Managing Ear Rots and Mycotoxins in Silage Corn

Manni Singh & Harkirat Kaur
(collaborators: M. Chilvers, C. Difonzo, K. Cassida)
Cropping Systems Agronomist
agronomy.msu.edu
msingh@msu.edu, 517-353-0226

Cropping Systems Agronomy MICHIGAN STATE UNIVERSITY

MICHIGAN STATE UNIVERSITY Extension

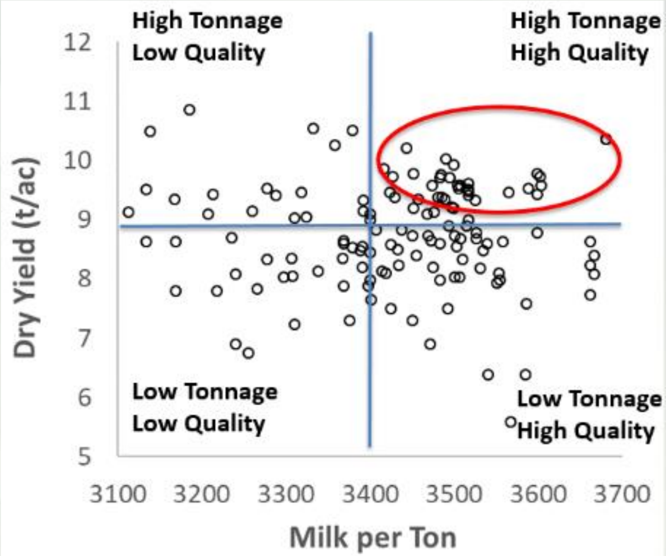
M-AAA Michigan Alliance for Animal Agriculture

EST. 1916 MMPA

Project GREEEN

Desirable Silage Corn Characteristics

- What makes a good silage corn?
  - High yield
  - High energy (high digestibility)
  - High intake potential (low fiber)
  - High protein
  - Proper moisture at harvest for storage
  - **NO Mycotoxins (e.g., VOM)!**



What are Mycotoxins?

- Toxic secondary metabolites produced by ascomycete fungi (causes ear/stalk rots)
- Elevated mycotoxin concentration makes corn unfit for consumption
  - Feed refusals, hormonal imbalance, edema

Mycotoxin	Dairy Cattle	Swine	Poultry
DON (Vomitoxin)	1.0 ppm	1.0 ppm	2.0 ppm
Zearalenone	0.4 ppm	0.3 ppm	0.01 ppm
Fumonisin	2.0 ppm	10 ppm	20 ppm

Goeser, 2015

Values for 50% diet ration

Mycotoxins and Ear/Stalk rots


Gibberella Ear/Stalk Rot (caused by *Gibberella zeae)*

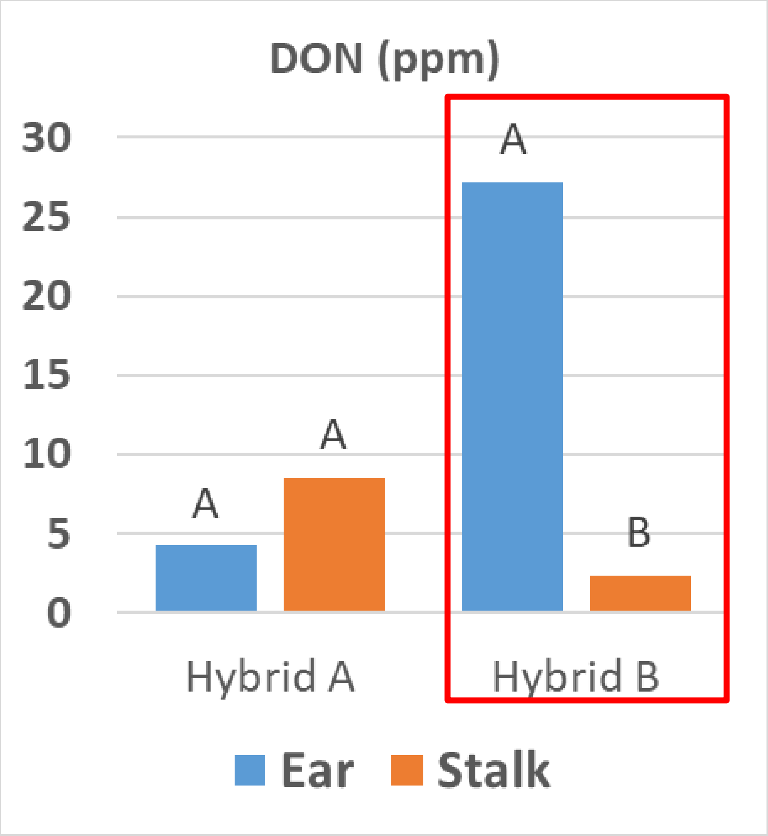
- Pinkish mold, often begins at ear tip
- Prefer cool and wet conditions
- Produces: Deoxynivalenol (DON or vomitoxin), Zearalenone (ZON)


***Fusarium* Ear/Stalk Rot** (caused by *Fusarium verticillioides)*

- White to purple mold, starburst pattern, scattered on ear, damaged kernels
- Prefer moderate-warm temp., wet conditions
- Produces: Fumonisins

