Corn Disease Assessments and Growing Season Projections, Fungicide Applications for Corn Grain and Silage

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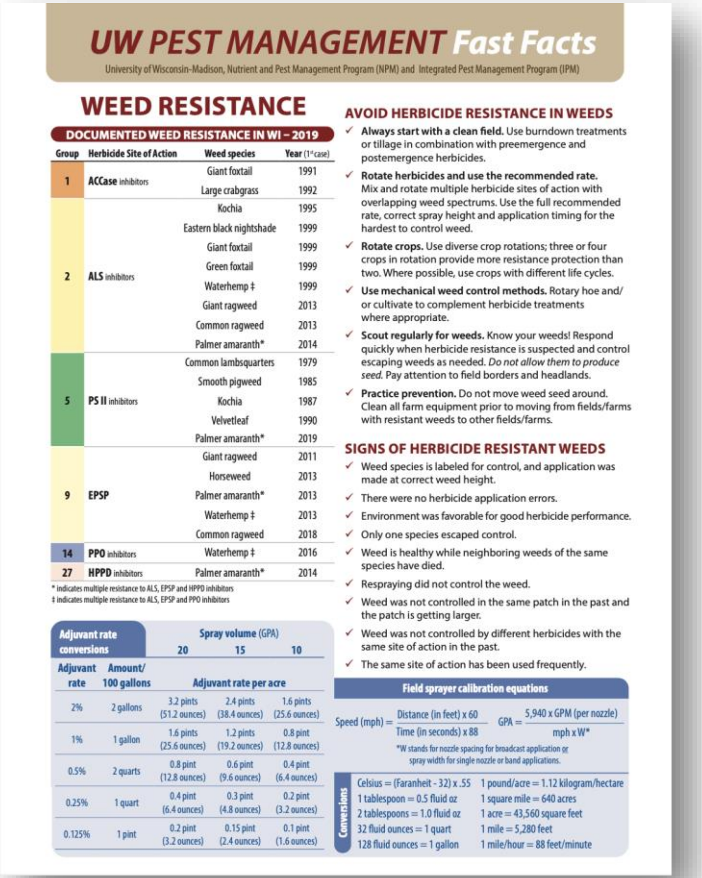
Key Resources



UW PEST MANAGEMENT *Fast Facts*

University of Wisconsin-Madison, Nutrient and Pest Management Program (NPM) and Integrated Pest Management Program (IPM)

WEED RESISTANCE

DOCUMENTED WEED RESISTANCE IN WI – 2019

Group	Herbicide Site of Action	Weed species	Year (1st case)
1	**ACCase** inhibitors	Giant foxtail	1991
		Large crabgrass	1992
2	**ALS** inhibitors	Kochia	1995
		Eastern black nightshade	1999
		Giant foxtail	1999
		Green foxtail	1999
		Waterhemp ‡	1999
		Giant ragweed	2013
		Common ragweed	2013
		Palmer amaranth*	2014
5	**PS II** inhibitors	Common lambsquarters	1979
		Smooth pigweed	1985
		Kochia	1987
		Velvetleaf	1990
		Palmer amaranth*	2019
9	**EPSP**	Giant ragweed	2011
		Horseweed	2013
		Palmer amaranth*	2013
		Waterhemp ‡	2013
		Common ragweed	2018
14	**PPO** inhibitors	Waterhemp ‡	2016
27	**HPPD** inhibitors	Palmer amaranth*	2014

* indicates multiple resistance to ALS, EPSP and HPPD inhibitors
‡ indicates multiple resistance to ALS, EPSP and PPO inhibitors

Adjuvant rate conversions		Spray volume (GPA) 20	15	10
Adjuvant rate	Amount/ 100 gallons	Adjuvant rate per acre		
2%	2 gallons	3.2 pints (51.2 ounces)	2.4 pints (38.4 ounces)	1.6 pints (25.6 ounces)
1%	1 gallon	1.6 pints (25.6 ounces)	1.2 pints (19.2 ounces)	0.8 pint (12.8 ounces)
0.5%	2 quarts	0.8 pint (12.8 ounces)	0.6 pint (9.6 ounces)	0.4 pint (6.4 ounces)
0.25%	1 quart	0.4 pint (6.4 ounces)	0.3 pint (4.8 ounces)	0.2 pint (3.2 ounces)
0.125%	1 pint	0.2 pint (3.2 ounces)	0.15 pint (2.4 ounces)	0.1 pint (1.6 ounces)

AVOID HERBICIDE RESISTANCE IN WEEDS

- ✓ **Always start with a clean field.** Use burndown treatments or tillage in combination with preemergence and postemergence herbicides.
- ✓ **Rotate herbicides and use the recommended rate.** Mix and rotate multiple herbicide sites of action with overlapping weed spectrums. Use the full recommended rate, correct spray height and application timing for the hardest to control weed.
- ✓ **Rotate crops.** Use diverse crop rotations; three or four crops in rotation provide more resistance protection than two. Where possible, use crops with different life cycles.
- ✓ **Use mechanical weed control methods.** Rotary hoe and/or cultivate to complement herbicide treatments where appropriate.
- ✓ **Scout regularly for weeds.** Know your weeds! Respond quickly when herbicide resistance is suspected and control escaping weeds as needed. *Do not allow them to produce seed.* Pay attention to field borders and headlands.
- ✓ **Practice prevention.** Do not move weed seed around. Clean all farm equipment prior to moving from fields/farms with resistant weeds to other fields/farms.

SIGNS OF HERBICIDE RESISTANT WEEDS

- ✓ Weed species is labeled for control, and application was made at correct weed height.
- ✓ There were no herbicide application errors.
- ✓ Environment was favorable for good herbicide performance.
- ✓ Only one species escaped control.
- ✓ Weed is healthy while neighboring weeds of the same species have died.
- ✓ Respraying did not control the weed.
- ✓ Weed was not controlled in the same patch in the past and the patch is getting larger.
- ✓ Weed was not controlled by different herbicides with the same site of action in the past.
- ✓ The same site of action has been used frequently.

Field sprayer calibration equations

$$\text{Speed (mph)} = \frac{\text{Distance (in feet)} \times 60}{\text{Time (in seconds)} \times 88} \qquad \text{GPA} = \frac{5{,}940 \times \text{GPM (per nozzle)}}{\text{mph} \times W^*}$$

*W stands for nozzle spacing for broadcast application or spray width for single nozzle or band applications.

Conversions

Celsius = (Faranheit - 32) x .55	1 pound/acre = 1.12 kilogram/hectare
1 tablespoon = 0.5 fluid oz	1 square mile = 640 acres
2 tablespoons = 1.0 fluid oz	1 acre = 43,560 square feet
32 fluid ounces = 1 quart	1 mile = 5,280 feet
128 fluid ounces = 1 gallon	1 mile/hour = 88 feet/minute

https://ipcm.wisc.edu/download/pubsPM/A3878FungicideResistance.pdf

http://badgercropdoc.com

A3878

Fungicide resistance management in corn, soybean, and wheat in Wisconsin

Fungicides are important tools for managing plant diseases in corn, soybean, and wheat. Unlike insecticides and herbicides that are used to kill insects and weeds, fungicides act as a barrier to protect healthy plant tissues from infection by fungi. Due to the protective nature of fungicides, they should be applied in a spray volume that provides sufficient coverage of plant parts. Fungicides are often reapplied to plants because they can be degraded by time and weathering, and are needed to protect new plant growth. Poor disease control can result from weathering, insufficient fungicide coverage, low application rates, poor efficacy of the selected fungicide on the pathogen of concern, and fungicide resistance (insensitivity to the fungicide). Fungicide resistance results from a complex interaction between fungicide mode of action, fungus biology, frequency of fungicide use, fungicide application, and cropping system.

Fungicide mobility

Understanding fungicide mobility can provide valuable information about fungicide selection and help you decide whether or not to use a fungicide. Fungicides are classified into two basic groups: contacts and penetrants. Regardless of mobility, fungicide efficacy will be limited when applied after symptom development and pathogen reproduction (spore production). Fungicides will not cure existing disease symptoms. However, timely application can result in slowing or eliminating symptom development and stop pathogen reproduction. Applying fungicides before a pathogen is well-established results in the best control.

Contact fungicides remain on the plant surface. They do not move on or into plant tissues and can be readily washed from the plant surface. Contact fungicides must be reapplied to protect new plant growth. Because of the limited mobility of contact fungicides and their protectant-only nature, these products should be used prior to fungal infection.

Penetrant fungicides are absorbed into plants after being applied to the surface. Because of the movement of the fungicide into the plant, these fungicides are generally considered systemic fungicides. This can be misleading since the degree of systemicity can vary among fungicides. Local penetrant fungicides only move a short distance, such as into the waxy plant cuticle, and remain in that location. Translaminar penetrants can move through the cuticle between cells toward the opposite side of the leaf. Acropetal penetrants are xylem (water conducting elements of plants) mobile and move between cells along a water potential gradient. Acropetal penetrants only move upwards in plants. Systemic penetrants move through cells and follow sugar gradients in plants. Therefore, systemic penetrants can move upward and downward in plants. Very few fungicides are considered systemic penetrants. Regardless of the level of systemicity, penetrant fungicides have very limited curative ability. Penetrative fungicides will only stop or slow infections within the first 24–72 hours after infection. Therefore, best control of fungal infection with penetrant fungicides is achieved when these products are applied on a preventative schedule.

Fungicide resistance

Fungicide resistance is defined as a genetic adjustment of the fungus that leads to reduced sensitivity to a fungicide. Genetic mutations in fungi that result in fungicide resistance are thought to occur at low frequency and can be governed by a single gene or multiple genes. Mechanisms that lead to reduced sensitivity to a fungicide can vary, but include the alteration of the target site, reduced fungicide uptake, active export of the fungicide out of the fungal cell, and breakdown of the fungicide active ingredient. Fungicide resistance in fungi becomes a problem when the frequency of resistant strains in the population outnumbers the fungicide-sensitive individuals. This arises through repeated and exclusive use of at-risk fungicides.

Practices that result in fungicide resistance

Application of fungicide at the wrong time (e.g., after the fungus has begun reproduction) or with inadequate coverage can result in poor control of a pathogen and lead to reapplication; this results in many individuals

Fungicide resistance management in corn, soybean, and wheat in Wisconsin (A3878) page 1

https://ipcm.wisc.edu/download/pubsPM/Pest-FastFacts.pdf

What to Watch for in 2020

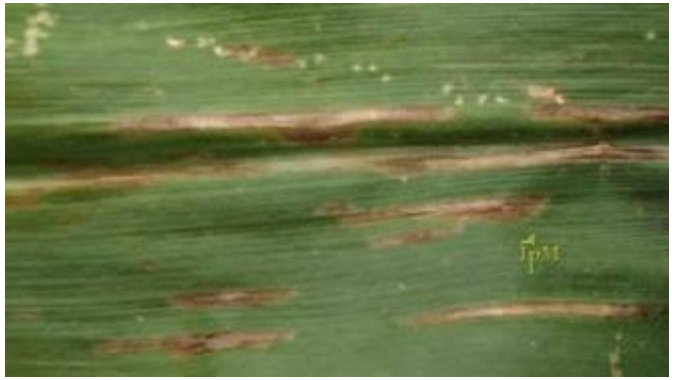
"The Foliar Trifecta"

- Tar spot
- Gray leaf spot
- Northern corn leaf blight

- Gibberella ear rot**
- Southern rust likely <u>NOT</u> an earlier issue (hot and dry after the tropical storm)

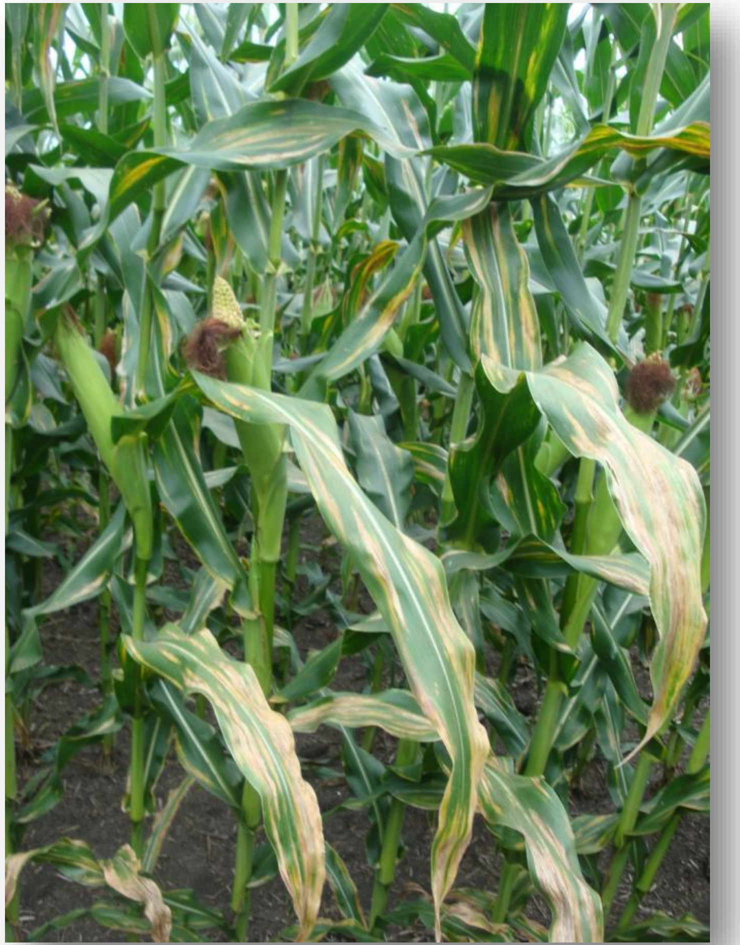
Factors that Promote Gray Leaf Spot (GLS)

- Increased under reduced and no-tillage systems
- Early infection = higher yield loss
- Environment: high humidity (extended periods of leaf wetness); warm temperatures (80s and 90s)



Factors that Promote Nortehrn Corn Leaf Blight (NCLB)

- Environment that favors: moderate temperatures (65-80°F) and prolonged periods of leaf wetness
- Large amounts of surface residue
- Susceptible hybrids
- Lack of rotation



Factors that Promote Tar Spot

Figure From Mottaleb et al., 2018

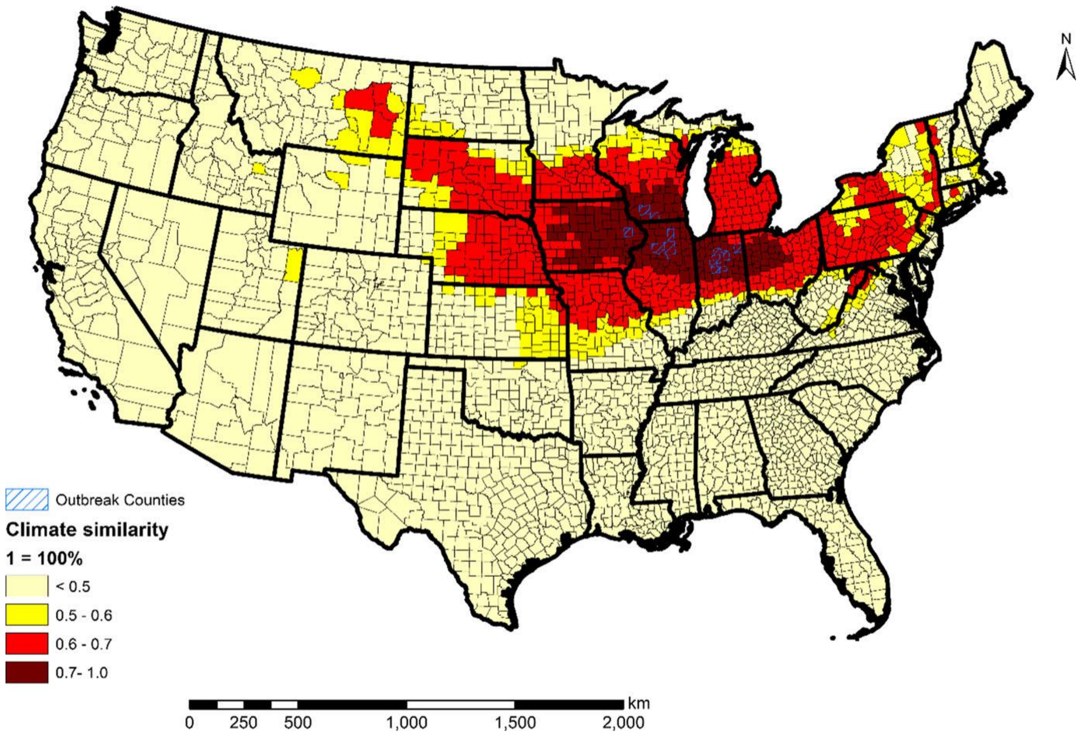


Fig. 4 Maize-producing counties vulnerable to tar spot complex (TSC) calculated based on climate similarity indices using historic climatic data from the counties where TSC has been detected. Source: developed by authors

Hock et al. 1995

- Monthly average temp of 63 F – 72 F
- Average RH greater than 75%
- Average of 7h/night of leaf wetness
- 10-20 foggy days per month
- Monthly rainfall total of at least 5.9 inches

What did We Learn about Tar Spot in 2019?

- Tar spot was wide spread across Wisconsin in 2019
- Overall severity reasonably low compared to 2018
  -Some isolated severe cases; mostly irrigated sites
- Occurrence in the same areas as 2018

Major Lesson of 2019: Irrigation Drives Tar Spot

- Image from Michigan Courtesy of Dan Heasley and Martin Chilvers, MSU
- Entire Field Treated with Headline AMP at R1
- Environment may be so favorable that fungicide nearly ineffective.

Image courtesy: Dan Heasley, 2019

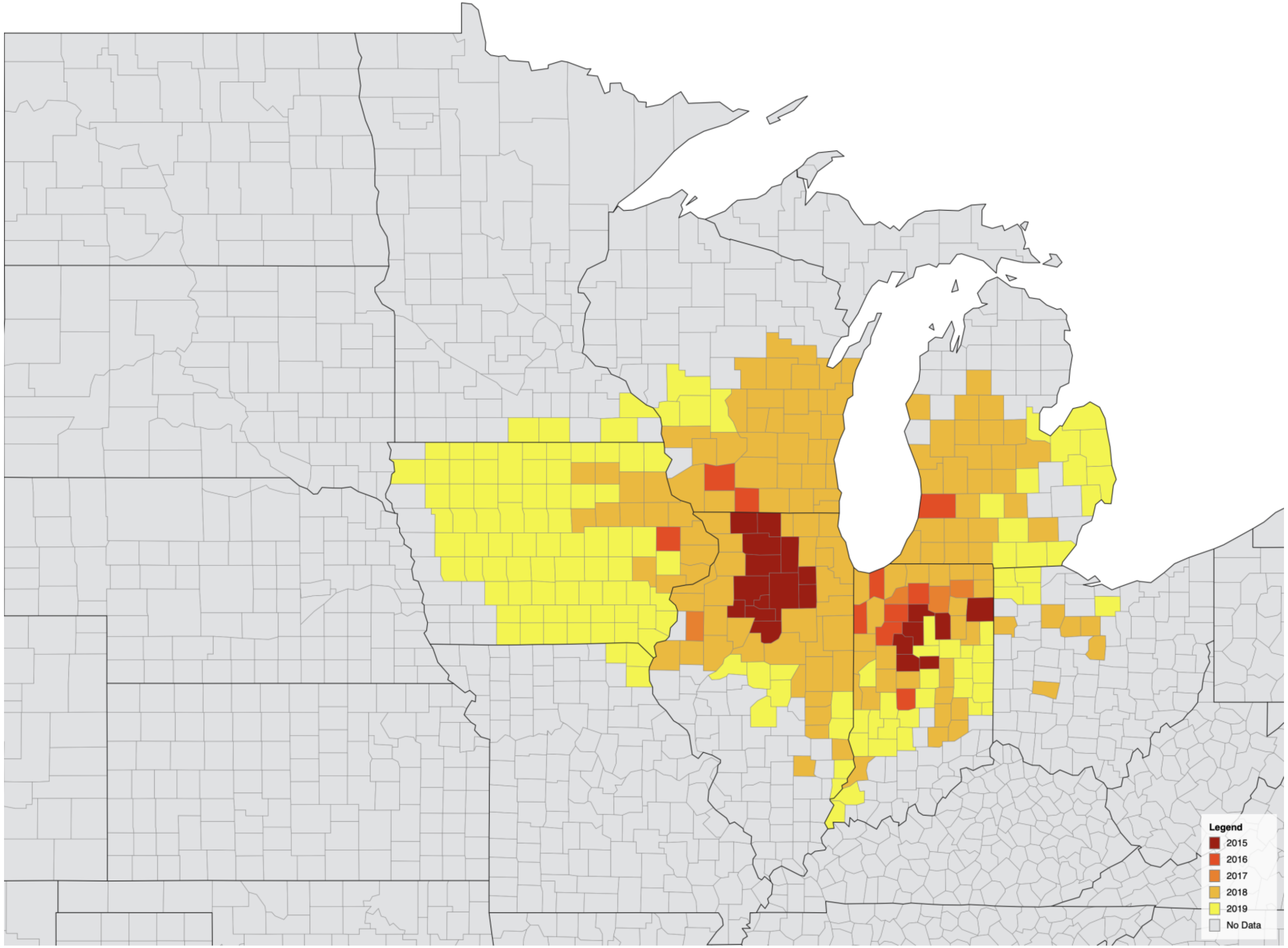
Can the Tar Spot Pathogen Overwinter in the Midwest?

