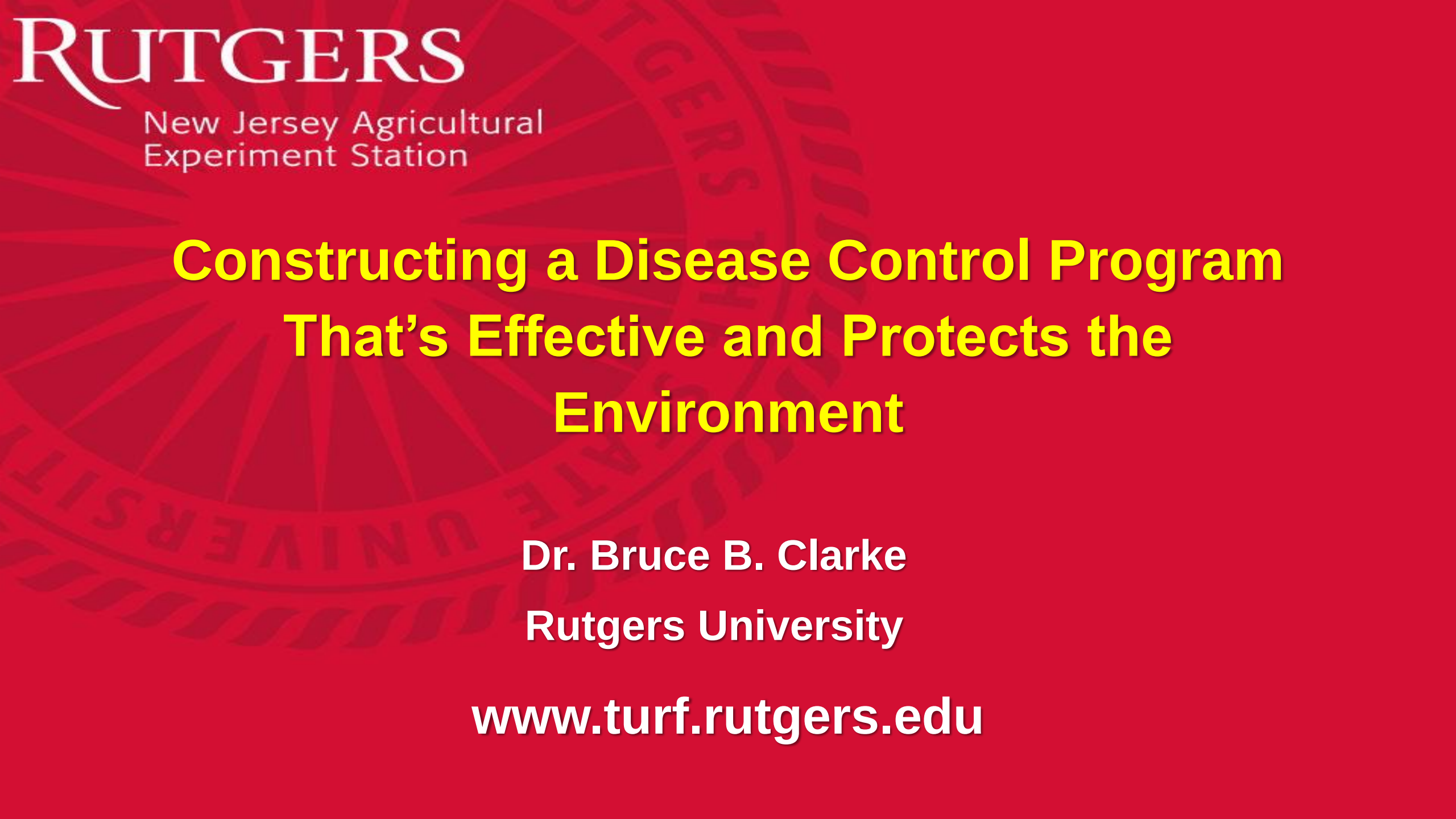


The background of the slide features a large, faint, circular seal of Rutgers University. The seal contains the text "RUTGERS UNIVERSITY" and "1823" around a central emblem. The entire slide has a solid red background.

RUTGERS

New Jersey Agricultural
Experiment Station

Constructing a Disease Control Program That's Effective and Protects the Environment

Dr. Bruce B. Clarke
Rutgers University

www.turf.rutgers.edu

Principles of an Effective Disease Control Program

1) Identify Major Diseases and when they typically occur on the golf course

- History of diseases on your course**
- Season when they typically occur**
- Areas (hot spots) prone to infection**

Principles of an Effective Disease Control Program

Separate Major Diseases by location on the course.

Greens and Tees:

- ❖ Spring - Brown Ring Patch, Take-all, Dollar Spot, Fairy Ring, Anthracnose
- ❖ Summer – Anthracnose, Dollar Spot, Brown Patch, Pythium Blight, Summer Patch, Yellow Tuft
- ❖ Autumn – Dollar Spot
- ❖ Winter – Snow Mold, Yellow Patch

Principles of an Effective Disease Control Program

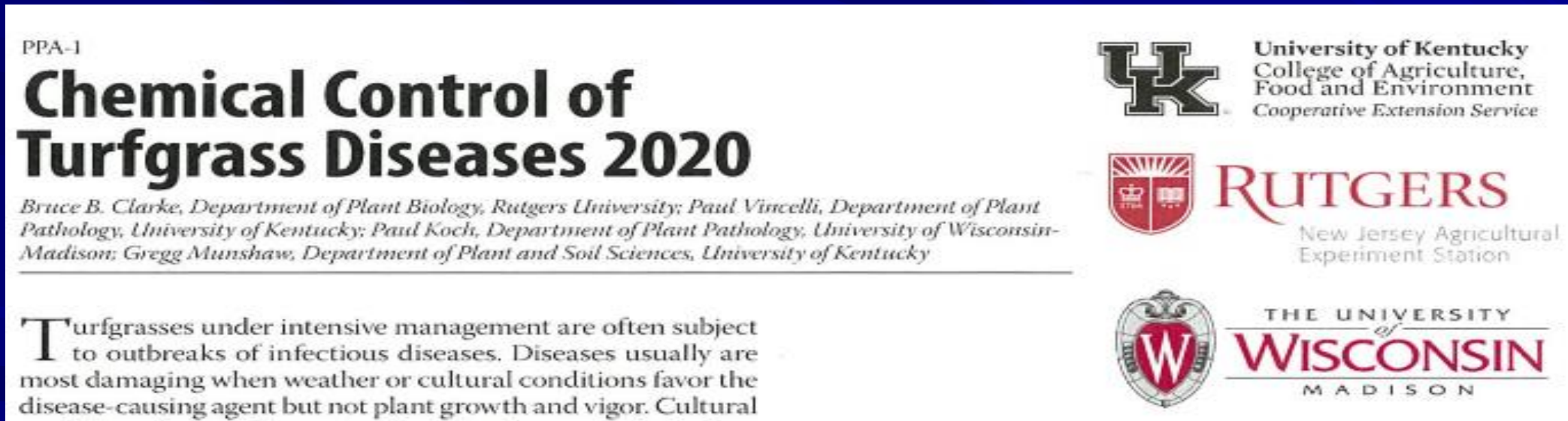
Fairways & Roughs:

- ❖ Spring – Take-all, Dollar Spot, Leaf Spot
- ❖ Summer – Dollar Spot, Brown Patch, Pythium Blight, Gray Leaf Spot, Summer Patch
- ❖ Autumn – Dollar Spot, Snow Mold

Principles of an Effective Disease Control Program

2) Select and apply the **Most Efficacious Fungicides** at the Optimum Rates, Timing, and Water Volumes

Refer to sources that provide unbiased efficacy ratings
(e.g., PPA-1 *Chemical Control of Turfgrass Diseases 2020*)



Google: PPA-1: Chemical Control of Turfgrass Diseases

Principles of an Effective Disease Control Program

To build your fungicide program:

- ❖ Develop a List of currently labeled products for each disease
- ❖ Look at Efficacy ratings (1-4 scale; where 4 = most effective)
- ❖ Look at strengths of each product and select broad spectrum fungicides or tank mix when expecting > 1 disease
- ❖ Use Fungicide Resistance Action Committee (Frac) Numbers to avoid overuse of products with high potential for resistance
 - rotate or tank-mix products with different biochemical modes of action.

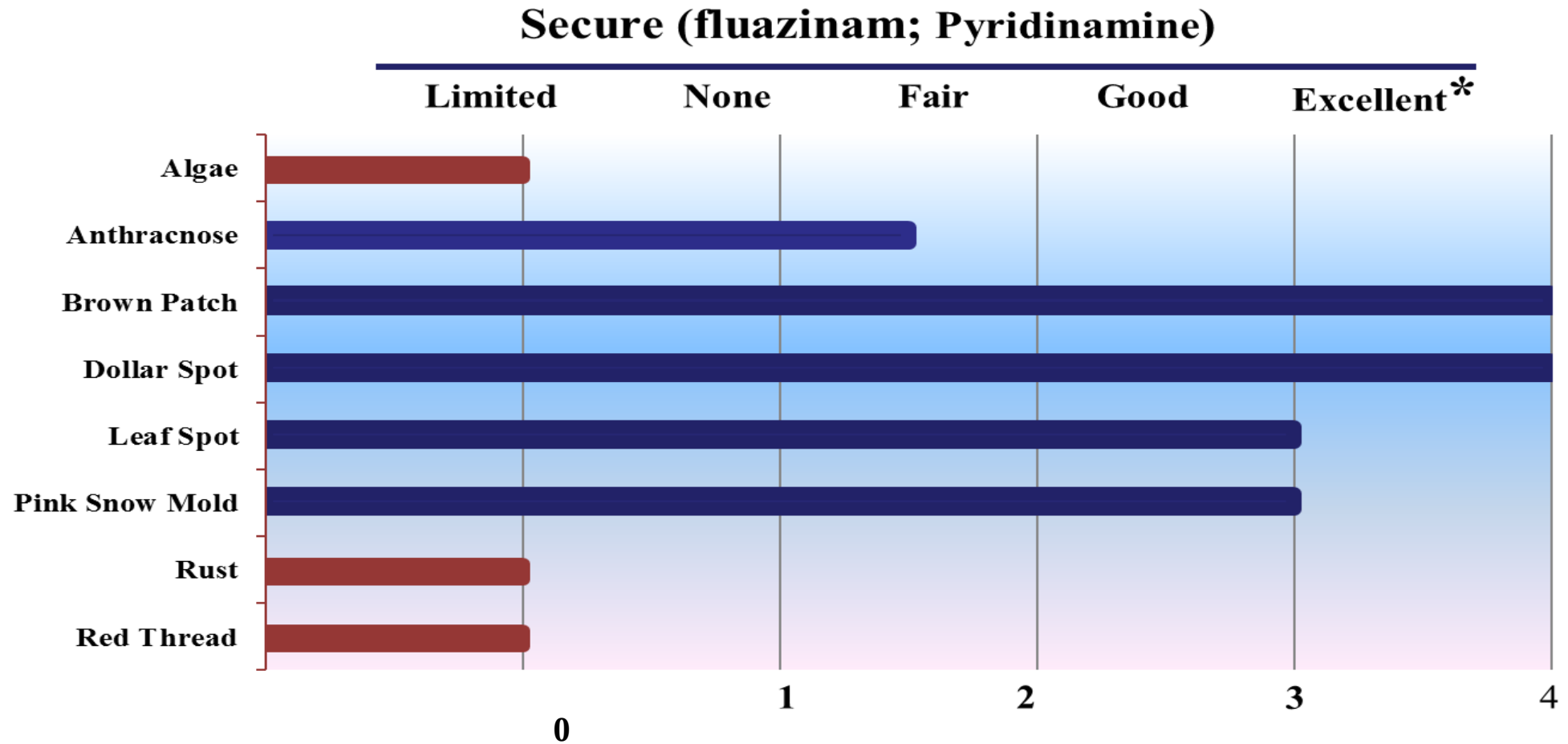
Principles of an Effective Disease Control Program

Lists of Fungicides and Efficacy Ratings by Disease

7. Dollar Spot

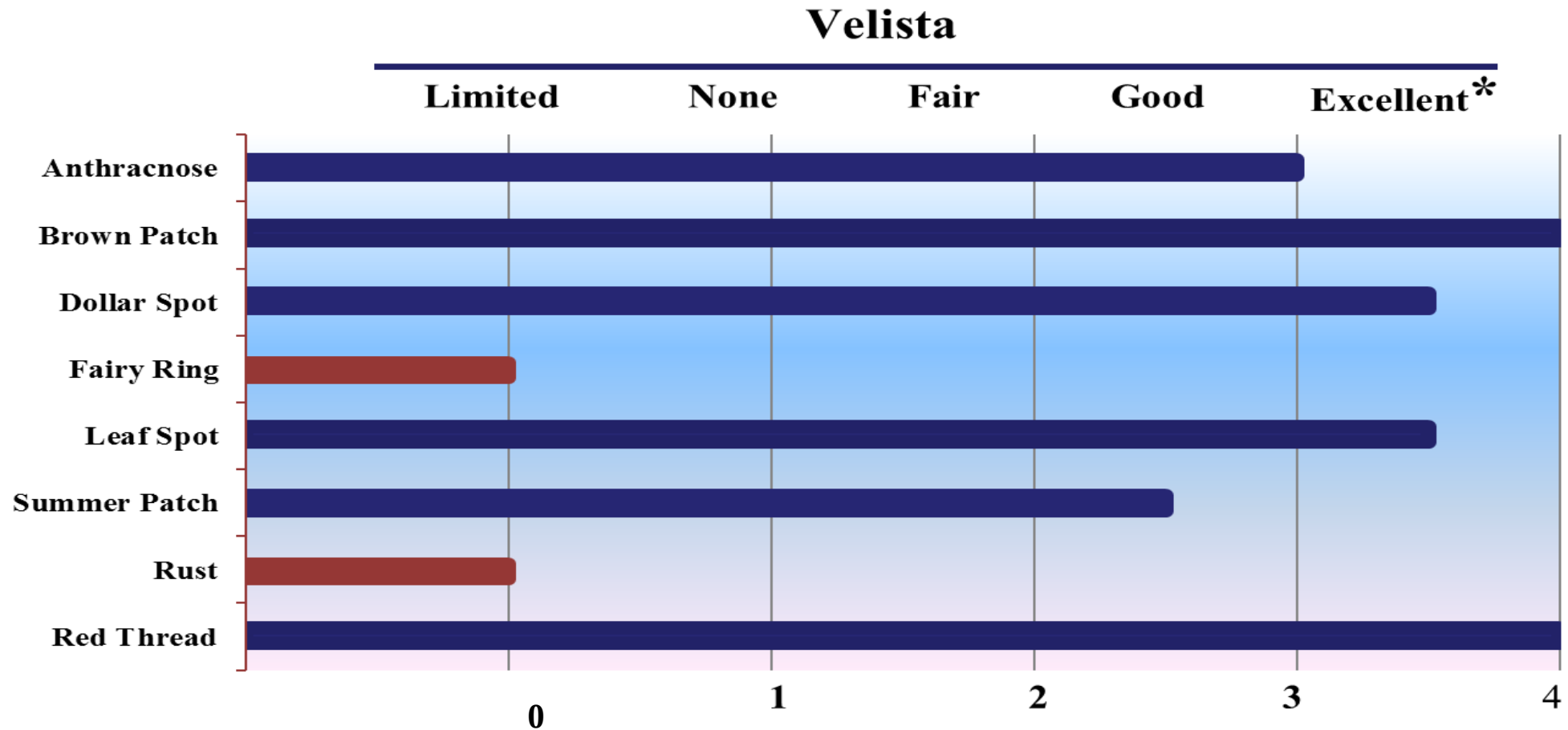
Fungicide: Some Trade Names	FRAC Code ^a	Efficacy [*]	Interval (days)
Bacillus licheniformis: EcoGuard	NC	2	3-14
Bacillus subtilis, strain QST 713: Rhapsody	NC	1	7-10
boscalid: Emerald	7	4/3.5 ^{b,e}	14-28
chlorothalonil: Daconil Ultrex, Manicure, Concorde SST, Chlorostar, Echo, Pegasus L	M5	3	7-14
fenarimol: Rubigan	3	3	10-30
fluazinam: Secure, Rotator, Soteria	29	4	14
fluoxastrobin: Fame	11	3	14-21
flutriamorphol: Mural	7	4	14-28

Relative Efficacy of New Fungicides for Cool - Season Turf Diseases : 2014- 2020 (Golf)



* Efficacy on a 1- 4 Scale, where 1 = not effective, 2 = fair – good control, 3 = good – excellent control, and 4 = excellent control. Limited = insufficient data.

Relative Efficacy of New Fungicides for Cool - Season Turf Diseases : 2005- 2020 (Golf)



* Efficacy on a 1- 4 Scale, where 1 = not effective, 2 = fair – good control, 3 = good – excellent control, and 4 = excellent control. Limited = insufficient data.

History of Fungicide Resistance in Turf

Disease	Chemical Class	FRAC Code	Year of Confirmation
Anthracnose	Qol	11	2002
Anthracnose	Benzimidazole	1	2002
Anthracnose	DMI	3	2005
Dollar Spot	Benzimidazole	1	1973
Dollar Spot	Dicarboximide	2	1983
Dollar Spot	DMI	3	1992
Dollar Spot	SDHI	7	2017
Gray Leaf Spot	Qol	11	2000
Microdochium Patch	Dicarboximide	2	1980
Pythium	Phenylamide	4	1984
Pythium	Qol	11	2003

Modified from Rob Golembiewski

Resistance Potential for Different Fungicide Groups

Fungicide	Genetic Factor	Site of Action	Resistance Risk Level
Benzimidazoles	Monogenic	Single	High
Phenylamides	Monogenic	Single	High
Strobilurins	Mono & Poly	Single	High
DMI	Polygenic	Single	Moderate - High
SDHIs	Polygenic	Single	Moderate – High
Propamocarb	Polygenic	Single	Moderate - High
Polyoxins	Polygenic	Single	Moderate - High
Fosetyl Al	Polygenic	Single	Moderate
Dicarboximides	Monogenic	Multiple	Moderate
A. Hydrocarbons	Polygenic	Multiple	Low
Dithiocarbamate	Polygenic	Multiple	Low
Nitrile	Polygenic	Multiple	Low
Pyridinamine	Polygenic	Multiple	Low

How to Reduce the Potential for Resistance

- Fungicide Resistance Action Committee has developed resistance management strategies to reduce the risk of resistance to fungicides that include:
 - Maximize cultural practices to limit disease pressure
 - limit total # of applications (3-4 SDHI apps/Yr.)
 - alternate modes of action (avoid sequential apps)
 - tank mix with fungicides active against pathogen (contacts)
 - preventative applications for high risk diseases
 - Avoid late-curative and reduced rate applications
 - Reduce interval &/or increase rates (high disease pressure)

Principles of an Effective Disease Control Program

2) Select and apply the Most Efficacious Fungicides at the **Optimum Timing**, and Water Volumes

- ◆ Calendar applications (every 7, 14, 21, or 28 days)
- ◆ Disease predictive models
- ◆ Threshold-based sprays



Using Disease Predictive Models to Time Fungicides

Application Timing is Based on Soil Temperature

- ✓ **Spring Dead Spot:** apply in fall when soil temperatures are between 60°F and 80°F
- ✓ **Summer Patch:** initiate applications in spring when soil temperatures are above 65°F
- ✓ **Take-all Patch:** apply in fall and spring when soil temperatures are between 40°F and 60°F
- ✓ **Fairy Ring:** Initiate when 5-day average soil temps reach 55°F.

Using Disease Predictive Models to Time Fungicides

Application Timing Based on Air Temps and RH

- ✓ **Dollar Spot:** 5-day rolling avg. of air temp and RH with a risk index of 20%. (Smith et al, 2018)
- ✓ **Brown Patch:** Min. Air Temp > 59F, RH > 95%, Rain / Irrig > 0.1 in within 36 hr. (Schumann et. al., 1994)
- ✓ **Pythium Blight:** Min. air temp + Max. RH > 150
Min Air Temp > 68F. (150 Rule)

OR

Min temp > 68 F > 18-24 hr. (Hall et al., 1985)

TOTAL # OF FUNGICIDE APPLICATIONS FOR THE CONTROL OF ANTHRACNOSE: COMPARISON OF THRESHOLD APPLICATIONS TO COMBINATIONS OF NITROGEN PROGRAMS AND MOWING HEIGHTS

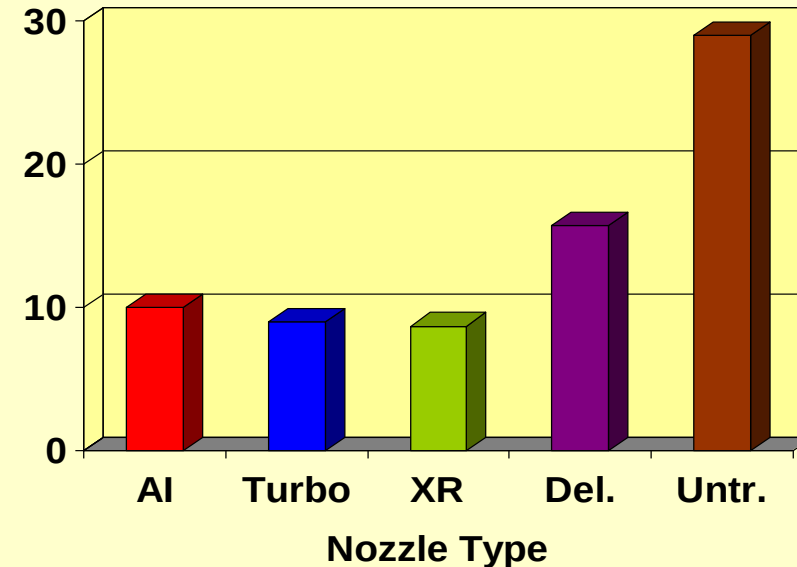
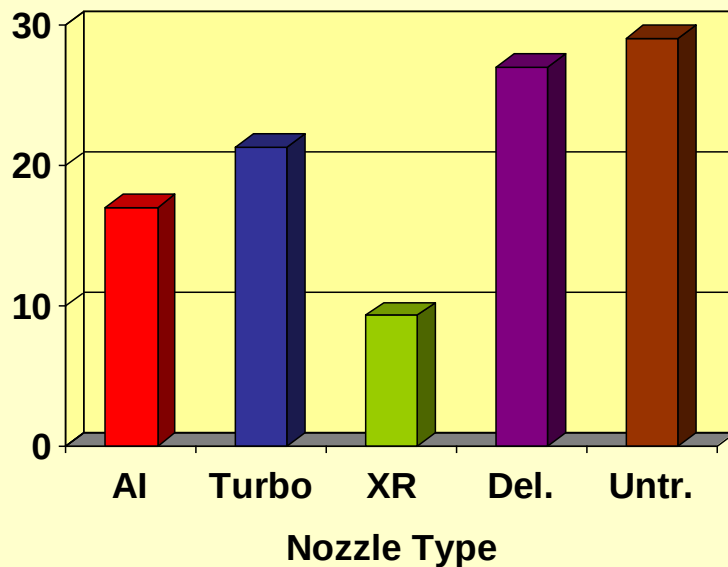
	Low Mow (0.090 in)	High Mow (0.125 in)
Low N (2.05 lbs N 1000 ft ⁻² yr ⁻¹)	9	9
High N (4.1 lbs N 1000 ft ⁻² yr ⁻¹)	5	2

80% less fungicide than calendar-based schedule

Principles of an Effective Disease Control Program

2) Select and apply the Most Efficacious Fungicides at the Optimum Timing, and **Water Volumes**

Impact of Water Volume and Nozzle Type on Dollar Spot Control
0.5 gal/1000 ft² (chlorothalonil) 2 gal/1000 ft² (chlorothalonil)



Principles of an Effective Disease Control Program

3) Follow **Best Management Practices** that reduce pathogen populations and the potential for fungicide resistance



A wide-angle photograph of a golf course green. In the background, a large, multi-story clubhouse with a stone facade and a balcony with green awnings is visible. A line of white golf carts is parked along a path to the left of the clubhouse. The foreground is a large, well-maintained green with several yellow flagsticks. The text "Putting It All Together: Using BMPs to Reduce Fungicide Inputs" is overlaid in red on the green.

Putting It All Together: Using BMPs to Reduce Fungicide Inputs

Combining Best Management Practices for Anthracnose

Factors:

Mowing Height

0.090 vs. 0.125 inch



N Fertility

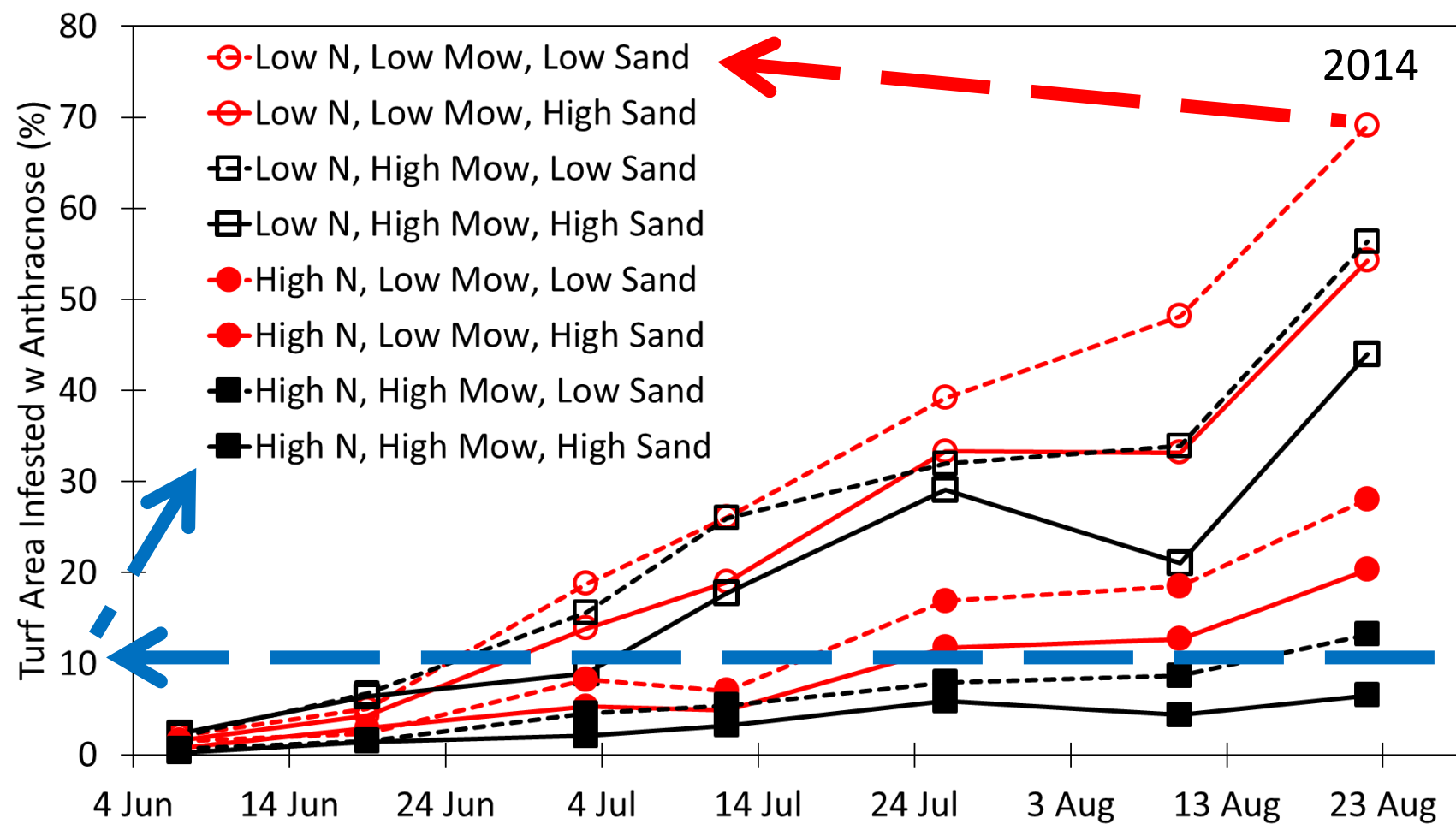
2.05 vs. 4.1 lbs N / 1,000-ft² / yr

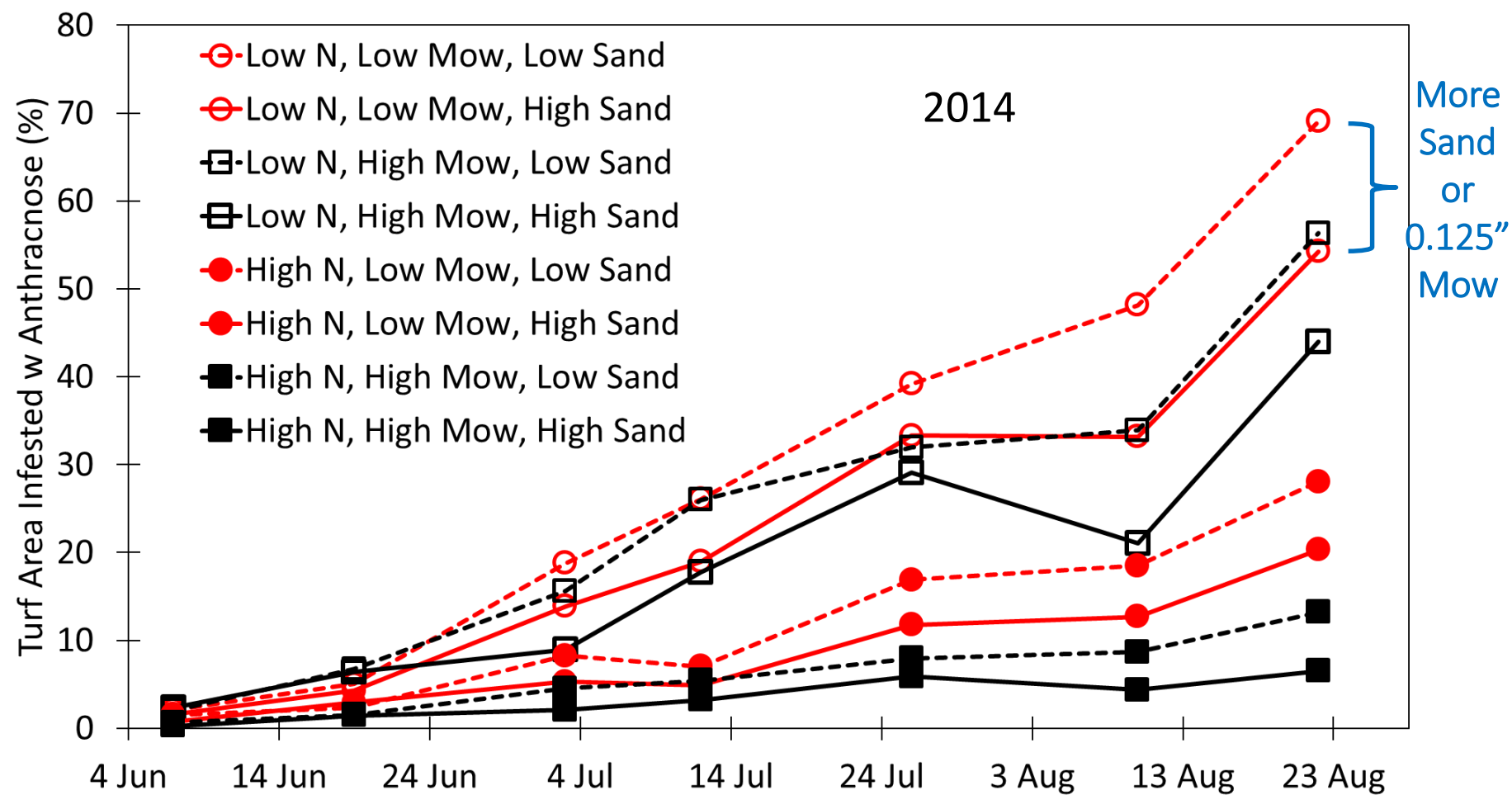


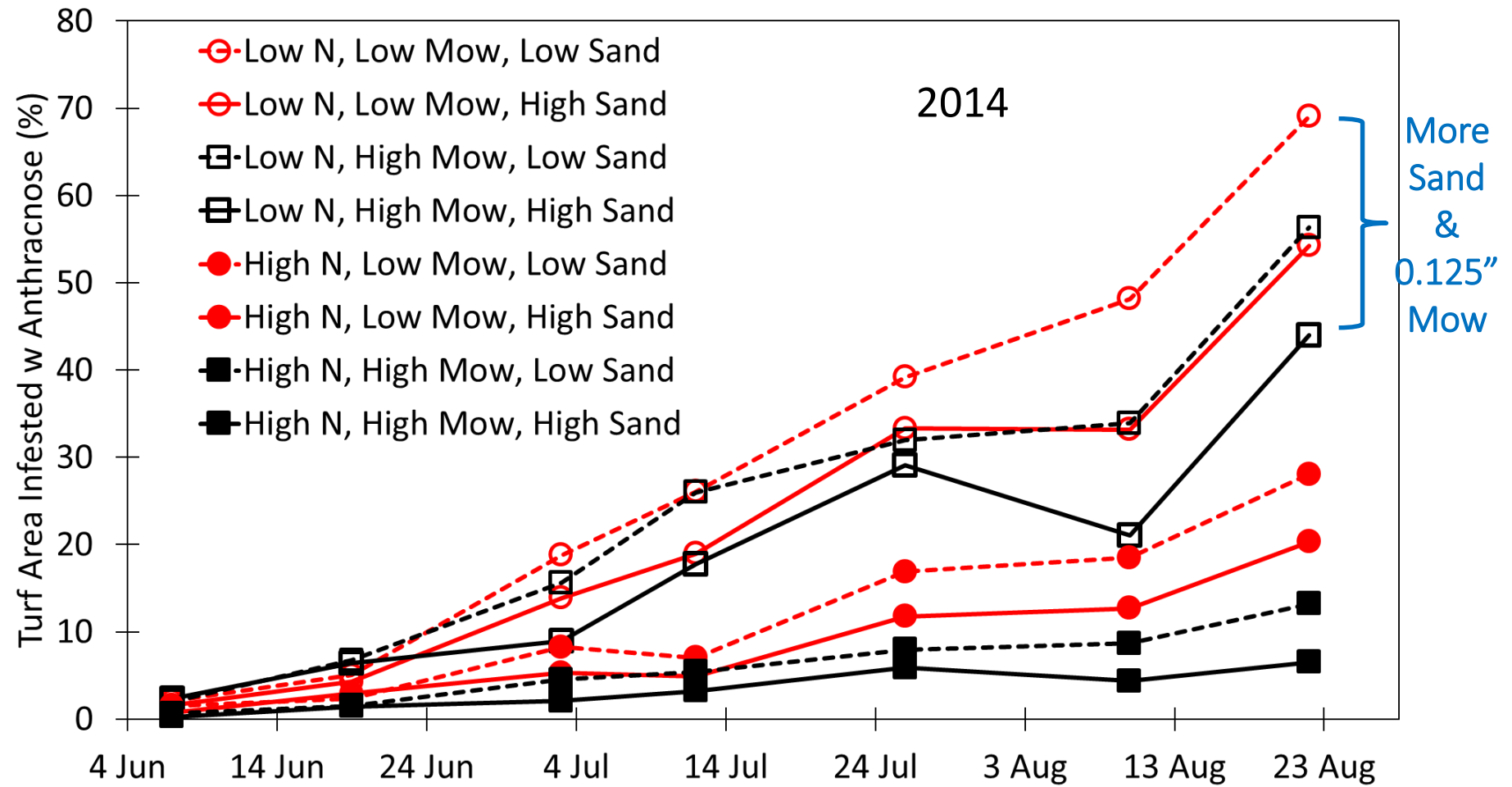
Topdressing Sand

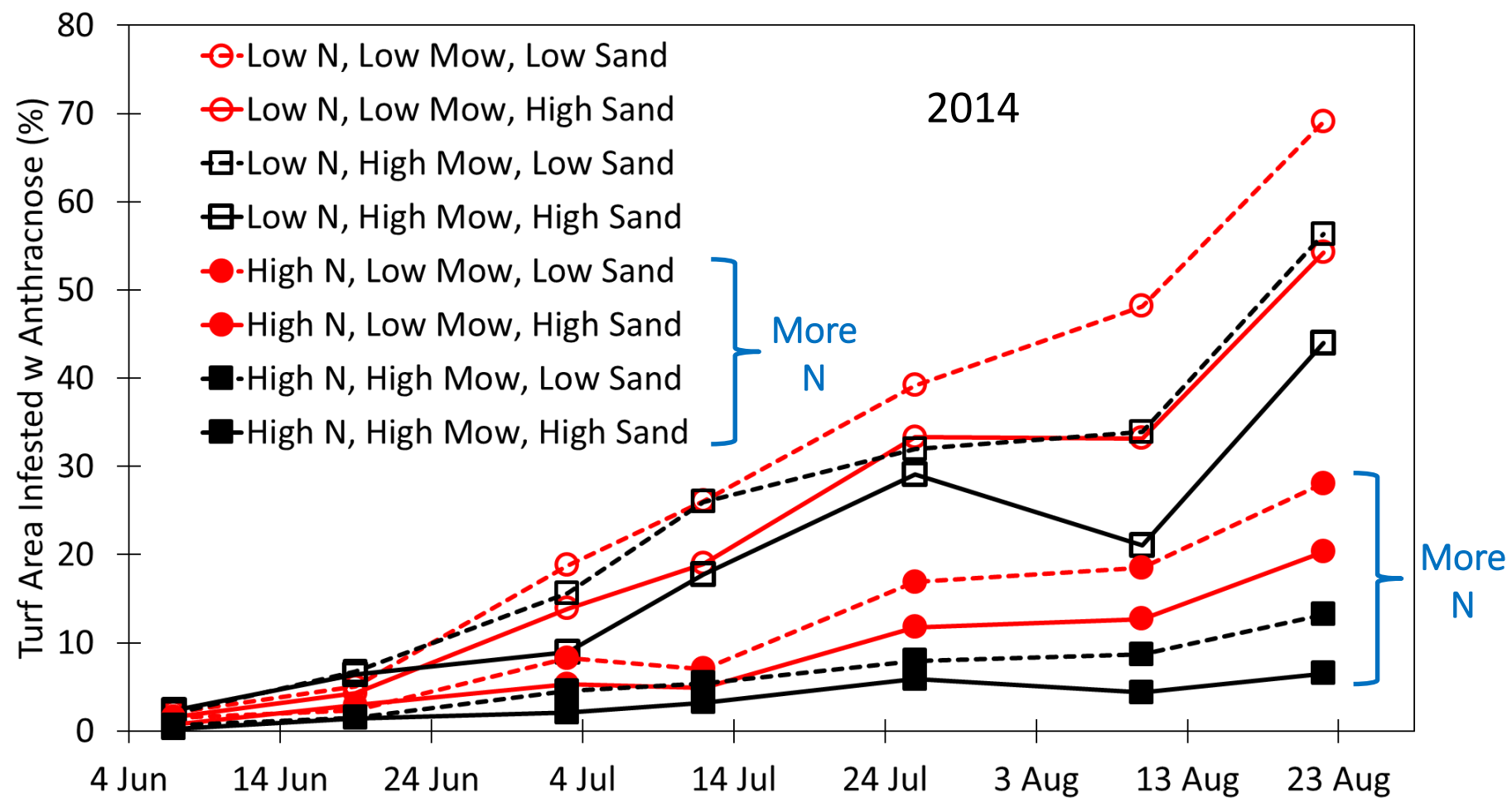
760 vs. 1,660 lbs. / 1,000-ft² / yr











Principles of an Effective Disease Control Program

4) Select fungicides that are Environmentally Friendly (low “Environmental Impact Quotient or “EIQ)

