecticide- I5 (SC)		
Insecticide- I3 (WDG)	Insecticide- I4 (WDG)		
Herbicide- H2 (WDG)	Fungicide- F3 (EC)		
Herbicide- H8 (WDG)	Fungicide- F5 (SE)		

(a)

50-mesh

100-mesh

(b)

Fig. 3. Sieve and jar images showing incompatibility between herbicide H8 and fungicide F5 at a) UAV rate compared to b) ground rate

Fig. 3. Sieve and jar images showing incompatibility between herbicide H8 and fungicide F5 at a) UAV rate compared to b) ground rate

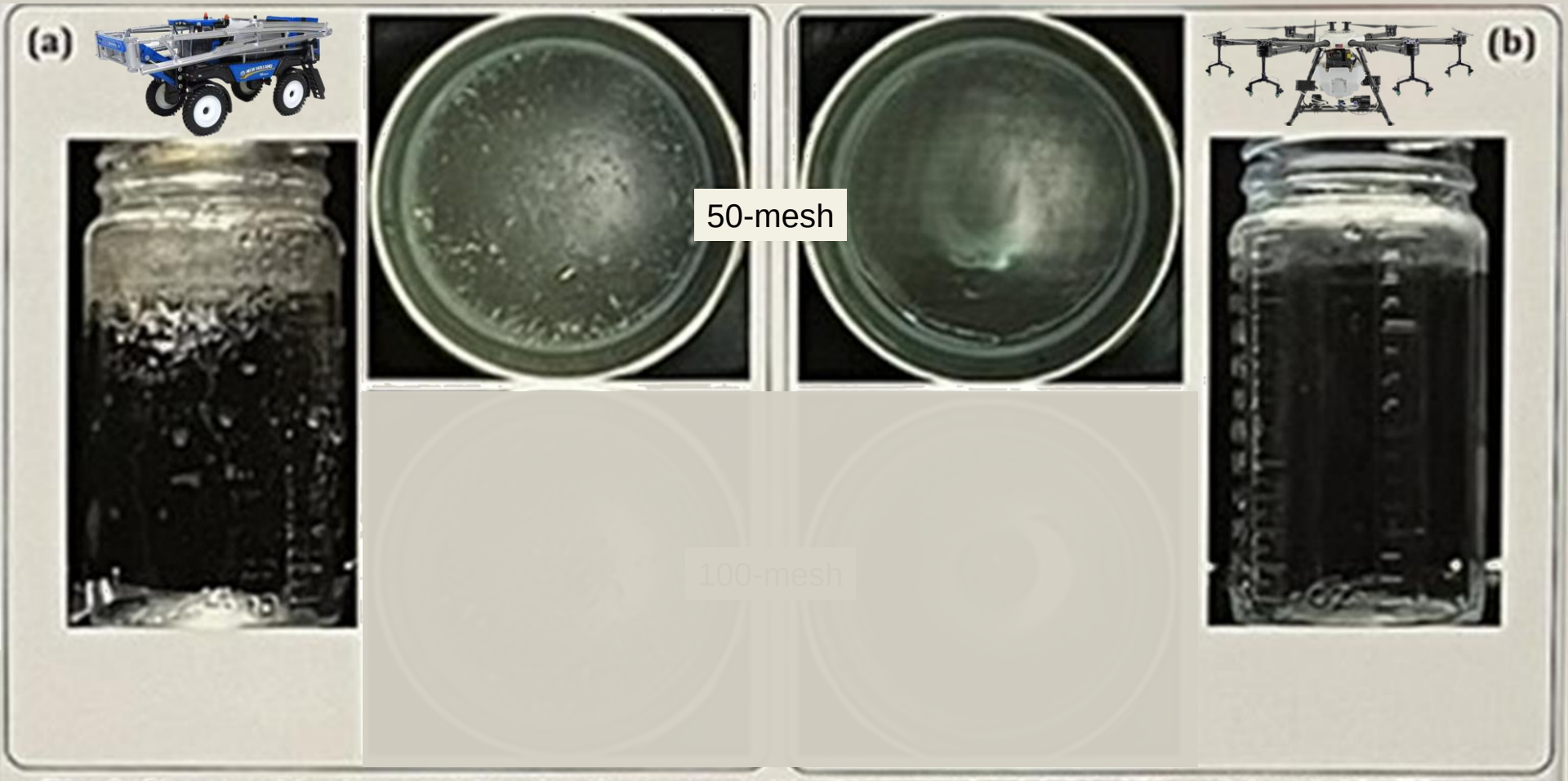

Fig. 3. Sieve and jar images showing incompatibility between herbicide H8 and fungicide F5 at a) UAV rate compared to b) ground rate

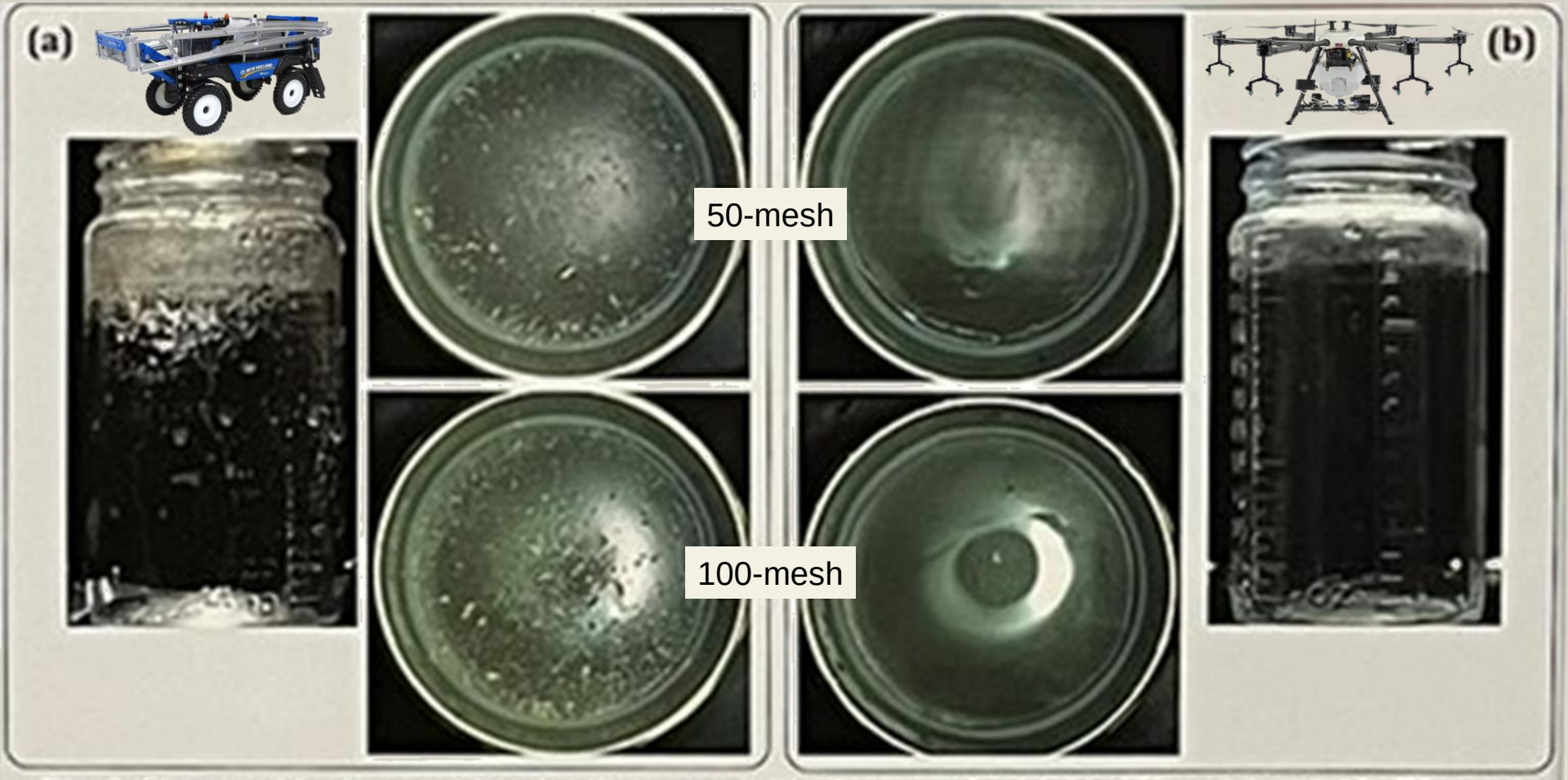

Fig. 3. Sieve and jar images showing incompatibility between herbicide H8 and fungicide F5 at a) UAV rate compared to b) ground rate