Mean total Phyllachora maydis ascospores released and mean percent ascospore germination after incubation for 4 or 24 hours.				
	4 hr		24 hr	
Sample	Mean Total ascospores[1]	Mean Spore Germination (%)[2]	Mean Total ascospores[1]	Mean Spore Germination (%)[2]
IL2	4,773,333 a	1.9 ef	4,379,000 a	2.8 c
IL3	2,065,000 a	6.3 cd	2,790,667 a	4.5 c
IL1	617,333 b	0.7 f	1,167,000 b	4.4 c
WIS2	126,800 c	15.3 ab	126,322 cd	15.0 ab
MI1	118,856 c	3.2 de	237,156 c	2.4 c
INE3	107,078 c	12.9 abc	97,944 de	17.0 ab
INA4	38,811 d	14.6 ab	44,822 ef	12.8 ab
WIA1	30,278 d	10.7 bc	28,033 fg	9.5 b
WIS1	20,556 d	12.1 abc	18,378 g	12.4 ab
INB4	20,167 d	18.5 ab	20,789 fg	21.2 a
WIA2	3,689 e	21.3 ab	3,289 h	20.9 a
INB1	3,556 e	24.1 a	3,700 h	24.9 a

[1]Mean total ascospores released after incubation in water for 4 or 24 hours. Different letters after each value indicate that mean is different based on Fisher's protected least significant difference (LSD) at α=0.05.
[2]Mean percent ascospores germinated after incubation in water for 4 or 24 hours. Different letters after each value indicate that mean is different based on Fisher's protected least significant difference (LSD) at α=0.05.

Groves, C.L., Kleczewski, N.M., Telenko, D.E.P., Chilvers, M.I., and Smith, D.L. 2020. *Phyllachora maydis* ascospore release and germination from overwintered corn residue. Plant Health Progress. https://doi.org/10.1094/PHP-10-19-0077-RS

Tar Spot Spread Over Years



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What about general fungicide efficacy in corn?

Meta-Analysis of Fungicide Efficacy in Corn

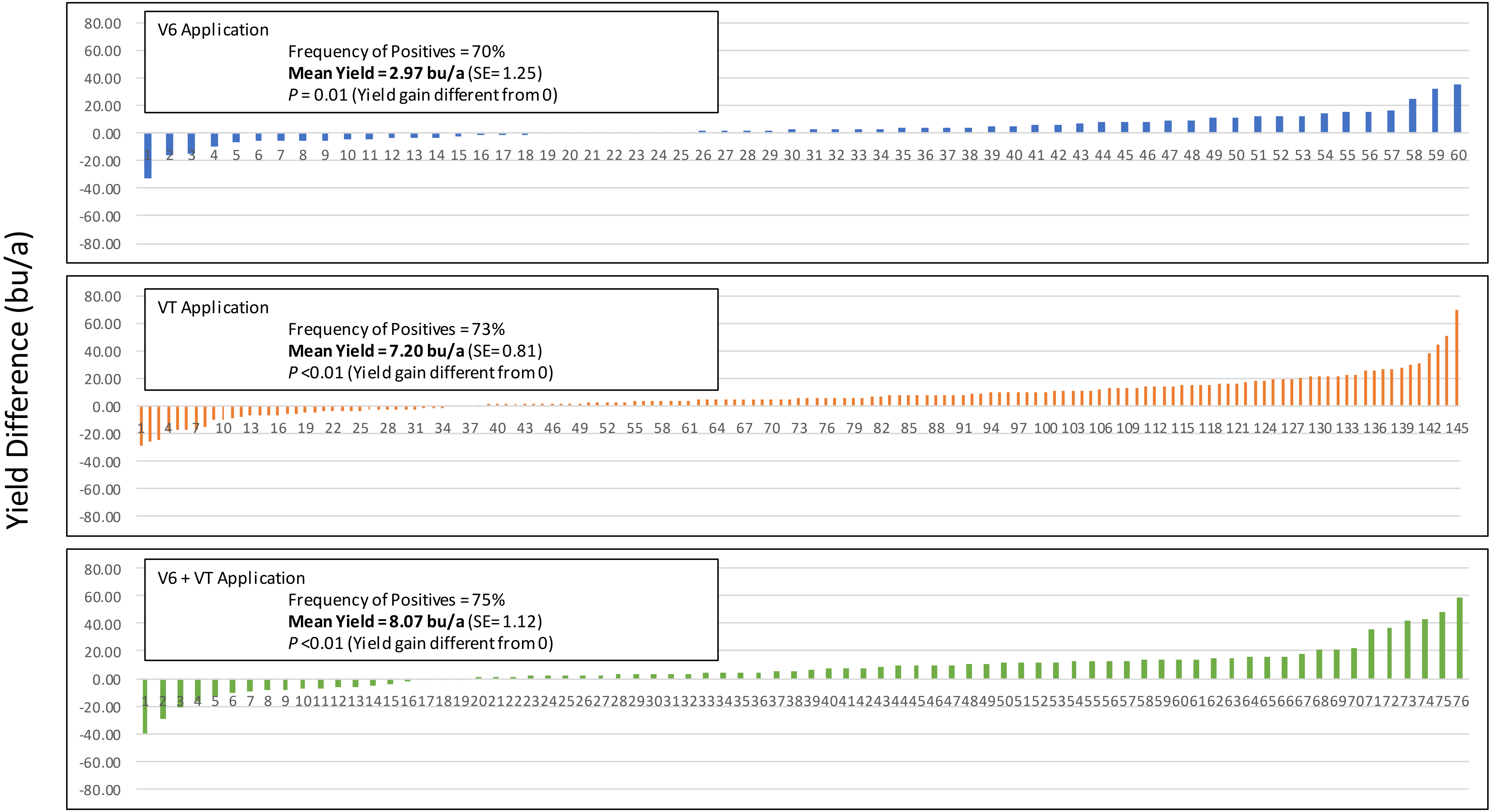
Table 4. Influence of application timing on yield response to fungicide from quinone outside inhibitors (QoI), and a premix of demethylation inhibitors (DMI) and QoI fungicide classes with the corresponding statistics based on mixed-effect meta-analysis of trials conducted in 12 U.S. states and Ontario, Canada in 2014 and 2015.

					Effect size[d]						
Fungicide class	**Application timing[a]**	**K[b]**	**Mean yield NTC (kg/ha)[c]**	$\bar{D}$	se($\bar{D}$)	CI_L	CI_U	t	P	PW	**Yield increase (%)**
QoI	V6 + VT	20	12,040	452.8	101.5	254.1	651.9	4.46	< .0001	0.9	3.8
(*P* <0.01)	V6	38	12,086	52.3	74.8	-94.4	199.0	0.70	0.4845	0.1	0.4
	VT	28	12,114	222.8	89.6	47.1	398.4	2.49	0.0129	0.7	1.8
DMI + QoI	V6 + VT	73	12,130	480.8	69.8	344.0	617.6	6.89	< .0001	1.0	4.0
(*P* <0.01)	V6	58	12,257	172.4	77.8	19.9	324.9	2.22	0.0267	0.6	1.4
	VT	141	12,016	432.1	50.8	332.4	531.8	8.50	< .0001	1.0	3.6

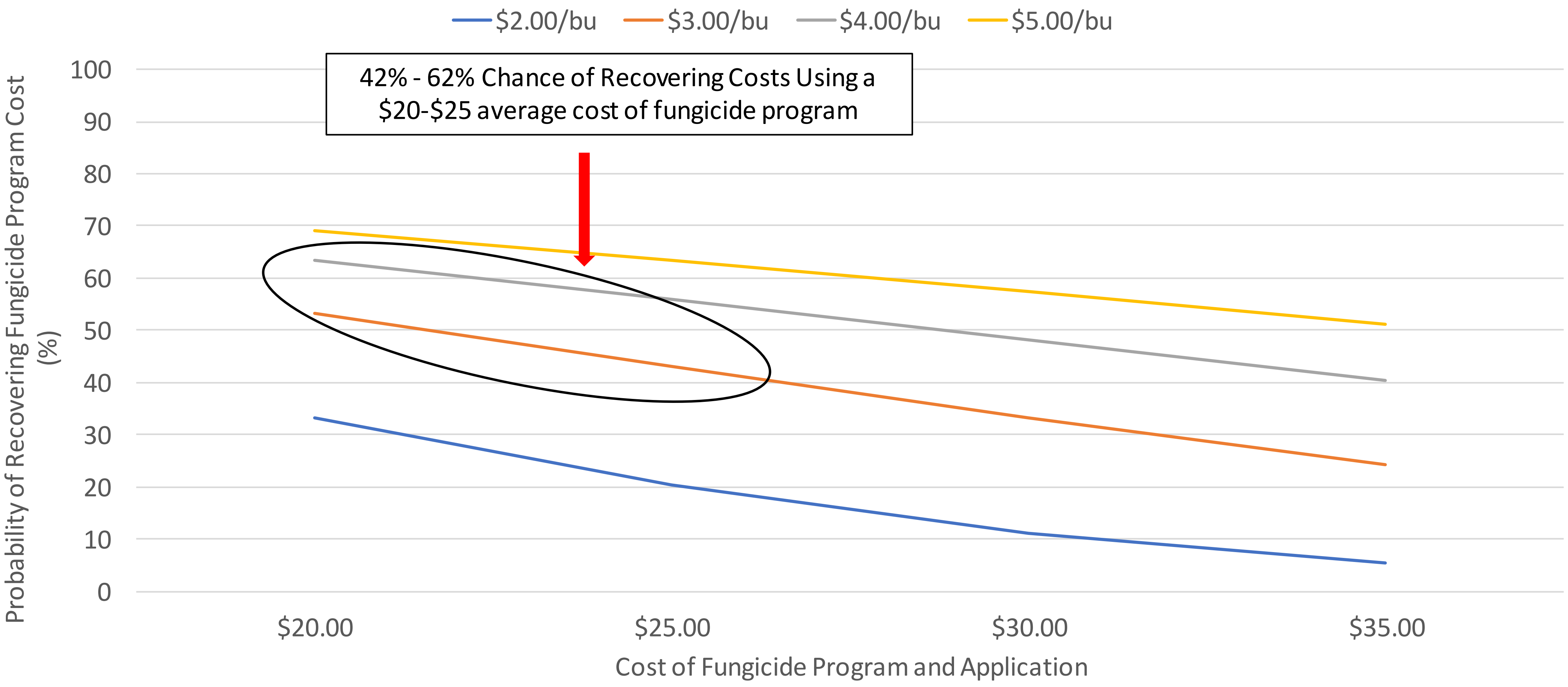
Wise KA, Smith D, Freije A, Mueller DS, Kandel Y, Allen T, et al. (2019) Meta-analysis of yield response of foliar fungicide-treated hybrid corn in the United States and Ontario, Canada. PLoS ONE 14(6): e0217510.

Wise KA, Smith D. et al. PLoS ONE 14(6): e0217510.

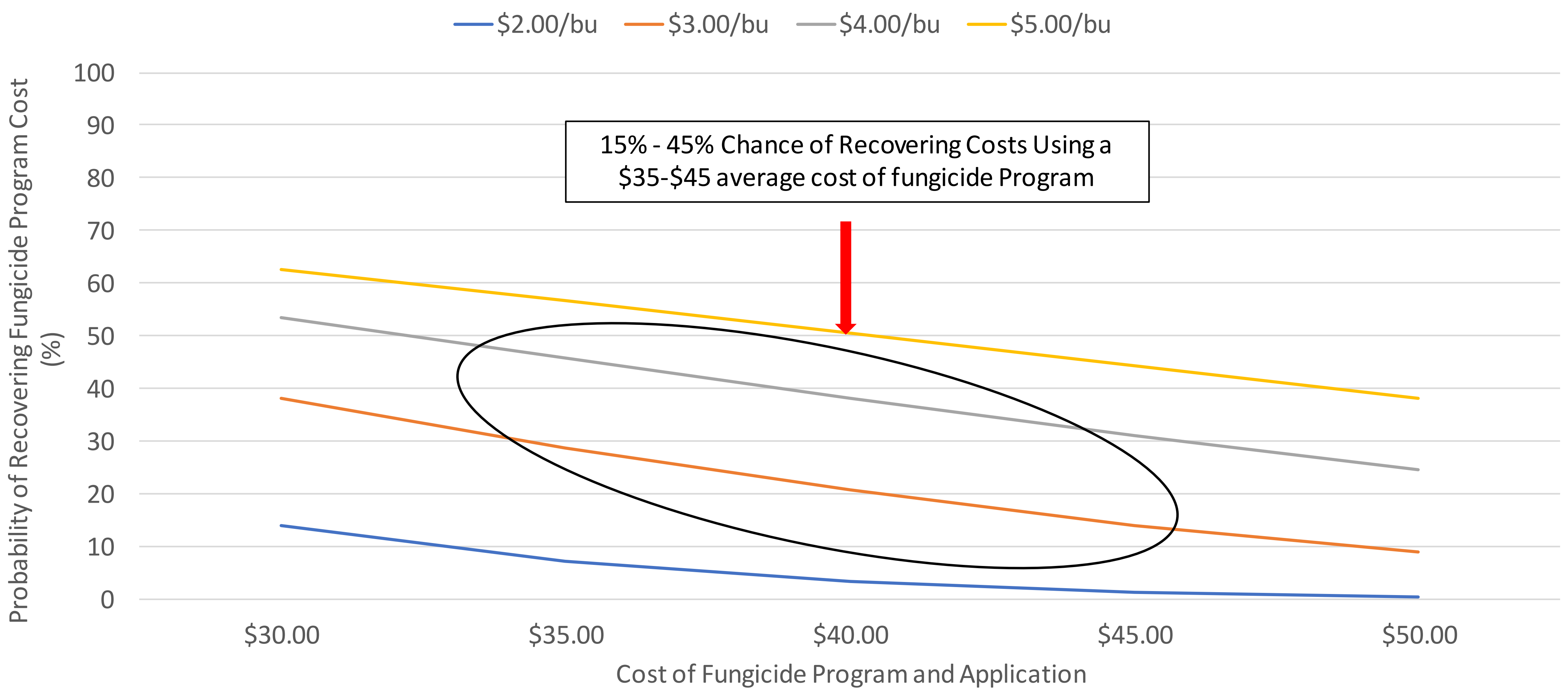
DMI + Strobilurin Results Across the U.S.



Probability of Breaking Even Based on Data from Across the U.S.
(VT Application Timing)



Probability of Breaking Even Based on Data from Across the U.S.
(V6 + VT Application Timing)



2019 Uniform trial

- Focus on new fungicides released
    - Products with three fungicide classes compared to two classes

- Compare VT/R1 timing to R3 timing

What is the new mode of action?

Succinate dehydrogenase inhibitors (SDHI) or FRAC 7

- Now added to field crop fungicide formulations in 2- and 3-way mixes
- Function is similar Quinone outside inhibitors (QoI or strobilurin) fungicides - inhibit mitochondrial respiration, stopping energy production, and resulting in fungal death

  -Effective on germinating spores and early fungal growth

Demethylation inhibitor (DMI) or FRAC 3 compounds – inhibits a specific enzyme in fungi that is important in sterol production

- Sterols are necessary in fungal cell membranes
- Lack of Sterols result in abnormal fungal growth