Others- Aspergillus Ear Rot, Diplodia Ear Rot


Mycotoxins from Ears vs Stalks

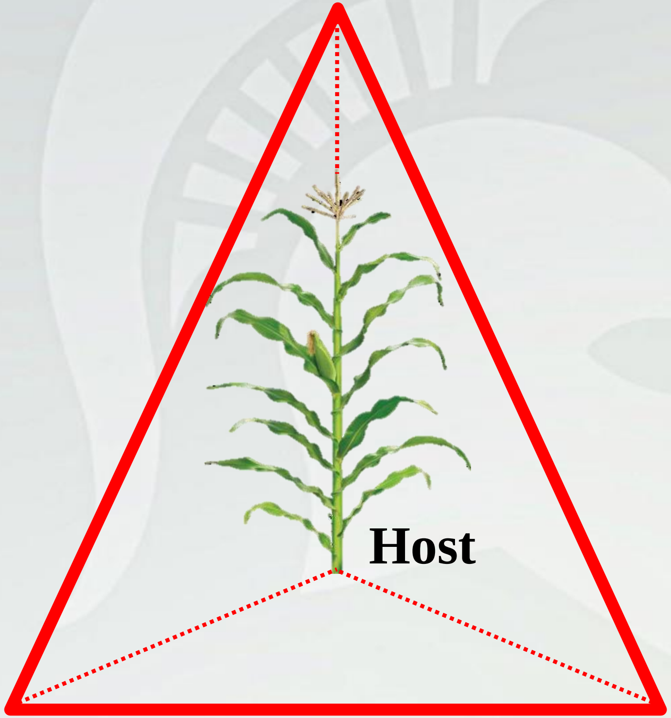


Source: Damon Smith, UW

Drivers of Mycotoxin issues

Favorable Environment

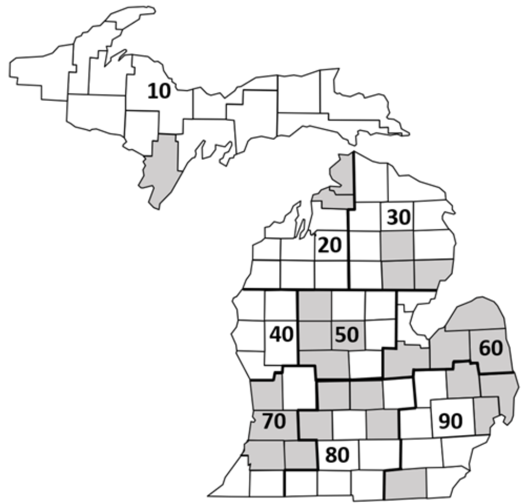
75-82 °F
>80% RH



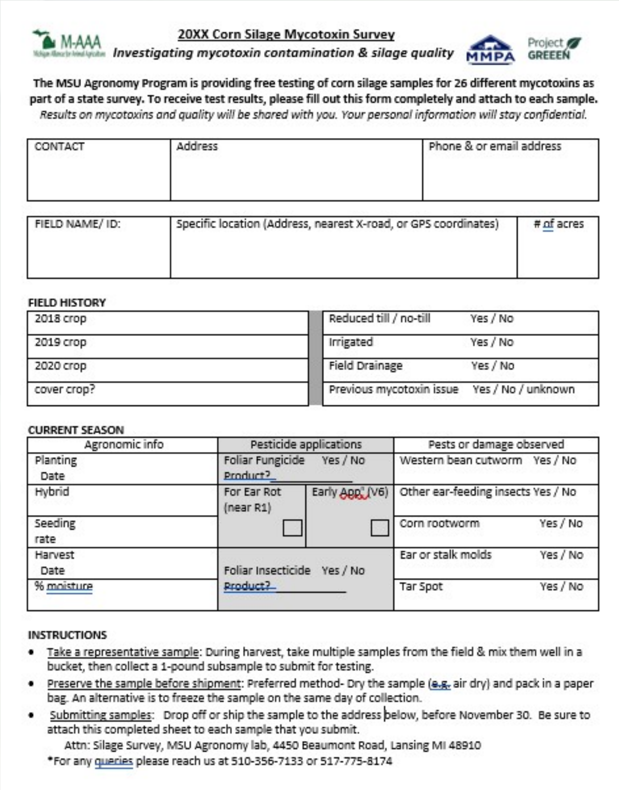
Ear/Stalk rot Pathogens

Insect injury

How widespread are Mycotoxins? Grower Survey



Crop reporting zone	Regions
Zone 10	Upper Peninsula
Zone 20	North-west Michigan
Zone 30	North-east Michigan
Zone 40	Western Michigan
Zone 50	Central Michigan
Zone 60	East Michigan
Zone 70	South-west Michigan
Zone 80	South-central Michigan
Zone 90	South-east Michigan



M-AAA

20XX Corn Silage Mycotoxin Survey

Investigating mycotoxin contamination & silage quality

MMPA Project GREEEN

The MSU Agronomy Program is providing free testing of corn silage samples for 26 different mycotoxins as part of a state survey. To receive test results, please fill out this form completely and attach to each sample. *Results on mycotoxins and quality will be shared with you. Your personal information will stay confidential.*

CONTACT	Address	Phone & or email address

FIELD NAME/ ID:	Specific location (Address, nearest X-road, or GPS coordinates)	# of acres

FIELD HISTORY

2018 crop		Reduced till / no-till	Yes / No
2019 crop		Irrigated	Yes / No
2020 crop		Field Drainage	Yes / No
cover crop?		Previous mycotoxin issue	Yes / No / unknown

CURRENT SEASON

Agronomic info	Pesticide applications		Pests or damage observed
Planting Date	Foliar Fungicide Yes / No Product?		Western bean cutworm Yes / No
Hybrid	For Ear Rot (near R1)	Early App. (V6)	Other ear-feeding insects Yes / No
Seeding rate			Corn rootworm Yes / No
Harvest Date	Foliar Insecticide Yes / No Product?		Ear or stalk molds Yes / No
% moisture			Tar Spot Yes / No

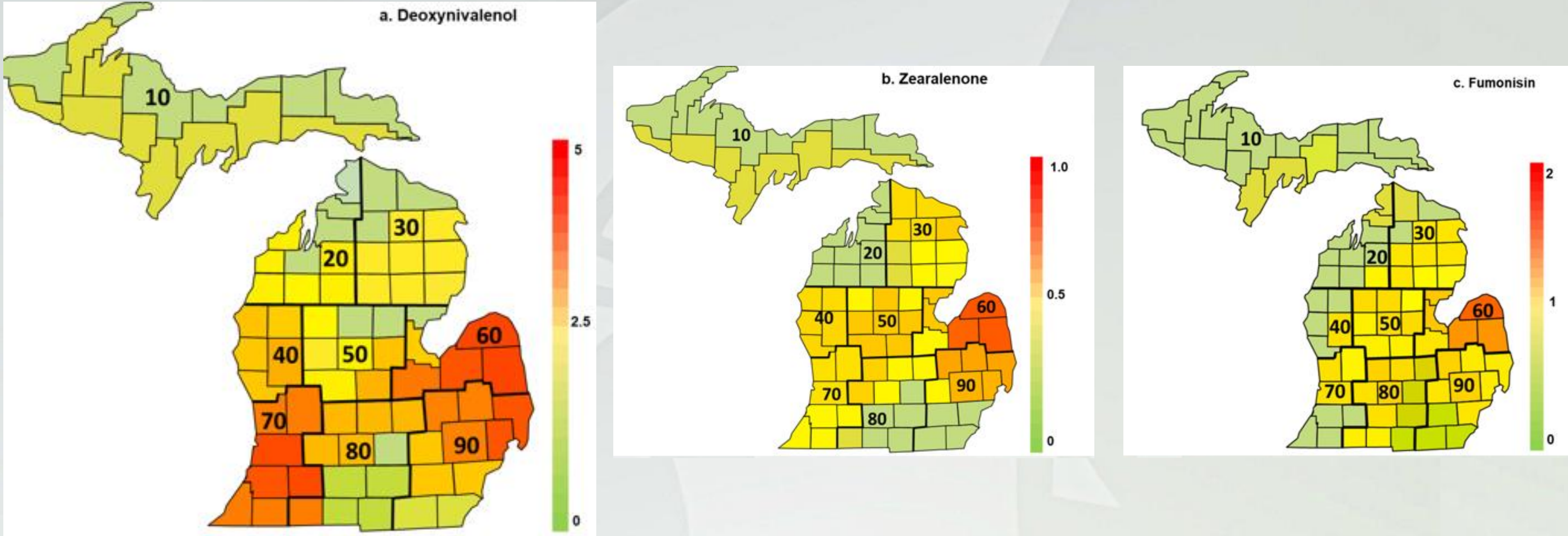
INSTRUCTIONS

- Take a representative sample: During harvest, take multiple samples from the field & mix them well in a bucket, then collect a 1-pound subsample to submit for testing.
- Preserve the sample before shipment: Preferred method- Dry the sample (e.g. air dry) and pack in a paper bag. An alternative is to freeze the sample on the same day of collection.
- Submitting samples: Drop off or ship the sample to the address below, before November 30. Be sure to attach this completed sheet to each sample that you submit.
  Attn: Silage Survey, MSU Agronomy lab, 4450 Beaumont Road, Lansing MI 48910
  *For any queries please reach us at 510-356-7133 or 517-775-8174

- Samples collected across Michigan (2019-2021)
- Growers also submitted their field history and management

Kaur et al., 2024 (World Mycotoxin Journal)

Mycotoxins across Michigan



- Mycotoxins present in 100% of the samples
- Higher mycotoxins in the thumb region and southwestern MI

Kaur et al., 2024 (World Mycotoxin Journal)

Mycotoxin co-occurrence

- Multiple mycotoxins were detected
- At least seven mycotoxins present in each sample
- Strong correlations between mycotoxins coming from same pathogen species

2019 data

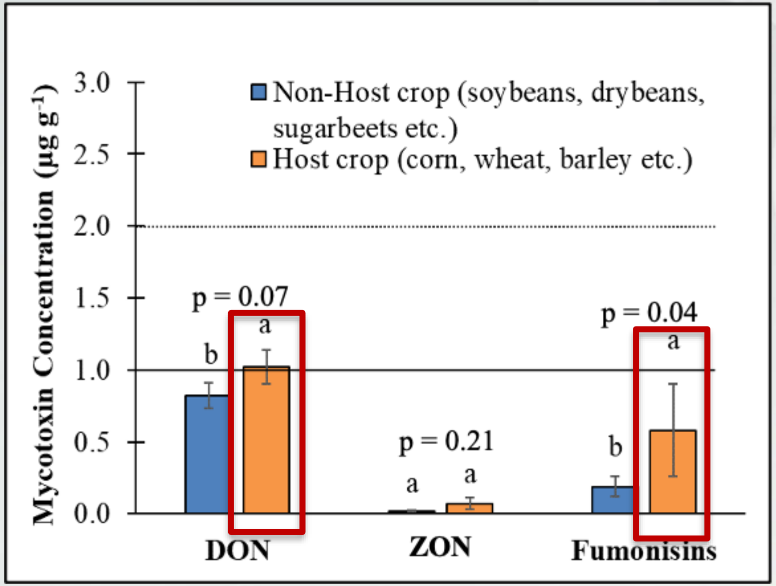
	Deoxynivalenol 3-β-D-glucoside	15-acetyl-deoxynivalenol	Zearalenone	Fumonisin B1	Fumonisin B2	Fumonisin B3	Moniliformin	Enniatin B	Enniatin B1	Enniatin A	Beauvericin	T-2 toxin
Deoxynivalenol	0.64***	0.72***	0.45**	0.27	0.26	0.26	0.27	0.23	0.19	0.16	0.33*	0.15
Deoxynivalenol 3-β-D-glucoside		0.84***	0.89***	0.38*	0.36*	0.35*	0.37*	0.38*	0.33*	0.3	0.51**	0.37*
15-acetyl-deoxynivalenol			0.73***	0.40**	0.47**	0.45**	0.48**	0.28	0.22	0.18	0.46**	0.3
Zearalenone				0.41**	0.41**	0.41**	0.37*	0.44**	0.29	0.32*	0.54**	0.40**
Fumonisin B1					0.94***	0.95***	0.83***	0.15	0.05	0.3	0.82***	0.36*
Fumonisin B2						1.00***	0.90***	0.19	0.11	0.35*	0.70***	0.34*
Fumonisin B3							0.90***	0.17	0.09	0.34*	0.70***	0.32*
Moniliformin								0.27	0.17	0.29	0.61***	0.34*
Enniatin B									0.80***	0.41**	0.25	0.59***
Enniatin B1										0.38*	0.18	0.65***
Enniatin A											0.34*	0.33*
Beauvericin												0.56**
T-2 toxin												

