Tar spot in corn
Managing a poorly understood disease
What do we know and what do we need to know?

Dr. Nathan Kleczewski
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University of Illinois
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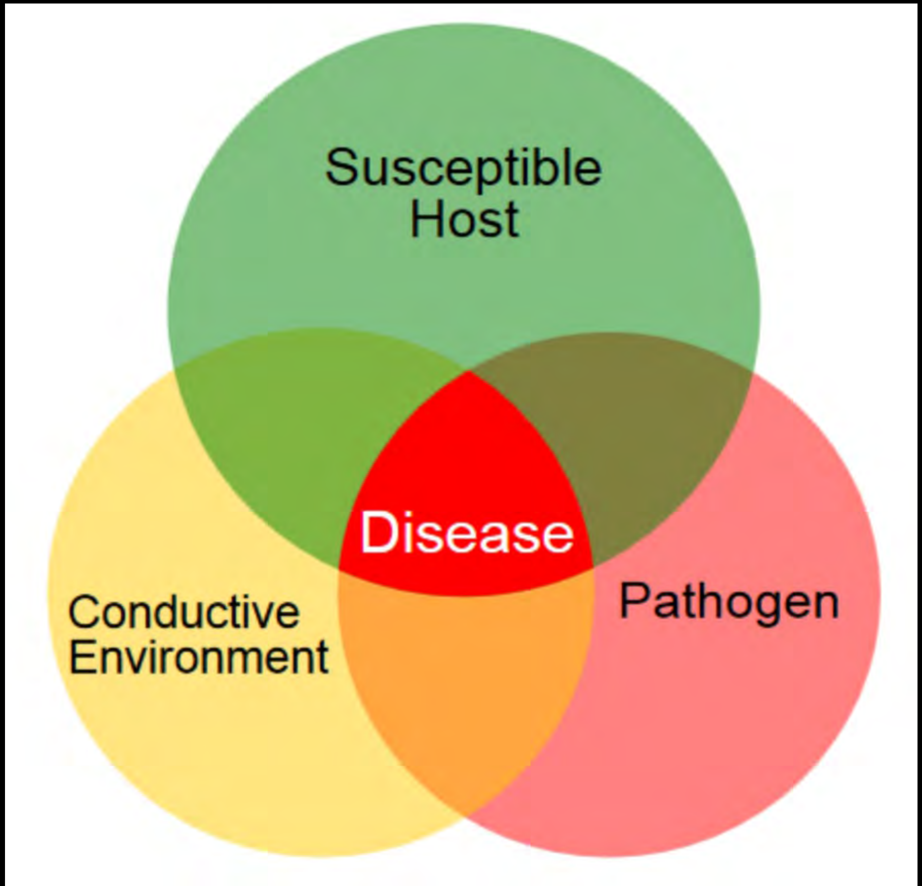
Illinois Field crop disease hub: **cropdisease.cropsciences.Illinois.edu**
Twitter: @**ILplantdoc**

What Causes Plant Diseases?

Correct species, cultivar, growth stage



Correct temperature, moisture, light, etc.

Correct species, pathovar, race, aggressive, growth stage

Goals of Disease Management

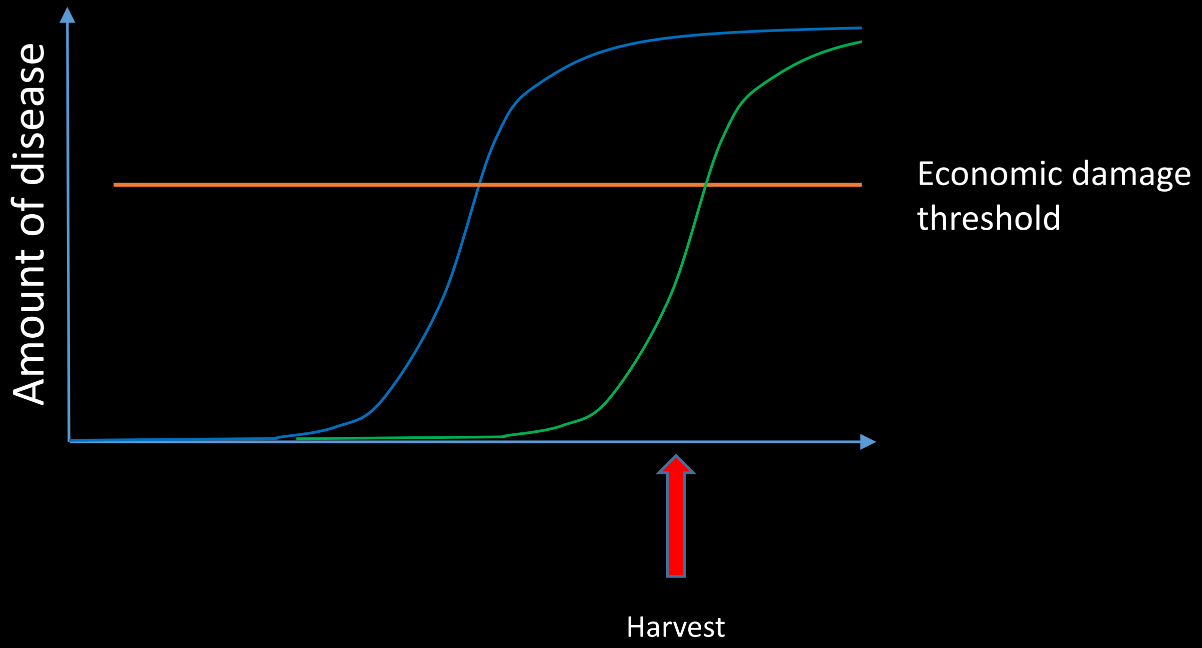
Economic threshold

Amount of disease needed to cause sufficient disease to warrant control treatment

Crop damage > control cost

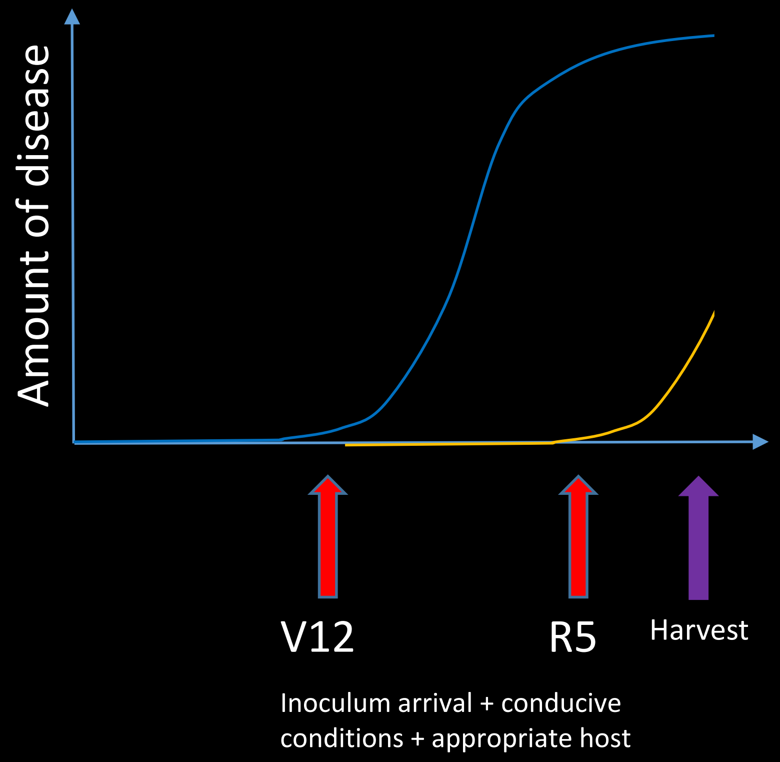
IDM helps push disease progress curve to the right

N.Kleczewski 2019



What other factors impact effects of disease on yield?

- When it arrives relative to plant growth
- How fast pathogen reproduces
  - Biological components of the pathogen
  - Resistance level of hybrid
  - Environment
- Type of damage or effects on host
  - Necrotroph vs biotroph
  - Foliar vs seed/root/stalk



N Kleczewski 2019

Tar Spot on Corn

- First identified in Corn in Mexico
  - Early 1900's
  - Cool, moderate climates
    - Mountains, near rivers
- Common, severe disease in Mexico
  - 50% disease losses
- First detected in 2015 in Illinois and Indiana
  - Largely ignored until 2018

DISEASE NOTES

OPEN

First Report of Tar Spot on Corn Caused by *Phyllachora maydis* in the United States

G. Ruhl, M. K. Romberg, S. Bissonnette, D. Plewa, T. Creswell, and K. A. Wise

Affiliations

Published Online: 1 Apr 2016 | https://doi.org/10.1094/PDIS-12-15-1506-PDN

e-Xtra

TOOLS SHARE

In early September 2015, the Purdue Plant and Pest Diagnostic Lab (PPDL) received leaves of hybrid corn (*Zea mays* L.) from Carroll and Cass counties, Indiana, and Bureau, Dekalb, and LaSalle counties, Illinois, showing small (0.5 to 1.5 mm), black, circular, raised structures on the epidermis of leaves. The black structures were observed on both healthy and necrotic tissue and were surrounded by narrow