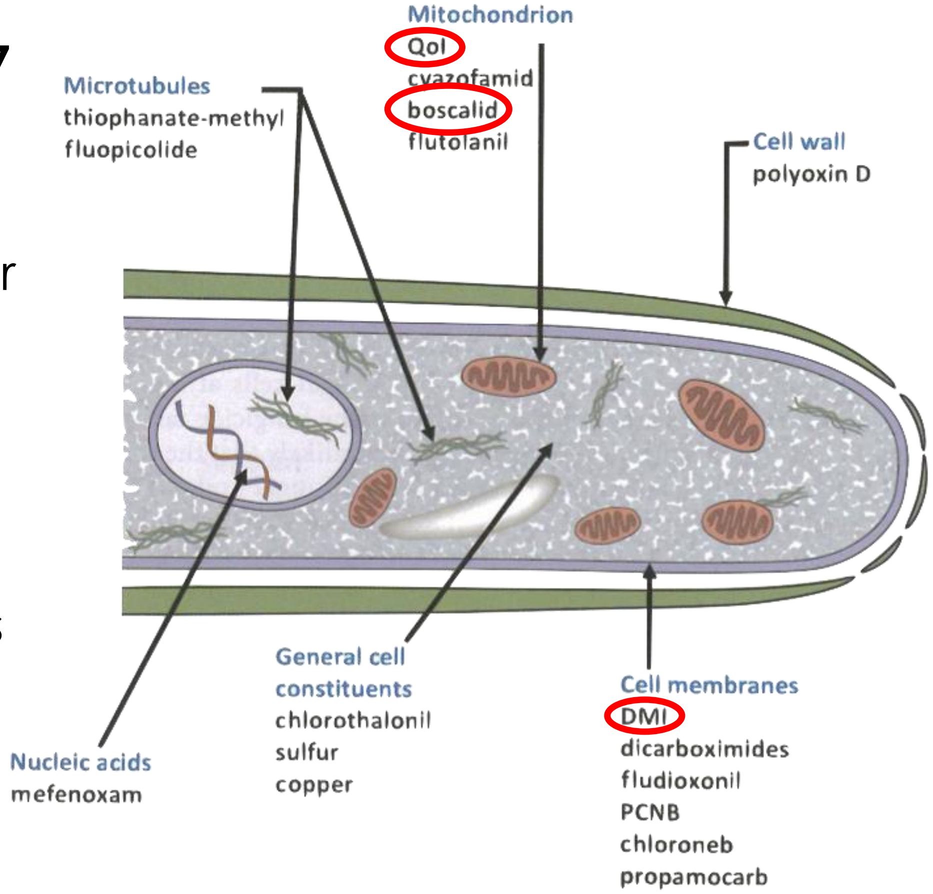
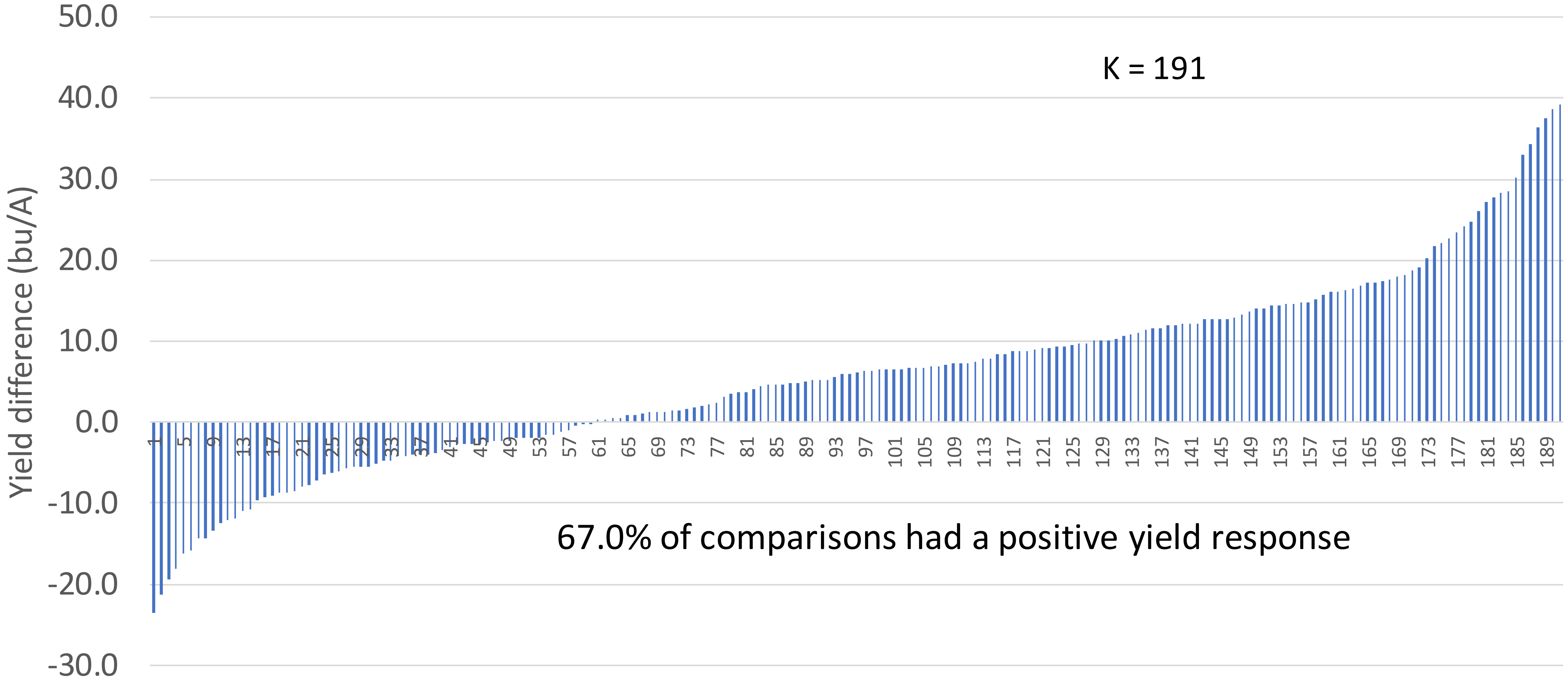


Image Credit: Fig. 2.4 from "A Practical Guide to Turfgrass Fungicides" by Richard Latin, Purdue University

Treatments

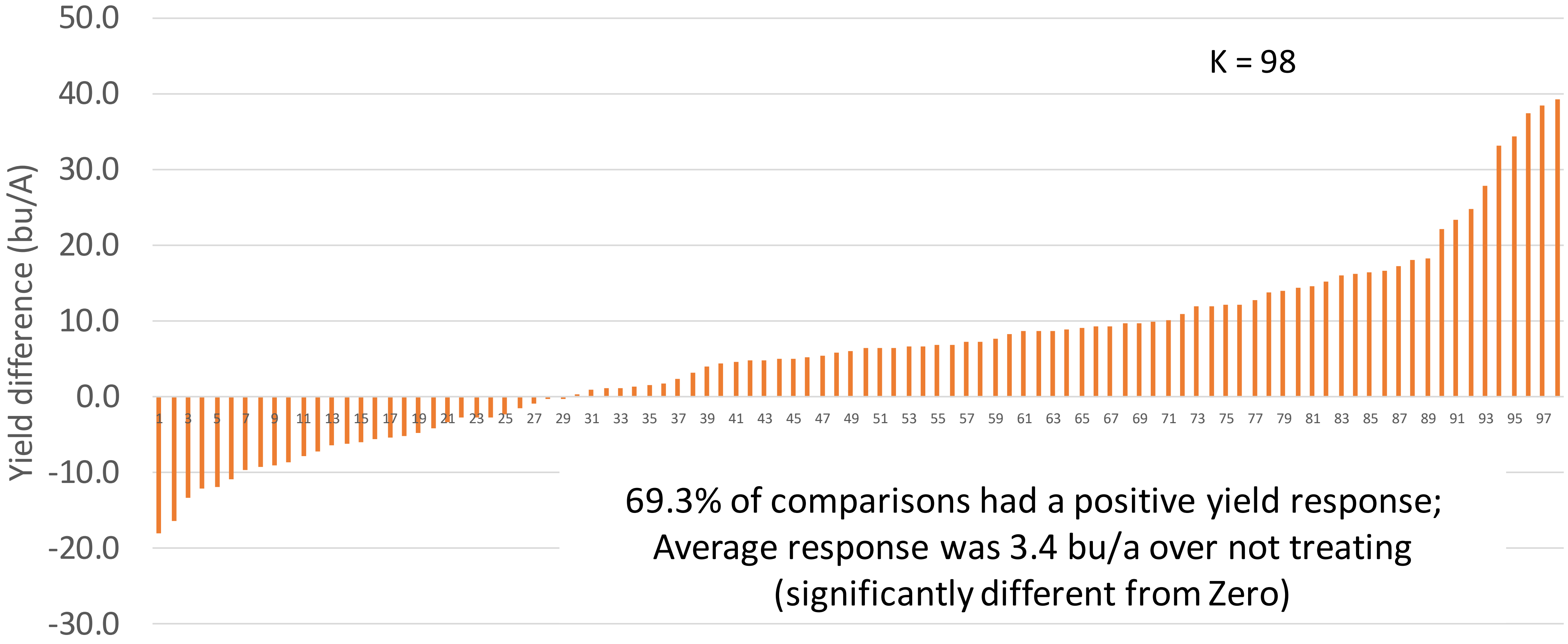
Fungicide common name	Fungicide class(es)	Rate (fl oz/A)	Fungicide application timing
Lucento	DMI + SDHI	5	VT/R1
Trivapro	QoI+ DMI + SDHI	13.7	VT/R1
Miravis Neo	QoI+ DMI + SDHI	13.7	VT/R1
Veltyma	QoI + DMI	7	VT/R1
Delaro	QoI+ DMI	8	VT/R1
Headline AMP	QoI + DMI	10	VT/R1
Revytek	QoI + DMI + SDHI	8	VT/R1
Quilt Xcel	QoI + DMI	10.5	VT/R1
Lucento	DMI + SDHI	5	R3
Trivapro	QoI+ DMI + SDHI	13.7	R3
Veltyma	QoI + DMI	7	R3
Delaro	QoI+ DMI	8	R3
Headline AMP	QoI + DMI	10	R3
Revytek	QoI + DMI + SDHI	8	R3
Quilt Xcel	QoI + DMI	10.5	R3

Distribution of mean yield difference in bushels per acre between the fungicide treatments and non-treated controls



Each bar represents the difference between the fungicide treatment and non-treated control averaged over four replications

Effect of QoI + DMI fungicide application on yield response across application timing



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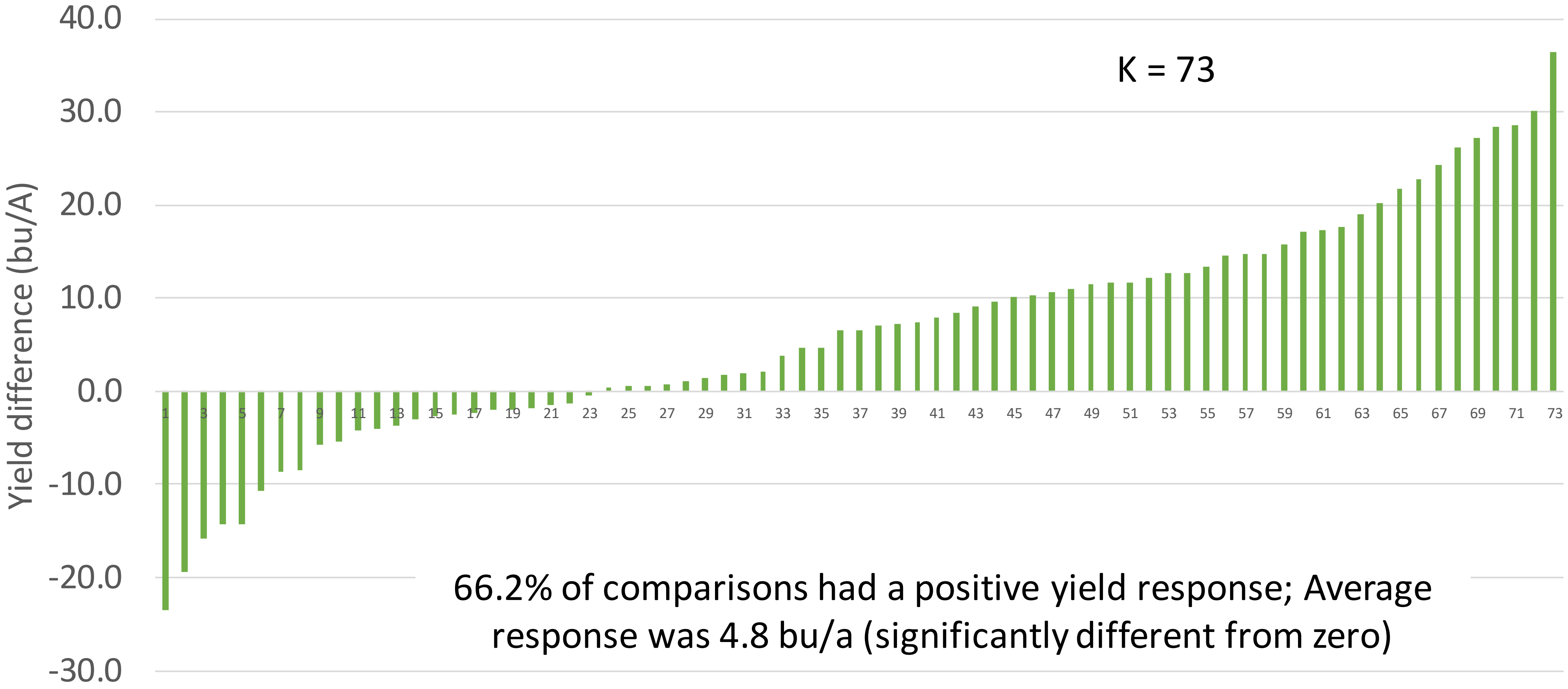
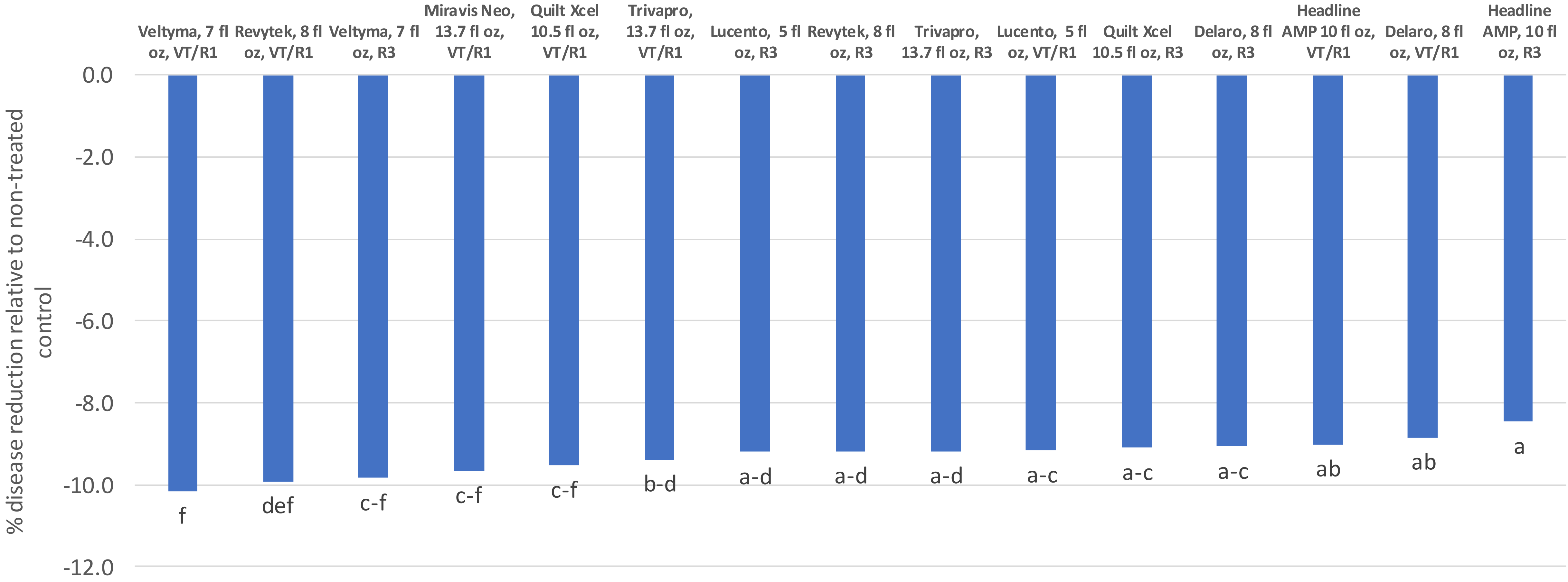
Effect of QoI + DMI + SDHI fungicide application on yield response across application timing

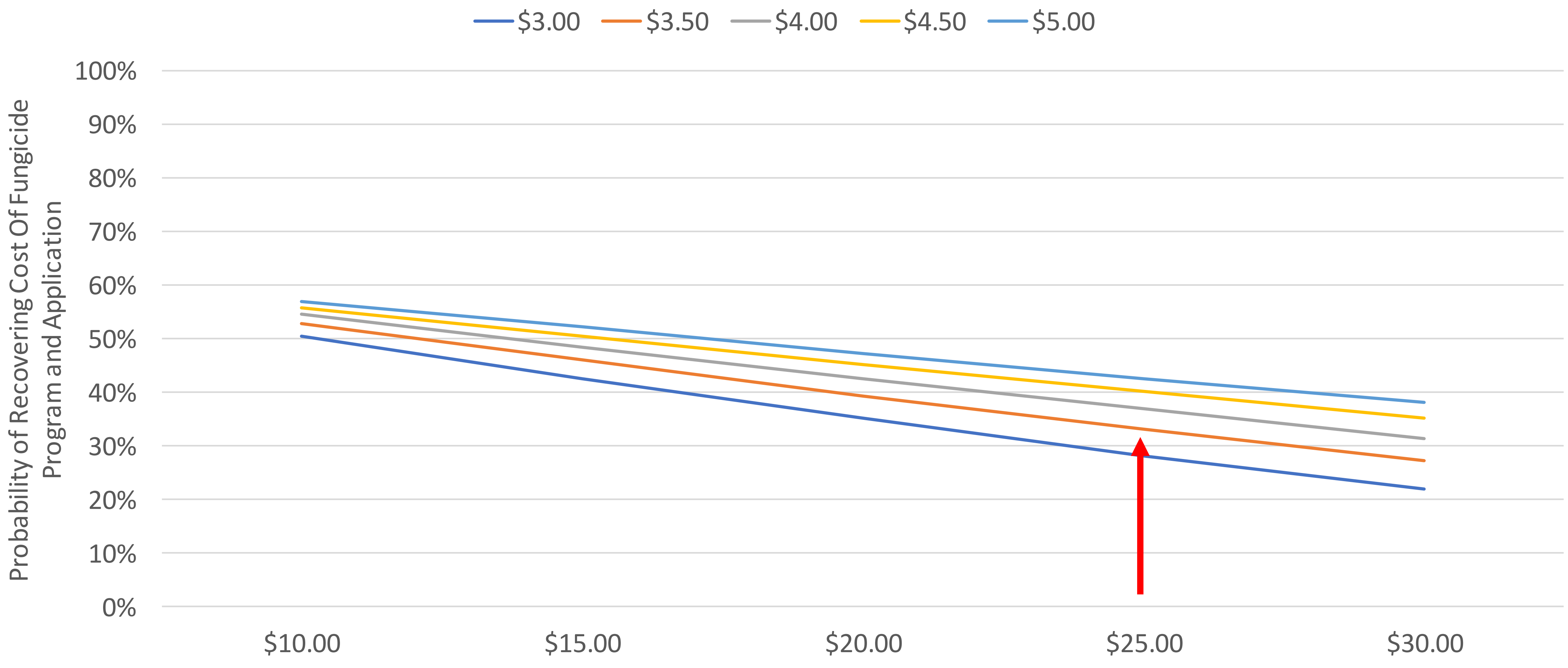


Each bar represents the difference between the fungicide treatment and non-treated control averaged over four replications

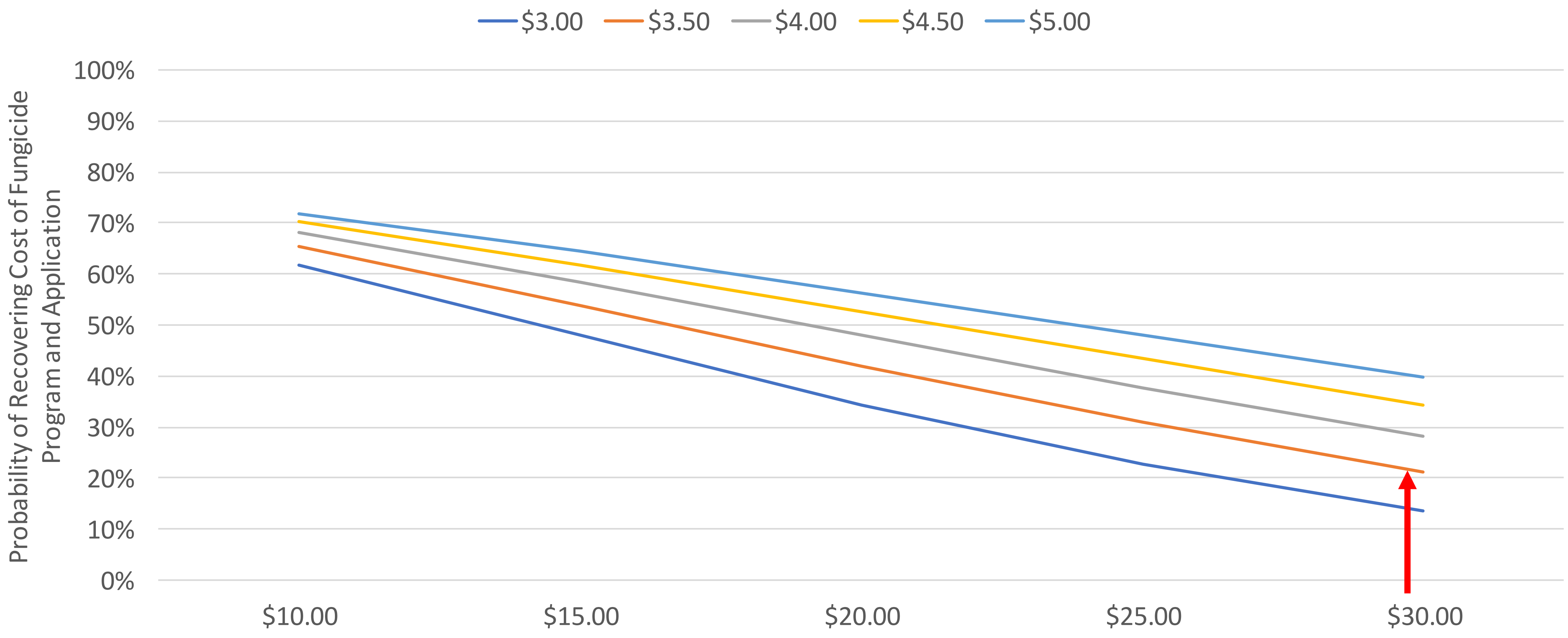
Effect of fungicide treatment on relative disease control