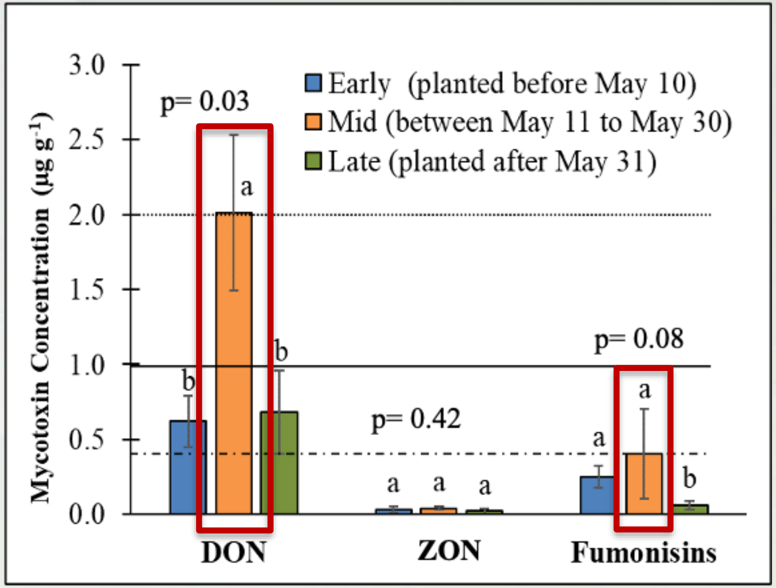
No Aflatoxins found!

Kaur et al., 2024 (World Mycotoxin Journal)

Agronomic factors

Agronomic Factor	DON		ZON		Fumonisin	
	p-value	Nagelkerke's R-squared	p-value	Nagelkerke's R-squared	p-value	Nagelkerke's R-squared
Crop Rotation	0.07	0.42	0.21	0.003	0.04	0.37
Planting Date	0.03	0.49	0.42	<0.001	0.08	0.31
Tillage	0.23	0.01	0.38	<0.001	0.20	0.03

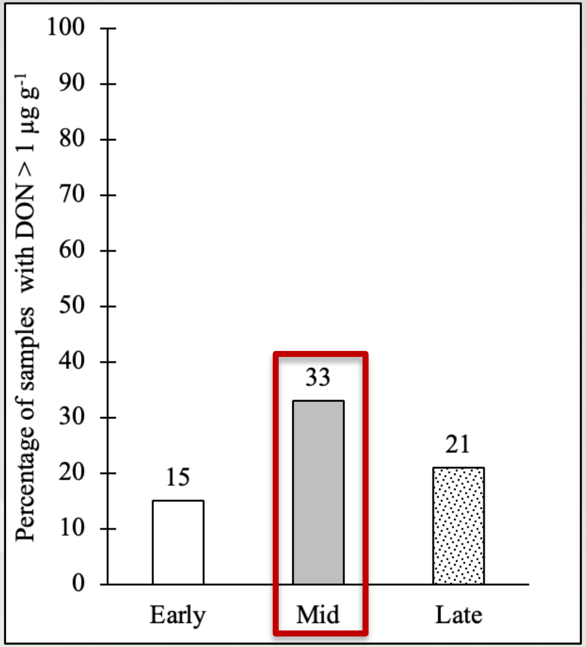




Kaur et al., 2024 (World Mycotoxin Journal)

Planting Date and Mycotoxins

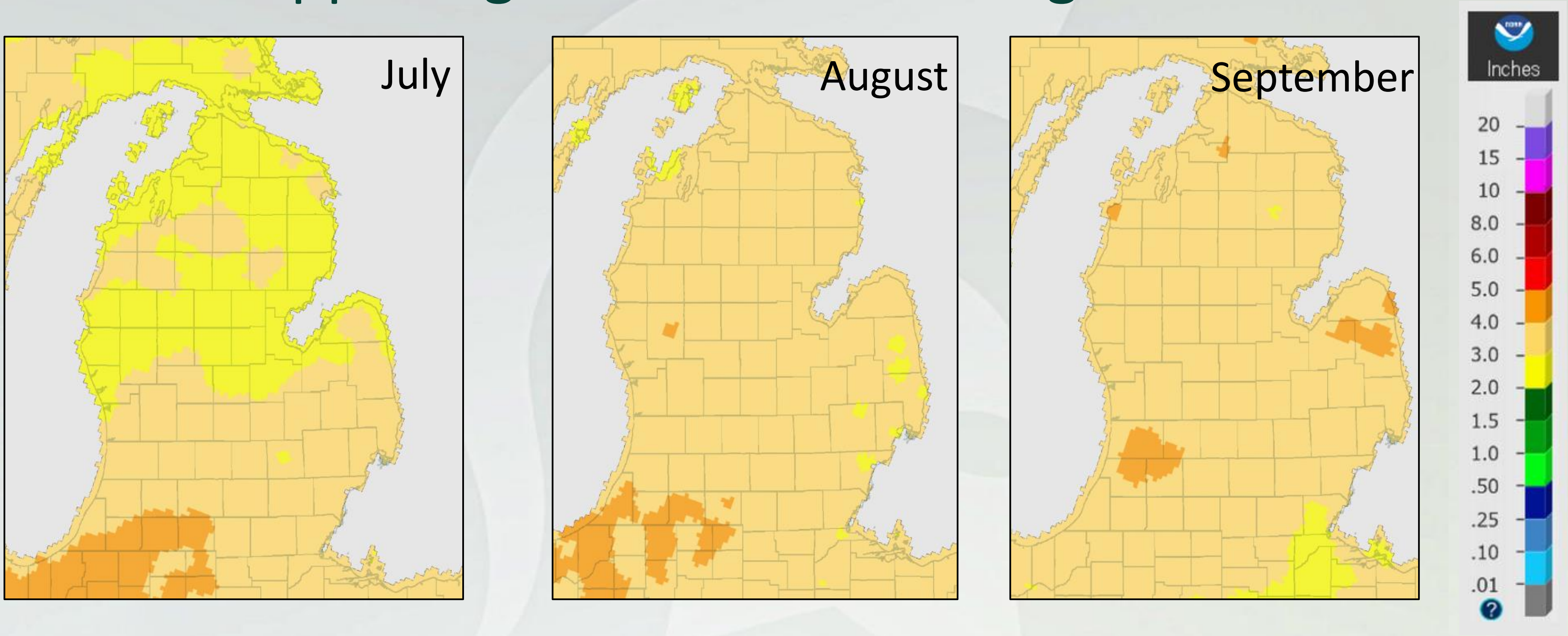
- Low concentrations across the study
- DON most frequently occurring
- Highest no. of samples with DON > 1µg g^{-1} in mid-planted silage
- Higher concentrations may occur in a more favorable year



Early: Planted before May 10; Mid: Planted between May 11 to May 30; Late: Planted after May 31

Kaur et al., 2024 (Agronomy Journal)

What's happening in Mid-Planted silage corn?



