Understanding Mycotoxins – What Are They? Where Do They Come From?

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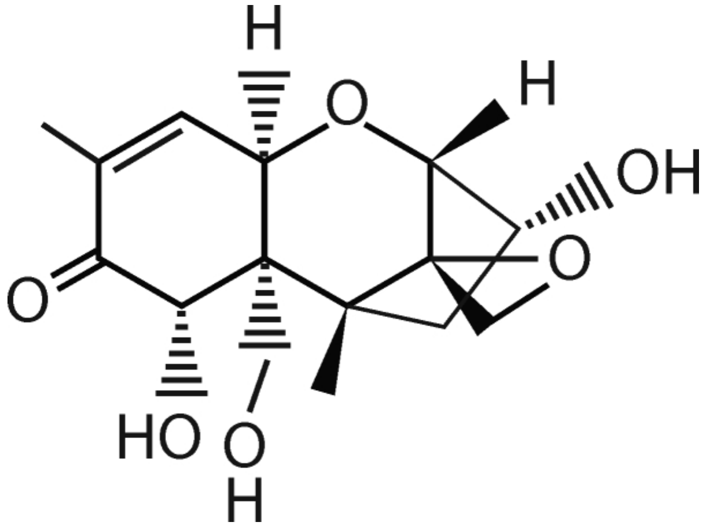
Mycotoxins

- Toxic, metabolic by-products (secondary metabolites) 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 and head molds (including those that produce toxins)

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

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

Deoxynivalenol - DON



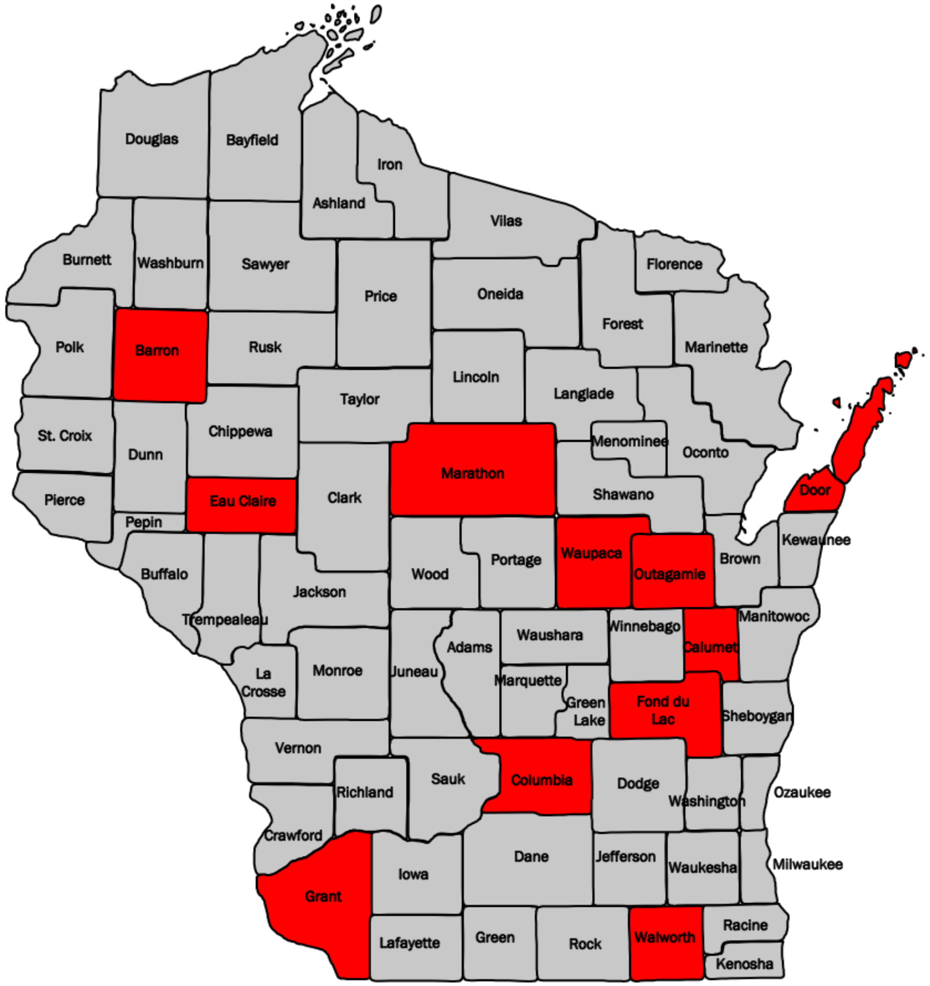
- Most common mycotoxin in Wisconsin
- Member of the trichothecene family
- Protein synthesis inhibitor
- Symptoms include nausea, vomiting, diarrhea, abdominal pain, headache, dizziness, and fever
- Extremely heat-stable, cold-stable, and water soluble - problem for processed foods.

Vomitoxins (DON) Produced by *Fusarium spp.* Come in Different "Flavors"

- *Fusarium* spp. produce an array of toxins, but their primary secondary metabolites are deoxynivalenol (DON) and nivalenol (NIV)
- There are 3 chemotype classifications of isolates
  - o Acetyldeoxynivalenol 3-ADON, 15-ADON, and NIV (Type B trichothecenes)
  - o 3-ADON isolates are typically more aggressive
    -low levels in population in U.S.
  - o 15-ADON isolates more prevalent in U.S.
  - o NIV is the most toxic mycotoxin produced by Fusarium spp., but is relatively rare in the Midwest
  - o Type A trichothecenes can also be produced (T-2, H-2 toxins)
- *Fusarium graminearum* AND *Fusarium culmorum* main species of importance on corn/wheat in Wisconsin

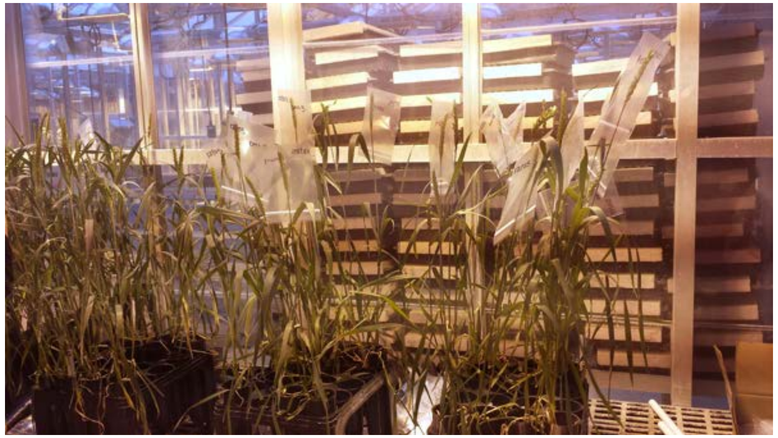
Multiple Chemotypes Can be found in Agronomic Landscapes – An example from Wheat

- 2016 Samples
  - Among 195 wheat head samples collected in 2016 in Wisconsin, 145 *Fusarium* spp. were positively chemotyped as 3ADON or 15ADON
  - 90% were of the 15ADON chemotype and 10% of isolates were 3ADON
- 2017 Samples
  - 185 samples were collected and 120 of them were chemotyped
  - 92% of the isolates were identified as 15ADON chemotype and 8% the 3ADON chemotype

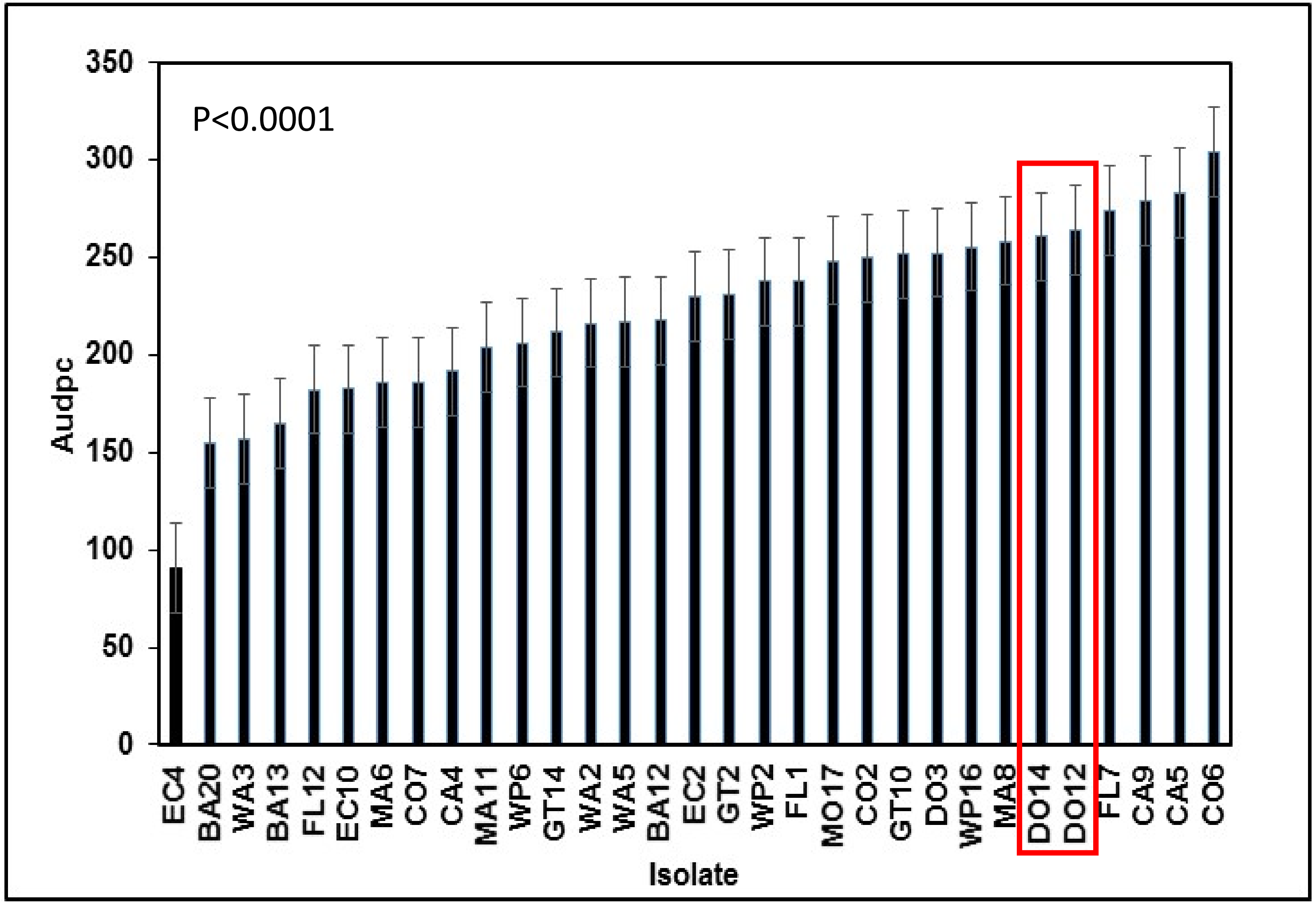


How Aggressiveness Are Wisconsin Isolates?