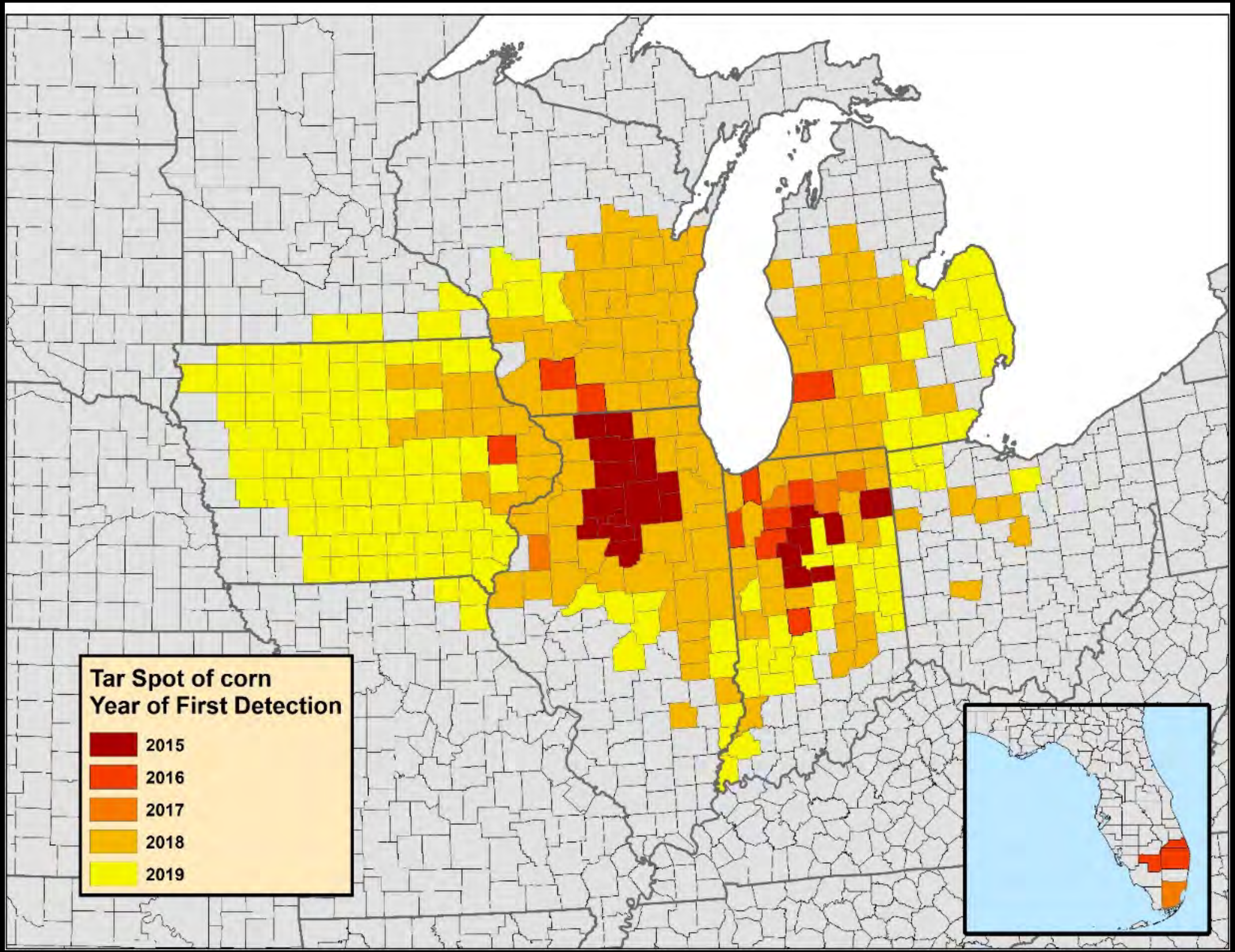
Tar spot overall impacts on yield

- In 2018: 25-60 bu / A losses in Midwestern corn production
  -approximately 9 billion lbs. grain lost across the region

- 2019: much less severe in IL : 5-10 bu / A losses in severe cases (NW part of state), Pockets of increased severity in IN, MI

- Similar to many widespread diseases, there will be pockets of greater severity every season depending on environment and host growth stage/susceptibility

- The number of these pockets and area affected likely will continue to increase as disease spreads and establishes
  e.g. Grey leaf spot, Fusarium head blight, white mold



Kleczewski et. al Documenting the spread, establishment, and severity of tar spot, caused by *Phyllachora maydis*, in the United States corn crop. 20XX In prep




Structures embedded within black fungal tissue- varies from few to several- each structure contains many ascospores

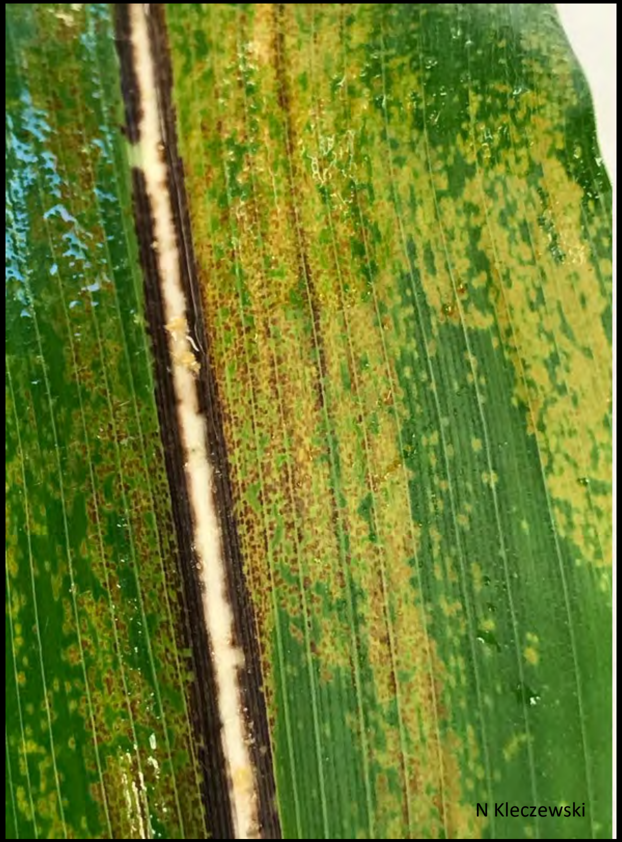
More black fungal tissue= more spore bearing structures = more spores

August 3rd 2018 DeKalb, IL Upper Canopy (VT July 6th)

August 27th 2018 DeKalb, IL Late Sweet Corn V4ish

Look Alike Disorders

- Physoderma Brown Spot on Corn
- No raised black structures
- Lines or strips of spots on foliage
- Discolored midrib

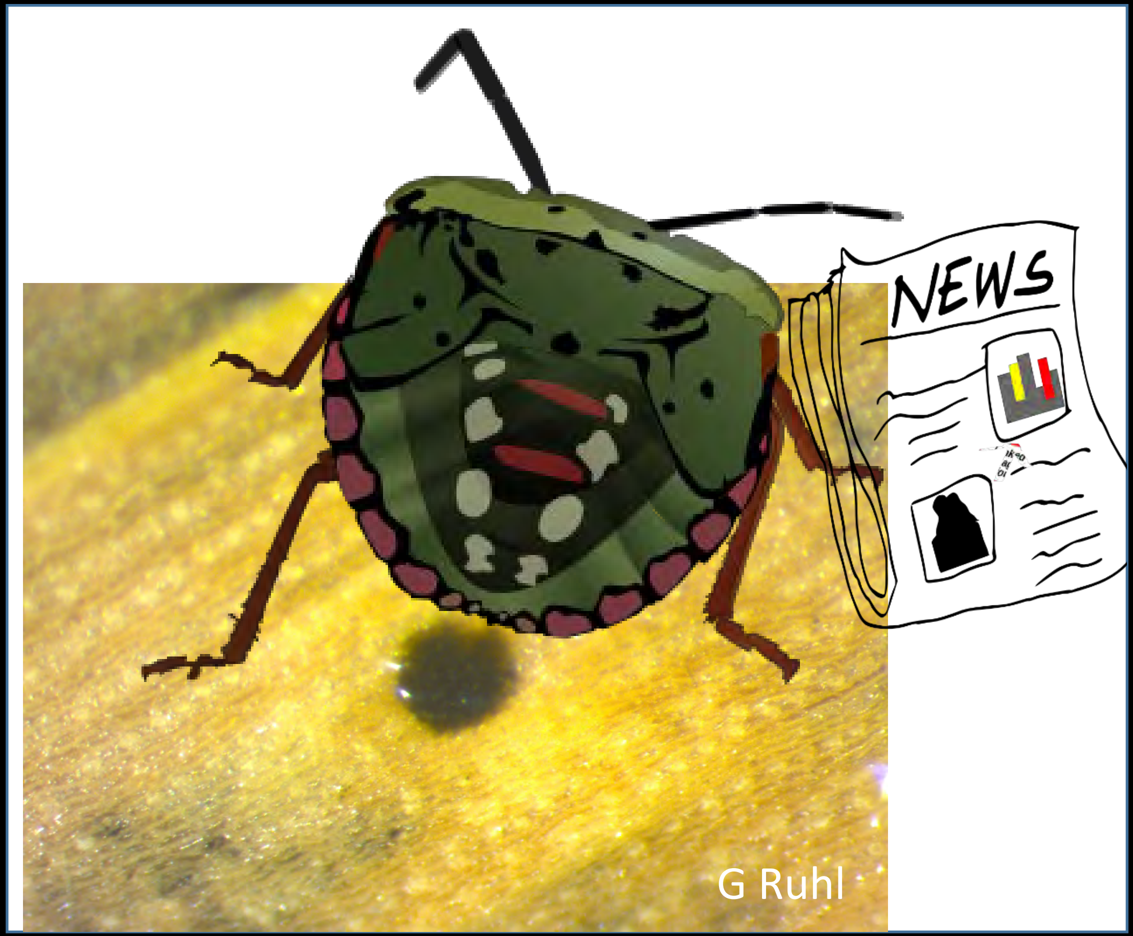


Look Alike Disorders

- Mature rust
  - Southern or Common
- Spores will rub off
- No white exudates
- Tissue ruptures

Look Alike Disorders

- Insect frass: “bug doo”
- May be glossy and wet in appearance, or dry and “lumpy”
- Will wash or rub off
- Number 1 cause of misdiagnosed Tar spot in 2019



Phyllachora spp.

