Meta-analysis of 19 years of fungicide trials for the control of Fusarium head blight of wheat

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Support from the U.S. Wheat and Barley Scab Initiative (USWBSI)

Introduction

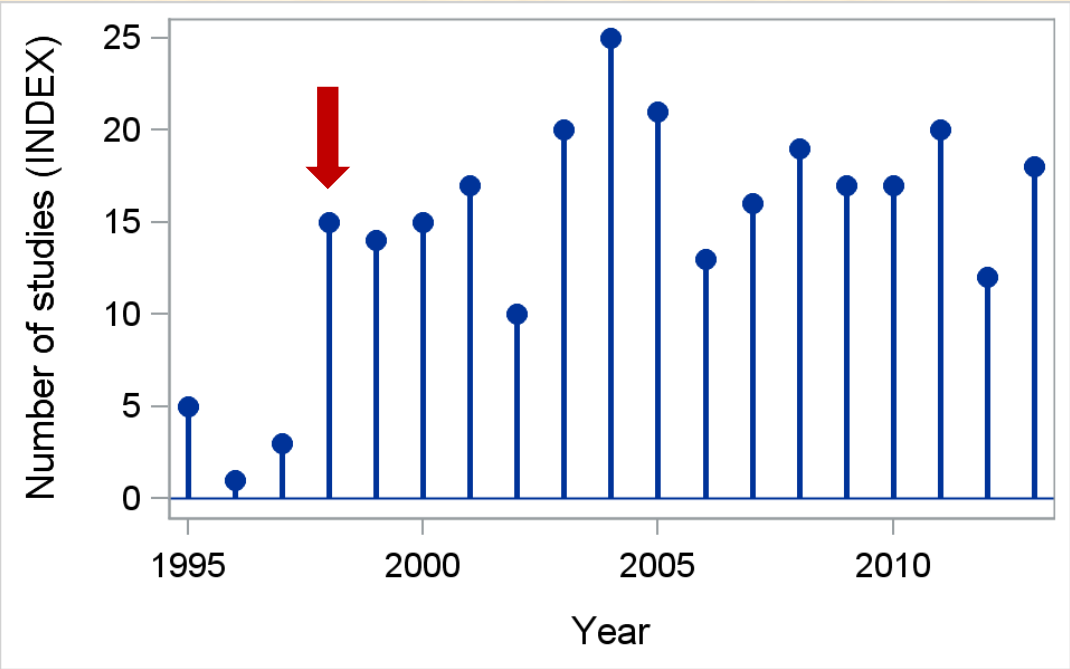
- In the aftermath of the 1993 major epidemic of Fusarium head blight (FHB), there was skepticism about the value of fungicides for controlling FHB (McMullen et al. 2012)
  - Initial studies in North Dakota (and elsewhere) showed that some control could be achieved using a single fungicide application
- The Uniform Fungicide Trials (UFTs) of the USWBSI were initiated in 1998 based, in part, on the field trials in North Dakota
- A quantitative research synthesis, utilizing **meta-analysis**, was conducted in the late 2000s to estimate the effects of five fungicides on the control of FHB Index and DON, as well as yield and test weight
  - Paul et al. 2007. *Phytopathology* 97: 211-220.
  - Paul et al. 2008. *Phytopathology* 98: 999-1011.
  - Paul et al. 2010. *Phytopathology* 100: 160-171.
  - Madden & Paul. 2011. *Phytopathology* 101: 16-30.