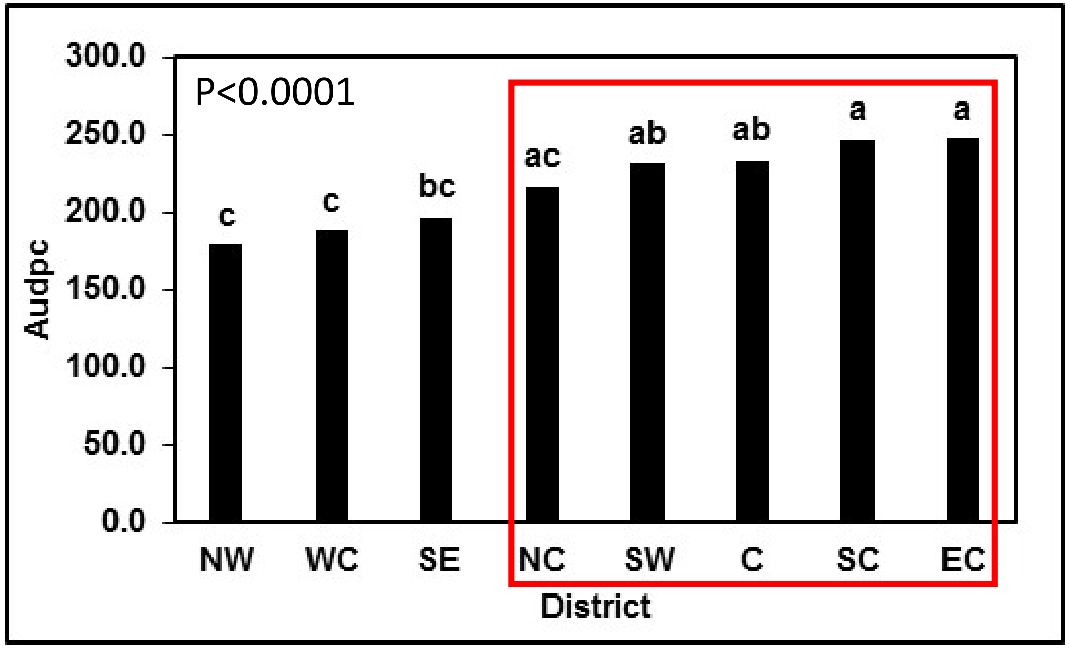
- Isolates were grouped by county and three isolates were randomly selected for each location in Wisconsin
  - 29 *F. graminearum* (15ADON) and 2 *Fusarium culmorum* (3ADON) isolates
- Randomized complete block design (RCBD)
  - four replications per isolate
  - two runs
- The central floret of a spikelet at anthesis was inoculated with 10 µl of inoculum using a pipette
- Inoculated heads were covered with plastic bag to promote infection and were removed 3 days after inoculation.
- Disease severity was taken 3, 7, 10 and 14 days after inoculation (dai) by measuring blighted spikelets using a digital caliper.

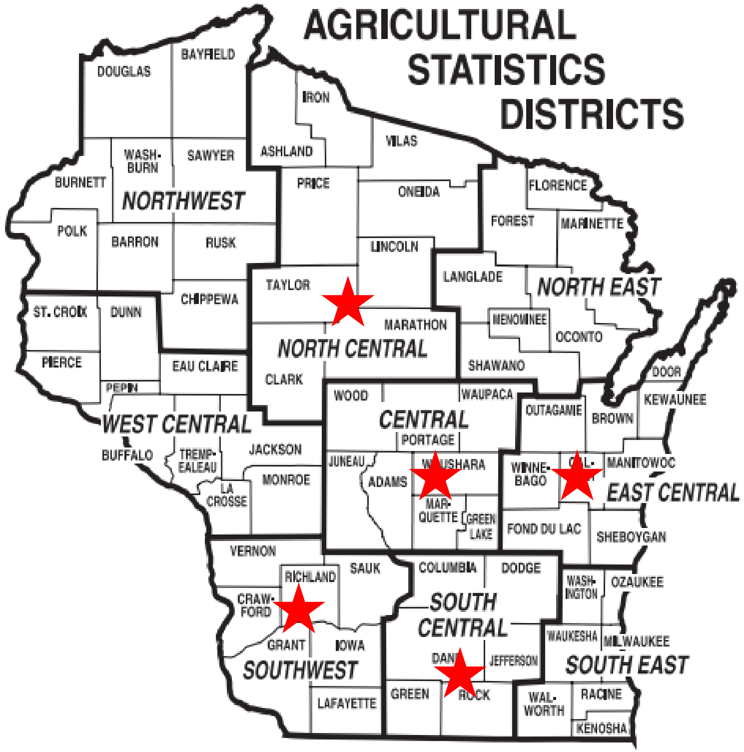


Aggressiveness (AUDPC) by Isolate



Aggressiveness (AUDPC) by Cropping District

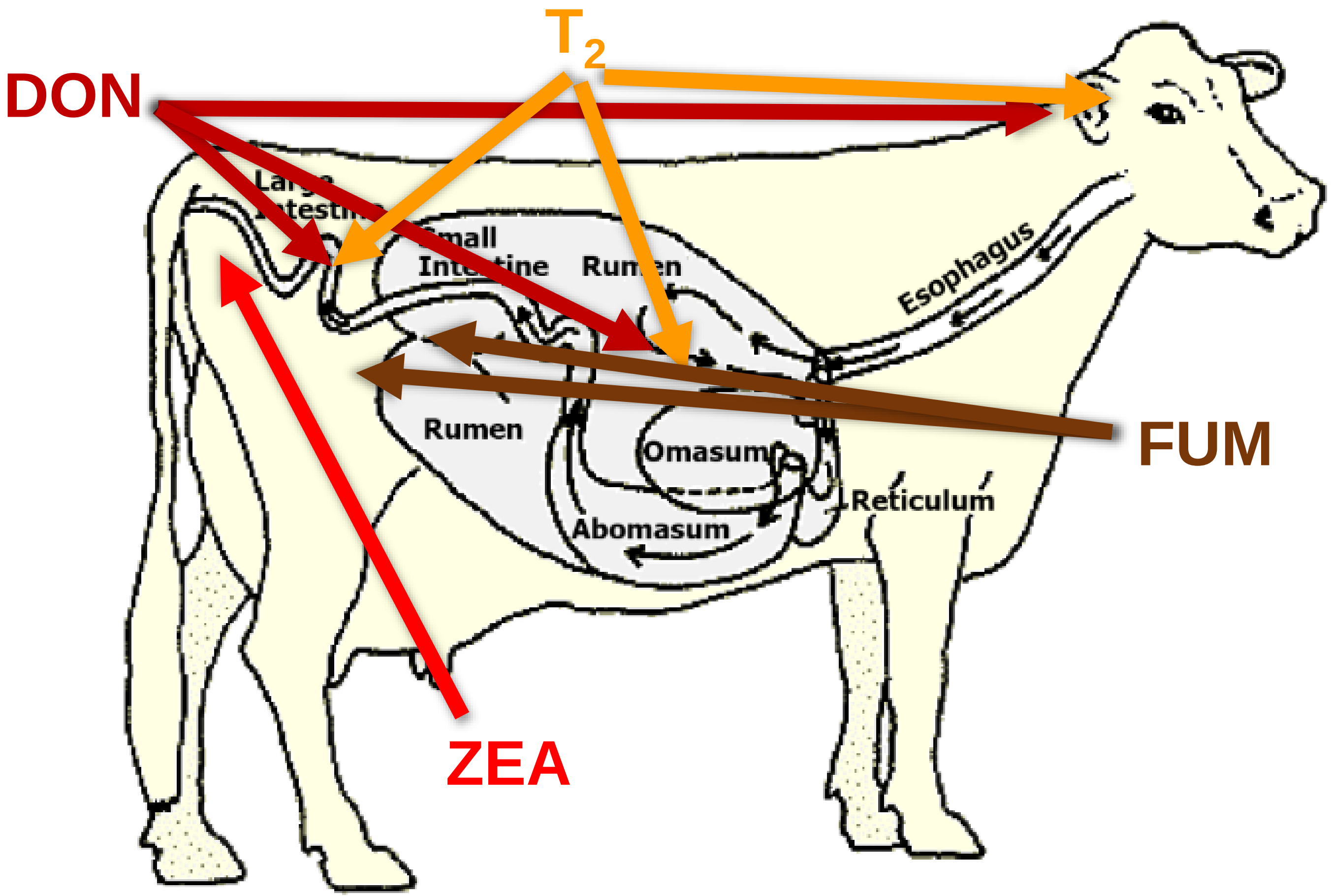




https://www.nass.usda.gov/Statistics_by_State/Wisconsin/index.php

FDA Deoxynivalenol (DON;Vomitoxin) Guidelines

- 1 ppm for finished wheat products (e.g. flour, bran, germ, etc) to be consumed by humans
- 10 ppm for total feed ration for ruminating beef cattle over 4 months
- 5 ppm in the total ration for dairy cattle older than 4 months
- 5 ppm for swine as long as the grain products are not more than 20% of the feed ration
- 5 ppm for as long as the grain products are not more than 40% of the feed ration for all other animals