Conclusions

- Using a low water volume (i.e. at drone rate) can increase the risk of incompatibility between pesticide partners

Conclusions

- Using a low water volume (i.e. at drone rate) can increase the risk of incompatibility between pesticide partners
- Complex formulations like OD, SC, and SE may result in considerable residue buildup along nozzle screens, while simpler formulations like EC and SL showed acceptable sprayability at drone rates

Sprayability Assessment

S. No.	Formulation Details				Application Volume	Pressure Drop Along Screens			Overall Rating
	Formulation	Type	Use rate	Unit		50-mesh	100-mesh	200-mesh	
1	Herbicide H1	OD	2.0	L/ha	1.07 gal/ac 10 L/ha	0.10%	0.00%	25.80%	Caution
2	Herbicide H2	WDG	70.0	g/ha		0.03%	0.01%	0.15%	Okay
3	Herbicide H3	EC	2.0	L/ha		0%	0.05%	0.30%	Okay
4	Herbicide H4	SL	2.3	L/ha		0.01%	0.01%	0.01%	Okay
5	Herbicide H5	OD	1.5	L/ha		0.01%	0.37%	15.00%	Caution
6	Herbicide H6	SE	1.0	L/ha		[illegible]	[illegible]	[illegible]	[illegible]
7	Herbicide H7	OD	0.6	L/ha		0.25%	[illegible]	[illegible]	[illegible]
8	Herbicide H8	WDG	100.0	g/ha		0.04%	0.04%	[illegible]	Caution
9	Herbicide H9	EC	1.3	L/ha		0.11%	0.07%	0.08%	Okay
10	Insecticide I1	SC	0.9	L/ha		0.16%	2.00%	[illegible]	Caution
11	Insecticide I2	SC	0.6	L/ha		0.04%	0.20%	[illegible]	Caution
12	Insecticide I3	WDG	192.6	g/ha		0.02%	1.14%	0.90%	Caution
13	Insecticide I4	WDG	490.4	g/ha		0.07%	0.06%	[illegible]	Caution

Sprayability Assessment

S. No.	Formulation Details
	Formulation
1	Herbicide H1
2	Herbicide H2
3	Herbicide H3
4	Herbicide H4
5	Herbicide H5
6	Herbicide H6
7	Herbicide H7
8	Herbicide H8
9	Herbicide H9
10	Insecticide I1
11	Insecticide I2
12	Insecticide I3
13	Insecticide I4

Sprayability Assessment

S. No.	Formulation Details	
	Formulation	Type
1	Herbicide H1	OD
2	Herbicide H2	WDG
3	Herbicide H3	EC
4	Herbicide H4	SL
5	Herbicide H5	OD
6	Herbicide H6	SE
7	Herbicide H7	OD
8	Herbicide H8	WDG
9	Herbicide H9	EC
10	Insecticide I1	SC
11	Insecticide I2	SC
12	Insecticide I3	WDG
13	Insecticide I4	WDG

Sprayability Assessment

S. No.	Formulation Details			
	Formulation	Type	Use rate	Unit
1	Herbicide H1	OD	2.0	L/ha
2	Herbicide H2	WDG	70.0	g/ha
3	Herbicide H3	EC	2.0	L/ha
4	Herbicide H4	SL	2.3	L/ha
5	Herbicide H5	OD	1.5	L/ha
6	Herbicide H6	SE	1.0	L/ha
7	Herbicide H7	OD	0.6	L/ha
8	Herbicide H8	WDG	100.0	g/ha
9	Herbicide H9	EC	1.3	L/ha
10	Insecticide I1	SC	0.9	L/ha
11	Insecticide I2	SC	0.6	L/ha
12	Insecticide I3	WDG	192.6	g/ha
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3	Herbicide H3	EC	2.0	L/ha	
4	Herbicide H4	SL	2.3	L/ha	
5	Herbicide H5	OD	1.5	L/ha	
6	Herbicide H6	SE	1.0	L/ha	
7	Herbicide H7	OD	0.6	L/ha	
8	Herbicide H8	WDG	100.0	g/ha	
9	Herbicide H9	EC	1.3	L/ha	10 L/ha
10	Insecticide I1	SC	0.9	L/ha	
11	Insecticide I2	SC	0.6	L/ha	
12	Insecticide I3	WDG	192.6	g/ha	
13	Insecticide I4	WDG	490.4	g/ha	

Sprayability Assessment

S. No.	Formulation Details				Application Volume	Pressure Drop Along Screens		
	Formulation	Type	Use rate	Unit		50-mesh	100-mesh	200-mesh
1	Herbicide H1	OD	2.0	L/ha	1.07 gal/ac			
2	Herbicide H2	WDG	70.0	g/ha				
3	Herbicide H3	EC	2.0	L/ha				
4	Herbicide H4	SL	2.3	L/ha				
5	Herbicide H5	OD	1.5	L/ha				
6	Herbicide H6	SE	1.0	L/ha				
7	Herbicide H7	OD	0.6	L/ha				
8	Herbicide H8	WDG	100.0	g/ha				
9	Herbicide H9	EC	1.3	L/ha	10 L/ha			
10	Insecticide I1	SC	0.9	L/ha				
11	Insecticide I2	SC	0.6	L/ha				
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Sprayability Assessment

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5	Herbicide H5	OD	1.5	L/ha					
6	Herbicide H6	SE	1.0	L/ha					
7	Herbicide H7	OD	0.6	L/ha					
8	Herbicide H8	WDG	100.0	g/ha					
9	Herbicide H9	EC	1.3	L/ha	10 L/ha				
10	Insecticide I1	SC	0.9	L/ha					
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Sprayability Assessment

S. No.	Formulation Details				Application Volume	Pressure Drop Along Screens			Overall Rating
	Formulation	Type	Use rate	Unit		50-mesh	100-mesh	200-mesh	
1	Herbicide H1	OD	2.0	L/ha		0.10%	0.60%	25.40%	Caution
2	Herbicide H2	WDG	70.0	g/ha		0.00%	0.01%	0.15%	Okay
3	Herbicide H3	EC	2.0	L/ha		0%	0.05%	0.10%	Okay
4	Herbicide H4	SL	2.3	L/ha		0.01%	0.01%	0.01%	Okay
5	Herbicide H5	OD	1.5	L/ha	1.07 gal/ac	0.01%	0.37%	13.00%	Caution
6	Herbicide H6	SE	1.0	L/ha		100%	100%	100%	Fail
7	Herbicide H7	OD	0.6	L/ha		0.25%	31.40%	37.60%	Fail
8	Herbicide H8	WDG	100.0	g/ha		0.04%	0.04%	0.04%	Caution
9	Herbicide H9	EC	1.3	L/ha		0.01%	0.02%	0.03%	Okay
10	Insecticide I1	SC	0.9	L/ha	L/ha	0.06%	2.60%	95%	Caution
11	Insecticide I2	SC	0.6	L/ha		0.04%	0.28%	23%	Caution
12	Insecticide I3	WDG	192.6	g/ha		0.02%	1.14%	0.90%	Caution
13	Insecticide I4	WDG	490.4	g/ha		0.01%	0.06%	0.08%	Caution

