Management of FHB in Barley: lessons from the Upper Midwest

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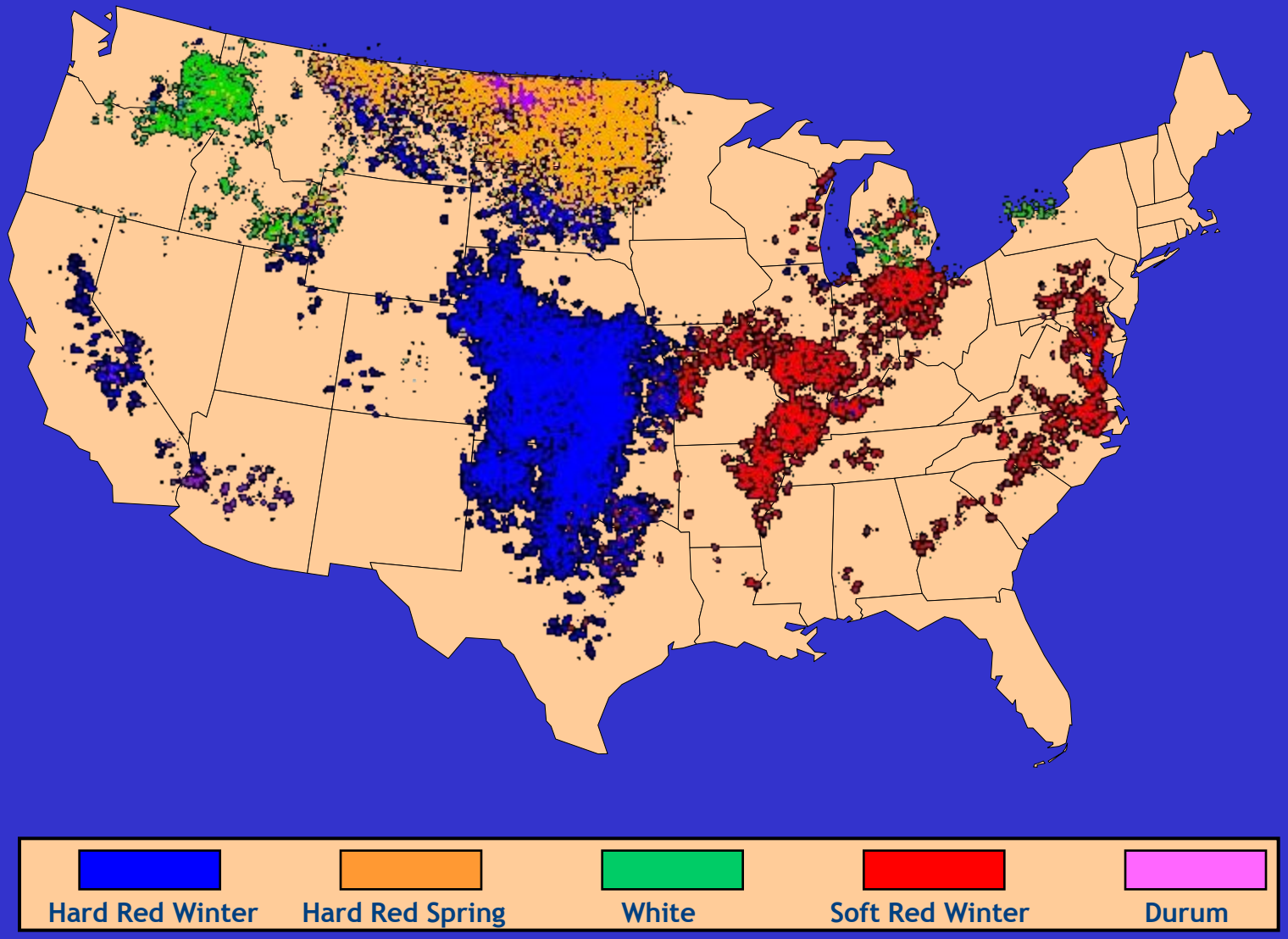
University of Minnesota

USA wheat production areas
- shown by class -



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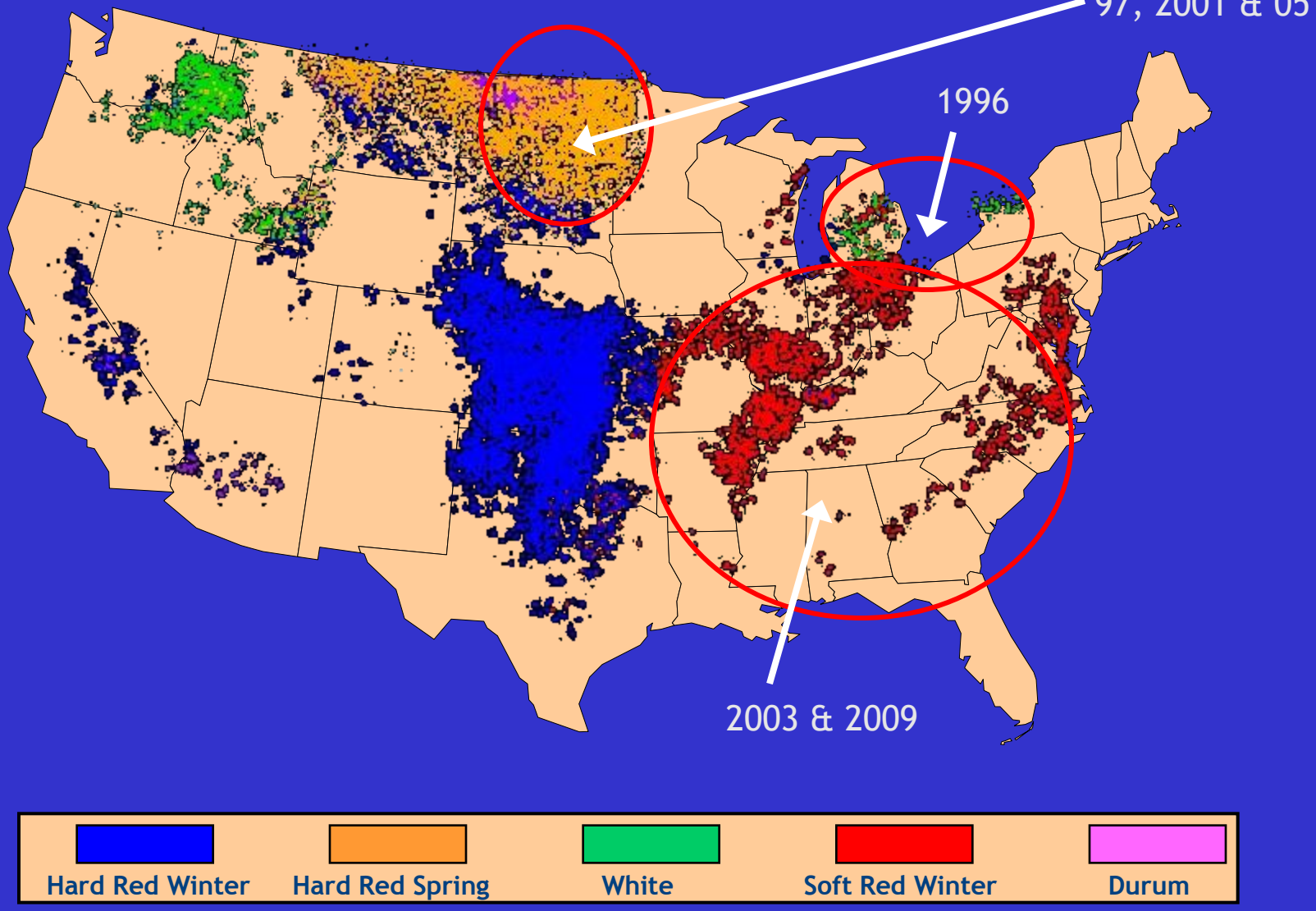