The Environmental Impact Quotient (EIQ) is a formula created to provide managers with data regarding the **environmental** and **health impacts** of their pesticide options so they can make better informed decisions regarding their pesticide selection



Tee to Green May/June 2018

Principles of an Effective Disease Control Program

- Select fungicides that are Environmentally Friendly (low “Environmental Impact Quotient or “EIQ)



Cornell **CALS**
College of Agriculture and Life Sciences

New York State Integrated Pest Management
A Method to Measure the Environmental Impact of Pesticides

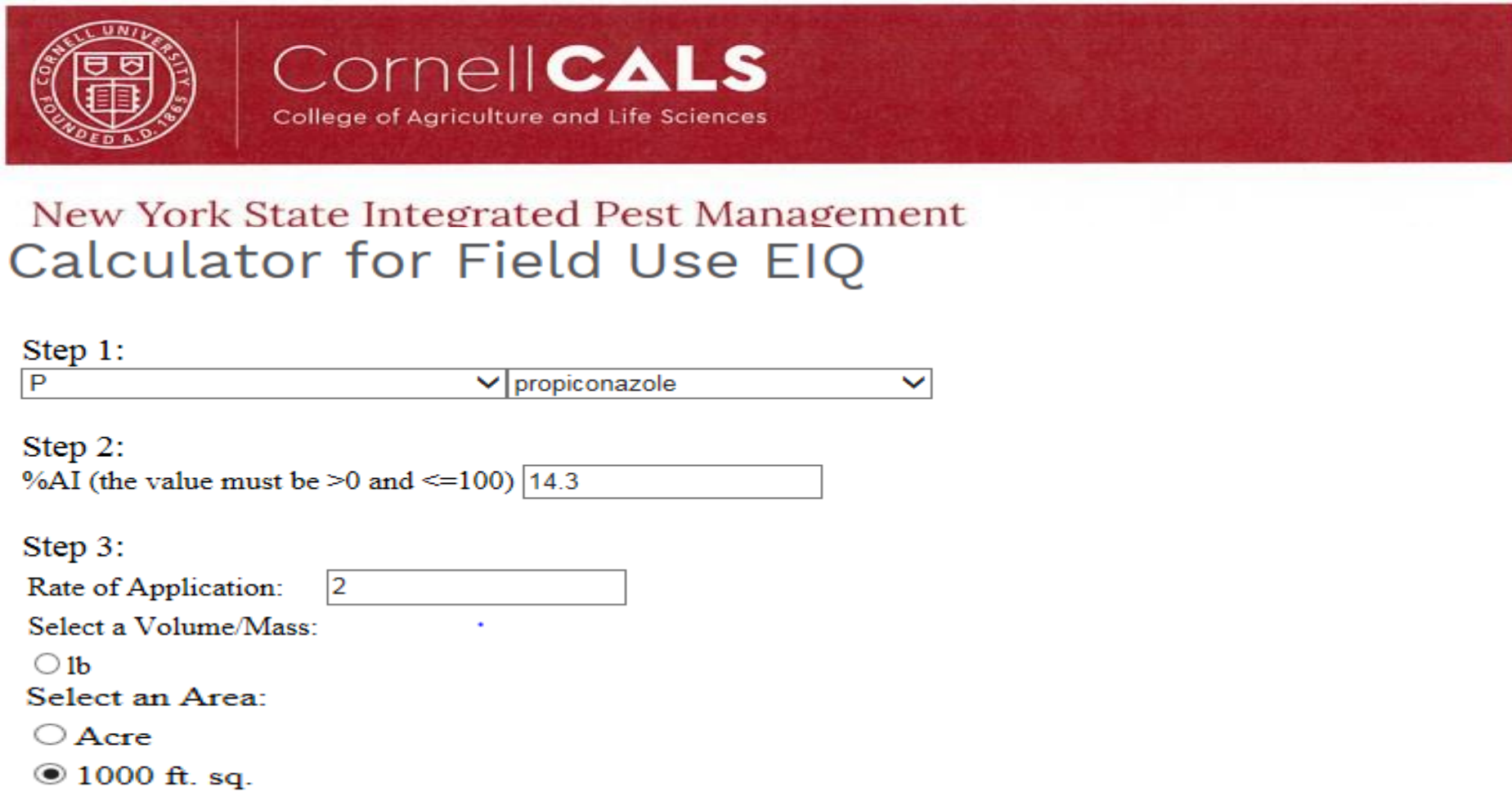
The Environmental Impact Quotient (EIQ) is a formula created to provide growers with data regarding the environmental and health impacts of their pesticide options so they can make better informed decisions regarding their pesticide selection.

The original paper [introducing and describing the EIQ](#) was written by members of the NYS Integrated Pest Management Program (NYSIPM) in 1992.

[An EIQ calculator](#) was also developed to aid users in computing Field Use EIQ values, and facilitate comparison of pest management options and systems.

Principles of an Effective Disease Control Program

- Select fungicides that are Environmentally Friendly (low “Environmental Impact Quotient or “EIQ)



The screenshot shows the Cornell CALS website header with the Cornell University logo and the text "Cornell CALS College of Agriculture and Life Sciences". Below the header is the title "New York State Integrated Pest Management Calculator for Field Use EIQ". The form is divided into three steps. Step 1 has a dropdown menu with "P" selected and a text input field containing "propiconazole". Step 2 has a label "%AI (the value must be >0 and <=100)" and a text input field containing "14.3". Step 3 has a label "Rate of Application:" with a text input field containing "2", a label "Select a Volume/Mass:" with a radio button selected, and a label "Select an Area:" with two radio buttons, "Acre" and "1000 ft. sq.", where "1000 ft. sq." is selected.

 Cornell CALS
College of Agriculture and Life Sciences

New York State Integrated Pest Management Calculator for Field Use EIQ

Step 1:

P ▼ propiconazole ▼

Step 2:

%AI (the value must be >0 and <=100) 14.3

Step 3:

Rate of Application: 2

Select a Volume/Mass: ☐

Select an Area:

☐ Acre

☒ 1000 ft. sq.

Principles of an Effective Disease Control Program

- Select and apply the Most Efficacious Fungicides at the best time, rate and water volume



Cornell**CALS**
College of Agriculture and Life Sciences

New York State Integrated Pest Management

EQ Calculator Output for: propiconazole

 Use the Field Use EQ for comparisons, not the base EQ Value.

USER INPUT
Active Ingredient: propiconazole
% AI: 14.3
Rate of Application: 2 fl oz/1000ft²

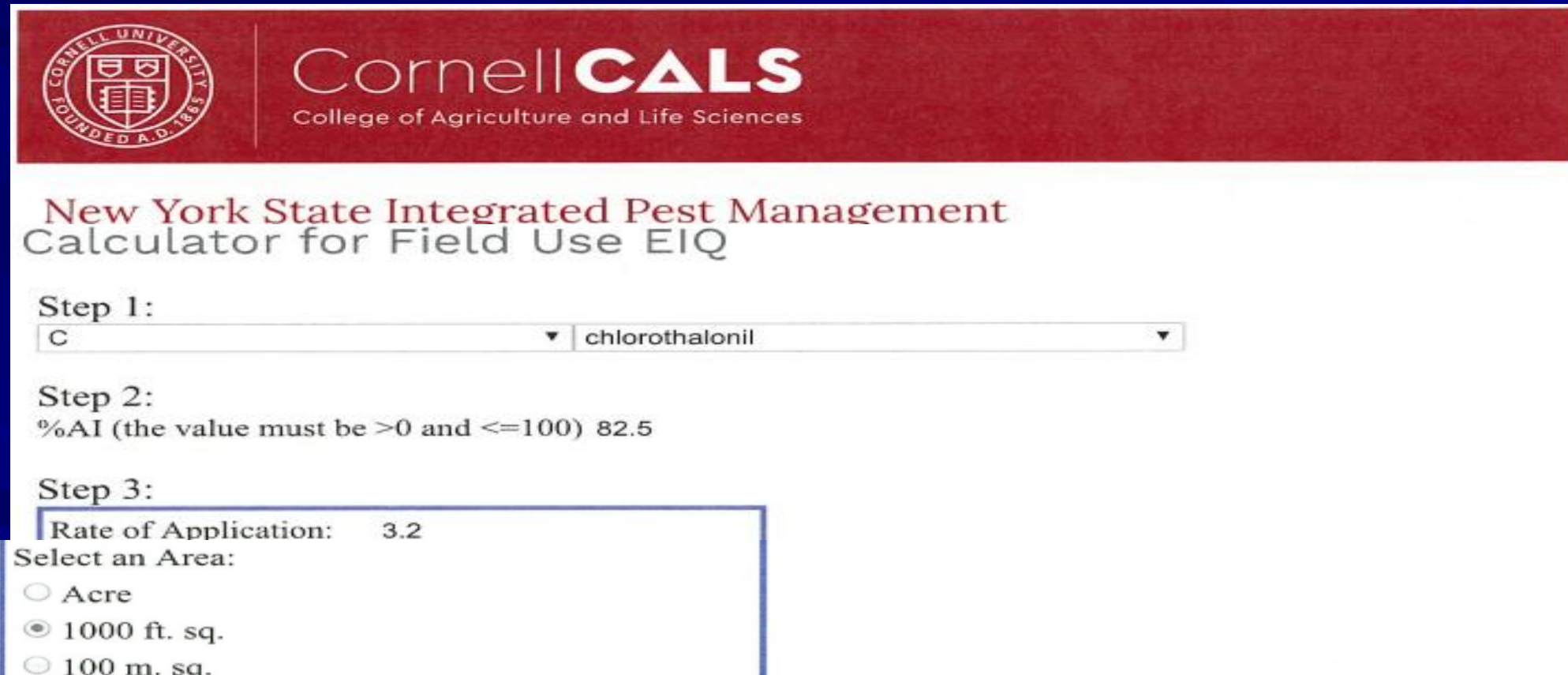
REFERENCE VALUE
EQ Value for Active Ingredient propiconazole: 31.6
Source: *NYS IPM EQ Database*

RESULTS
Field Use EQ: 24.6

[illegible]

Principles of an Effective Disease Control Program

- Select fungicides that are Environmentally Friendly (low “Environmental Impact Quotient or “EIQ)



The screenshot shows the Cornell CALS website header with the Cornell University logo and the text "Cornell CALS College of Agriculture and Life Sciences". Below the header is the title "New York State Integrated Pest Management Calculator for Field Use EIQ". The form is divided into three steps. Step 1 shows a dropdown menu with "C" selected and another dropdown menu with "chlorothalonil" selected. Step 2 shows the input "%AI (the value must be >0 and <=100)" with the value "82.5". Step 3 shows the input "Rate of Application:" with the value "3.2". Below Step 3 is a section titled "Select an Area:" with three radio button options: "Acre", "1000 ft. sq." (which is selected), and "100 m. sq.".

 Cornell **CALS**
College of Agriculture and Life Sciences

**New York State Integrated Pest Management
Calculator for Field Use EIQ**

Step 1:
C ▼ chlorothalonil ▼

Step 2:
%AI (the value must be >0 and <=100) 82.5

Step 3:
Rate of Application: 3.2

Select an Area:

☐ Acre
☒ 1000 ft. sq.
☐ 100 m. sq.

Principles of an Effective Disease Control Program

- Select and apply the Most Efficacious Fungicides at the best time, rate and water volume



Cornell **CALS**
College of Agriculture and Life Sciences

New York State Integrated Pest Management

EIQ Calculator Output for: chlorothalonil

 Use the Field Use EIQ for comparisons, not the base EIQ Value.

USER INPUT
Active Ingredient: chlorothalonil
% AI: 82.5
Rate of Application: 3.2 oz/1000ft²

REFERENCE VALUE
EIQ Value for Active Ingredient chlorothalonil: 37.4
Source: *NYS IPM EIQ Database*

RESULTS
Field Use EIQ: 269.0

Date	Target pest	Product	Active Ingredient	%AI	AI EIQ	Amt	t	Amt	Unit	Targ et Area	GAL /M	Total PR Used	Total AI Used	Un it	Total EIQ
4/16/2019	Fairy Ring	Banner ME3:E72	Propiconazole	14.30%	31.63	2	oz	4.1	Acres	Greens	2	357.2	51.1	oz	101
4/30/2019	Fungi	Emerald	Boscalid	70.00%	26.44	0.2	oz	4	Acres	Greens	2	31.36	22	oz	36.28
5/6/2019	Dollar spot	Emerald	Boscalid	70.00%	26.44	0.2	oz	4	Acres	Greens	2	31.36	22	oz	36.28
5/7/2019	Dollar spot	Emerald	Boscalid	70.00%	26.44	0.2	oz	28	Acres	airway	1	31.36	22	oz	36.28
5/9/2019	Fungi	Headway	Azoxystrobin	5.73%	26.92	3	oz	12	Acres	irways	2	1569	89.9	oz	151.3
			Propiconazole	9.54%	31.63							1569	150		295.9
5/10/2019	Dollar Spot	Daconil Ultrex	chlorothalonil	82.50%	37.40	3.2	oz	28	Acres	airway	1	3,903	3220	oz	7527
DEC	snow mold	Tartan	trifloxystrobin	4.17%	29.78	1	oz	174	000 ft²	Greens		174.2	7.27	oz	13.52
			triademefon	20.86%	26.96	1	oz	174	000 ft²	greens		174.2	36.3	oz	61.24
DEC	snow mold	Interface	Iprodione	23.10%	24.25	3	oz	174	000 ft²	greens		522.7	121	oz	183
			trifloxystrobin	1%	29.78	3	oz	174	000 ft²	greens		522.7	7.53	oz	14.01
															16017
													EIQ per ho		889.9

Summary: Building an Effective Fungicide Program

- ❖ Identify Major Diseases and when they typically occur
- ❖ Follow Best Management Practices that reduce pathogen populations and the potential for fungicide resistance
- ❖ Develop a List of currently labeled products for each disease
- ❖ Select and apply the Most Efficacious Fungicides at the Optimum Rates, Timing, and Water Volumes
- ❖ Look at strengths of each product and select broad spectrum fungicides or tank mix when expecting > 1 disease
- ❖ Rotate chemistries & elect fungicides with a low EIQ

Greens Fungicide Program Top Notch CC

- ♦ April: Emerald (4/30)
- ♦ May: Maxtima (5/13), Velista (5/28)
- ♦ June: Briskway (6/18), Segway (6/23), Secure (6/25), Affirm (6/25)
- ♦ July: Banol (7/4), Briskway (7/9), Segway (7/18), Secure Action (7/23), Medallion (7/23)
- ♦ August: Banol (8/1), Daconil Ultrex (8/6), Segway (8/18), Maxtima (8/18)
- ♦ September: Posterity (9/3), Secure (9/17)
- ♦ December: Tartan (12/3), Interface (12/3)

Fairway Fungicide Program Top Notch CC

- ♦ May: Emerald (5/7), Banner (5/21),
- ♦ June: Briskway (6/5), Headway (6/26)
- ♦ July: Secure (7/2), Briskway (7/17)
- ♦ August: Secure (8/1), Headway (8/7), Insignia (8/21)
- ♦ September: Exteris Stressgard (9/3), Briskway (9/11),
`Secure (9/25)

Are There Any Questions ?

RUTGERS *Center For Turfgrass Science*

New and Emerging Fungicides for use on Golf Courses

January 7, 2020

Bruce B. Clarke, Ph.D.

*Extension Specialist in Turfgrass Pathology
School of Environmental and Biological Sciences
Rutgers University*

Overview: New Fungicides for Golf Course Turf

- ◆ New Single Product Fungicides
- ◆ New Formulations and Rebranded /Generic Single Product Fungicides
- ◆ New Fungicide Pre-Mixes
- ◆ Soon to be Released Fungicides

New Single Product Fungicides for Golf Turf

Trade Name	Common Name	FRAC #
Autilus	PCNB (rebranded)	14
Appear	potassium phosphite	33
Fiata StressGard	potassium phosphite	33
Kabuto	Isofetamid	7 (SDHI)
Pedigree	flutolanil (SC)	7
Pinpoint	mandestrobin	11 (QOI)
Posterity	pydiflumetofen	7
Secure, Rotator, Soteria	Fluazinam (Pyridinamine)	29
Signature Xtra Stress	aluminum tris (fosetyl-AL)	33
Velista	penthiopyrad	7
Xzemplar	fluxapyroxad	7

PPA-1

Chemical Control of Turfgrass Diseases 2020

Bruce B. Clarke, Department of Plant Biology, Rutgers University; Paul Vincelli, Department of Plant Pathology, University of Kentucky; Paul Koch, Department of Plant Pathology, University of Wisconsin-Madison; Gregg Munshaw, Department of Plant and Soil Sciences, University of Kentucky

Turfgrasses under intensive management are often subject to outbreaks of infectious diseases. Diseases usually are most damaging when weather or cultural conditions favor the disease-causing agent but not plant growth and vigor. Cultural



University of Kentucky
College of Agriculture,
Food and Environment
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THE UNIVERSITY
of
WISCONSIN
MADISON

Google: PPA-1: Chemical Control of Turfgrass Diseases

Currently 6 Major Groups of SDHI (Succinate dehydrogenase inhibitors) Turfgrass Fungicides

- Pyridine-carboxamide (boscalid = Emerald)
- Phenyl-benzamide (flutolanil = ProStar)
- Pyrazole-4-carboximide (fluxapyroxad = Xzemplar)
(penthhiopyrad = Velista)
- Pyridinyl-ethyl-benzamide (fluopyram = Exteris StressGard)
- Phenyl-oxo-ethyl-thiophene amide (isofetamid = Kabuto)
- N-methyl-(phenyl-ethyl)-pyrazole-carboximide
(pydiflumetofen=Posterity)

Frac Group 7: SDHIs

Year	Manufacturer	Active Ingredient(s)	Product Name*
1986	Bayer	Flutolanil	Prostar ¹
2003	BASF	Boscalid	Emerald ²
2003	BASF	Boscalid + Pyraclostrobin	Honor
2014	BASF	Fluxapyroxad	Xzemplar ³
2014	BASF	Fluxapyroxad + Pyraclostrobin	Lexicon
2015	Syngenta	Penthiopyrad	Velista ³
2016	Syngenta	Benzovindiflupyr + Difenoconazole	Contend A ³
2016	PBI Gordon	Isofetamid	Kabuto ⁴
2016	Bayer	Fluopyram	Indemnify* ⁵
2017	Bayer	Fluopyram + Trifloxystrobin	Exteris Stressgard ⁵
2018	Syngenta	Pydiflumetofen	Posterity/Adepidyn ⁶
2018	PBI Gordon	Isofetamid + Tebuconazole	Tekken

* Sold as a nematicide. SDHI = Succinate dehydrogenase Inhibitor

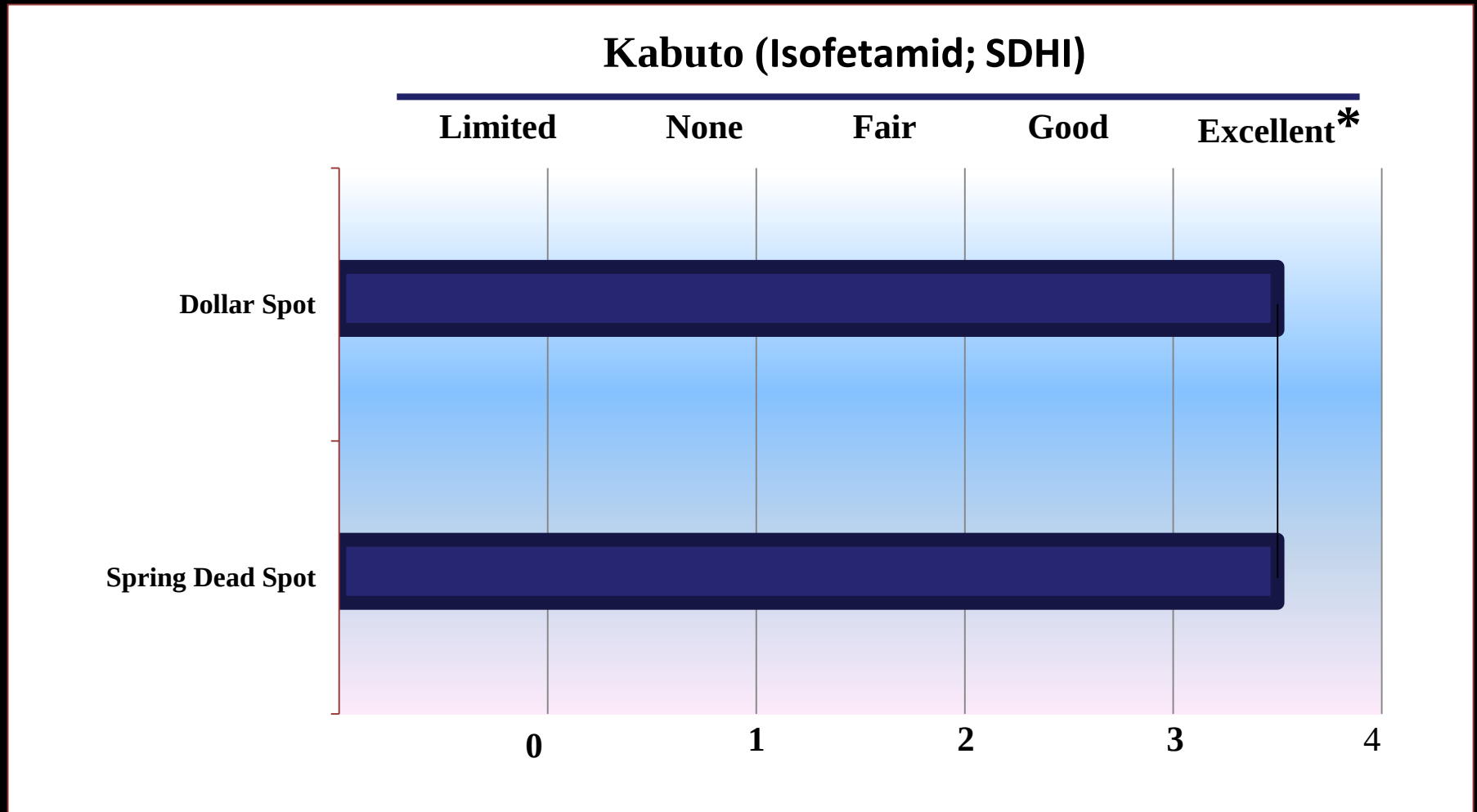
** Fungicides with same # are in same SDHI sub-group

Paul Giordano, 2018

Kabuto (Isofetamid; SDHI)

- 3.3SC formulation; Frac group 7
- Use Rate:
 - Dollar Spot 0.4 – 0.5 fl oz/1,000 ft² at a 14 day interval
 - Spring Dead Spot – 0.5 -3.2 fl oz/1,000 ft²
 - Once @ 3.2 fl oz preventive fall prior to dorm.
 - 2 x @ 0.5 - 2 fl oz 1 month prior to dormancy and 14-28 days later (max seasonal rate = 3.2 fl oz)
- Dollar Spot, Spring Dead Spot
- Modes of Action:
 - Inhibits respiratory pathway

Relative Efficacy of New Fungicides for Turf Disease Control : 2015- 2019 (Golf)



* Efficacy on a 1- 4 Scale, where 1 = not effective, 2 = fair – good control, 3 = good – excellent control, and 4 = excellent control. Limited = insufficient data.

Spring Dead Spot Golf Course Demo: Salisbury, MD



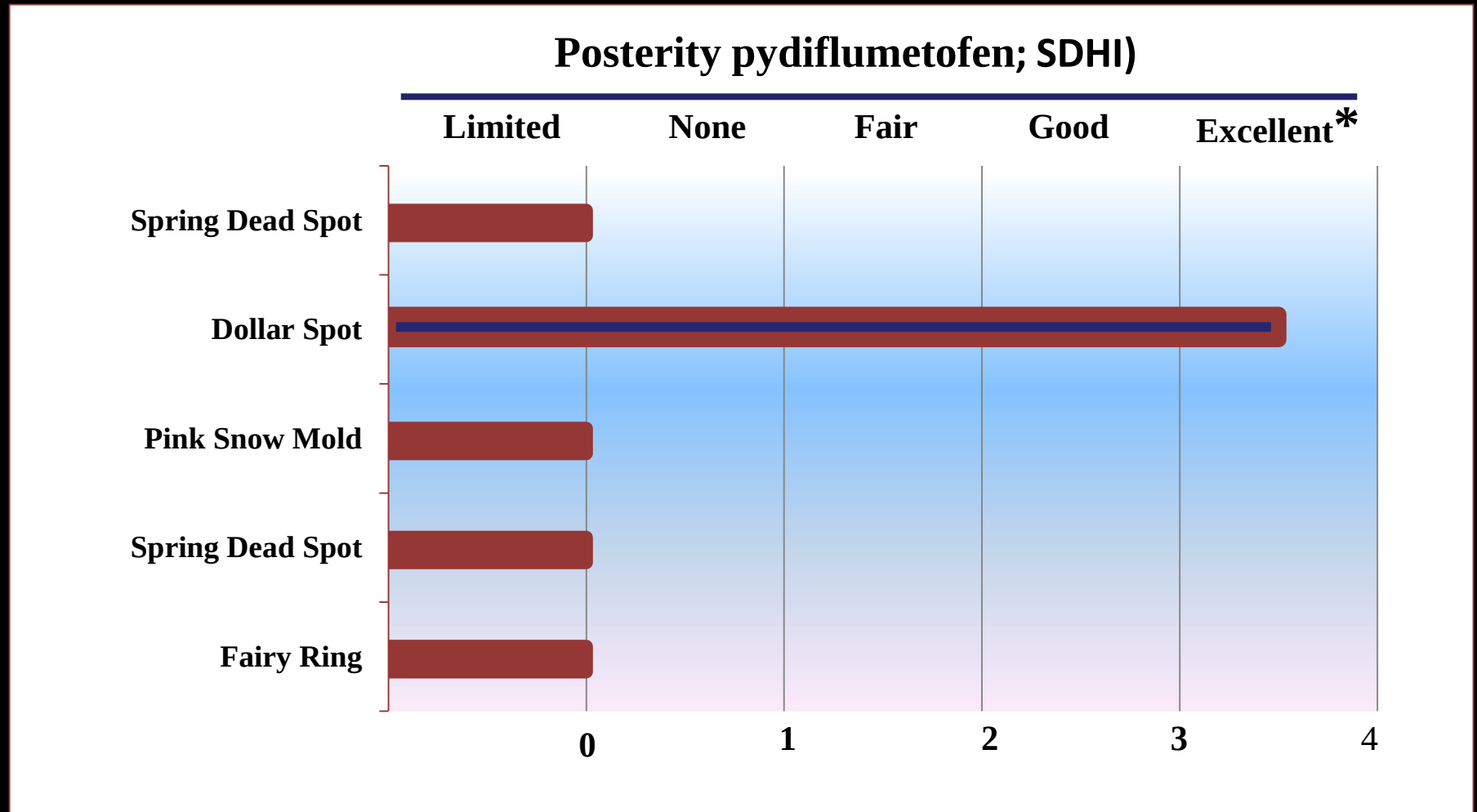
Control of SDS April 24, 2019. Kabuto @ 1.6 fl oz – 2 apps
(Right) and Non-treated control (left).

Photos courtesy of Brian Aynardi

Posterity (pydiflumetofen; SDHI)

- 1.67SC formulation; Frac group 7
- Use Rates:
 - 0.08 to 0.32 fl oz/1,000 ft² at a 14 to 28 day interval
 - Dollar Spot, Fairy Ring, Pink Snow mold, Spring Dead Spot
- Modes of Action:
 - Inhibits respiratory pathway

Relative Efficacy of New Fungicides for Turf Disease Control : 2015- 2019 (Golf)



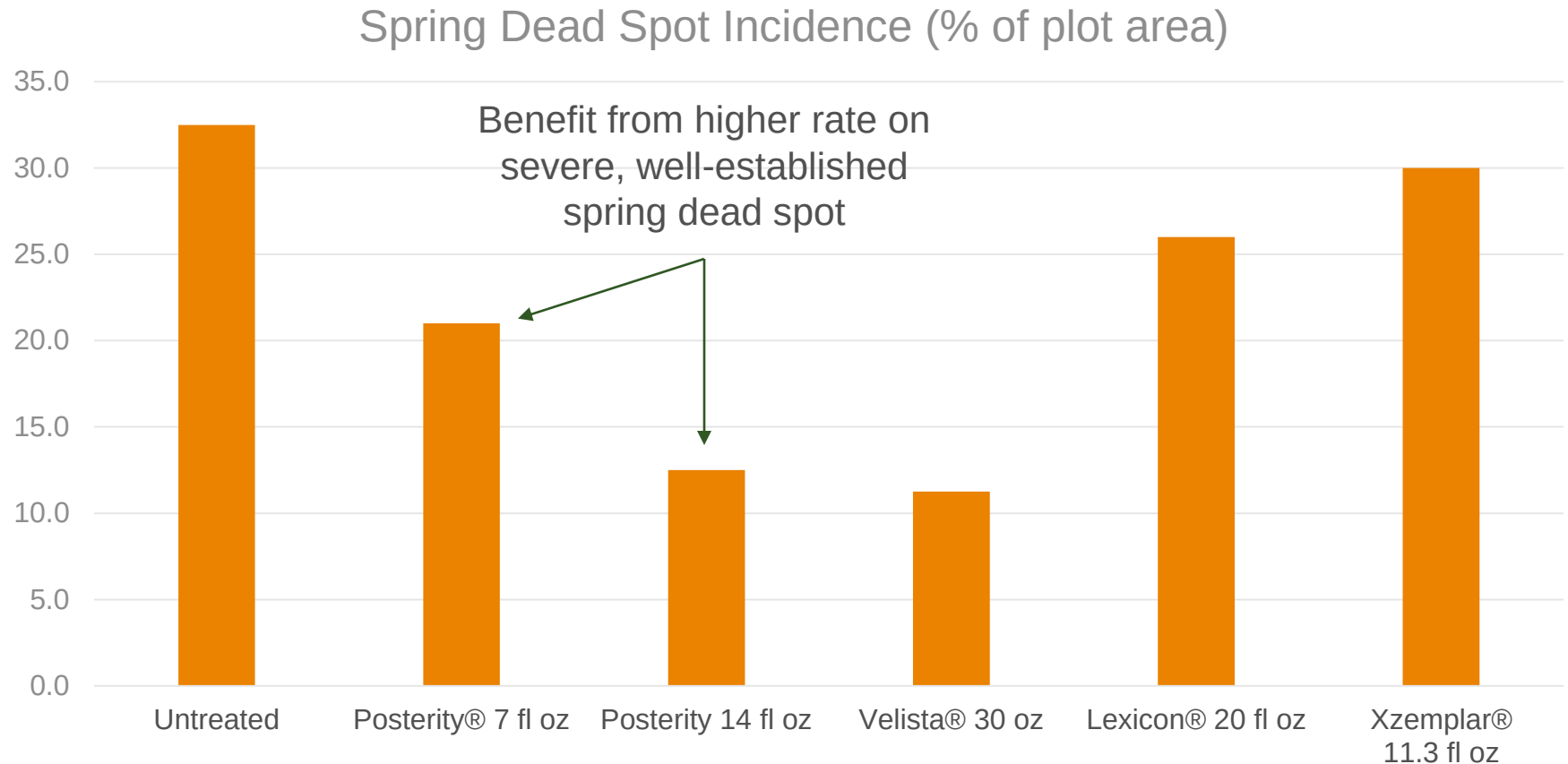
* Efficacy on a 1- 4 Scale, where 1 = not effective, 2 = fair – good control, 3 = good – excellent control, and 4 = excellent control. Limited = insufficient data.