- Thirty years average rainfall data for July, August, September

Early: Planted before May 10; Mid: Planted between May 11 to May 30; Late: Planted after May 31

Planting date: Yield and Nutritive value

Site-year	Planting Date	Biomass Yield	ADF	NDF	Starch	CP	IVTD	NDFD	Milk per ton	Milk per acre
		Mg ha^{-1}	g kg^{-1} of DM					g kg^{-1} of NDF	lbs ton^{-1}	tons acre^{-1}
MSU 2020	Early	16.9 a	153 b	200 a	463 a	76.7 a	881 a	605 a	3080 a	12.9 a
	Mid	14.8 b	198 a	209 a	409 b	70.5 b	843 b	552 b	2474 b	9.01 b
	Late	17.6 a	196 a	217 a	356 c	75.4 a	844 b	581 b	2180 b	9.54 b
MSU 2022	Early	17.9 a	161 b	264 a	459 a	74.3 a	905 a	636 a	3336 a	14.1 a
	Mid	13.6 b	172 a	258 a	406 b	54.2 b	864 b	570 b	3060 b	11.1 b
	Late	19.7 a	168 ab	221 b	412 b	76.9 a	863 b	589 b	3270 ab	13.9 a

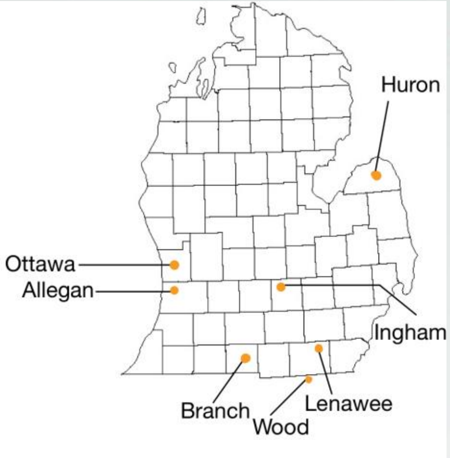
- Early planted corn consistently had higher dry yield and nutritive value

Early: Planted before May 10; Mid: Planted between May 11 to May 30; Late: Planted after May 31

Kaur et al., 2024 (Agronomy Journal)

Hybrid Selection & Fungicide impacts

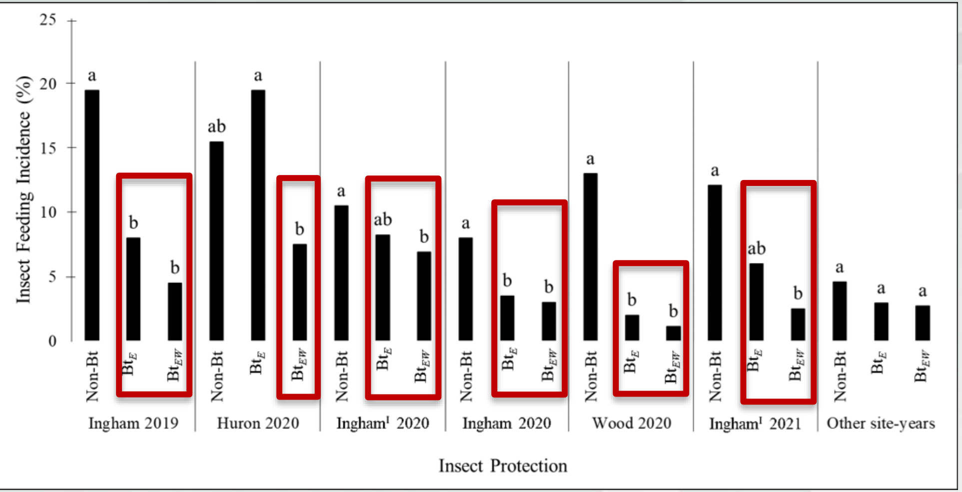
- Multi-location field trials (2019-2021)
- RCBD with five replications
  - 3 Levels of **hybrid insect protection trait**
  - 2 levels of fungicide treatment using Proline 480SC (Prothioconazole) @ 5.7 oz acre^{-1} at Silking stage

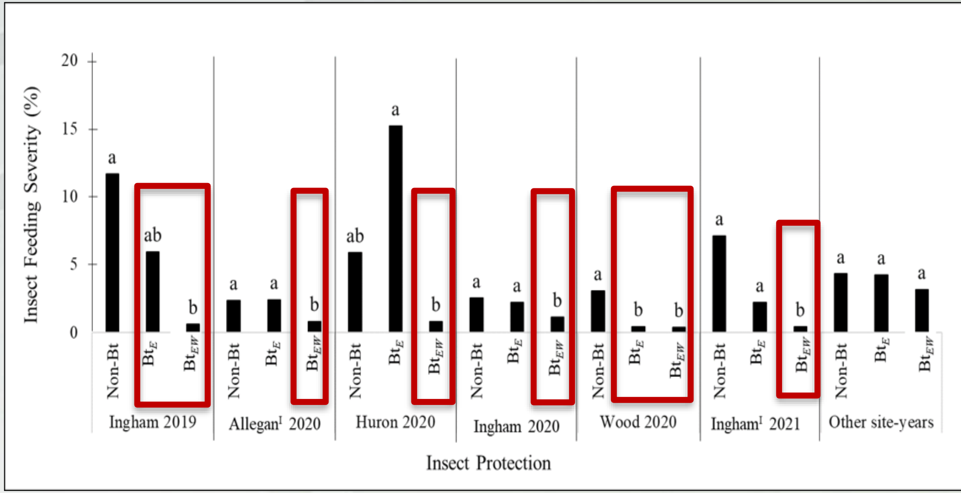


Hybrid Insect Protection Trait	Protein	Insect Protection
Bt_N	none	No Insect protection
Bt_E	Cry1F	ECB
Bt_{EW}	Cry1F + Vip3A	ECB & WBC

WBC: Western Bean Cutworm
ECB: European Corn Borer

Insect protection trait: Insect feeding



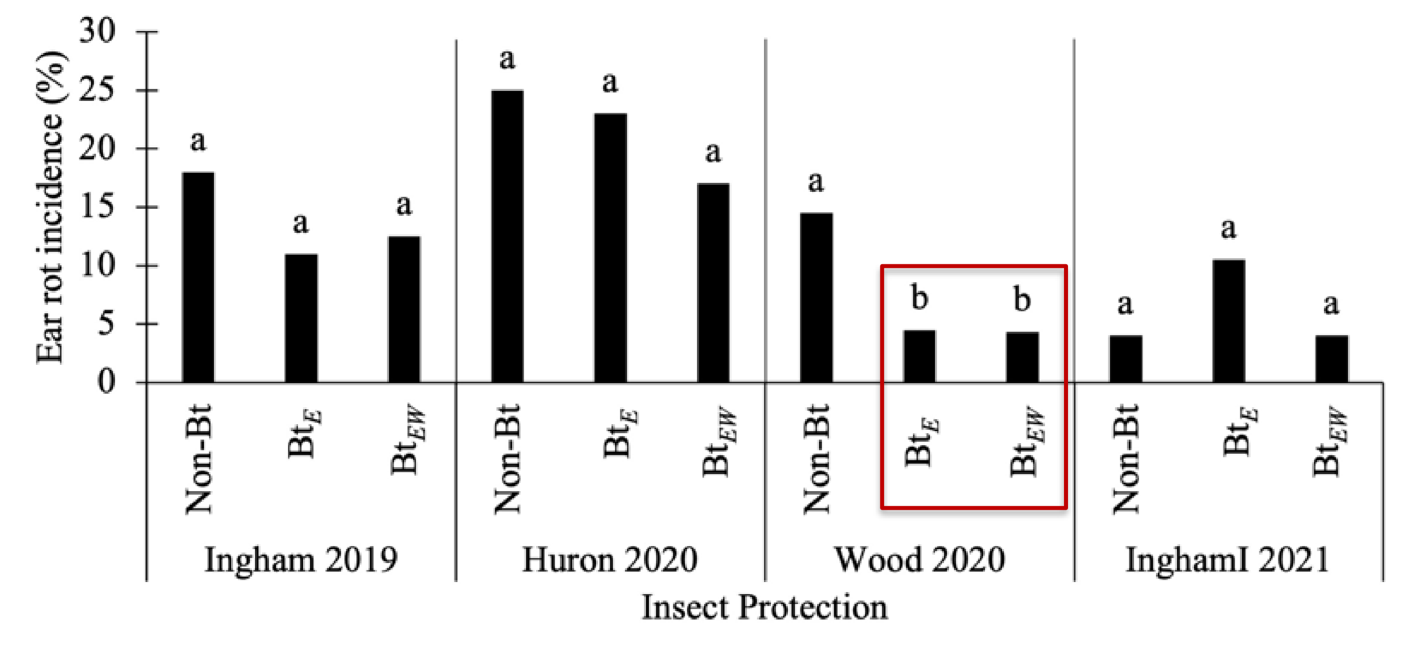


- ➢ Presence of two insect protection proteins help control insect damage

Non-Bt: No protection; Bt_E: protection against ECB; Bt_{EW}: protection against ECB and WBC. ECB (European corn borer), WBC (Western bean cutworm)