Slide Courtesy of John Goeser

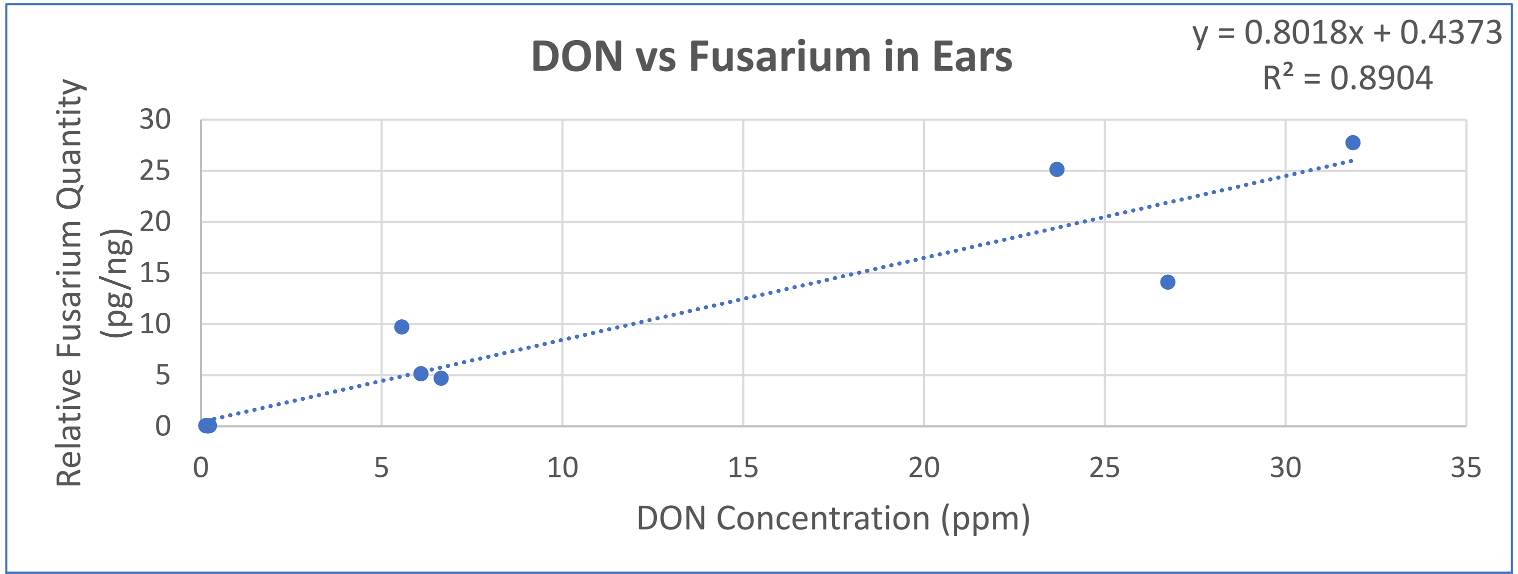
Real-World Animal Dietary Mycotoxin Limit Guidelines

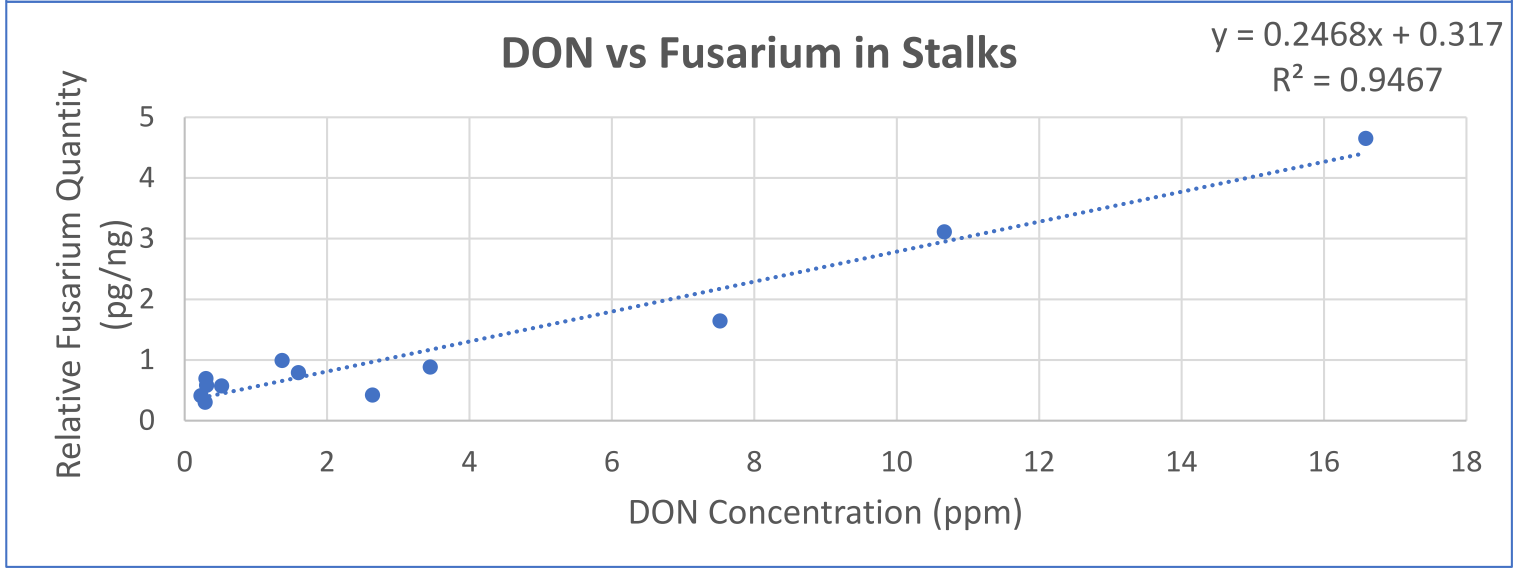
Summarized by Dr. John Goeser, PAS & Dipl. ACAN
Revised January, 2015

Potentially Harmful Toxin Levels for a Total Diet (DM)					
	Dairy	**Feedlot**	**Swine**	**Poultry**	**Equine**
Toxin Type	Values listed in blue are PPM, all other listed are in PPB				
Aflaoxi n	20	20	20	20	20
Deoxynivalenol (DON or Vomitoxin)*	0.5 to 1.0	10	1	2	500
Fumonisin	2	7	10	20	500
T-2 Toxin	100	500	100	100	NA
Zearalenone	400	5	300	10	50
Ochratoxin	5	5	700	700	35
Ergot Toxins (combined)	500	500	500	750	300

Note: The table lists maximum concentrations for the total diet. These values were summarized from the literature cited below and conservatively chosen to represent the lowest values recommended without causing animals harm. Measured toxin is likely not the only type of toxin present in a sample; multiple toxins (including those not measured or masked toxins) may interact to further impact health and performance.

Managing the Fungus Manages Mycotoxin Levels





Major Wisconsin Field Crops and *Fusarium* spp. Associated With Them

- **Wheat** (*Fusarium graminearum* and *F. culmorum*)
- **Corn** (*Fusarium graminearum* and *F. verticillioides*)
- **Soybean** (Many species however *Fusarium virguliforme*, *F. graminearium*, and *F. oxysporum* most prominent)
- **Alfalfa** (*Fusarium oxysporum* f. sp. *medicaginis* is primary pathogen)
- **Industrial Hemp** (*Fusarium graminearum* and others?)