Probability of recovering fungicide program cost (%) for QoI + DMI fungicide



Probability of recovering fungicide program cost (%) for QoI + DMI + SDHI fungicide

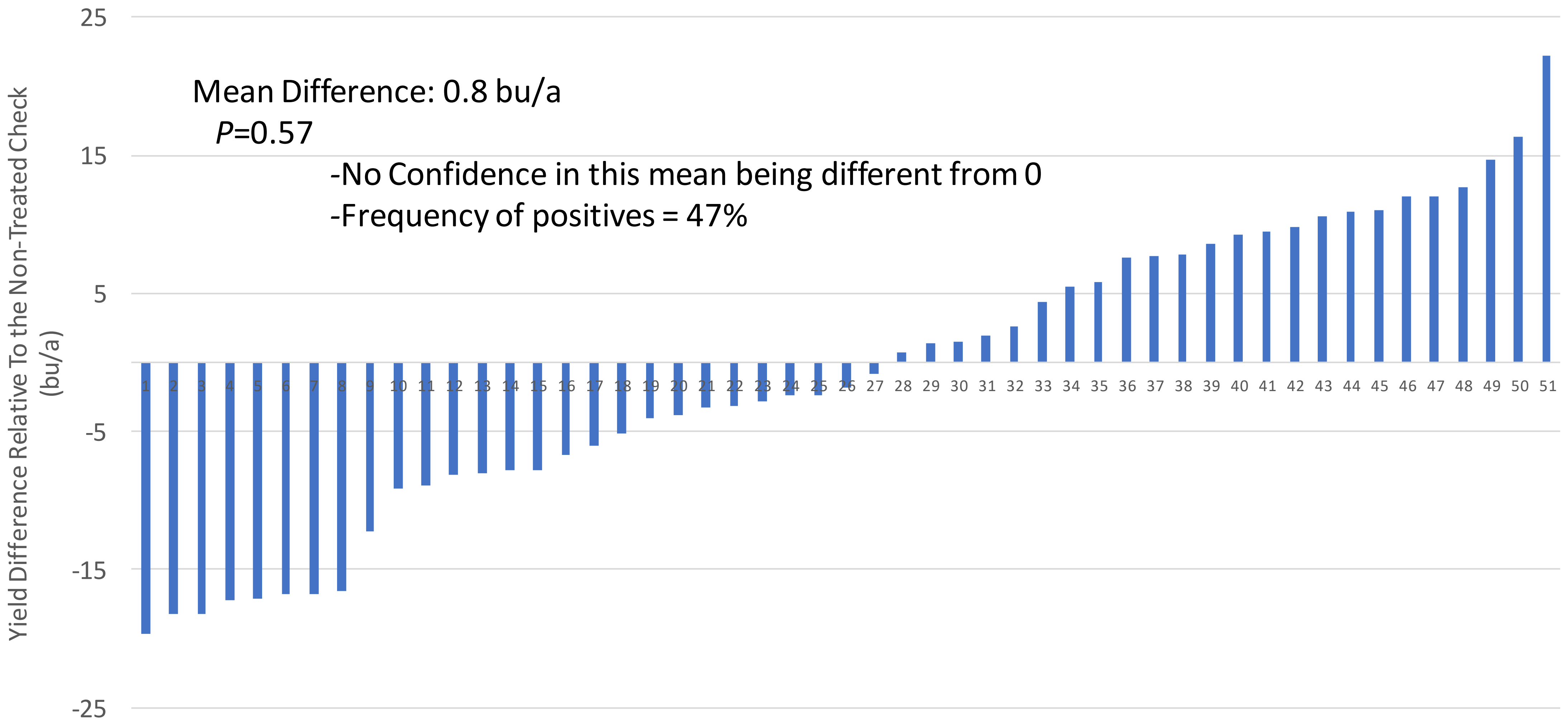


Disease Severity can Impact Likelihood of Positive ROI

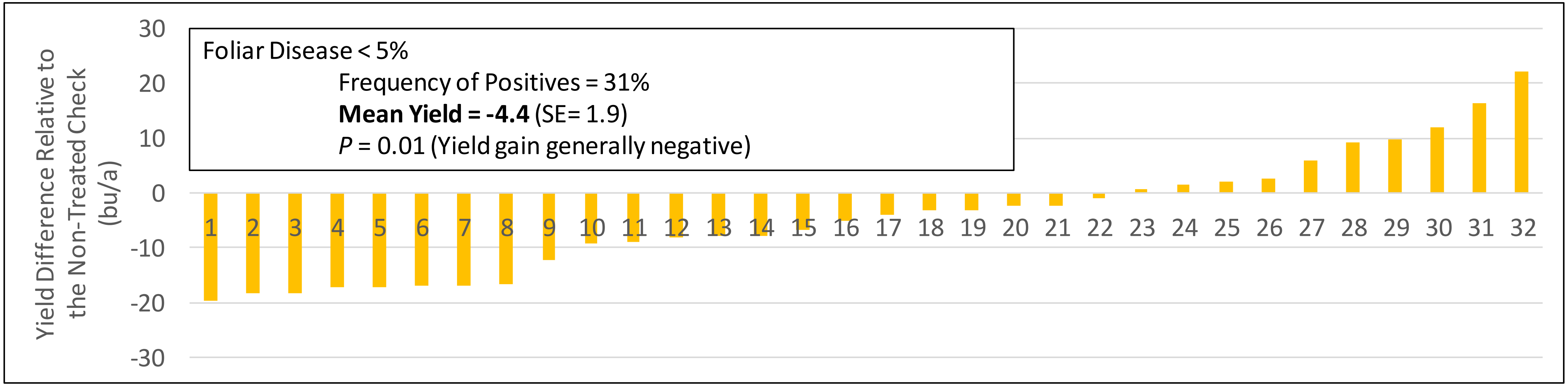
Wisconsin Dataset

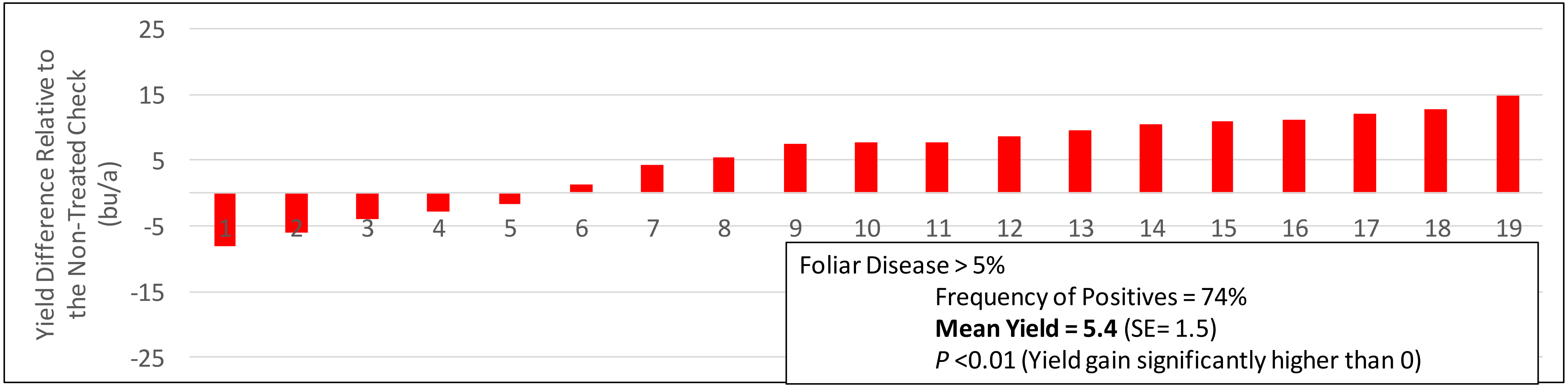
- 4 years of field data at Arlington Wisconsin (2013-2016)
- Used observations for Pre-Mix Fungicide Products Only (DMI + Strobilurins)
  - Most popular products being sprayed on corn
  - Had the largest number of observations over the three-year period
- Used Single-Application Trials Only
  - V6, V8, or VT (No computed difference in chance of yield increase at the various timings)
  - Total of 51 replicated treatment observations
- Looked at
  - Frequency distributions
  - Mean yield advantage
  - Considered variation across a field
  - Calculated Odds of a Positive ROI

Yield Difference Compared to Not-Treating for 51 Treatments

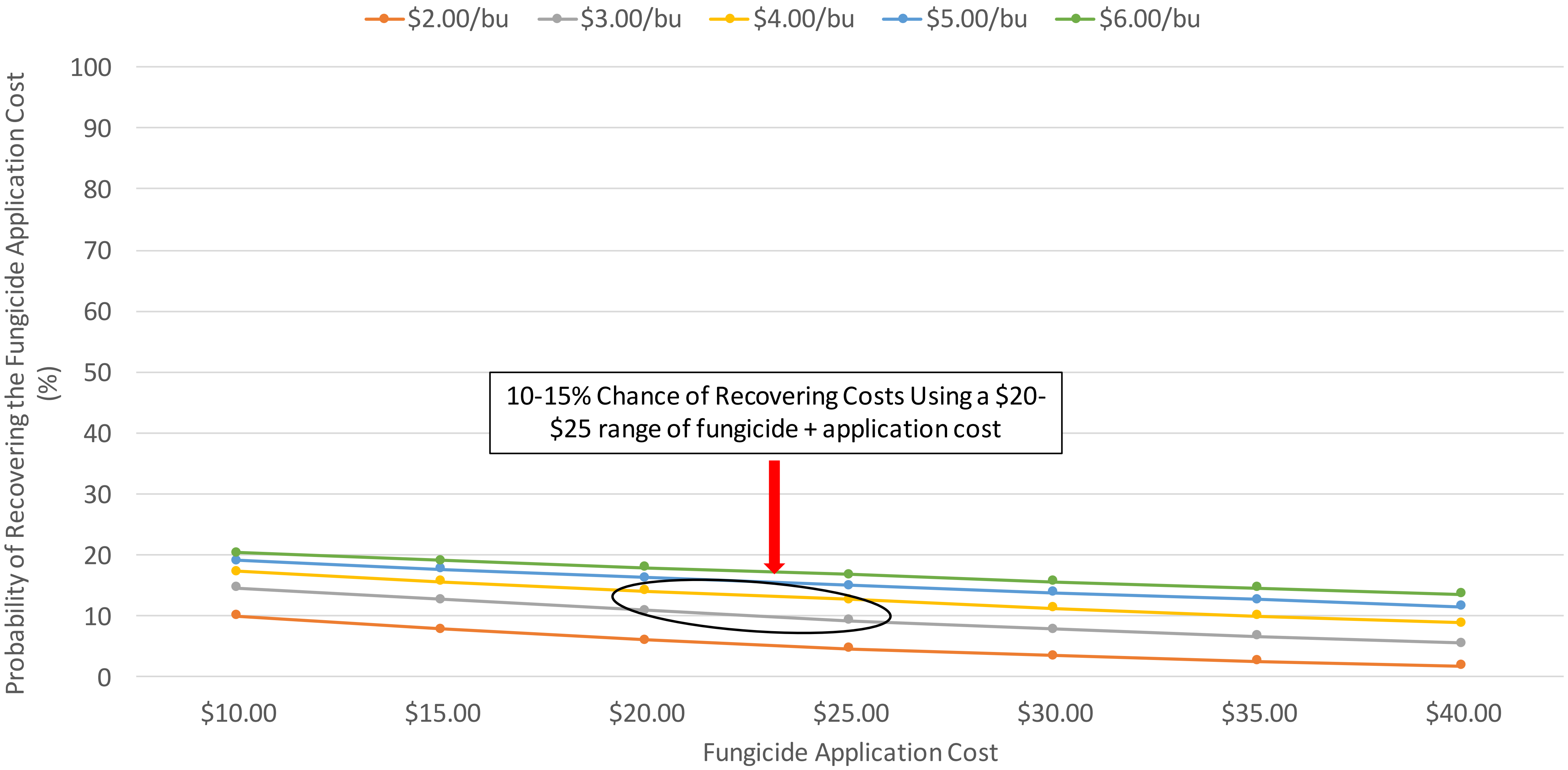


Effect of Disease Level Highly Significant on Yield Response to Fungicide

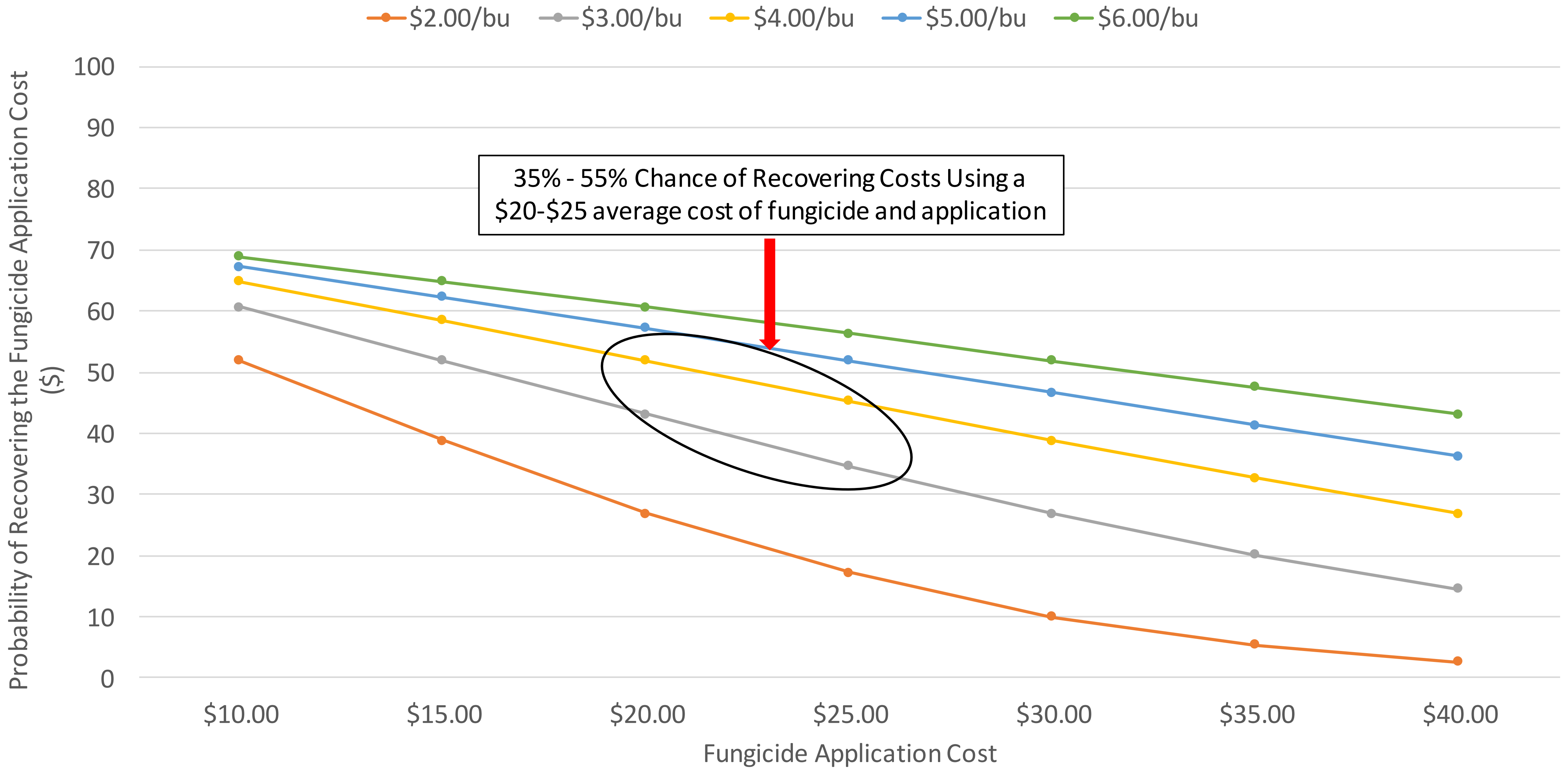




Probability Of Recovering the Cost of A Fungicide Application Under **Low** Foliar Disease Pressure



Probability Of Recovering the Cost of A Fungicide Application Under **High** Foliar Disease Pressure



Foliar Fungicide 'Take Home'

- **Fungicide application**
  - -Product not necessarily as critical as application timing – lots of fungicides that give acceptable disease reduction
  - -Best chance for economic return = VT/R1 growth stage
  - -Scout prior to VT to assess severity of corn disease on lower leaves
  - -<u>Likelihood of positive ROI linked to active disease</u>
  - -Goal is to protect ear leaves in the reproductive growth stages of corn
- **Additional tactics to improve success fighting corn disease**
  - -Start with a resistant hybrid appropriate for your location
  - -Manage corn residue
    - *Most corn diseases are initiated from inoculum on residue in the field
  - -Rotate
    - *Can help manage local inoculum loads

Ear Rots





Mycotoxins

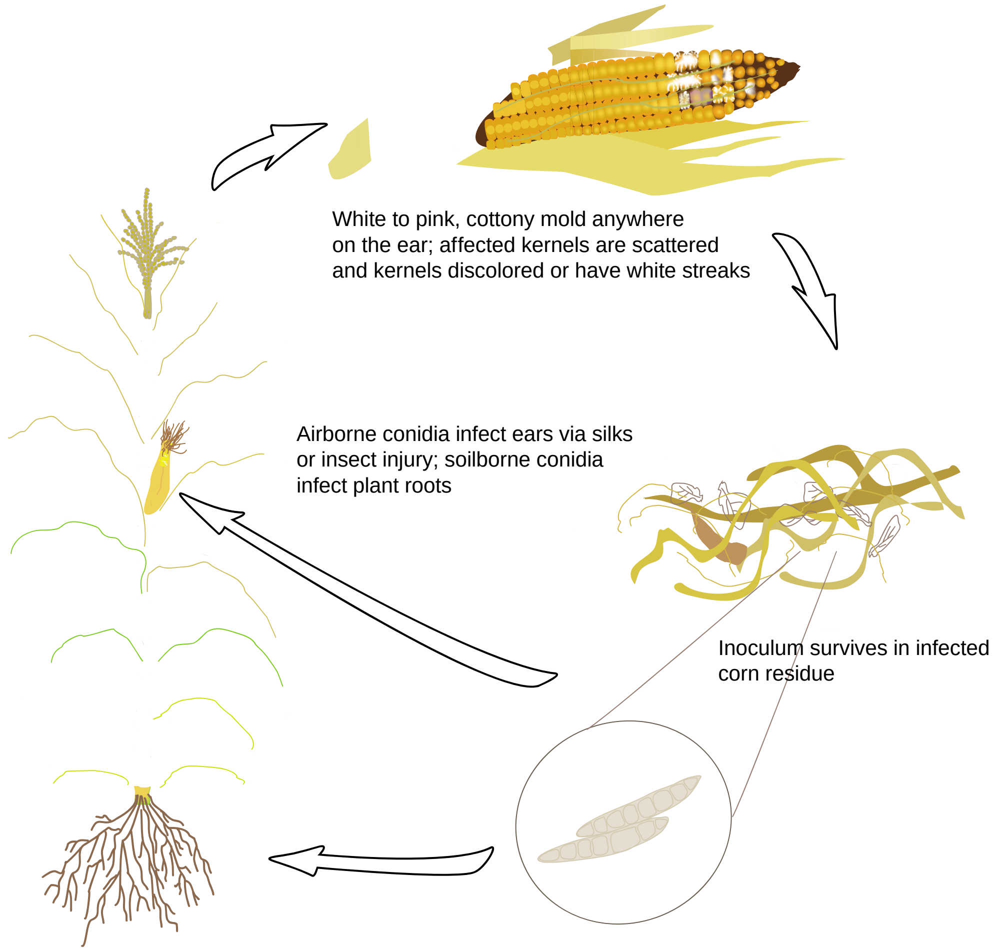
- Toxic, metabolic by-products produced by fungi (molds) growing on grain, feed, or food in the field or in storage
- 400-500 known mycotoxins
- Production of mycotoxins is highly dependent on
  - Environment
  - Factors that may cause wounding on plants (e.g. hail, insect feeding)
  - Situations where resource demand is high or resources are limiting (e.g. plant stress)
- Kernel moisture >18-20% does favor growth of all ear molds (including those that produce toxins)

  -"Wet" corn is a primary means of further increasing mycotoxins in grain storage systems
- Presence of mold on an ear **<u>DOES NOT EQUAL</u>** mycotoxins are present
- Similarly, no mold **<u>DOES NOT EQUAL NO</u>** mycotoxins are present
- Most important organisms in Wisconsin = *Fusarium* spp.