Sprayability Assessment

S. No.	Formulation Details				Application Volume	Pressure Drop Along Screens			Overall Rating
	Formulation	Type	Use rate	Unit		50-mesh	100-mesh	200-mesh	
1									
2									
3	Herbicide H3	EC	2.0	L/ha	1.07 gal/ac	0%	0.05%	0.30%	Okay
4	Herbicide H4	SL	2.3	L/ha		0.01%	0.01%	0.01%	Okay
5									
6									
7									
8									
9	Herbicide H9	EC	1.3	L/ha	10	0.11%	0.07%	0.04%	Okay
10									
11									
12									
13									

Sprayability Assessment

S. No.	Formulation Details				Application Volume	Pressure Drop Along Screens			Overall Rating
	Formulation	Type	Use rate	Unit		50-mesh	100-mesh	200-mesh	
1	Herbicide H1	OD	2.0	L/ha	1.07 gal/ac	0.10%	0.60%	25.40%	Caution
2	Herbicide H2	WDG	70.0	g/ha		0.03%	0.01%	0.15%	Okay
3	Herbicide H3	EC	2.0	L/ha		0%	0.05%	0.30%	Okay
4	Herbicide H4	SL	2.3	L/ha		0.01%	0.01%	0.01%	Okay
5	Herbicide H5	OD	1.5	L/ha		0.01%	0.37%	13.00%	Caution
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9	Herbicide H9	EC	1.3	L/ha	10 L/ha	0.11%	0.09%	0.04%	Okay
10	Insecticide I1	SC	0.9	L/ha		0.06%	2.60%	95%	Caution
11	Insecticide I2	SC	0.6	L/ha		0.04%	0.28%	23%	Caution
12	Insecticide I3	WDG	192.6	g/ha		0.02%	1.14%	0.90%	Caution
13	Insecticide I4	WDG	490.4	g/ha		0.07%	0.06%	100%	Caution

Pressure Drop Along Screens @ 1.07 gal/ac AV

Herbicide H7	OD	0.6	L/ha

0.25%	31.40%	37.60%

Fungicide F5	SE	2.0	L/ha

9.75%	100%	100%

Fungicide F1	EC	3.5	L/ha

0.04%	0.20%	0.66%

Herbicide H2	WDG	70.0	g/ha

0.03%	0.01%	0.15%

Pressure Drop Along Screens @ 1.07 gal/ac AV

Herbicide H7	OD	0.6	L/ha

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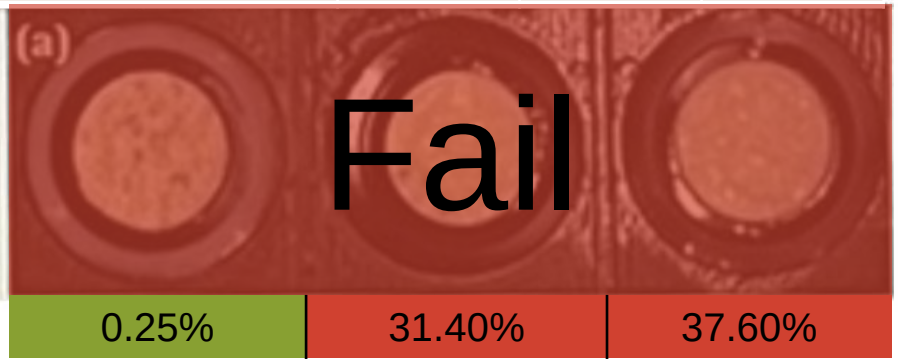

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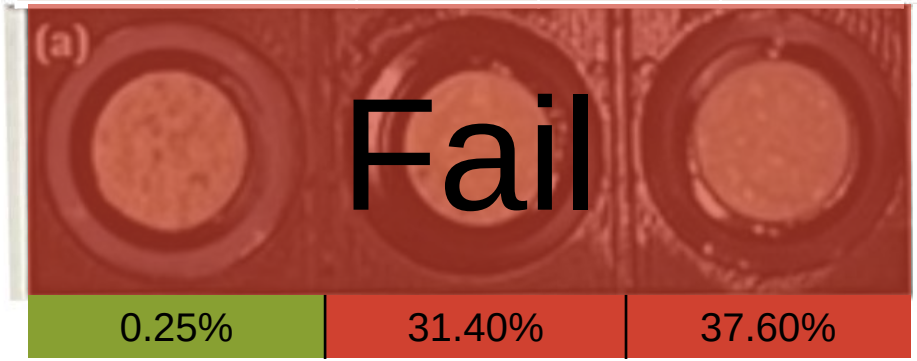

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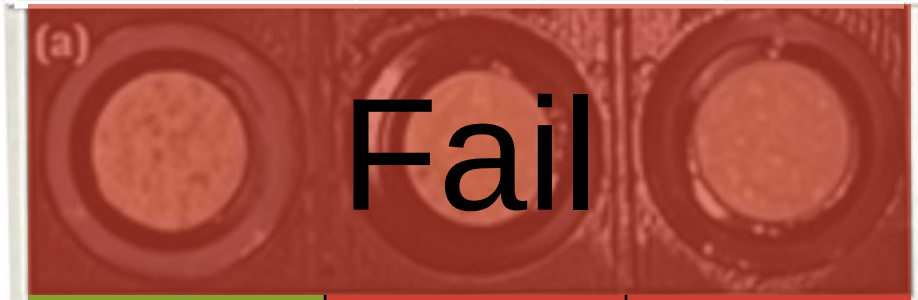

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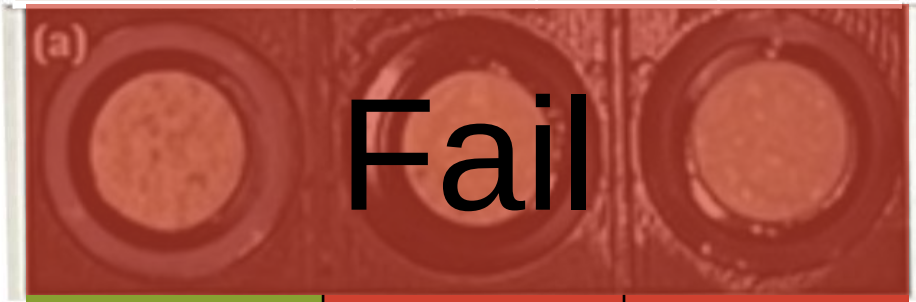

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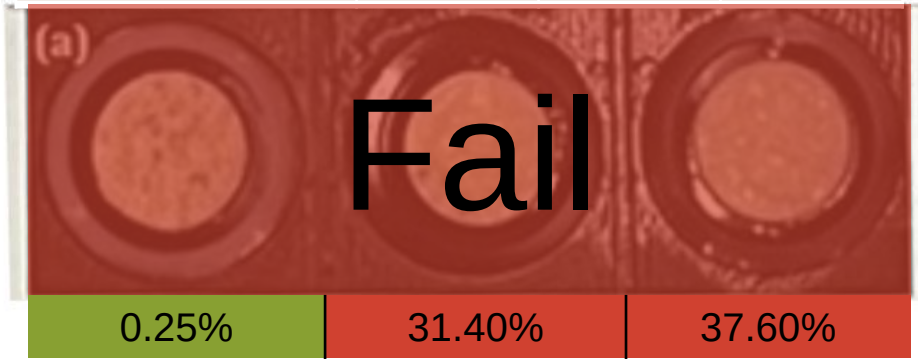