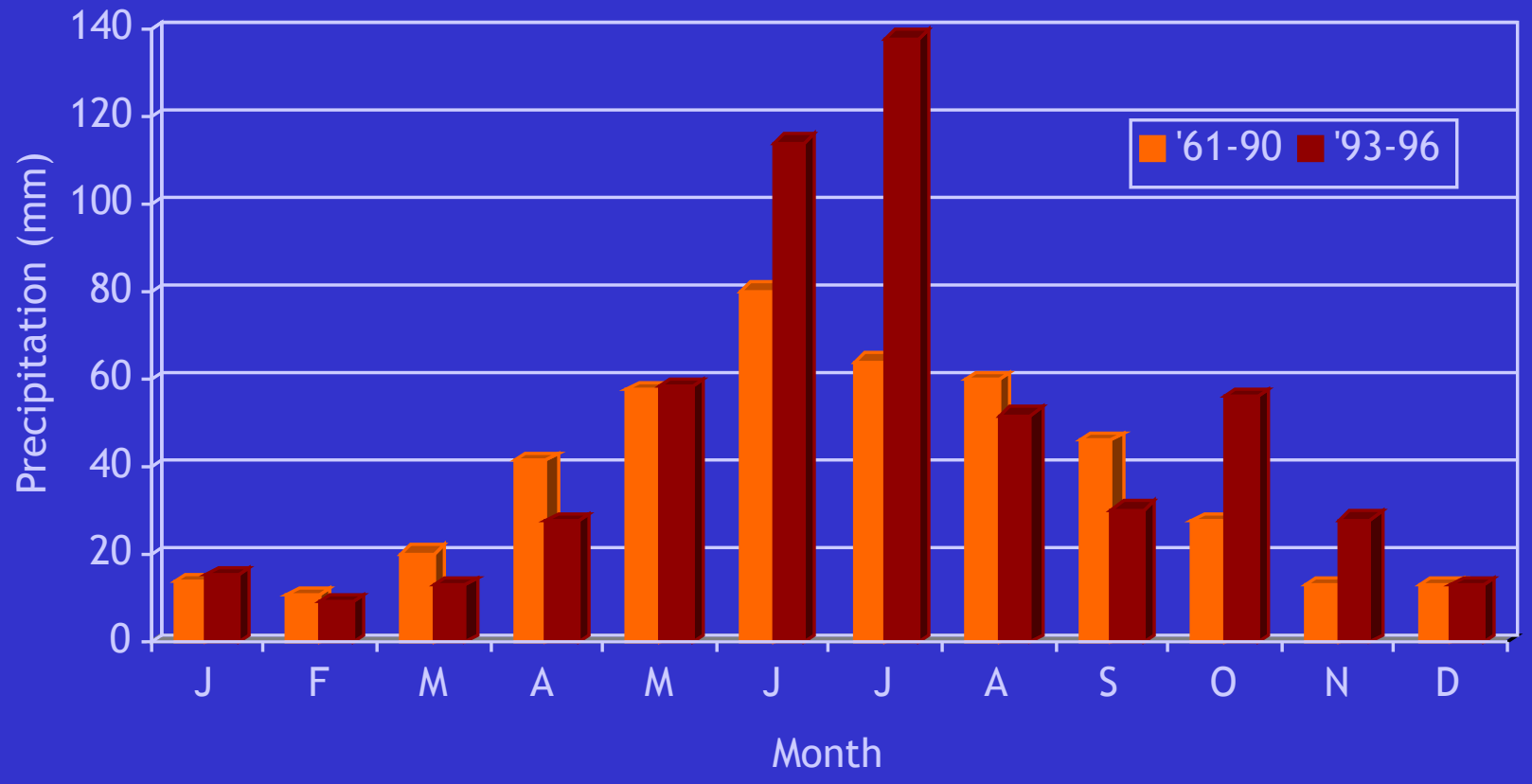
Probable Causes of the Increase in Fusarium Head Blight

weather patterns favoring disease development

susceptible wheat and barley cultivars and expanded corn production

reduced tillage practices adopted for soil conservation

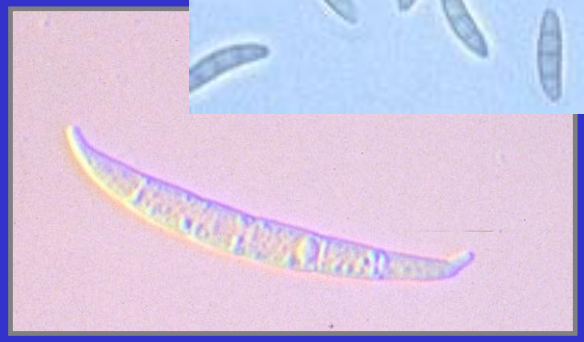
Precipitation patterns
Red River Valley, MN



Fusarium Head Blight

Predominance of
F. graminearum
as causal fungus in FHB

The increase of FHB
has been associated with
increased corn production



FHB Pathogens

- *Fusarium graminearum (Gibberella zeae)*, *F. culmorum*, *F. poae*, *F. avenaceum*, *F. equiseti*, *F. acuminatum*, *F. sporotrichioides* and others…

Broad host range

Fusarium species recovered from residues

Wheat and barley: *F. graminearum (G. zeae)*, *F. avenaceum*, *F. equiseti*, *F. acuminatum*, *F. trincictum*, *F. sambucinum*, *F. semitectum*, *F. poae* (barley), *F. culmorum* (wheat), *F. sporotrichioides*, *F. subglutinans*, *F. oxysporum*, *F. solani*

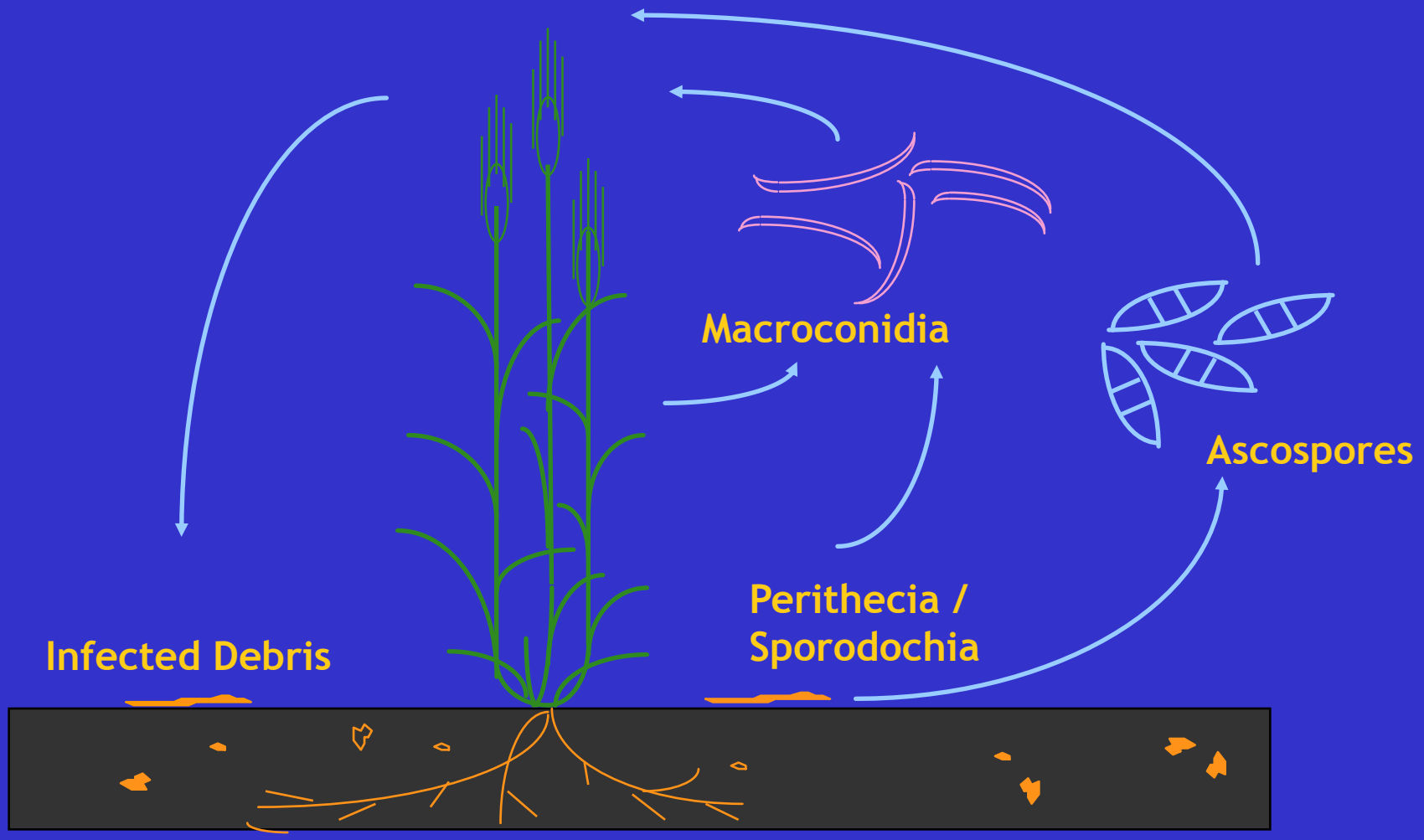
Corn: *F. verticillioides* , *F. subglutinans*, *F. graminearum*, *F. proliferatum*, *F. oxysporum*, *F. equiseti*, *F. solani*

Gramineous weeds: *F. equiseti*, *F. avenaceum*, *F. poae*, *F. oxysporum*, *F. solani*, *F. sambucinum*, *F. graminearum*, *F. subglutinans*