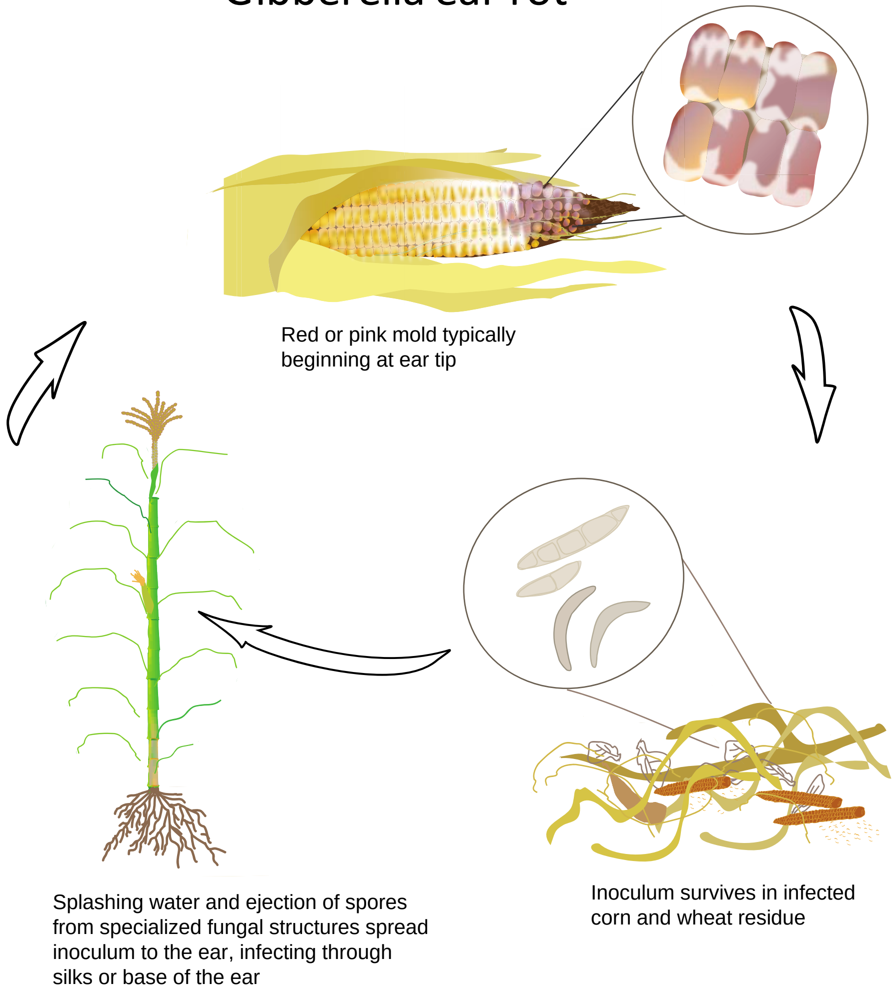
  -DON (vomitoxin), T-2 Toxin, Zearalenone, Fumonisons

The Major Ear Rots in Wisconsin

Fusarium ear rot



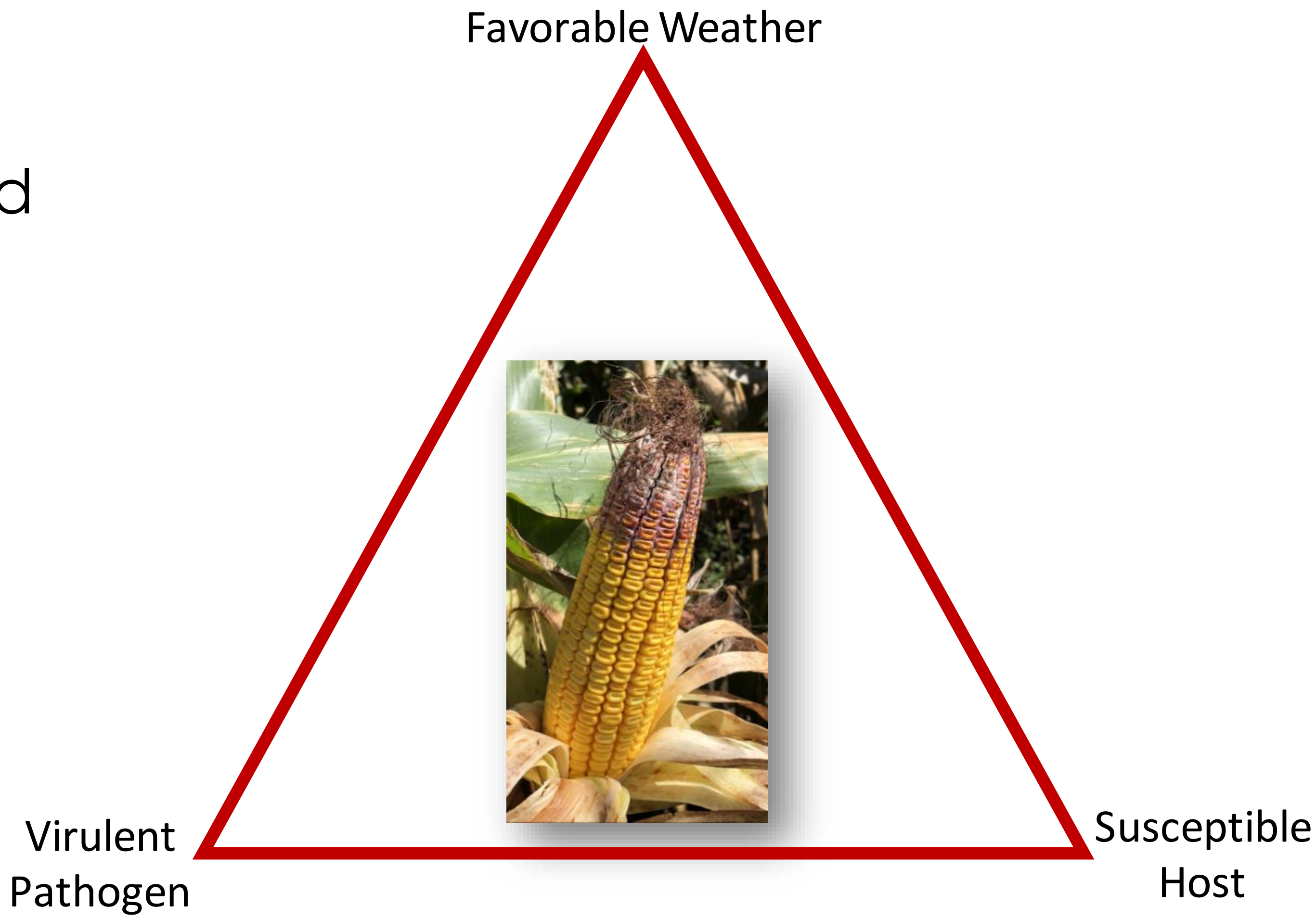
Gibberella ear rot



Weather Conditions that Promote *Fusarium spp.*

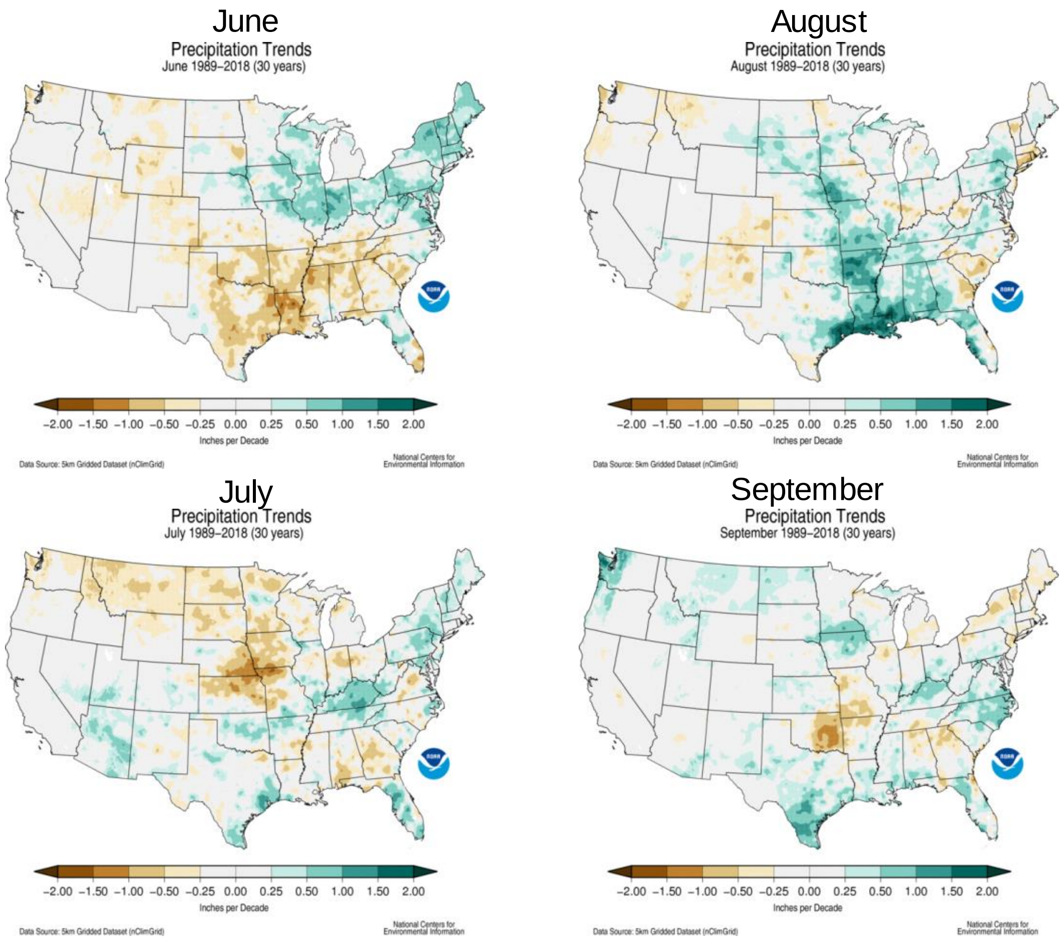
- Warm and excessively wet and humid conditions promote these species

- Ear rot phase especially significant when these conditions occur during silking
  - -Temperature range of 65°- 85°F before and during silking
  - -Prolonged rain and/or humidity during silking and after



Why Have Fusarium-related Diseases Re-Emerged/Increased in Frequency Recently?

- Short Rotations
  - -Corn-Corn and Corn-Soybean are not rotations!
- No-Till Cropping Systems
  - -Good for soil conservation
  - -Downside = Lots of crop surface residue where pathogens can overwinter
- Wetter Seasons
  - -30-year NOAA precipitation trends increasing During Growing season
  - -Especially true for June (Anthesis for Wheat) and August (Silking and ear fill in corn)
  - -Drier July adding a stress component?



Management of Ear Rot/Stalk Rot in Corn

Reducing stress and damage to the corn plant is important

- Choose hybrids rated resistant to the primary pathogen of interest (e.g. Gibberella ear rot, Fusarium ear rot, etc.)
- Choose a hybrid well adapted to your environment (Pushing RM can lead to stress)
- Plant early and allow normal heat unit accumulation (this has been a challenge in recent years, especially 2019!)
- Irrigate, if dry, to reduce stress (irrigation during silking could increase mycotoxin issues)
- Manage insects to minimize insect damage (Bt traits have been useful in this regard for Fusarium ear rot)
- Harvest at optimum moisture to facilitate proper fermentation
- Need to pack bunker quickly and promote rapid fermentation (Mycotoxin-producing fungi don't grow well at low pH)
- Fungicide applications? – Product and timing are important

Fungicides For Reducing Vomitoxin (DON) in Corn – Is This a Viable Strategy in The Absence of Complete Resistance in Corn Hybrids?

Fungicide Applications on Silage Corn Originally Focused on Improving Digestibility

- Foliar fungicide applications improve silage quality which results in increased feed conversion (Haerr et al., 2015. J. Dairy Sci.)
- Fungicide application on corn may reduce negative impacts by plant pathogens and reduce the fibrous content within plants (Kalebich et al., 2017. Animal Feed Science and Technology)
  - -Silage made with fungicide treated corn may reduce the bulk of the corn and enhance quality of the feedstuff.
- Reduced fungal activity might lead to lower mycotoxin levels?

Fungicide Treatments

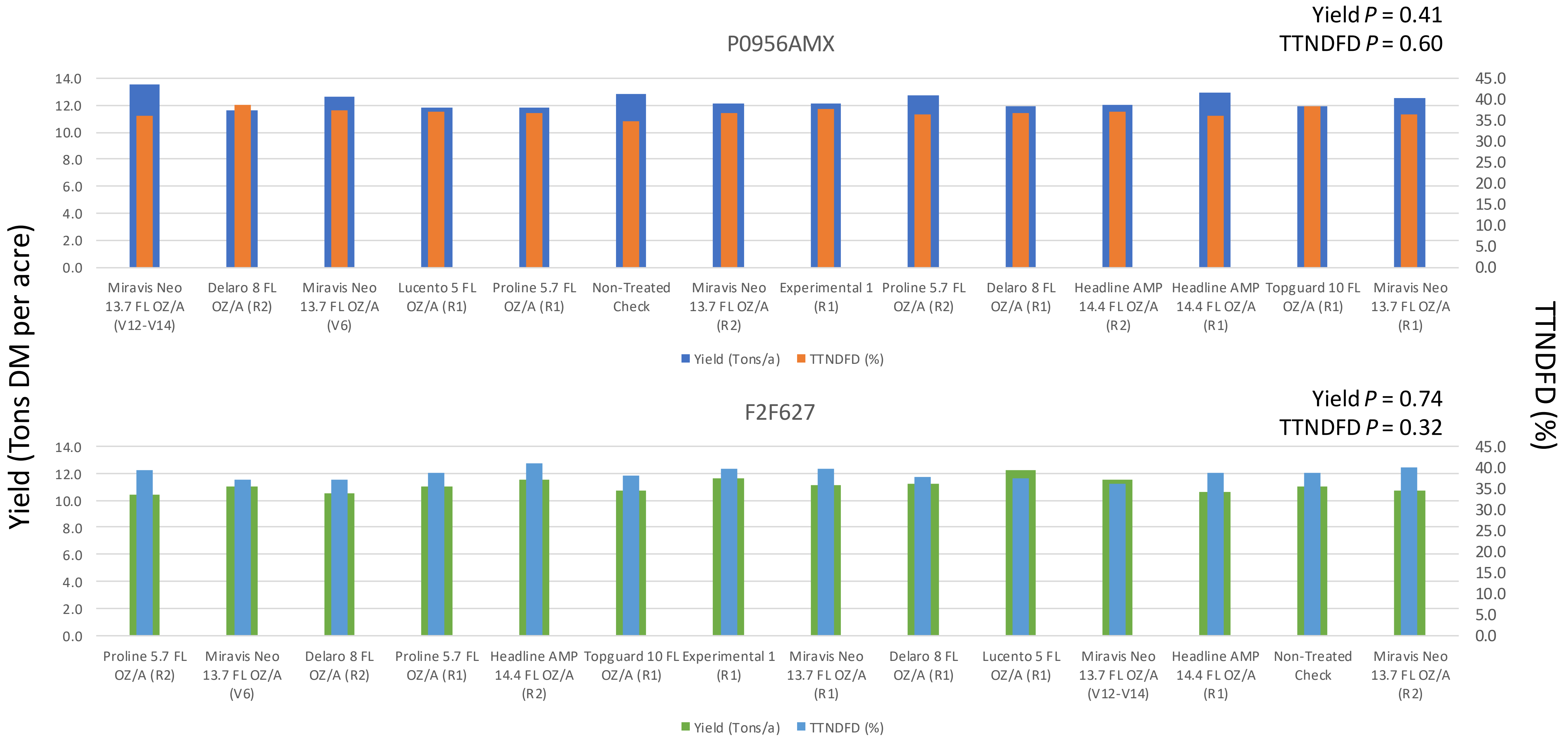
Application Time	Treatment	Year	
		2018	2019
	Non-Treated Check	x	x
V6	Miravis Neo 13.7 FL OZ/A;NIS 0.25%	x	x
V6 R1	Miravis Neo 13.7 FL OZ/A V6;NIS 0.25 % V/V V6 Miravis Neo 13.7 FL OZ/A R1		x
V14	Miravis Neo 13.7 FL OZ/A V12-V14	x	x
R1	Proline 5.7 FL OZ/A	x	x
	Headline AMP 14.4 FL OZ/A	x	x
	Delaro 8 FL OZ/A	x	x
	Miravis Neo 13.7 FL OZ/A	x	x
	Miravis Ace 13.7 FL OZ/A	x	x
	Topguard 10 FL OZ/A	x	x
	Lucento 5 FL OZ/A	x	x
R2	Miravis Neo 13.7 FL OZ/A	x	x
	Proline 5.7 FL OZ/A	x	
	Headline AMP 14.4 FL OZ/A	x	
	Delaro 8 FL OZ/A	x	