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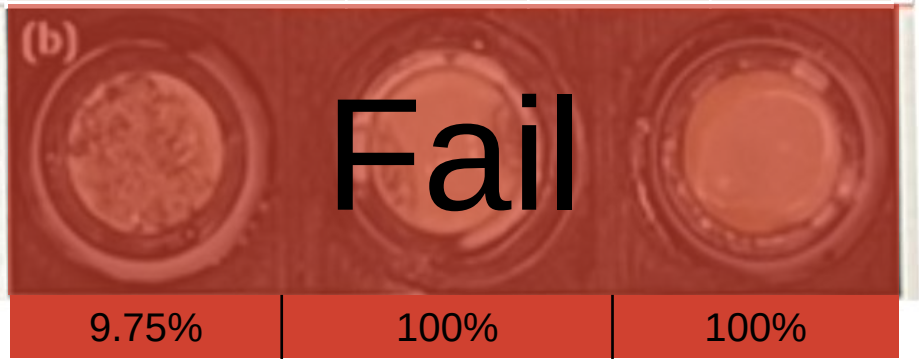

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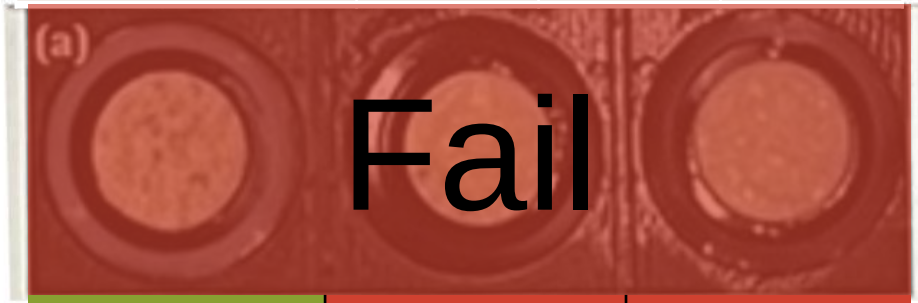

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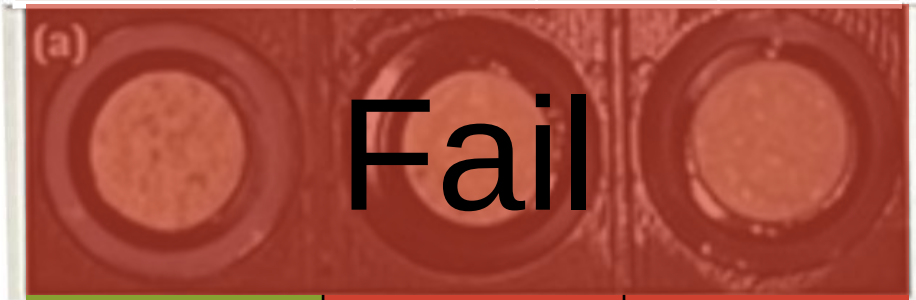

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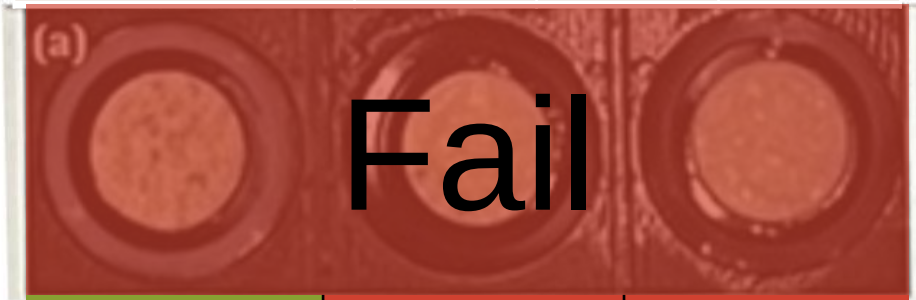

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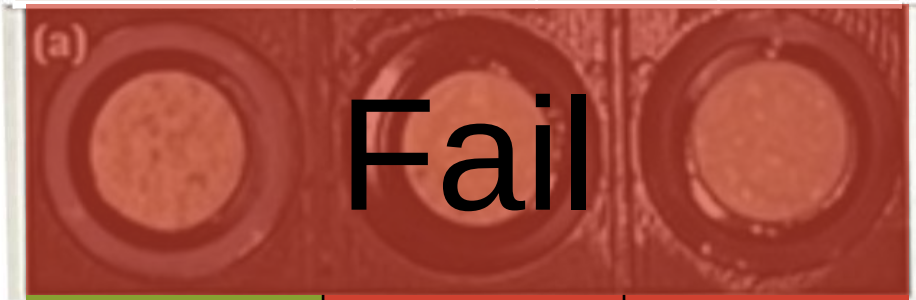

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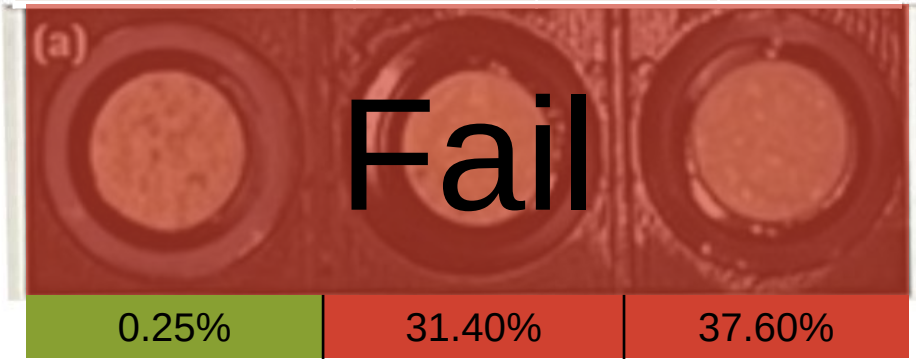

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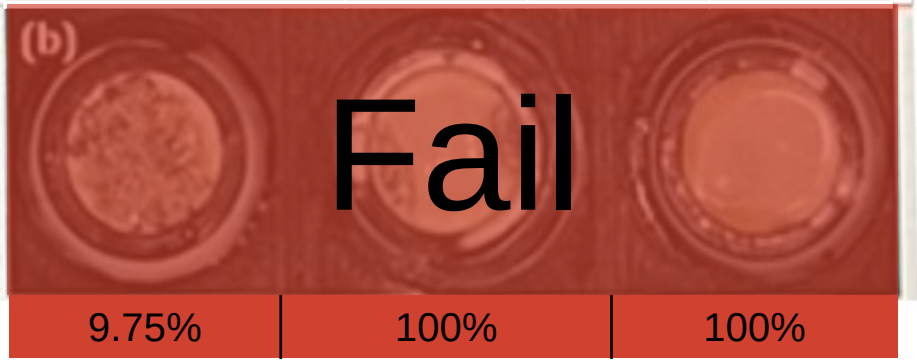

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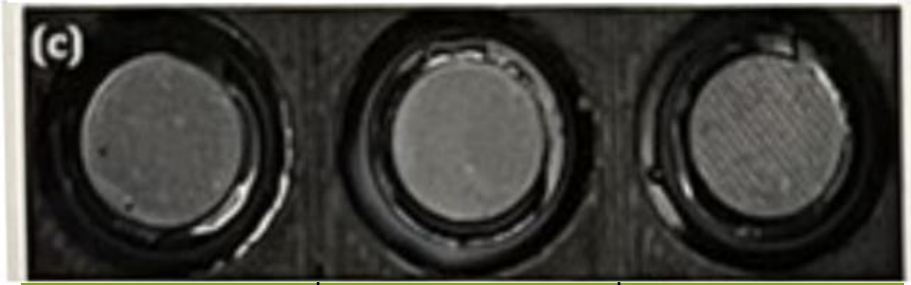