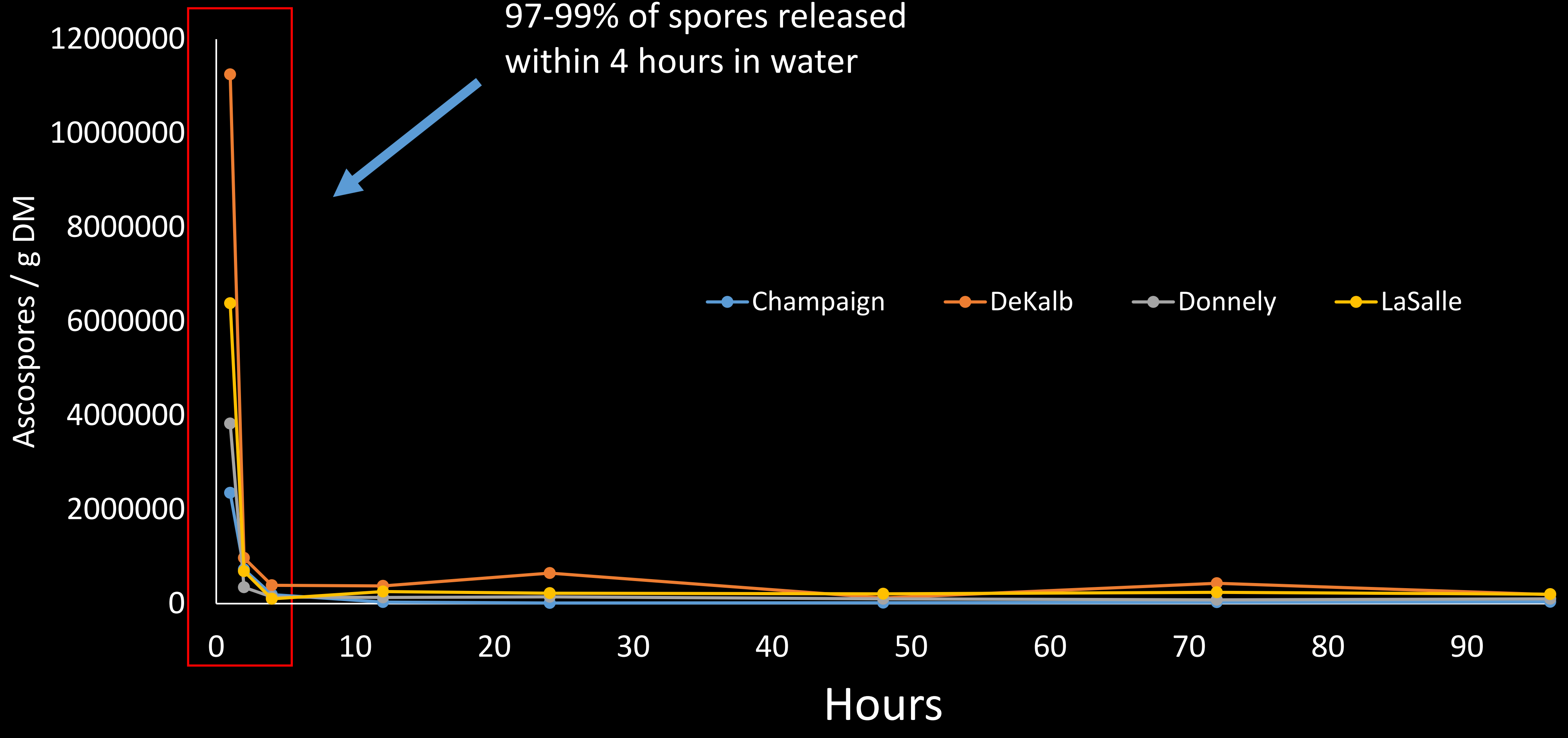
- Currently 1500 species
- Obligate biotrophs
- Named after host association
- Assumed to have narrow host range

P. dactylidis (on orchard grass)

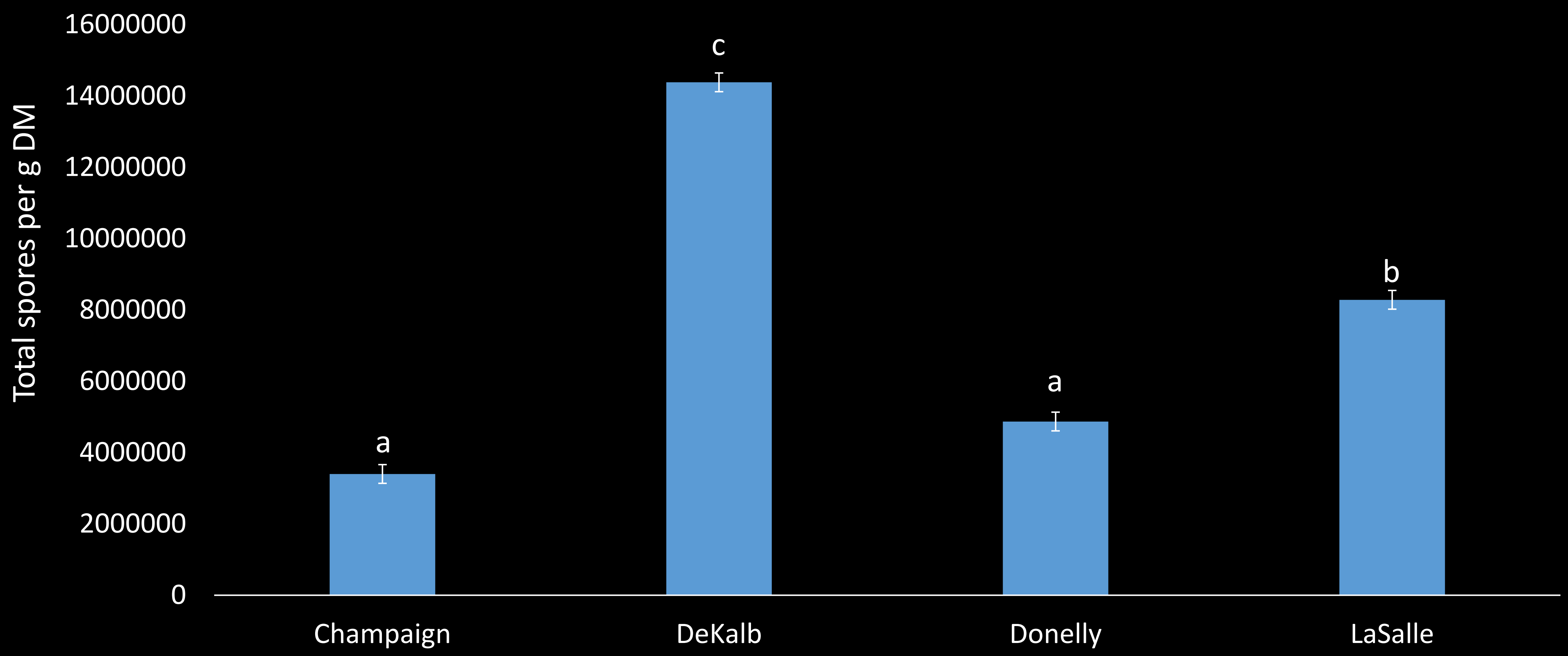
Phyllachora sp. on Rye

Ascospore release by location

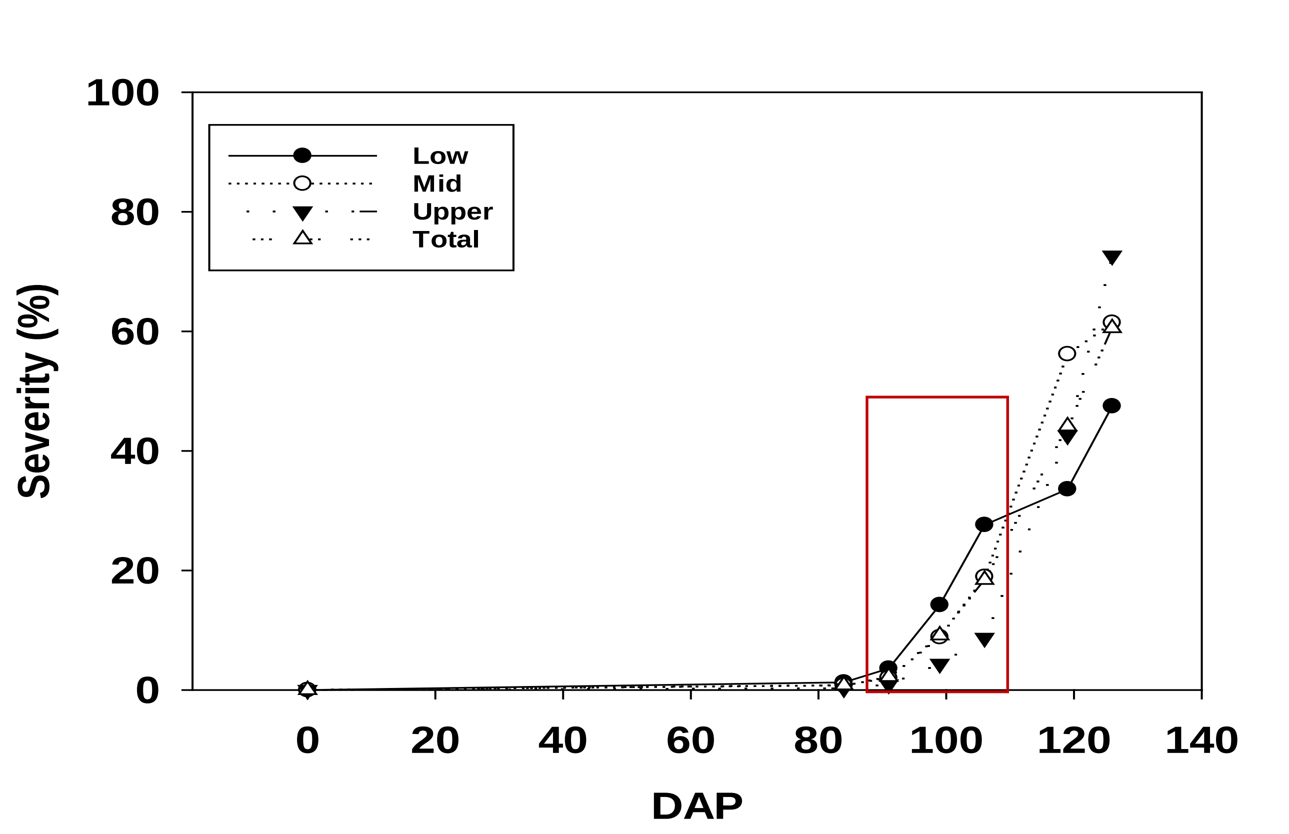
97-99% of spores released within 4 hours in water