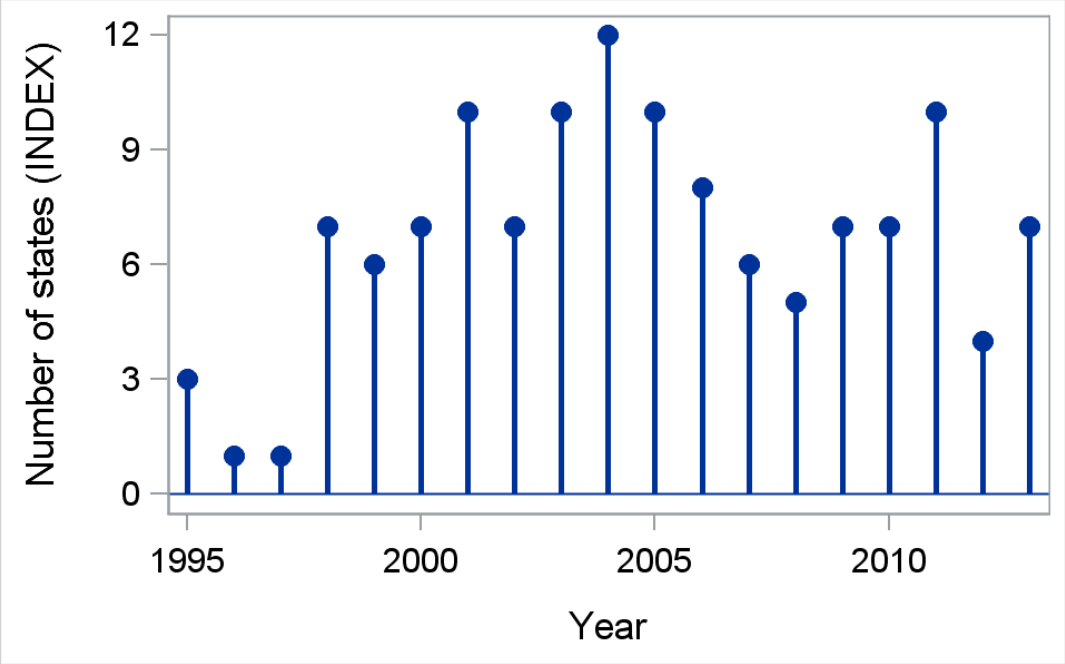
Results up to 2005 for INDEX and DON, and up to 2007 for YIELD

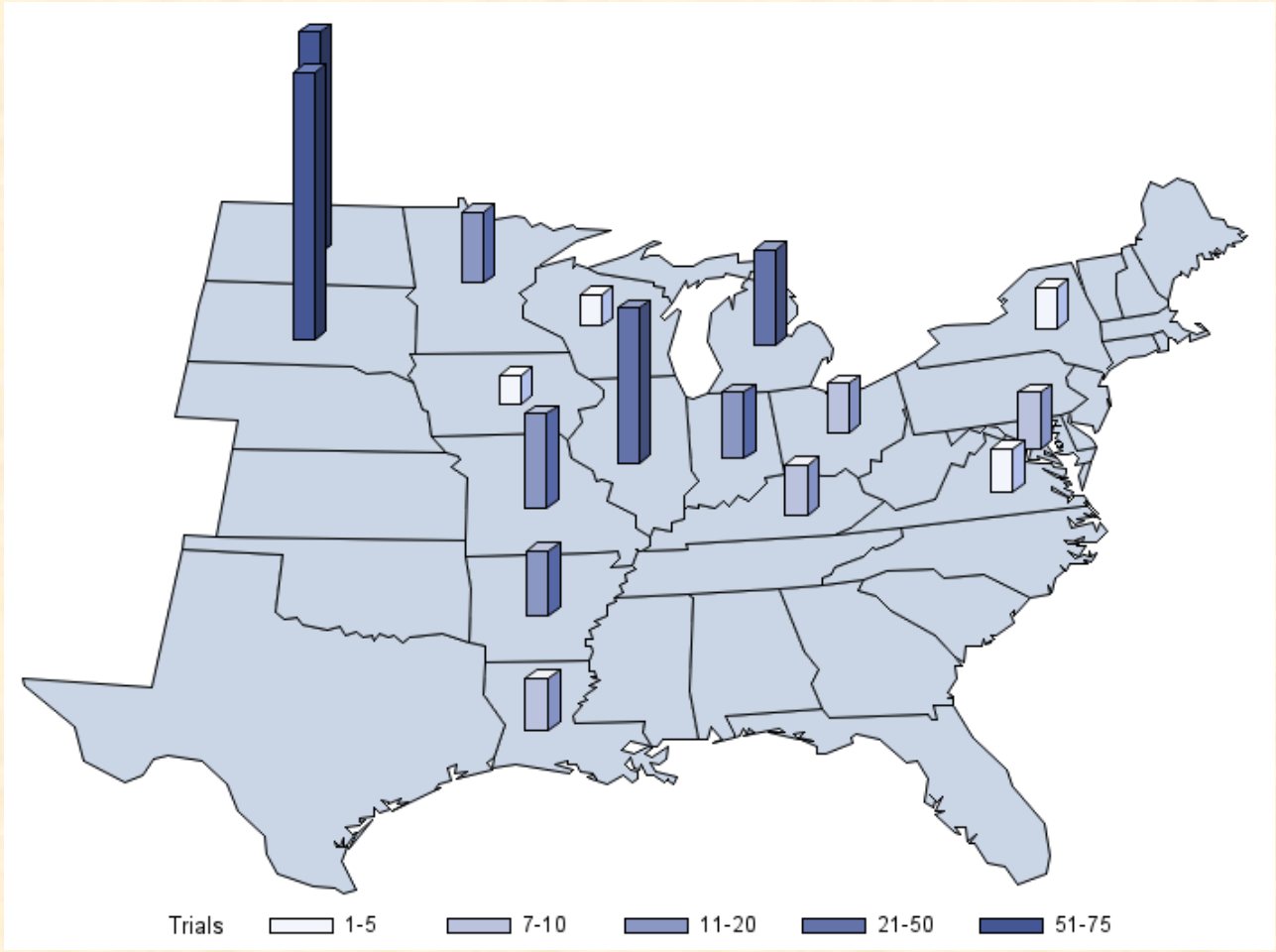
- Results showed a *reasonable* efficacy of the best fungicides
- The UFTs have continued until the present, in order to develop a better understanding of fungicide effects and to explore alternatives to the now standard fungicide program for this disease