R1 Sprays - 07/30/2019

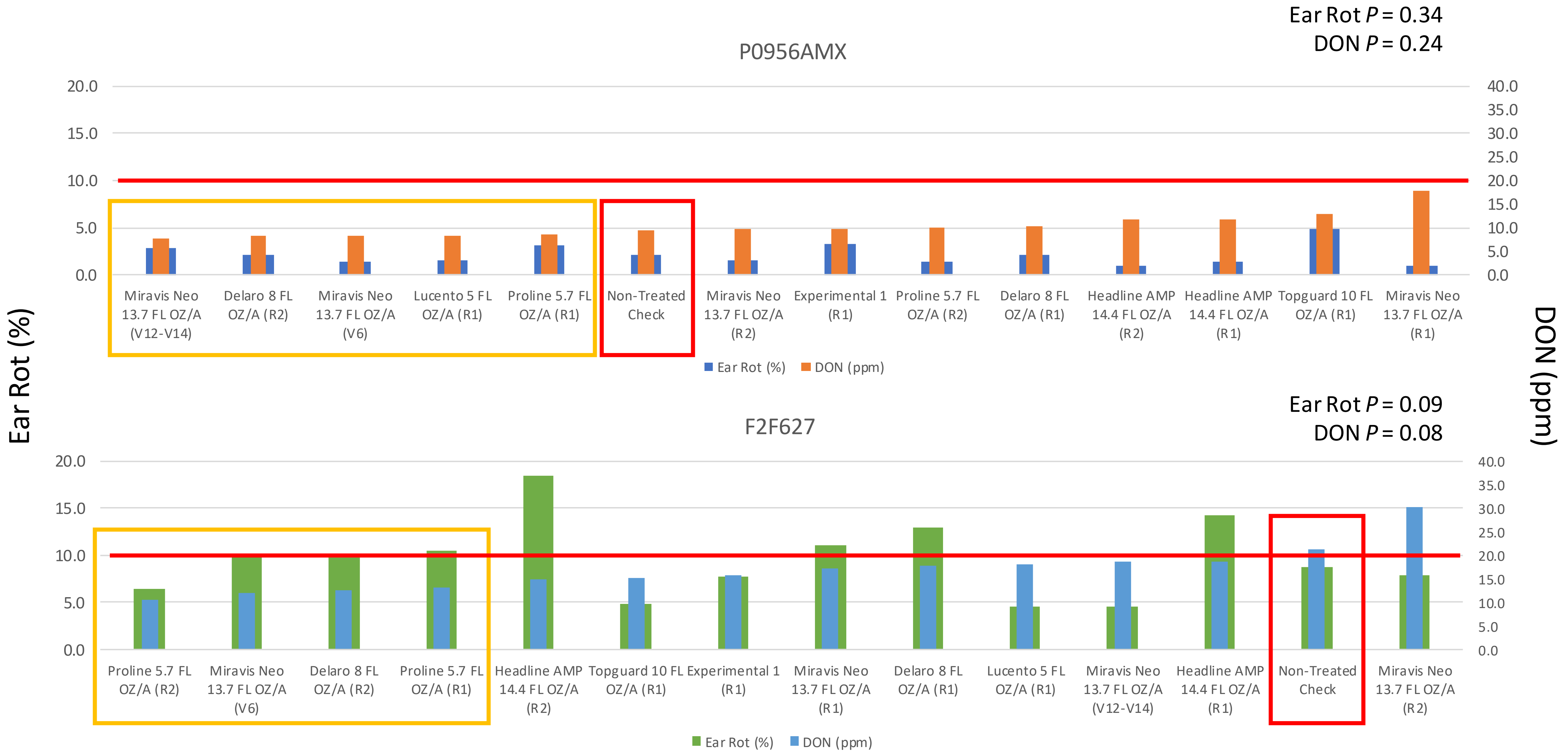
2018-2019 Wisconsin Silage Corn Trials

- Arlington ARS - Arlington, Wisconsin
- Small Plots (15 x 20 ft)
- 2 BMR Hybrids – P0956AMX (109 RM) and F2F627 (109 RM)
- Seeding rate: 35,000 seeds per acre
- Fungicide apps of various products x application timings (V6, V12, R1, R2)
- Harvested with a small plot silage chopper
- Sub-samples of silage taken for forage, and DON analysis (center 2 rows)
- Hand harvested and chopped partition-samples from rows 2 and 5 (separated ear portion from stalk portion)** and tested for DON

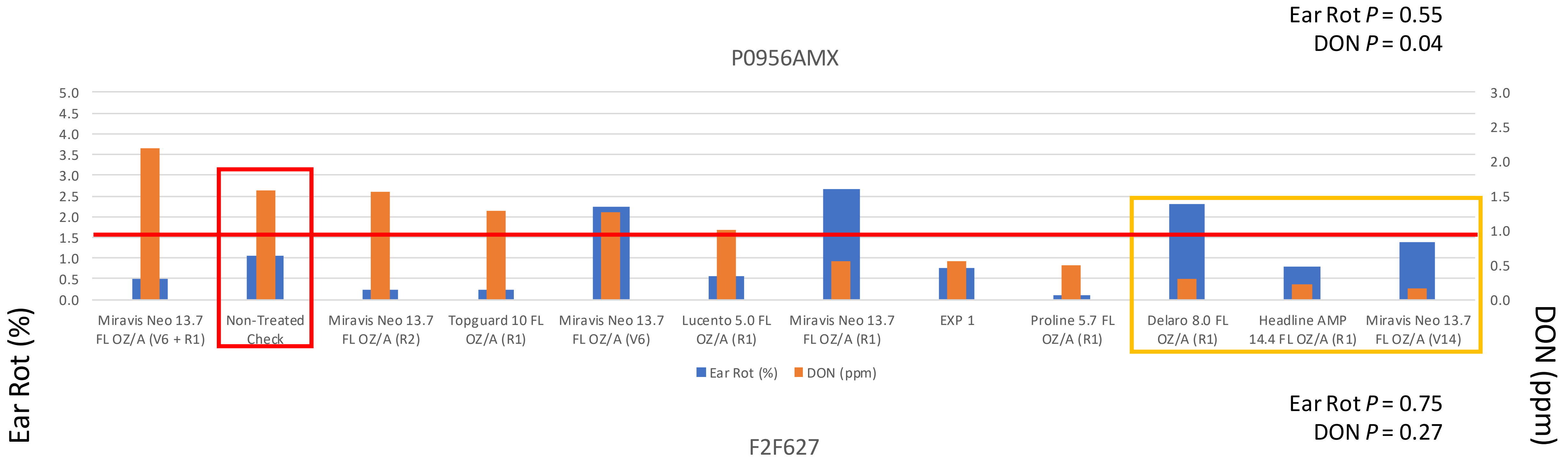
2018 Yield and TTNDFD

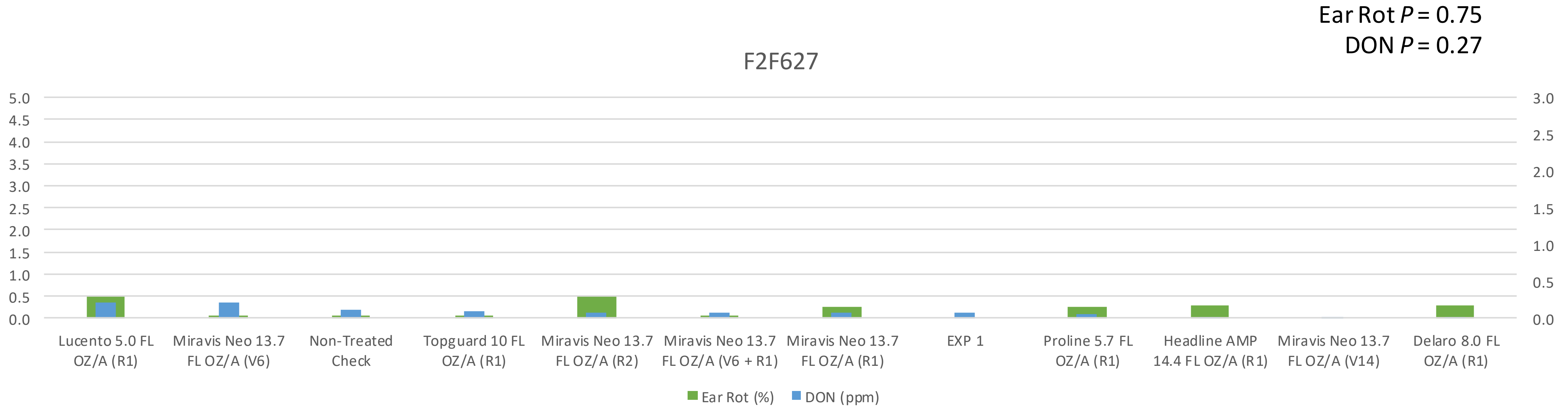


2018 Ear Rot and DON

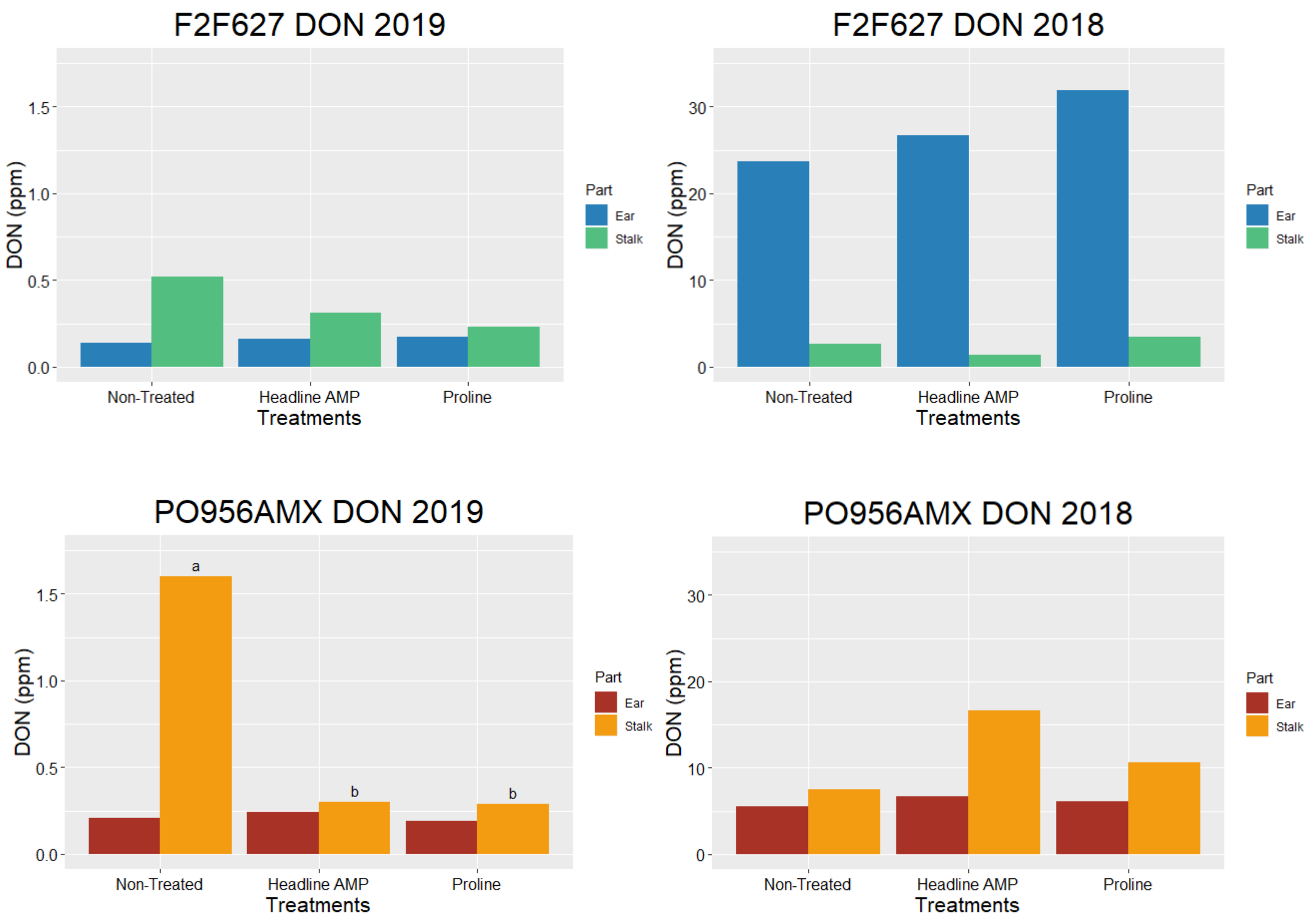


2019 Ear Rot and DON





Plant Part Influences DON Accumulation



2018 Corn-Silage Fungicide Trial – Arlington, WI

	GLS Severity (%)	NCLB Severity (%)	Tar Spot Severity (%)	Ear Rot (%)	DM Yield (Tons/a)	TTNDFD (%)	DON (ppm)
Headline AMP 14.4 FL OZ/A (R2)	2.4 c	17.5 ef	1.4 e	18.4	11.5	40.9	14.9
Delaro 8 FL OZ/A (R2)	3.8 bc	28.8 cde	2.0 ef	9.7	10.5	37.1	12.7
Headline AMP 14.4 FL OZ/A (R1)	1.8 c	36.3 bcd	2.8 def	14.2	10.6	38.7	18.7
Delaro 8 FL OZ/A (R1)	2.1 c	22.5 de	4.3 cde	12.9	11.2	37.8	17.7
Miravis Neo 13.7 FL OZ/A + NIS (V6)	10.5 a	50.0 ab	4.9 cde	10.0	11.0	37.0	12.0
Miravis Neo 13.7 FL OZ/A (R2)	2.4 c	15.0 e	5.5 cde	7.8	10.7	39.9	30.3
Topguard 10 FL OZ/A (R1)	2.4 c	23.8 de	5.6 cde	4.8	10.7	38.1	15.1
Lucento 5 FL OZ/A (R1)	1.0 c	18.8 ef	5.8 bce	4.5	12.2	37.5	18.0
Experimental 1 (R1)	1.4 c	42.5 bc	6.3 b-f	7.7	11.7	39.7	15.7
Miravis Neo 13.7 FL OZ/A (R1)	1.0 c	21.3 de	6.9 a-d	11.1	11.1	39.5	17.2
Proline 5.7 FL OZ/A (R1)	2.1 c	31.3 c-f	7.4 a-d	10.4	11.0	38.5	13.2
Proline 5.7 FL OZ/A (R2)	6.1 b	27.5 cde	8.6 abc	6.5	10.4	39.4	10.7
Non-Treated Check	10.5 a	62.5 a	10.5 ab	8.8	11.0	38.7	21.2
Miravis Neo 13.7 FL OZ/A (V12-V14)	1.4 c	27.5 cde	11.3 a	4.6	11.6	36.2	18.6
F-value	**8.89**	**5.86**	**2.97**	**1.74**	**0.71**	**1.19**	**1.75**
P-value	**<.0001**	**<.0001**	**0.0043**	**0.0901**	**0.7395**	**0.3247**	**0.0880**

In-Field Disease Management Reducing DON

- DON can accumulate in ears AND stalks
  -Farmers should consider that stalks could be a source of DON
- Choose Hybrids with a good balance of resistance to all primary diseases
  -No silver bullet
- Balance DON reduction strategies with foliar disease control
  -Don't get tunnel vision!
- Fungicide may not always reduce DON or foliar diseases to acceptable levels
  -Hard to get fungicide into stalks to reduce stalk infection; Thus, DON still accumulates in stalk portion independent of ear infection control by fungicide applied at R1
  -Have reasonable expectations
- Best all around fungicide timing still likely R1; reduces ear DON levels substantially AND balances foliar disease control
  -Be sure product contains a DMI and not just a sole strobilurin containing product
- Don't forget plant stress can play a major roll in mycotoxin accumulation, fungicide is just part of the management plan
  -Adjust planting populations
  -Manage residue
  -Crop Rotation!
  -Be careful with supplemental irrigation
  -Balance control of ear rot with other diseases (e.g. GLS, NCLB, tar spot)

Smith's Pointers on Making the Fungicide Decision on Corn

<u>Know what your "target disease" is and focus on making good decisions (e.g. Foliar disease vs. ear/stalk disease)</u>

Foliar Diseases

1. **The best time to apply fungicide for foliar disease control in Wisconsin corn is during VT–R1 growth stages.**
2. Use past history of disease, scouting information and weather forecasts to make the decision to spray or not.
3. For diseases such as gray leaf spot and northern corn leaf blight, scout the lower canopy prior to the VT growth stage. If symptoms of these diseases are present on the lower leaves on 50% or more plants, there is a history of these diseases in the field, and weather is warm, wet/humid, then a fungicide might be warranted to protect the upper leaves.
4. Other factors to consider are the susceptibility of the hybrid being grown, the presence of previous crop corn residue and supplemental irrigation.

Ear/Stalk Diseases

1. **The best time to apply fungicide for ear rot control in Wisconsin corn is to target the R1 growth stage with the window of opportunity running about 7-10 days after the start of R1 (Will also effectively control foliar disease active in the field at this timing too).**
2. Use past history of disease, scouting information and weather forecasts to make the decision to spray or not.
3. Other factors to consider are the susceptibility of the hybrid being grown, the presence of previous crop corn residue and supplemental irrigation.
4. Product choice important here; choose a mixed-mode-of-action product that contains a DMI (FRAC group 3) as one of the components

Questions?

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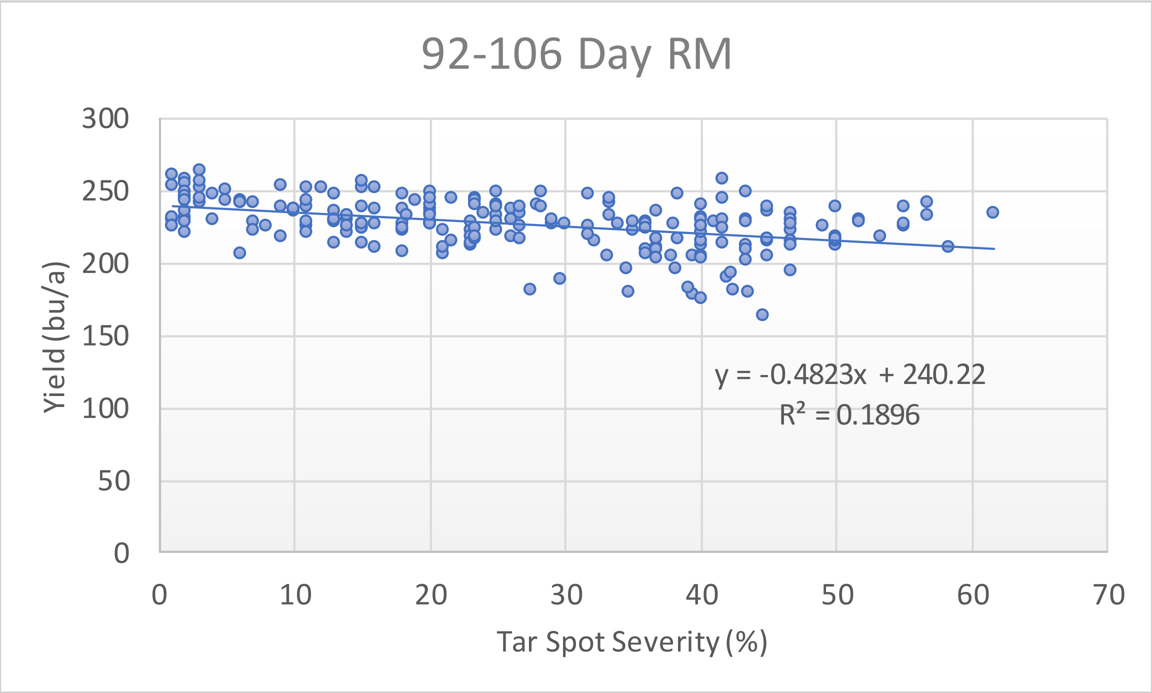
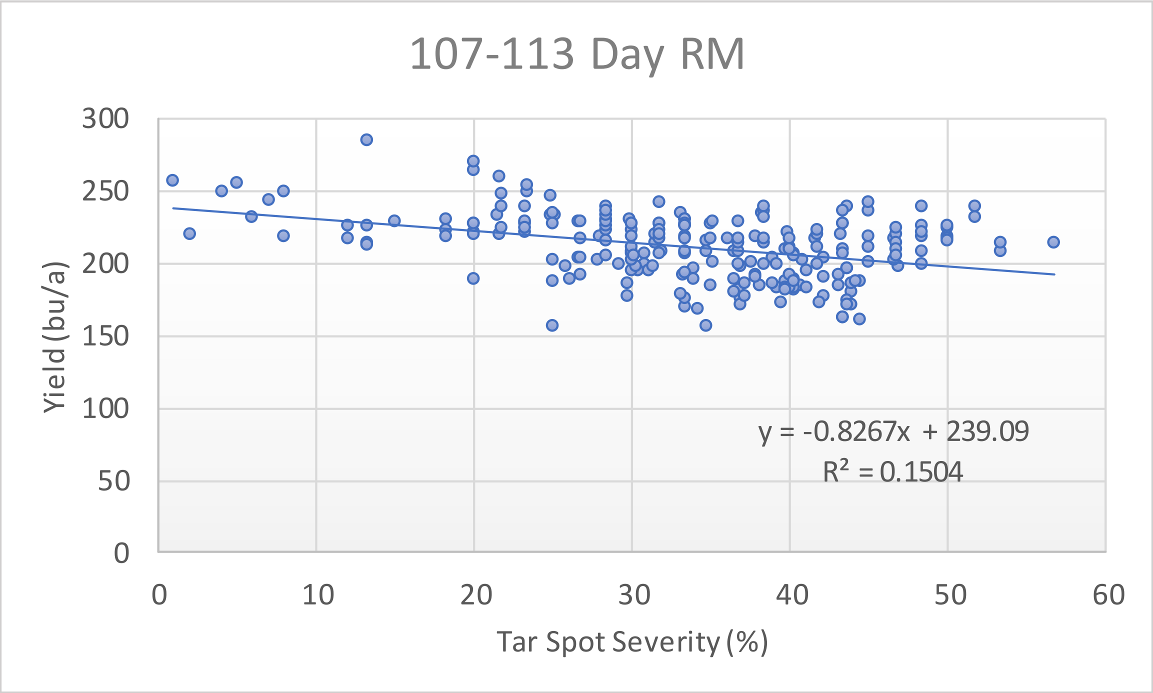
Impact of Tar Spot on Corn Hybrid Yield