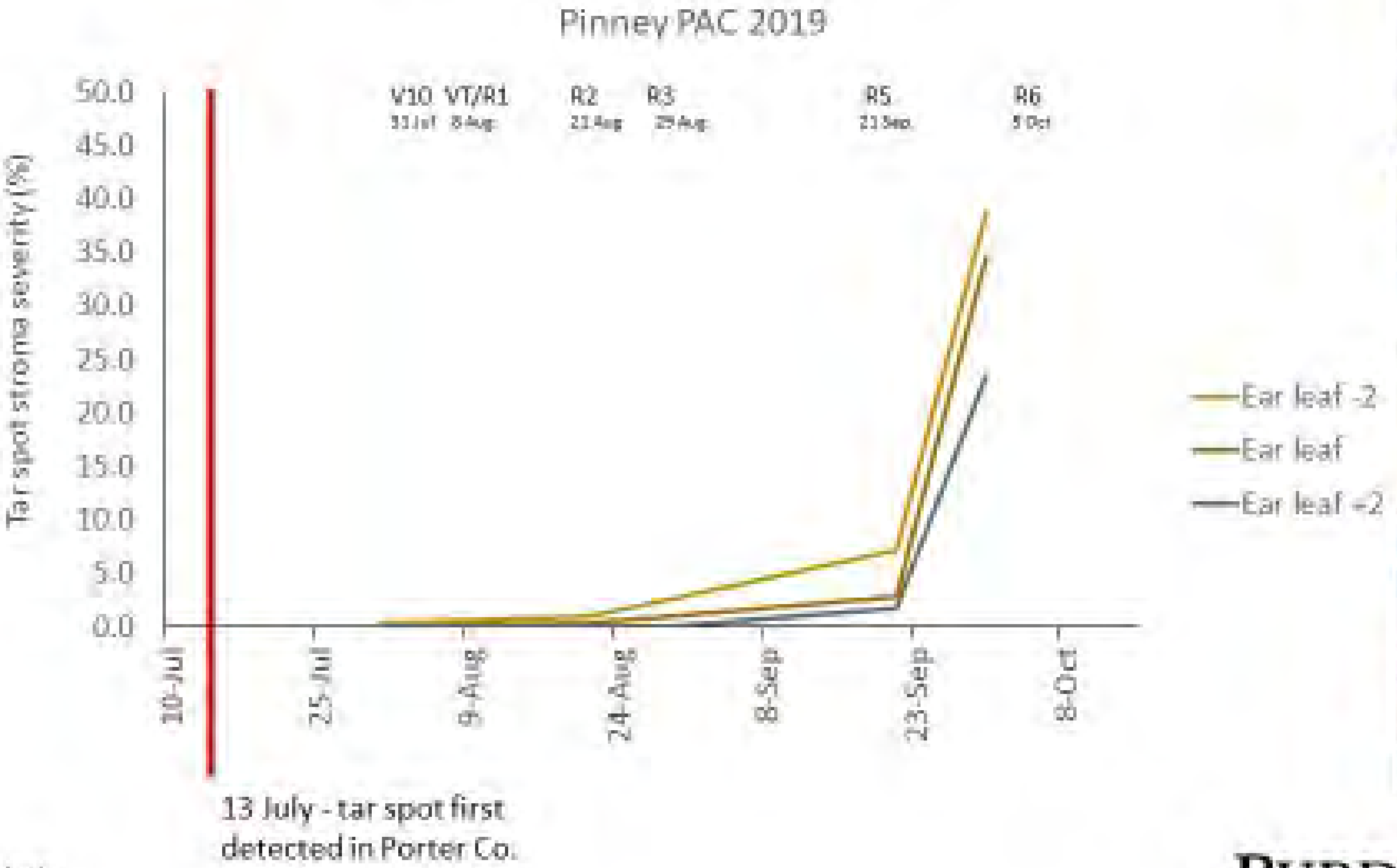
Total ascospore release by location



TS Severity curves by canopy
Savoy, Illinois, 2019 Cruz Lab Purdue University



Tar Spot Development in Non-Treated Canopy, Indiana 2019



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COLLEGE OF AGRICULTURE

Summary

- It doesn’t take much to get this disease going- reproduces fairly quickly

- Light infections can result in severe disease relatively fast

P. maydis Overwinters in Corn Residue

APS Publications

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Phyllachora maydis, Causal Agent of Tar Spot on Corn, Can Overwinter in Northern Illinois

Nathan M. Kleczewski, James Donnelly, and Russ Higgins

Affiliations

Published Online: 31 Jul 2019 | https://doi.org/10.1094/PHP-04-19-0030-BR

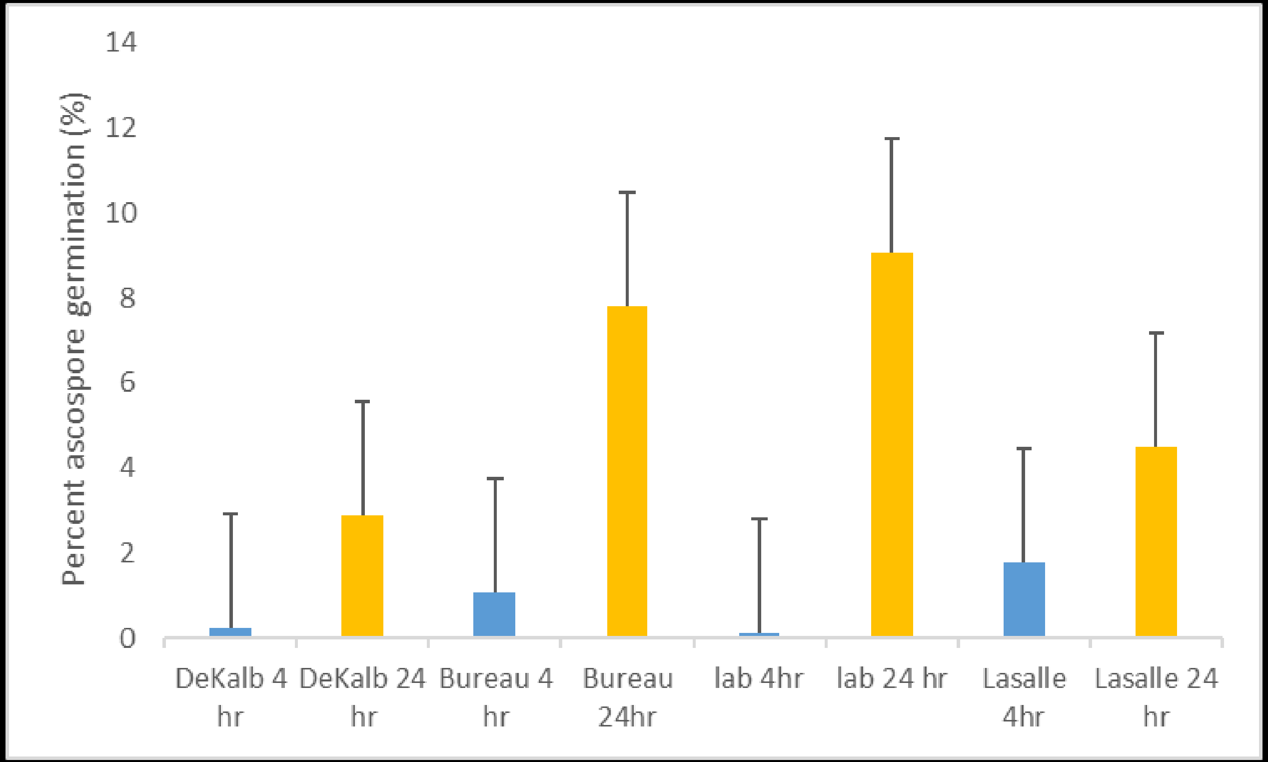
Germination of *P. maydis* Spores in Overwintered Surface Residue

Surface residue collected in March, 2019.
Lab in September 2018.

Stored at 4C until 4/2/19

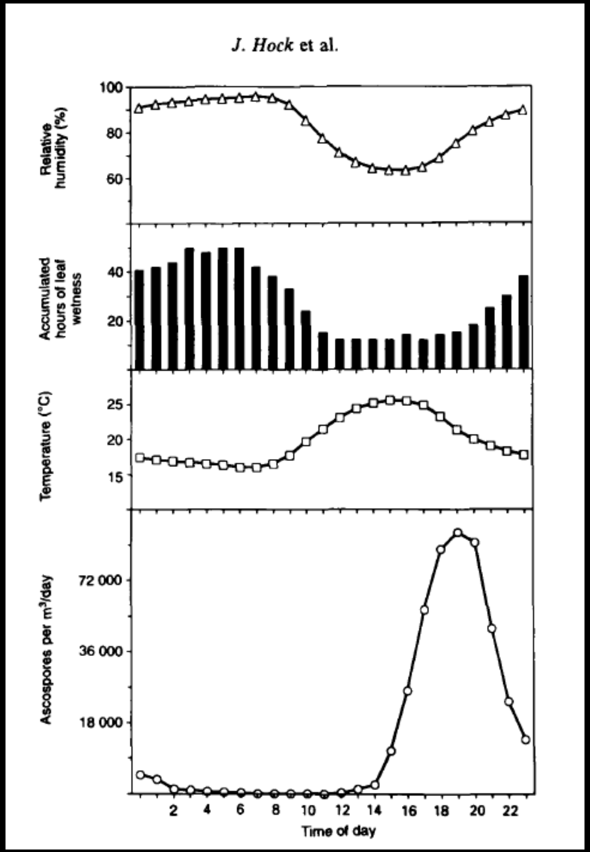
Spores assessed for germination at 4 hr and 24 hr after extraction in water

Approximately 166,000-500,000 viable spores per g tissue (minimum)



Phyllachora maydis Biology in Latin America

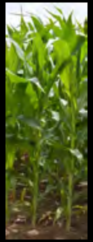
- Disease favored by cool , wet conditions
  - 60-72 F
  - 7 hrs of leaf wetness at night
  - >75% RH
- Spores released predominantly **at night**
- Spores can disperse **at least** 75 m (approx. 250 ft) from source
  - Rapid spread in US, observations of “top down” infections
  - Likely from distal sources
- Observations in US have not detected tar spot on corn prior to canopy closure
  - Breaking dormancy? Light, temperature, humidity?



Mean catches of ascospores of *P maydis* per hour in relation to average hourly temperature, RH, and leaf wetness duration over 80 days in 1987. From Hock et al, 1995.

J. Hock, Kranz, J, and B.L. Renfro. 1995. Studies on the epidemiology of the tar spot disease complex of Maize in Mexico. Plant Pathology 44: 490-502.

Putative life cycle of *P. maydis*



3) Symptoms are observed at least 14 days after infection, and new ascospores produced in stromata soon thereafter

3.5) Cycle repeats under conducive conditions

4) Infected tissue dries down and is returned to field.

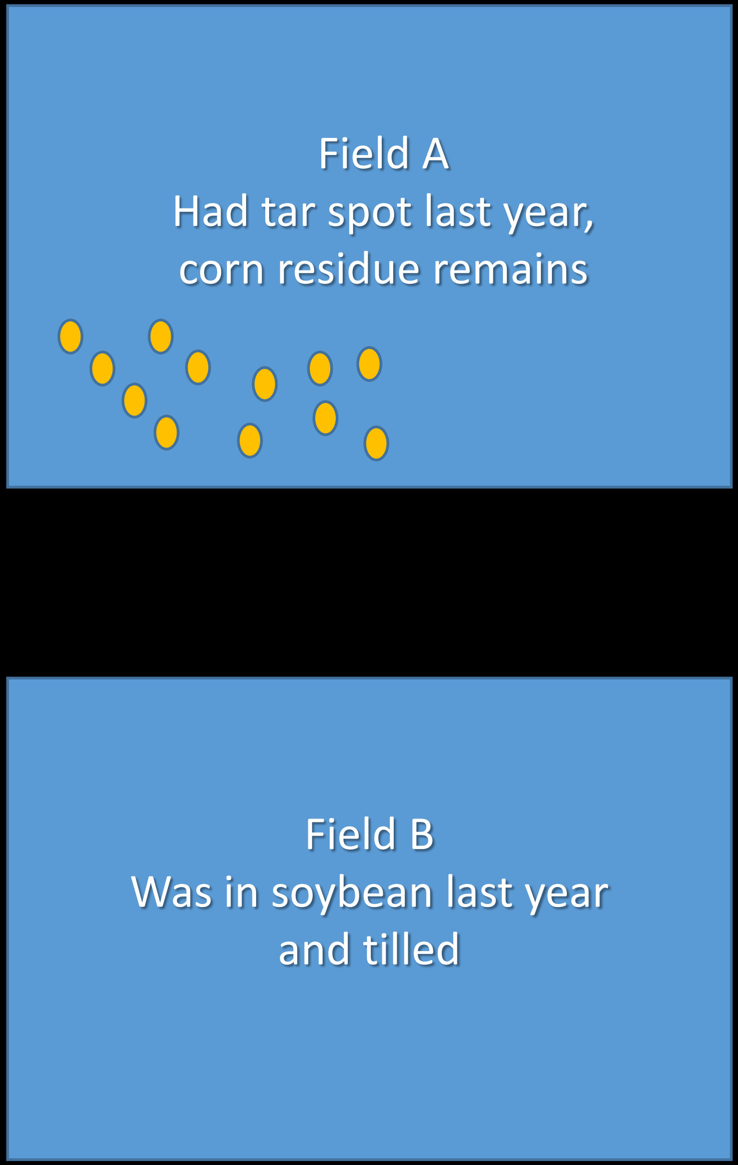
2) Ascospores are released from stromata and moved to foliage under periods of moderate temperature, wet weather, and high RH, and infect foliage, husks. (How far? Under what conditions?)