Kaur et al., 2023 (Agronomy Journal)

Insect protection trait: Ear rot incidence

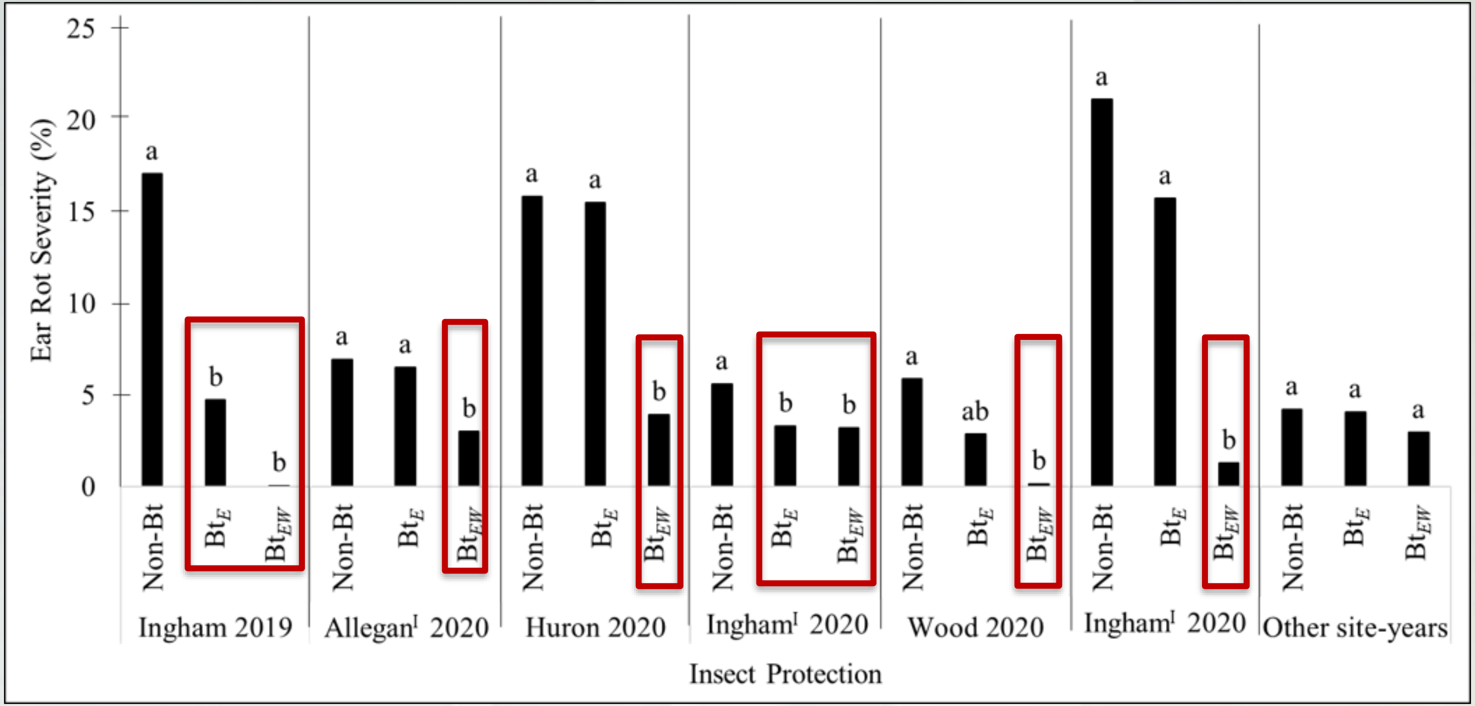


➤ Ear rot incidence did not differ among insect protection levels (except Wood 2020)

Non-Bt: No protection; Bt_E: protection against ECB; Bt_{EW}: protection against ECB and WBC. ECB (European corn borer), WBC (*Western bean cutworm)*

Kaur et al., 2023 (Agronomy Journal)

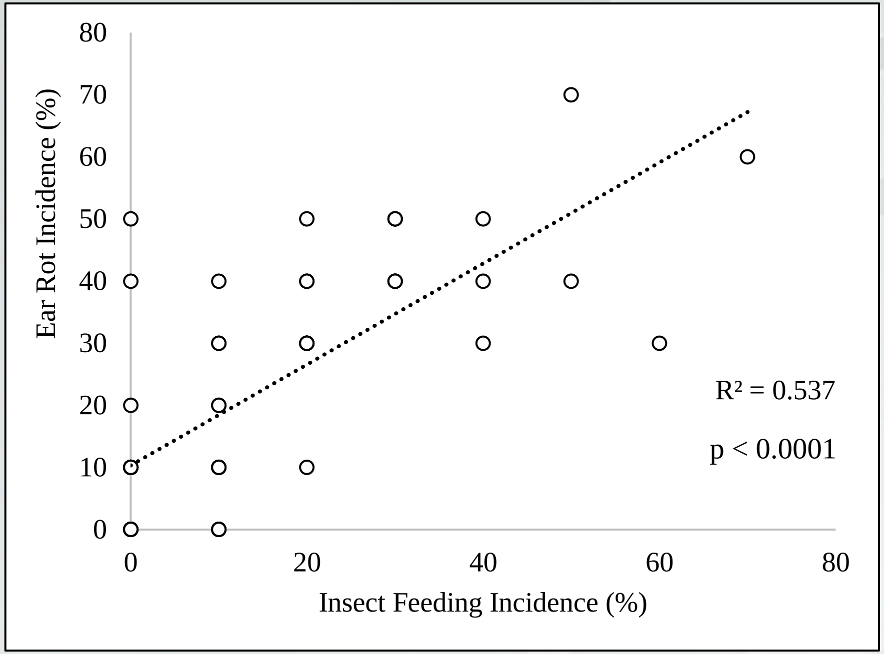
Insect protection trait: Ear rot severity



Non-Bt: No protection; Bt$_E$: protection against ECB; Bt$_{EW}$: protection against ECB and WBC. ECB (European corn borer), WBC (Western bean cutworm)

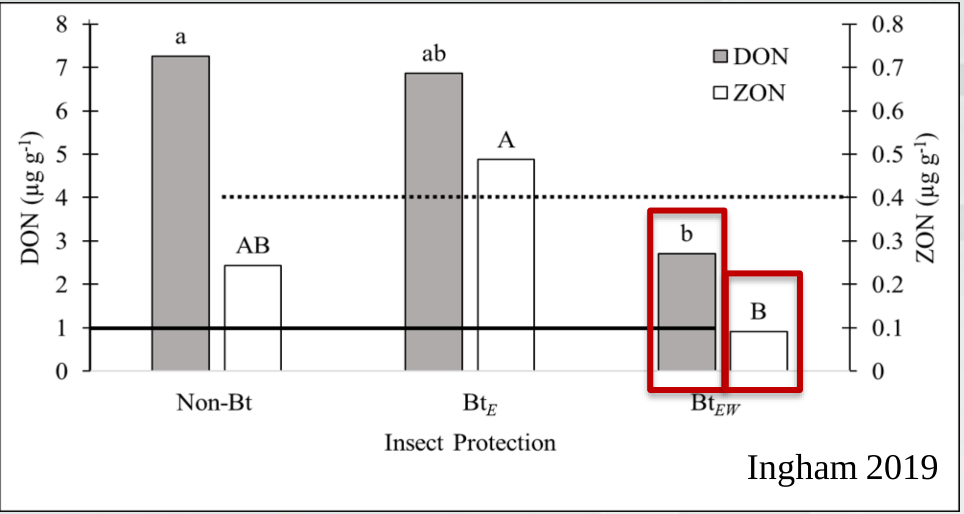
Kaur et al., 2023 (Agronomy Journal)

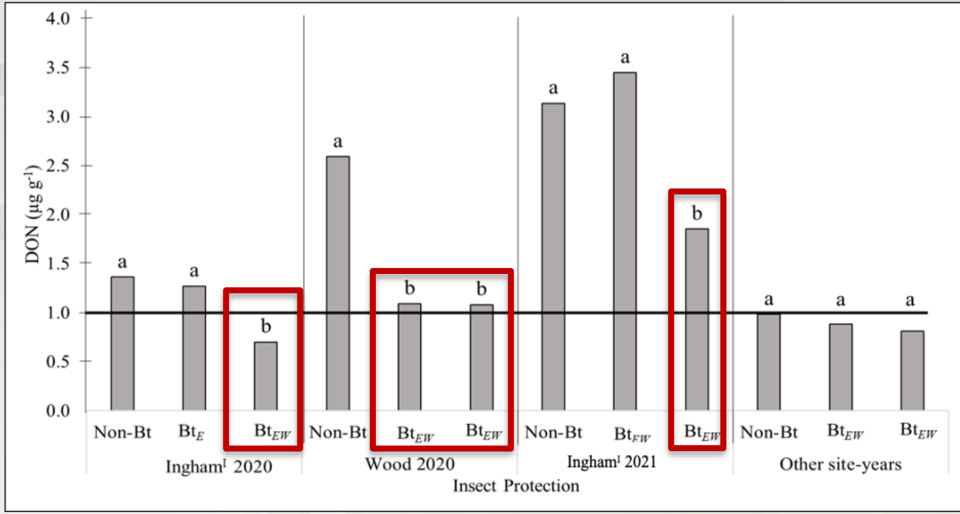
Relation between insect injury and ear rots