*Data from Wisconsin, Michigan, Illinois, and Indiana - 2018

Telenko, D. E. P., Chilvers, M. I., Kleczewski, N., Smith, D. L., Byrne, A. M., Devillez, P., Diallo, T., Higgins, R., Joss, D., Lauer, J., Muller, B., Singh, M. P., Widdicombe, W. D., and Williams, L.A. 2019. How tar spot of corn impacted hybrid yields during the 2018 Midwest epidemic. Crop Protection Network. doi.org/10.31274/cpn-20190729-002

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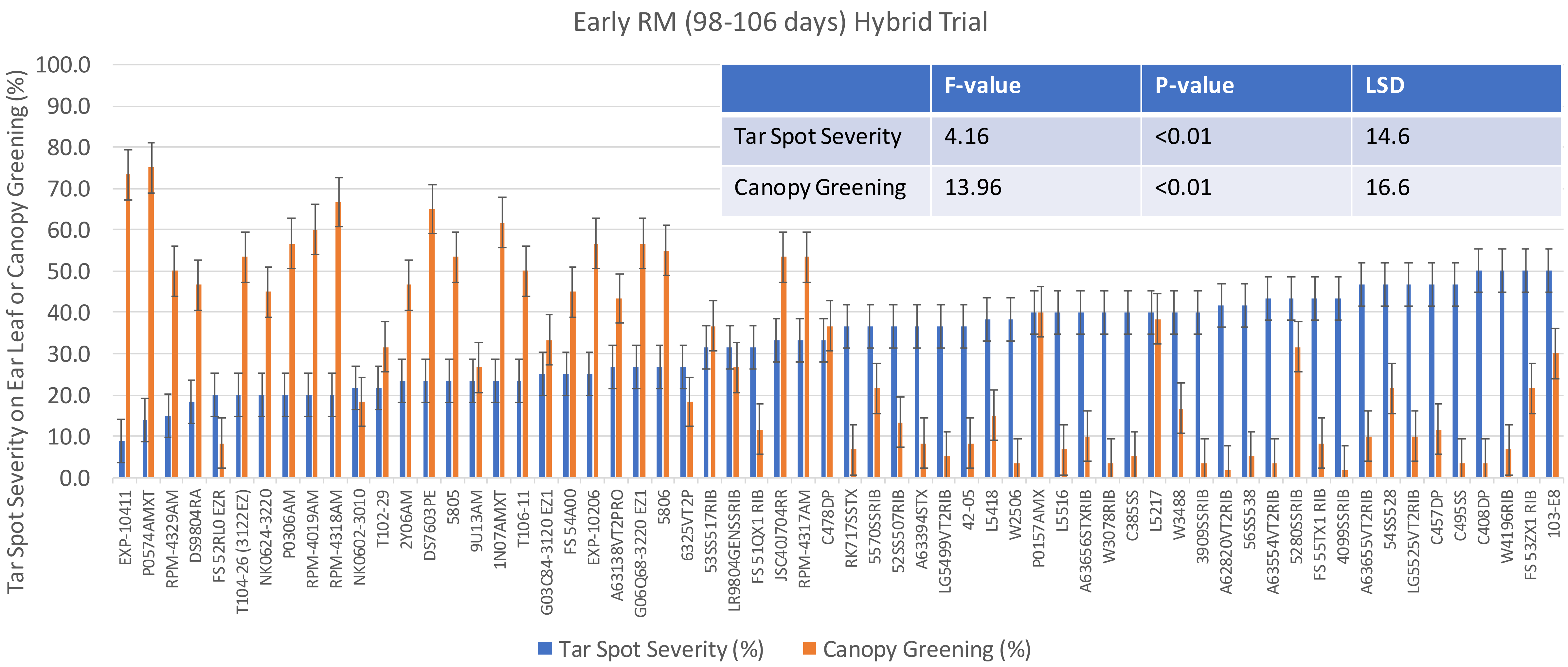
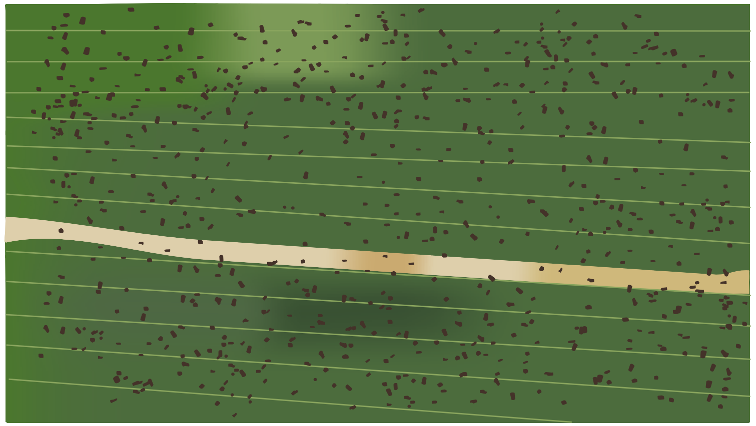
Early RM Hybrid Trial - Montfort, WI (8/31/2018)



	F-value	P-value	LSD
Tar Spot Severity	4.16	<0.01	14.6
Canopy Greening	13.96	<0.01	16.6

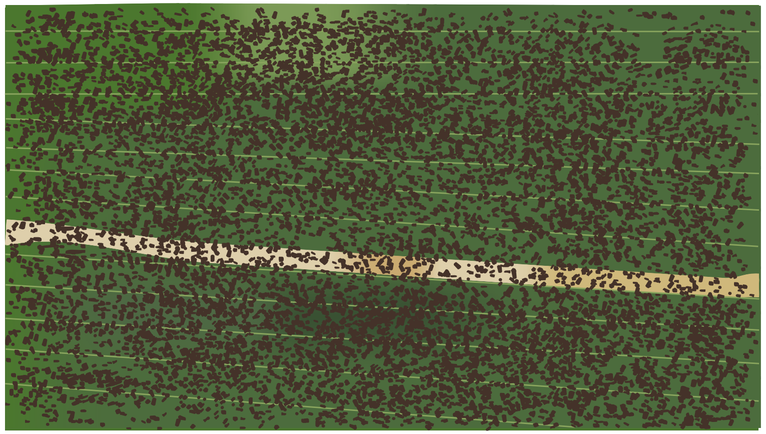
What Does 50% Severity Mean?

5%



10%

50%



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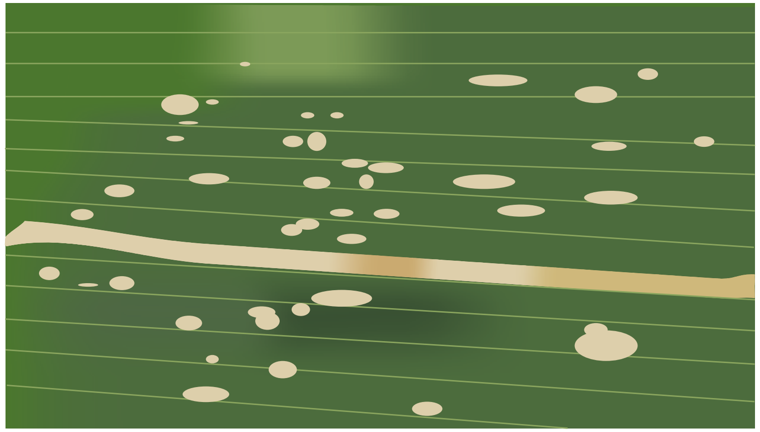

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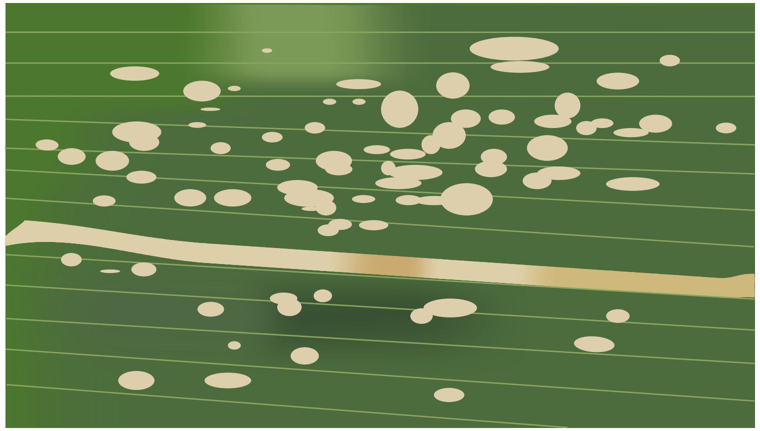
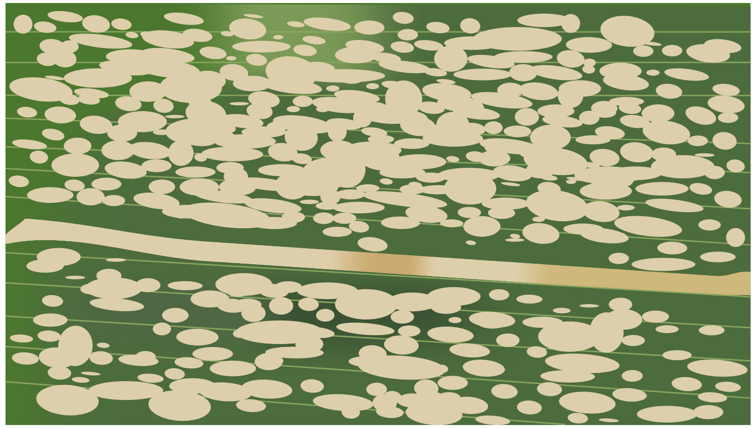
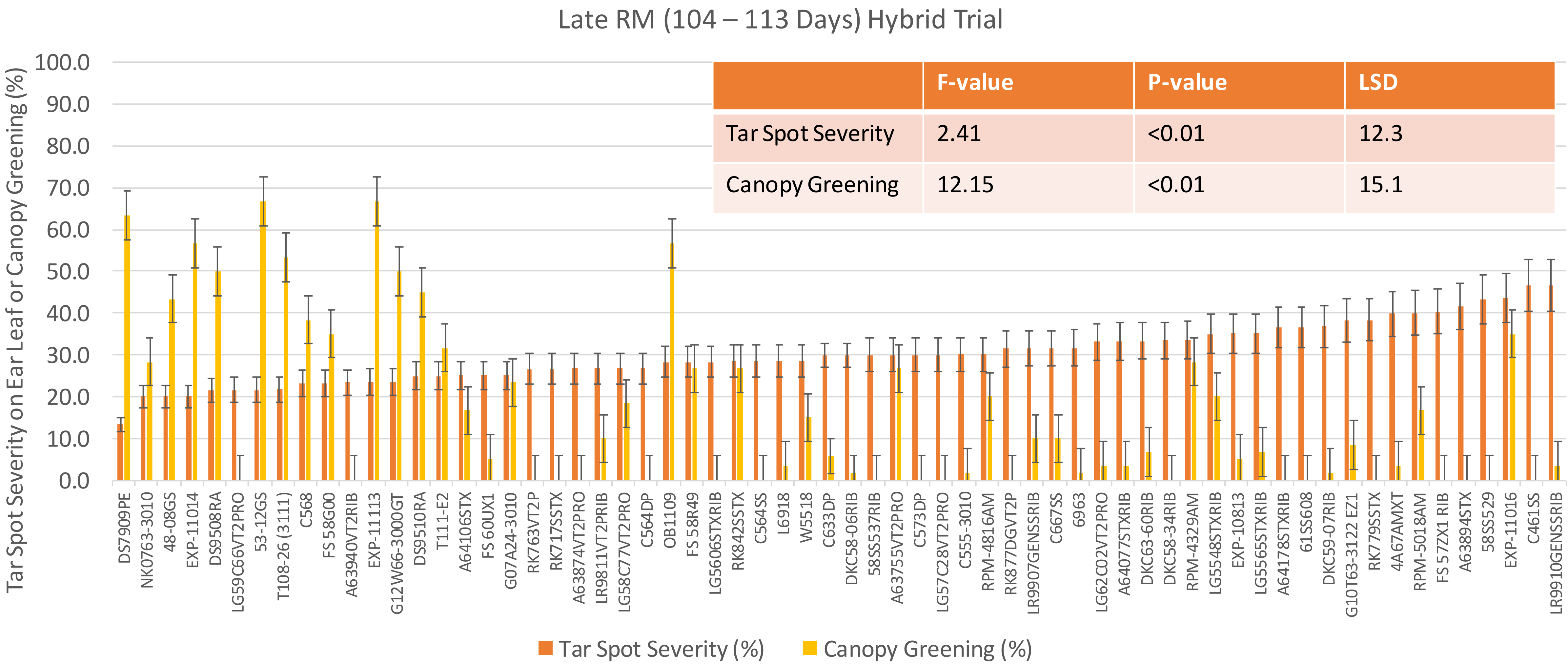


50%



Late RM Hybrid Trial - Montfort, WI (9/4/2018)



	F-value	P-value	LSD
Tar Spot Severity	2.41	<0.01	12.3
Canopy Greening	12.15	<0.01	15.1

Fungicide Efficacy in 2019 – Spray Rodeo

	Canopy Temperature at R3 (C)	Tar Spot Severity Late R5 (%)	Stalk Rot Severity (%)	Canopy Greening (%)	Yield (bu/a)
Trivapro 13.7 fl oz/a (VT/R1)	22.3	5.3 a	10.4	40.0	285.7
Delaro 8.0 fl oz/a (VT/R1)	22.2	4.3 ab	9.2	43.8	283.7
Non-Treated Check 1	22.6	4.3 ab	24.8	32.5	276.5
Trivapro 13.7 fl oz/a (V12)	22.6	3.8 abc	19.8	45.0	282.0
Lucento 5.0 fl oz/a (VT/R1)	22.2	3.8 abc	20.4	38.8	280.0
Non-Treated Check 2	22.5	3.8 abc	9.6	33.8	285.3
Headline AMP 10.0 fl oz/a (R3)	22.4	3.8 abc	9.9	41.3	285.2
Miravis Neo 13.7 fl oz/a (V12)	22.7	3.5 a-e	0.0	50.0	285.6
Miravis Neo 13.7 fl oz/a (V6) + NIS	23.0	3.1 a-e	20.3	37.5	280.2
Quilt Xcel 10.4 fl oz/a (VT/R1)	22.5	3.0 a-e	9.6	40.0	282.8
Lucento 5.0 fl oz/a (R3)	22.6	2.7 a-e	9.6	47.5	290.8
Trivapro 13.7 fl oz/a (R3)	22.9	2.6 a-e	15.7	40.0	273.7
Miravis Neo 13.7 fl oz/a (R3)	22.4	2.5 b-e	0.0	43.8	282.1
Veltyma 7.0 fl oz/a (VT/R1)	22.4	2.5 b-e	9.9	42.5	285.8
Trivapro 13.7 fl oz/a (V6) + NIS	22.6	2.4 b-e	9.8	30.0	278.8
Revytek 8.0 fl oz/a (VT/R1)	22.2	2.1 b-e	9.9	45.0	288.1
Headline AMP 10.0 fl oz/a (VT/R1)	22.7	1.9 cde	9.6	47.5	283.4
Revytek 8.0 fl oz/a (R3)	22.7	1.9 de	31.1	50.0	287.9
Miravis Neo 13.7 fl oz/a (VT/R1)	22.9	1.8 ef	9.9	47.5	293.6
Quilt Xcel 10.4 fl oz/a (R3)	22.7	1.8 ef	10.4	42.5	288.6
Veltyma 8.0 fl oz/a (VT/R1)	22.9	1.8 ef	21.1	42.5	290.7
Veltyma 7.0 fl oz/a (R3)	22.5	1.7 ef	13.7	37.5	279.1
Experimental 1 (VT/R1)	22.8	1.7 ef	9.6	42.5	298.0
Delaro 8.0 fl oz/a (R3)	22.7	1.6 ef	0.0	47.5	290.2
F-value	0.82	2.00	2.00	1.07	0.41
P-value	NS	0.01	NS	NS	NS

Uniform Fungicide Trials for Tar Spot - 2019

Trial Information

Location	Hybrid	Planting date	VT/R1 application	Irrigation (Y/N)	Harvest date	1st report of tar spot in trial
Illinois (Freeport)	P0306Q	24 May	14 Aug	N	8 Nov	23 Aug
Indiana (Pinney)	W2585SSRIB/ P9998AM	8 Jun	7, 8, or 9 Aug	Y/N	25 and 28 Oct	13 Jul
Michigan (Allegen)	G09Y24-522A.OEZ	3 Jun	7 Aug	Y	NA	8 Aug
Wisconsin (Arlington)	Jung 56SS538	13 May	31 Jul	Y	30 Oct	5 Sep

Uniform Fungicide Trials for Tar Spot – Tar Spot Severity on Ear Leaf in 2019 (8 Trials)

Treatments (n)	Rate	Illinois (1)	Indiana (5)	Michigan (1)	Wisconsin (1)	Mean
Revytek (4)	8	.	7.1 b	.	.	**4.61 b**
Affiance (4)	10	.	.	1.6 ab	.	**4.90 b**
Veltyma (20)	7	8.1 d	7.5 b	.	.	**5.24 b**
Headline (20)	12	9.5 bc	8.4 b	1.1 b	1.9	**5.28 b**
Aproach Prima (16)	6.8	7.1 d	8.2 b	1.4 ab	2.0	**5.46 b**
Delaro (24)	12	9.2 bc	10.1 b	1.8 ab	2.2	**6.76 b**
Topguard (20)	7	9.8 ab	10.7 b	2.2 ab	1.7	**6.91 b**
Headline AMP (16)	14.4	.	8.7 b	2.8 ab	2.3	**7.29 b**
Lucento (12)	5.5	.	12.0 b	2.6 ab	.	**7.64 b**
Miravis Neo (28)	13.7	9.9 ab	10.9 b	3.5 a	2.2	**7.92 ab**
Tilt (4)	4	10.3 ab	.	.	.	**8.08 ab**
Trivapro (28)	13.7	9.4 bc	13.0 ab	2.8 ab	2.1	**8.13 ab**
Domark (4)	6	.		2.5 ab	.	**8.68 ab**
Quilt Xcel (20)	14	.	13.0 ab	2.7 ab	2.9	**8.76 ab**
Proline (12)	5.7	.	14.9 ab	2.9 ab	2.5	**8.84 ab**
Revysol (4)	8	.	.	.	3.0	**9.82 a**
Nontreated control (8)		11.4 a	23.9 a	3.1 ab	3.3	**13.42 a**
	F-Value	11.32	9.99	2.52	1.52	9.64
	P-Value	0.0001	0.0001	0.0118	0.1809	0.0001

Fungicide applications made at VT/R1. Mean separation Tukey-Kramer P=0.05.