Year	*Some* major developments in the Uniform Fungicide Trials of the USWBSI
1995	DMI: Propiconazole (Tilt) → 2007 DMI: Tebuconazole (Folicur*) →2013
1998	******Uniform Fungicide Trials (UFTs) begin****** ***(support by USWBSI)***
2000	DMI: Metconazole (Caramba*) →2013
2001	DMI: Prothioconazole (Proline*) →2004, ’07, ’08, ’12
2002	DMI: Tebuconazole+Prothioconazole (Prosaro*) →2013
2008	Strobilurins at different times: Pyraclostrobin (Headline)→2012 Metconazole at low rate (only 2008)
2009	DMIs at different times→2013 Mixtures of DMIs→2013 (not all years)
2011	Strobilurin (early) + DMI (late) →2012 Other strobilurins (only 2011)

DMI: demethylation inhibitor fungicide (a sterol inhibitor).
The DMIs used in this investigation are triazoles.


Number of studies (INDEX)
25
20
15
10
5
0
1995
2000
2005
2010
Year


Number of states (INDEX)
12
9
6
3
0
1995
2000
2005
2010
Year


Trials
1-5
7-10
11-20
21-50
51-75

UFT Collaborators

- **A.P. Grybauskas**, University of Maryland (*retired*)
- **P. Hart**, Michigan State Univ. (*retired*)
- **W.W. Kirk**, Michigan State Univ.
- **D. Brown-Rytlewski**, Michigan State Univ.
- **M. Nagelkirk**, Michigan State Univ.
- **E.A. Milus**, Univ. Arkansas (*retired*)
- **M. Draper**, South Dakota State Univ. (now at USDA, D.C.)
- **L.E. Osborne**, South Dakota State Univ. (now with Pioneer Hi-Bred)
- **K.R. Ruden**, South Dakota St. Univ.
- **E. Byamukama**, South Dakota St. Univ.
- **B.G. Young**, Southern IL Univ. (now with Purdue Univ.)
- **D. Hershman**, Univ. of Kentucky (*retired*)
- **E. Stromberg**, Virginia Tech (*retired*)
- **C. Bradley**, Univ. of Illinois
- **W. Pedersen**, Univ. of Illinois (*retired*)
- **L. Sweets**, Univ. of Missouri
- **P. Paul**, Ohio State Univ.
- **P. Lipps**, Ohio State Univ. (*retired*)
- **K.A. Wise**, Purdue Univ.
- **G. Shaner**, Purdue (*retired*)
- **G. Buechley**, Purdue
- **P.D. Esker**, Univ. Wisconsin (now at Univ. of Costa Rica)
- **S. Conley**, Univ. Wisconsin
- **D. Smith**, Univ. Wisconsin
- **G. Bergstrom**, Cornell Univ.
- **M.P. McMullen**, North Dakota State Univ. (*retired*)
- **A. Friskop**, North Dakota St. Univ.
- **S. Halley**, North Dakota St. Univ. (now with Valent)
- **R. Dill-Macky**, Univ. Minnesota
- **J.J. Wiersma**, Univ. Minnesota
- **M. Smith**, Univ. Minnesota
- **C.R. Hollingsworth**, Univ. Minnesota (now with USDA-APHIS)
- **R. Jones**, Univ. Minnesota
- **G. Padgett**, Louisiana State Univ.
- **G. Munkvold**, Iowa State Univ.