Dollar Spot Control on CBG Fwy – 21 day



Spring Dead Spot Control in Hybrid Bermudagrass Roughs

Syngenta Internal Trial, Greenville SC, 2016-2017



All rates are per acre. Treatments applied Sept 22 and Oct 24, 2016. Data collected May 24, 2017.

Spring Dead Spot Control in Hybrid Bermudagrass Roughs

Syngenta Internal Trial, Greenville SC, 2016-2017



Untreated Control



Posterity® 14 fl oz/acre



Lexicon® 20 fl oz/acre



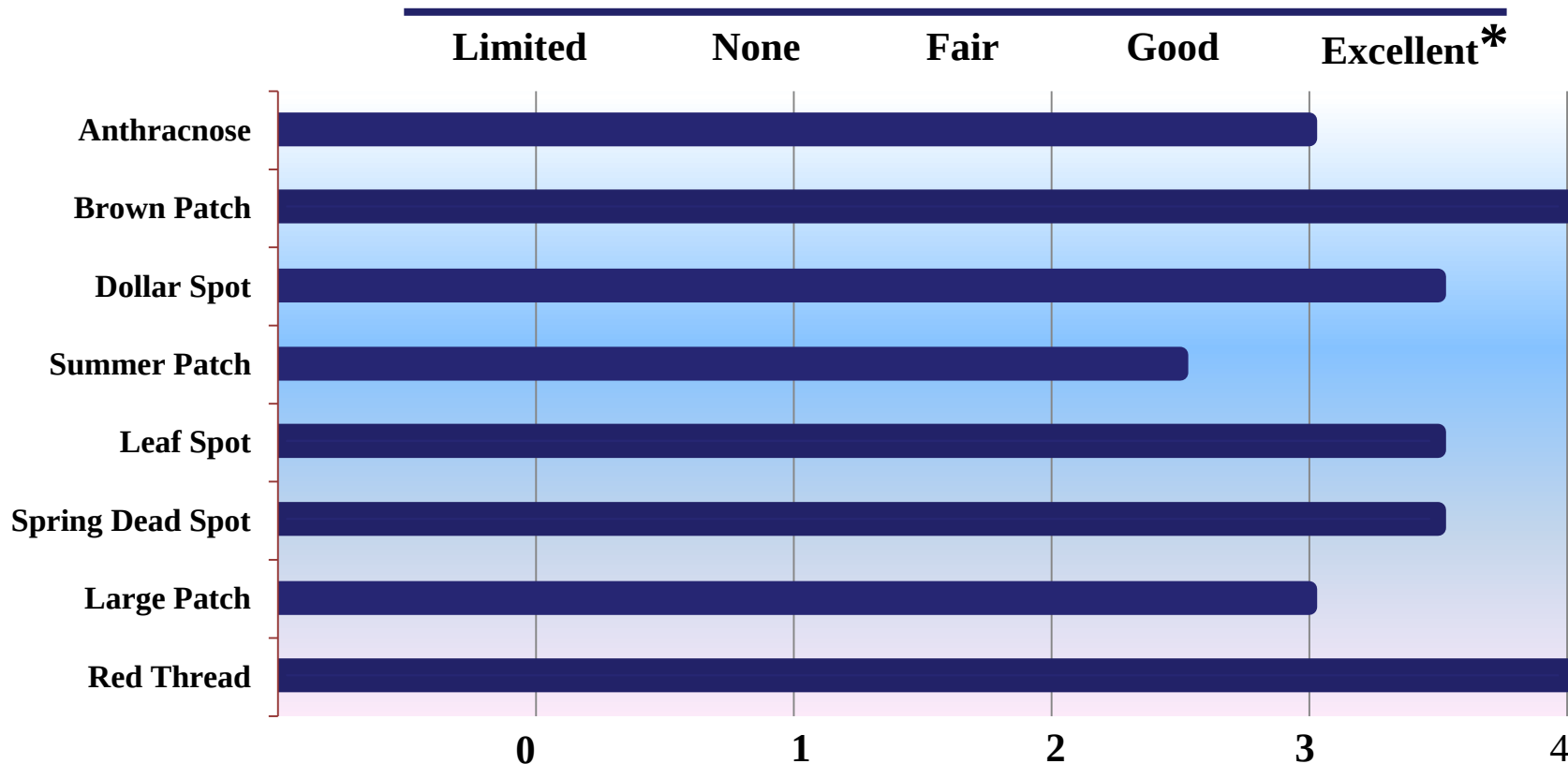
Xzemplar® 11.3 fl oz/acre

Velista (penthiopyrad)

- 50WG formulation; Frac group 7
- Use Rate:
 - 0.3 – 0.5 fl oz/1,000 ft² at a 14 to 21 day interval
 - Anthracnose, Brown patch, Dollar Spot, Large Patch, Leaf spot, Red thread, Rust,
- Modes of Action:
 - Inhibits respiratory pathway (SDHI)

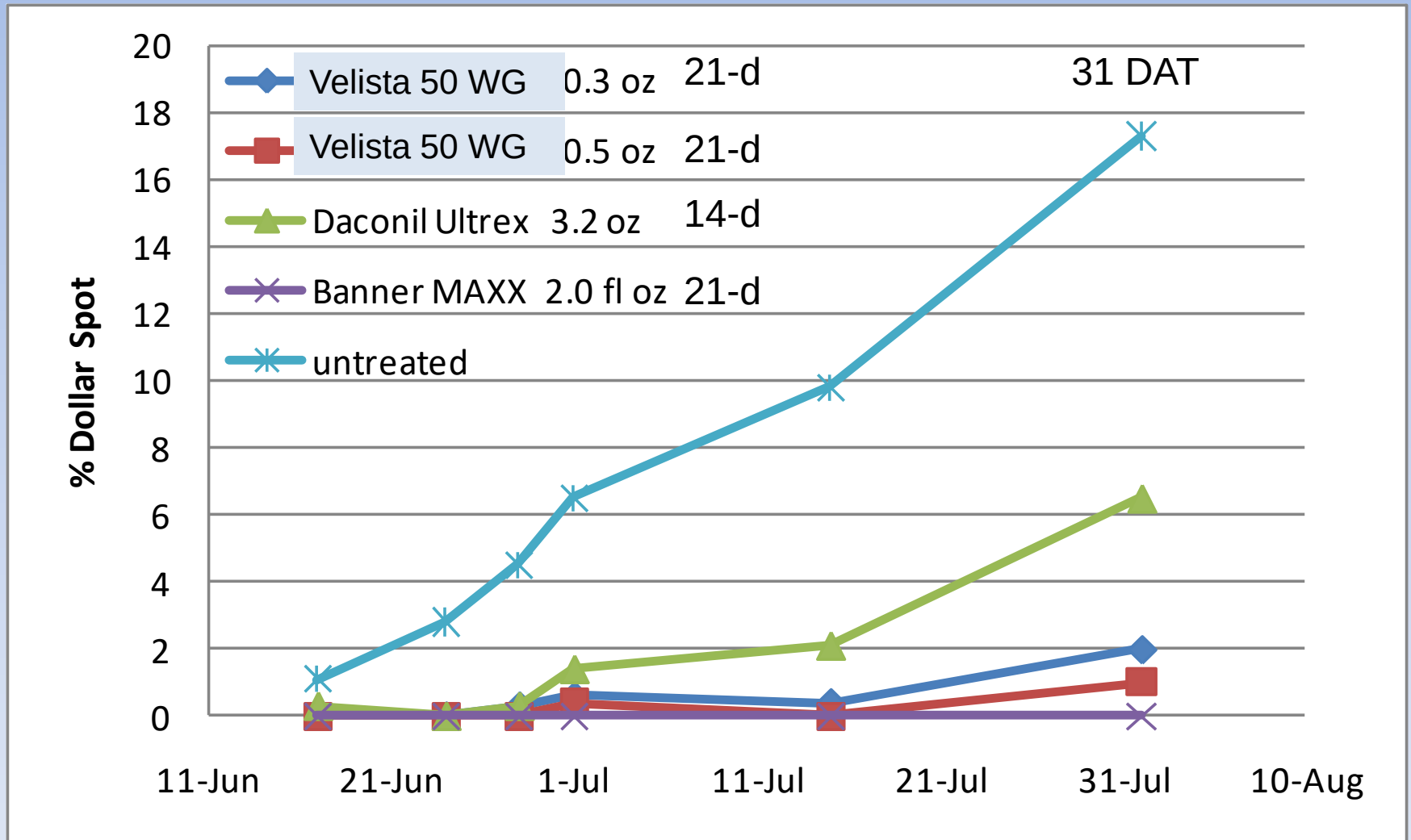
Relative Efficacy of New Fungicides for Turf Disease Control : 2015- 2019 (Golf)

Velista



* Efficacy on a 1- 4 Scale, where 1 = not effective, 2 = fair – good control, 3 = good – excellent control, and 4 = excellent control. Limited = insufficient data.

Dollar spot control on creeping bentgrass fairway—UCONN 2010

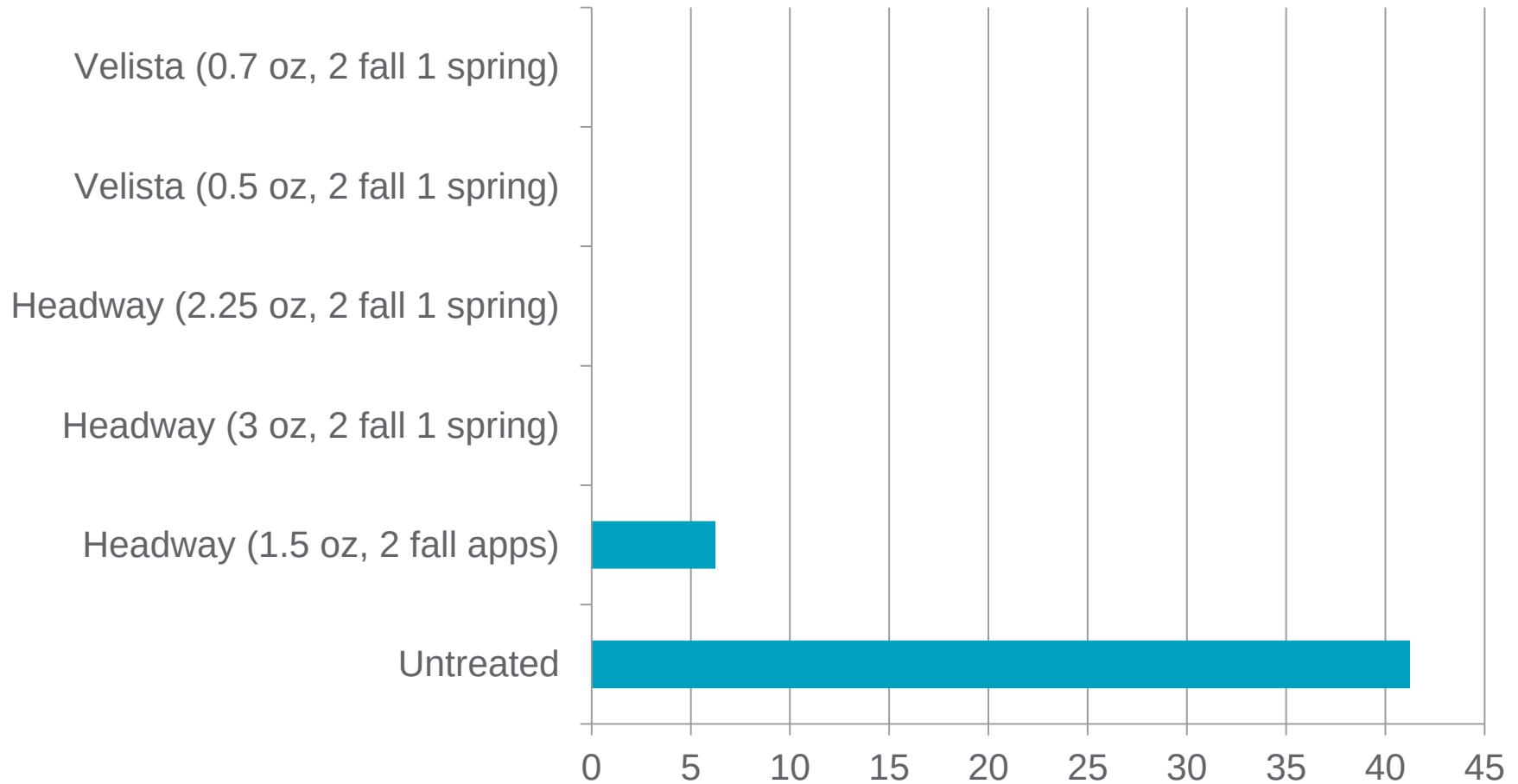


*Applied every 14-d or 21-d from early-Jun through late-Jul 2010

Large Patch Control in 'Cavalier' Zoysiagrass

Mike Richardson, University of Arkansas

% Large Patch, May 5 2015



Large Patch Control in 'Cavalier' Zoysiagrass

Mike Richardson, University of Arkansas



Untreated Control

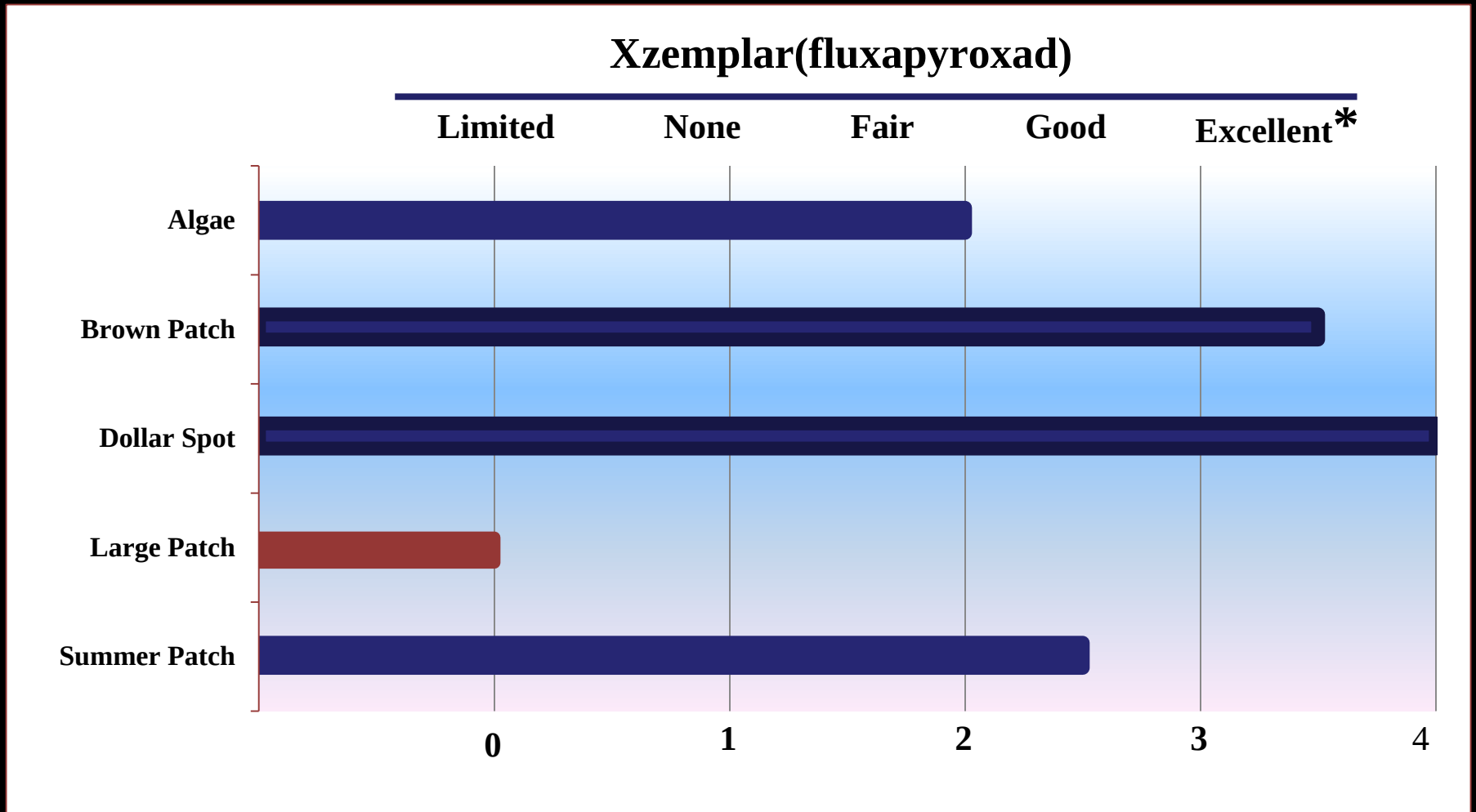


Velista, 0.5 oz
applied 9/23, 10/20, and 4/9

Xzemplar (fluxapyroxad)

- 2.47SC formulation; Frac group 7
- Use Rate:
 - 0.16 – 0.26 fl oz/1,000 ft² at a 14 to 28 day interval
 - Brown patch, Dollar Spot, Large Patch, Summer Patch, Pink Snow Mold, Algae
- Modes of Action:
 - Inhibits respiratory pathway (SDHI)

Relative Efficacy of New Fungicides for Turf Disease Control : 2015- 2019 (Golf)



* Efficacy on a 1- 4 Scale, where 1 = not effective, 2 = fair – good control, 3 = good – excellent control, and 4 = excellent control. Limited = insufficient data.

Preventative Dollar Spot Trial on Bentgrass Greens



Untreated



Xzemplar (0.26 fl. oz./1,000 sq. ft.)
28-day interval
Applications on 6/6, 7/3, 7/31



Xzemplar (0.21 fl. oz./1,000 sq. ft.)
21-day interval
Applications on 6/6, 6/27, 7/17, 8/9

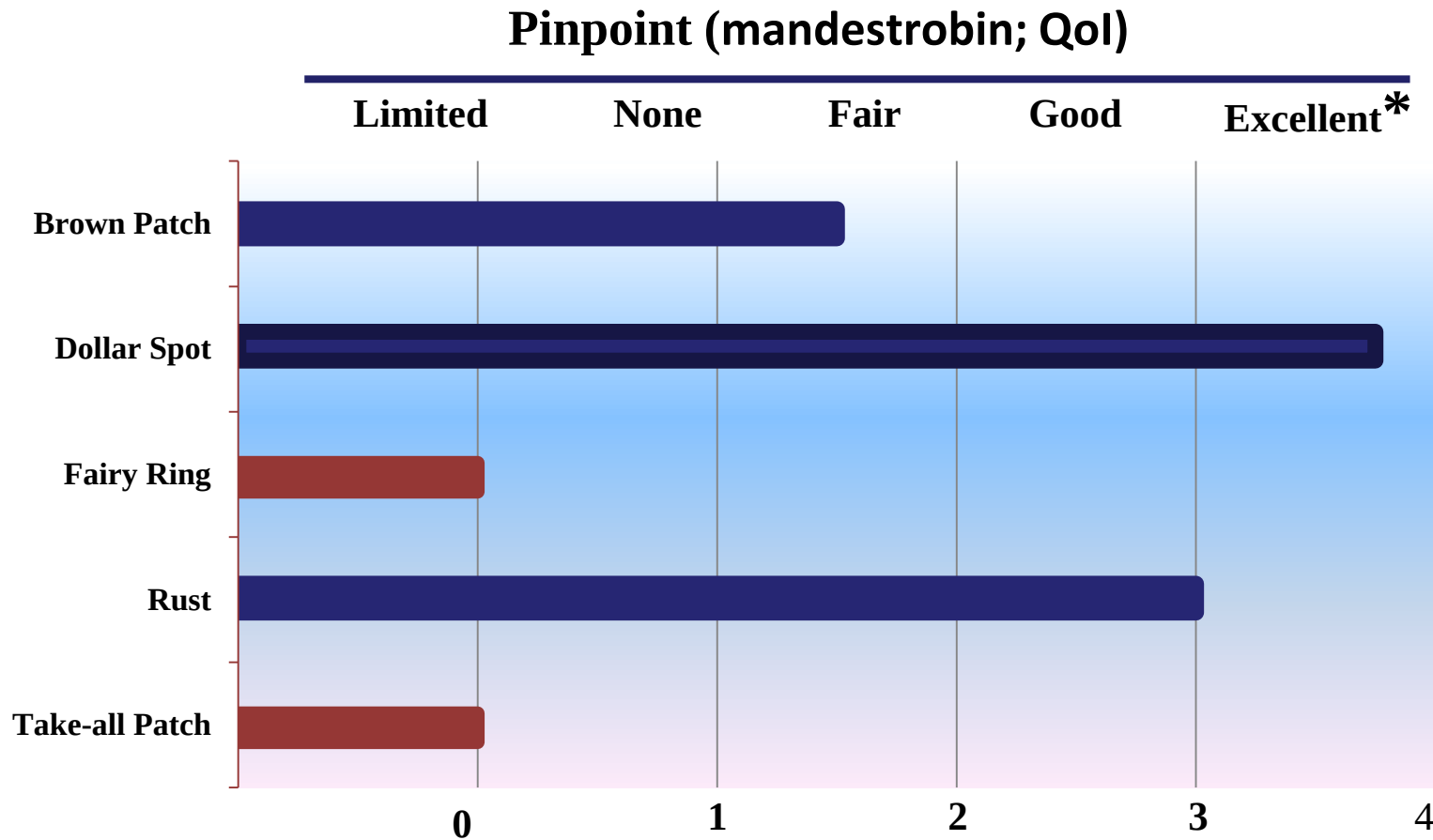
Photos taken on 8/6/13

Kansas State University, 2013

Pinpoint (mandestrobin; QoI)

- 4SC formulation; Frac group 11
- Use Rate:
 - 0.17 – 0.31 fl oz/1,000 ft² at a 14 to 21 day interval
- Brown patch, Dollar Spot, Fairy Ring, Rust, Take-All
- Modes of Action:
 - Inhibits respiratory pathway

Relative Efficacy of New Fungicides for Cool - Season Turf Diseases : 2014- 2018 (Golf)

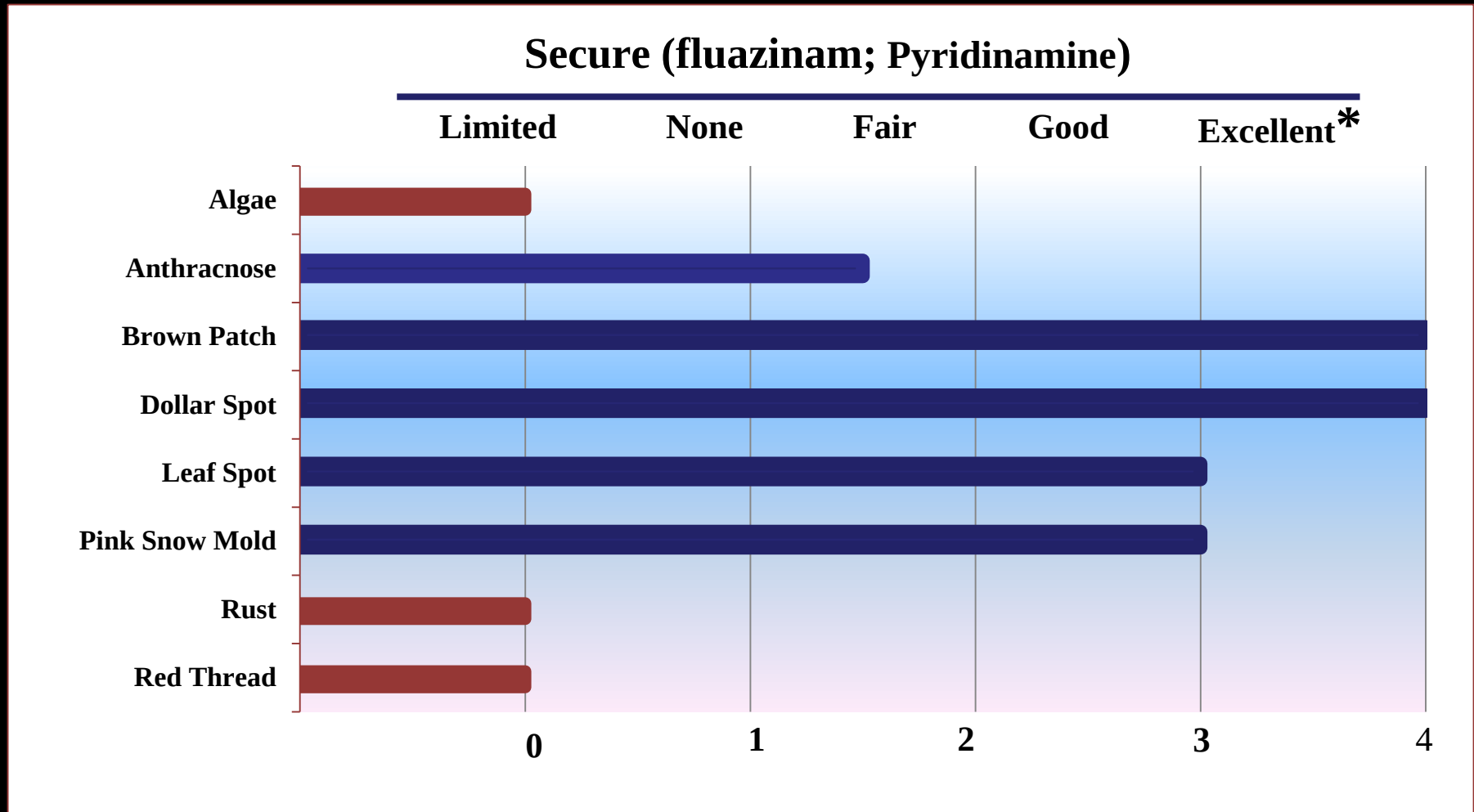


* Efficacy on a 1- 4 Scale, where 1 = not effective, 2 = fair – good control, 3 = good – excellent control, and 4 = excellent control. Limited = insufficient data.

Secure (fluazinam)

- 4.17SC; Frac group 29 (Pyridinamine)
- Dollar Spot 14-21 day spray interval
 - 0.5 fl oz/1,000 ft² (under higher disease pressure, use shorter interval)
- Anthracnose, Brown patch, Dollar Spot, Leaf spot, Red thread, Pink Snow mold, Rust, Fairy Ring, Algae
- Modes of Action:
 - Inhibits respiration by uncoupling oxidative phosphorylation (contact; multi-site fungicide)

Relative Efficacy of New Fungicides for Turf Disease Control : 2015- 2019 (Golf)



* Efficacy on a 1- 4 Scale, where 1 = not effective, 2 = fair – good control, 3 = good – excellent control, and 4 = excellent control. Limited = insufficient data.

Dollar Spot Trial 2011: Rutgers University

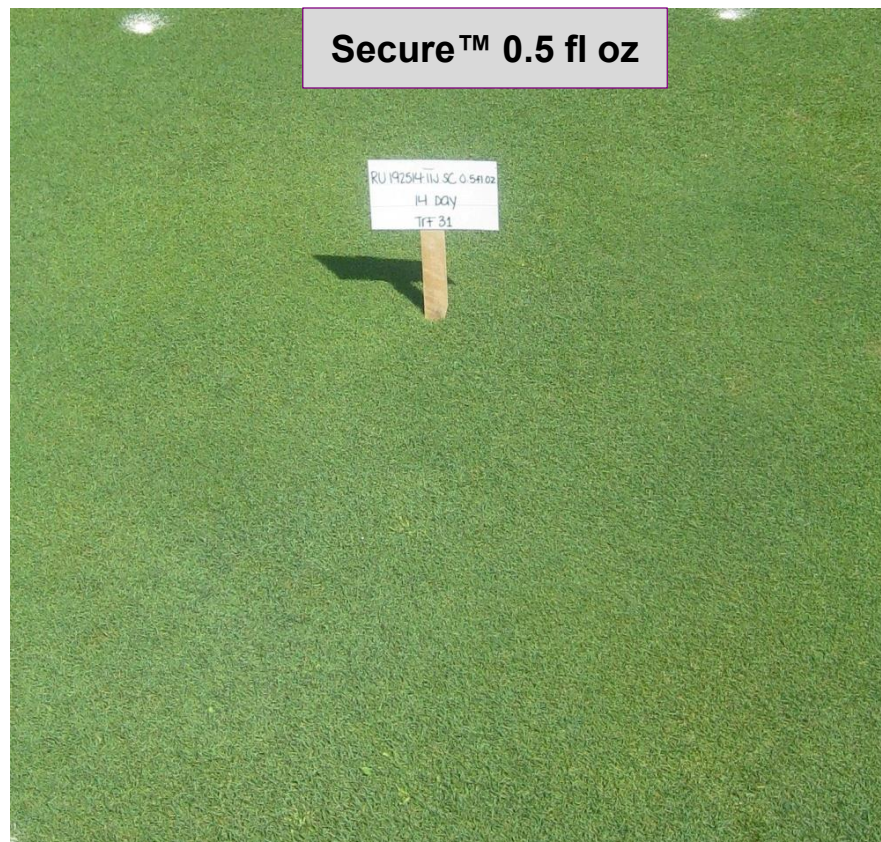
Crenshaw Creeping Bentgrass (Fairway Height)

July 26, 2011

Chlorothalonil 2.0 fl oz



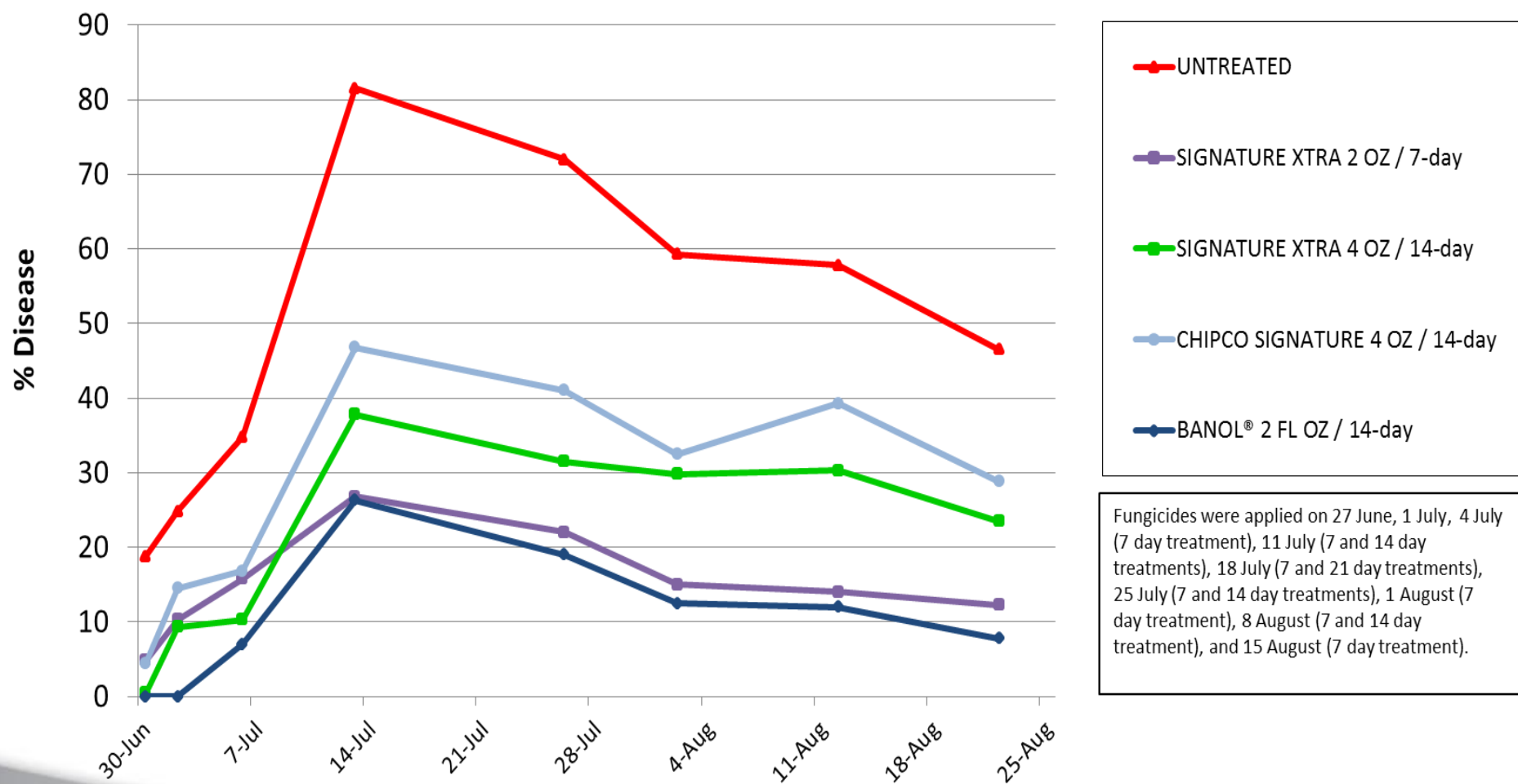
Secure™ 0.5 fl oz



Signature Xtra Stressgard (fosetyl-AL)