1) Fungus overwinters in infected residue as stromata at least one winter

Cultural practices

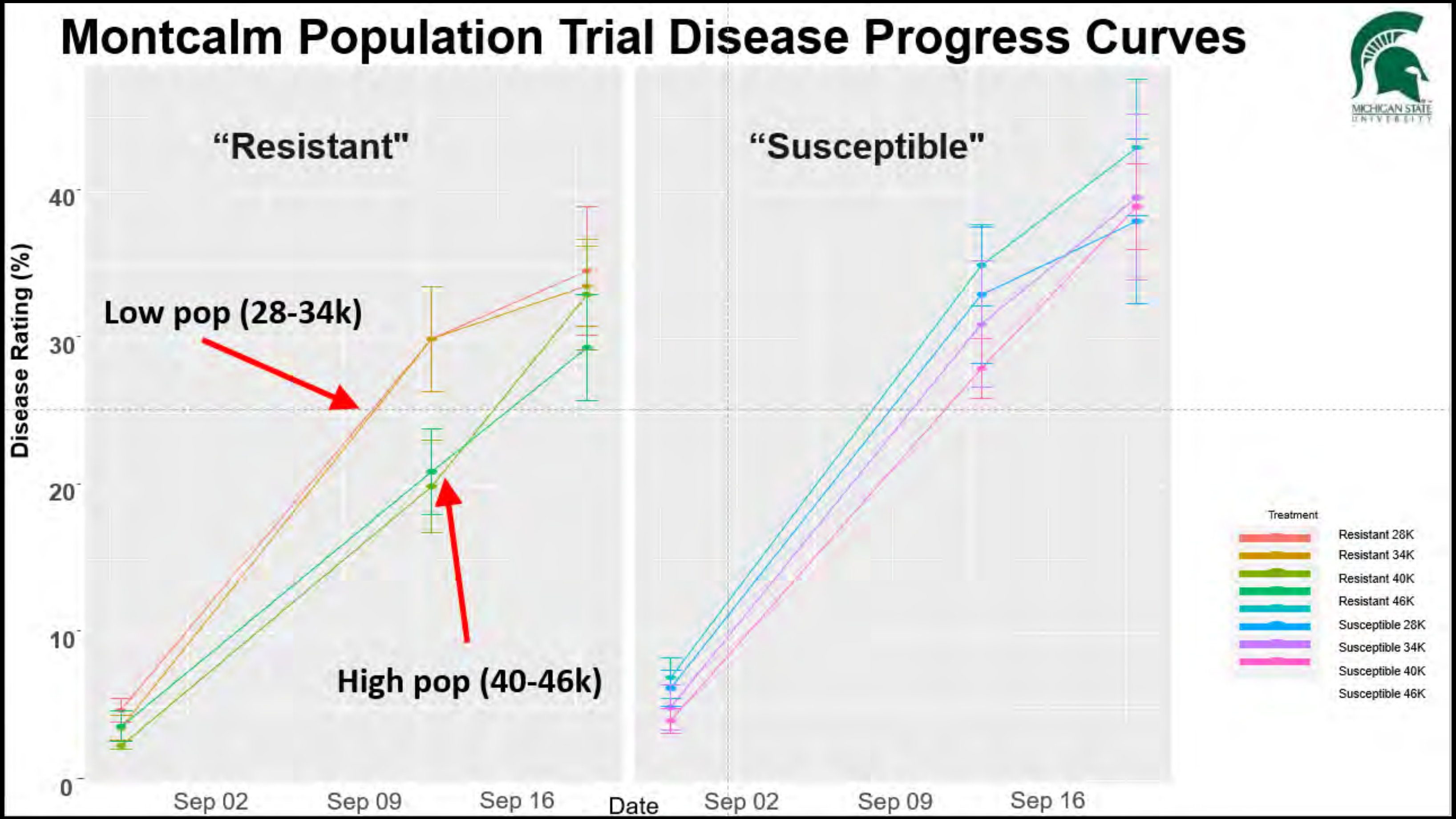
- Tillage (minimal benefit)
  - Borne on residue
  - Observations and rapid spread indicate greater dispersal than indicated
  - May have limited local impact but distal sources may provide inoculum

- Rotation (minimal benefit)
  - Similar issues to tillage
  - Observed in fields previously in soybeans for multiple seasons

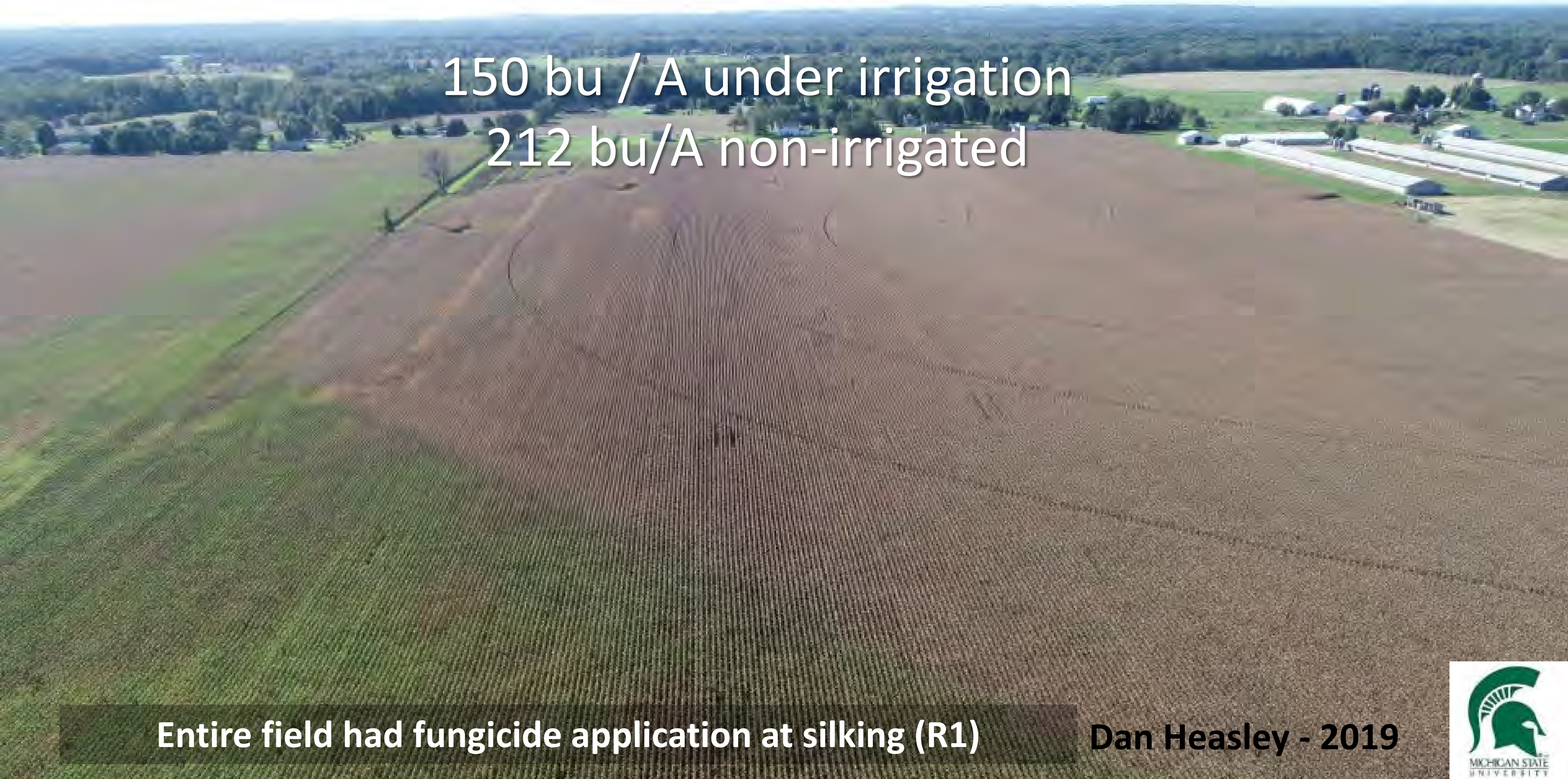


Disease onset may be later. Not likely to be beneficial in conditions favoring severe epidemics