Data analysis

- Four response variables: **FHB Index**, **DON**, **Yield**, **Test Weight**
  - Mean for each treatment of each study
- Results from a total of K = 309 studies over 19 years
  - Index: 292 studies
  - DON: 207 studies
  - Yield: 245 studies
  - Test wt.: 225 studies
- Number of treatments: 27 (including the control)
  - A treatment must be included in at least 10 studies to be used
- Analysis:
  - Multi-treatment random-effects meta-analysis as described in Paul et al. (2008), with a 2^{nd} order factor-analytic among-study variance-covariance structure for the treatment means
    - Within-study variances (sampling variances) determined from the residual variance for each individual study, and fixed for each study

Data analysis

- For analysis of disease index and DON, interest is in **Percent Control** (C), not necessarily in the difference in means between the control (check) and treatment
  - For instance, a reduction in mean DON of **2 ppm** is small if the control mean is **15 ppm**, but large if the control mean is **3 ppm**
  - By using C, one scales the treatment effect by the magnitude of the control mean
  - For the example with a reduction of 2 ppm:
    - C = 13% when the control mean is 15 ppm,
    - C = 67% if the control mean is 3 ppm

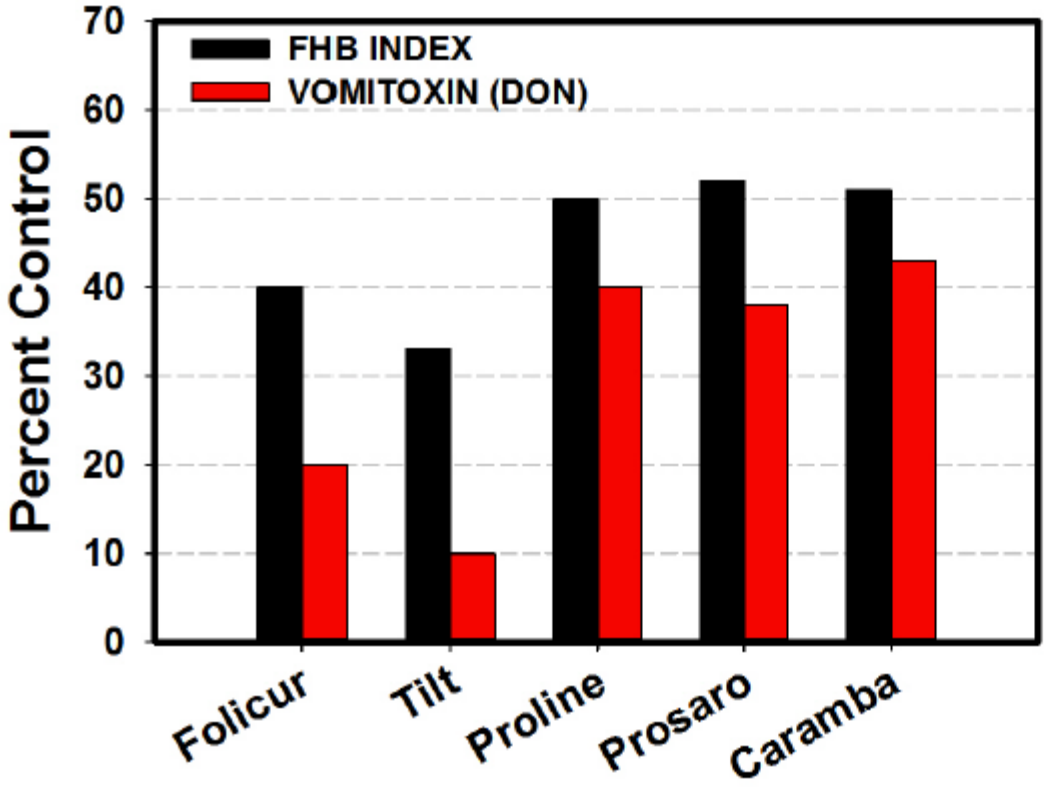
A negative value for C indicates that the treatment mean is *greater* than the control

$$C = 100 \cdot \frac{\bar{X}_{Control} - \bar{X}_{Treat}}{\bar{X}_{Control}} = 100 \cdot \left(1 - \frac{\bar{X}_{Control}}{\bar{X}_{Treat}}\right)$$

- To account for the complex statistical properties of ratios, the meta-analysis is based on the log of the means for each study as the response variable: $Y_{ij} = \ln(\bar{X}_{ij})$, for the i-th study and j-th treatment

Percent Control: *Reduction* in Fusarium head blight (scab) disease index and DON relative to the non-sprayed control

Spraying triazole (DMI) fungicide at anthesis (flowering; growth stage 10.5.1)



Portion of a meta-analysis involving, in total, 309 trials over 19 years.