- Pythium, yellow tuft, anthracnose (tank mixed)
- Fosetyl-AL rate lowered, now 60 WDG vs. 80 WDG
- Reduction allows for inclusion of additional components to optimize plant health
- Alleviates biotic and abiotic stress
- Enhanced formulation for improved tank-mix compatibility

Pythium Blight



100% ET

60% ET

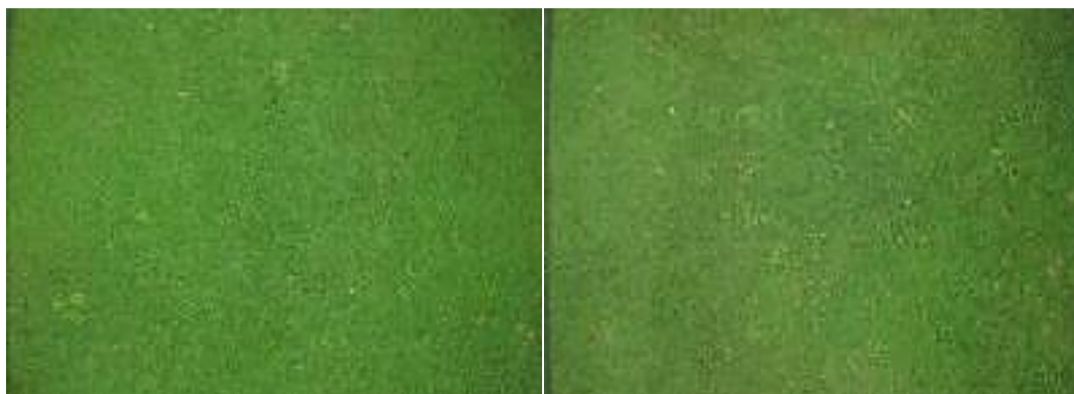
Untreated Control



Signature Xtra Stressgard
4 oz @ 14 days



Signature Xtra Stressgard
2 oz @ 7 days



August 21, 2015

New Formulations and Rebranded /Generic Single Product Fungicides for Golf Turf

Trade Name	Common Name	FRAC #
ArmorTech ZOXY SC**	azoxystrobin	11
ArborTech IP **	Iprodione	2
Fame (Disarm) G*	fluoxastrobin	11
Fame (Disarm) SC*	fluoxastrobin	11
Goliath**	Azoxystrobin + propiconazole	11 + 3
Insignia Intrinsic*	pyraclostrobin	11
Previa**	chlorothalonil	M5

* Rebranded product, ** New generic of existing product

New Fungicide Pre-Mixes for Golf Turf

Trade Name	Common Name	FRAC #
Briskway	azoxystrobin + difenoconazole	11 + 3
Contend A	benzovinduiflupyr + difenoconazole	7 + 3
Exteris Stressgard	fluopyram + trifloxystrobin	7 + 11
FFIII	PCNB + chlorothalonil	14 + M5
Heritage Action	azoxystrobin + acibenzolar	11 + P1
Lexicon	Insignia + fluxapyroxad	11 + 7
Premion	PCNB + + tebuconazole	14 + 3
Tekken	isofetamid + + tebuconazole	7 + 3
Traction	fluazinam + tebuconazole	29 + 3
Secure Action	fluazinam + acibenzolar-s-methyl:	29 + P1

* Rebranded product, ** New generic premix of existing

Briskway Fungicide

(Azoxystrobin + difenoconazole)

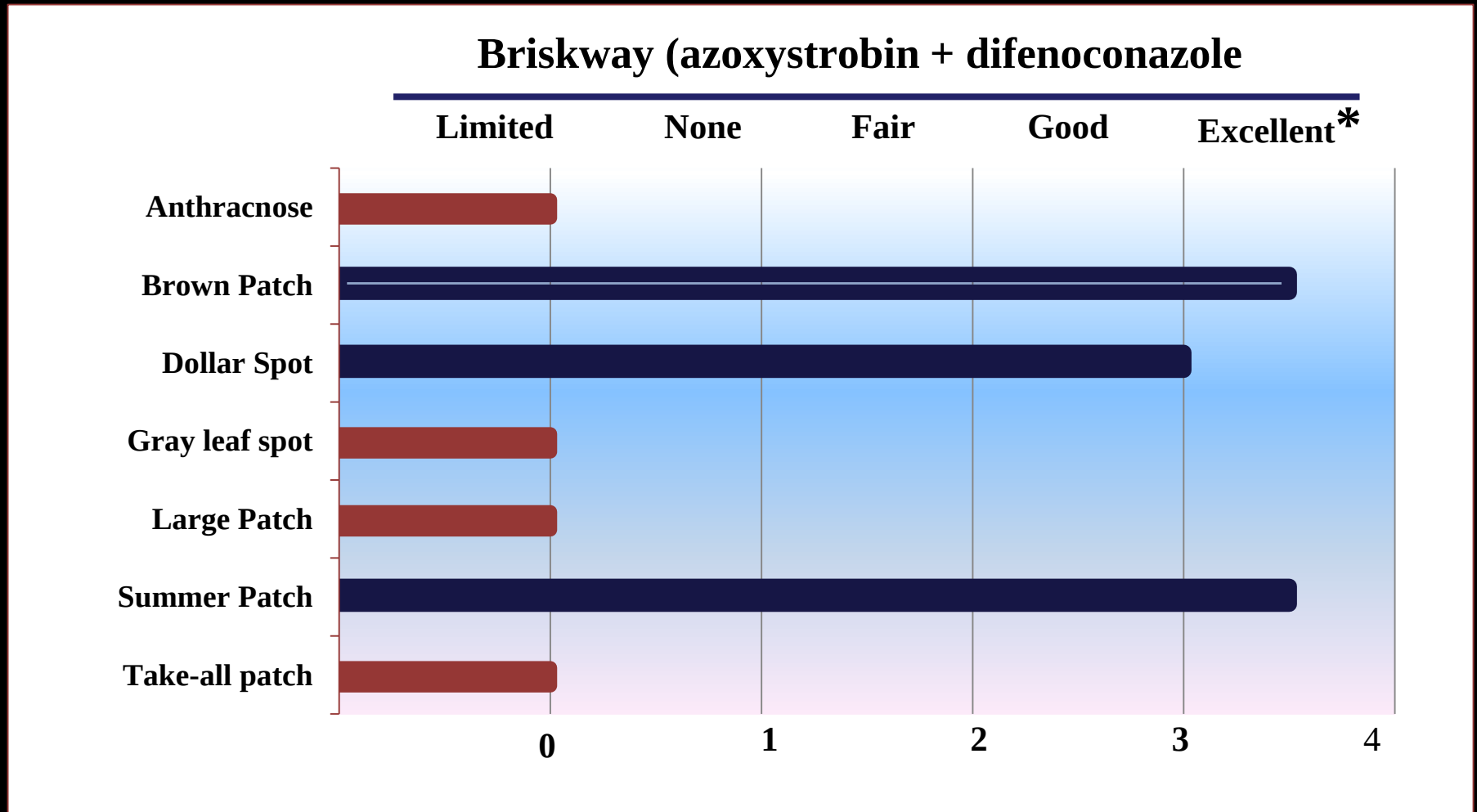
2.72SC formulation, Frac groups 11 + 3

Anthracnose, Brown Patch, Brown Ring Patch,
Dollar Spot, Fairy Ring, Gray Leaf Spot, Large
Patch, Leaf Spot, Red Thread, Snow Mold,
Summer Patch, Take-all Patch

Basic Application Guidelines

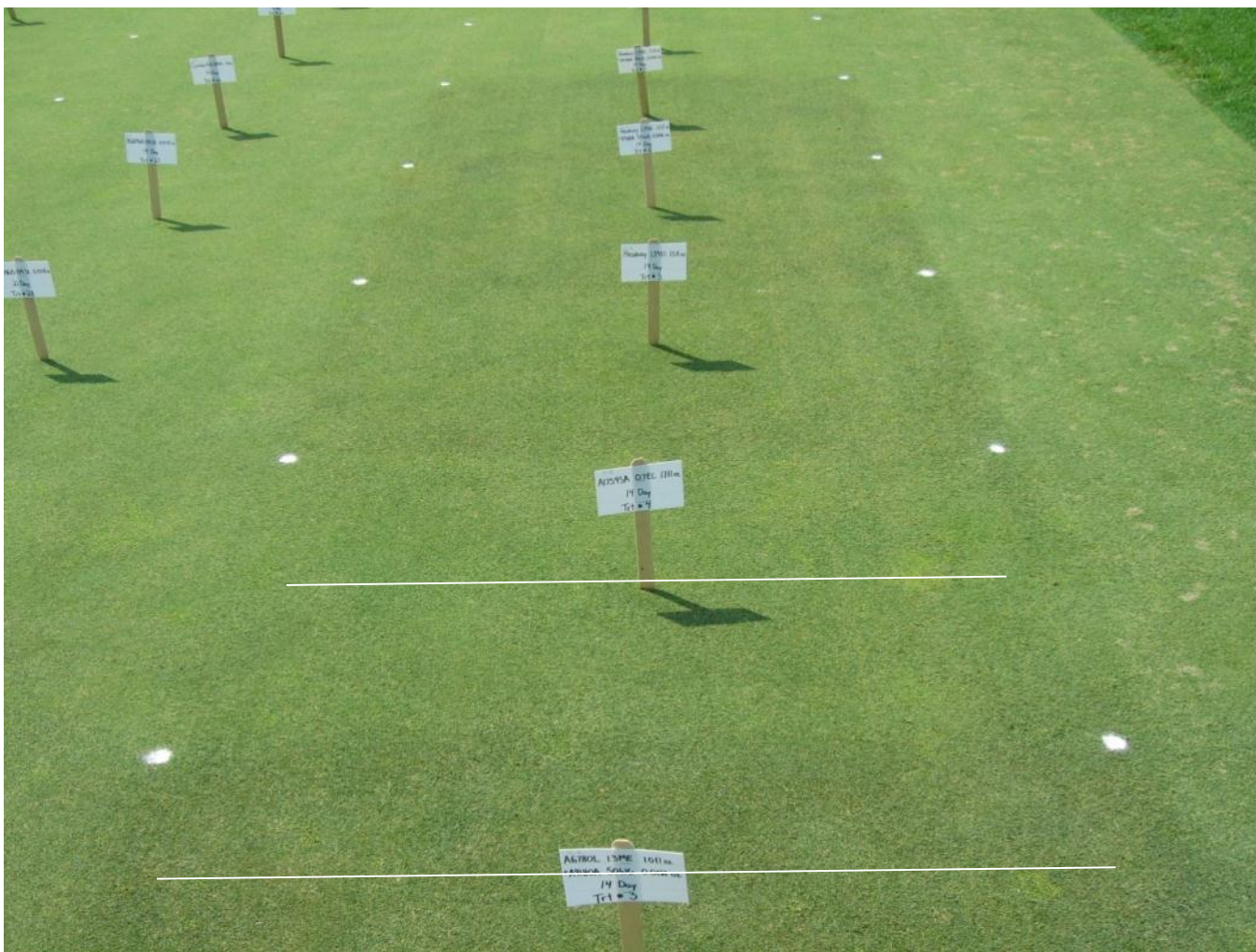
Rate: 0.3 to 0.725 fl oz per 1000 ft², Application interval: 14 to 28 days
(3 apps @ 0.5 fl. oz./1000 sq. ft. per season)

Relative Efficacy of New Fungicides for Turf Disease Control : 2015- 2019 (Golf)



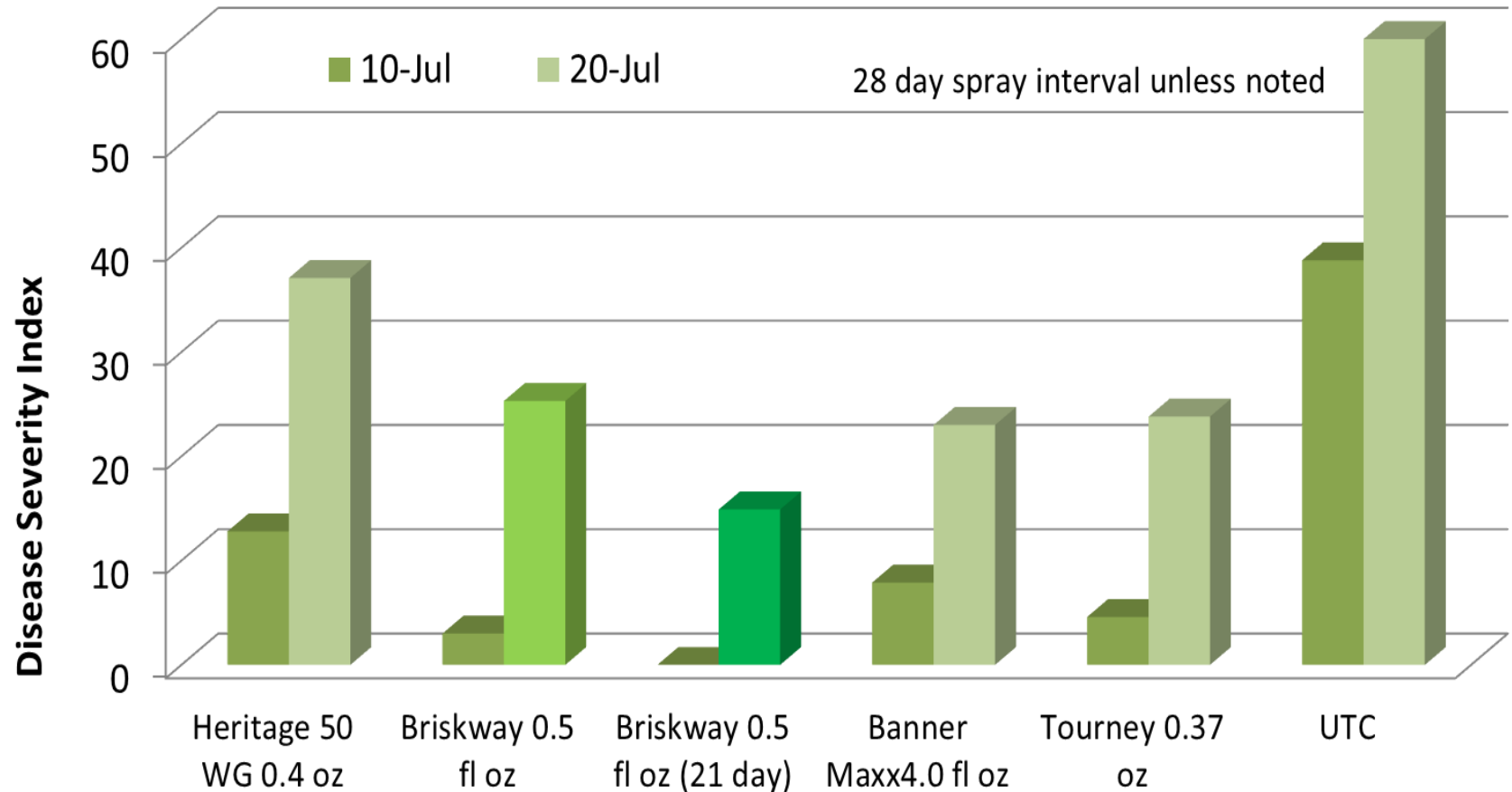
* Efficacy on a 1- 4 Scale, where 1 = not effective, 2 = fair – good control, 3 = good – excellent control, and 4 = excellent control. Limited = insufficient data. Limited data for : Red thread, Rust, Leaf Spot, Fairy Ring.

Difenoconazole Safety on Creeping Bentgrass



Rutgers, 2009

Severe Summer Patch Pressure Rutgers University



Note: Excessive rainfall followed by extreme temperatures led to extremely high disease pressure

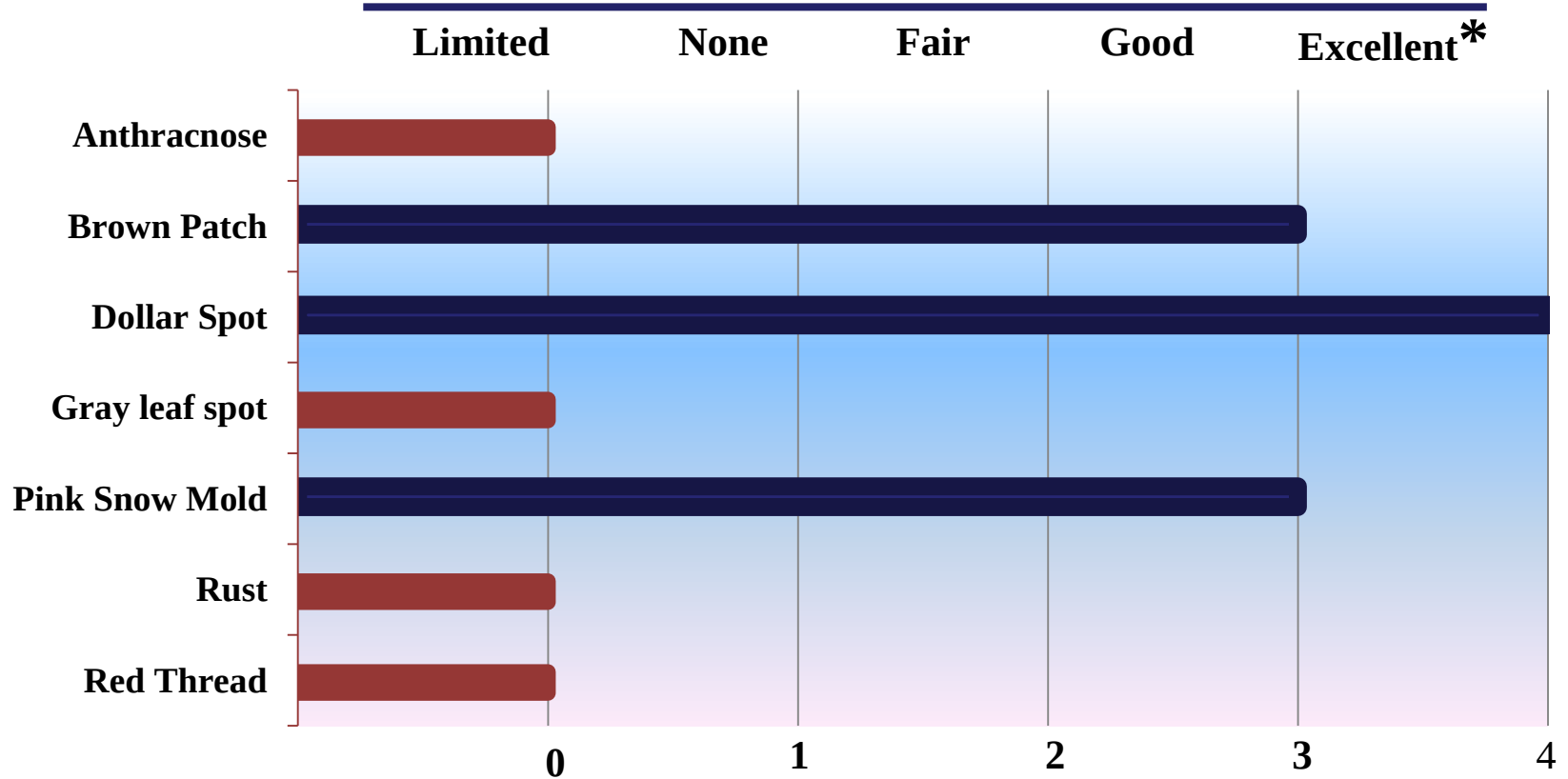
Rutgers, 2013

Exteris Stressgard (fluopyram + trifloxystrobin)

- 0.27SC formulation; Frac groups 7 and 11
- Use Rates:
 - 1.5 – 6.0 fl oz/1,000 ft² at a 7 to 28 day interval
- Anthracnose, Brown patch, Dollar spot, Gray leaf spot, Red thread, Pink Snow mold, Rust
- Modes of Action:
 - Inhibits respiration pathway (SDHI) and Inhibits sterol synthesis in fungal cell membrane (DMI)

Relative Efficacy of New Fungicides for Turf Disease Control : 2015- 2019 (Golf)

Exteris Stressgard (fluopyram + trifloxystrobin)



* Efficacy on a 1- 4 Scale, where 1 = not effective, 2 = fair – good control, 3 = good – excellent control, and 4 = excellent control. Limited = insufficient data.

Evaluation of Exteris Stressgard: Dollar Spot

Rutgers University - Clarke

Form	Rate	Int.	Rating†				yr
			1	2	3	4	
0.27 SC	1.5 fl oz	7 d				✓	2015
	1.5 fl oz	14 d				✓	
	2 fl oz	14 d				✓	
	3 fl oz	14 d				✓	
	4 fl oz	21 d				✓	
	4 fl oz	CUR - 21 d		✓			
	6 fl oz	28 d			✓		
0.27 SC	1.5 fl oz	7 d				✓	2014
	1.5 fl oz	14 d				✓	
	2 fl oz	14 d				✓	
	3 fl oz	14 d				✓	
	4 fl oz	14 d				✓	
	4 fl oz	CUR - 21 d				✓	
	6 fl oz	28 d			✓		
	9 fl oz	CUR once				✓	

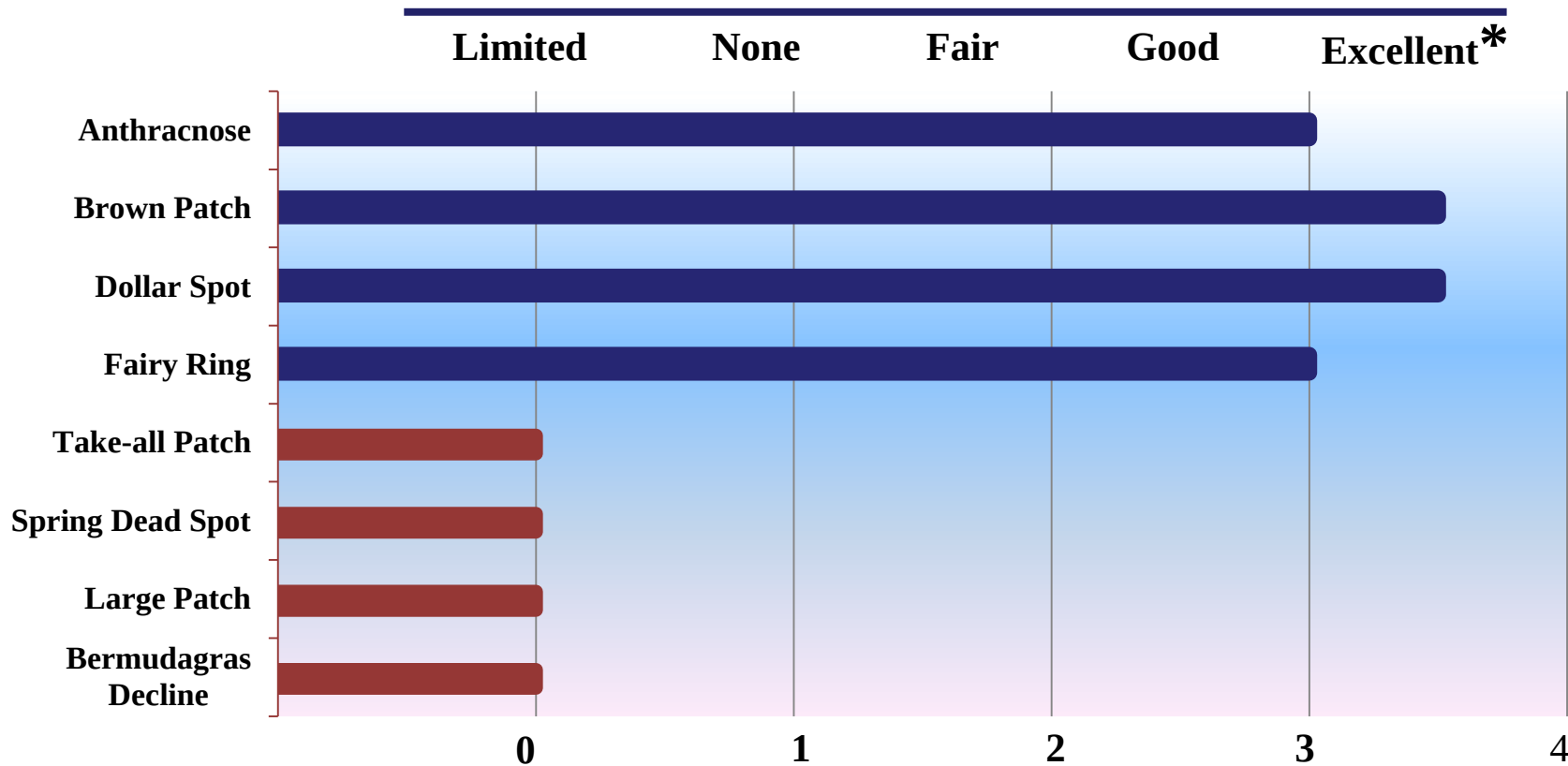
† 1 = Poor, 2 = Fair, 3 = Good, 4 = Excellent

Lexicon (fluxapyroxad + pyraclostrobin)

- 4.17SC formulation; Frac group 7 + 11
- Use Rate:
 - 0.34 – 0.47 fl oz/1,000 ft² at a 14 to 28 day interval
 - Bermudagrass Decline, Large Patch, Spring Dead Spot, Anthracnose, Brown patch, Dollar Spot, Fairy Ring, Snow Mold, Gray Leaf Spot, Rapid Blight, Red thread, Pythium, Rust, Summer Patch, Take-all Patch
- Modes of Action:
 - Inhibits respiratory pathway (SDHI)

Relative Efficacy of New Fungicides for Turf Disease Control : 2015- 2019 (Golf)

Lexicon (fluxapyroxad + pyraclostrobin)

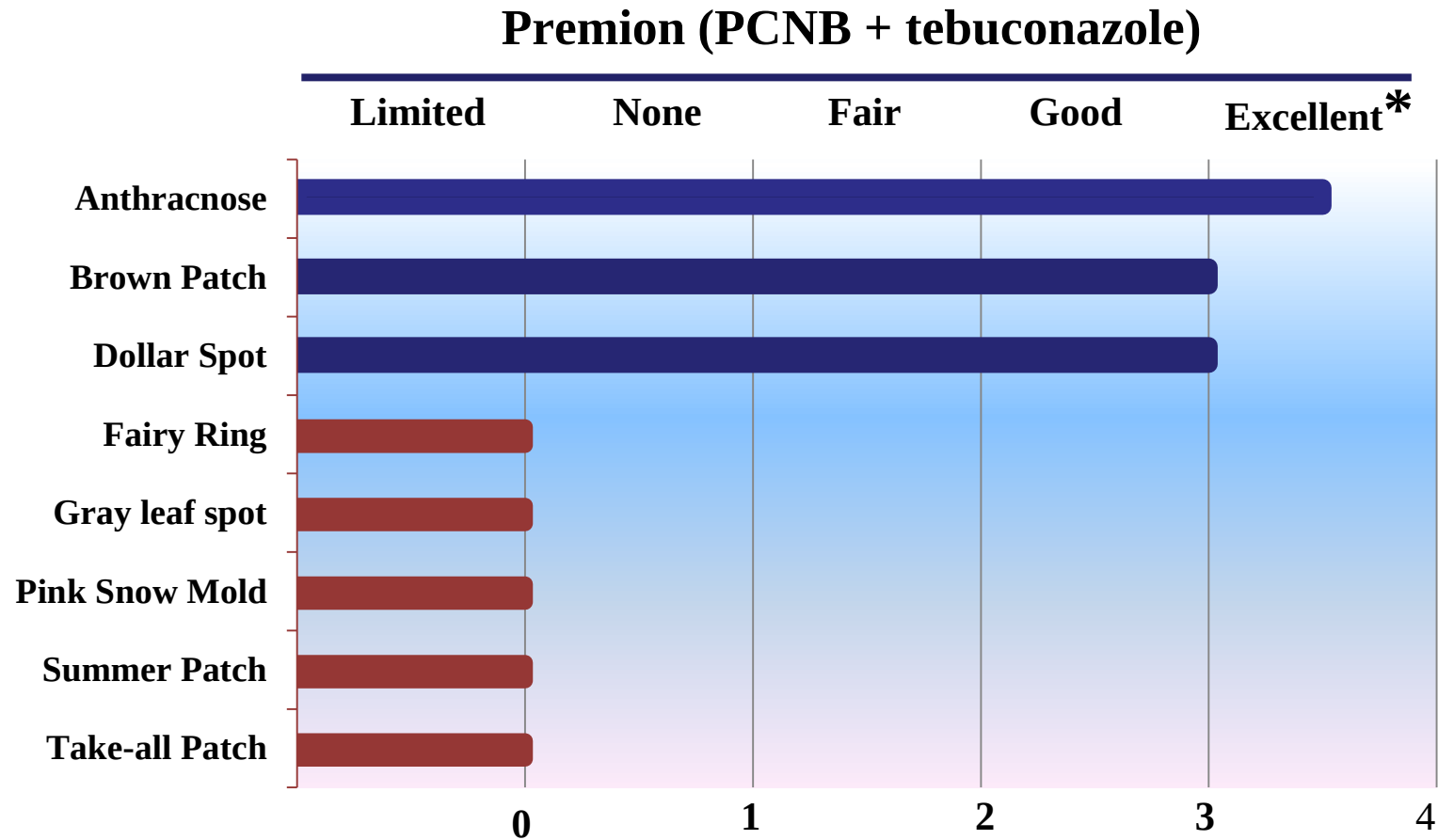


* Efficacy on a 1- 4 Scale, where 1 = not effective, 2 = fair – good control, 3 = good – excellent control, and 4 = excellent control. Limited = insufficient data.

◆ Premion Fungicide

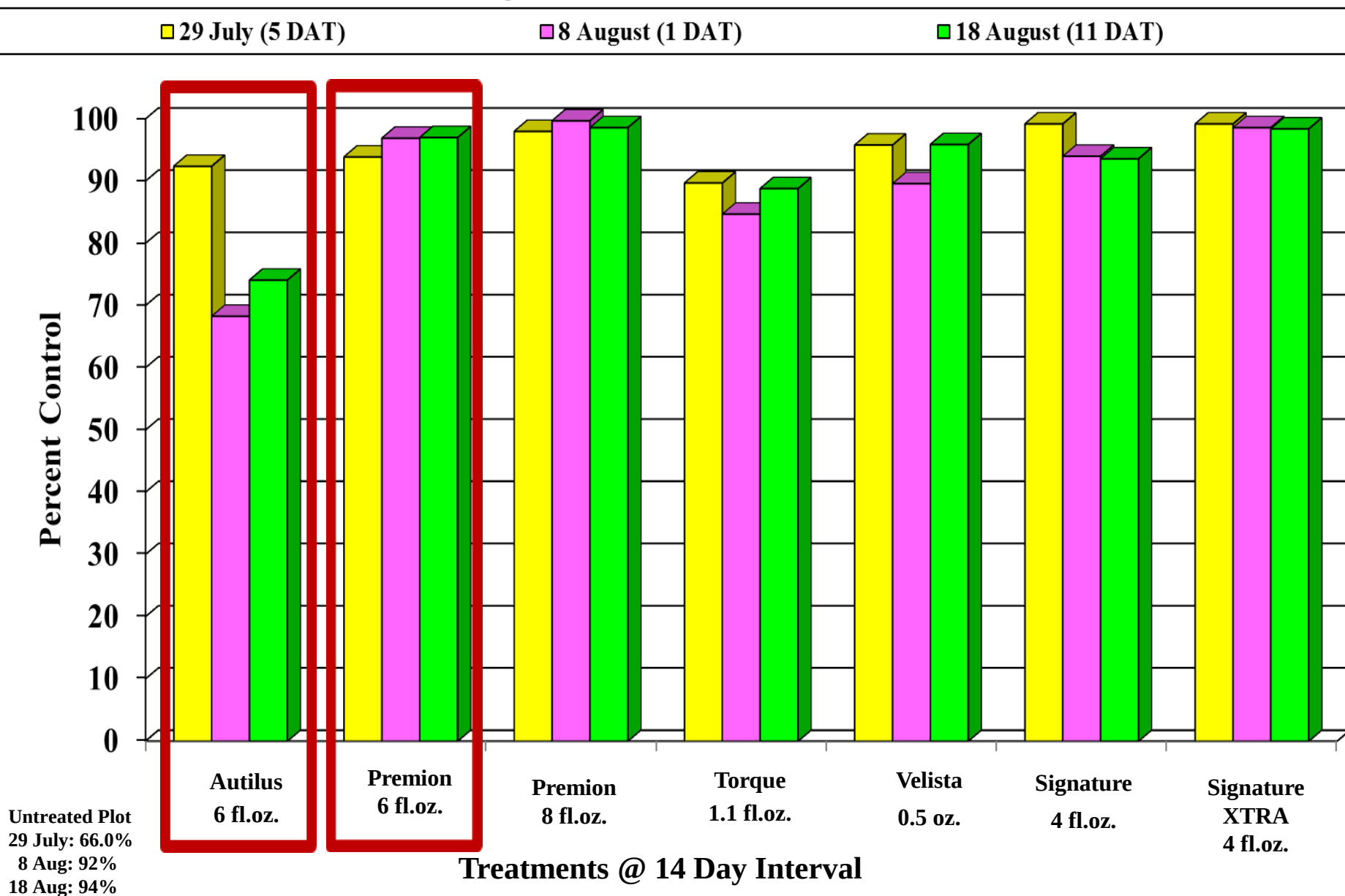
- ◆ Active ingredients: PCNB plus tebuconazole
- ◆ New water-based 4.27SC formulation
- ◆ Labeled for golf course greens, tees and fairways
- ◆ Excellent efficacy against anthracnose, as well as Brown patch, Dollar spot, Fairy ring, Gray leaf spot, Leaf Spot, Snow mold, Red thread, Rust, Summer patch, Take-all patch
- ◆ Application Windows: May – June; Sept. – Oct.
- ◆ Dual modes of action – FRAC Groups 14 (AH) and 3 (DMI)
 - Use Rates: 4-8 (12 snow mold) fl oz / 1,000 sq ft
- ◆ Should be tank-mixed with a pigment product

Relative Efficacy of New Fungicides for Turf Disease Control : 2015- 2019 (Golf)



* Efficacy on a 1- 4 Scale, where 1 = not effective, 2 = fair – good control, 3 = good – excellent control, and 4 = excellent control. Limited = insufficient data. Limited Data for : Rust, Red Thread.