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Conclusions

- Using a low water volume (i.e. at drone rate) can increase the risk of incompatibility between pesticide partners
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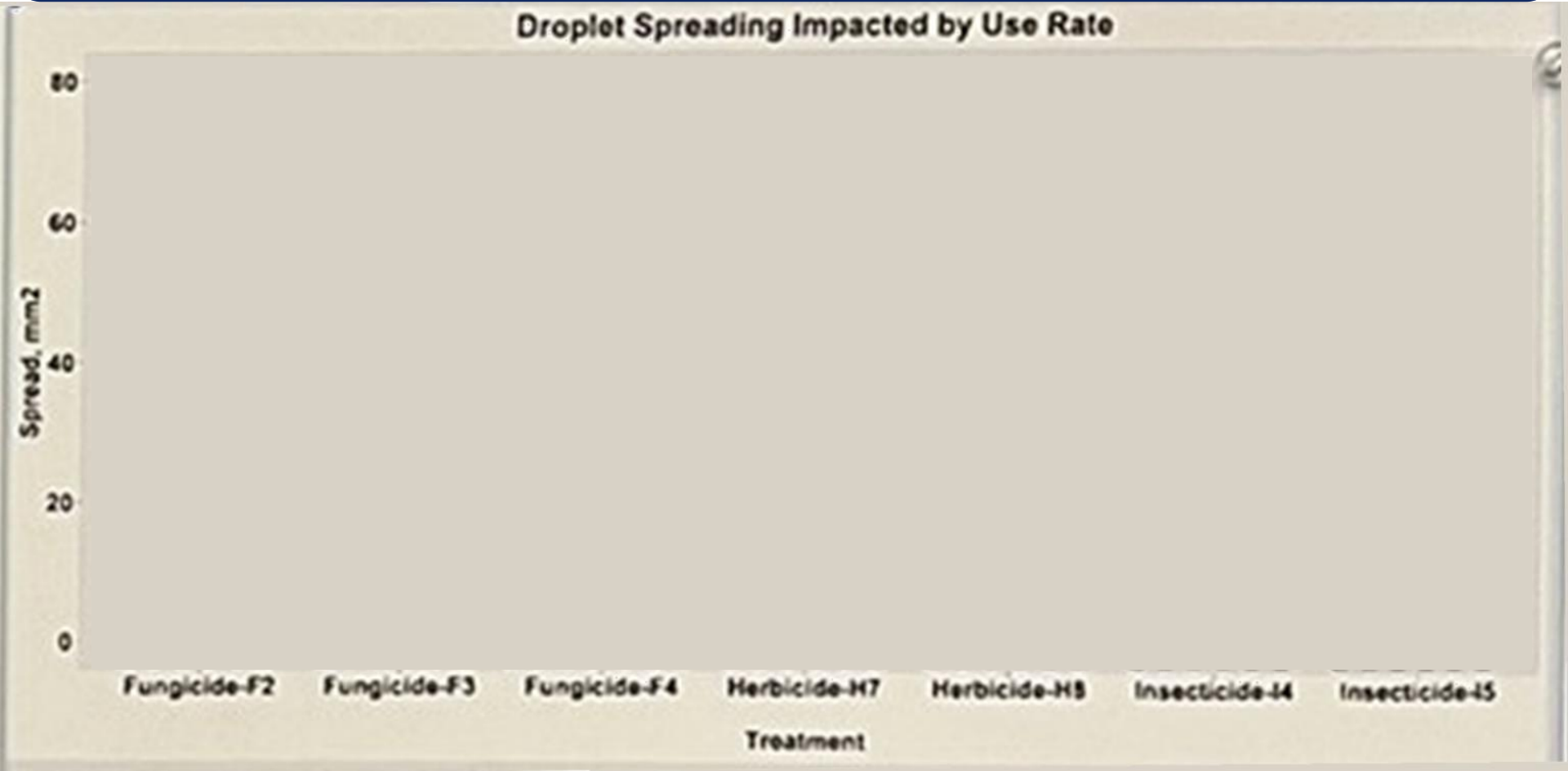
Droplet Spreading



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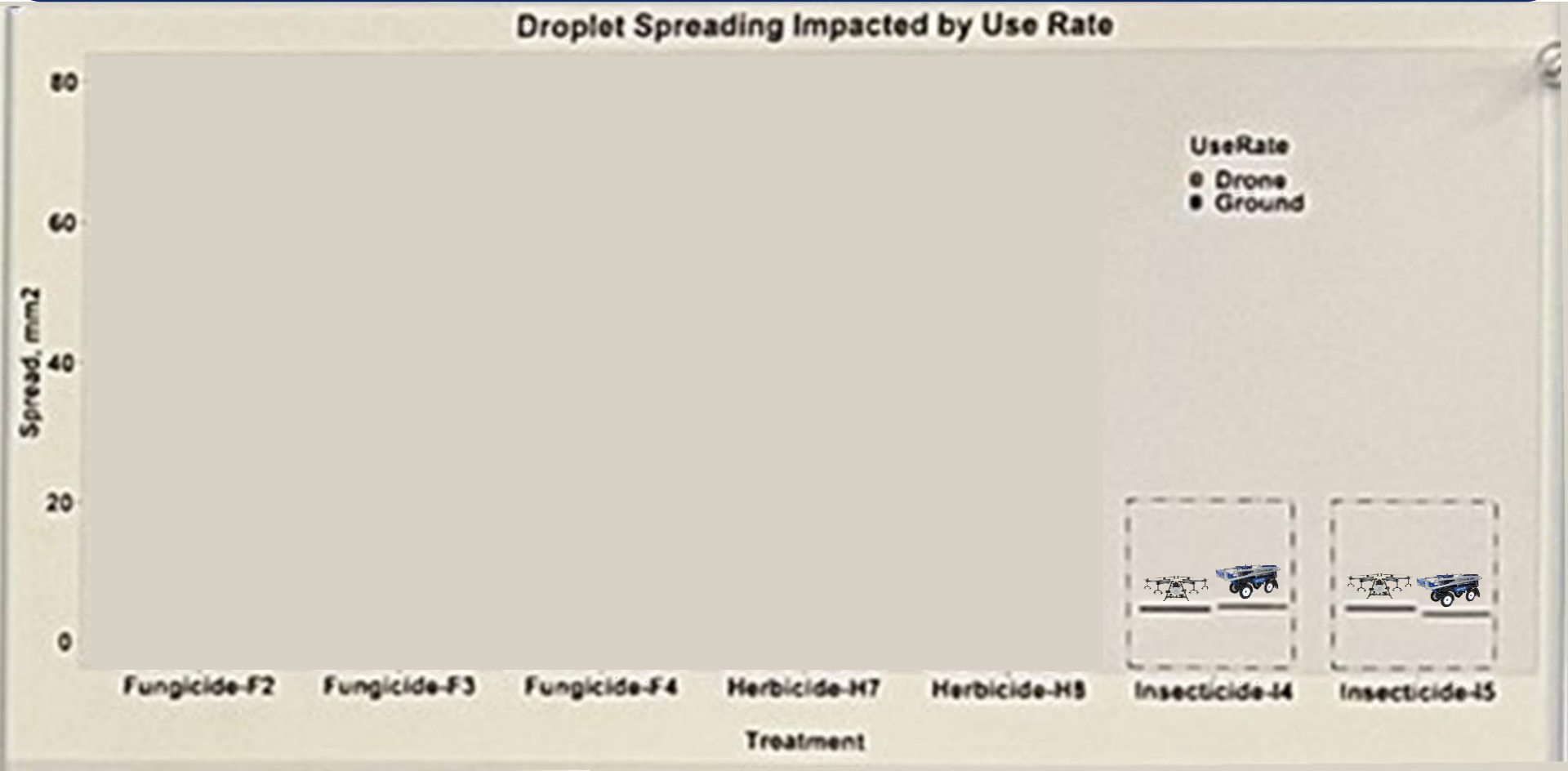