Population effects on tar spot
M. Chilvers, MSU



Environment is a strong driver of tar spot disease



Host Resistance

Hybrid Response to Tar Spot

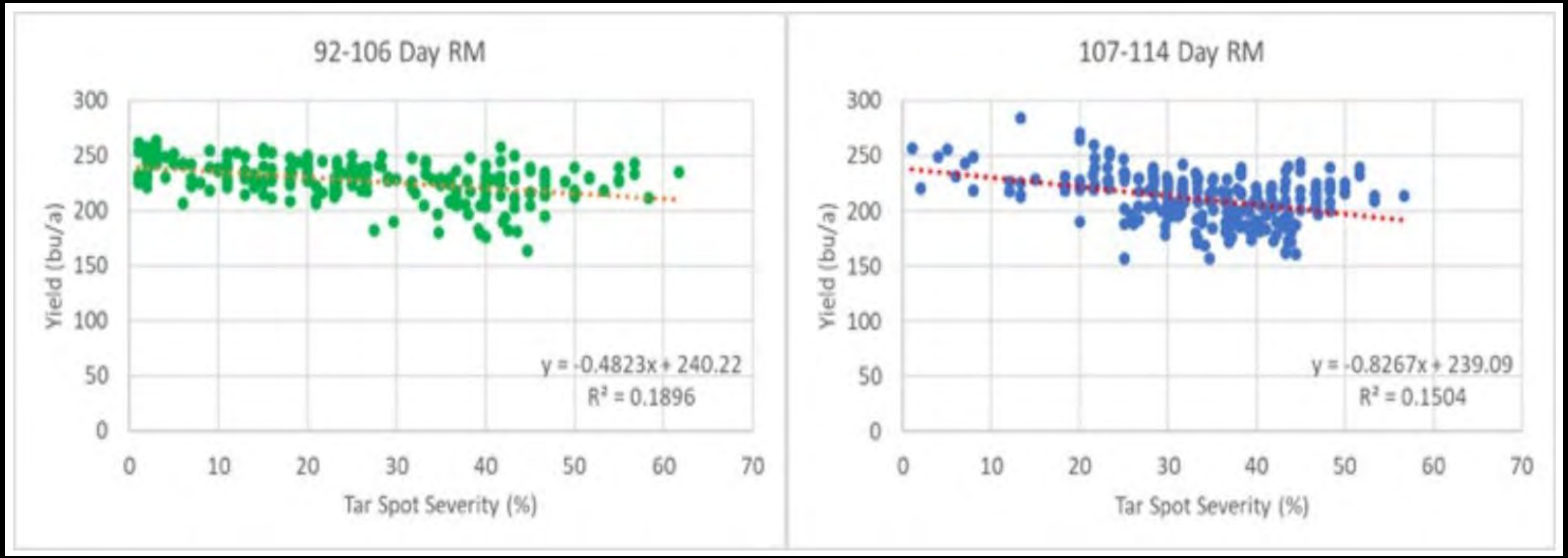
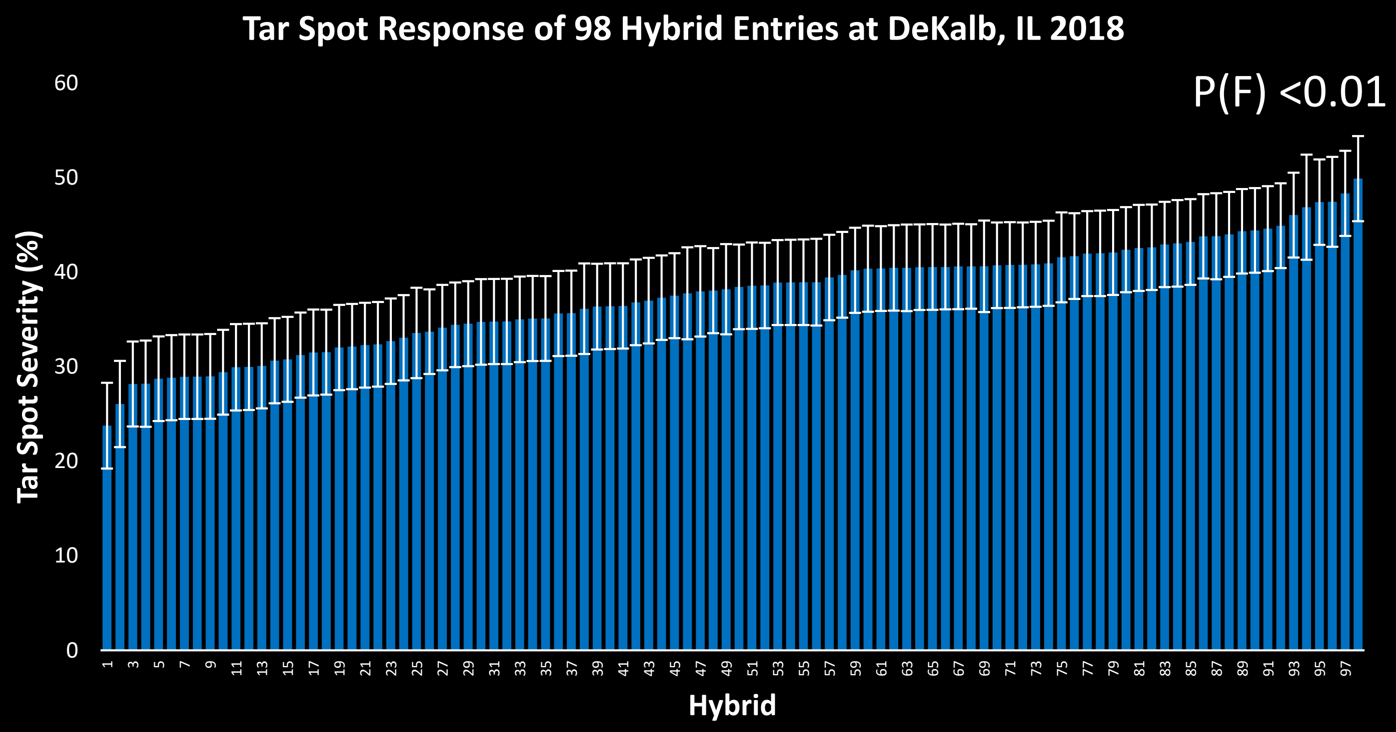


Image from Crop protection network :
https://cropprotectionnetwork.org/resources/features/how-tar-spot-of-corn-impacted-hybrid-yields-during-the-2018-midwest-epidemic

Hybrid Susceptibility



98 hybrids- 102-114 maturity. Based off of 3 replicates in uniform variety trial located in DeKalb, IL. Negligible GLS, NCLB. N. Kleczewski.

Tar spot host resistance

Sarah Lipps

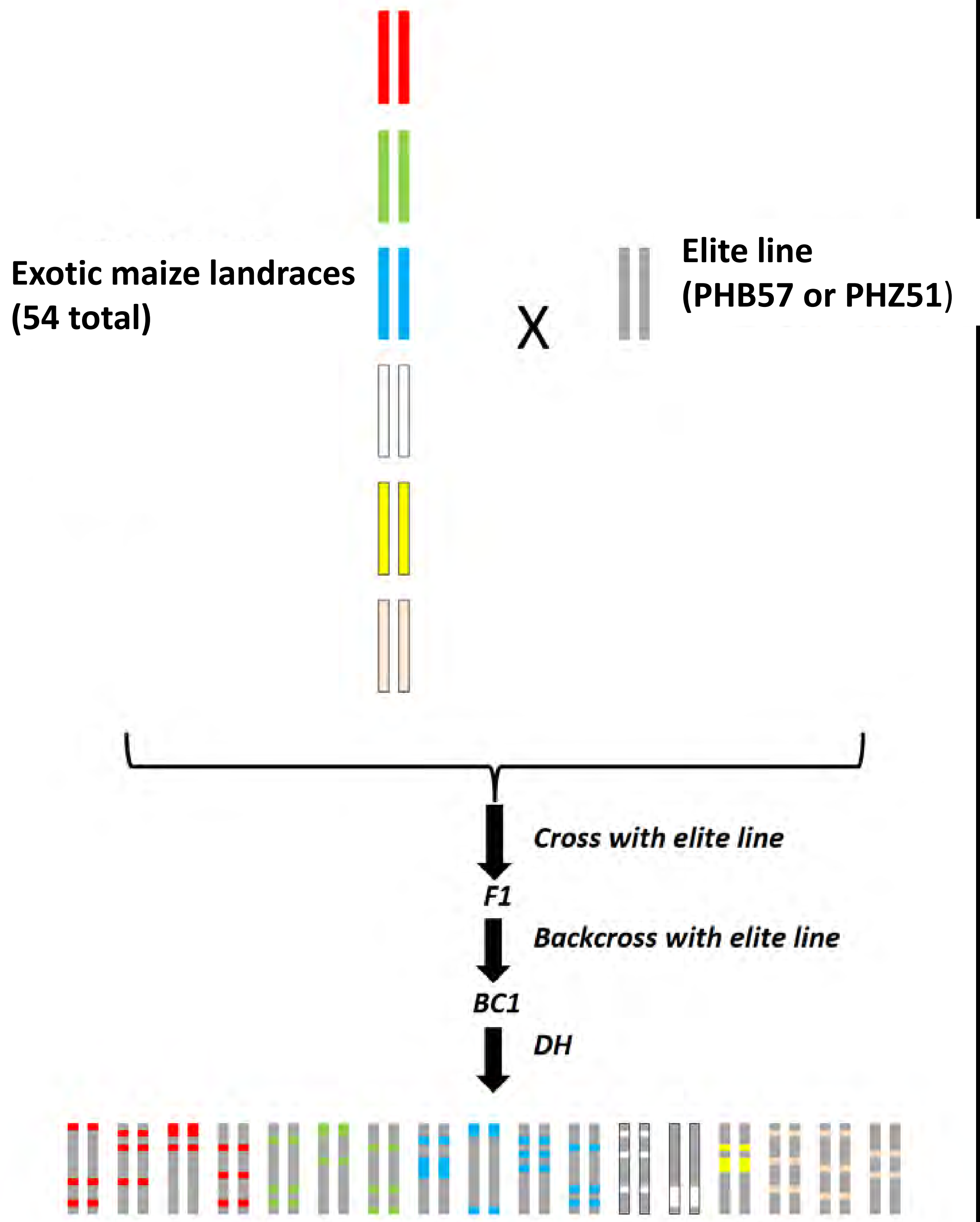
4 Dec, 2019

PI: T. Jamann

GEM: Germplasm Enhancement of Maize

- BGEM Population- Exotic derived double haploid introgression lines
- 54 exotic maize lines crossed and backcrossed to one of 2 ex-PVP hybrids
  - 71 unique BC_1F_1 families
  - Population of 252 lines
  - Good source of novel alleles

(Smelser et al. 2016, Vanous et al. 2018, Sanches et al. 2018, Vanous et al. 2019)



Adapted from Lubberstadt [power point slides], 2018

2019 GEM screening results

- Identified 5 lines that were consistent winners
- Identified 5 lines that were consistent losers
- More data needed, but potential use for tar spot resistance sources in US corn populations

I kid because I love

Fungicides for Tar Spot

Labeled

Trivapro

FIFRA 2(ee)

Delaro

Headline AMP

Miravis Neo

Quilt Xcel

Topguard EQ

Aproach Prima

Priaxor

Fungicide Efficacy Trials vs Management Trials

Item	Efficacy	Management
Cultivar/hybrid	Susceptible to highly susceptible	Typical for production, multiple, contrasting resistance types
Environment	Often irrigated, highly conducive	Natural, typical conditions, contrasting conditions
Pathogen	Inoculated or highly conducive conditions	Natural
Take home message	Which fungicides or fungicide programs work best for controlling a disease-easier to differentiate under high disease pressure. Duration of control	What conditions favor disease Likelihood of needing fungicide, Likelihood of covering input cost, Probability or frequency of observing conditions that result in economic damage
Be careful because:	Disease severity and yield results often inflated	Need many site years to have confidence in data

Uniform Fungicide Efficacy 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 Efficacy 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