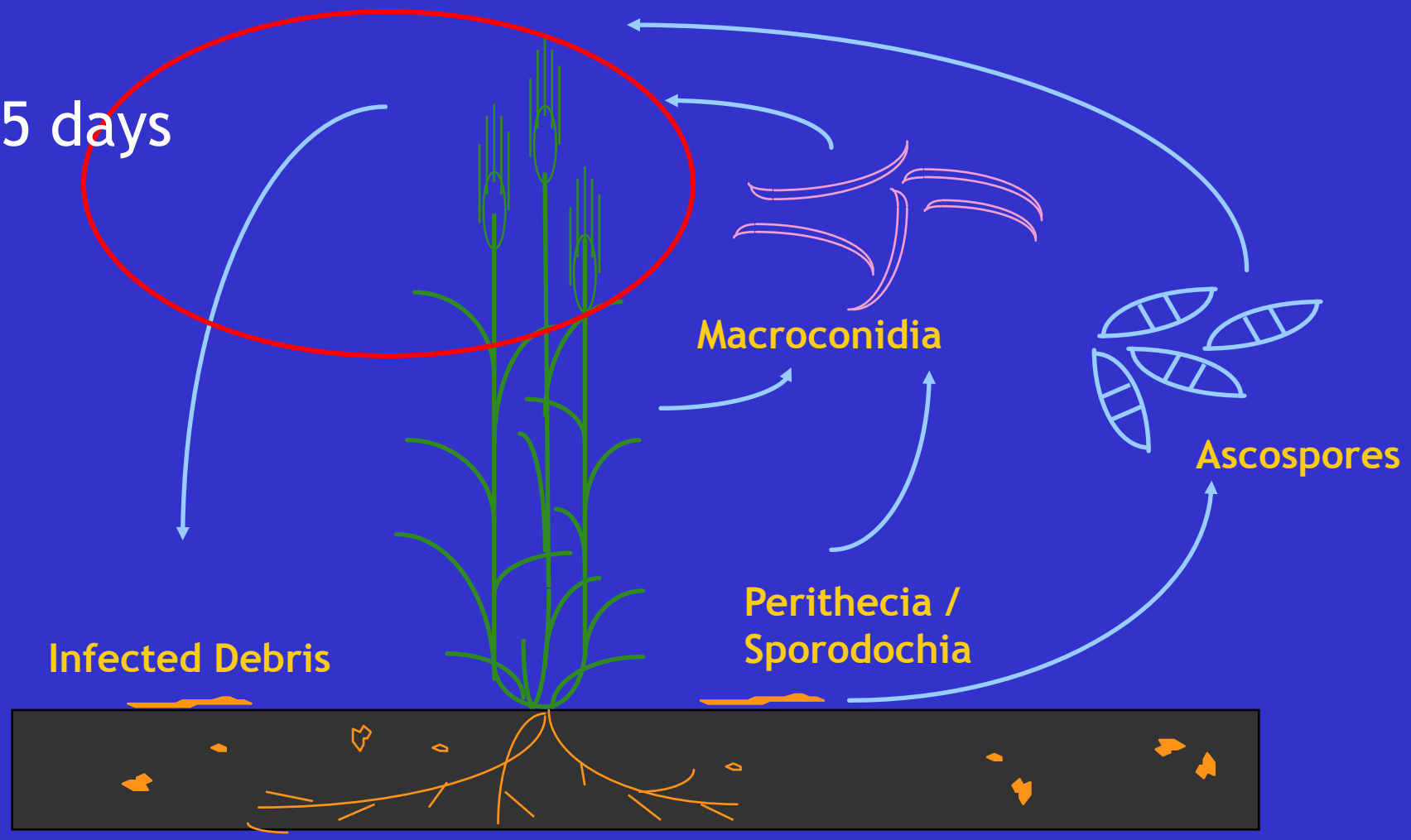
Sunflower: *F. oxysporum*, *F. solani*, *F. equiseti*, *F. acuminatum*, *F. semitectum*, *F. poae*, *F. graminearum*

Broader host range as a saprophyte

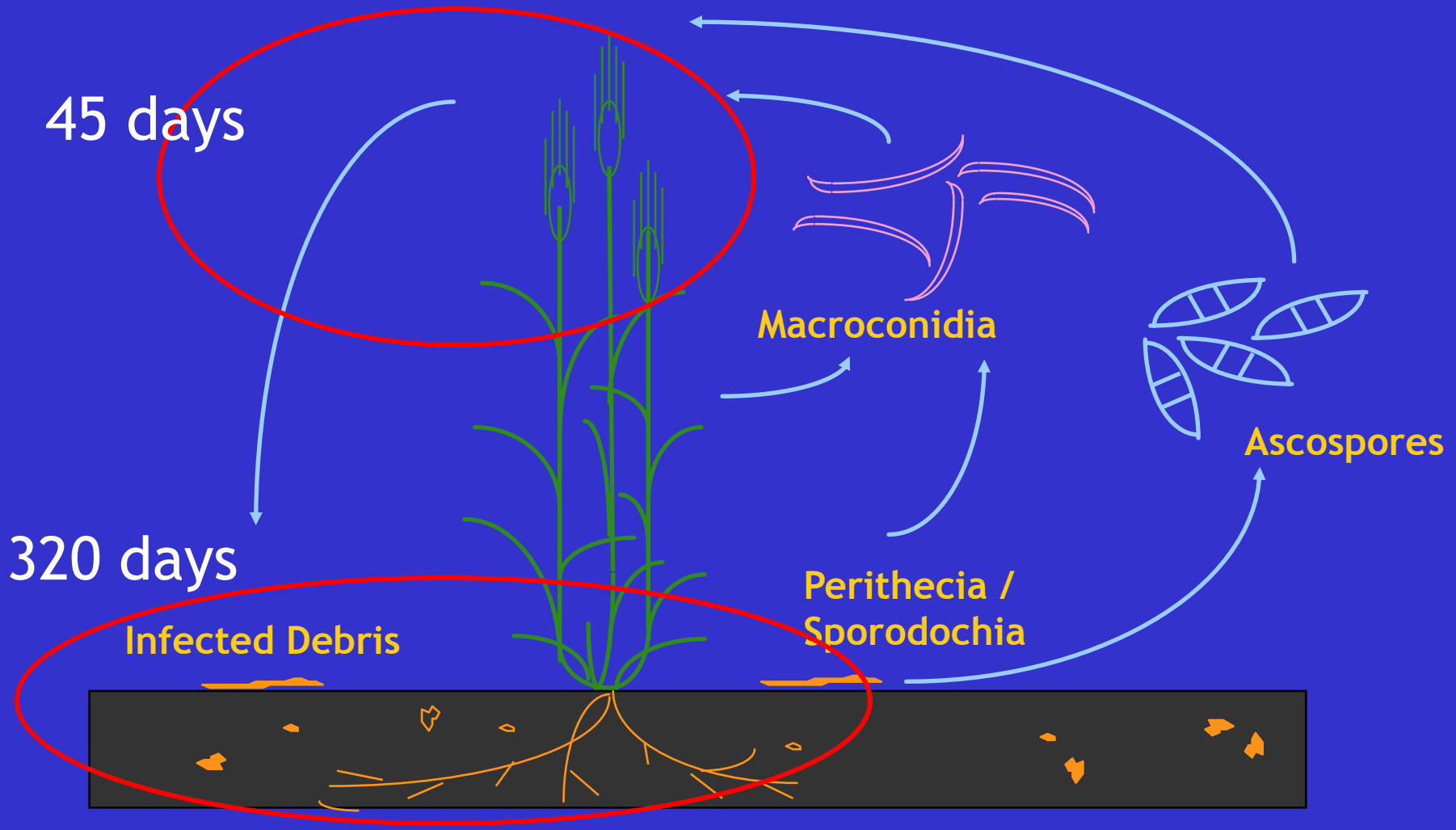
Disease cycle of *Fusarium graminearum*



Disease cycle of *Fusarium graminearum*



Disease cycle of *Fusarium graminearum*



Fusarium Head Blight

Sporadic epidemics reported since wheat and barley production established in the USA

From a historical perspective FHB was most effectively controlled from the end of WWII to the mid-1980's

- the era of the moldboard plow -

CHEMICAL CONTROL

Chemical Control

- Seed treatments - seedling blight
- Heading applications - 50-60% reductions in severity
  - Early to mid 1990's: mancozeb (protectant) and systemic MBC fungicides (benomyl)
  - Late 1990's: Tilt (propiconazole), Folicur (tebuconazole), Quadris (azoxystrobilurin)
  - 2000's: Caramba (metconazole), Proline (prothioconazole), Prosaro (prothioconazole & tebuconazole)
- Application technology
  - Nozzle type and direction

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    Associated with Increased DON
  - 2000's: Caramba (metconazole), Proline (prothioconazole), Prosaro (prothioconazole & tebuconazole)
- Application technology
  - Nozzle type and direction

Fungicides – Best Recommendations

Fungicide[1]	Product names	Rate/A fl oz/A	Head Scab efficacy	Preharvest interval
Metconazole	Caramba	10.0 – 17.0	G[2] (VG)[2,3]	30 days
Propiconazole	Tilt, PropiMax, others	4.0	P[2]	40 days
Prothioconazole	Proline	5.0 – 5.7	G[2] (VG)[2,3]	30 days (32 for barley)
Prothioconazole + Tebuconazole	Prosaro	6.5	VG[2]	30 days
Tebuconazole	Folicur, Embrace, Onset, Orius, Monsoon, TebuStar, Tergol, Toledo, others	4.0	F[2]	30 days

Scabsmart: www.scabsmart.org

Fungicides – Best Timings

Table 1. Effect of timing of application of Folicur (4 fl oz/acre) on field severity of FHB in greenhouse, 1999.

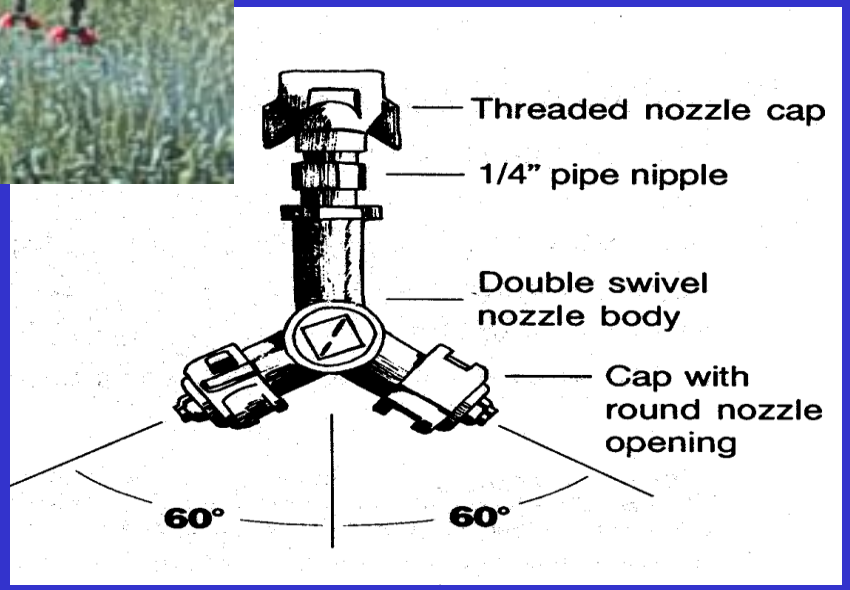
Application Growth Stage (Feekes)*	FHB Field Severity (Field Severity = Incidence x Head Severity)		
	Grandin HRS	Munich Durum	Robust Barley
10.3	1.6	16.4	1.5
10.51**	0.5	3.5	1.3
10.54	7.0	22.5	1.9
Untreated	7.0	32.1	3.2