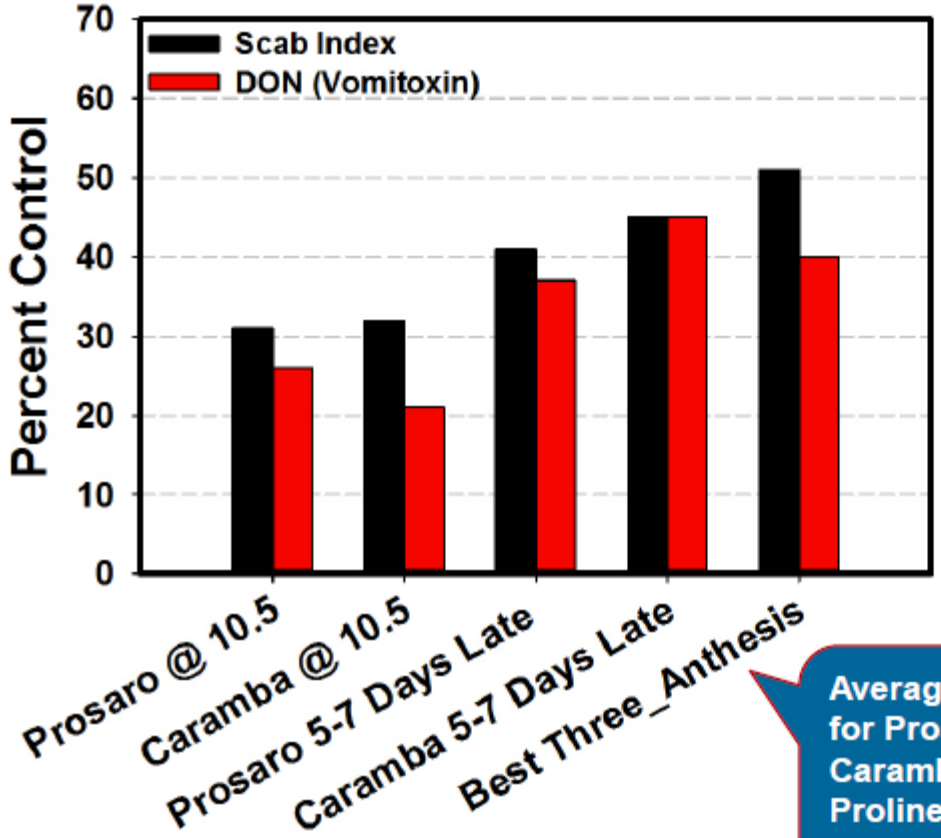
Incomplete analysis.

Source: Madden, Paul, Bradley.

Research support from the U.S. Wheat and Barley Scab Initiative (USWBSI)

Percent Control: *Reduction* in Fusarium head blight (scab) disease index and DON relative to the non-sprayed control

Spraying triazole fungicide early (heading: growth stage 10.5), or late (5-7 days after flowering or anthesis), compared with average of the best three fungicides applied at anthesis (growth stage 10.5.1)



Portion of a meta-analysis involving, in total, 309 trials over 19 years.

Incomplete analysis.

Source: Madden, Paul, Bradley.

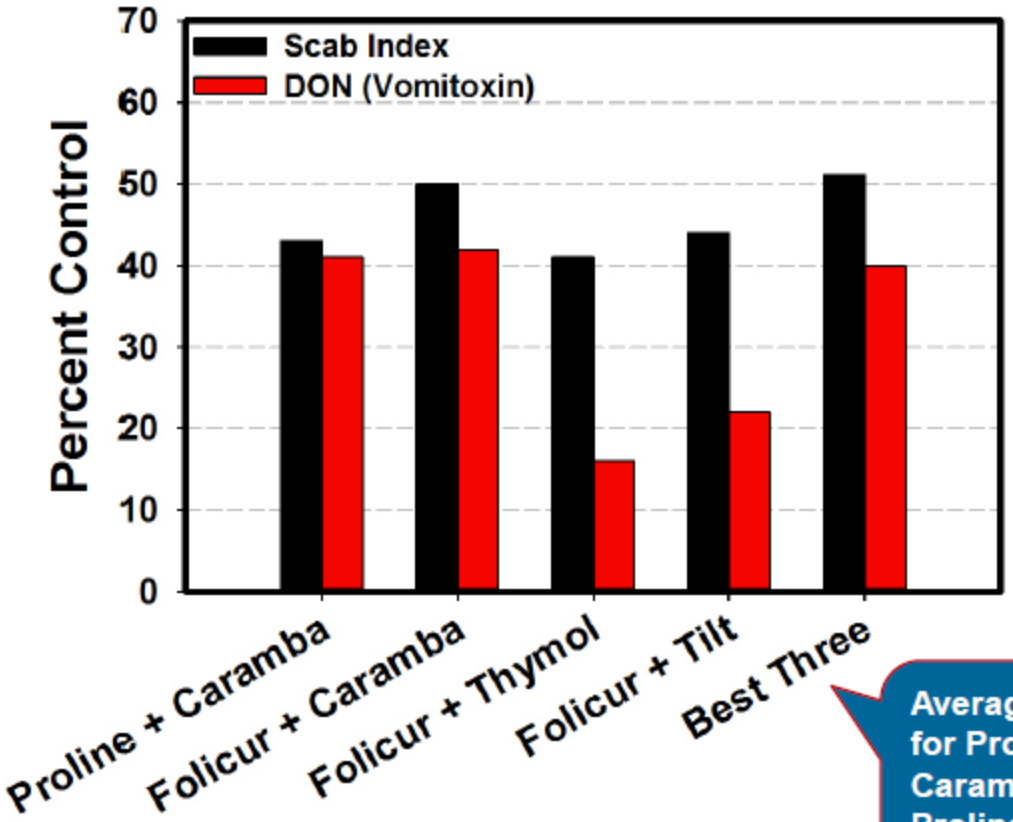
Average result for Prosaro, Caramba, and Proline applied at anthesis