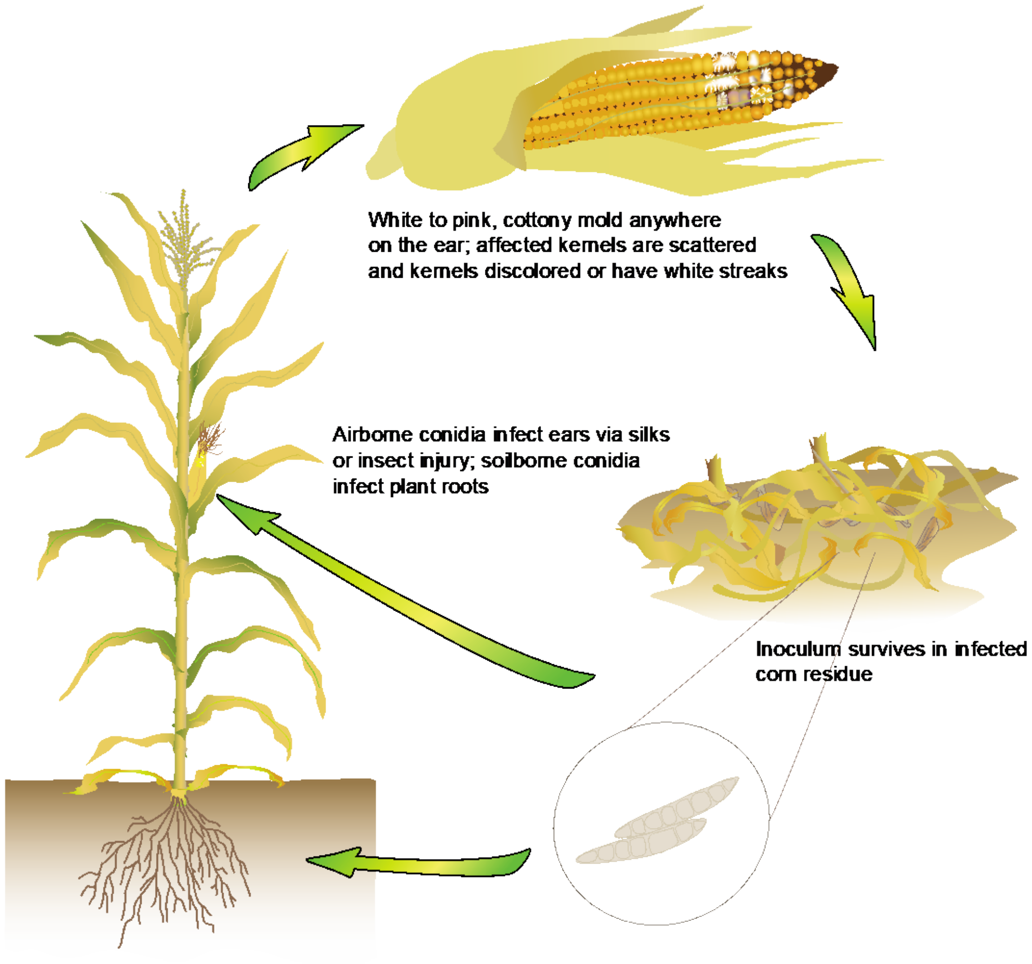
Ear Rots



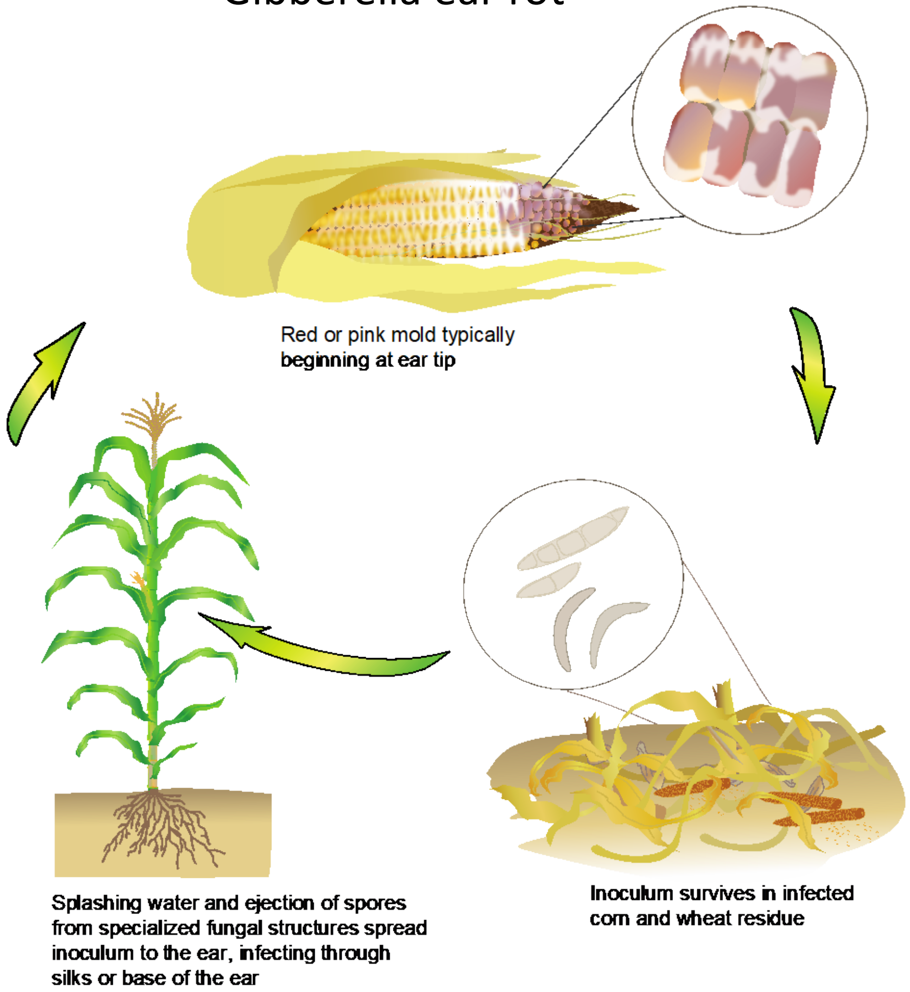


The Major Ear Rots/Stalk rots in Wisconsin

Fusarium ear rot



Gibberella ear rot



Top Wheat Diseases in Wisconsin (Last 5 years)

- Fusarium head blight (scab)
  - Caused by *Fusarium graminearum* and *F. culmorum*
  - Especially troublesome for organic wheat producers
- Stripe rust
  - Caused by *Puccinia striiformis* f. sp. *tritici* (*Pst*)
- Septoria leaf blotch
  - Caused by *Septoria tritici*
- Leaf rust
  - Caused by *Puccinia triticina*