* Feekes growth stage 10.3 = 50% head emergence; 10.51 = early flowering; 10.54 = kernel water ripe

** Barley sprayed at Feekes 10.5 = head fully emerged

Scabsmart: www.scabsmart.org

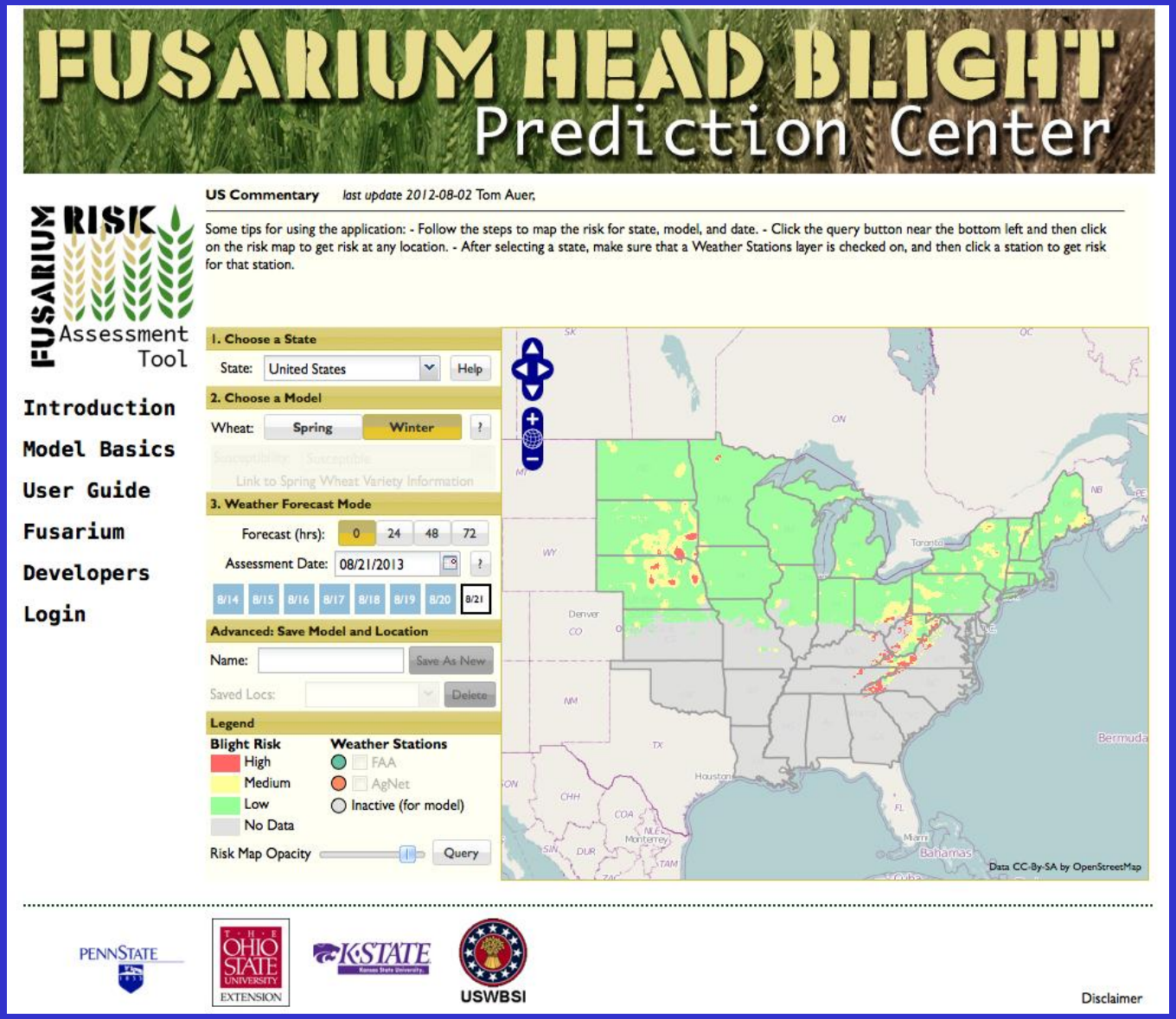
Fungicide Spray Angle and Direction



Hofman, McMullen et al.

NDSU NORTH DAKOTA STATE UNIVERSITY

FORECASTING - www.wheatscab.psu.edu



Chemical Control – Best Practices Barley

- Recommended Fungicides: Caramba, Proline and Prosaro. Use a good adjuvant
- Timing: Early Heading Applications (Feekes 10.3-10.5)
- Ground Applications: twin directional nozzles, Increase spray volume to improve coverage
- Air Applications: evening or early morning to utilize dew as additional water, small droplet size

BIOLOGICAL CONTROL

Biological Control Agents

Bacteria (*Bacillus* and *Lysobacter* spp.) and several yeasts have been examined in greenhouse and field tests

Consistent FHB suppression and DON reduction in greenhouse

but not in the field….

Biological Control Agents Tested

Bacillus spp. – these are attractive candidates because of their ability to produce endospores and potential to express a number of biocontrol mechanisms

- *Bacillus subtilis* Trigocor 1448 (da Luz *et al*. 2003)
- *Bacillus sp*. 1BA (Draper *et al*. 2001)
- *Bacullus subtilis* var. *amyloliquefaciens* FZB24 – a.i. in Taegro (Novozymes Biologicals) – shown to control a range of pathogens - not tested for FHB

C3 *Lysobacter enzymongenes*

Cryptococcus flavescens OH182.9 / *C. aureus* OH 71.4 – yeasts

BCA strains tested either alone or in combination with Prosaro

Effect of BCA's on FHB and DON

None of the BCA strains alone had a consistent effect on the disease parameters measured in the field

Prosaro, applied alone or in combination with a BCA, was effective in reducing FHB measurements in multiple trials

Prosaro reduced DON levels in most trials – TrigoCor 1448 and the two yeasts appear to also reduce DON in some trials

No single strain appeared superior across environments

May be some synergy of BCA's applied with fungicides – esp. for durability of protection or for applications after heading

Understanding why BCA's fail in the field

TrigoCor strain of *Bacillus subtilis* shows potential in the greenhouse BUT… is inconsistent in the field

Populations on wheat florets appear to be able to survive at levels ($>10^6$) which suggests they should be able to actively protect plants

The production and persistence of antifungal metabolites (lipopeptides) appears to be important in disease control and the concentrations of these might be critical

Kawamoto *et al*.
Proc. USWBSI Forum 2008

CULTURAL CONTROL

Residue Decomposition

Fusarium Head Blight

Less debris decomposition in cold winter regions leads to greater inoculum pressure

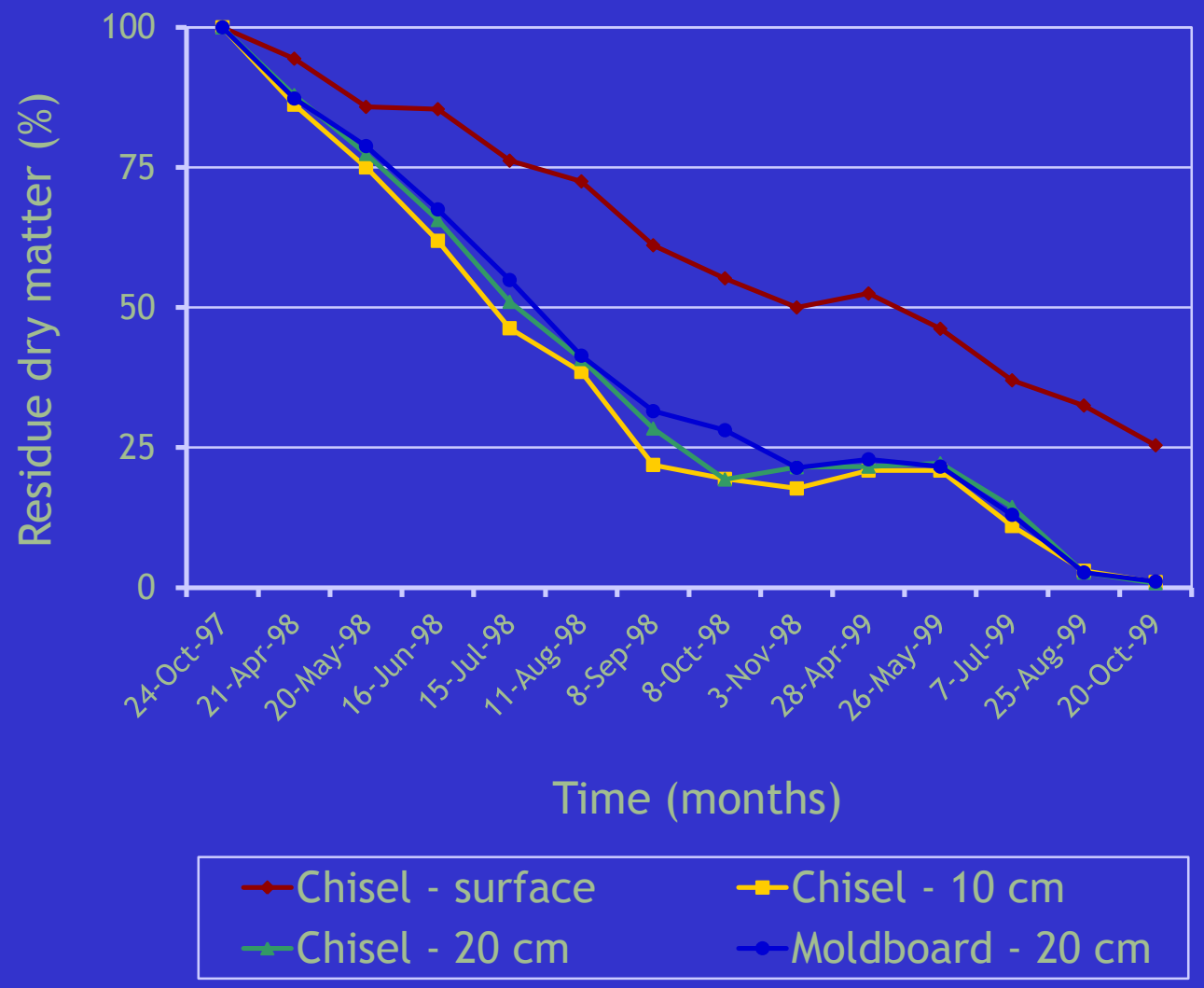
Residue decomposition and survival of *Fusarium* in residues