Research support from the U.S. Wheat and Barley Scab Initiative (USWBSI)

A late application of a DMI fungicide can be effective for disease and DON control

Percent Control: *Reduction* in Fusarium head blight (scab) disease index and DON relative to the non-sprayed control

Spraying with tank mixes of triazole (or other) fungicides, applied at anthesis (flowering; growth stage 10.5.1).



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Average result for Prosaro, Caramba, and Proline applied at anthesis

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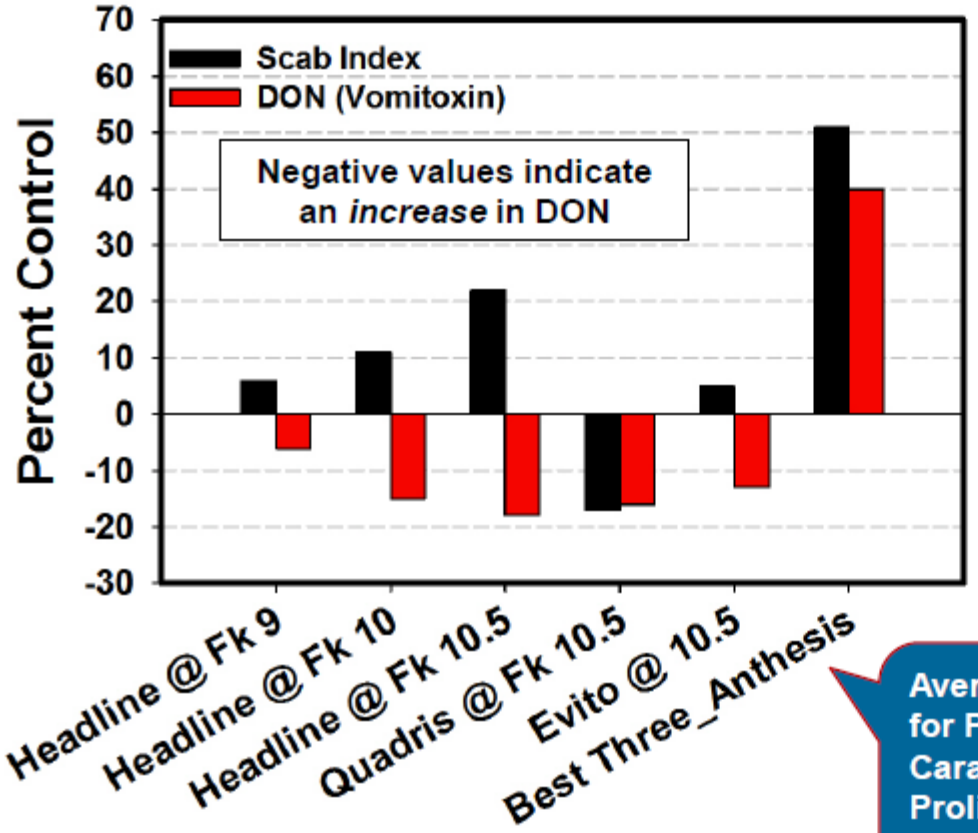
Some tank mixes of DMI fungicides are very effective

Percent Control: *Reduction* in Fusarium head blight (scab) disease index and DON relative to the non-sprayed control

Spraying with a strobilurin fungicide at different growth stages (flag leaf [Fk 9], boot [Fk 10], heading [Fk 10.5]), compared with average of best three triazoles applied at anthesis (Fk 10.5.1)



Portion of a meta-analysis involving, in total, 309 trials over 19 years.

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Source: Madden, Paul, Bradley.