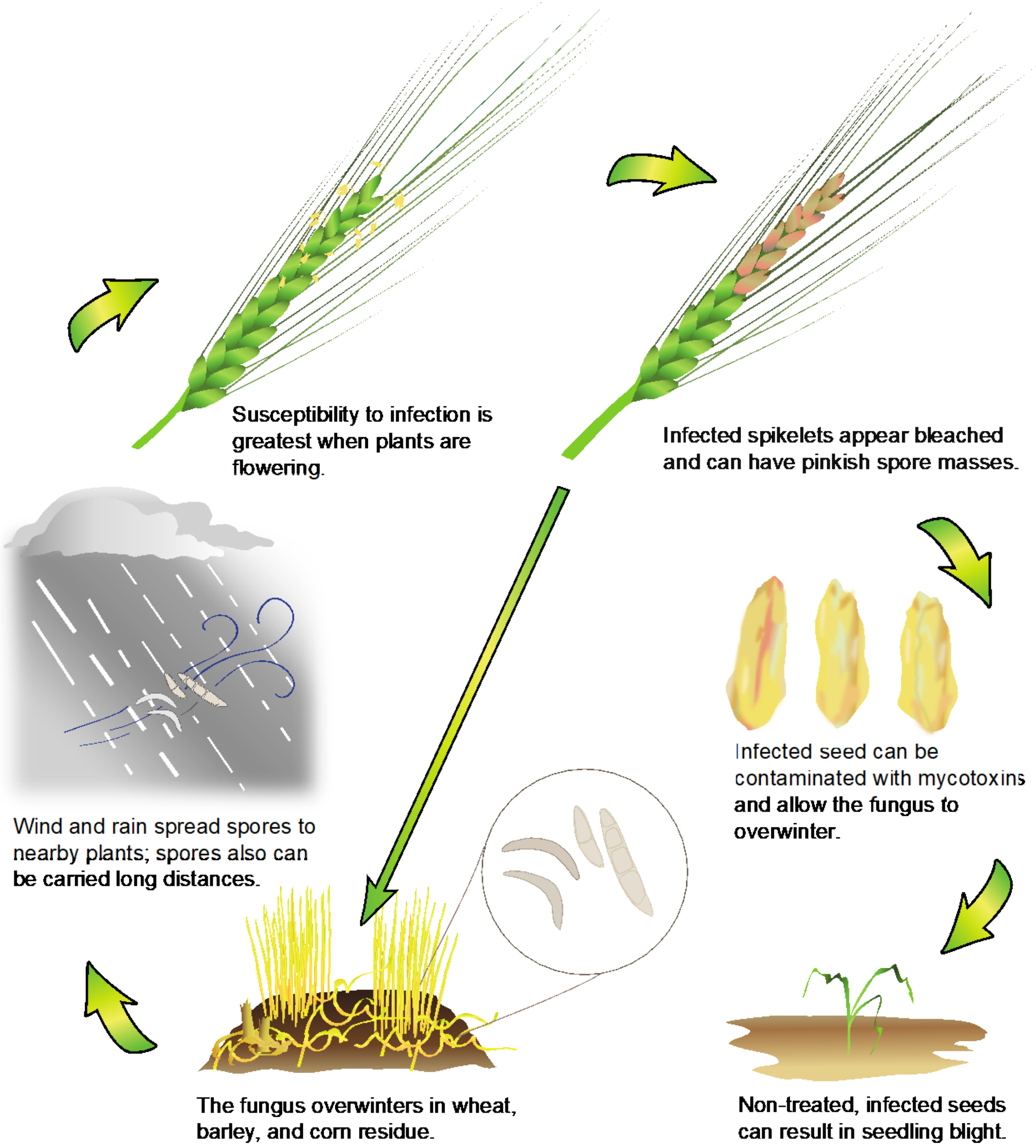

Septoria leaf blotch


Stripe rust


Leaf rust


Fusarium head blight

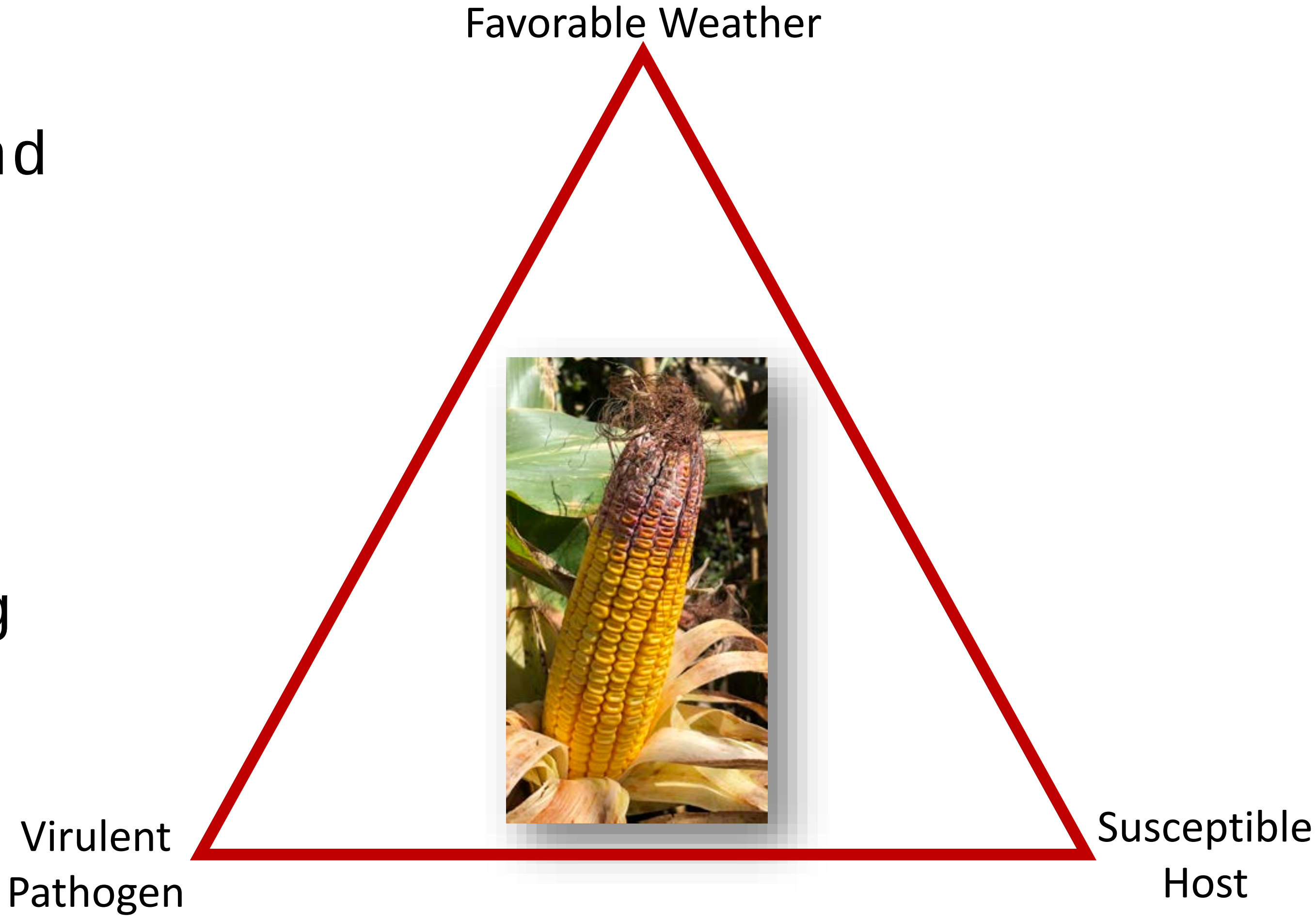
Fusarium Head Blight Cycle



Weather Conditions that Promote *Fusarium spp.*

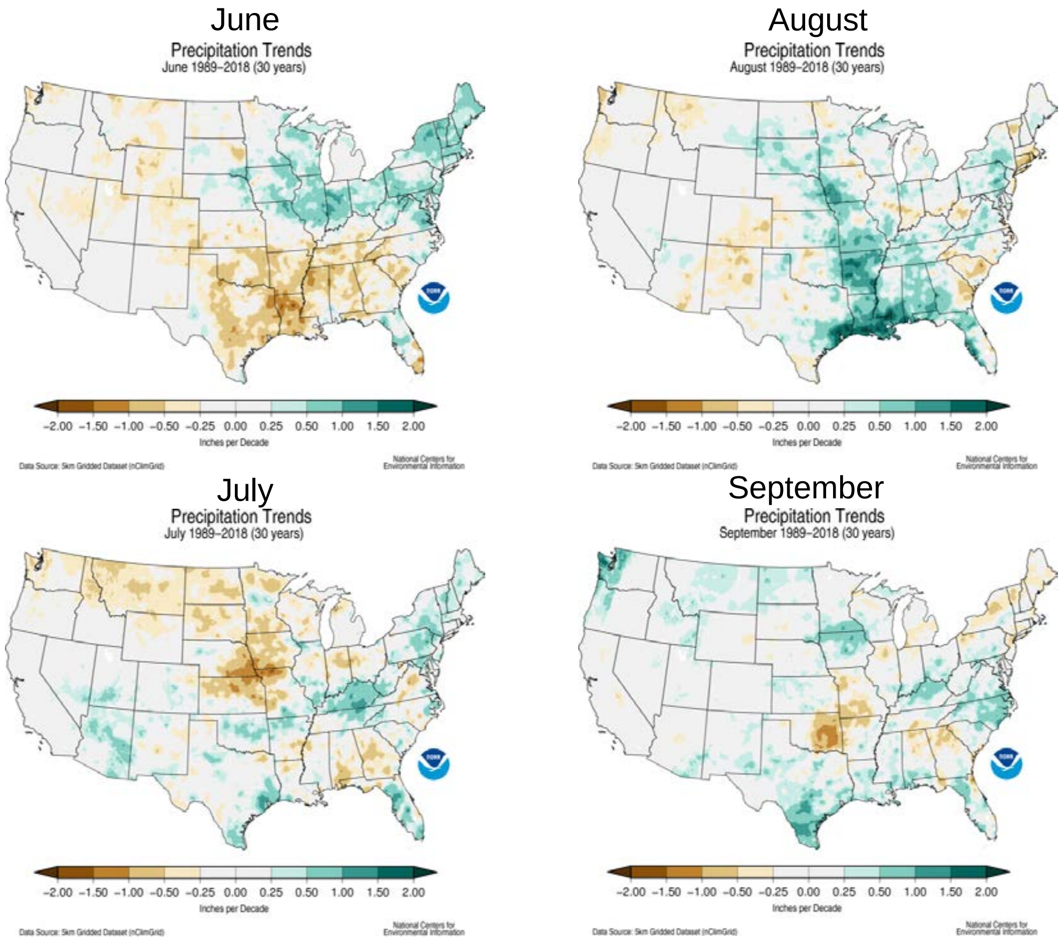
- Warm and excessively wet and humid conditions promote these species

- 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 FHB in Wheat

- Resistant Varieties
  - No complete resistance – partial only
  - Type 1 Resistance – Resistance to initial infection
    - -Pursuing this type of resistance has been elusive
  - Type 2 Resistance – Resistance to spread within the spike
    - -Most breeding emphasis has been here
    - -*Fhb1* first gene associated with this resistance
- Fungicide application
  - Product choice important
    - -DMI fungicides (Prosaro or Caramba) preferred
    - -Strobilurin fungicides (ex. Headline) can make FHB worse
  - Timing of application important
    - -Anthesis (Feekes 10.5.1)applications have been the standard
    - -More recently applications 5-7 days after anthesis show excellent reductions in DON
    - -Applications can be made too early (ex. When the head is still in the boot)
      - -A new fungicide is helping with this issue

Management of Ear 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

In Wheat, There is a Long History of Using Fungicide for FHB Management - Combining Partial Resistance Can Enhance Control

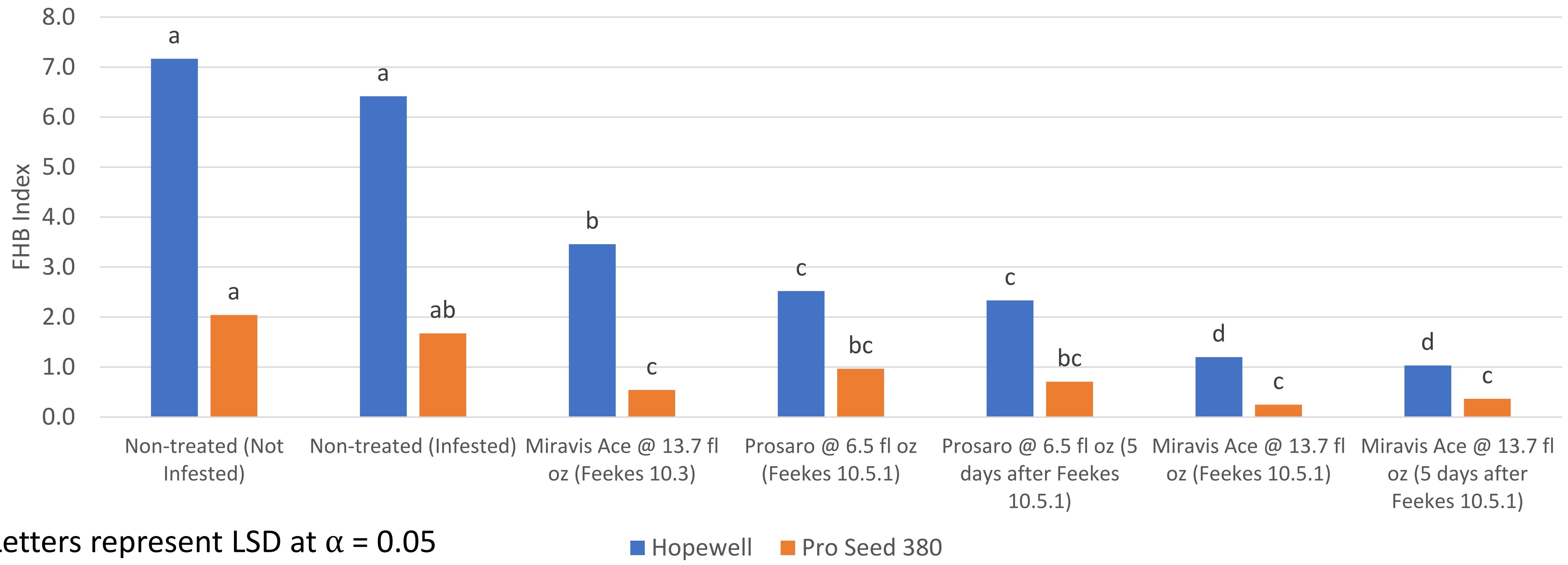
FHB and DON - 2015

FHB Disease Incidence (%)	Hopewell	Kaskaskia	Pro 200	Sunburst
Prosaro SC @ 6.5 fl oz/a (Feekes 10.5.1)	9.5b	2.0b	0.5	4.0
Prosaro SC @ 6.5 fl oz/a (5 days after Feekes 10.5.1)	7.5b	5.3b	2.8	2.8
Non-treated control	31.3a	17.5a	3.0	1.5
Pr>F	<0.01	<0.01	ns	ns
LSD	6.44	6.44	ns	ns

DON (ppm)	Hopewell	Kaskaskia	Pro 200	Sunburst
Prosaro SC @ 6.5 fl oz/a (Feekes 10.5.1)	2.0b	0.9b	0.7ab	0.9ab
Prosaro SC @ 6.5 fl oz/a (5 days after Feekes 10.5.1)	1.3c	1.0b	0.5b	0.8b
Non-treated control	2.5a	1.5a	1.0a	1.3a
Pr>F	<0.01	<0.01	<0.01	ns
LSD	0.40	0.40	0.40	ns