Field trial - Crookston, MN

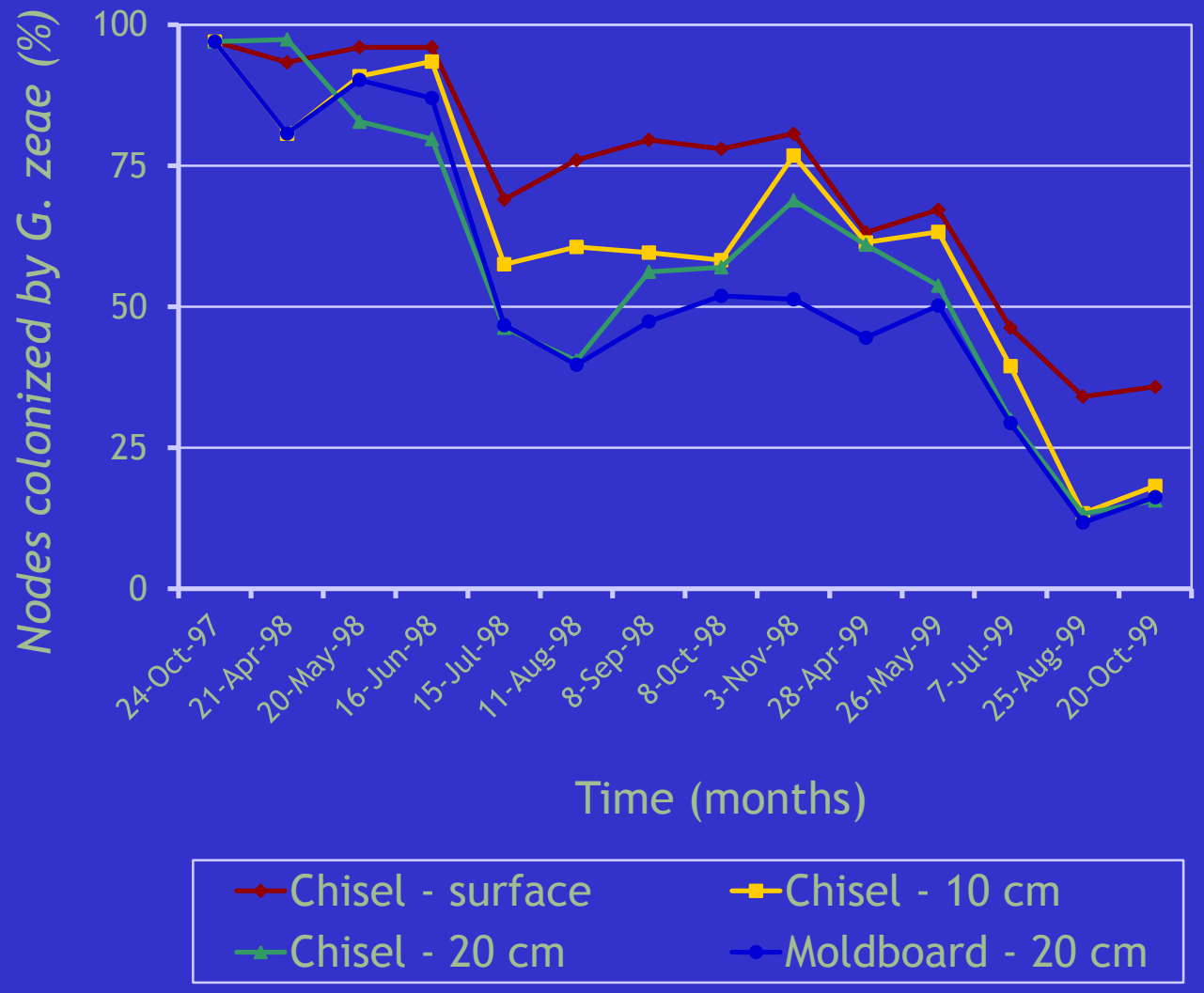
- wheat residue - harvested October 1997
- placement - chisel plow at 0, 10, 20 cm depths & moldboard plow at 20 cm
- collected - April 1998 till July 2000

Pereyra, Dill-Macky and Sims
Plant Disease 2004

Residue Decomposition

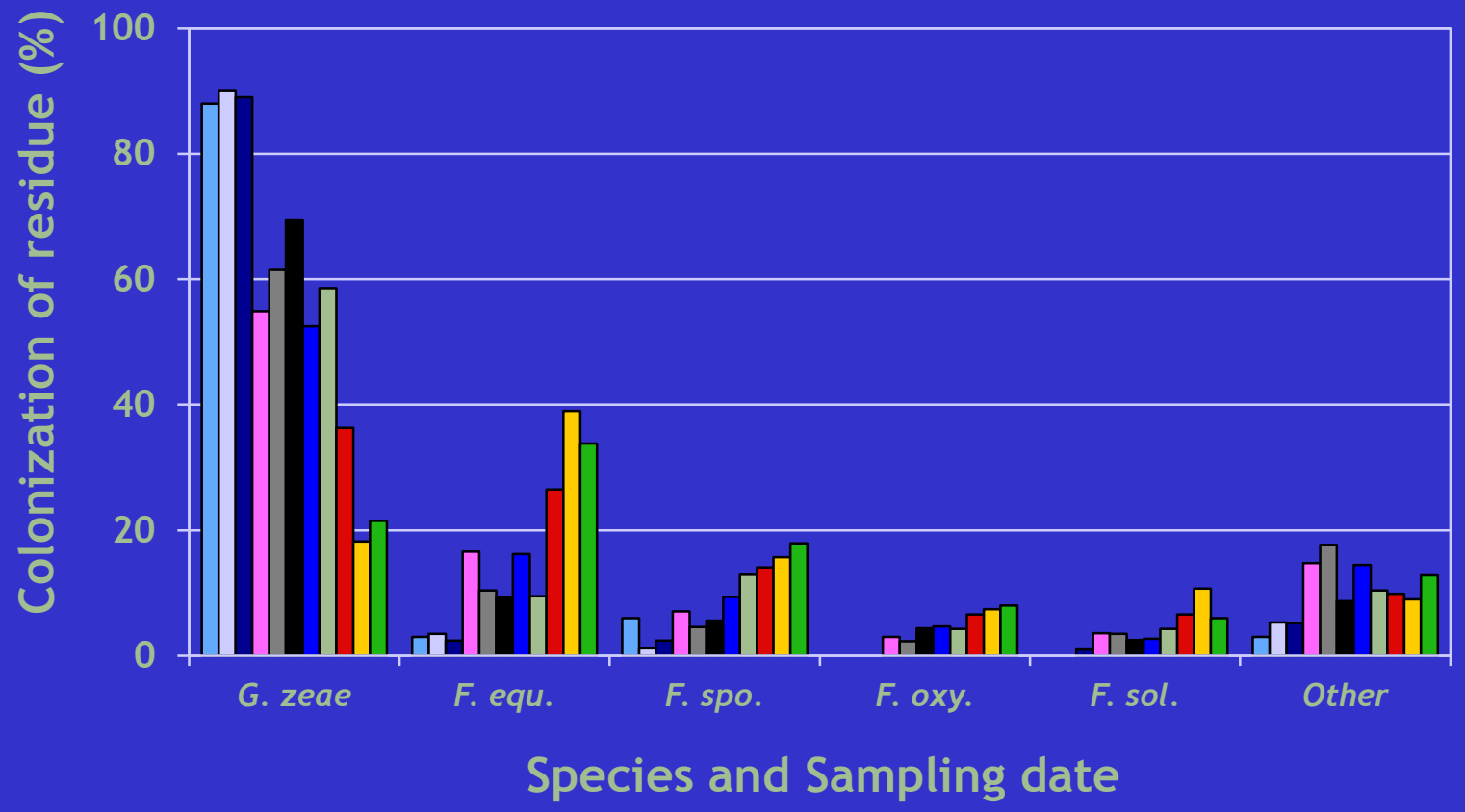


Colonization of Residue



SURVIVAL

Fusarium spp. - succession on residues



Recovered *F. graminearum* isolates were capable of producing perithecia and viable ascospores

Residue Decomposition

Wheat and barley residues support *Fusarium* survival and inoculum as long as they are 'recoverable' - in MN residues may impact FHB for up to three subsequent cropping seasons

Burying residues will eliminate the threat from residues and speed residue decomposition - BUT residues returned to the soil surface will still support inoculum production

F. graminearum appears to be one of the earlier colonizers of residues - pathogenic phase may give it a competitive advantage as a saprophyte

Previous Crops and Tillage

Previous crops and tillage study

Field trial - Morris, MN

- previous crops - corn, wheat and soybean
- tillages - moldboard plow, chisel plow and no-till
- followed with a crop of 'Norm' wheat (FHB susceptible)

Dill-Macky and Jones
Plant Disease 2000

Replications: 5

Plot size: 9 m x 6 m

Location/years: 6

(3 yr, dryland and irrigated)

Residue cover (%)

	Corn	Wheat	Soy	Avg.
MP	12 bc	9 ab	5 a	9 r
CP	42 e	34 d	17 c	31 s
NT	67 f	83 g	46 e	65 t
Avg.	41 y	42 y	23 z	

Disease severity (%)

	Corn	Wheat	Soy	Avg.
MP	17 b-e	16 a-d	14 a-c	16 r
CP	26 f	19 c-e	16 a-e	20 s
NT	26 f	20 de	17 b-e	21 s
Avg.	23 z	18 y	16 x	

DON (ppm)

	Corn	Wheat	Soy	Avg.
MP	9.7 c-f	7.9 a-e	6.5 a-c	8.1 r
CP	15.0 g	9.2 b-f	7.4 a-e	10.6 s
NT	15.6 g	10.7 d-f	6.9 a-d	11.1 s
Avg.	13.5 z	9.2 y	6.9 x	

Previous Crop Residues and Tillage

Wheat and barley residues likely as good a host as corn - BUT corn residues persist longer as they are larger and resist breakdown - Bt-corn may exacerbate this!