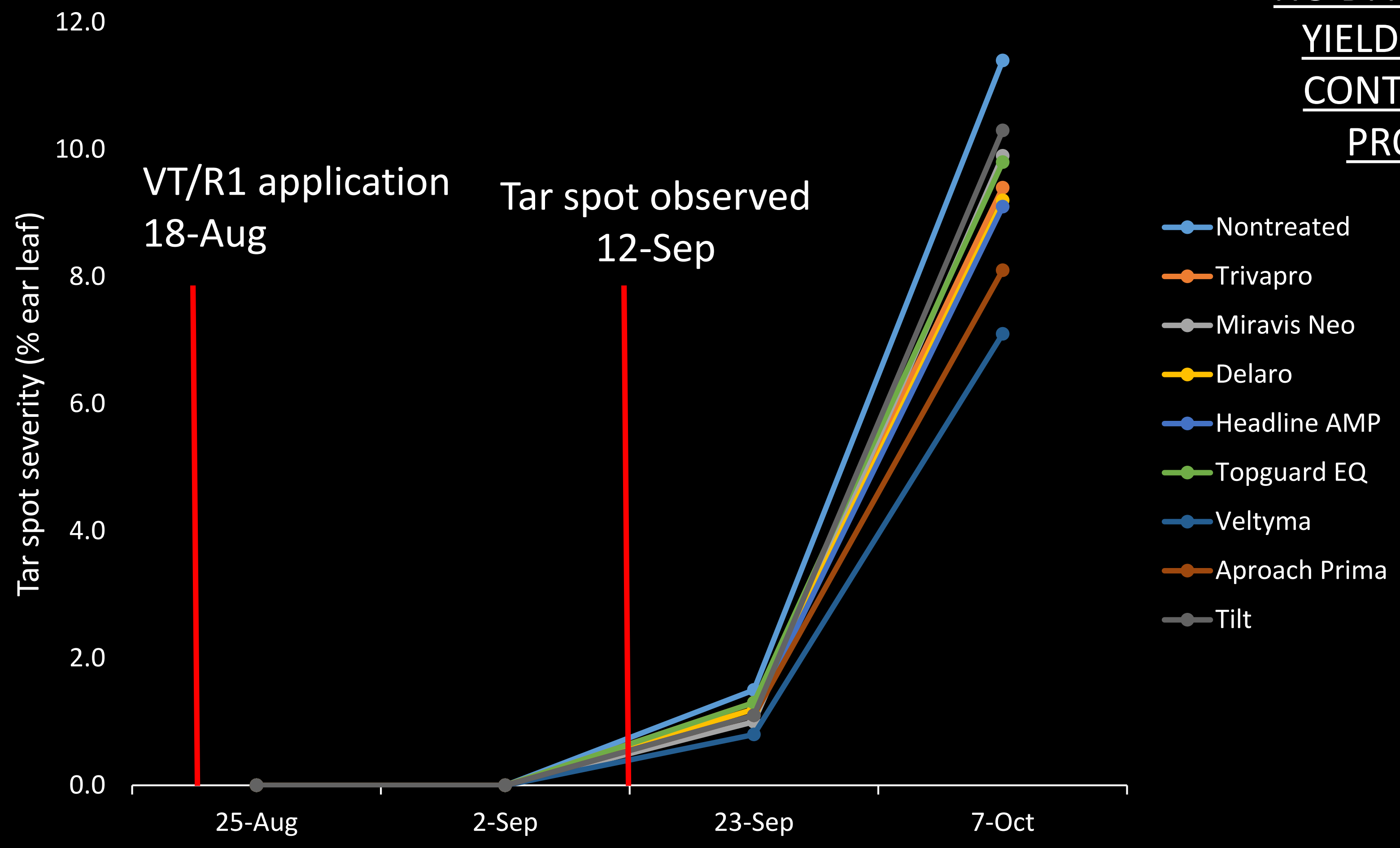
Fungicide applications made at VT/R1. Mean separation Tukey-Kramer P=0.05.

Uniform Fungicide Efficacy 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	219.59 a	.	.	225.06 ab
Headline (14)	12	.	208.69 ab	.	261.88	216.21 abc
Aproach Prima (10)	6.8	183.10	208.46 ab	.	249.83	204.66 bc
Delaro (19)	12	224.02	218.66 a	.	263.93	226.61 a
Topguard (16)	7	201.48	211.96 ab	.	248.41	213.78 abc
Headline AMP (9)	14.4	168.09	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	216.22 a	.	266.65	222.78 ab
Tilt (4)	4	176.96	.	.	274.28	185.99 c
Trivapro (24)	13.7	222.01	213.91 ab	.	.	219.56 abc
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	195.51 b	.	244.85	204.72 bc
	F-Value		4.67		1.52	5.47
	P-Value	NS	0.0001		NS	0.0001

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

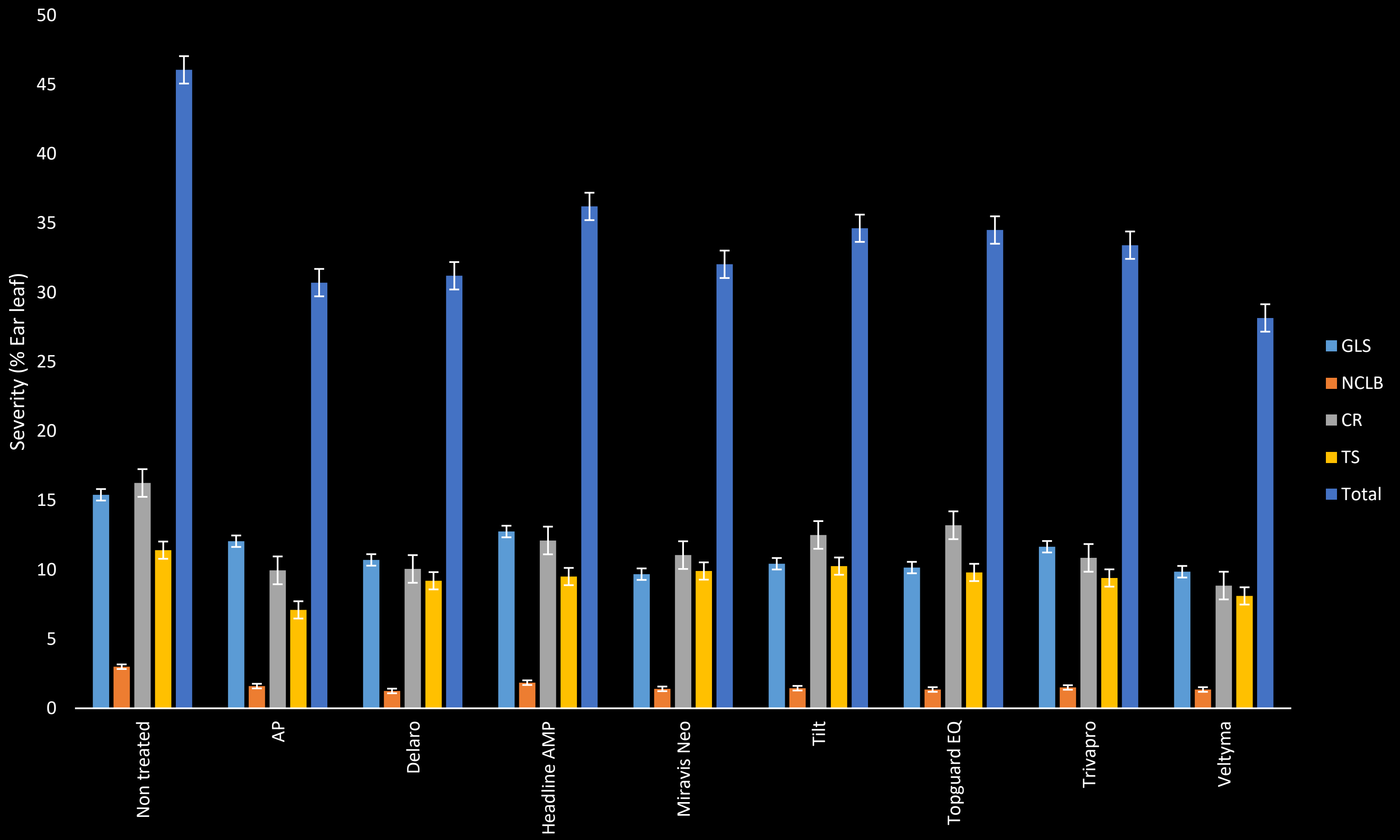
Uniform Fungicide Trial for Tar Spot – Freeport IL (Late disease arrival)



NO DFFERENCES IN YIELD BETWEEN CONTROLS AND PRODUCTS

Kleczewski, Alberti, Ames
UIUC
P0306Q (103 RM)

Uniform Fungicide Trial for Tar Spot – Freeport IL (all foliar diseases)



Kleczewski, Alberti, Ames
UIUC
P0306Q (103 RM)

University of Illinois Late Season Tarspot Fungicide Timing Trial
Monmouth, Illinois 2019
N. Kleczewski, K. Ames- UIUC

Applied at R5 on 9/4
15 gpa, 35PSI
Tukey's HSD α = 0.05
0.1% disease at application

		9/17/19		10/3/19			
	fl oz /A	Ear leaf Severity %	Senescence %	Ear leaf Severity %	Senescence %	Lodging %	Yield bu/A
Non-treated		1.2	23.7	7.9 a	71.8 a	5	255
Delaro	8	0.3	26.3	2.9 cd	53.5 b	3	289
Tilt	2	0.3	30.0	3.7 cd	60.0 b	3	257
Aproach	6	1.4	21.8	5.5 b	57.3 b	8	271
Miravis Neo	13.7	0.1	16.3	1.6 d	45.0 c	5	261
	P(F)	N.S.	N.S.	<0.0001	<0.0001	N.S.	N.S.

Building on Our Existing Framework – Tarspotter- Damon Smith UW Madison

- 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 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.