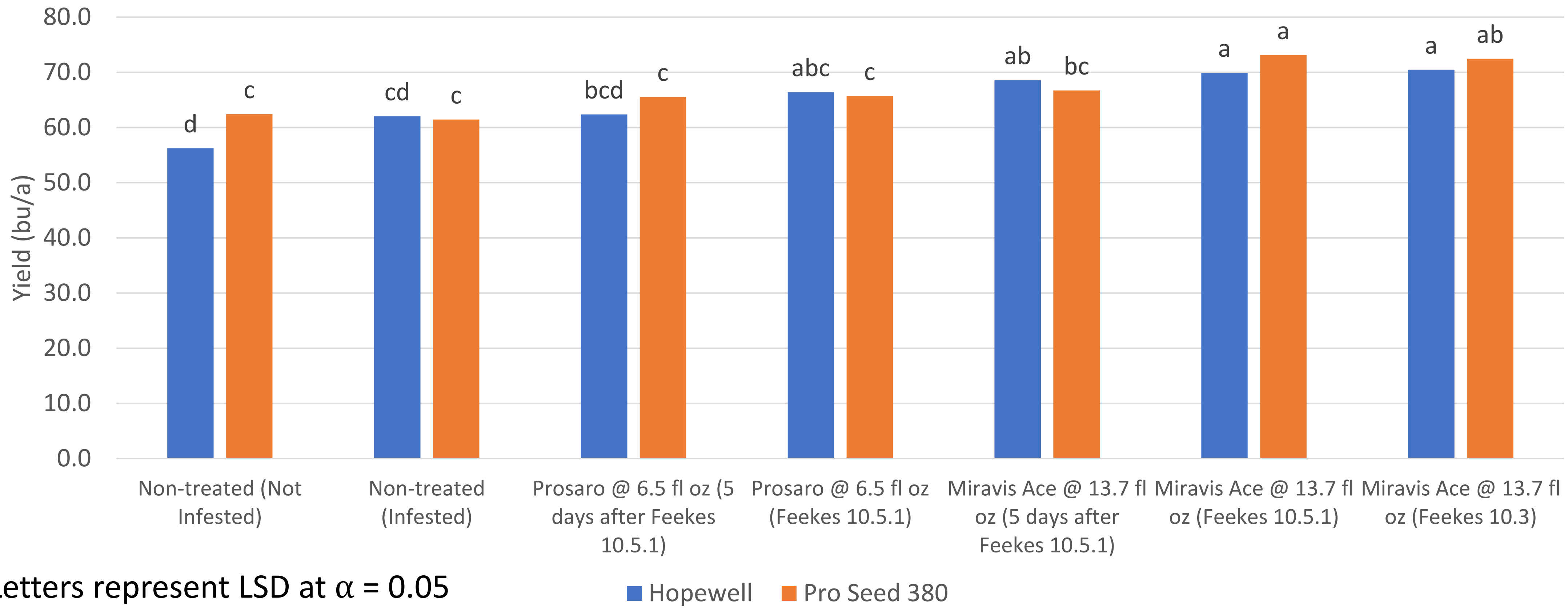
*Resistance is helpful! Also, better to wait a day or two after anthesis, rather than spray before anthesis

2018 Arlington Integrated Management Trial – FHB Index



*Letters represent LSD at α = 0.05 within each variety

2018 Arlington Integrated Management Trial – Yield



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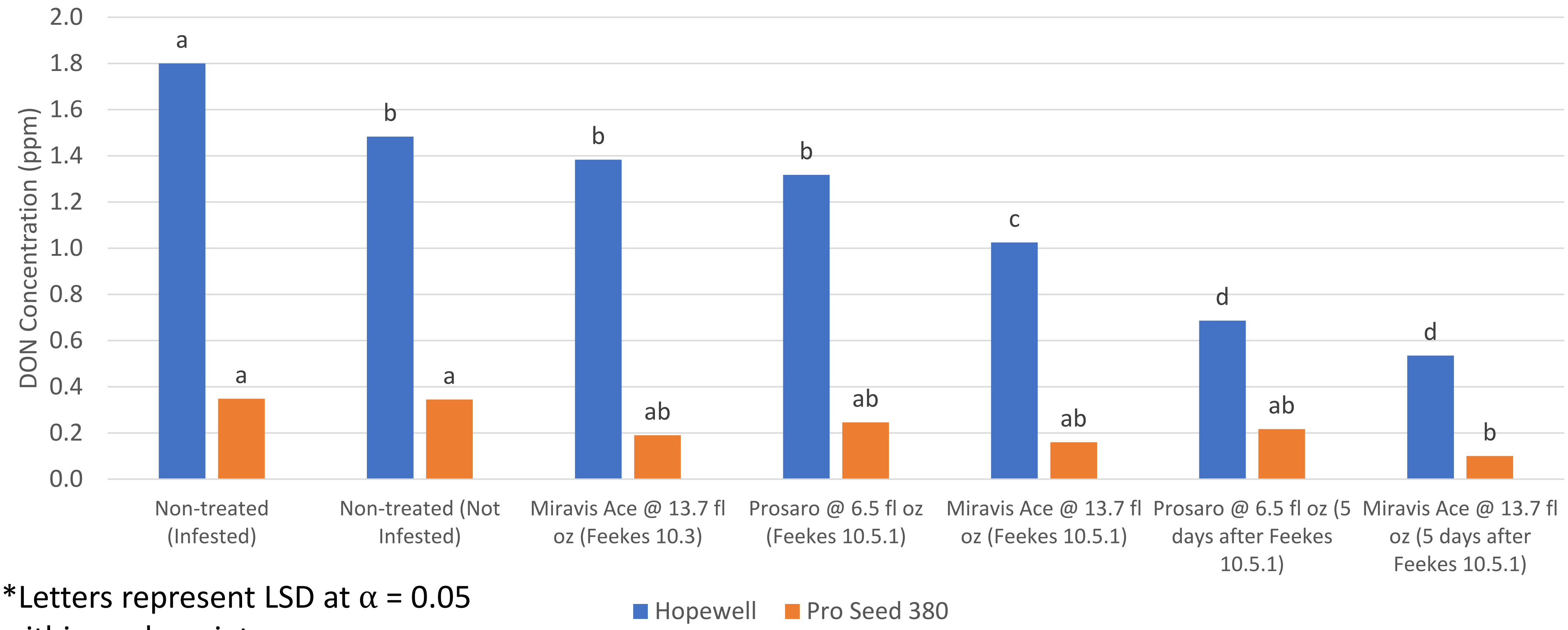
2018 Arlington Integrated Management Trial – DON



*Letters represent LSD at α = 0.05 within each variety

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

Corn Fungicide Update

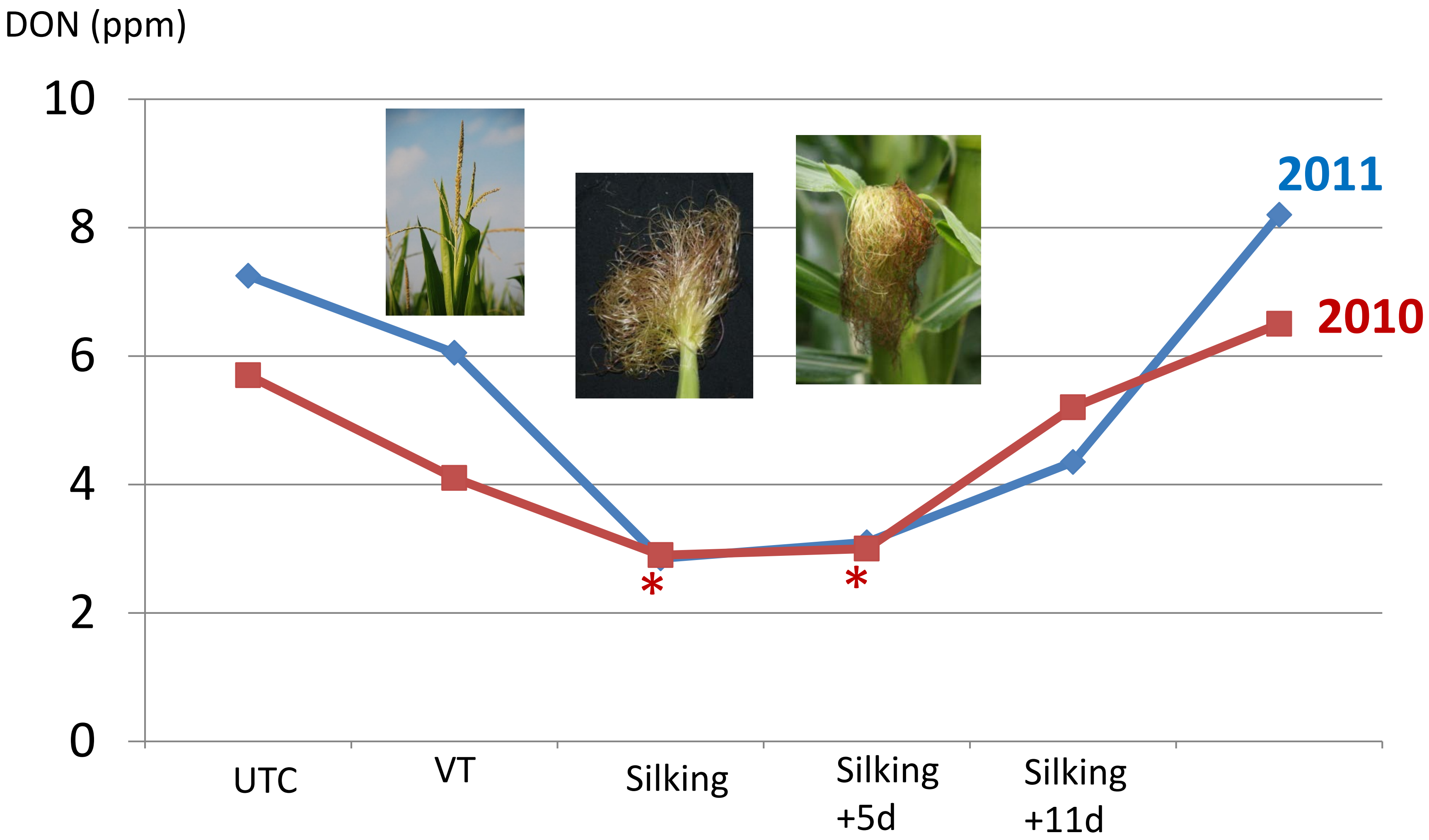
Victor Limay-Rios (UG Ridgetown)
Dave Hooker (UG Ridgetown)
Art Schaafsma (UG Ridgetown)
Albert Tenuta (OMAFRA Ridgetown)

Application technology and product for managing DON

Fungicide	GPA	Nozzle	% DON of UTC 2011		% DON of UTC 2010	
.	UTC	.	100	a	100	a
Proline	5	Above	58	bc	100	a
Proline	10	Above	61	bc	75	b
Proline	20	Above	61	bc	60	ab
Proline	10	Drop	58	bc	65	ab
Proline	20	Drop	52	c	70	ab
Proline	10	Above+Drop	66	b	70	ab
Proline	20	Above+Drop	56	bc	65	a
Headline	10	Above	96	a	150	a
Quilt	10	Above	93	a	110	a
			2 locations 3.5 ppm		3 locations 1.0 ppm	

Limay-Rios, Schaafsma, Hooker, Ridgetown (2011)

Timing of Proline Application on DON 2010-2011



Limay-Rios, Schaafsma, Hooker, Ridgetown (2011)