Average result for Prosaro, Caramba, and Proline applied at anthesis

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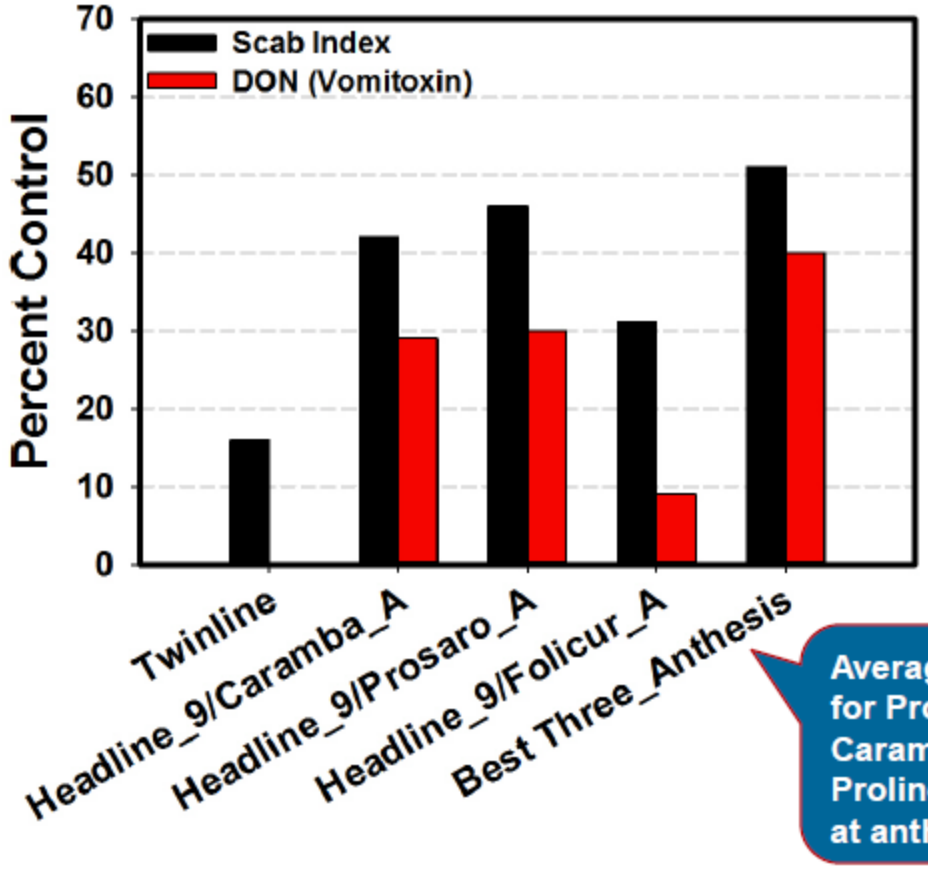
Strobilurin fungicides increase DON relative to the control

Percent Control: *Reduction* in Fusarium head blight (scab) disease index and DON relative to the non-sprayed control

Spraying with a *mixture* of a strobilurin and triazole at heading (Twinline), or with a strobilurin (Headline) at flag leaf (growth stage 9) followed by a triazole fungicide at anthesis (stage 10.5.1), compared with average of best three triazoles applied at anthesis



Average result for Prosaro, Caramba, and Proline applied at anthesis

Portion of a meta-analysis involving, in total, 309 trials over 19 years.

Incomplete analysis.