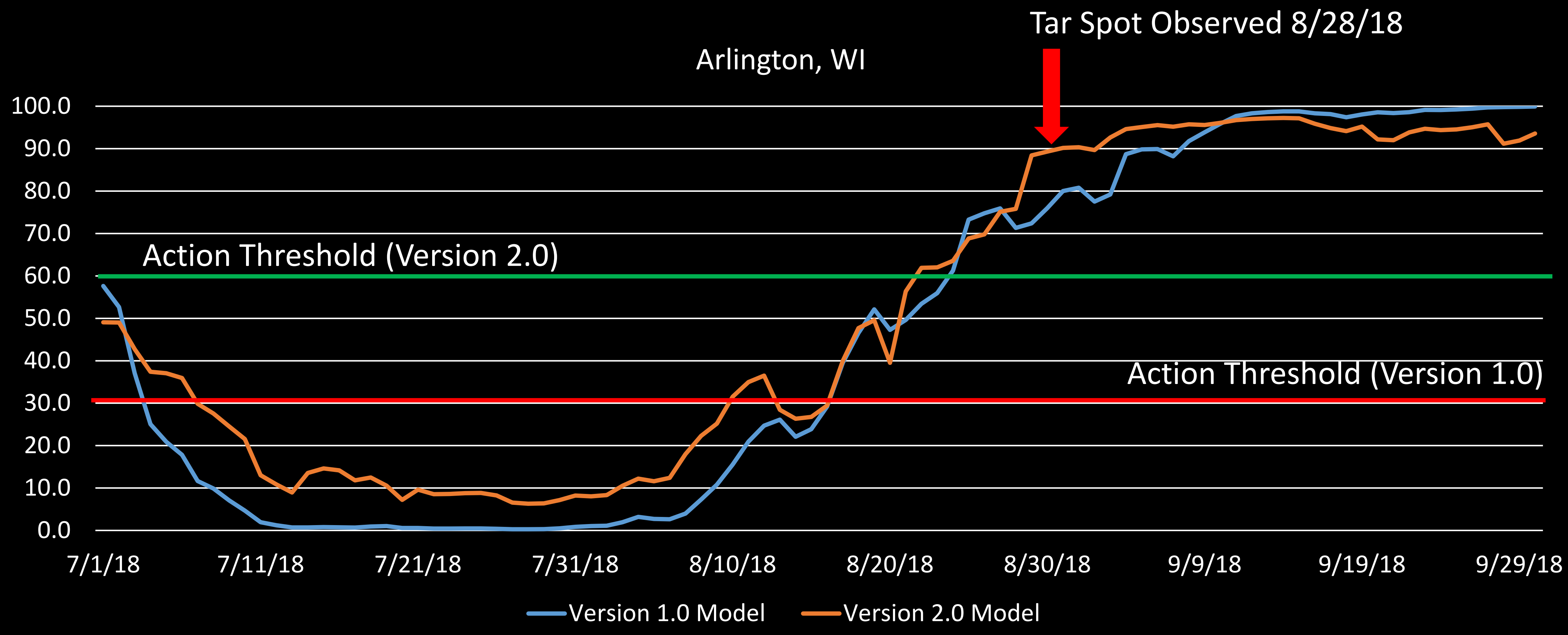
Trt No.	Active ingredient	Tradename (company)	Rate fl oz/A	Application Timing
1	Non-treated	--	--	--
2	Benzovindiflupyr 2.9% Azoxystrobin 10.5% Propiconazole 11.9%	Trivapro (Syngenta)	13.7	V6
3	Benzovindiflupyr 2.9% Azoxystrobin 10.5% Propiconazole 11.9%	Trivapro (Syngenta)	13.7	V8
4	Benzovindiflupyr 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

Model v. 1.0 Needs Refinement to Improve Accuracy

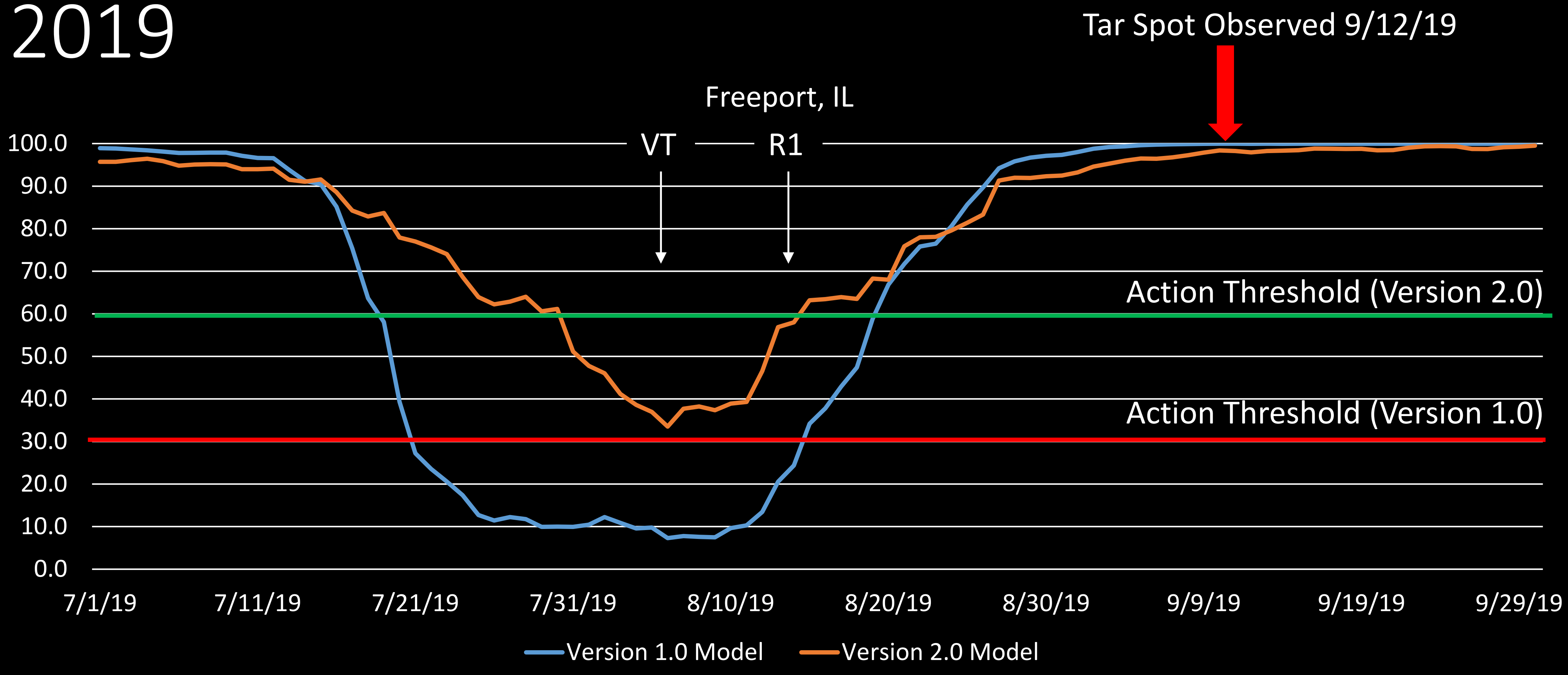
- Added Site Years (Total of 8)
  - -Arlington, WI 2018
  - -Allegan, MI 2018
  - -Arlington, WI 2019
  - -Lancaster, WI 2019
  - -Allegan, MI 2019
  - -Wanatah, IN 2019
  - -Freeport, IL 2019
  - -Urbana, IL 2019
- Total of 374 data points
  - -Loc x Trt x Rating

- Investigated new weather variables
  - -Dew Point
  - -Total rainfall
- Now forcing model to account for fungicide application

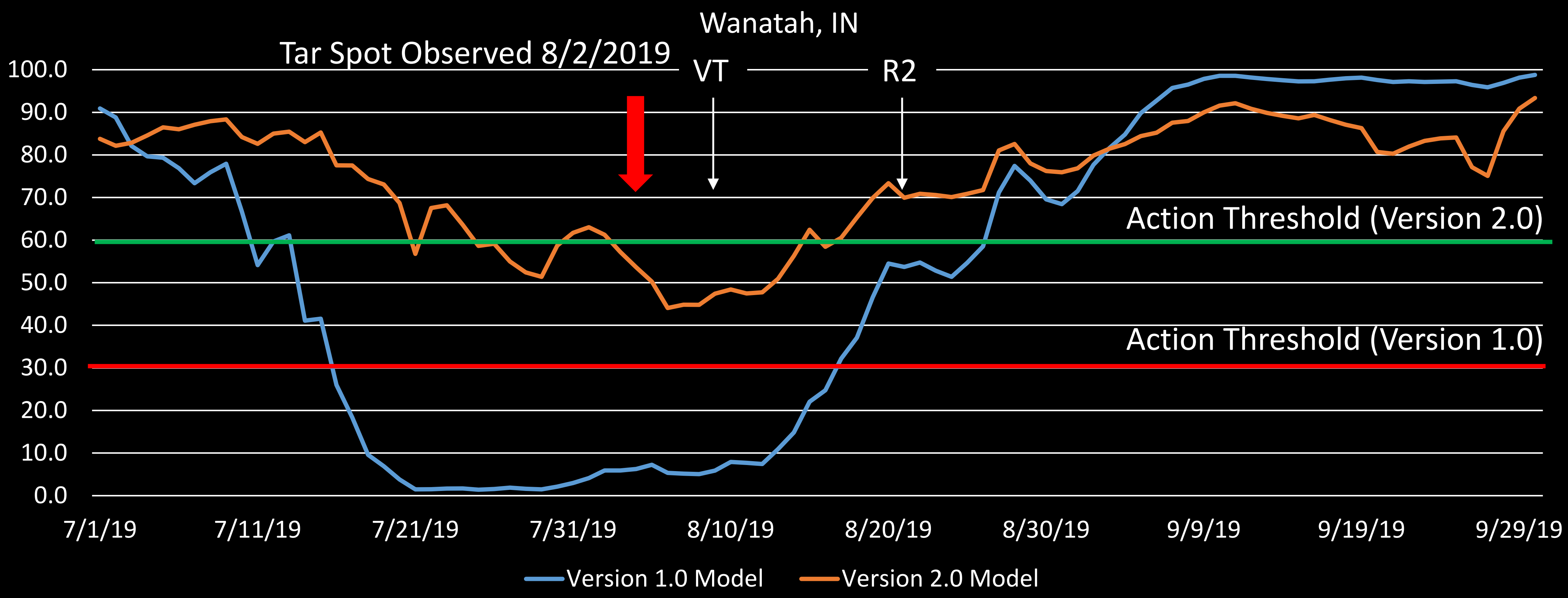
Let's Revisit Arlington, WI - 2018



Late Onset Tar Spot Epidemic – Freeport, IL 2019



Epidemic Where Version 1.0 Completely Missed – Wanatah, IN



Management Practices for Tar Spot as Suggested in CPN-2012-W

- **Avoid highly susceptible hybrids**
- **Consider fungicides**
  - Mixed mode of action
  - **Timing very important**
  - Application will need to occur close to the onset of the epidemic
- **Manage irrigation**
- **Rotate to other crops**
- **Manage residue**
- **Scout**

Tar Spot Working Group

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NPDN Diagnosticians: John Bonkowski[3], Brian Hudlson, Diane Plewa[5], and Ed Zaworski[7]

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Funding Sources

- FFAR-Roar
  - National Corn Board
  - Pioneer
  - Illinois Corn Promotion Board
  - Indiana Corn Marketing Council
  - Purdue University
  - Wyffels Hybrids
  - Wisconsin Corn Board
- Syngenta
- Bayer
- FMC
- Gowan
- BASF