In field inoculum impacts FHB - BUT likely will only have impact on epidemics when exogenous inoculum is limiting - which might not be often

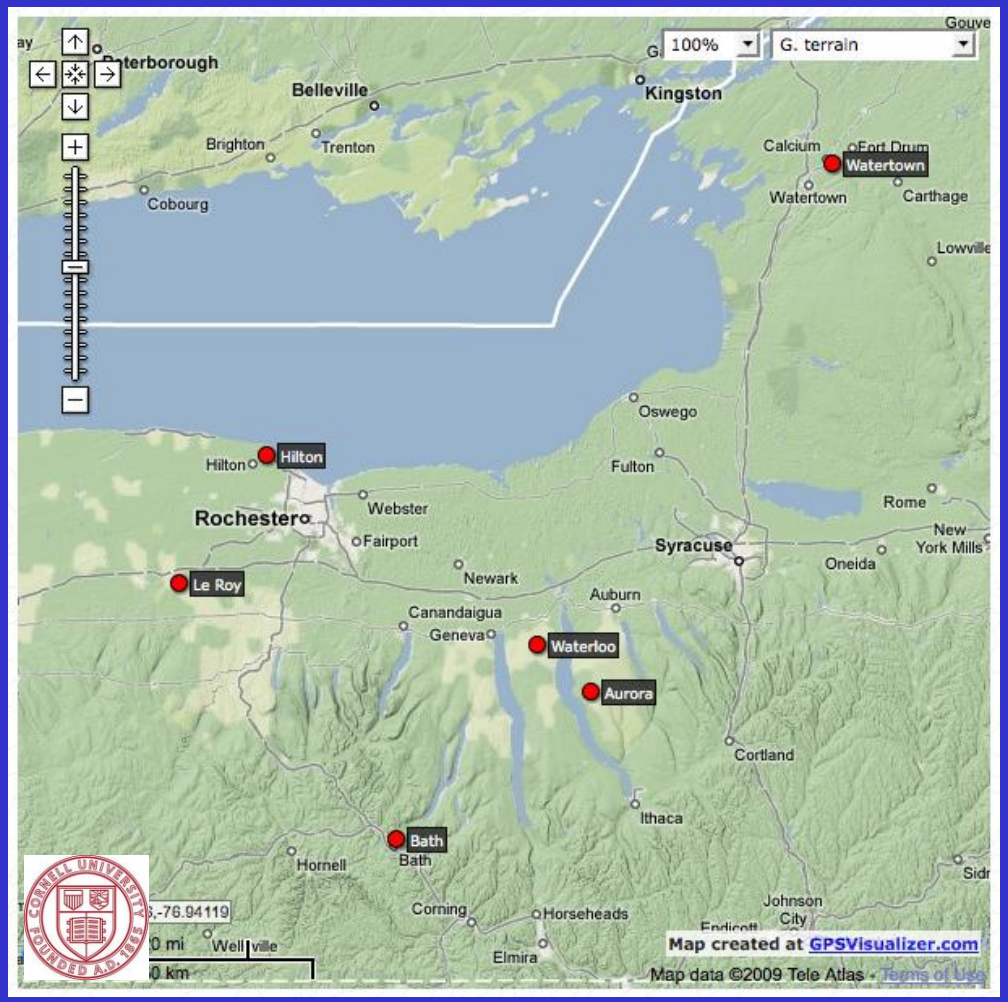
No-till might actually be better than some reduced tillage practices (chisel plowing) residue-moisture interactions

Corn microplot experiments:
Consequences of having corn residues in a wheat field?

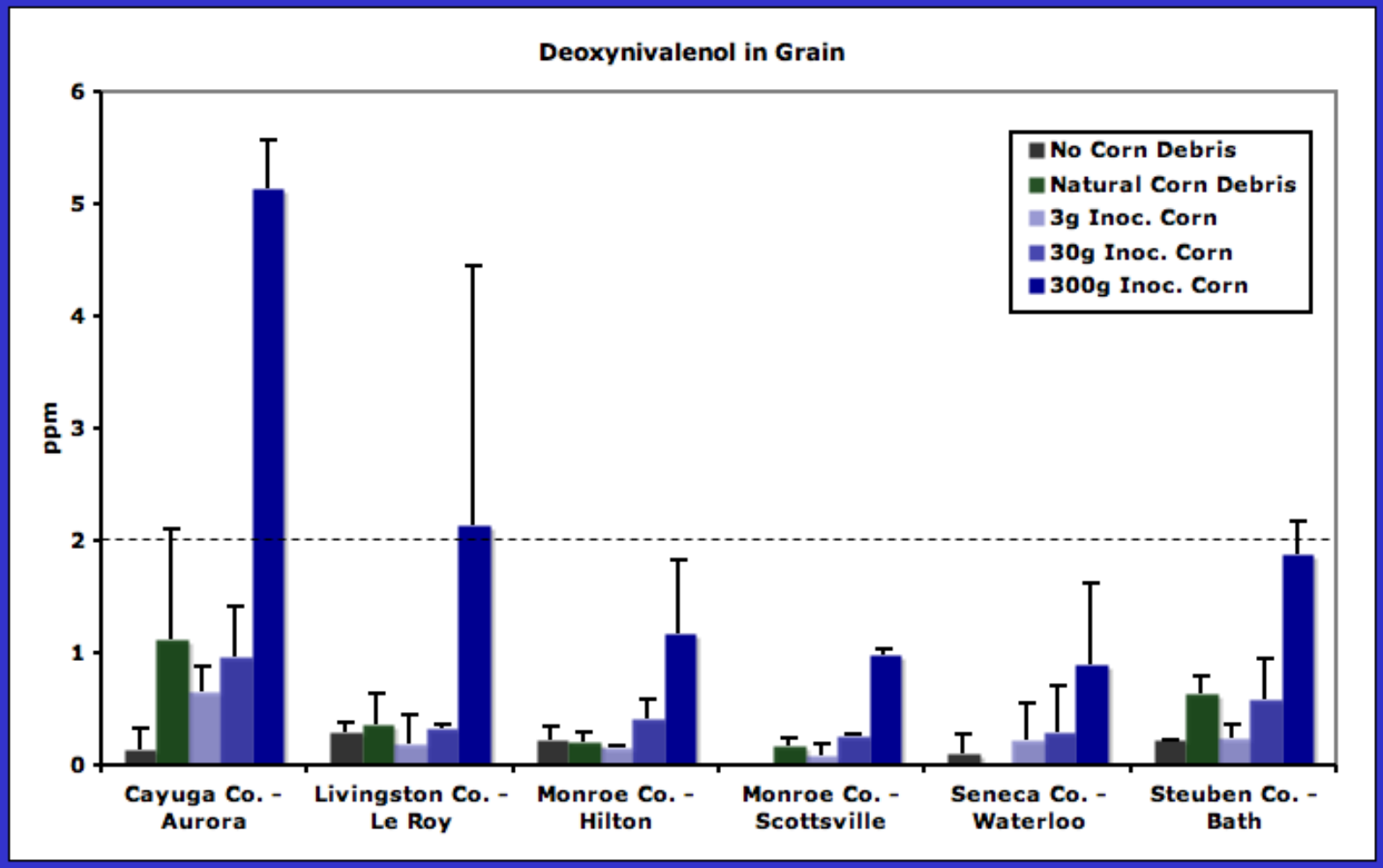
Naturally overwintered, local corn stalks

Lab-inoculated corn stalks

Pilot corn debris microplot experiments
commercial wheat fields in New York in 2007-08



Pilot corn debris microplot experiments commercial wheat fields in New York in 2008



Spikes above natural corn debris and above clonal inoculum one-tenth or one-hundreth strength showed higher infection and DON than control, but not statistically significant different