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Uniform Fungicide Trials for Tar Spot – Yield in 2019 (8 Trials)

Treatments (n)	Rate	Illinois (1)	Indiana (5)	Michigan (1)	Wisconsin (1)	Mean
Revytek (4)	8	.	221.51 a	.	.	**226.08 ab**
Affiance (0)	10	.	.	.	.	
Veltyma (20)	7	215.28 ab	219.59 a	.	.	**225.06 ab**
Headline (14)	12	.	208.69 ab	.	261.88	**216.21 abc**
Aproach Prima (10)	6.8	183.10 ab	208.46 ab	.	249.83	**204.66 bc**
Delaro (19)	12	224.02 a	218.66 a	.	263.93	**226.61 a**
Topguard (16)	7	201.48 ab	211.96 ab	.	248.41	**213.78 abc**
Headline AMP (9)	14.4	168.09 b	217.35 a	.	276.28	**215.01 abc**
Lucento (8)	5.5	.	210.38 ab	.	.	**217.21 abc**
Miravis Neo (24)	13.7	210.88 ab	216.22 a	.	266.65	**222.78 ab**
Tilt (4)	4	176.96 ab	.	.	274.28	**185.99 c**
Trivapro (24)	13.7	222.01 a	213.91 ab	.	.	**219.56 abc**
Domark (0)	6	.	.	.	.	
Quilt Xcel (16)	14	.	215.05 ab	.	262.51	**221.24 abc**
Proline (8)	5.7	.	205.35 ab	.	245.96	**209.14 abc**
Revysol (4)	8	.	.	.	3.0	**237.32 a**
Nontreated control (8)		209.78 ab	195.51 b	.	244.85	**204.72 bc**
	F-Value	11.32	4.67		1.52	5.47
	P-Value	0.0001	0.0001		0.1809	0.0001

Fungicide applications made at VT/R1. Mean separation Tukey-Kramer P=0.05.

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2019 Uniform Tar Spot Epidemiology and Modeling Trials

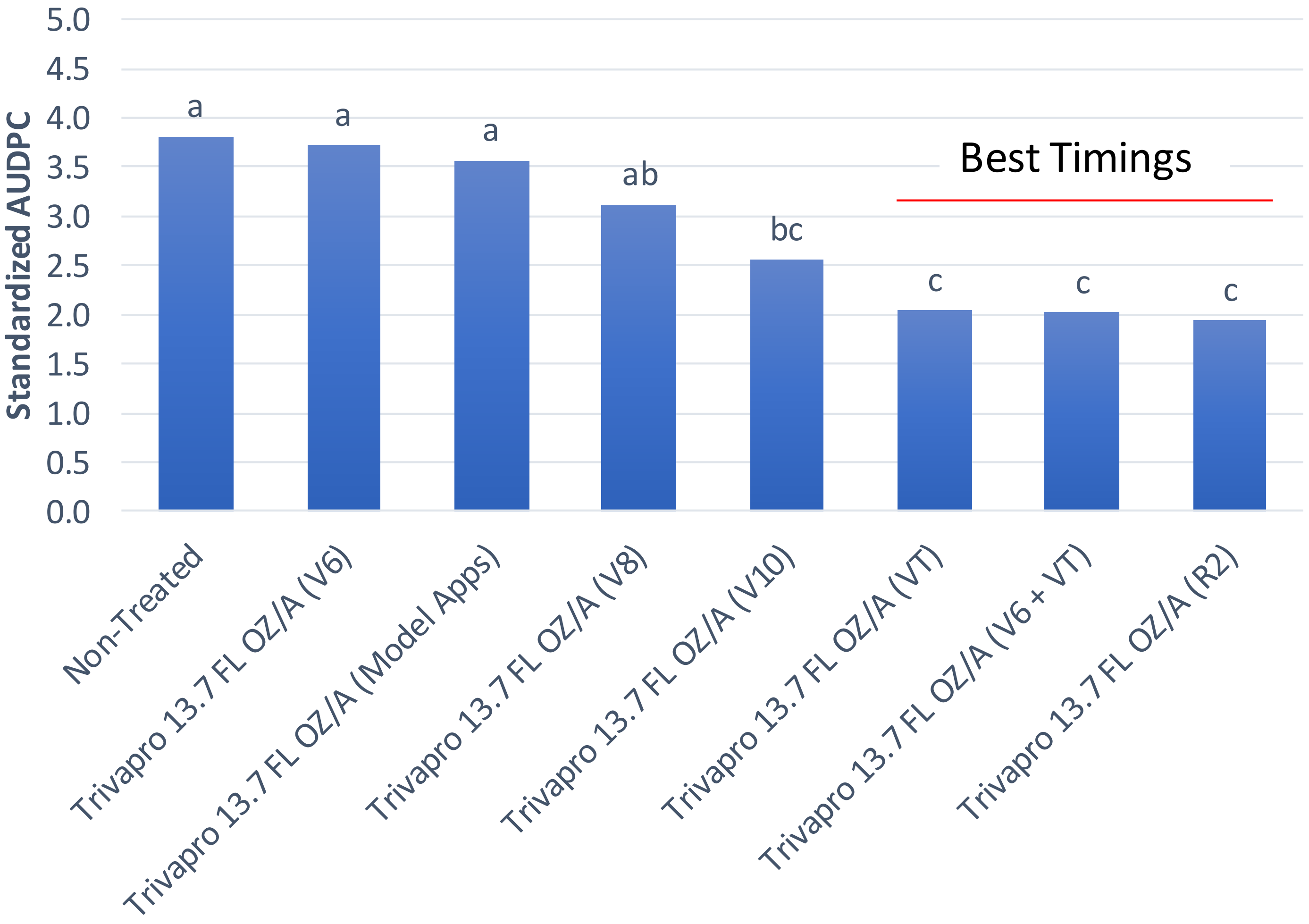
Main Goals

1. To test fungicide application timing using just one fungicide chemistry, with efficacy against tar spot.
2. To test version 1 of the tar spot prediction tool.

Trt No.	Active ingredient	Tradename (company)	Rate fl oz/A	Application Timing
1	Non-treated	--	--	--
2	Benzovindiflupyr 2.9% Azoxystrobin 10.5% Propiconazole 11.9%	Trivapro (Syngenta)	13.7	V6
3	Benzovindiflupyr 2.9% Azoxystrobin 10.5% Propiconazole 11.9%	Trivapro (Syngenta)	13.7	V8
4	Benzovindiflupyr 2.9% Azoxystrobin 10.5% Propiconazole 11.9%	Trivapro (Syngenta)	13.7	V10
5	Benzovindiflupyr 2.9% Azoxystrobin 10.5% Propiconazole 11.9%	Trivapro (Syngenta)	13.7	VT
6	Benzovindiflupyr 2.9% Azoxystrobin 10.5% Propiconazole 11.9%	Trivapro (Syngenta)	13.7	R2
7	Benzovindiflupyr 2.9% Azoxystrobin 10.5% Propiconazole 11.9%	Trivapro (Syngenta)	13.7	V6+VT
8	Benzovindiflupyr 2.9% Azoxystrobin 10.5% Propiconazole 11.9%	Trivapro (Syngenta)	13.7	Based on Tarspotter App

2019 Uniform Tar Spot Epidemiology and Modeling Trials

- 6 Locations with tar spot data in 2019
  - -Arlington, WI
  - -Lancaster, WI
  - -Allegan, MI
  - -Wanatah, IN
  - -Freeport, IL
  - -Urbana, IL
- Model-based Spray Applications
  - -V6 Applications: Arlington and Allegan
  - -V6+V8 Applications: Lancaster
  - -R1 Applications: Freeport
  - -No Applications: Wanatah and Urbana



Disease Prediction is Key - Tarspotter

- **Development and validation work supported by Wisconsin Corn Promotion Board and National Corn Growers Association**
- Sporecaster set the framework to build on for deploying models for other diseases
- Platform is easy to use and flexible
- Simply retrain the models using the biologically appropriate weather variables and moving averages
- Validate, retrain, validate – this is an iterative process

2019 Model Refinement – Version 2.0

Version 1.0 Model

- Non-intercept model
- 30-day moving average of **Mean Temperature**
- 30-day moving average of **Mean Relative Humidity**

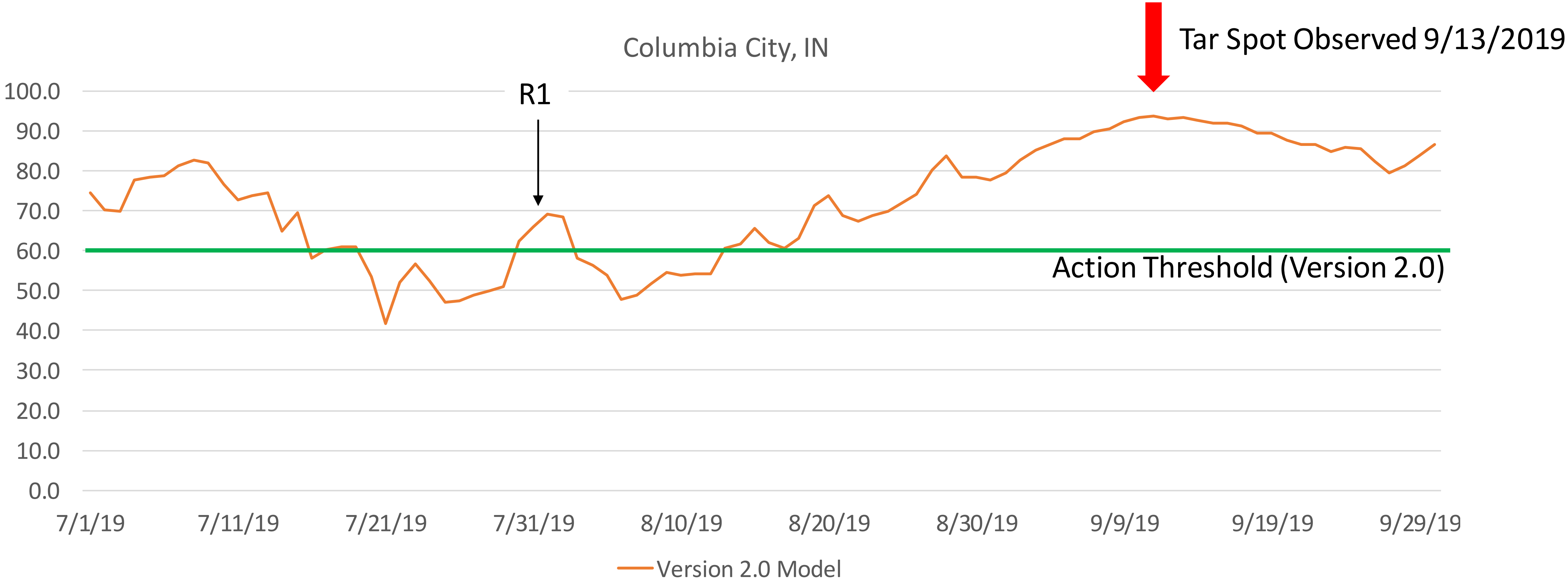
Association of Predicted Probabilities and Observed Responses			
Percent Concordant	84.3	**Somers' D**	0.739
Percent Discordant	10.4	**Gamma**	0.78
Percent Tied	5.3	**Tau-a**	0.358
Pairs	9922	**c**	0.869

Version 2.0 Model

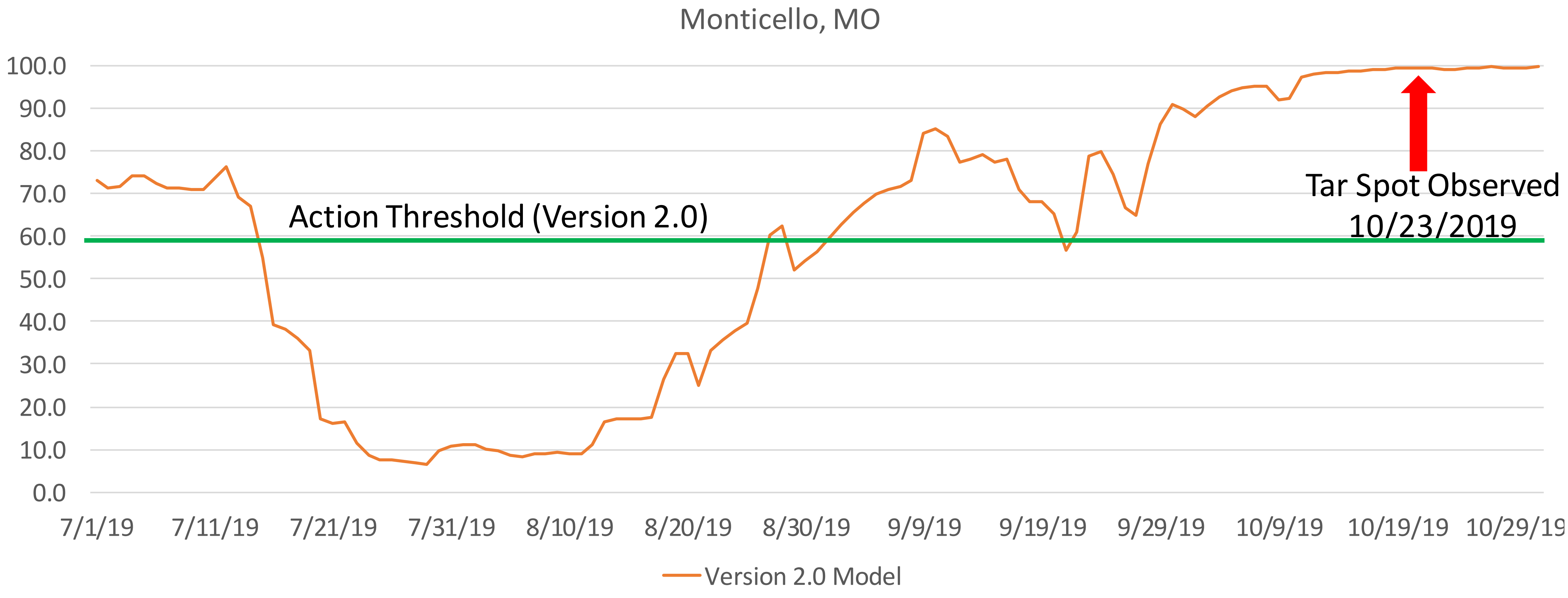
- Intercept model
- Fungicide applied? (0 or 1)
- 30-day moving average of **Mean Temperature**
- 30-day moving average of **Mean Dew Point**
- 30-day **Total Rainfall**

Association of Predicted Probabilities and Observed Responses			
Percent Concordant	85.7	**Somers' D**	0.721
Percent Discordant	13.6	**Gamma**	0.73
Percent Tied	0.7	**Tau-a**	0.309
Pairs	29928	**c**	0.860

2019 Epidemic – Columbia City, IN



Area of New First Report in 2019 – Monticello, MO



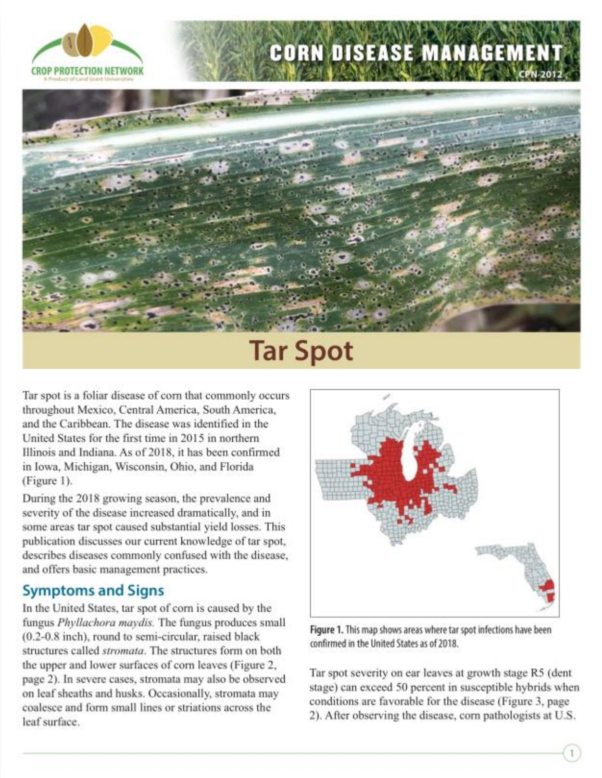
The 'Tar Spot Take Home'

- **There will tar spot in 2020 – Pay attention to Wisconsin Crop Manager**
  - -Severity level will be a function of the hybrid planted, weather conditions, and if epidemic initiates earlier vs. later in the season (ex 2018 vs. 2019) – Episodic disease like white mold or Fusarium head blight
  - -The 2018 epidemic was so problematic, because tar spot started in some fields before tasseling
- **The tar spot fungus can overwinter in the upper Midwest**
  - -Rotation, rotation, rotation
  - -Tillage may help reduce or delay onset of disease – However, inoculum can travel long distances, so tillage won't solve it all
- **Some hybrids are more resistant than others**
  - -Resistance not tied to brand – Every hybrid stands on its own
  - -Strong hybrid resistance can be overcome by a favorable disease environment (Manage irrigation!)
- **Fungicide application can reduce tar spot severity**
  - -Product important (QoI + DMI or QoI + DMI + SDHI)
  - --Timing very important
  - -Application needs to occur close to the onset of the epidemic
- **Scout early = Catch tar spot early**
  - -Tarspotter – Being tested again in 2020 to aid in prediction
  - -Have infrastructure in place to launch as a research smartphone application
  - -Will push predictions via newsletters, blogs, and Twitter in 2020

More Information

- Visit the Crop Protection Network Site and download fact sheet CPN-2012 (https://cropprotectionnetwork.org/download/5830/)

- YouTube Video (https://youtu.be/bY4lCwsyP28)



CROP PROTECTION NETWORK

CORN DISEASE MANAGEMENT

CPN-2012

Tar Spot

Tar spot is a foliar disease of corn that commonly occurs throughout Mexico, Central America, South America, and the Caribbean. The disease was identified in the United States for the first time in 2015 in northern Illinois and Indiana. As of 2018, it has been confirmed in Iowa, Michigan, Wisconsin, Ohio, and Florida (Figure 1).

During the 2018 growing season, the prevalence and severity of the disease increased dramatically, and in some areas tar spot caused substantial yield losses. This publication discusses our current knowledge of tar spot, describes diseases commonly confused with the disease, and offers basic management practices.

Symptoms and Signs

In the United States, tar spot of corn is caused by the fungus *Phyllachora maydis*. The fungus produces small (0.2-0.8 inch), round to semi-circular, raised black structures called *stromata*. The structures form on both the upper and lower surfaces of corn leaves (Figure 2, page 2). In severe cases, stromata may also be observed on leaf sheaths and husks. Occasionally, stromata may coalesce and form small lines or striations across the leaf surface.

Figure 1. This map shows areas where tar spot infections have been confirmed in the United States as of 2018.

Tar spot severity on ear leaves at growth stage R5 (dent stage) can exceed 50 percent in susceptible hybrids when conditions are favorable for the disease (Figure 3, page 2). After observing the disease, corn pathologists at U.S.

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