- Weak or no correlation was seen between ear rot and WBC damage at other site years

Insect protection trait: Mycotoxin



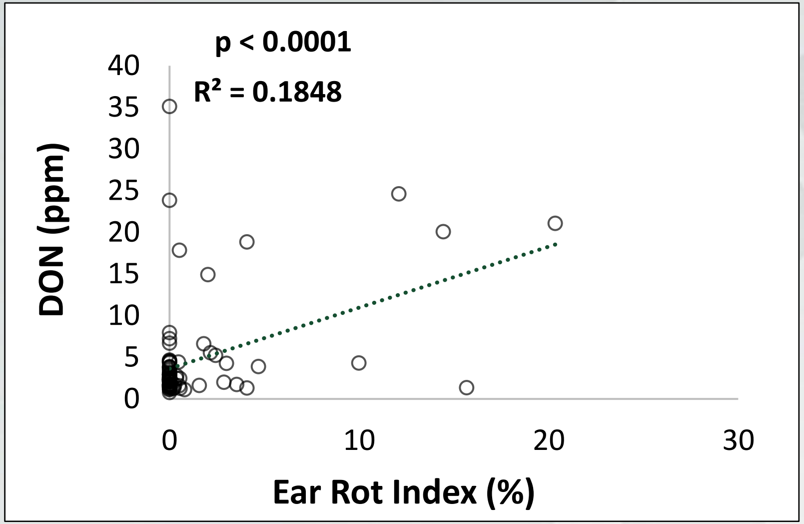


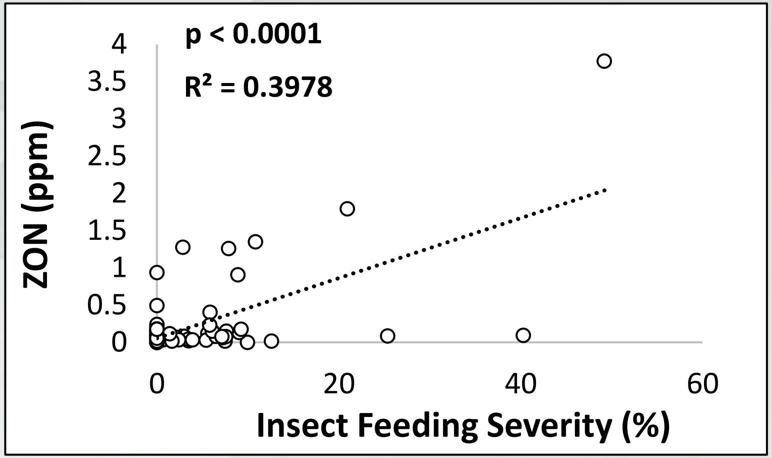
- Using "effective" hybrid insect protection traits reduces mycotoxin accumulation

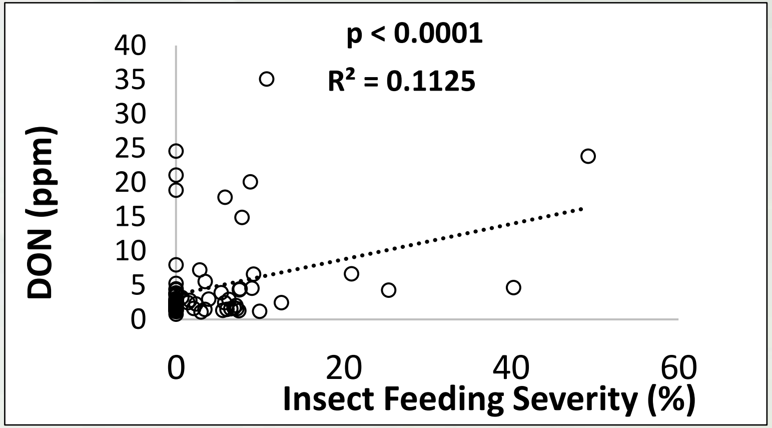
Non-Bt: No protection; Bt_E: protection against ECB; Bt_{EW}: protection against ECB and WBC. ECB (European corn borer), WBC (Western bean cutworm)

Kaur et al., 2023 (Agronomy Journal)

Mycotoxins and Ear Damage







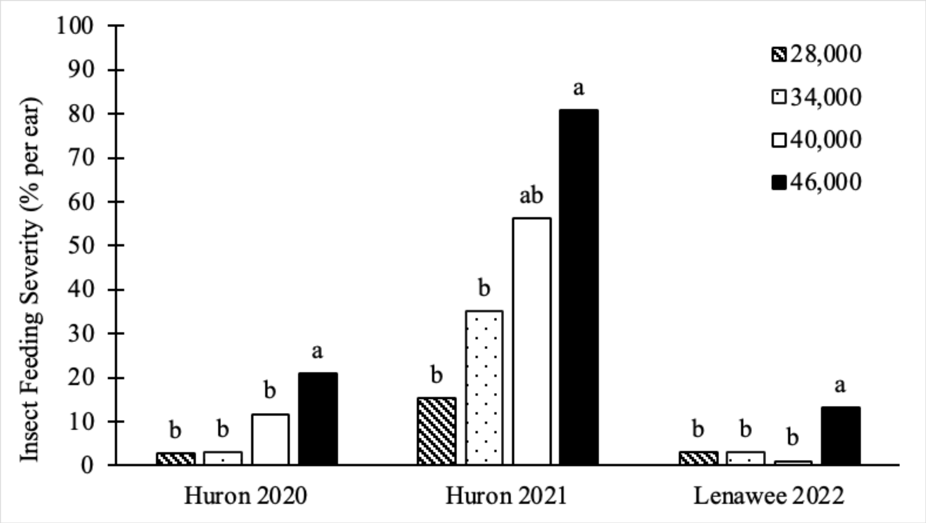
- Scout & spray and/or use **effective** insect protection traits
- Environmental conditions still a key

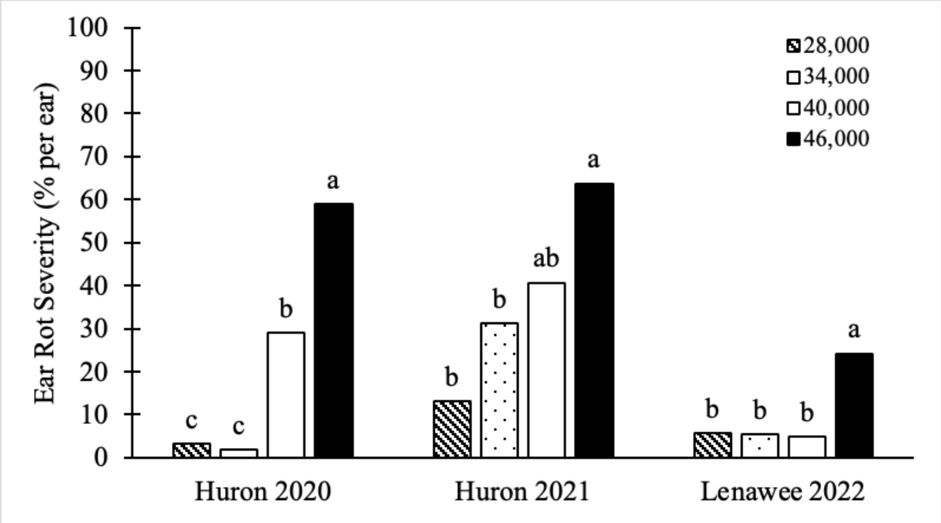
Fungicide Applications – Ear Rot and DON