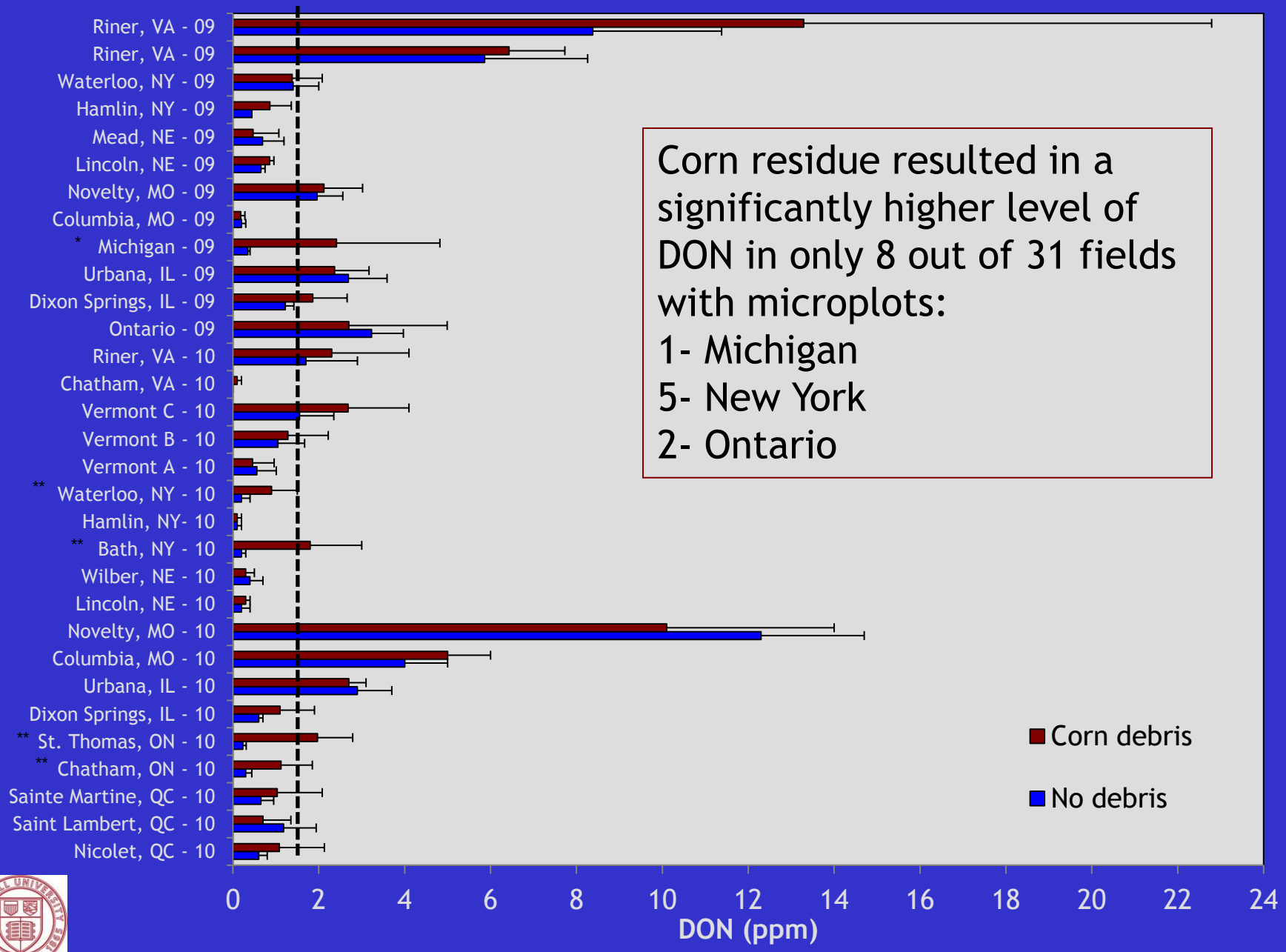
Twenty-one corn debris microplot experiments in winter wheat fields in five states (2009-2010)

Gary Bergtrom, Carl Bradley, David Schmale, Laura Sweets, Stephen Wegulo

Plus nine satellite experiments in Michigan, Vermont, Ontario, and Quebec

Collaborators:
Ann Hazelrigg, Martin Nagelkirk, Albert Tenuta, Pierre Filion, Sylvie Rioux

DON Concentration in Mature Grain



Corn residue resulted in a significantly higher level of DON in only 8 out of 31 fields with microplots:

1- Michigan
5- New York
2- Ontario

Previous Crop Residues and Tillage

Spores liberated from within-field debris may provide a significant fraction of inoculum for a given field though often less than 30% (most important in FHB-limiting environments)

Regional, atmospheric spore populations generally provide more inoculum than within-field sources (especially under FHB-conducive environments)

Inoculum (debris) management strategies in individual fields may result in incremental reductions of FHB & DON, and thus contribute to integrated management

Residue Management

Influencing the survival of *Fusarium* in wheat residues

Field trials - Crookston, Ulen & Humboldt, MN

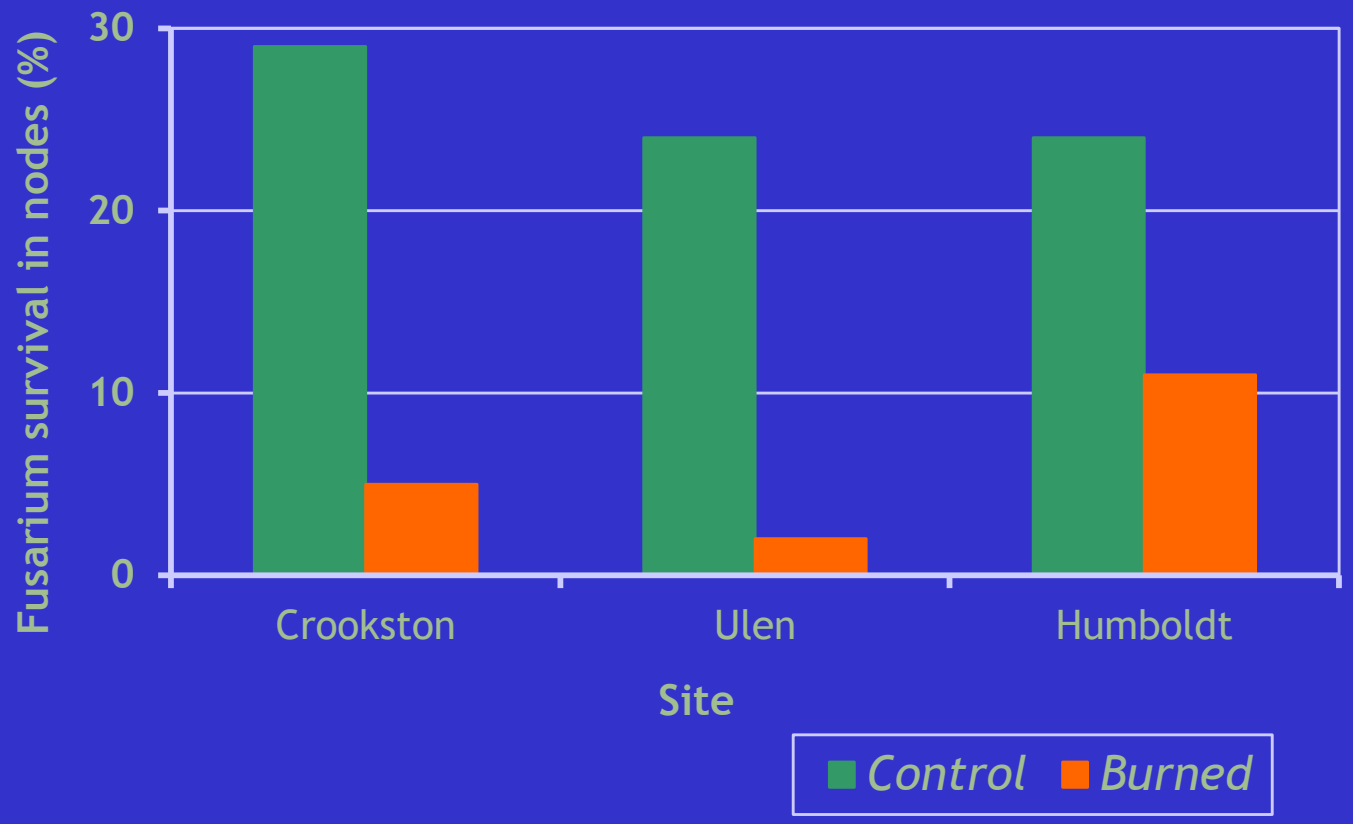
- wheat residue - crop harvested
- residue flamed 1-5 days post planting (wheat and barley) using a propane-powered alfalfa burner
  - light (1.3 m/s) and severe (0.5 m/s)
- wheat residues, soil samples and wheat and barley plants were collected over the season for analysis

Dill-Macky and Salas
Plant Disease 2004

Effect of flaming residues

	Nodes (no./m^2)	*F.g.* survival (%)	*F.g.* in soil (cfu/g)
Control	62 a	33 a	693 a
Light	46 b	13 b	598 b
Severe	36 c	9 b	522 b

Impact of flaming on *Fusarium* survival in residues



Targeting *Fusarium* in residues

Residues need not be entirely destroyed to reduce the colonization by pathogens, including *F. graminearum*

Flaming residues is an impractical solution for FHB - BUT demonstrates proof of concept that treating residues to reduce *Fusarium* pathogens may provide a measure of control esp. when sources of exogenous inoculum are limiting

F. graminearum, and other pathogens of wheat and barley, are not evenly distributed in the canopy (data not shown) - the distribution may provide clues as to the source(s) of inoculum