Anthracnose Control in Annual Bluegrass Putting Green Turf: Rutgers University - 2015

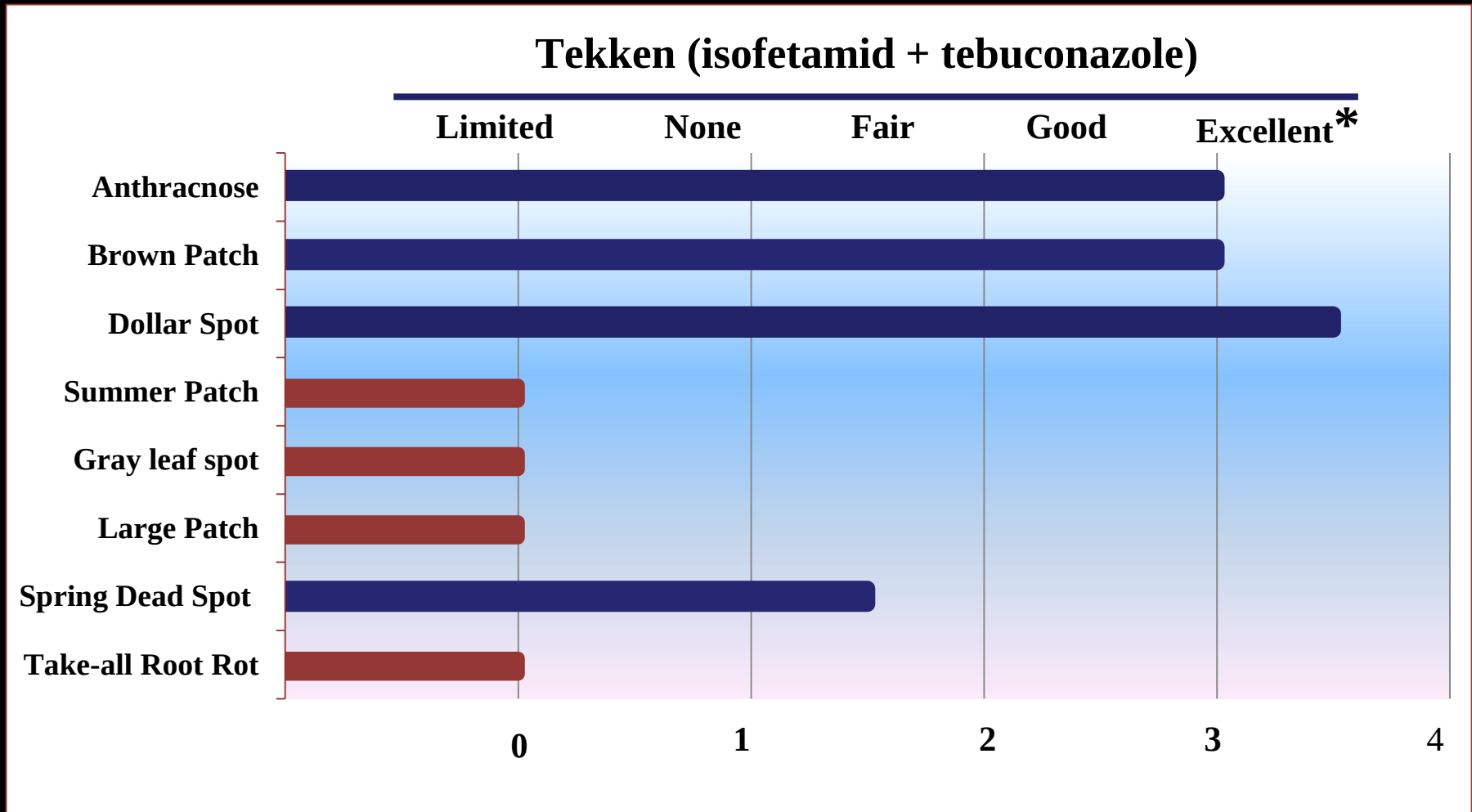


* Treatment included the pigment product Par at 1 pint/A

Tekken (isofetamid + tebuconazole)

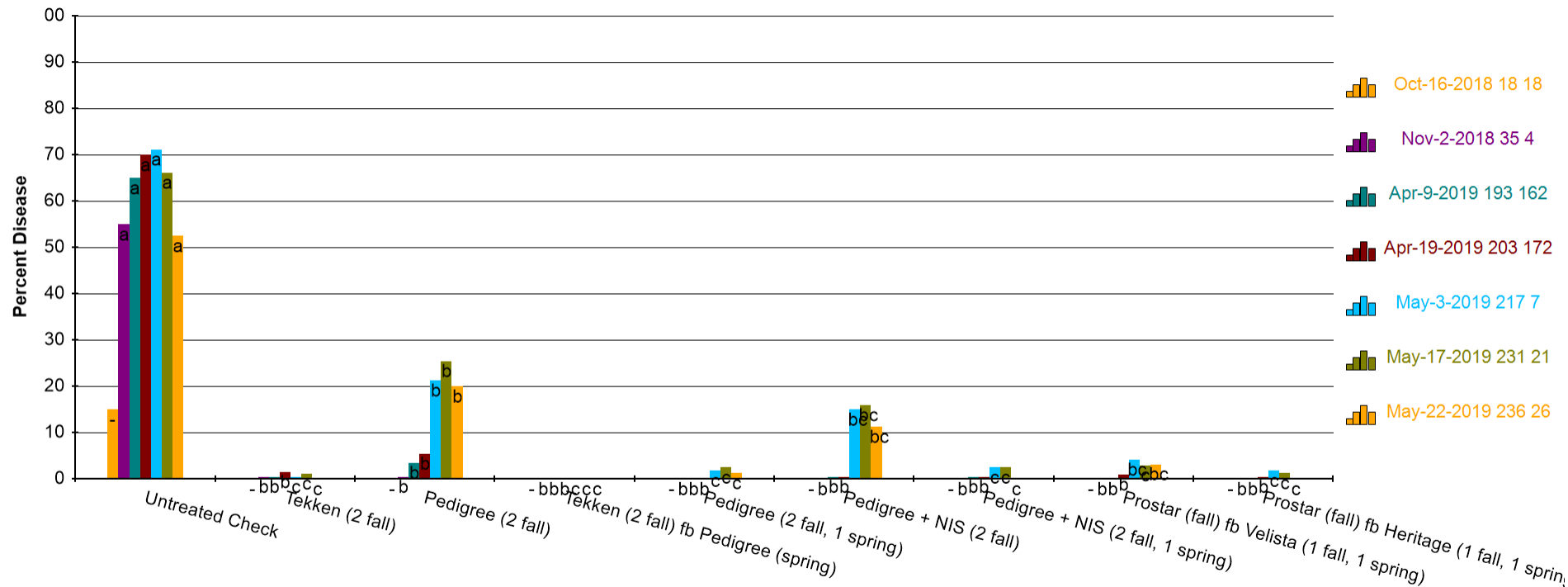
- 1.8SC formulation; Frac groups 7 + 3
- Use Rates:
 - 3.0 fl oz/1,000 ft² at a 14-28 day interval)
- Anthracnose, Dollar Spot, Brown Patch, Bermudagrass Decline, Fairy Ring, Gray Leaf Spot, Large Patch, Red Thread, Rust, Snow Mold, Spring Dead Spot, Stripe Smut, Summer Patch, and Take-all Patch
- Modes of Action:
 - Inhibits respiration pathway (SDHI) and Inhibits sterol synthesis in fungal cell membrane (DMI)

Relative Efficacy of New Fungicides for Turf Disease Control : 2015- 2019 (Golf)



* Efficacy on a 1- 4 Scale, where 1 = not effective, 2 = fair – good control, 3 = good – excellent control, and 4 = excellent control. Limited = insufficient data. Limited data for: Rust, Red thread

Large Patch Control on 'Cavalier' Zoysiagrass Arkansas



Applications Initiated: September 28, 2018

slide courtesy of Brian Aynardi

Traction (fluazinam + tebuconazole)

- Golf turf (only); Cool & warm season grasses:
greens, tees, fairways, roughs

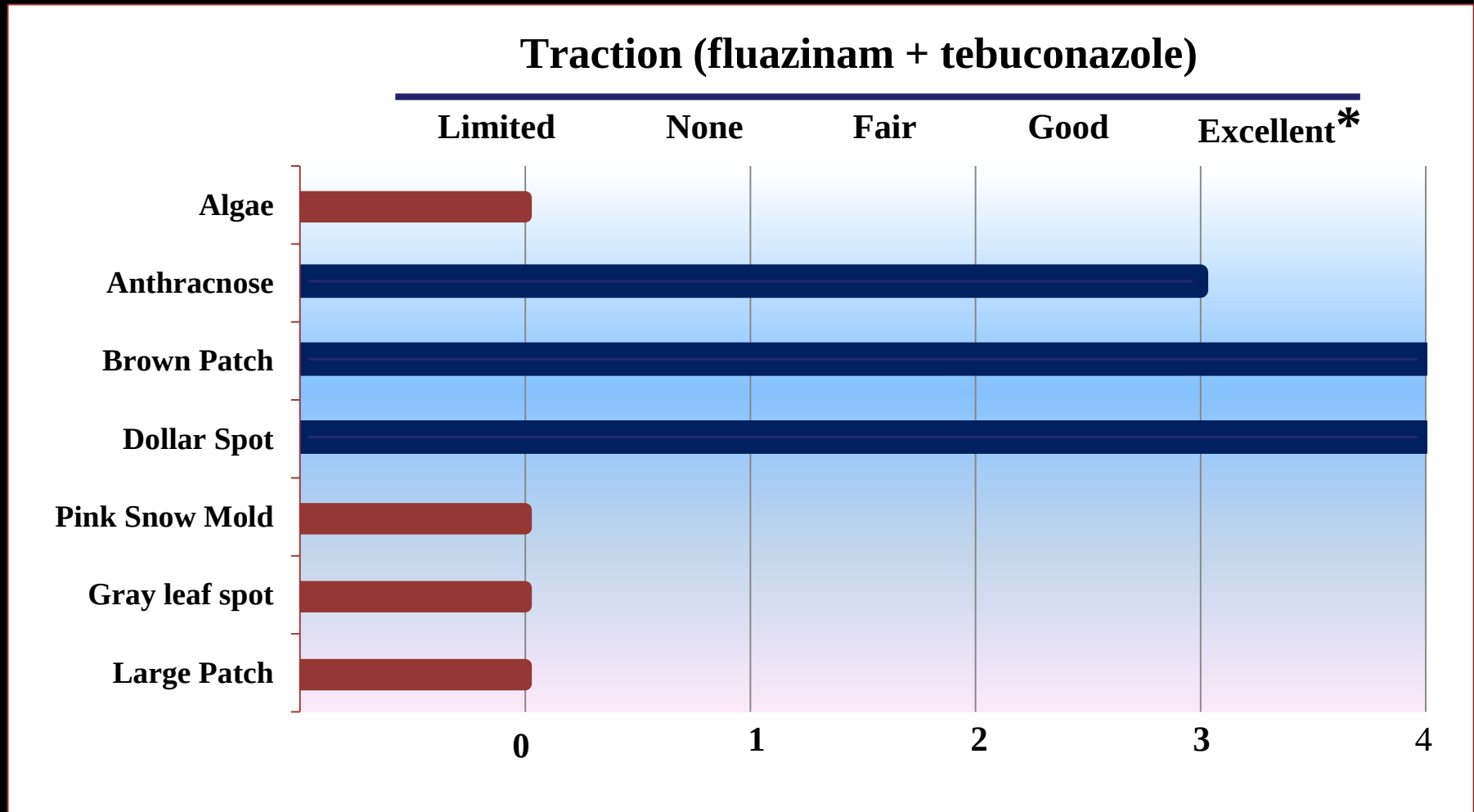
- Use rate:

1.3 fl oz/1,000 sq ft at a 14-21 day interval
(3.24SC formulation, Frac groups 7 + 3)

- Diseases

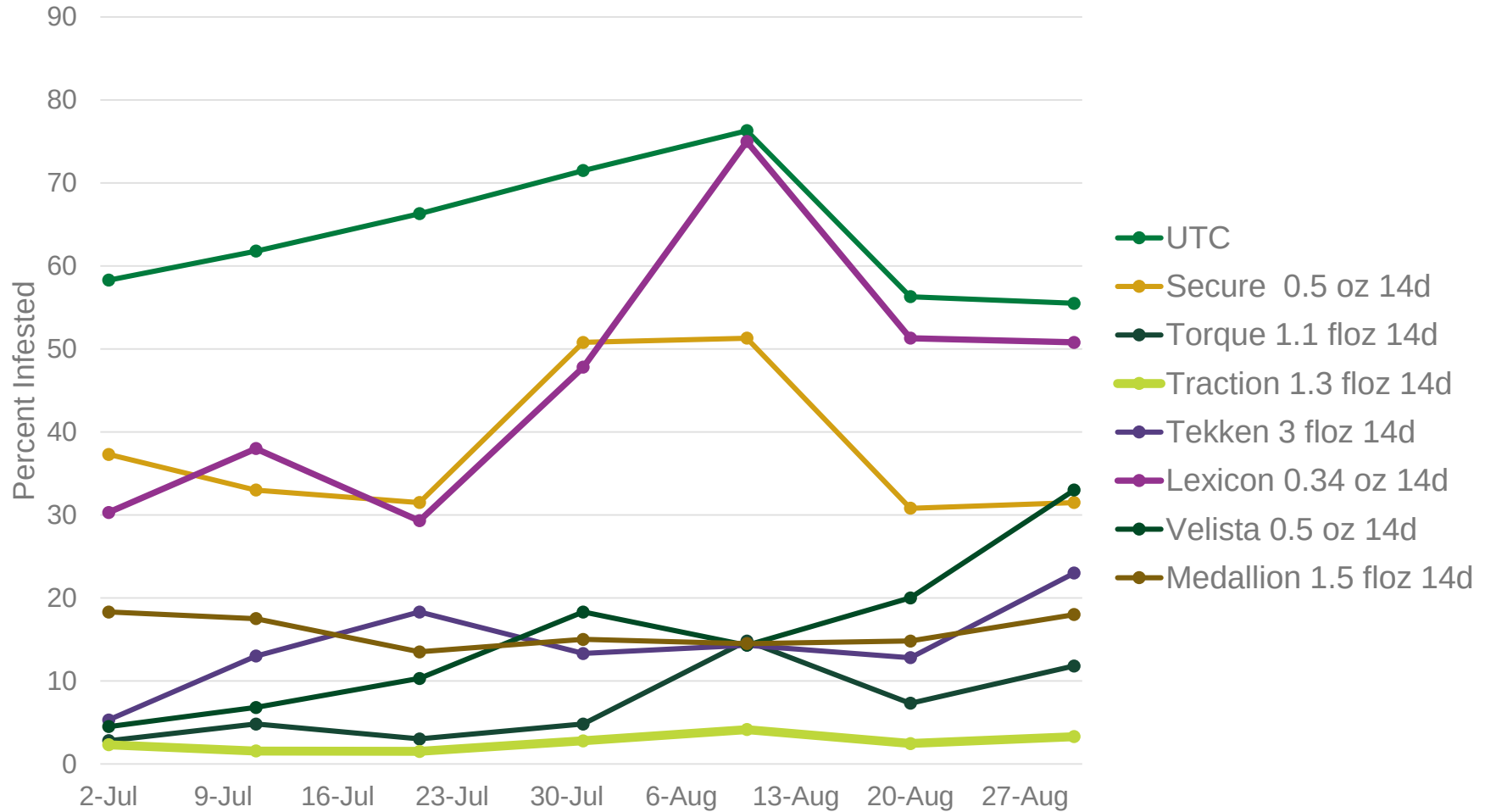
Dollar spot, Anthracnose, Brown patch, pink and gray snow molds, large patch, brown ring patch, leaf spot, copper spot, red thread, rust, gray leaf spot, stripe smut, algae (suppression)

Relative Efficacy of New Fungicides for Turf Disease Control : 2015- 2019 (Golf)

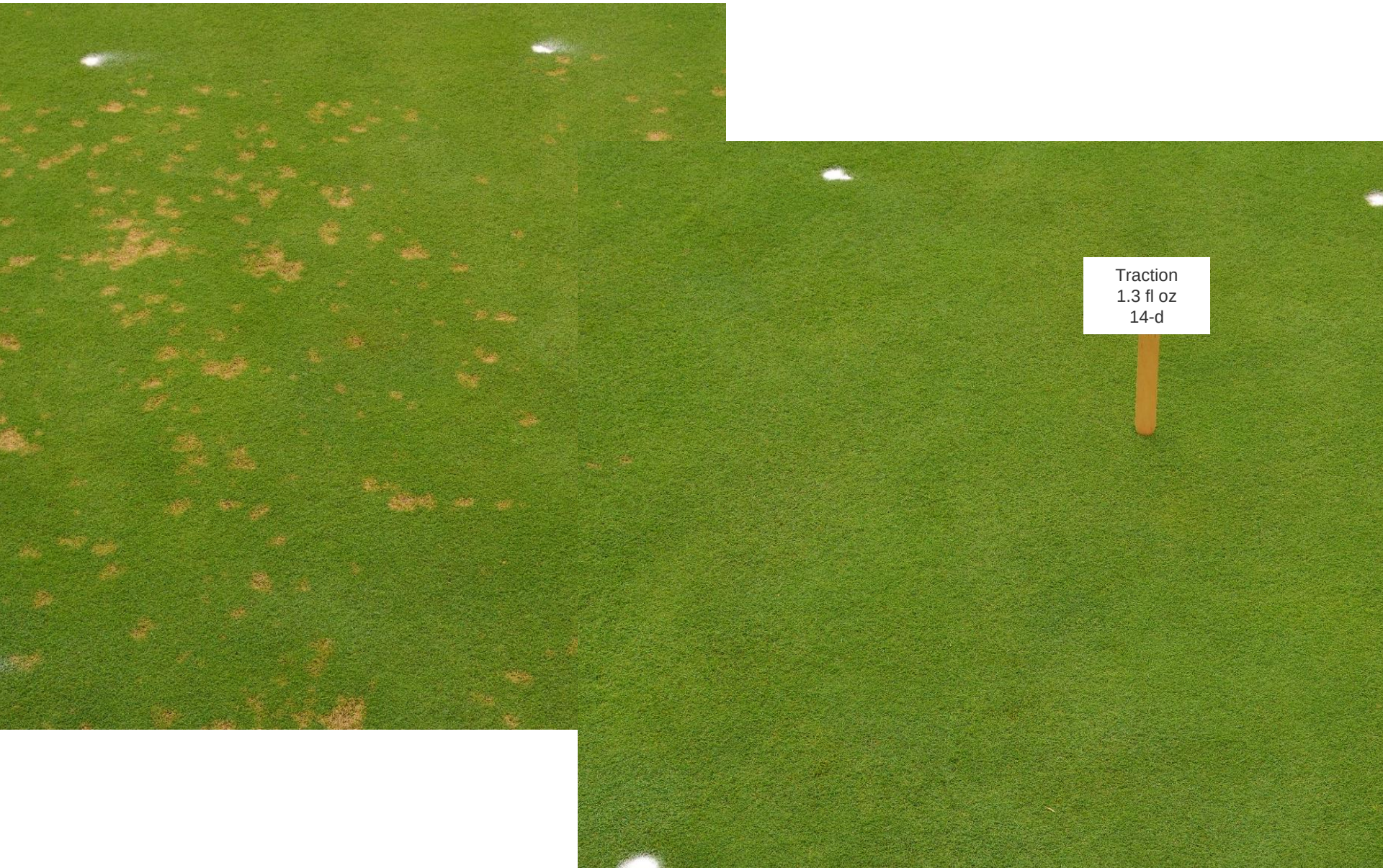


* Efficacy on a 1- 4 Scale, where 1 = not effective, 2 = fair – good control, 3 = good – excellent control, and 4 = excellent control. Limited = insufficient data. Limited Data : Rust, Red thread, Leaf Spot

Basal Rot Anthracnose – ABG Greens



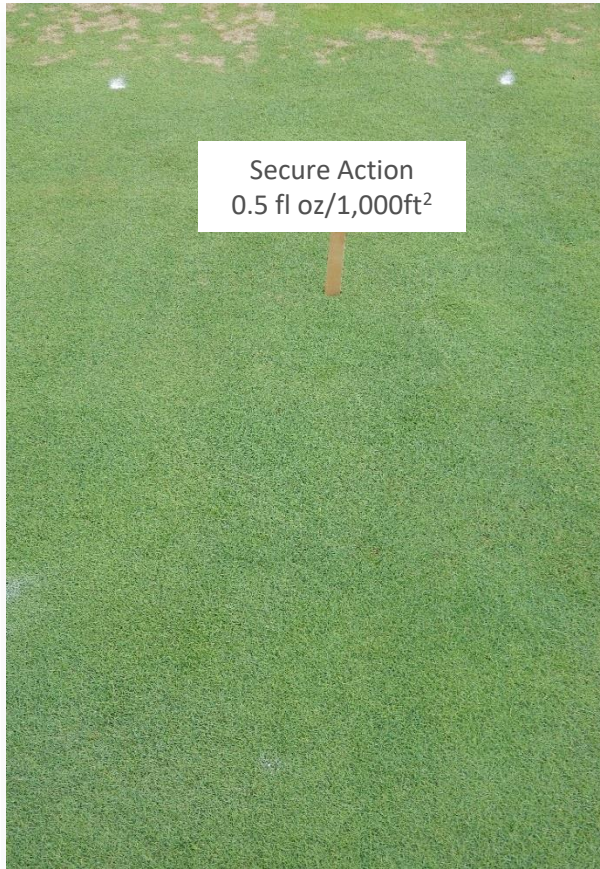
Dollar Spot Control on Greens with Traction - 14-day interval Rutgers 2016



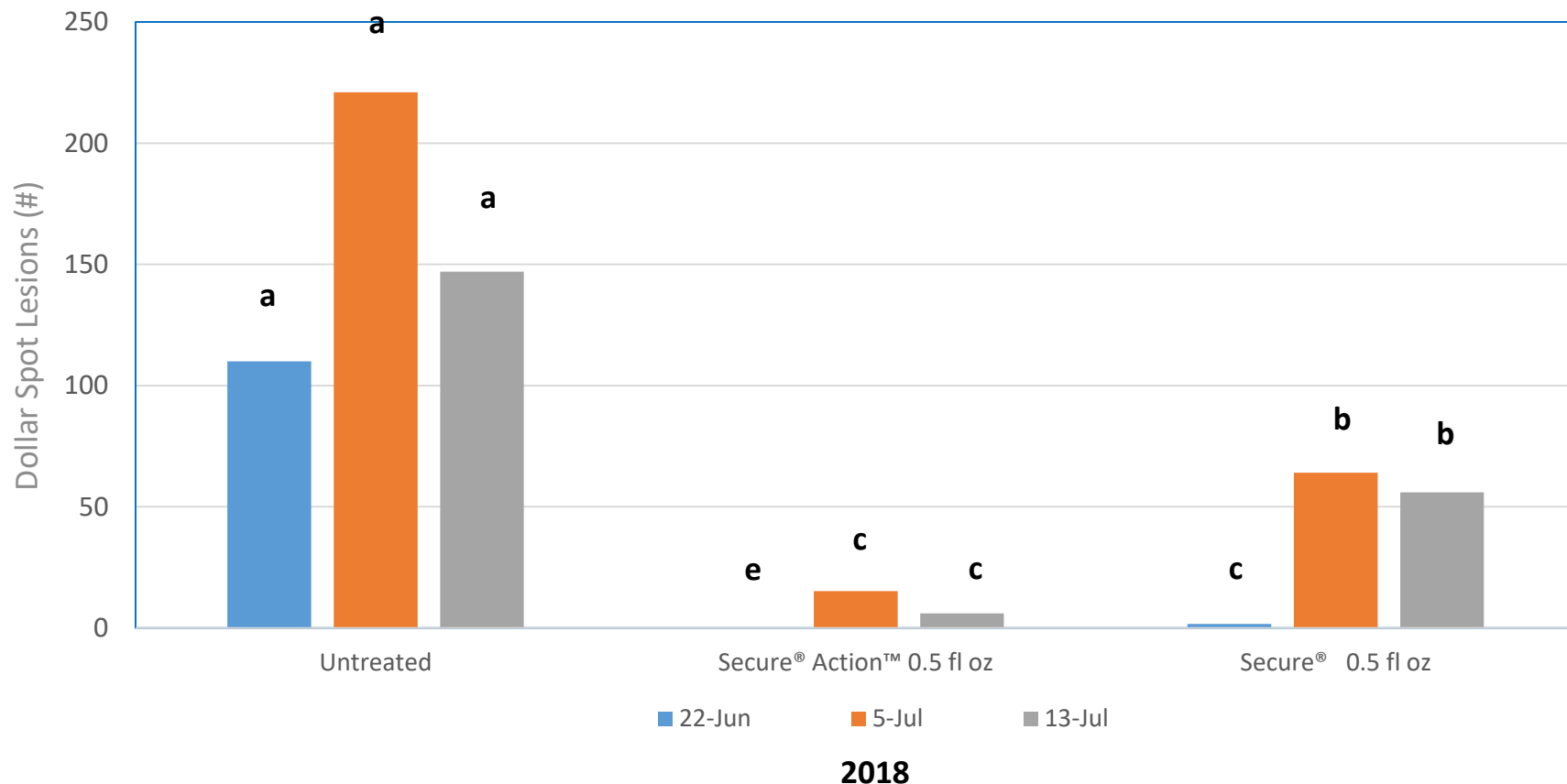
Secure Action (fluazinam and acibenzolar)

- Induces host plant defense (SAR) (systemic)
- Dollar Spot 14-21 day spray interval
 - 0.5 fl oz/1,000 ft² (under higher disease pressure, use shorter interval); no clogging issue with new formulation
 - Anthracnose, Brown patch, Leaf spot, Red thread, Snow mold,
 - Pink patch, Stem rust, Algae, Bacterial wilt (suppression)
- Modes of Action:
 - Inhibits respiration by uncoupling oxidative phosphorylation (contact)

Dollar Spot Control on CBG Fwy with Secure: 21-day Spray Interval – Rutgers Univ. 2016



Dollar Spot Control on CBG Fwy with Secure: 21-day Spray Interval – UCONN 2018



Recently or Soon to be Released Fungicides for Golf Turf

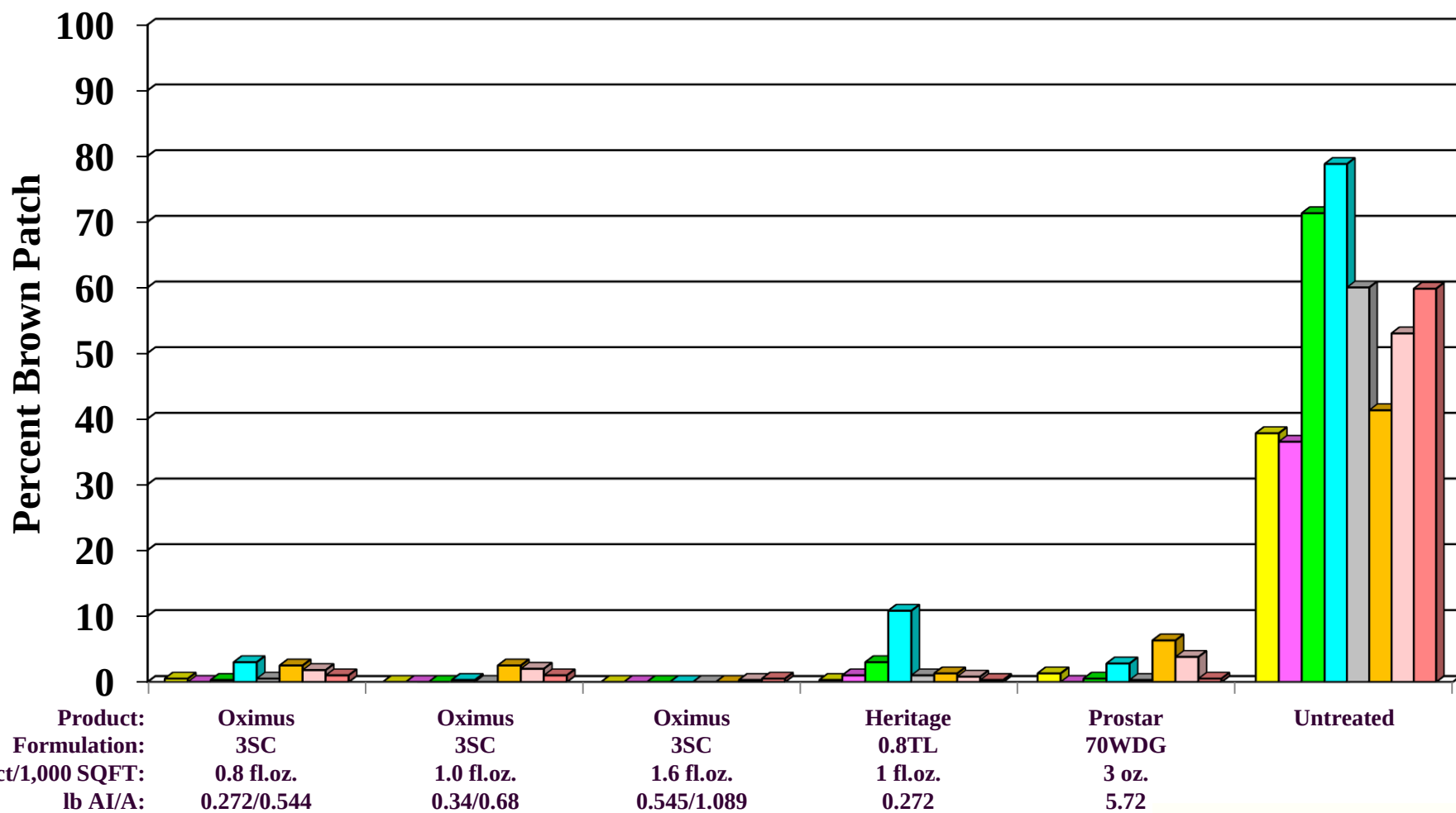
Trade Name	Common Name	FRAC #
Oximus (2020)	azoxystrobin + tebuconazole	11 + 3
Maxtima (July 2019)	mefentrifluconazole	3
Navicon (July 2019)	pyraclostrobin + mefentrifluconazole	11 + 3
Union (late-2019)	azoxystrobin + cyazofamid	11 + 21

Oximus (azoxystobin + tebuconazole)

- 3SC formulation
- Proposed rates: 2.9 and 5.75 fl oz / 1,000 sq ft
- Anticipated Diseases: Anthracnose, Brown Patch, Dollar Spot, Pink Snow Mold, Gray Leaf Spot.
- Feb-2019
- Modes of Action:
 - Inhibits respiration pathway (QoI) and sterol synthesis in fungal cell membrane (DMI)

Brown Patch Control in CBG with Oximus (azoxystobin + tebuconazole): Rutgers University - 2018

■ 14 DA-1
 ■ 3 DA-2
 ■ 13 DA-2
 ■ 2 DA-3
 ■ 12 DA-3
 ■ 1 DA-4
 ■ 11 DA-4
 ■ 21 DA-4



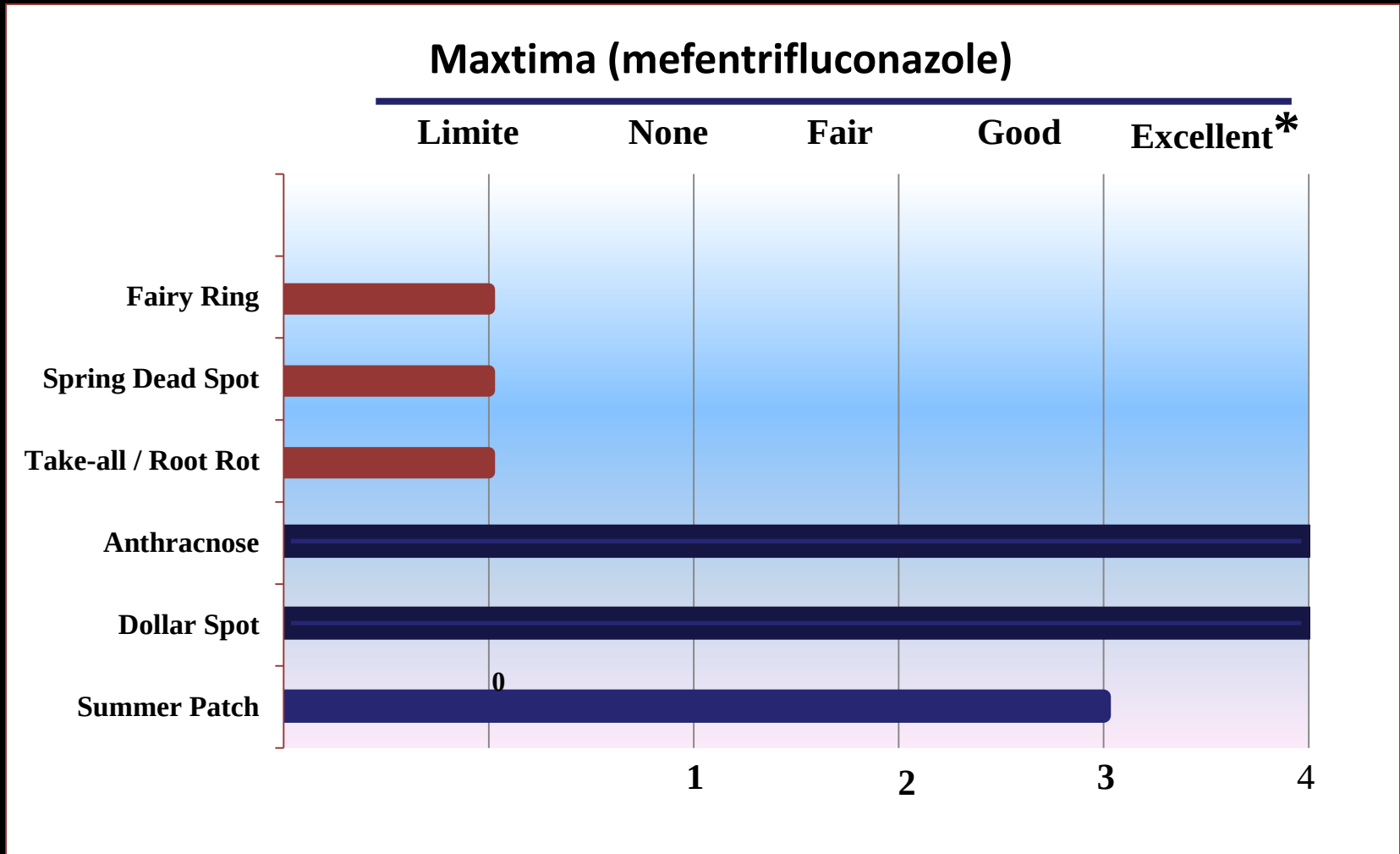
Treatments Applied on a 21 Day Interval

Rating Dates:
 27 – Jun – 5 Sept 2018

Maxtima (mefentrifluconazole)

- 3.3SC formulation
- Rates: 0.2 – 0.8 fl oz / 1,000 sq ft
- Diseases: Anthracnose, Brown Ring Patch, Dollar Spot, Summer Patch, Take-all Root Rot/Patch, Fairy Ring, Spring Dead Spot
- Approved for sale July 2019
- Modes of Action:
 - Inhibits sterol synthesis in fungal cell membrane

Relative Efficacy of New Fungicides for Turf Disease Control : 2015- 2019 (Golf)



* Efficacy on a 1- 4 Scale, where 1 = not effective, 2 = fair – good control, 3 = good – excellent control, and 4 = excellent control. Limited = insufficient data.