Site-year	Fungicide treatment	Ear Rot Incidence (%)	DON conc. (μg g^{-1})
Allegan 2020	Non-treated	16.3 a	1.50 a
	Treated	6.70 b	0.59 b
Branch 2020	Non-treated	10.3 a	1.94 a
	Treated	7.2 a	0.95 b
Ingham 2020	Non-treated	19.6 a	1.35 a
	Treated	23.3 a	0.83 b
Lenawee 2020	Non-treated	20.0 a	1.64 a
	Treated	10.7 b	0.78 b
Other site-years	Non-treated	10.5 a	2.07 a
	Treated	10.3 a	1.81 a

Kaur et al., 2023 (Agronomy Journal)

Seeding Rate: Insect feeding and Disease



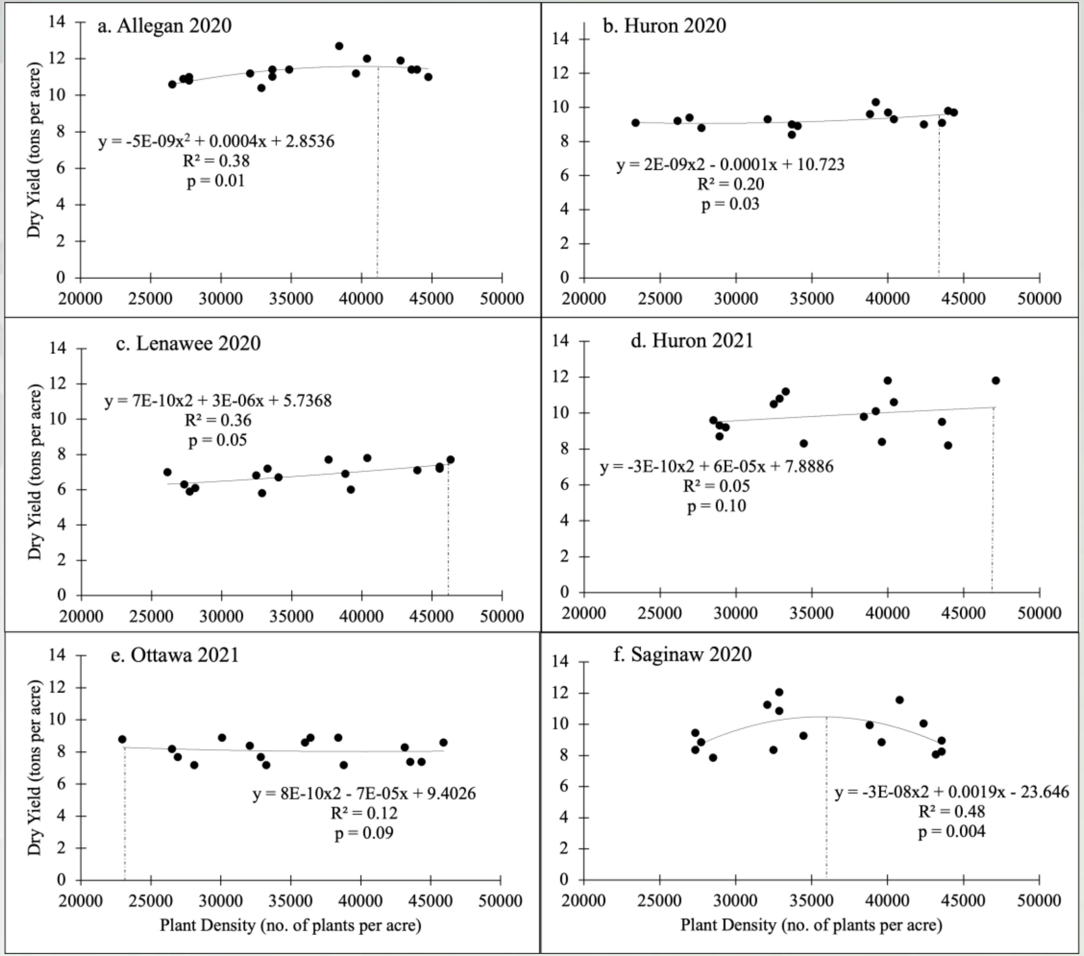


- Insect feeding and ear rot severity increased with increase in seeding rate
- No differences observed in mycotoxin concentration

Kaur et al., 2024 (Agronomy Journal)

Forage yield

- Quadratic relation between plant population and yield
- Agronomic optimal plant density: 36,000 to 42,000 seeds acre^{-1}



Kaur et al., 2024 (Agronomy Journal)

Nutritive Value

Forage nutrients	Site-year	Seeding Rate (no. of seeds ha^{-1})			
		28,000	34,000	40,000	46,000
ADF (g kg^{-1} of DM)	Huron 2021	210 b	200 b	230 ab	272 a
	Lenawee 2022	174 b	184 ab	207 ab	223 a
NDF (g kg^{-1} of DM)	Huron 2021	373 bc	358 c	381 b	466 a
	Lenawee 2022	341 b	353 b	384 ab	407 a
Starch (g kg^{-1} of DM)	Huron 2021	378 a	405 a	397 a	298 a
	Lenawee 2022	372 ab	399 ab	415 a	339 b
IVTD (g kg^{-1} of DM)	Huron 2021	841 a	846 a	841 a	791 b
	Lenawee 2022	855 b	846 b	891 a	868 ab
NDFD (g kg^{-1} of NDF)	Huron 2021	585 a	571 ab	576 ab	552 b
	Ottawa 2021	603 a	607 a	595 b	594 b
	Lenawee 2022	682 a	625 b	625 b	626 b

Kaur et al., 2024 (Agronomy Journal)

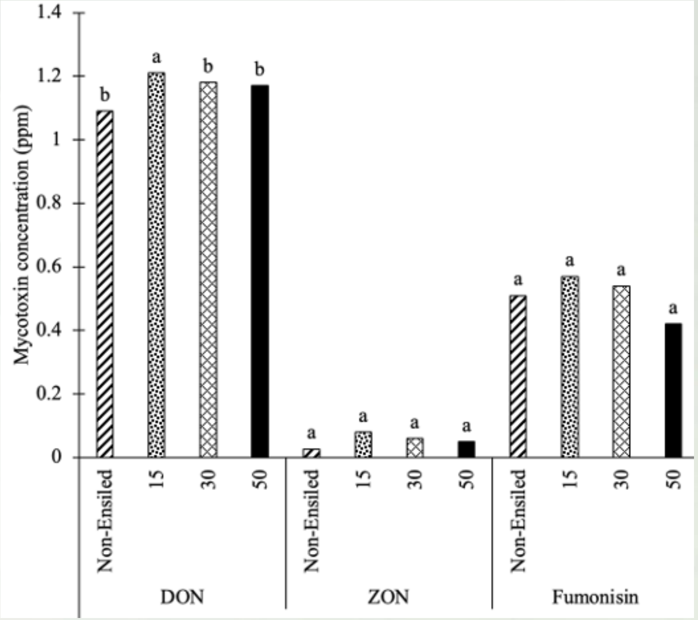
Nutritive Value

Forage nutrients	Site-year	Seeding Rate (no. of seeds ha^{-1})			
		28,000	34,000	40,000	46,000
ADF (g kg^{-1} of DM)	Huron 2021	210 b	200 b	230 ab	272 a
	Lenawee 2022	174 b	184 ab	207 ab	223 a
NDF (g kg^{-1} of DM)	Huron 2021	373 bc	358 c	381 b	466 a
	Lenawee 2022	341 b	353 b	384 ab	407 a
Starch (g kg^{-1} of DM)	Huron 2021	378 a	405 a	397 a	298 a
	Lenawee 2022	372 ab	399 ab	415 a	339 b
IVTD (g kg^{-1} of DM)	Huron 2021	841 a	846 a	841 a	791 b
	Lenawee 2022	855 b	846 b	891 a	868 ab
NDFD (g kg^{-1} of NDF)	Huron 2021	585 a	571 ab	576 ab	552 b
	Ottawa 2021	603 a	607 a	595 b	594 b
	Lenawee 2022	682 a	625 b	625 b	626 b

Kaur et al., 2024 (Agronomy Journal)

Impacts of Ensiling

- Important for forage conservation
- Compaction density determines the porosity and airflow
- Fiber digestibility increased post-ensiling
- Mycotoxin concentrations increased post-ensiling (at low density)

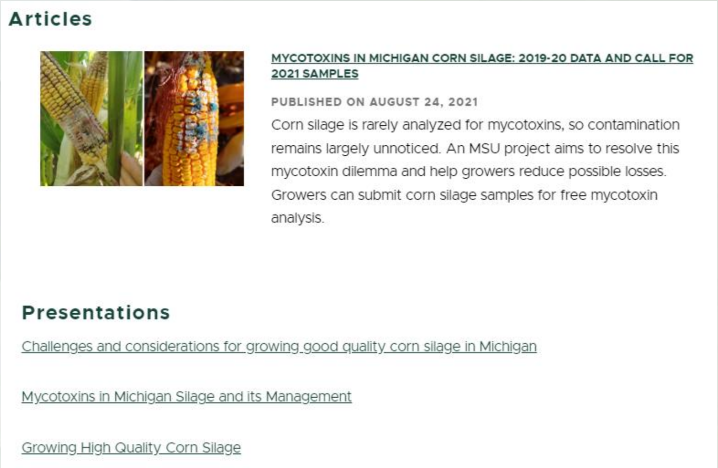


Density: 15, **30**, 50 lbs ft^{-3}

Mycotoxin Management Options

- **Hybrid selection**
- Residue management:
  - Crop rotation with a non-host crop
- Timely planting, reduce plant stress
- Manage for uniformity
- **Fungicide** application (timing: soon after silking, chemistry: use Triazoles but NOT Headline (Strobilurins)
- Insect control (Bt traits, scout and spray)
- Harvest high risk fields first, optimize ensiling
- Diet: dilute, add binders?