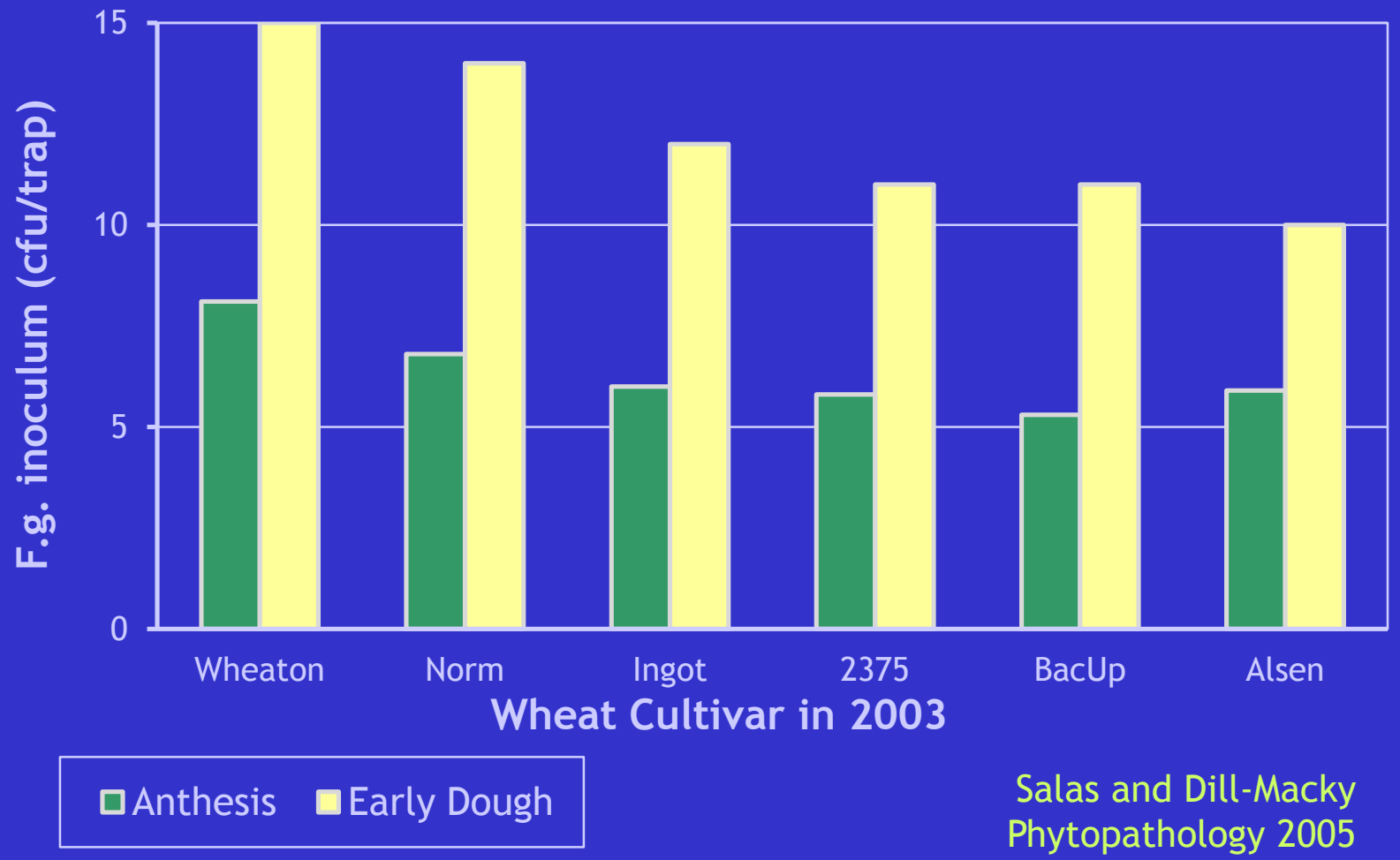
Effect of host resistance on FHB

Field trials - Rosemount, MN

- wheat residues
  - susceptible - Wheaton, Norm
  - mod. susceptible - 2375, Ingot
  - mod. resistant - Backup, Alsen
- chisel plowed after harvest
- planted to 'Wheaton' wheat in spring
- *F.g.* isolated from i) residues, ii) air in canopy at early dough - Komada plates, iii) plants at hard dough

Dill-Macky and Salas
Plant Disease 2004

Effect of 2003 wheat cultivar selection on the airborne *Fusarium* inoculum in 2004 crop



Salas and Dill-Macky
Phytopathology 2005

Effect of host resistance on *Fusarium* survival

Resistance to FHB in wheat influences the colonization of residues as measured by their ability to support *Fusarium* survival and inoculum production

FHB resistance can provide a benefits in future cropping seasons by reducing future inoculum – differences likely to be more evident in commercial fields than small plots used in research

Residues are problematic as they harbor the initial inoculum from which epidemics may develop

increased corn acreage

esp. Bt-corn

other host & nonhost residues

Residues Management Strategies for FHB in Barley

Avoid growing barley in proximity to cereal debris
Crop Rotation: follow non-host crops
Use underseeded crops as a barrier to splash dispersal

Remove or destroy cereal debris
Tillage: bury debris by plowing, burning or harvesting residue
Chopping, splitting, or other size reduction

Treat debris to reduce *Fusarium* survival/sporulation
Green manures, organic acids, C/N sources, soil, clay, lime, microbial inoculants

Reduce *Fusarium* content in debris
Plant resistant cereals

An argument for cultural control practices in the management of FHB

Very susceptible cultivars have been eliminated from production in FHB prone regions

Resistance has been improved - BUT it is unrealistic to anticipate that barley or wheat cultivars immune to FHB will be developed or that the best resistance(s) available will be sufficient to eliminate the risk of FHB

Improved levels of resistance will however:
i) reduce the risk of FHB in the growing season AND
ii) reduce the risk of future epidemics by reducing the level of *Fusarium* in crop residues

An argument for cultural control practices in the management of FHB

Chemical control is needed in the management of FHB

Improved application technologies and the development of forecasting systems have improved our ability to use fungicides as control measures

High inoculum pressure and weather conditions favorable for disease can still overwhelm best management practices

- research possibilities for cultural control of FHB -

Eliminating *Fusarium* inoculum from residues - chemical control directed to the residues, interfering with *Fusarium* sporulation

Promoting residue decomposition - shredding (Bt-corn), soil amendments that increase decomposition rates

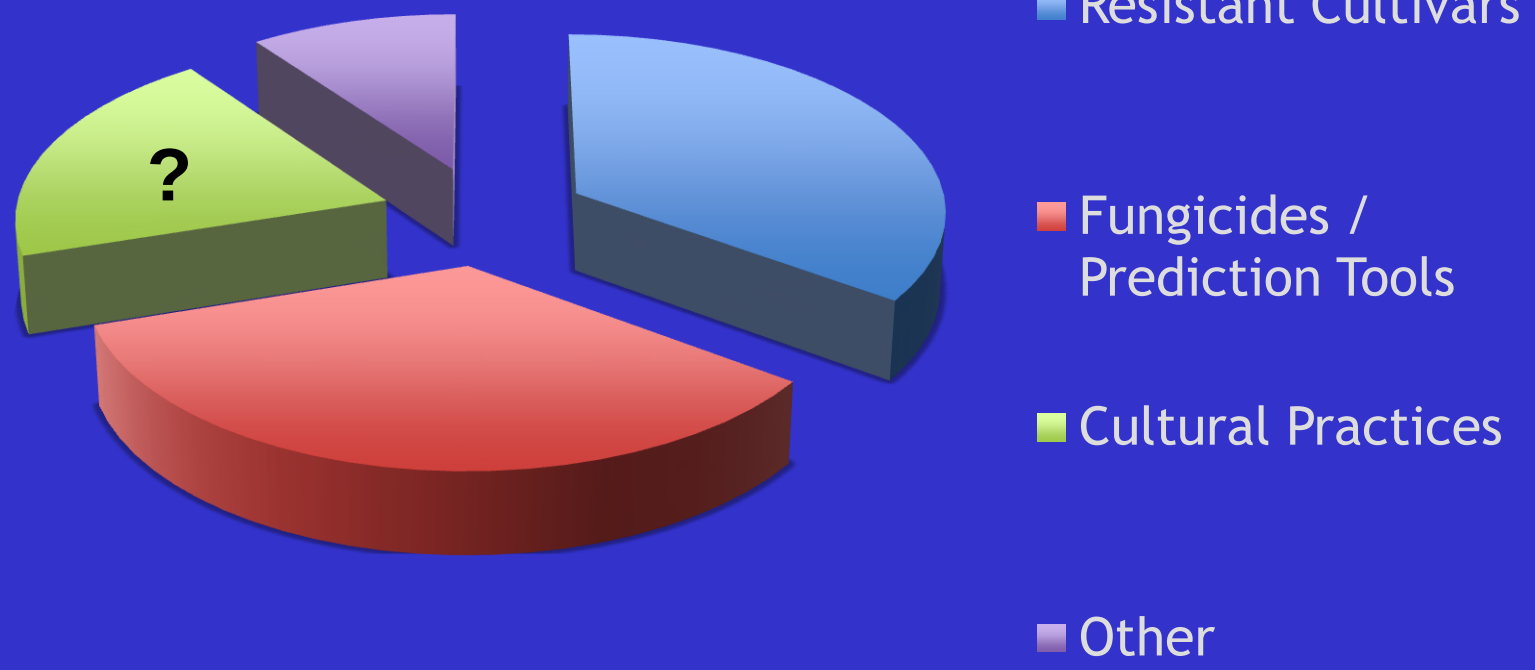
Formulating biological control agents for greater efficacy

Promoting *Fusarium*-antagonists - green manures, soil amendments or applications of fungicides or BCA's directed to reducing *Fusarium* in residues

Any solution must be able to be effectively integrated into the production system for cereal crops

What is the contribution of cultural control to integrated management of FHB/DON?

No single answer for all environments and cropping systems



SCAB SMART - www.scabsmart.org

Scab Smart provides information on key management information for each small grain class affected by this disease in the US. **Scab Smart** is intended as a **quick guide** to the integrated strategies that result in optimum reduction in Fusarium Head Blight (FHB=Scab) and the primary associated mycotoxin (DON). Click on the following links to learn about strategies for your grain class or use the top drop-down menus for faster navigating:

Variety Resistance

Scab Forecasting

Fungicides

Crop Rotation

Other Management Strategies: Residue Management, Planting Date, Harvest Practices, Seed Treatment

All information provided is based on successful strategies identified by extensive research supported by the US Wheat and Barley Scab Initiative with funding provided by USDA-ARS.

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