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

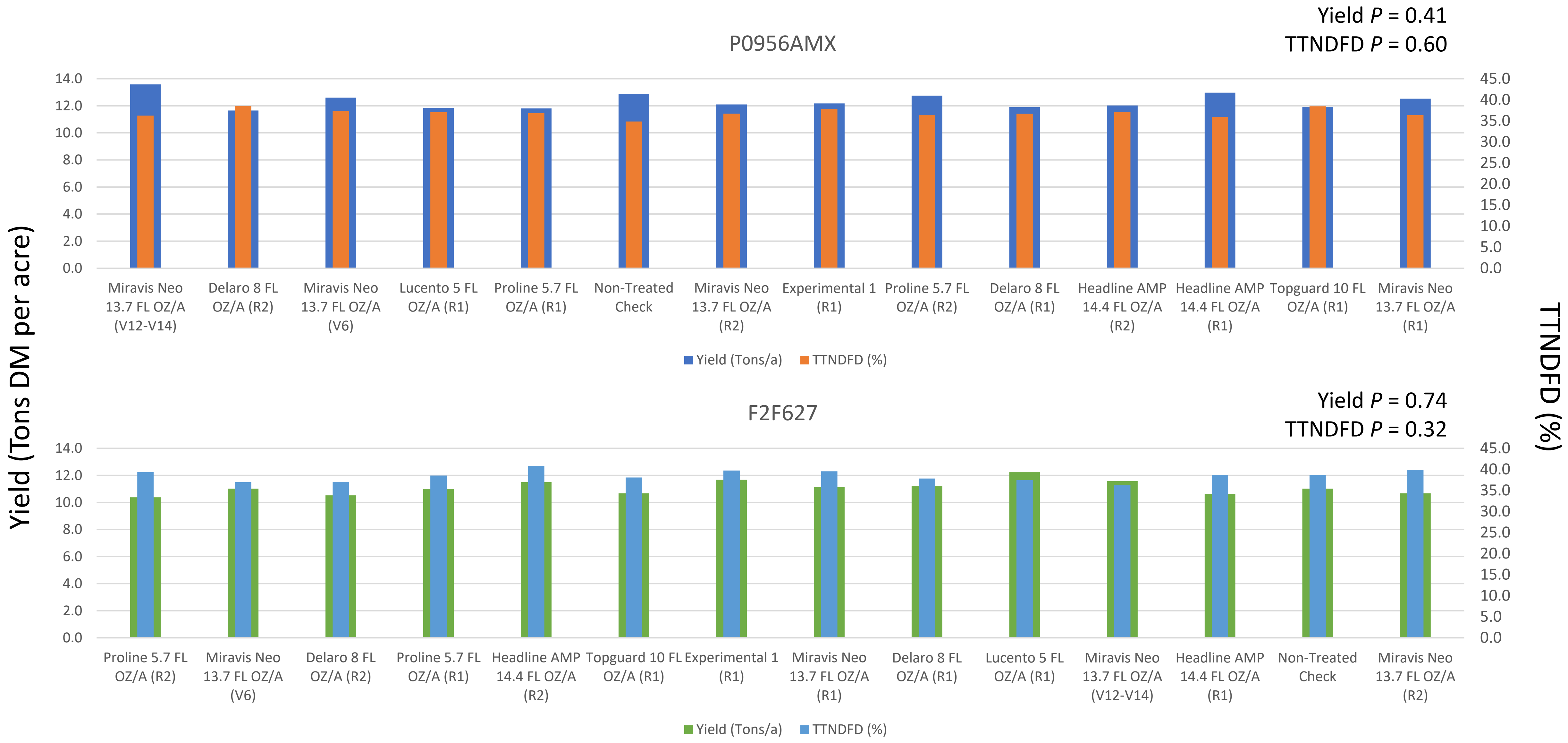
Application Time	Treatment	Year	
		2018	2019
	Non-Treated Check	x	x
V6	Miravis Neo 13.7 FL OZ/A;NIS 0.25%	x	x
V6 R1	Miravis Neo 13.7 FL OZ/A V6;NIS 0.25 % V/V V6 Miravis Neo 13.7 FL OZ/A R1		x
V14	Miravis Neo 13.7 FL OZ/A V12-V14	x	x
R1	Proline 5.7 FL OZ/A	x	x
	Headline AMP 14.4 FL OZ/A	x	x
	Delaro 8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