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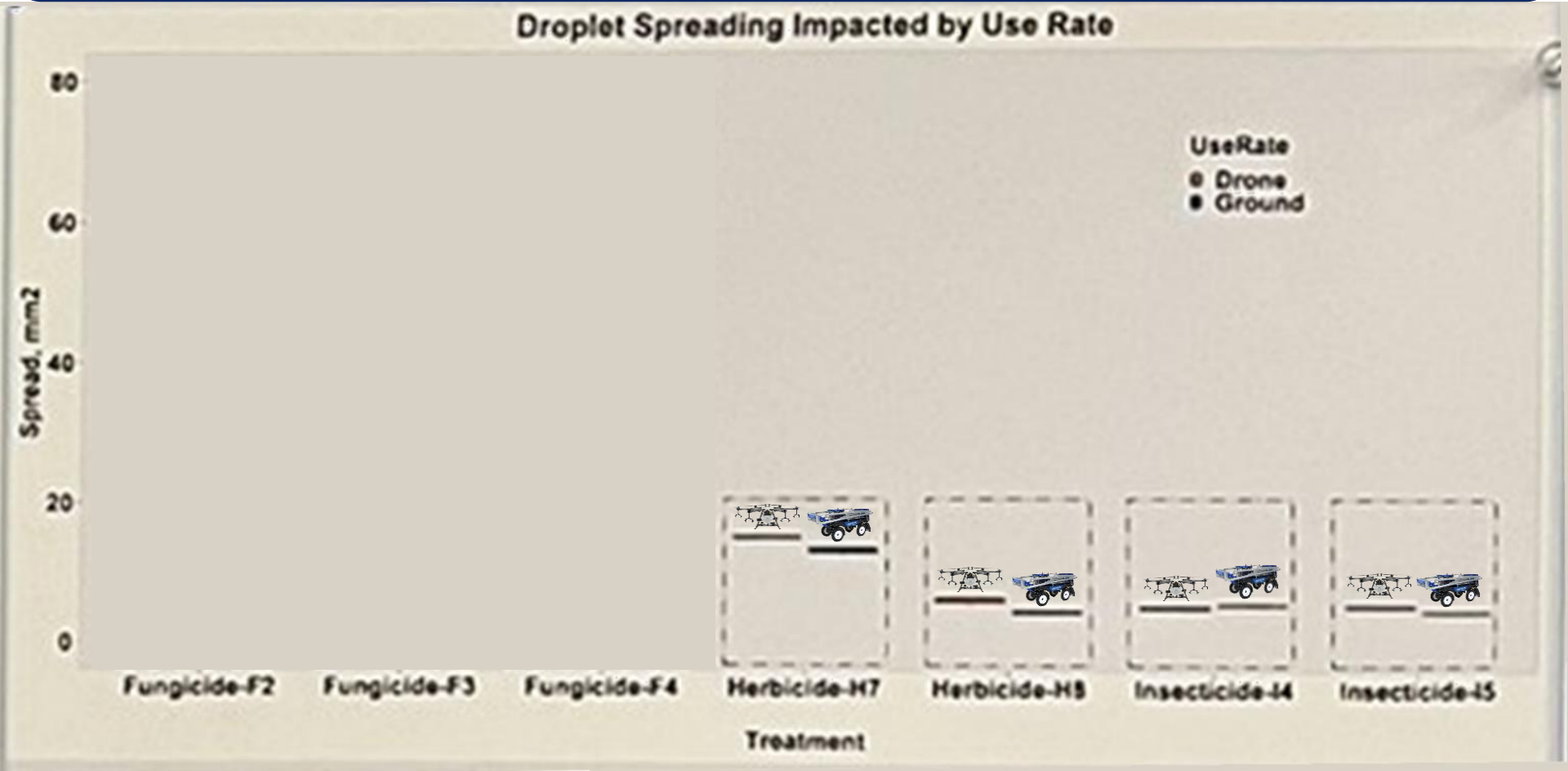

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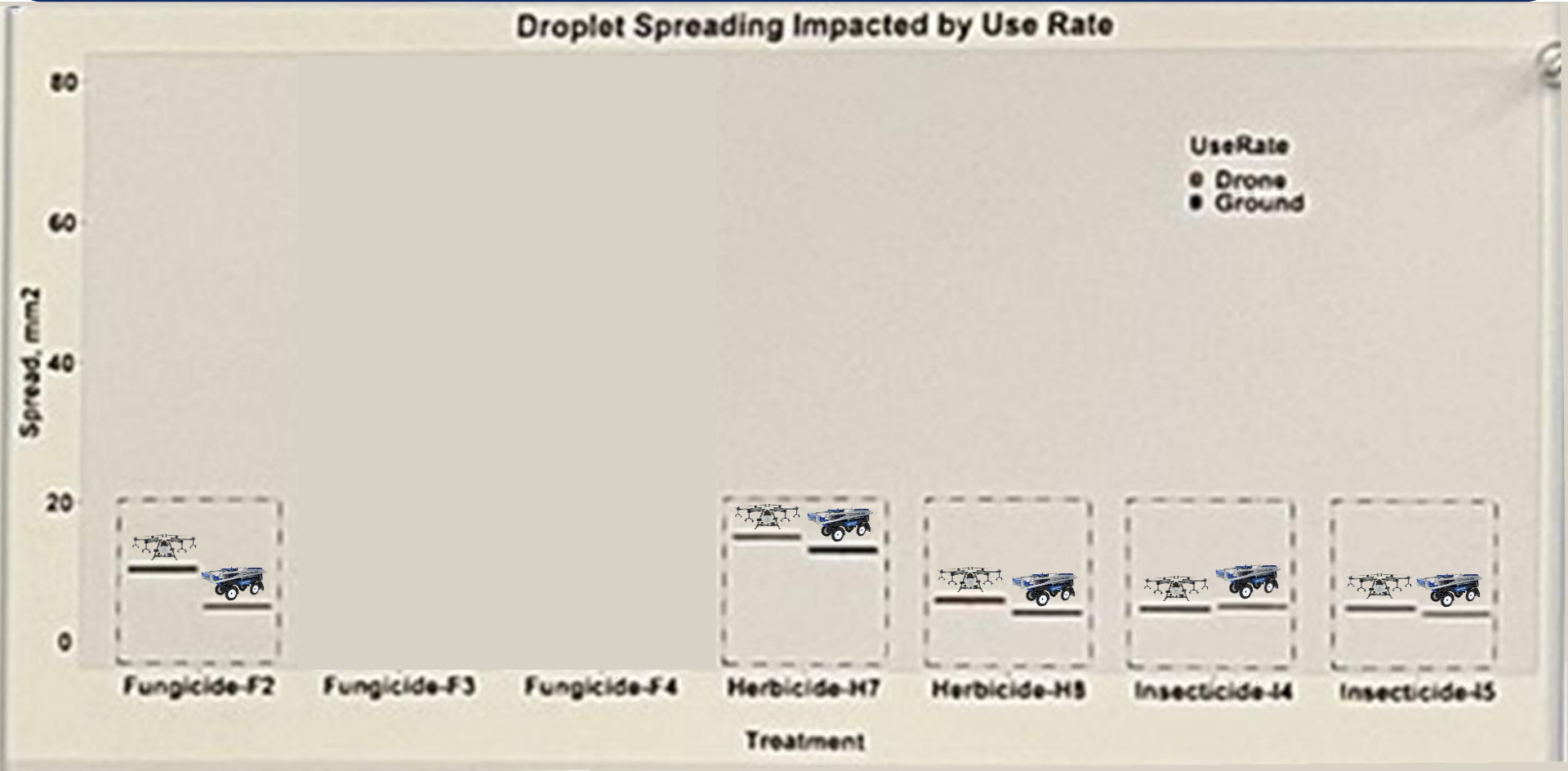