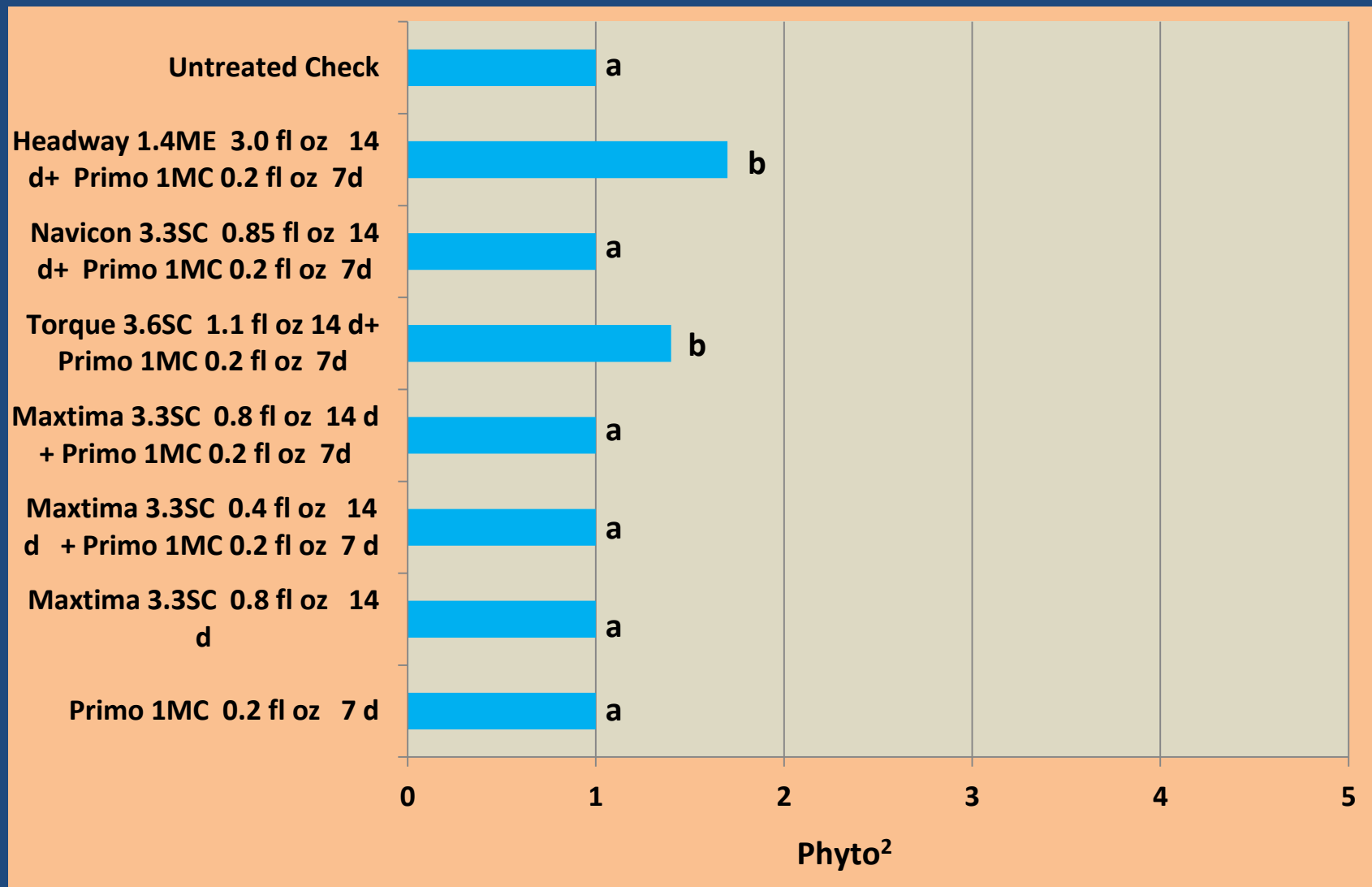
Evaluation of Phytotoxicity Induced
by Selected DMI Fungicides on
Annual Bluegrass and Creeping
Bentgrass Putting Green Turf –
Rutgers University

Phytotoxicity of DMIs on ABG Green : Rutgers, (2014 – 18)

	July 2018	July 2017	Aug 2015	Aug 2014
Maxtima 3.3SC 0.2 fl oz	-	1.0	1.0	1.0
Maxtima 3.3SC 0.4 fl oz	1.0	1.0	1.0	1.0
Maxtima 3.3SC 0.6 fl oz	1.0	-	-	-
Maxtima 3.3SC 0.8 fl oz	1.0	1.0	1.0	1.0
Torque 3.6SC 1.1 fl oz	2.6	1.8	1.9	-
Headway 1.4ME 3.0 fl oz	1.0	1.0	1.1	-
Navicon 3.3SC 0.85 fl oz	1.0	1.0	1.0	-
Tourney 50WG 0.28 oz	-	-	1.8	1.3
Trinity 1.69SC 1.5 fl oz	-	-	2.5	-
Banner Maxx 1.3ME 1.5 fl oz	-	-	-	1.1

¹ Phyto 1-5 Scale (1 = no phyto, 2 = slight necrosis or chlorosis , 3 = moderate necrosis or chlorosis, 4 = SV necrosis or chlorosis, 5 = all dead)

Phytotoxicity of PGRs & DMIs on a CBG Green : Rutgers, 26 June, 2018¹



¹ Applied 22 May – 17 Jul; 2 gal water, 40 psi; 0.125 inch height of cut, mowed daily

² Phyto 1-5 Scale (1 = no phyto, 2 = slight necrosis or chlorosis , 3 = moderate necrosis or chlorosis, 4 = SV necrosis or chlorosis, 5 = all dead)



Study Area



UTC



Primo 7 d



Maxtima 0.8 14d



Maxtima 0.8 14 d + Primo 7 d



Nav 0.85 14 d + Primo 7 d



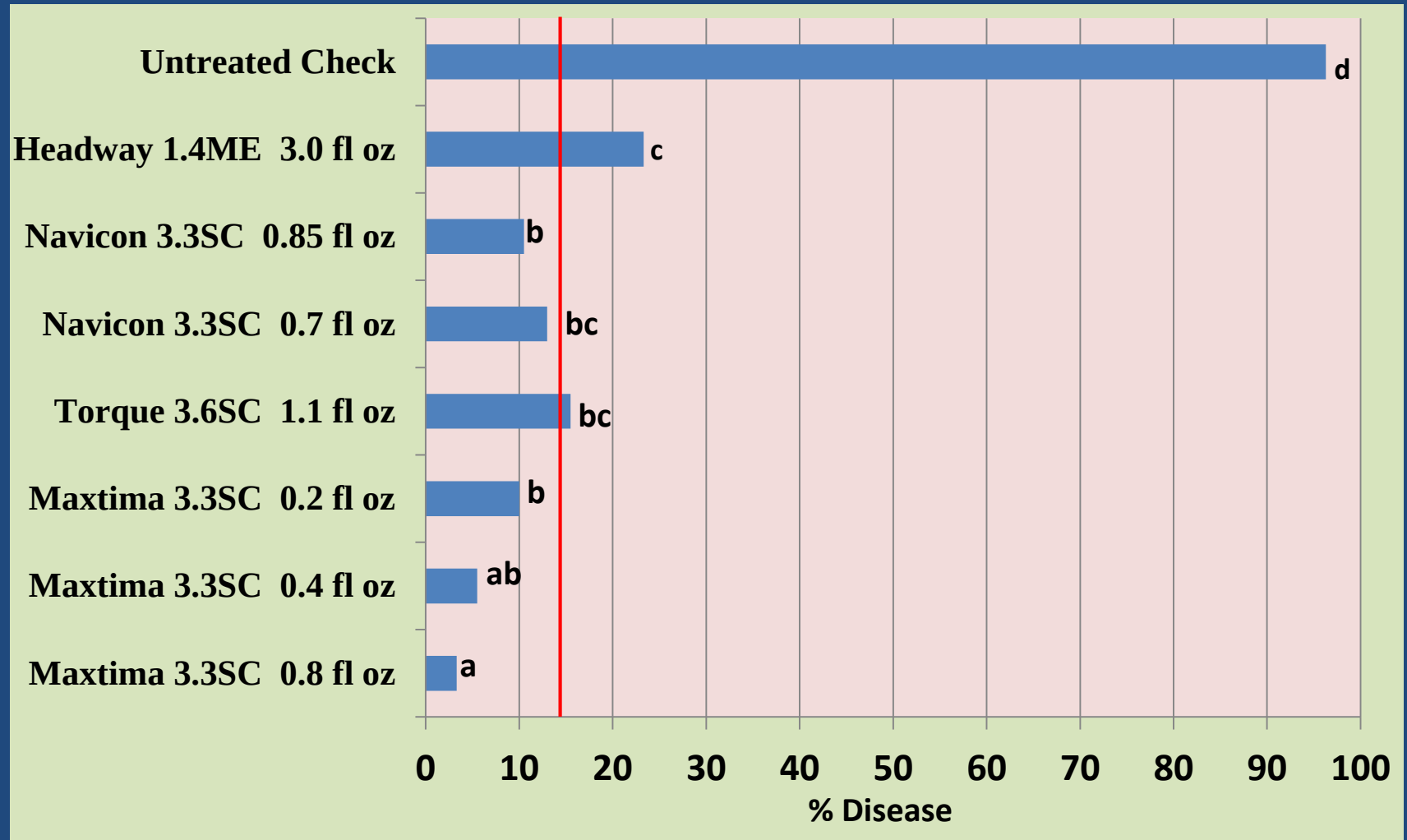
Headway 14 d + Primo 7 d



Torque 14 d + Primo 7 d

Anthracnose Control - ABG Green : Rutgers

28 August, 2015 (14 d)¹



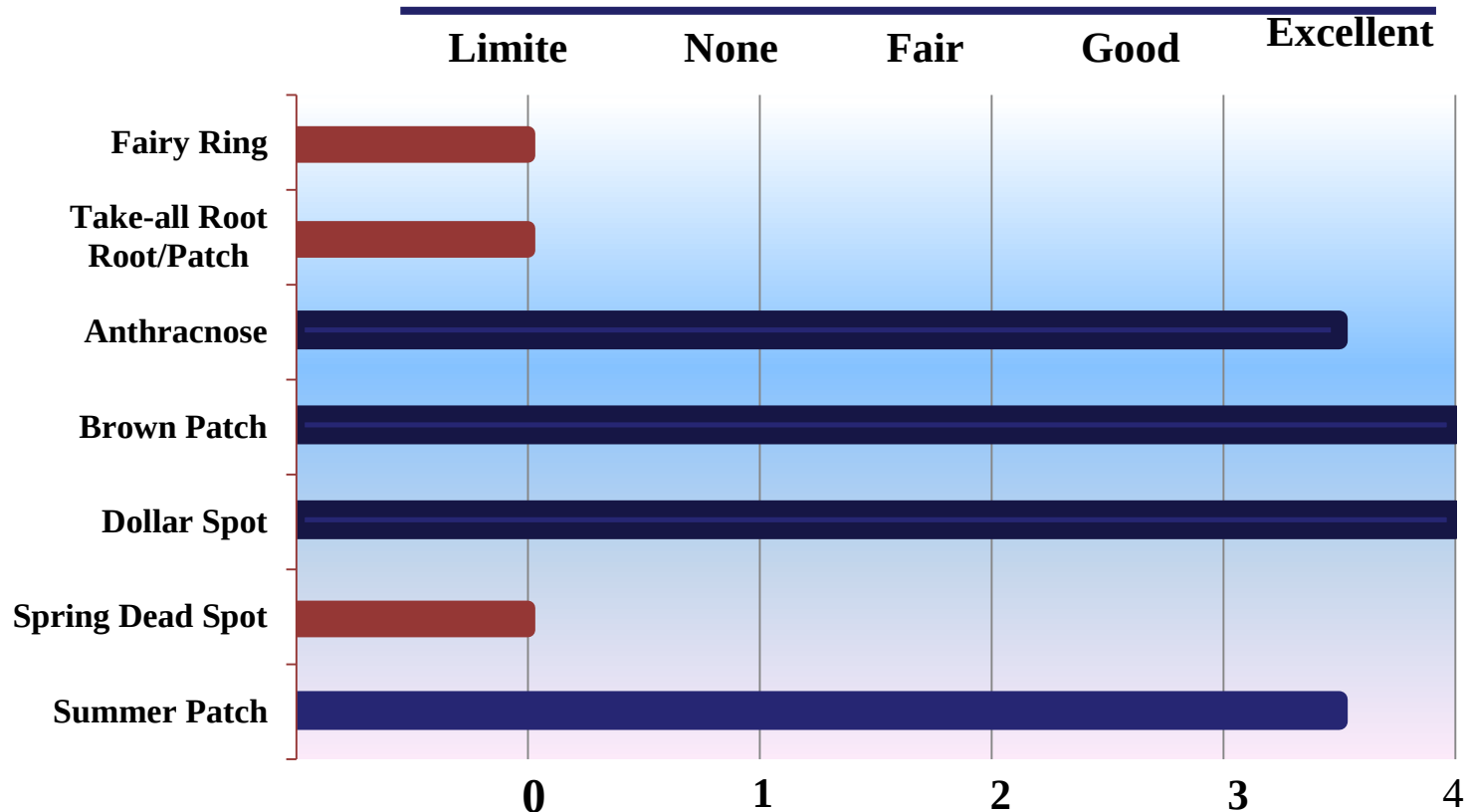
¹ Applied 15 May – 7 Aug 14 d interval; 2 gal water, 40psi

Navicon (pyraclostrobin + mefentrifluconazole)

- 3.34SC formulation; Frac group 11 + 3
- Proposed rates: 2.9 and 5.75 fl oz / 1,000 sq ft
- Anticipated Diseases: Anthracnose, Brown Patch, Dollar Spot, Summer Patch
- Feb-2019
- Modes of Action:
 - Inhibits respiration pathway (QoI) and sterol synthesis in fungal cell membrane (DMI)

Relative Efficacy of New Fungicides for Turf Disease Control : 2015- 2019 (Golf)

Navicon (pyraclostrobin + mefentrifluconazole)



* Efficacy on a 1- 4 Scale, where 1 = not effective, 2 = fair – good control, 3 = good – excellent control, and 4 = excellent control. Limited = insufficient data.

Rhizoctonia Blight (Brown Patch)

Causal Agent :

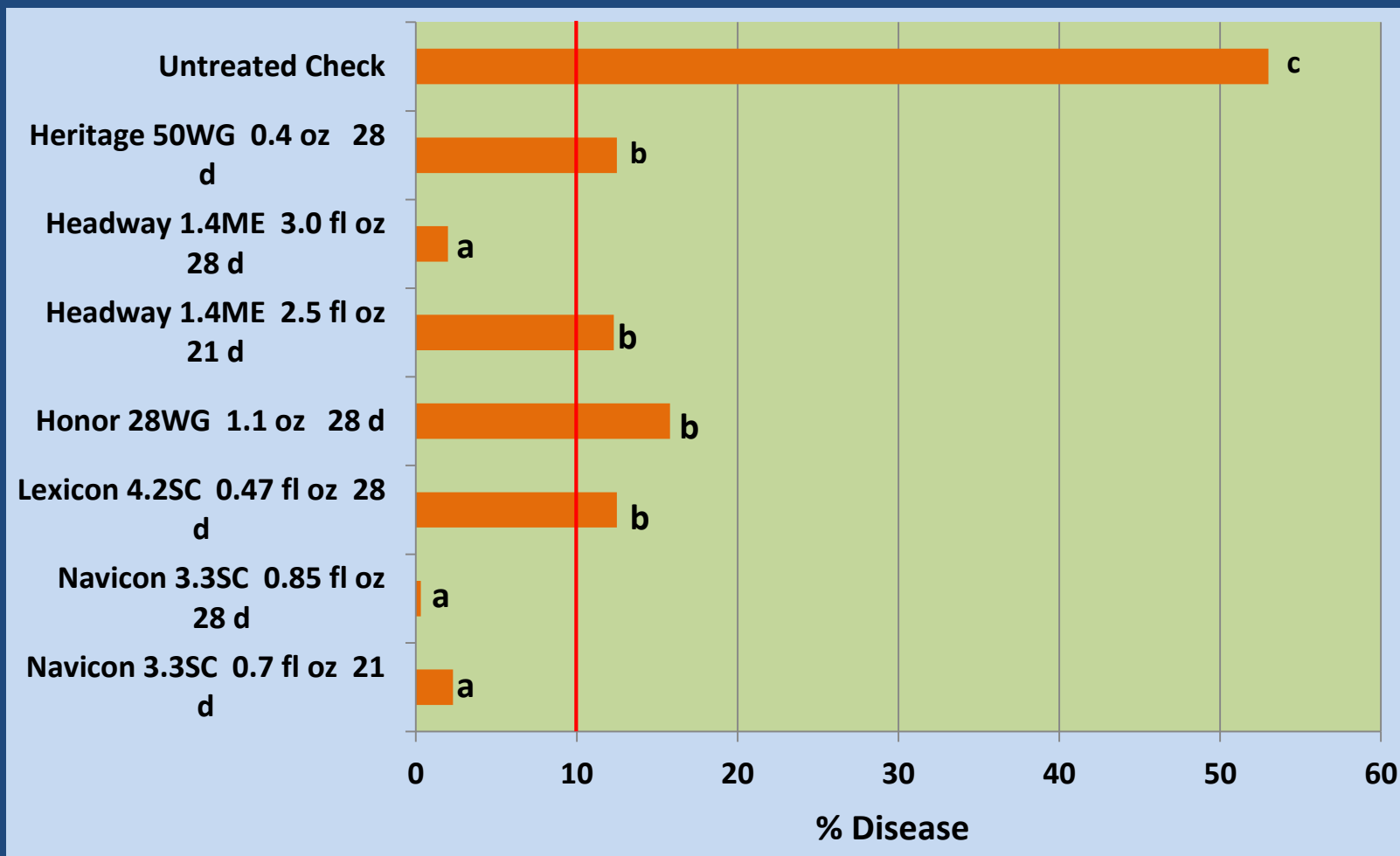
Rhizoctonia solani



Brown patch on a creeping bentgrass tee – Rutgers research farm

Brown Patch Control - Colonial Bent : Rutgers Univ.

5 September, 2018 ¹

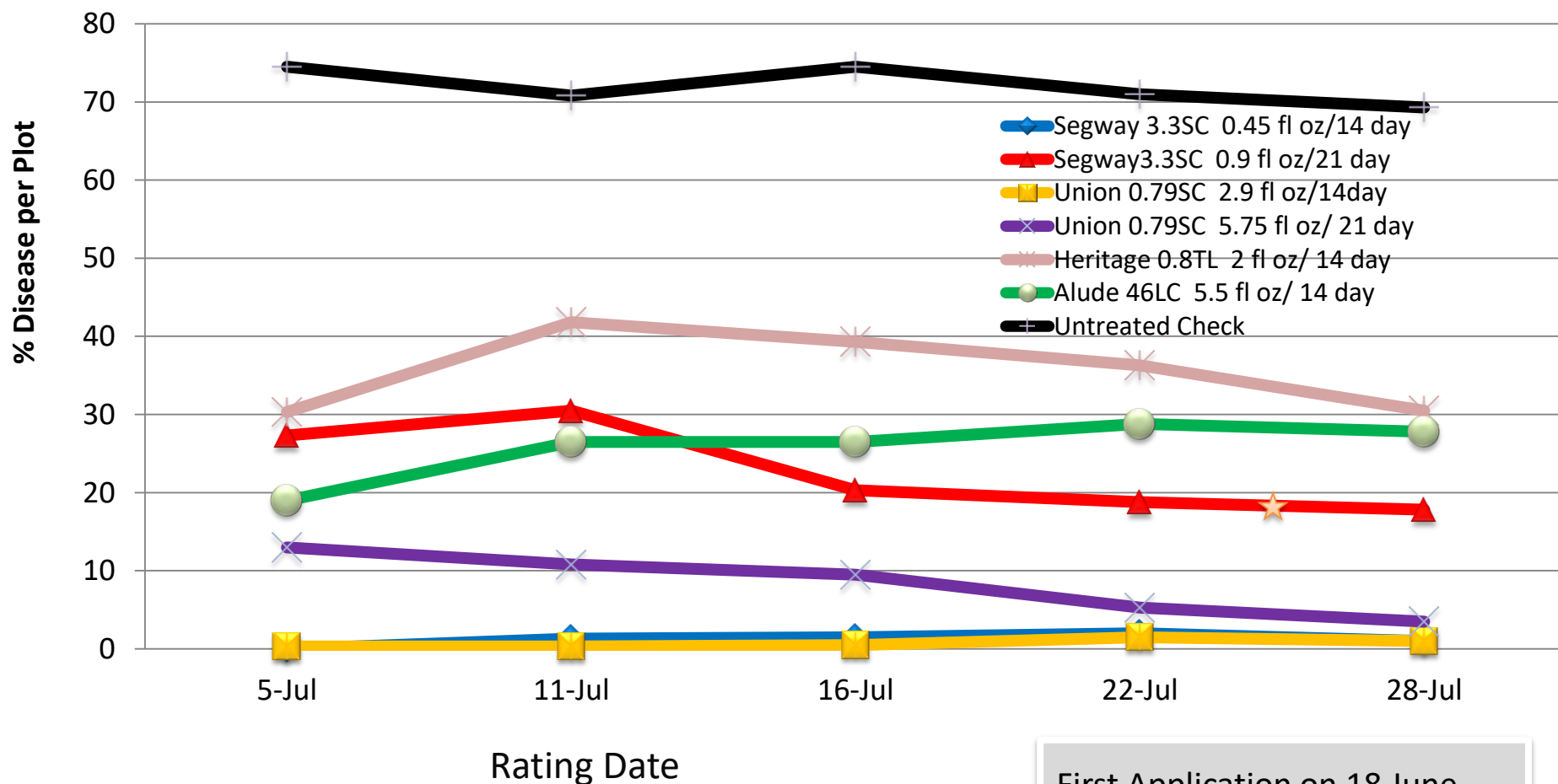


¹ Applied 20 June – 8 Aug (28 d) , 20 June - 15 Aug (21 d); 2 gal water, 40 psi

Union (azoxystrobin + cyazofamid)

- 0.79SC formulation; Frac groups 11 + 21
- Pythium diseases of turf (2.9 and 5.75 fl oz / 1,000 sq ft)
- late-2019
- Modes of Action:
 - Inhibits respiration pathway (QoI and QiI)

Control of Pythium Blight on PRG – Rutgers Univ 2018



First Application on 18 June
Last Application on 6 August



Thank You for Listening !

***Bruce Clarke, Ph.D.
Director, Center for Turfgrass Science and
Extension Specialist in Turfgrass Pathology
Rutgers University***



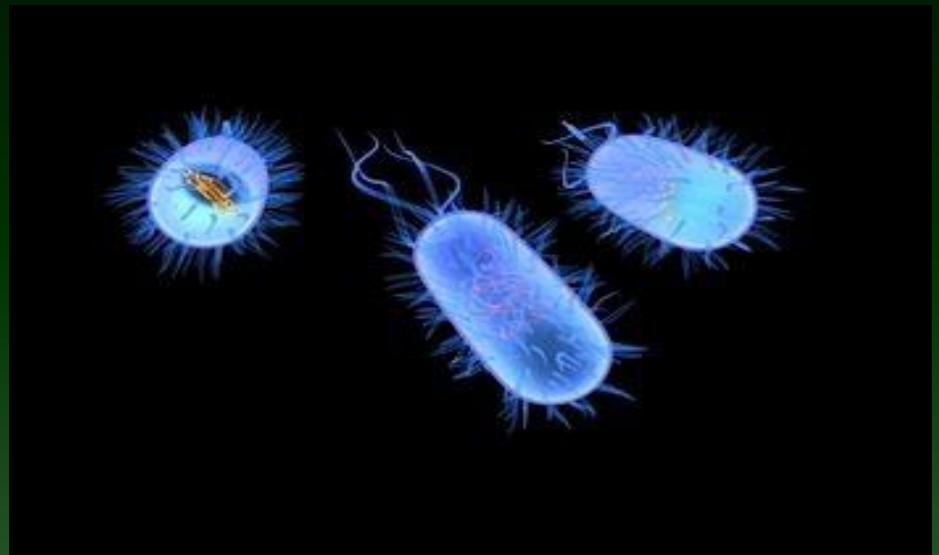
New Jersey Agricultural
Experiment Station

**Plant Defense Activators and
Beneficial Microbes:
Novel Approaches to Turf Disease Control**

**Bruce B. Clarke, Ph.D.
Department of Plant Biology and Pathology,
Rutgers University**

What are Plant Defense Activators

- Plant defence activators are products that stimulate the natural defense mechanisms of plants against the attack of pathogens (fungi and bacteria).
 - They can be chemical, biotic or environmental in nature
 - Prime the host's natural defenses



Plant Defense Activator

- A compound must satisfy the following three criteria to qualify as a **plant activator**:
 - Chemically treated plants must provide the **same resistance expression** as induced by plant pathogens
 - The product must **not** show any **direct activity** on the **pest**.
 - **Biochemical processes** induced by the **compound** should be the **same** as those induced by challenge inoculation with the **pathogen**.

From: Kesserman, et al.1994. Induction of Systemic Acquired Disease Resistance in Plant by Chemicals. Annual Review of Phytopathology 32:439-59

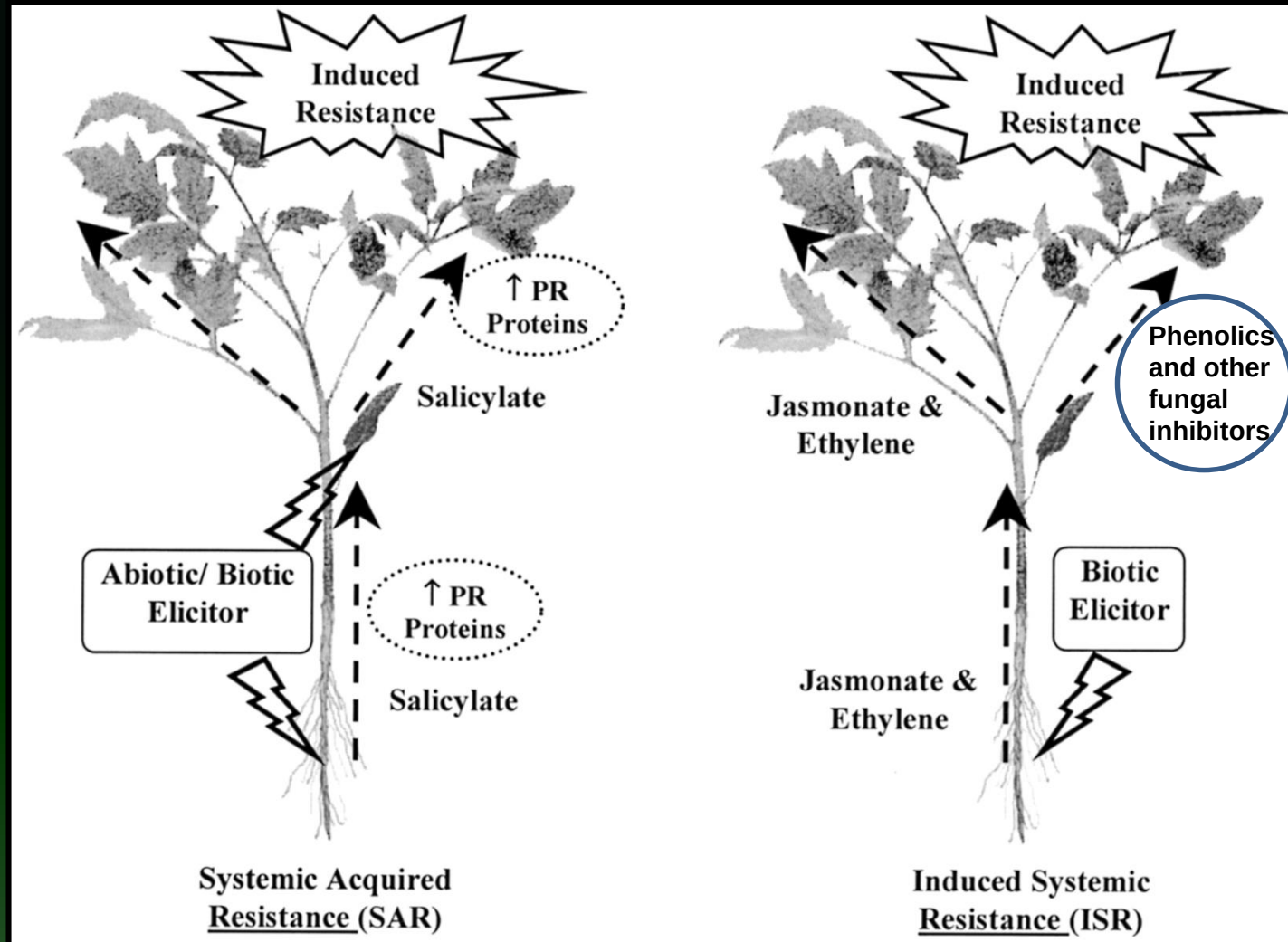
Induced Resistance in Plants

- Physiological state in which **environmental, chemical, or biological *activators*** increase a plant's defenses against subsequent pathogen attack
 - This induces a plant's defense mechanisms
- Two of the most widely studied types of induced resistance include:
 - 1) **Systemic Acquired Resistance (SAR)**
 - 2) **Induced Systemic Resistance (ISR)**

Induced vs Systemic Resistance

- **Systemic Acquired Resistance (SAR)**
 - Pathogen, stress or activator triggers **salicylic acid (SA)** pathway
 - **Systemic signal** induces defense response genes
 - Results in **PR protein** production
- **Induced Systemic Resistance (ISR)**
 - Results from colonization of non-pathogenic bacteria around the root or other biological or chemical activators.
 - Involves **jasmonic acid and ethylene** signaling **pathway**
 - Expression of defense response genes in response
 - **Production of phenolics** and other toxic compounds

Induced vs Systemic Resistance



Modified from Vallad and Goodman, 2003 Crop Science

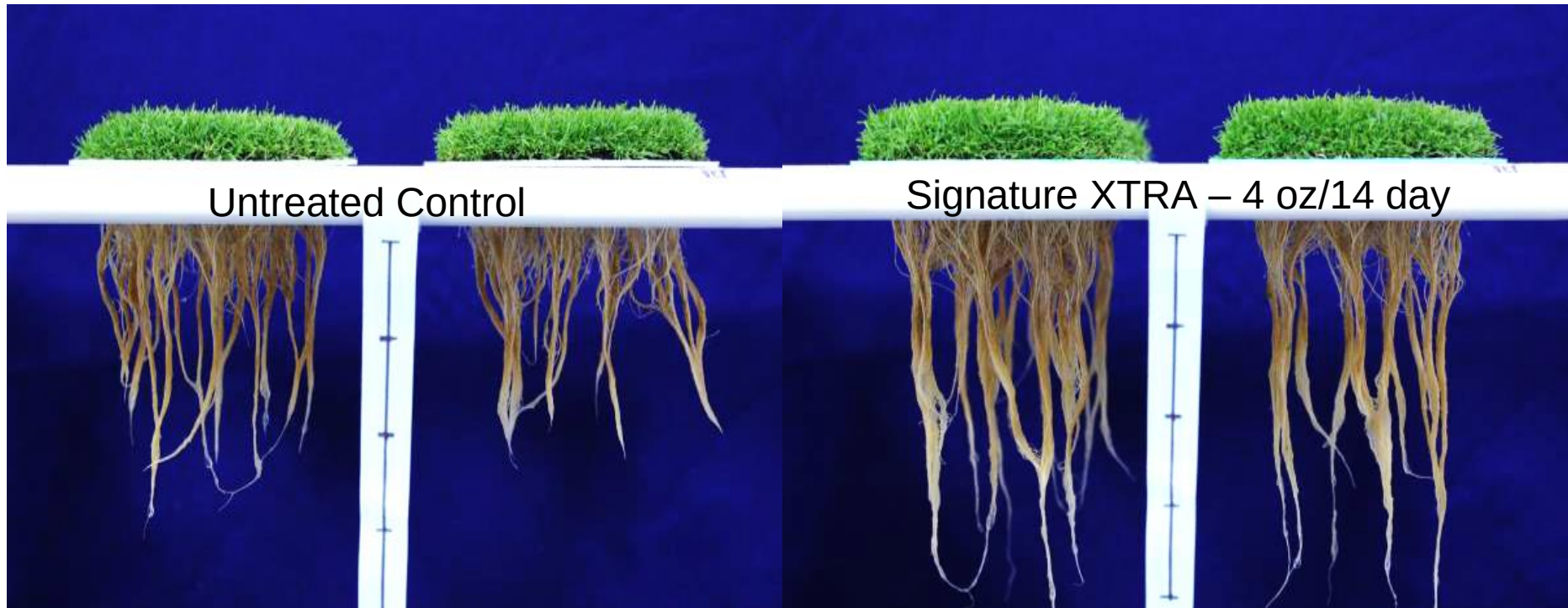
Commercial Products with SAR Activity

- Phosphonate fungicides (used in turf since 80's)
 - Weak SAR Response; Direct toxicity in fungi
- QoI fungicides (e.g., pyraclostrobin; 2000's)
 - Induction of disease suppressing genes are minor and contributes little to disease control. Research has focused on plant health aspects
- Acibenzolar-S-methyl (registered on turf in 2011) induces SAR activity in plants

Signature Xtra Stressgard (fosetyl-AL) is a phosphonate that controls disease & reduces plant stress

- Pythium, yellow tuft, anthracnose (tank mixed)
- Fosetyl-Al rate lowered, now 60 WDG vs. 80 WDG
- Reduction allows for inclusion of additional components to optimize plant health
- Alleviates biotic and abiotic stress, increases chlorophyll production and photosynthesis
- Increases rooting and improves plant health

Root Growth



100% ET

60% ET

Untreated Control



Signature Xtra Stressgard
4 oz @ 14 days



Signature Xtra Stressgard
2 oz @ 7 days



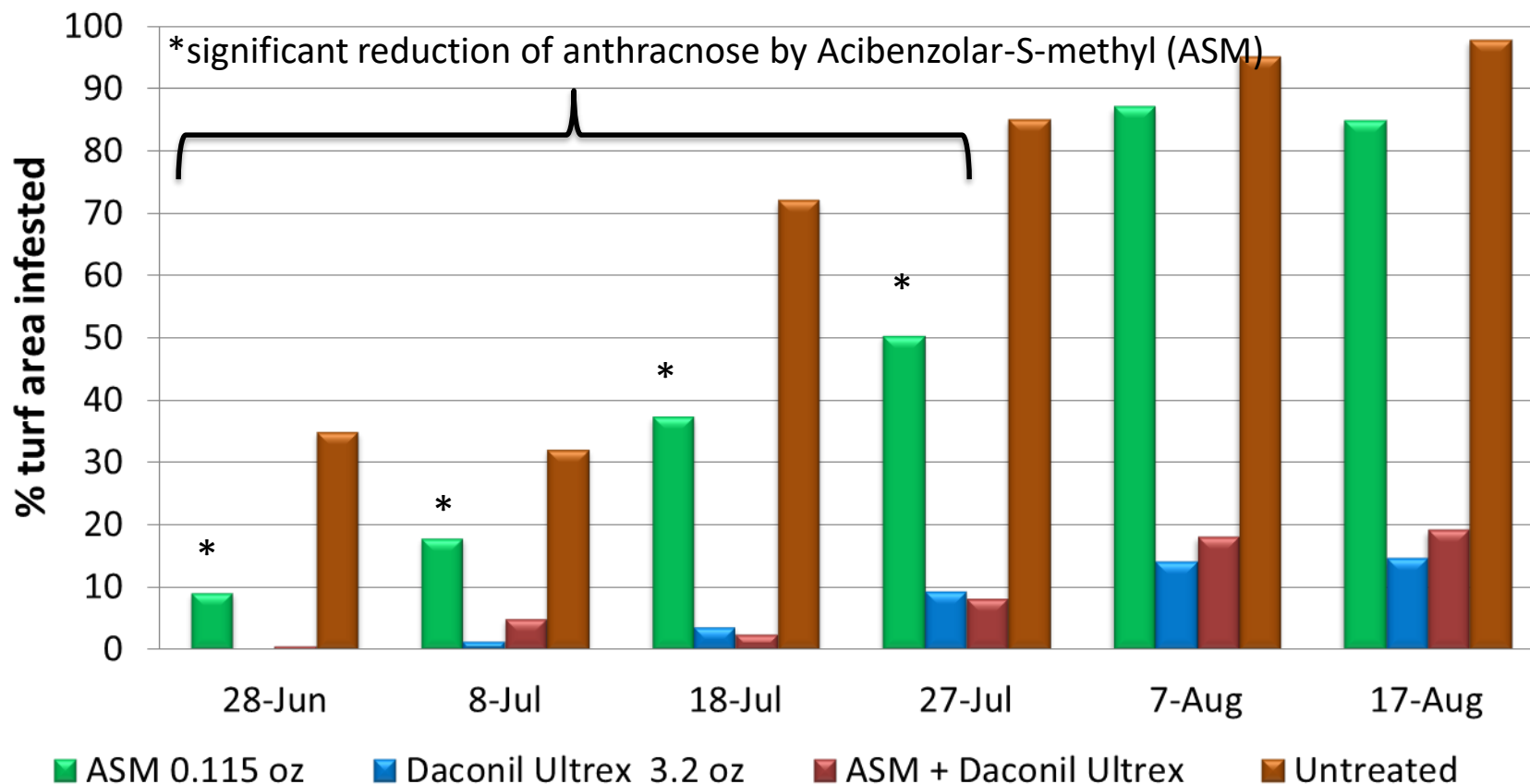
August 21, 2015

Acibenzolar-S-methyl

- Compound with documented SAR activity; used to control crop diseases since 2000; on turf since 2011
- No direct toxicity to fungi
- Enhanced Plant Defense activity for the control of:
 - Bacterial Pathogens:
 - Xanthomonas, Pseudomonas, Acidovorax
 - Fungal Diseases:
 - Dollar spot, anthracnose, downey mildew, powdery mildew, scab, blue mold, rust, rice blast, Pythium diseases

Control of Anthracnose on a Annual Bluegrass Green - Rutgers

Anthracnose– 14 day spray interval (2006)



Application dates: May 17, May 31, June 14, June 28, July 12, July 27 and August 9, 2006.