Resources: agronomy.msu.edu



- Extension articles: https://www.canr.msu.edu/news/fungal-infections-of-corn-and-management-strategies
- Handy Bt Trait Table https://www.texasinsects.org/bt-corn-trait-table.html
- Corn hybrid performance trials (from universities or seed companies)
- Research papers from our lab
  - https://doi.org/10.1163/18750796-bja10005
  - https://doi.org/10.1002/agj2.21620
  - https://doi.org/10.1002/agj2.21342
  - https://doi.org/10.3390/toxins14070431
  - https://doi.org/10.1002/cft2.20258

- **Technicians**:
  - Patrick Copeland
  - Lorato Wood
- **Graduate Students**
  - Benjamin Agyei
  - Paulo Arias
  - Wallas da Silva
  - Previous students
- **Undergrad/Intern students**
- **Past students**
- Mike Particka
- Tom Wenzel
- **Farmer cooperators**

- Dr. Chris Difonzo
- Dr. Marty Chilvers
- Dr. Kim Cassida

- Phil Kaatz
- Phil Durst
- Martin Mangual
- Brook Wilke

Manni Singh

msingh@msu.edu

517-353-0226

agronomy.msu.edu

Thanks!

MMPA EST. 1916

M-AAA Michigan Alliance for Animal Agriculture

Project GREEEN

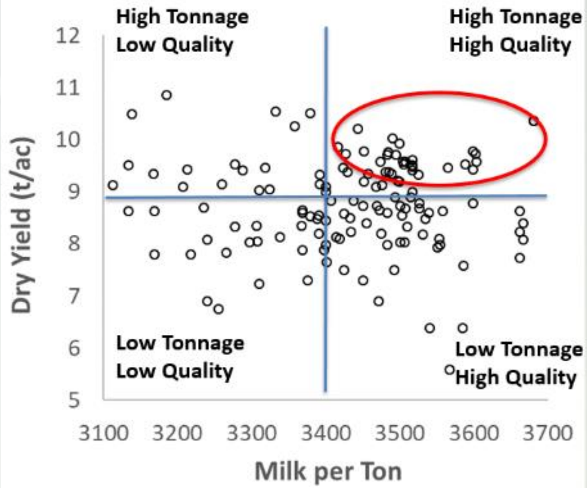
Cropping Systems Agronomy MICHIGAN STATE UNIVERSITY

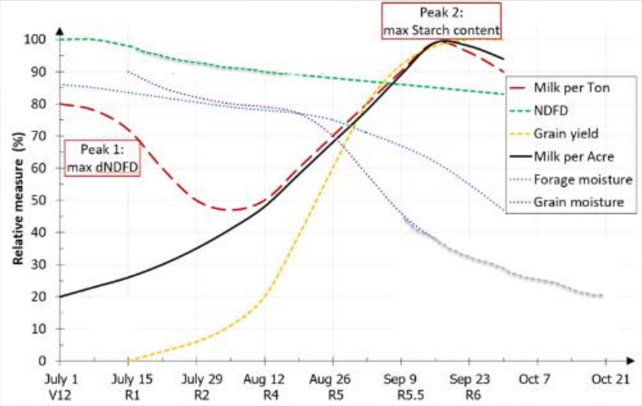
MICHIGAN STATE UNIVERSITY Extension

Seed companies

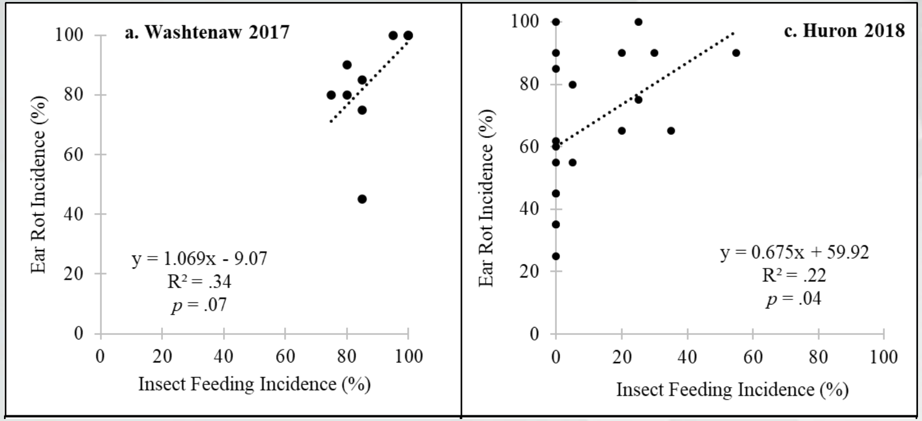
Summary: Silage corn

- Hybrid selection considerations:
  - High silage yield and quality
  - Relative maturity of hybrid (match local GDD)
  - Trait package- based on pest pressure
  - Dual vs silage type hybrids (short corn?)
  - Agronomic traits- disease/drought tolerance
- Key management decisions:
  - Crop rotation, Timely planting
  - Optimum seeding rate (≥ 36,000 seeds/ac)
  - Harvest at peak quality
  - Fungicide/insecticide application (based on scouting)
  - Mycotoxin management

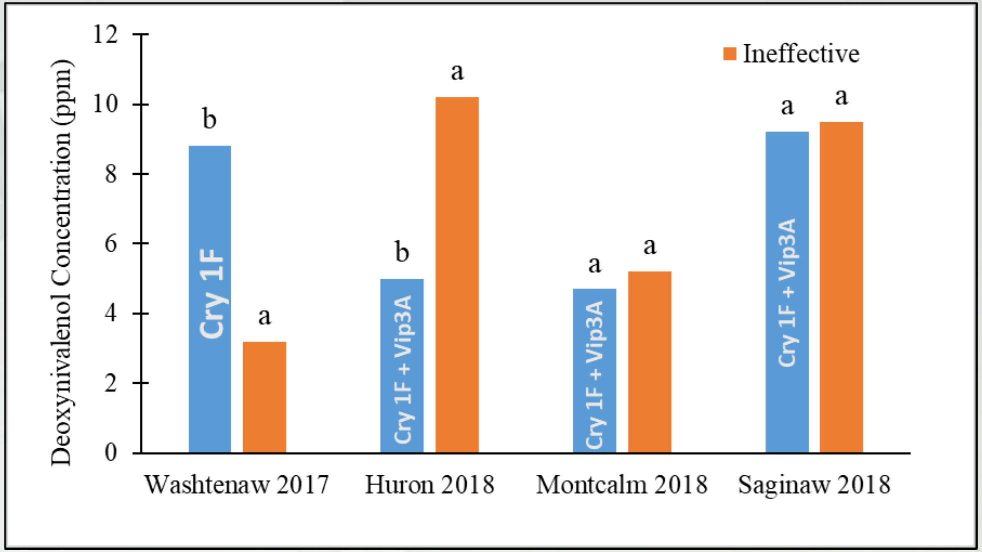




Grain corn: Ear-feeding insects vs Mycotoxins



Singh et al., 2024 (CFTM)



- Scout & spray and/or use **effective** insect protection traits
- Environmental conditions still play a key role in mycotoxin accumulation

Handy Bt trait table: https://www.texasinsects.org/bt-corn-trait-table.html

Critical Agronomic Decisions for Silage Corn Production

- **Hybrid Selection**
- **Planting date**
- **Seed Rate, row spacing**
- Fertility
- Irrigation
- Weed Management
- **Pest Management**
- **Harvest timing**