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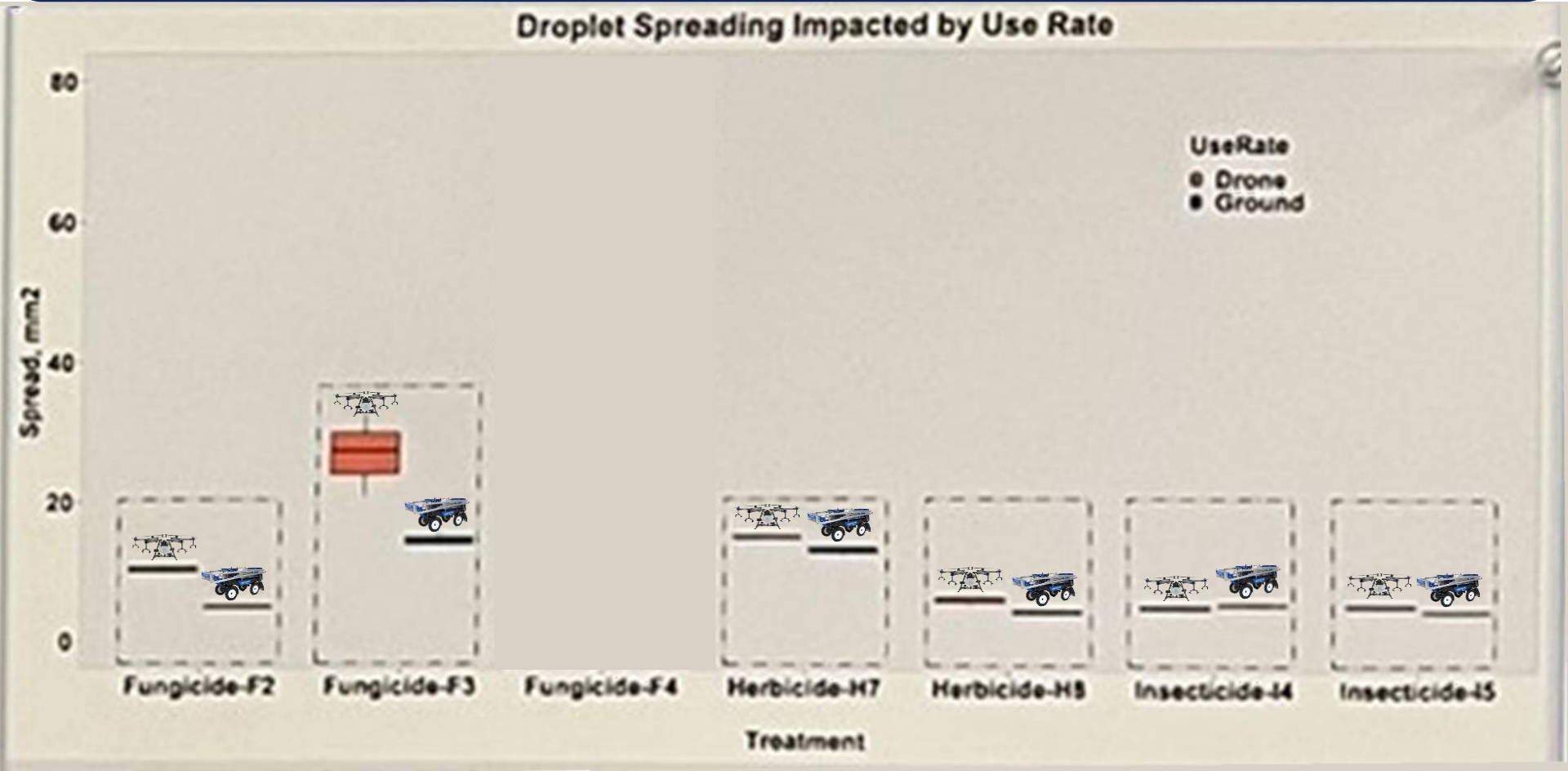

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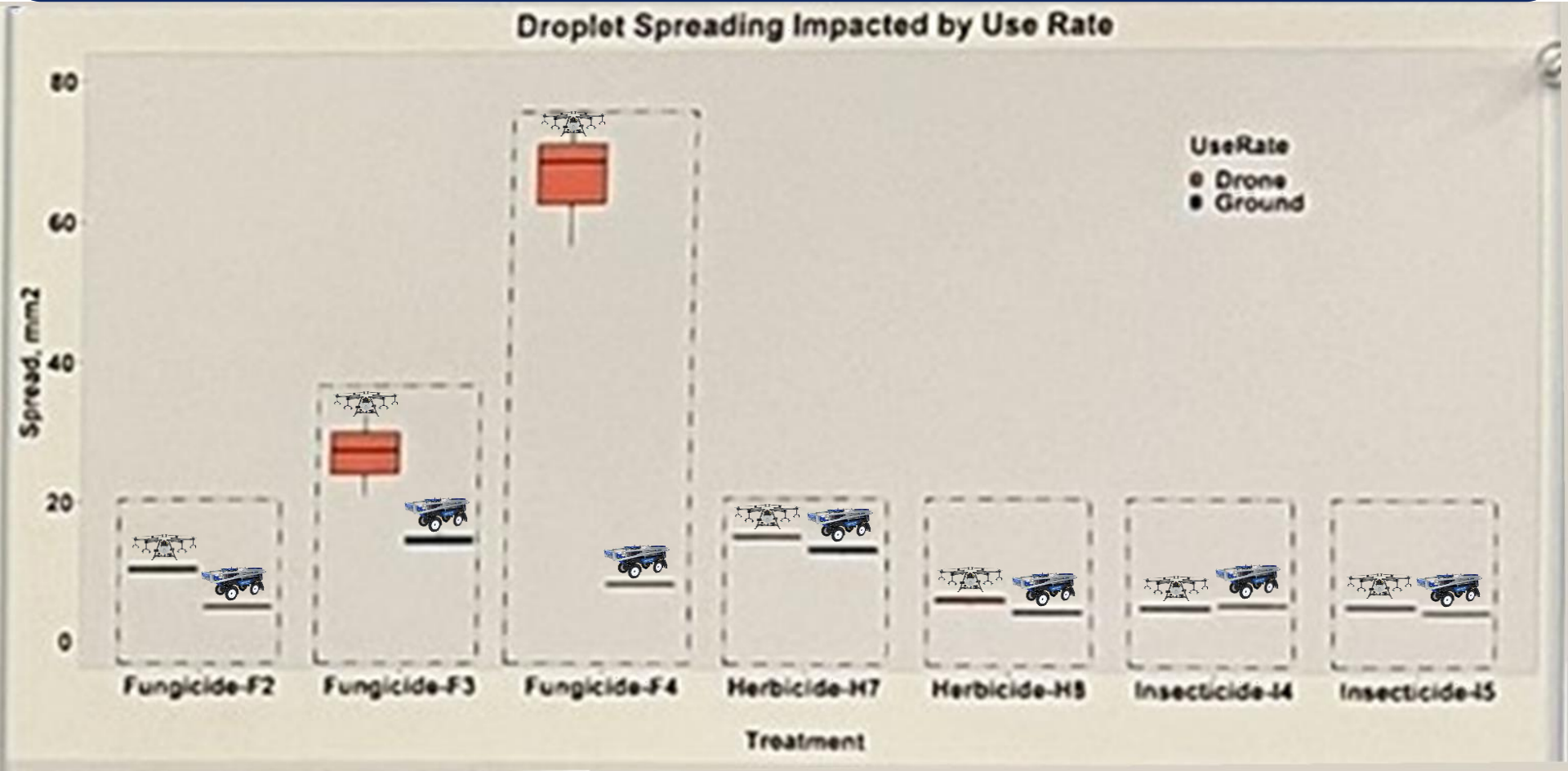