Location: Hort Farm II – Rutgers University

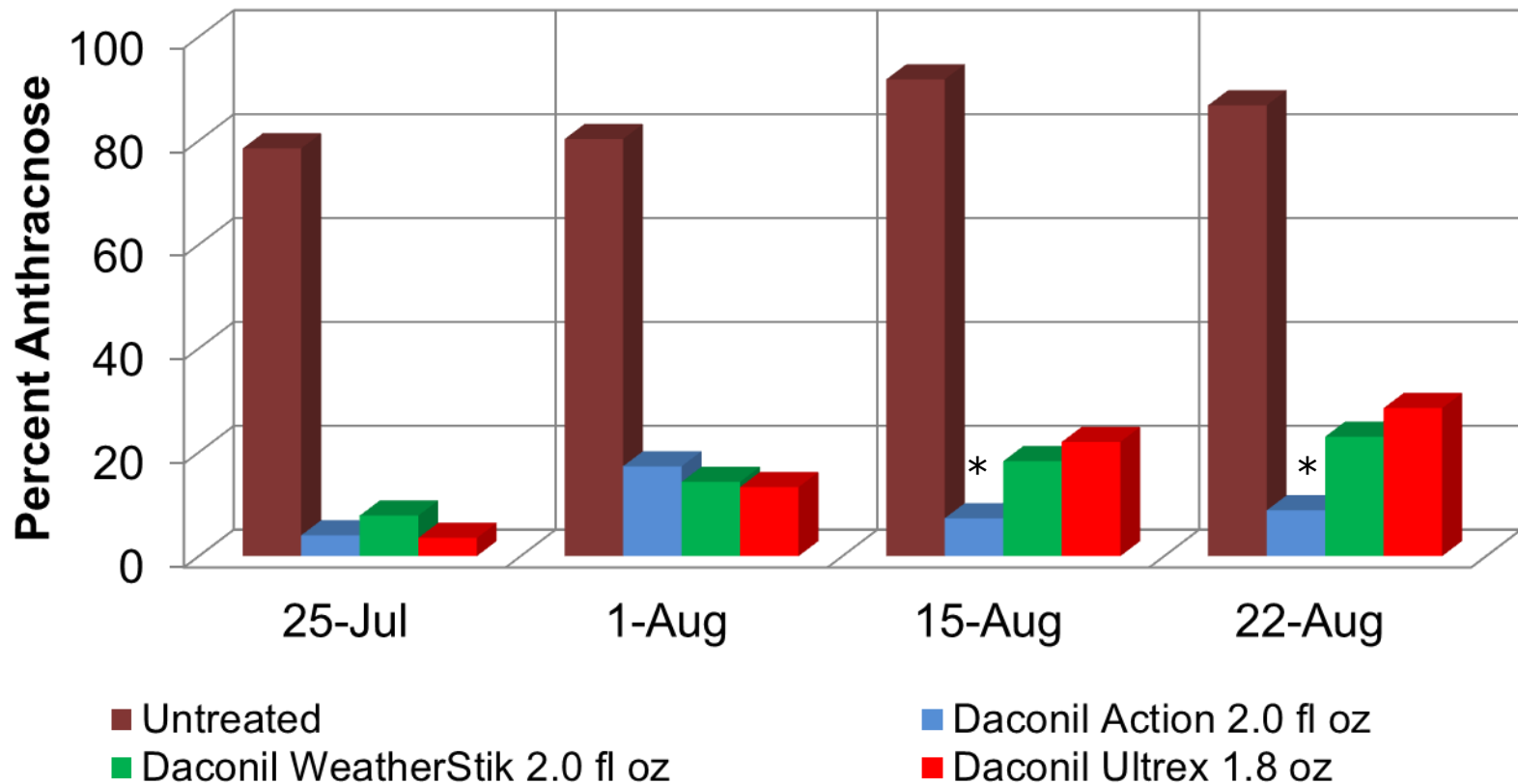
Rates are listed at product per 1,000 sq ft. ASM = Acibenzolar-S-Methyl applied as a 50 WP

Daconil Action (chlorothalonil + acibenzolar)

- Controls every disease that Daconil does plus some suppression of Pythium
- Improves turfgrass quality compared to chlorothalonil-alone
- On many rating dates has shown improved disease control when compared to same rate of chlorothalonil

Control of Anthracnose with chlorothalonil + acibenzolar (Daconil Action®) on an Annual Bluegrass Green - RU

2008 Anthracnose Trial



Treatments applied every 14 days (15 May – 15 Aug 2008) *sign. 0.05

Untreated

T1#80

Daconil Action 1.5 fl oz – 7 day

AL-552A 650-11
7 Day
T1#79

ASM 0.006 oz – 7 day

Daconil Ultrex 3.2 oz – 14 day

T1#85

Photos taken at Rutgers Univ. bent green
on August 27, 2007

Pythium Blight* Trial Conducted by Dr. Bruce Clarke Rutgers University - 2011



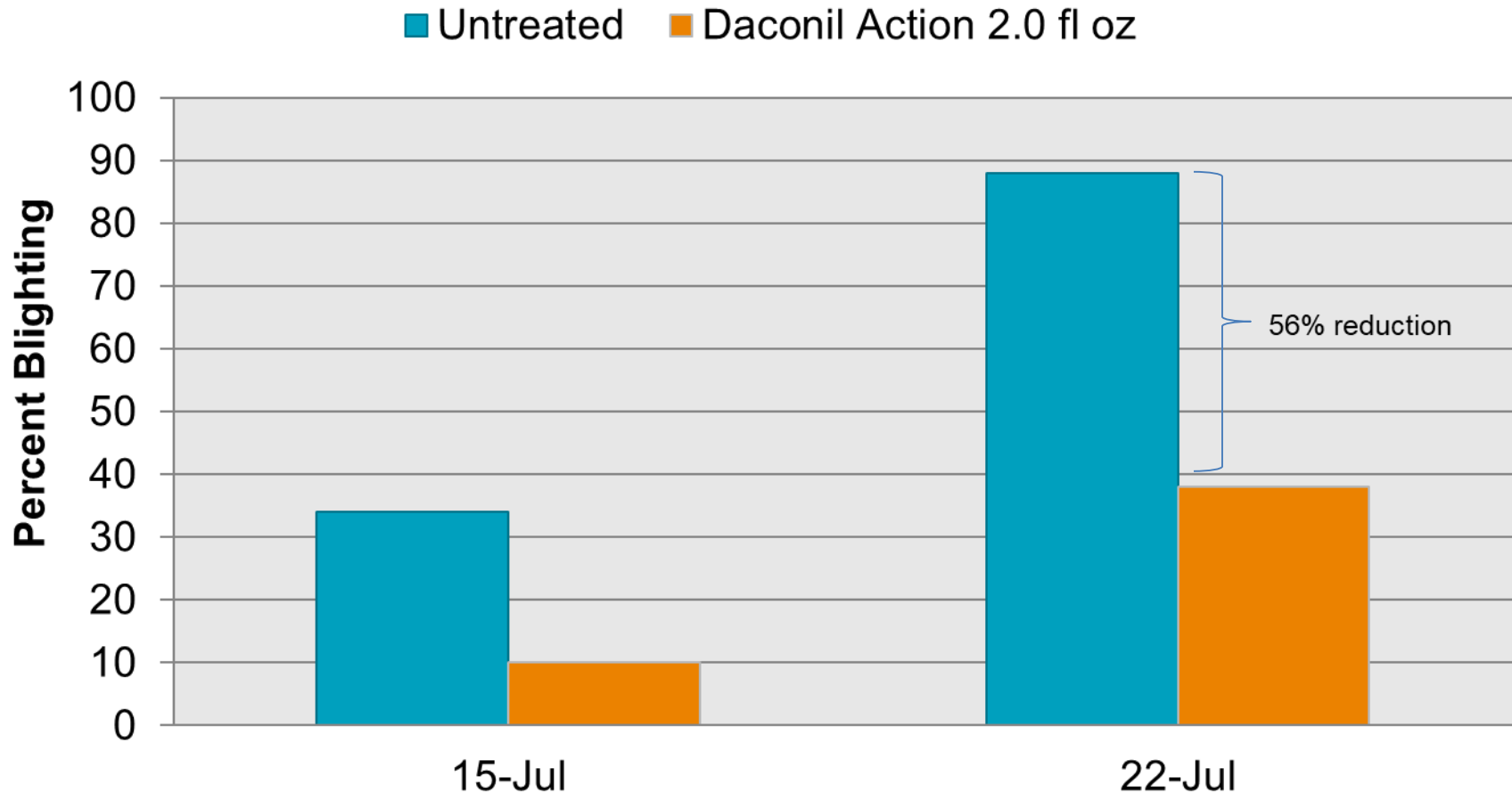
Untreated



Daconil Action™ 2.0 fl oz

Photos taken on July 26, 2011

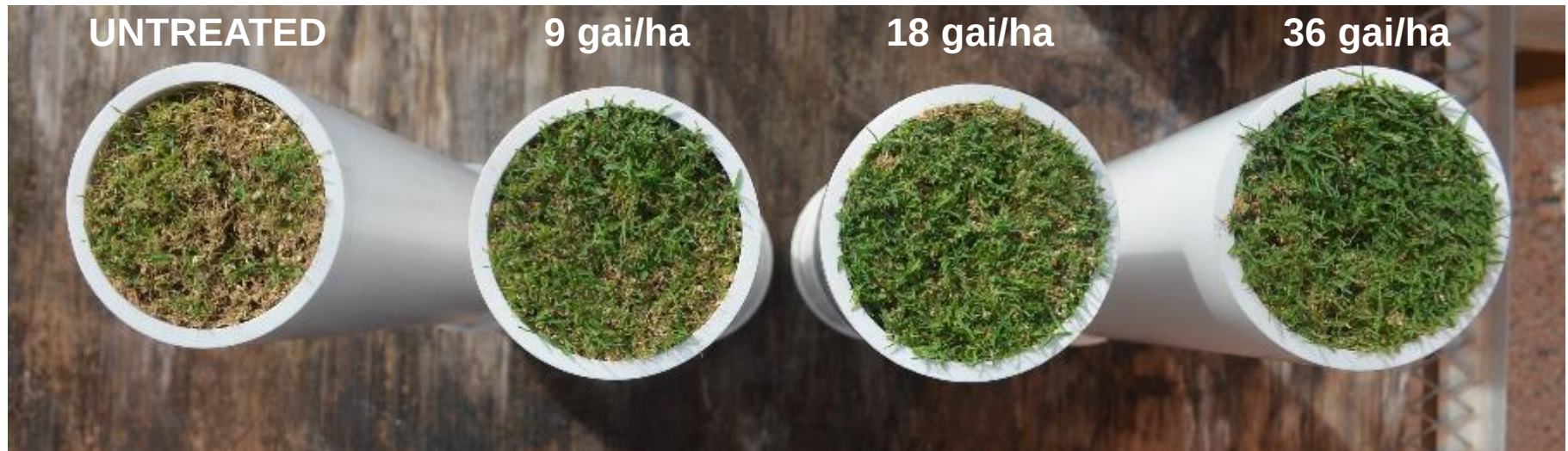
Pythium Blight Prevention with Daconil Action, Rutgers University, 2011



*Syngenta supports a FIFRA Section 2(ee) recommendation for use of Daconil Action for suppression of Pythium Blight and Bacterial Wilt on both Group A and Group B Turf as listed on the federal label. Please see the Section 2(ee) Recommendation to confirm that the recommendation is applicable in your state.

Influence of Heritage Action and Daconil Action on Drought Stress 'TifEagle' Hybrid Bermudagrass

Young, Univ. FL



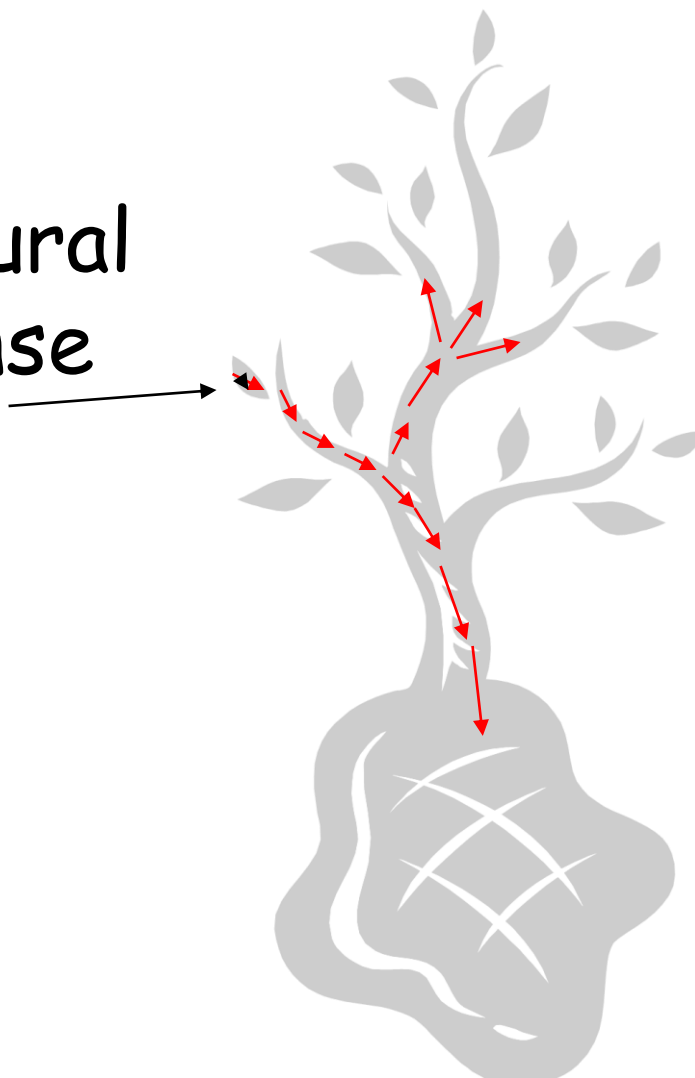
Under severe, repeated water deficits, acibenzolar (ASM) improved 'TifEagle' bermudagrass (**3 drought cycles**).

ASM applied on a **14 day interval**. 9 gai/ha = 2 fl oz Daconil Action or 0.2 oz Heritage Action

Slide courtesy Lane Tredway

Induced Systemic Resistance

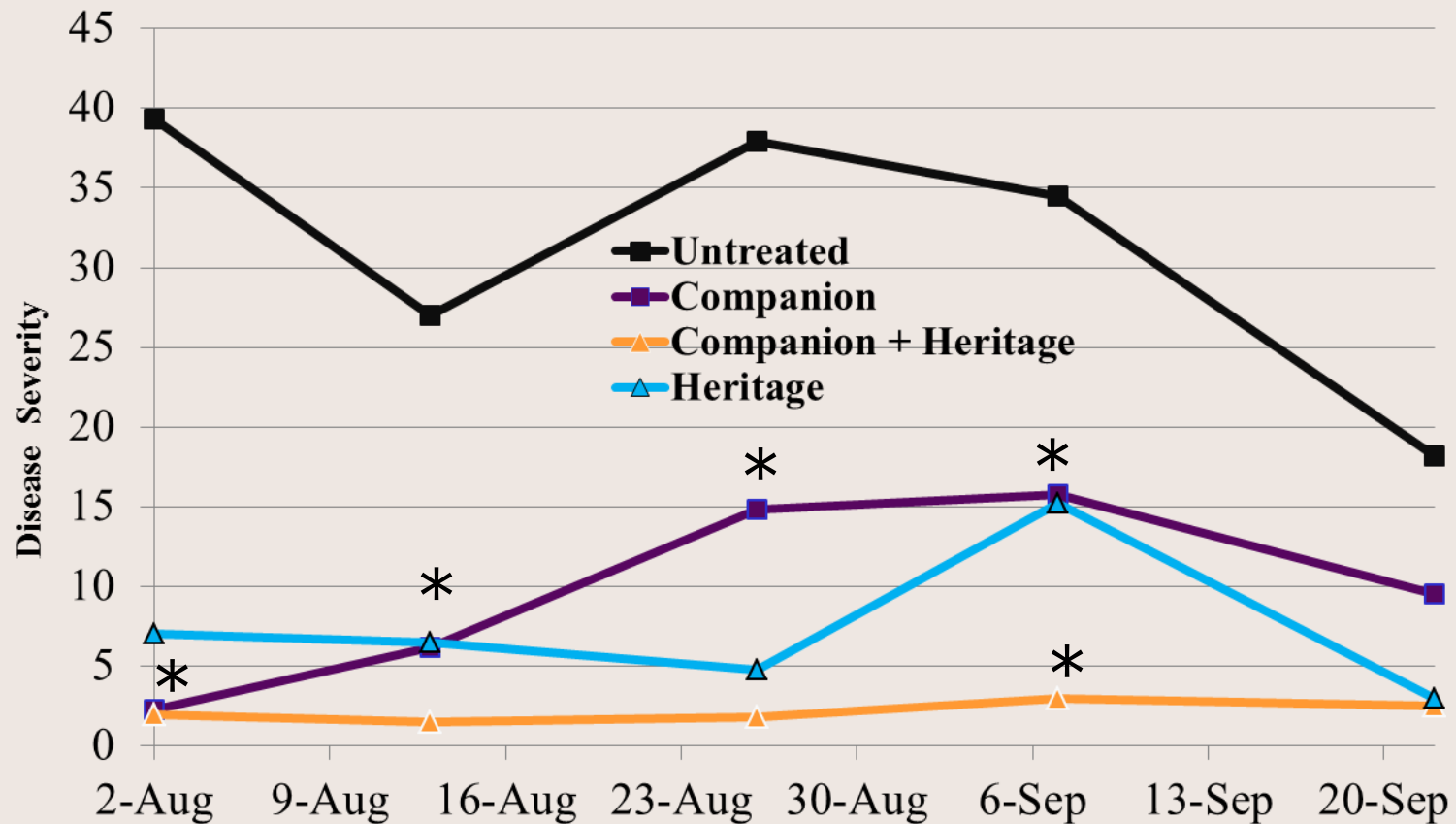
- Stimulates natural defense response in plants



Commercial Products with ISR Activity

- Certain biocontrol agents (*Bacillus subtilis*)
 - QST 713 strain for Turf (Rhapsody)
 - GB03 strain for Turf (Companion)
 - Both marketed for preventive, broad spectrum control of fungal diseases - including Brown Patch, Summer Patch, Anthracnose, Dollar Spot)
 - *Limited activity under high disease pressure*

Suppression of Summer Patch by the Biological Control Product Companion on Kentucky Bluegrass Turf



1999

Companion microbial inoculant contains *Bacillus subtilis* ($> 1.5 \times 10^{10}$ CFU/L);
Heritage 50WG (azoxystrobin) @ 0.4 oz / 1,000 sq ft every 14-d; 3.9 cm cutting ht

Commercial Products with ISR Activity

- Mineral Oil (Civitas + pigment Harmonizer)
 - Mixture of a food-grade synthetic isoparaffin and a food-grade emulsifier
 - registered in the U.S for use on turf in Feb 2009

History of Mineral Oils and Pest Management

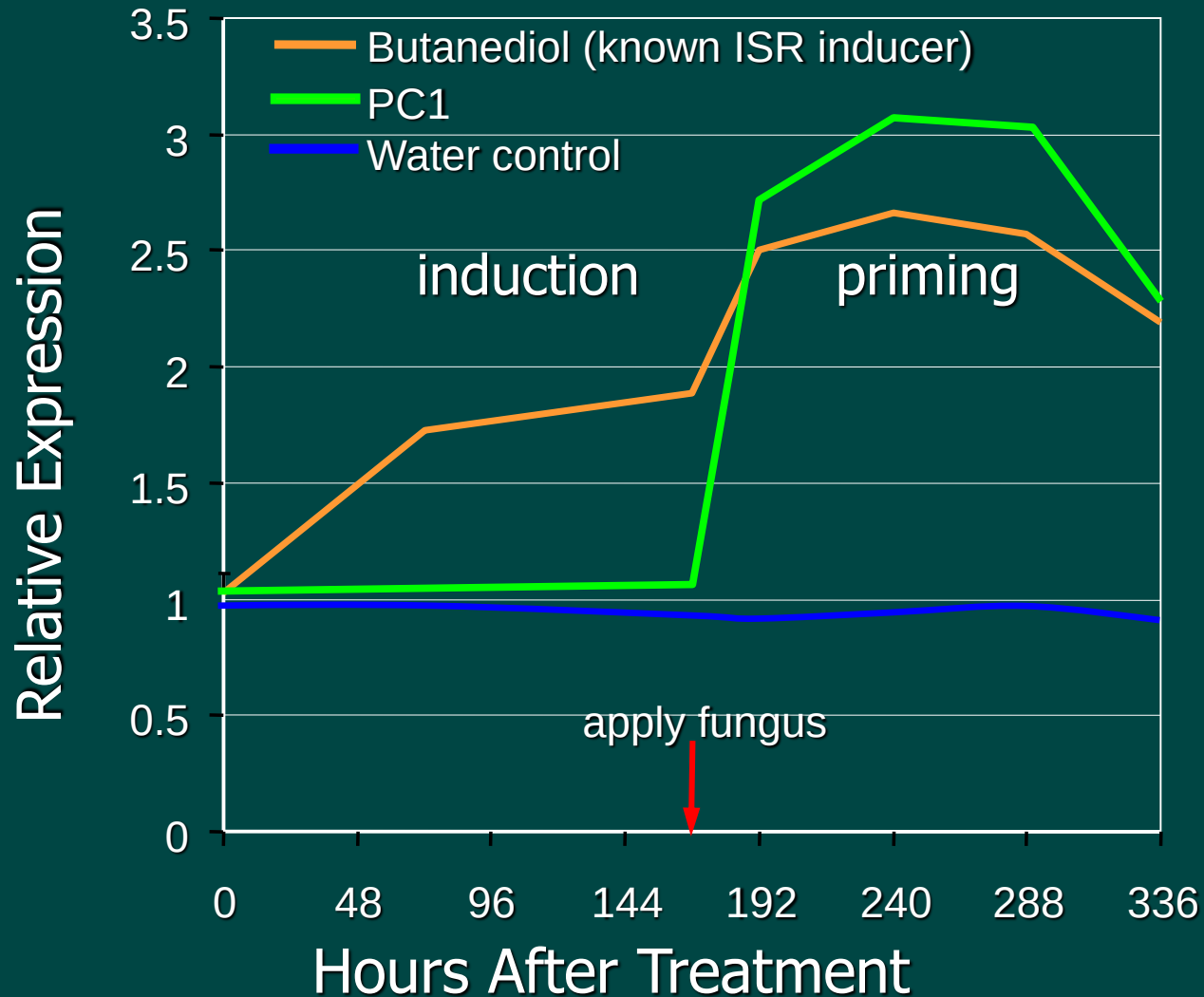
- Mineral oils have been used in crop protection to control insects, mites etc for many years (Metcalf et al., 1962)
- Oils have been used to control plant diseases since the 1950s:
 - Sigatoka disease of banana caused by *Mycosphaerella musicola* (Calpouzos et al., 1959)



Gene Expression Studies with Civitas to Determine Mechanism of Action (Cortes-Barco et al, 2010)

- Treatments
 - Butanediol (ISR inducer in broad-leaf plant)
 - PC1 (Civitas)
- Identify marker genes for ISR by looking for genes known to be activated during ISR in other grasses

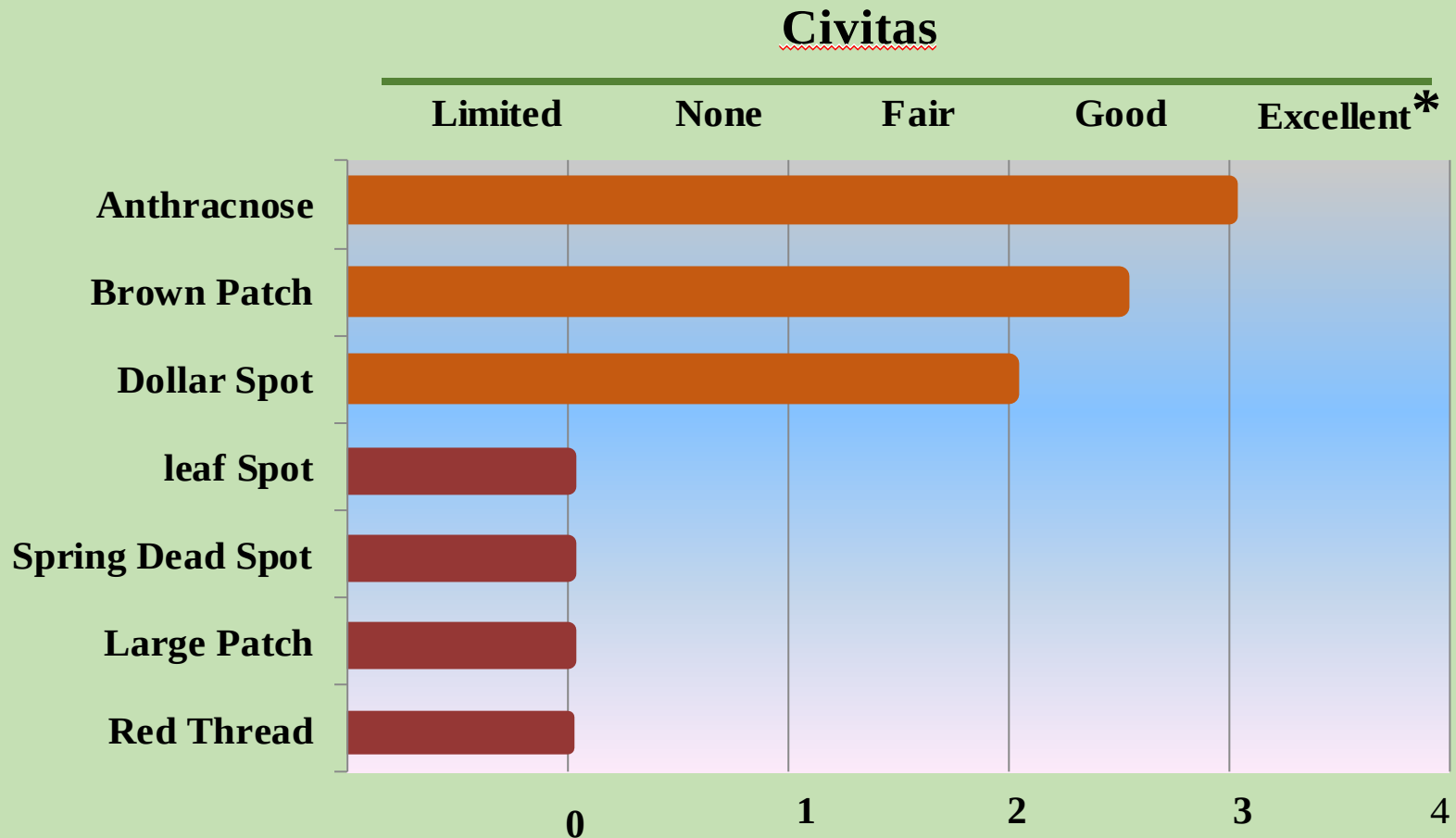
Gene expression in *Bentgrass*



Conclusions on gene expression by Civitas

- Civitas primes disease resistance genes in turf for expression upon infection
- Testing of these genes shows that mode of action of Civitas is Induced Systemic Resistance

Relative Efficacy of New Fungicides for Turf Disease Control : 2015- 2019 (Golf)



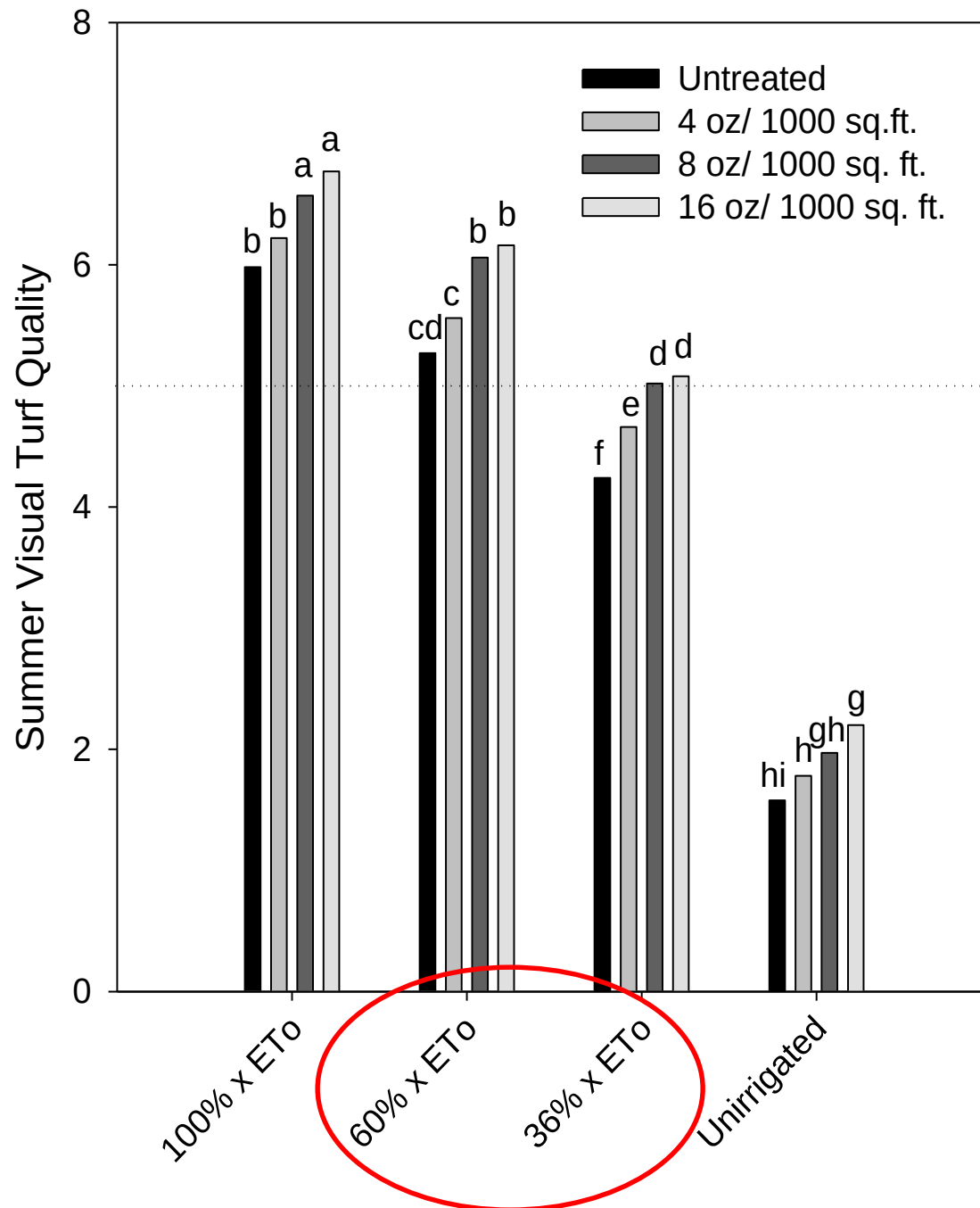
* Efficacy on a 1- 4 Scale, where 1 = not effective, 2 = fair – good control, 3 = good – excellent control, and 4 = excellent control. Limited = insufficient data.