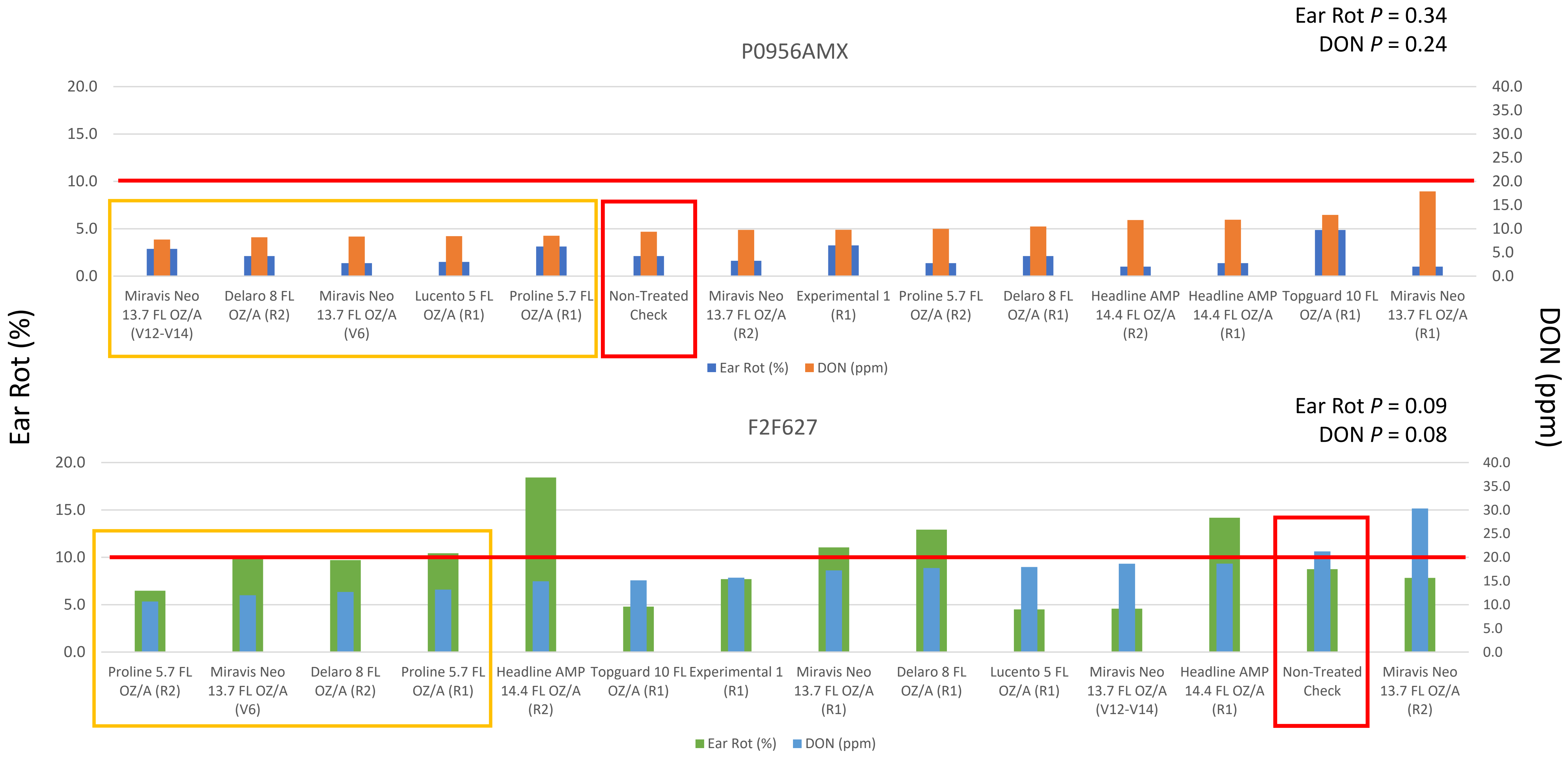
2018-2019 Wisconsin Silage Corn Trials

- 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

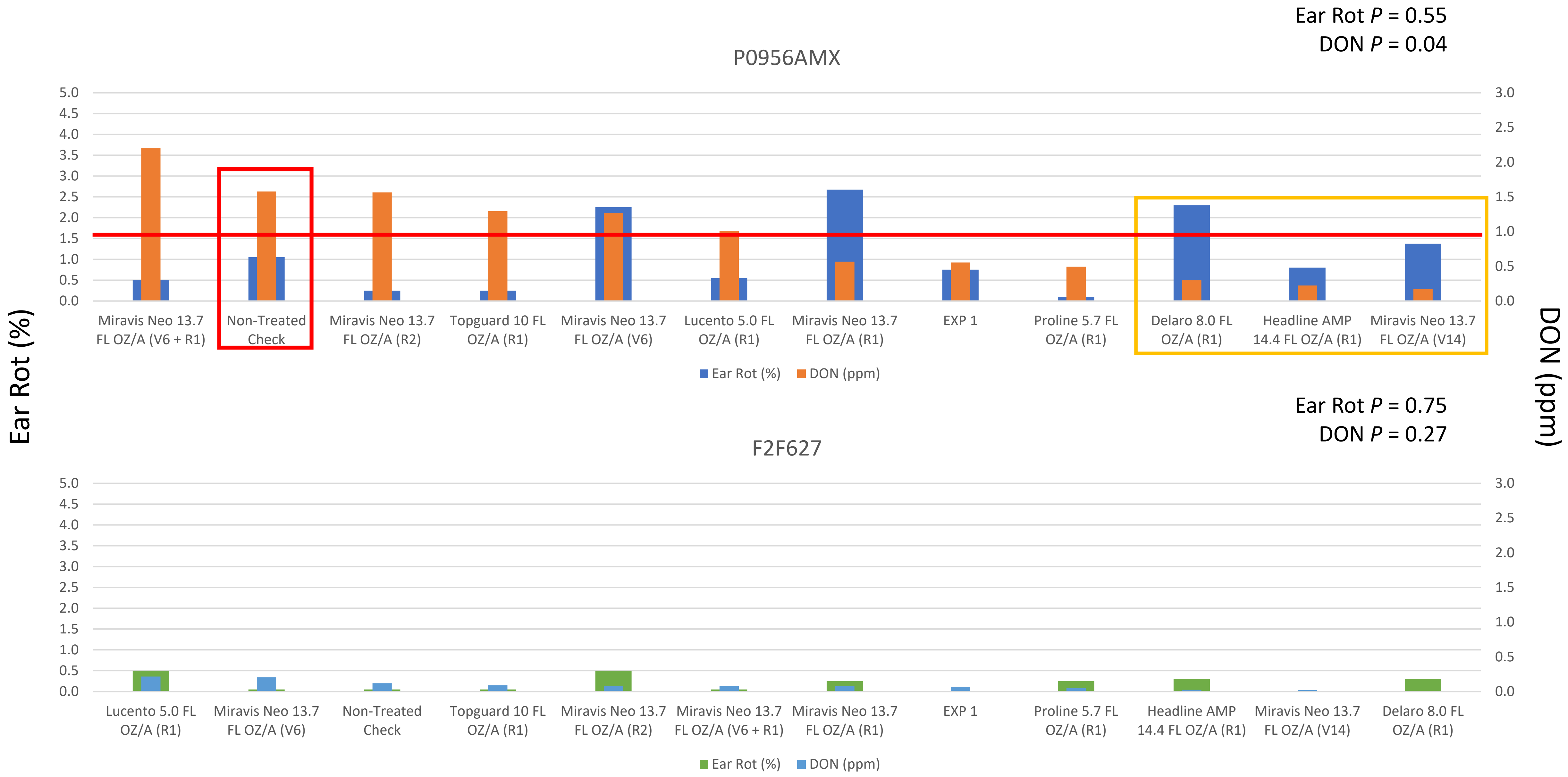
2018 Yield and TTNDFD



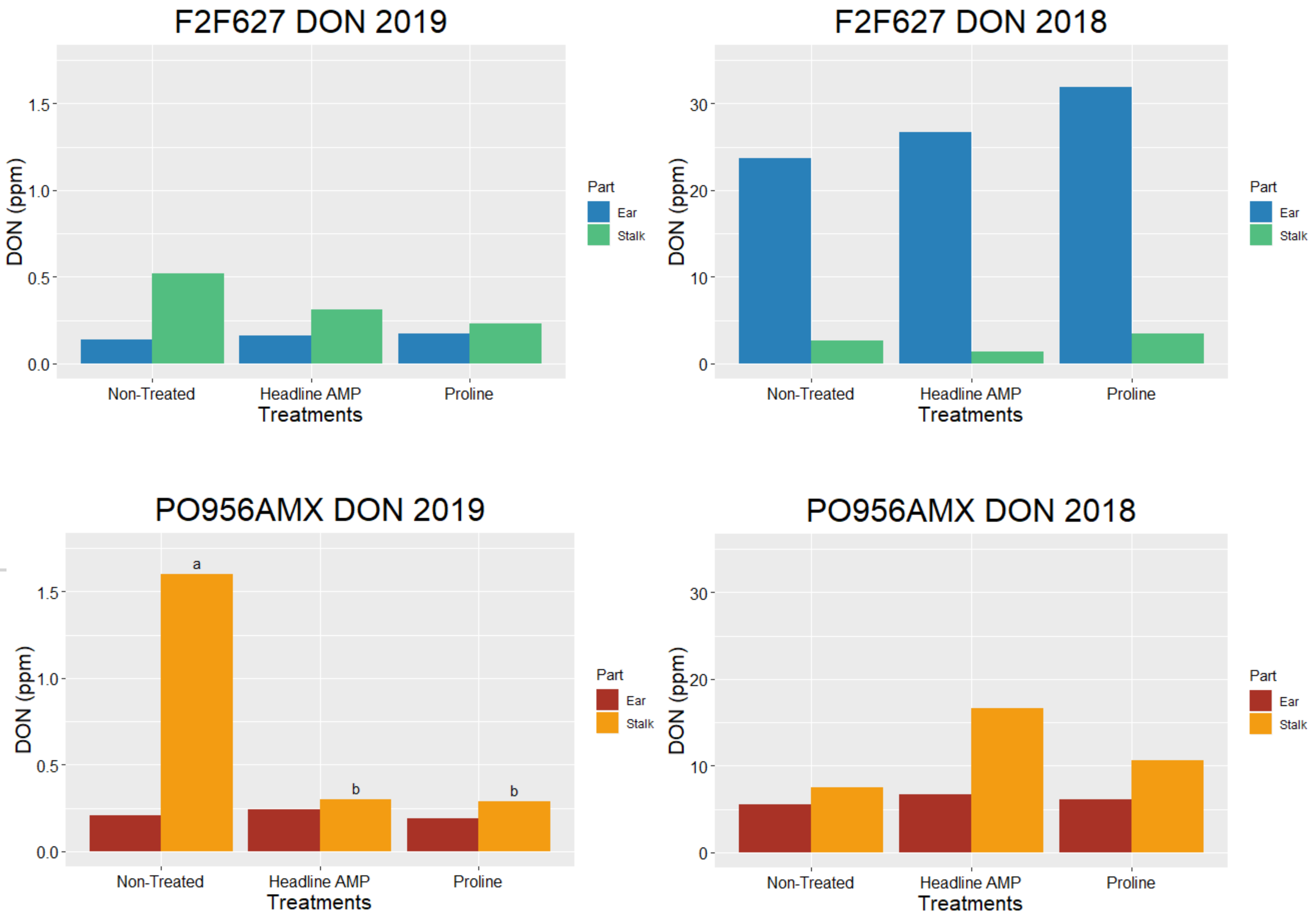
2018 Ear Rot and DON



2019 Ear Rot and DON



Plant Part Influences DON Accumulation



The 'Take Home' For Managing Mycotoxins in the Field

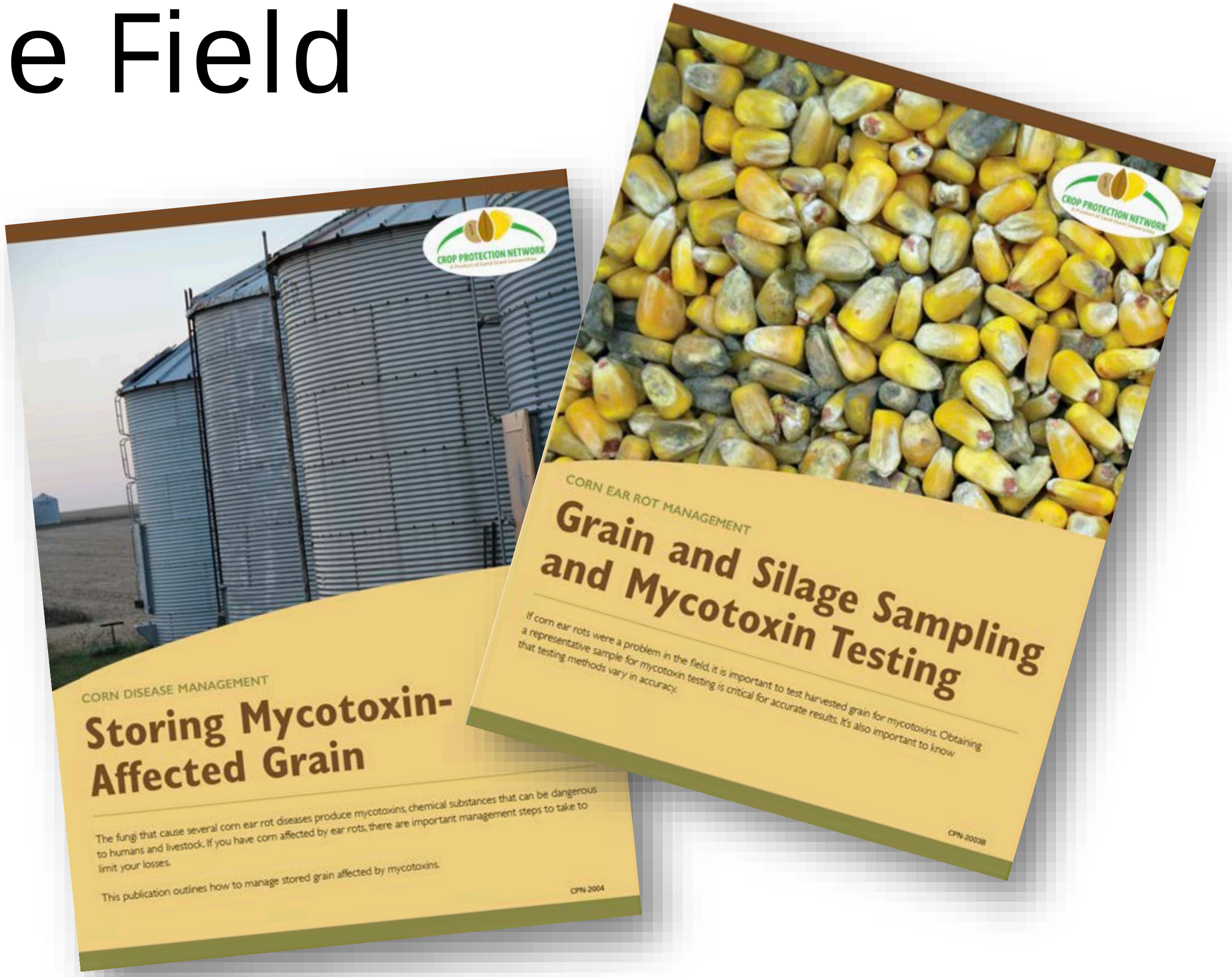
It is a multi-pronged approach!

- Manage residue in-field
- Choose resistant varieties/hybrids
- Choose adapted varieties/hybrids
- Limit stress
    - Watch seeding rates, especially in corn
- Apply fungicides
    -Timing important
    -Product important
    -Lower expectations of fungicide efficacy
- Harvest in a timely fashion
- Set the combine fan and shutter appropriately and screen "fines"

The ‘Take Home’ For Managing Mycotoxins after the Field

Also a multi-pronged approach!

- Test, Test, Test! – Sampling is tricky but do your best!
- Clean grain before storage
  - -Reduced levels of damaged grain
- Manage grain moisture!
  - -Short-term, cold months = 15% in corn 13% in wheat
  - -Long-term, warm months = 12-13%
- Make sure the bin is clean
- Be sure that there is good air exchange to reduce condensation
- Check for leaks in the bin



Questions?

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