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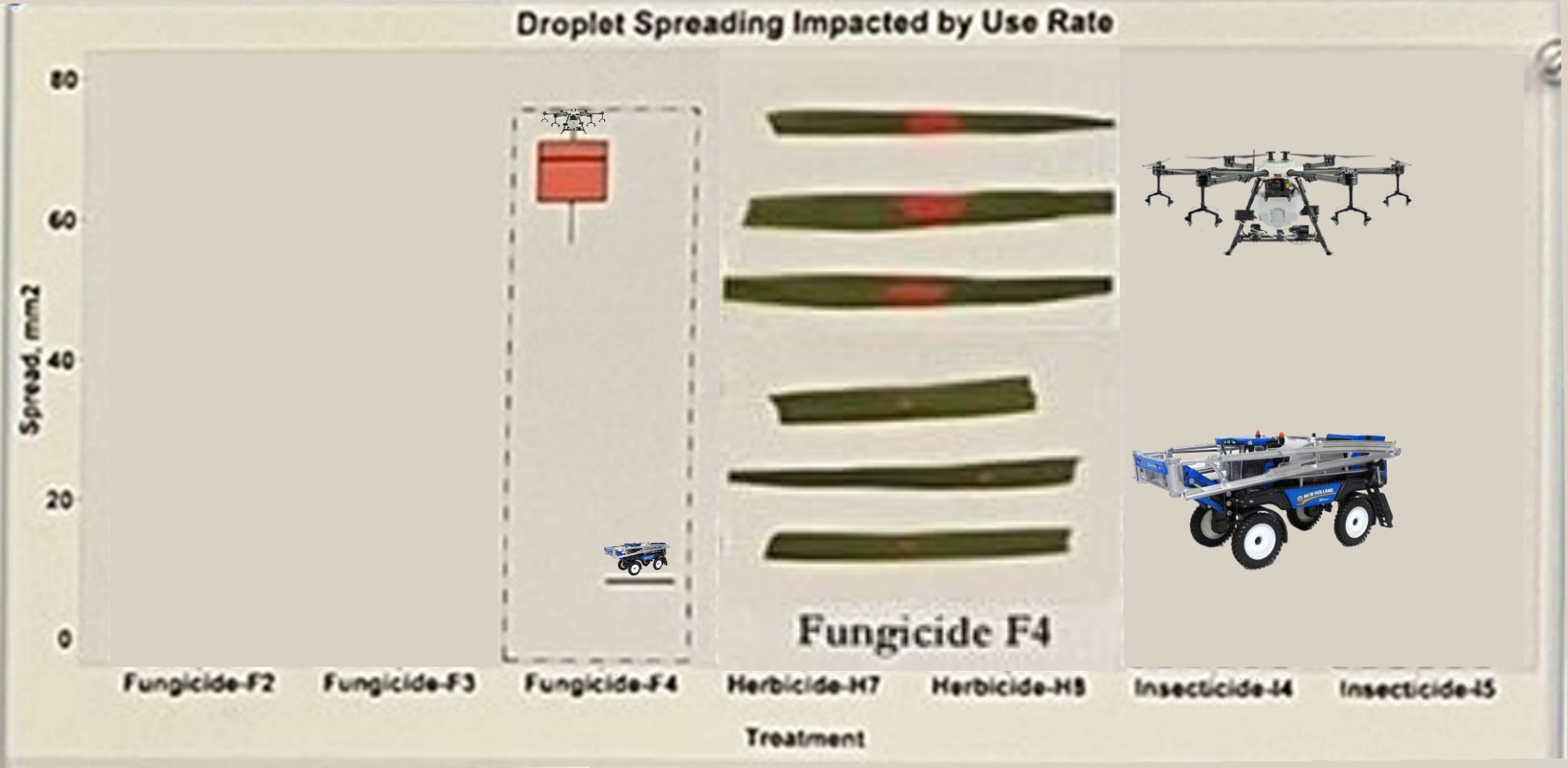

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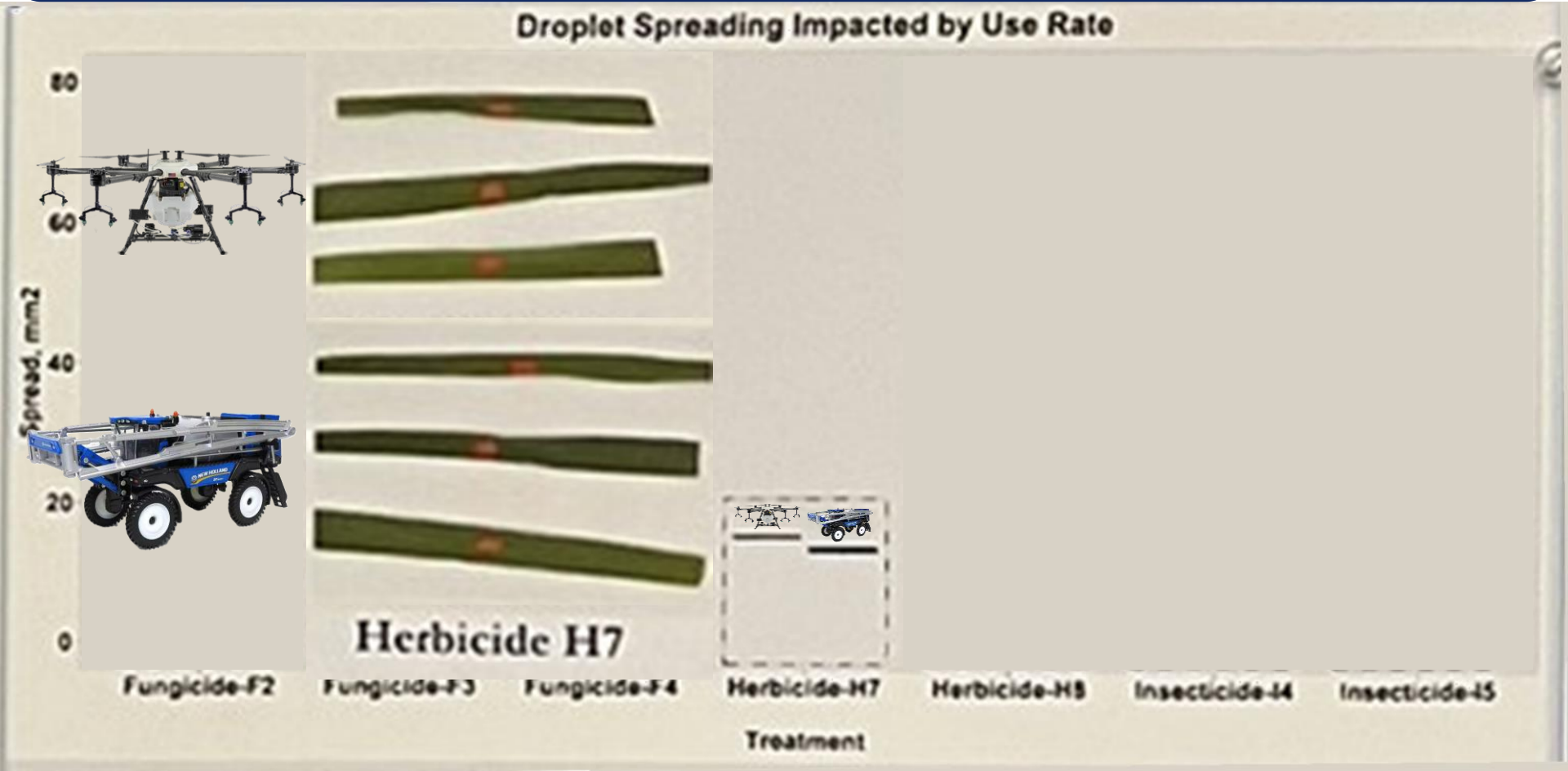

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- A wetter/spreader may be recommended for contact chemistries (e.g., fungicides) to compensate for low coverage pertinent to drone spraying