Benefits of Civitas on Zoysiagrass Fairway Turf Managed Under Reduced Inputs

Ben Wherley, PhD
Assistant Professor- Turfgrass Ecology
Texas A&M University



CIVITAS improved zoysiagrass performance under reduced water (40% reduction).



36% x ET_0 (~1/2" H_2O /wk)

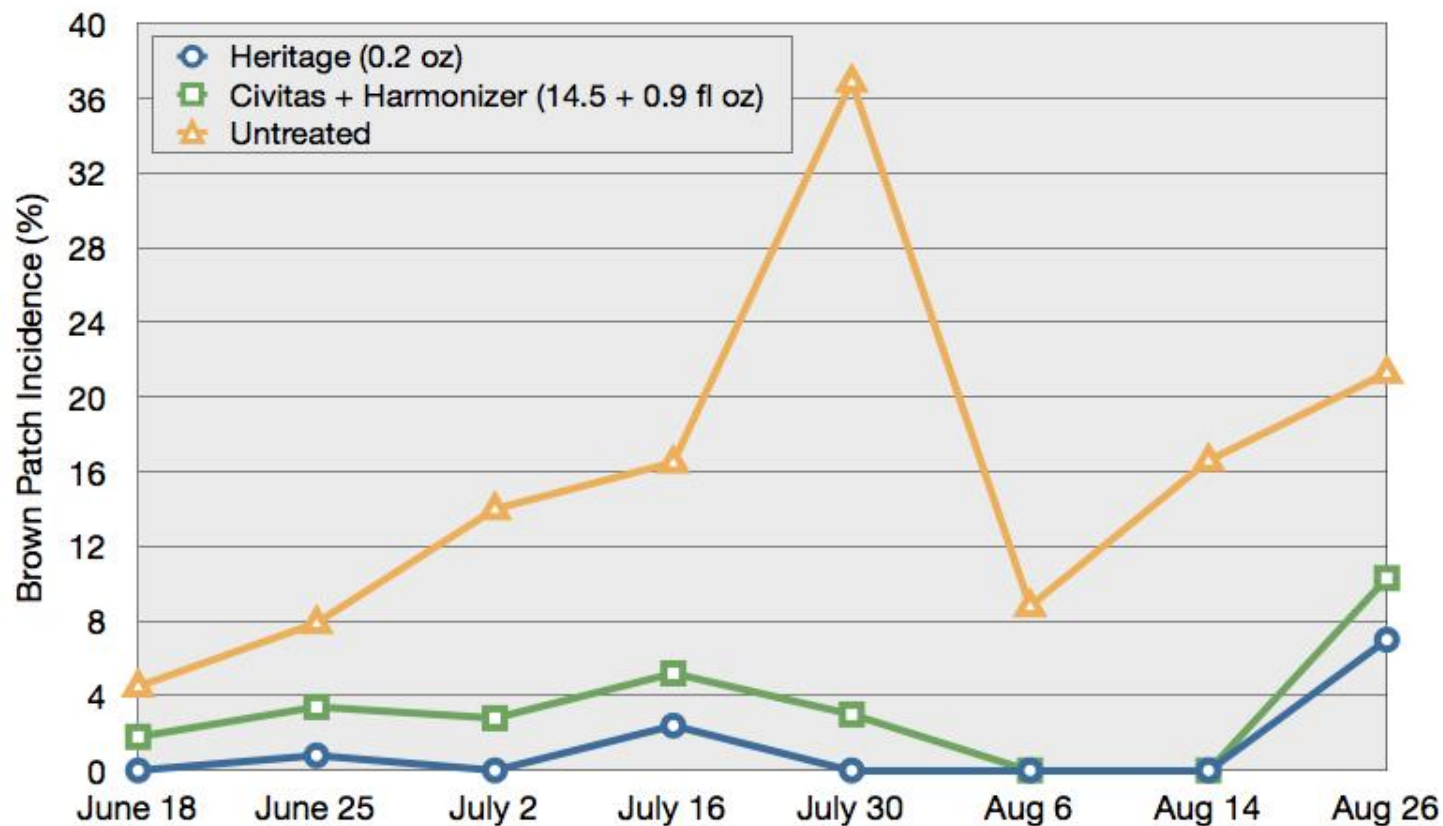
Untreated

Civitas

(16 oz/M/14 days)

60% x ET_0 (~1" H_2O /wk)

Control of brown patch with Civitas, 2009



Control of Bipolaris leaf spot with CIVITAS on Bermudagrass

Program	Bipolaris leaf spot (% area) ¹	Turf quality (1-9) ²	RVI ³
Non-treated	15.0 a	5.18 c	5.425 a
CIVITAS	0.8 b	7.05 abc	6.400 b
Fungicide	0.5 b	7.73 ab	6.473 b

²Turf Quality based on a 1 – 9 scale with 9 = dark green turf, 1=dead/brown turf and 6=minimally acceptable.

³RVI = Ratio Vegetation Index. Index increases as quality of turf increases.

Clemson University – Bermudagrass disease and quality control programs.

Pee Dee Research and Education Center, Florence, SC

August 24, 2012

A decorative border at the bottom of the slide consisting of a dense, green, stylized grass texture.

What's the Future Use of SAR and ISR Compounds for the Management of Turfgrass Diseases

- ❖ SAR and ISR compounds typically do not provide acceptable control alone but they:
 - make good tank mix partners to improve control with reduced rates of standard fungicides
 - have a low probability of resistance
 - are often considered reduced risk materials
- ❖ Likely to increase in use as standard pesticide use becomes more restricted
- ❖ Provide manufacturers with the ability to extend longevity of post-patent products.

Turf Microbiome / Phytobiome

- Is the diverse microbial community including fungi, bacteria and other organisms that lives on (or in) the plant and in the soil.
- Composed of beneficial and pathogen organisms
- Similar to topic of “Pro-Biotics” in human health
- Current research is primarily in the descriptive phase (“Inventory” of what’s present);
- Future research will focus on “functionality” (what do they do and how can beneficials be encouraged. e.g., disease suppressive soils

Outlook for Turf Microbiome Research

- Focus: Improving our knowledge of beneficial microbes that establish with turfgrasses
 - Reducing fertilizer and water inputs
 - Identifying new sources of biological controls
 - Developing resistant turfgrass varieties through better understanding plant-microbe interactions
- Soil microbiome may help reduce disease and improve stress tolerance and be transferable (disease suppressive soils)

Microbes are not always external to plants

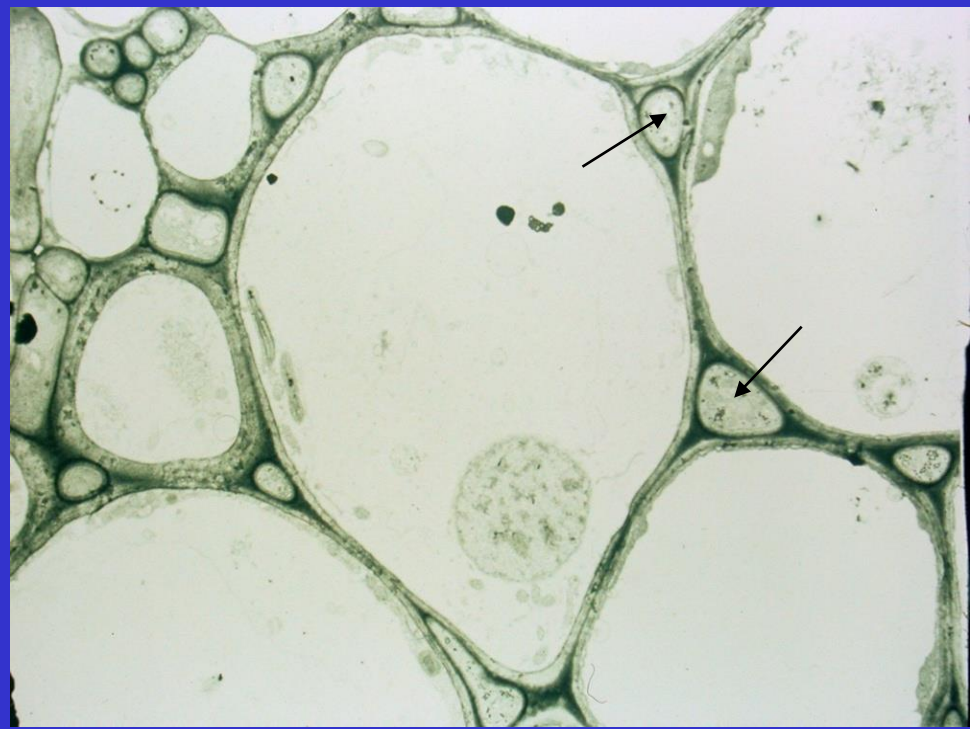


**Endophytes
are
everywhere!**

Plants can contains multiple endophytes

Endophytes

- Symbiotic fungi and bacteria living within plant tissues
- Usually systemic
- All levels of plant tissue can be infected (stems, roots, seeds, leaves)
- Typically cause little or no negative effects on plants, often a mutualistic association



Microbial Endophytes

- Fungi and bacteria
- Common in most plants
- Improve insect and stress tolerance
- Suppress some pathogenic fungi
- Enhance root development
- Improve nutrient absorption

Endophytes confer fungal disease resistance in Cool-season Turf

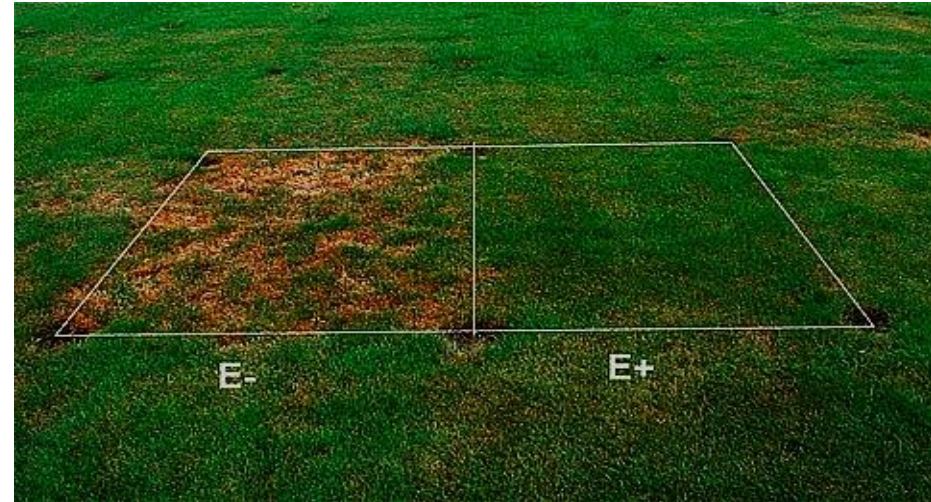
Endophytes are not as common in Warm-Season Turf but they do exist!



E-

E+

Dollar spot disease resistance
(Clarke et al. 2006)



E-

E+

Red thread disease resistance
(Bonos et al. 2005)

Endophyte Antifungal Protein Identified

Purified the protein active
against dollar spot fungus

SCIENTIFIC REPORTS

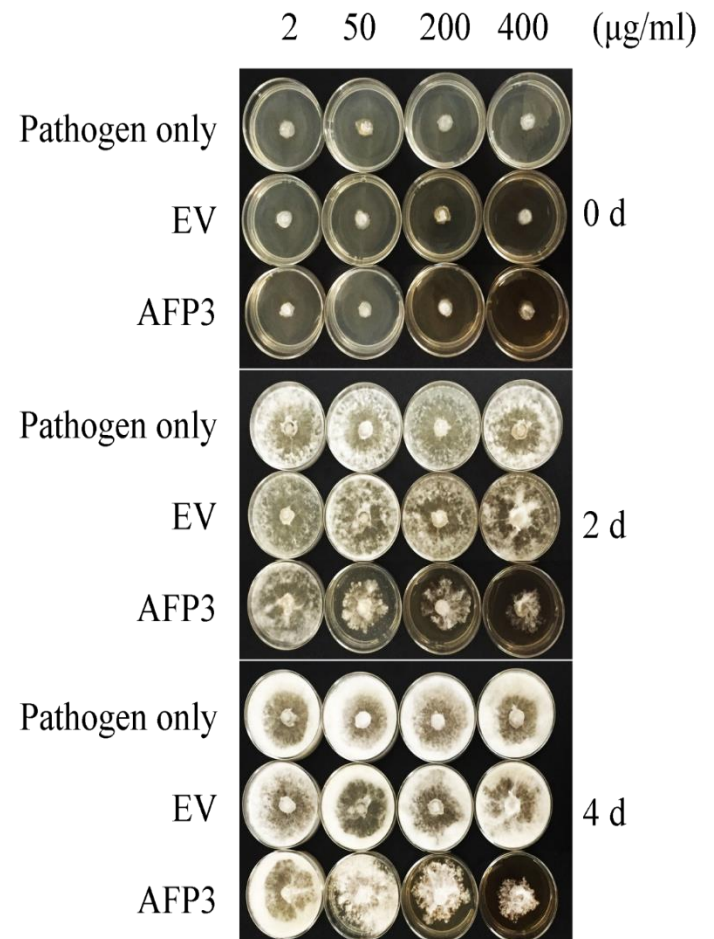
OPEN The *Epichloë festucae* antifungal protein has activity against the plant pathogen *Sclerotinia homoeocarpa*, the causal agent of dollar spot disease

Received: 21 March 2017

Accepted: 7 June 2017

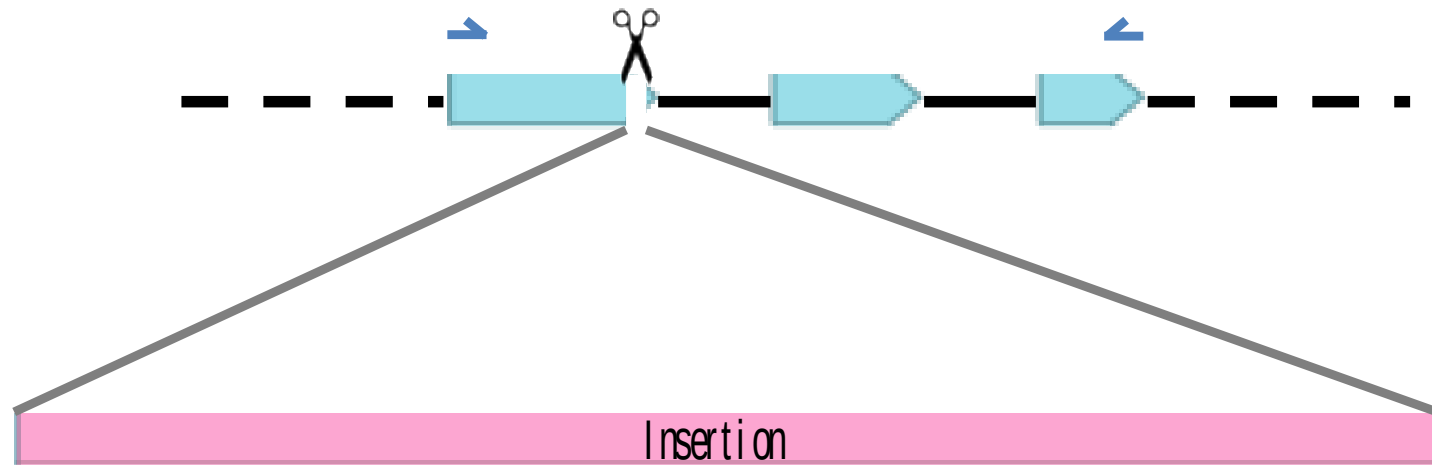
Published online: 17 July 2017

Zipeng Tian¹, Ruying Wang¹, Karen V. Ambrose^{1,2}, Bruce B. Clarke¹ & Faith C. Belanger¹



CRISPR-Cas9 gene knockout

- Found 3 fungal isolates without the anti-fungal gene

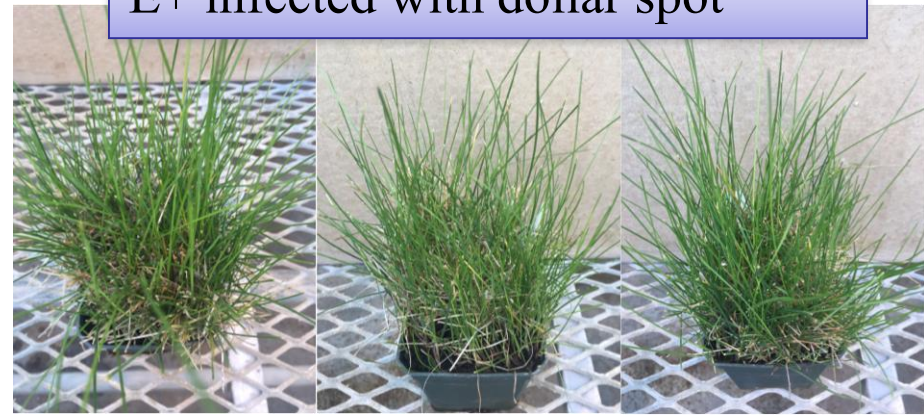


Next Steps: Inoculate E- plants; Greenhouse assay with dollar spot

E- infected with dollar spot



E+ infected with dollar spot



ME+ infected with dollar spot



FEATURES

ScienceNews
MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC

FEATURE

How plant microbes could feed the world and save endangered species

Scientists have only scratched the surface of the plant microbiome, but they already believe it might increase crop yield and save species from extinction.

BY AMBER DANCE | AGRICULTURE, MICROBES, PLANTS

We are seeing increasing interest and use of
biological control for production agriculture
&

Products are becoming more available in turf

Beneficial Microbes form the Basis for Biological Control in Turf



Hyatt Hills Golf Complex

Constraints to Using Beneficial Microbes

- Microbes must be viable
 - Biological products have a shelf-life
- Need to have enough microbes to bring about a change
- Microbes must be successful in surviving and multiplying

Biological Controls for Turfgrass Diseases

Product name	Pathogen Targets
Actinovate	Soilborne pathogens
Companion	Brown patch; Summer Patch; Pythium Blight
DiTera	Nematodes
EcoGuard	Dollar spot (low and moderate pressure)
Spot-Less	Dollar spot
Rapsody	Anthrachnose; brown patch; dollar spot; powdery mildew; rust
RootShield/TurfShield	Brown patch; dollar spot; many soilborne pathogens
Mycostop Mix (Primastop)	Many

Commercial Turf Disease Control Products in the United States

Organism	Trade Name	Status
<i>Trichoderma harzianum</i> 1295-22	Turf Shield (BioTrek)	Registered 1996
<i>Gliocladium catenulatum</i> J1446	Primastop	Registration Application 5/97
<i>Pseudomonas aureofaciens</i> Tx-1	SpotLess	Registered 1999
<i>Streptomyces lydicus</i> WYEC 108	Actinovate	Registration Application 2000
<i>Bacillus subtilis</i> GB03	Companion	Registered 2003
<i>Bacillus licheniformis</i> SB3086	Ecoguard	Registered 2003

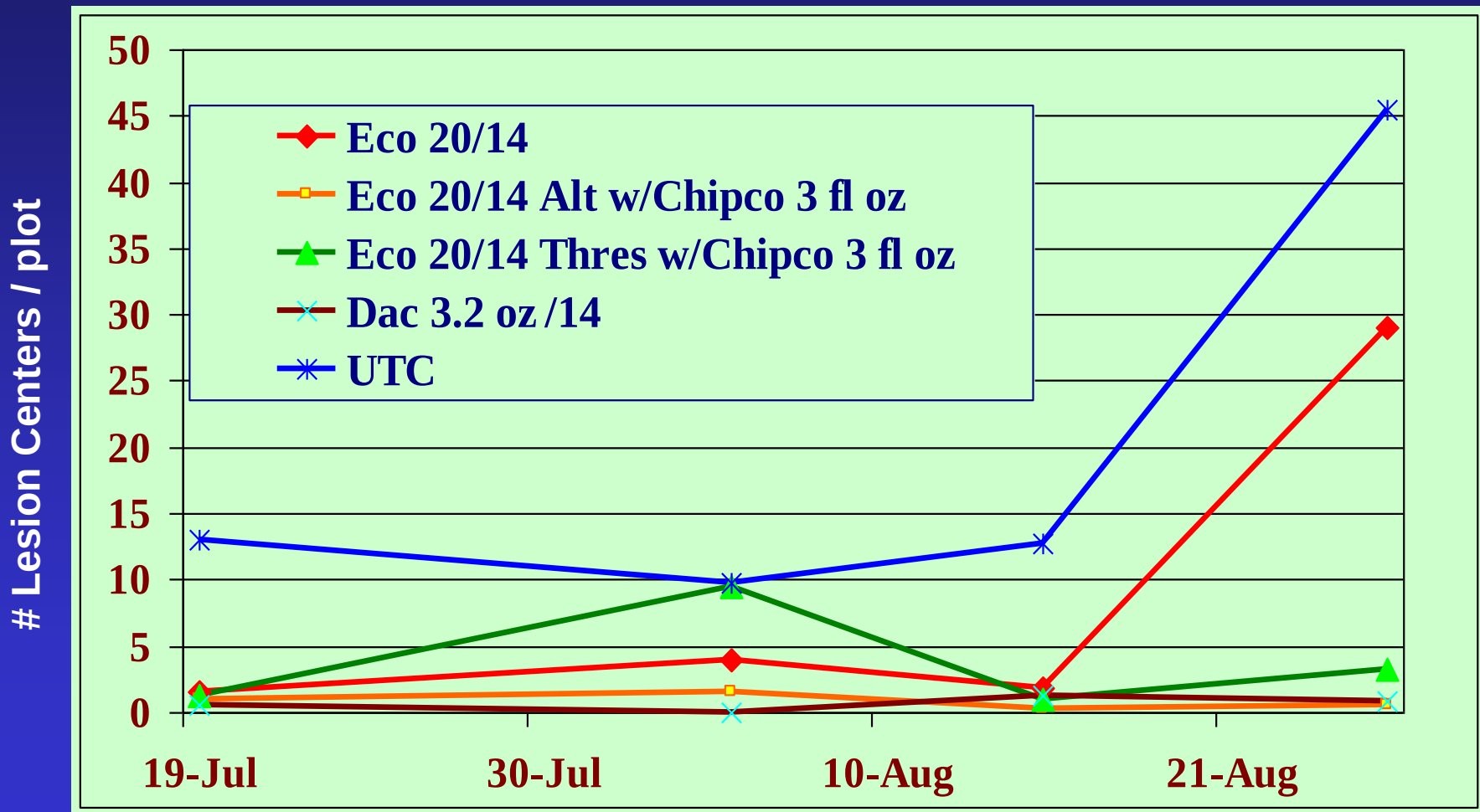
**There Have Been
Successes!**

Green plots were treated with *Typhula phacorrhiza* to control gray snow mold



Hsiang, 2000

Efficacy of *Bacillus licheniformis* for the Control of Dollar Spot in Crenshaw Creeping Bentgrass



How do biocontrols work?

Mechanisms of action

- Antibiosis

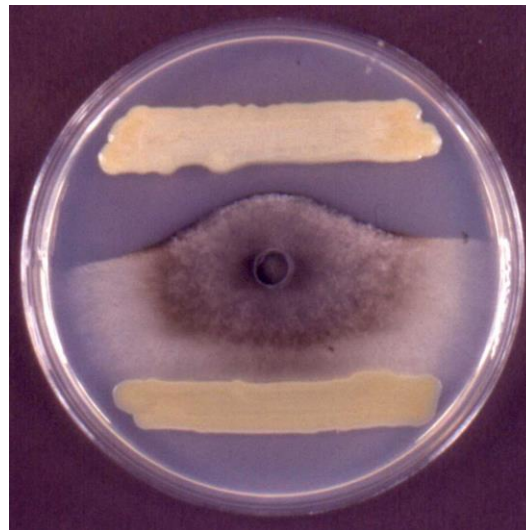
How do biocontrols work?

Mechanisms of action

- Antibiosis
- Destructive parasitism
- Competition
- Induced resistance

Antibiosis

Inhibition of pathogen growth through the production of antibiotics by the biocontrol agent



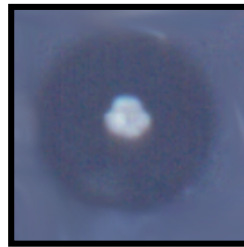
How do biocontrols work?

Mechanisms of action

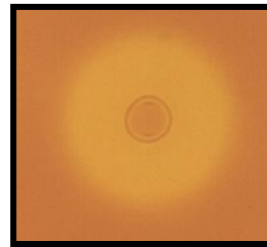
- Antibiosis
- Destructive parasitism
- Competition
- Induced resistance

Destructive parasitism

Killing or debilitating the pathogen by a parasitic biocontrol agent.
(For example, lysis of the cell wall through the production of enzymes and/or other compounds)



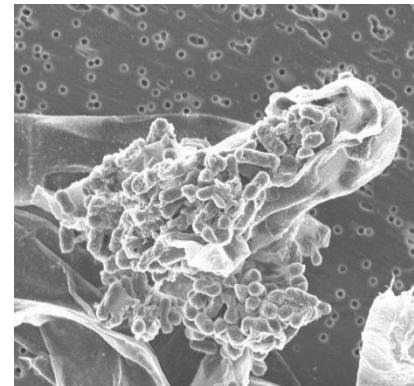
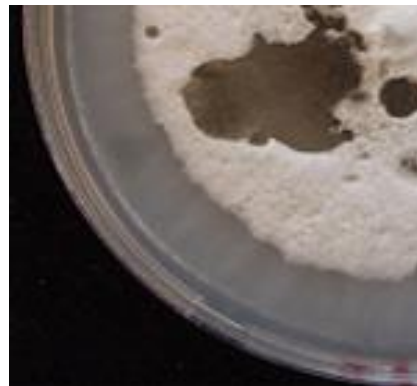
chitinase



β -1,3-
glucanase



protease



Gray leaf spot pathogen, *Magnaporthe grisea*

How do biocontrols work?

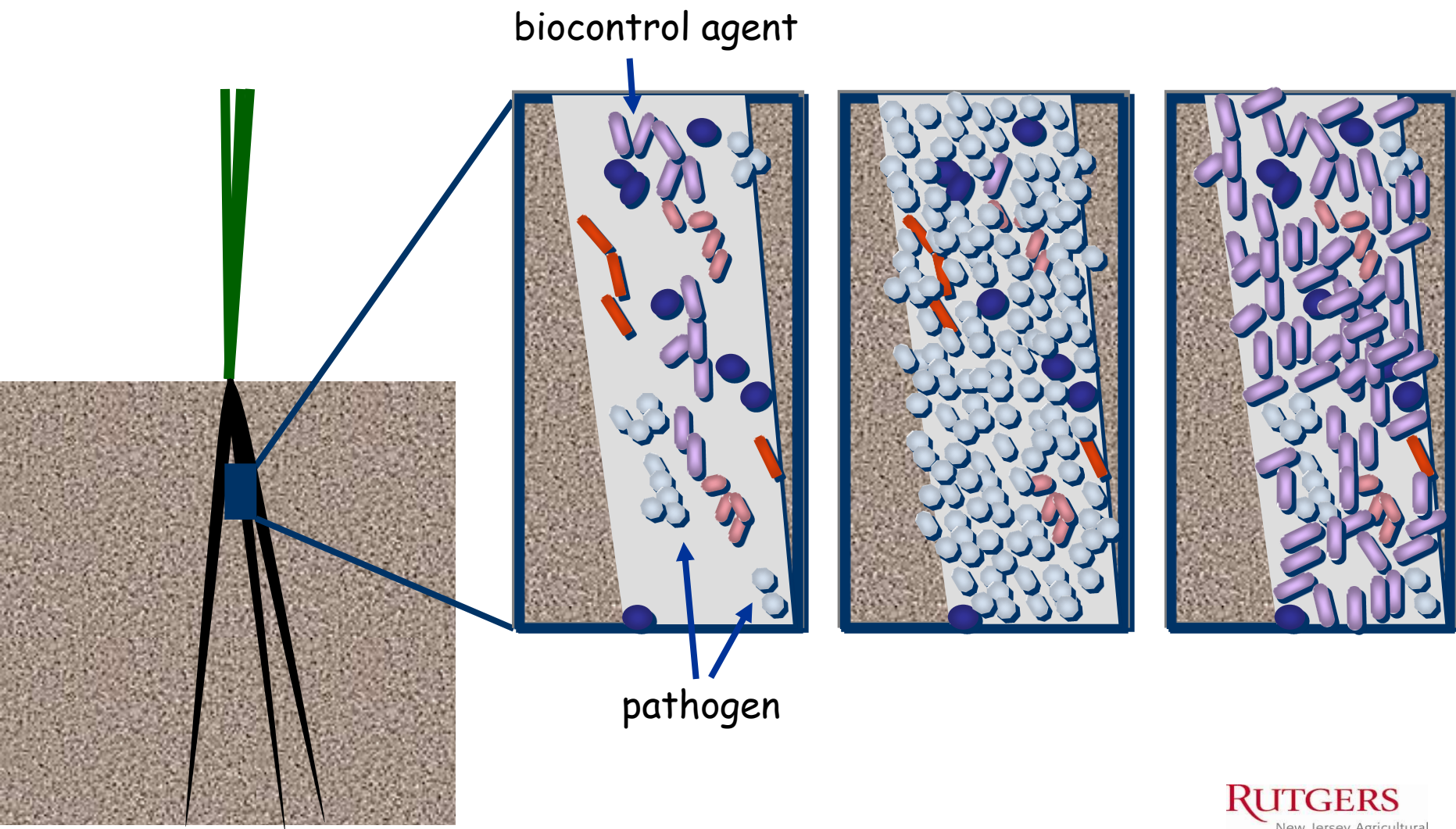
Mechanisms of action

- Antibiosis
- Destructive parasitism
- **Competition**
- Induced resistance

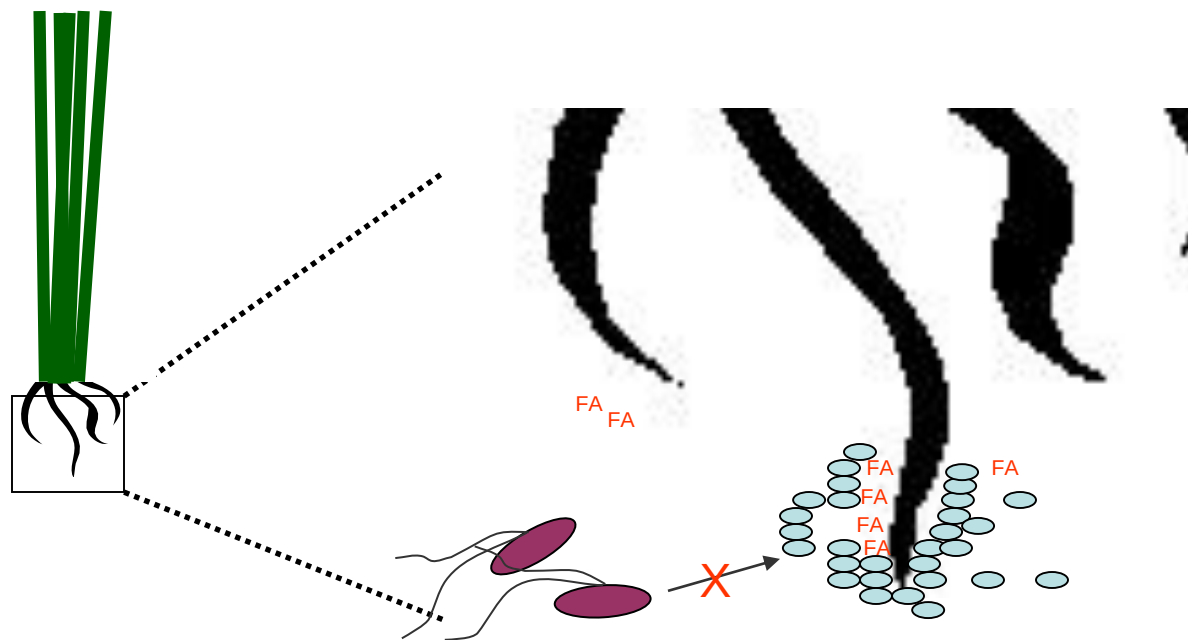
Competition

Preventing the pathogen from growing and/or infecting the host by out-competing it for limiting resources (for example, nutrients or space)

Competition for space



Competition for nutrients



How do biocontrols work?

Mechanisms of action

- Antibiosis
- Destructive parasitism
- Competition
- Induced Resistance
- Induced resistance

The Future

Where are we going with biocontrol
and biorational products?

Integrated Strategies for Disease Control :

We are already seeing a change in the chemical paradigm.

Complementary, not alternative, strategies

- Combining biologicals with chemical controls
- Combining biologicals with cultural practices
- Combining with disease tolerant varieties

Field of Genomics: The Future of Biocontrol?

- The 1st two turfgrass biocontrol bacteria with sequenced genomes:
 - *Pseudomonas fluorescens* Pf-5
 - *Lysobacter enzymogenes* C3
- This may result in a new source of naturally produced antifungal products (e.g., Medallion)
- New strategies for disease control?



Thank You for Listening !

***Bruce Clarke, Ph.D.
Director, Center for Turfgrass Science and
Extension Specialist in Turfgrass Pathology
Rutgers University***