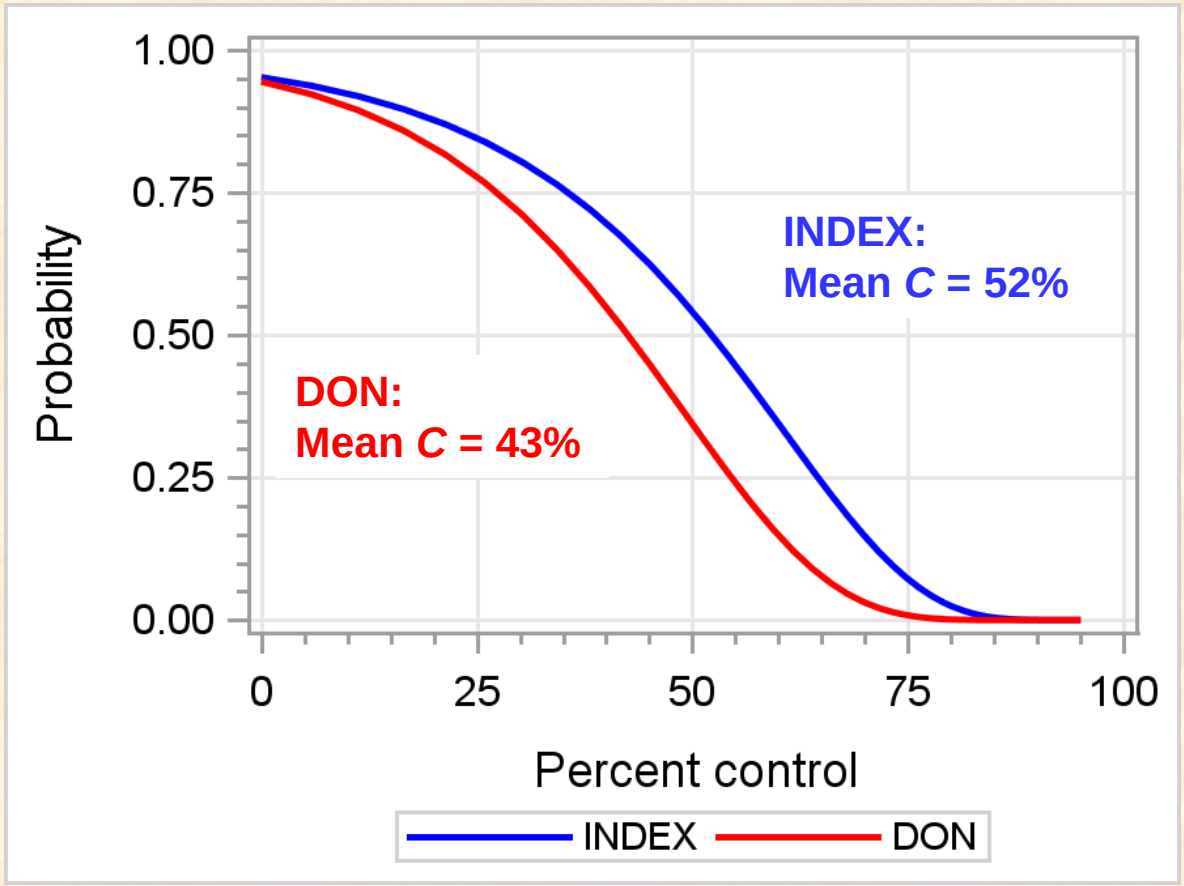
Source: Madden, Paul, Bradley.

Research support from the U.S. Wheat and Barley Scab Initiative (USWBSI)

One cannot counteract the negative effects of an early strobilurin fungicide on DON with a later application of a DMI fungicide

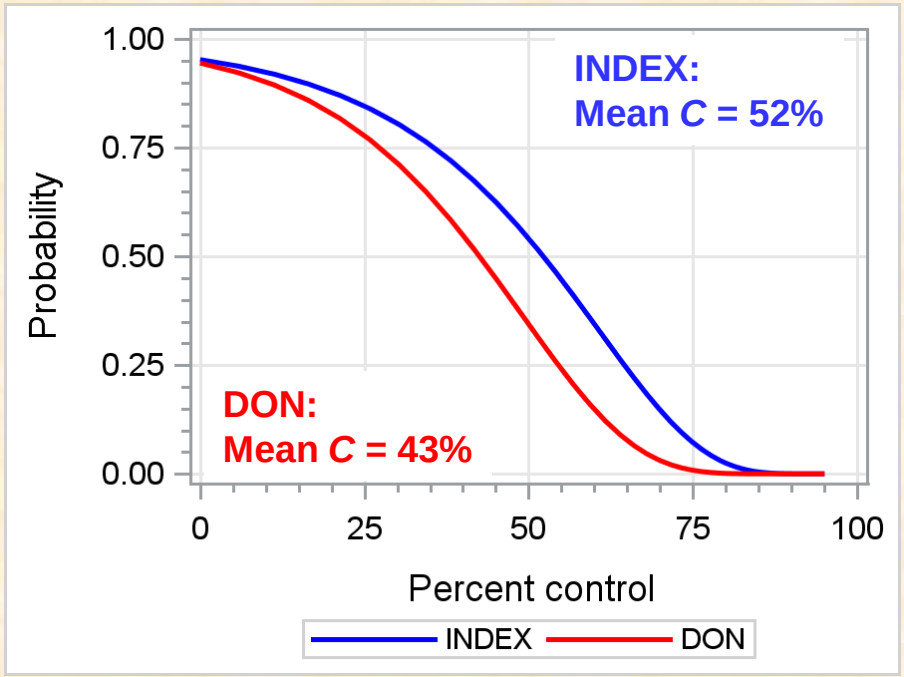
Probability of percent control in a randomly chosen future study (or field) exceeding specified values (e.g., Prob(*C* ≥ 50%))

Metconazole (Caramba) @ anthesis(10.5.1)

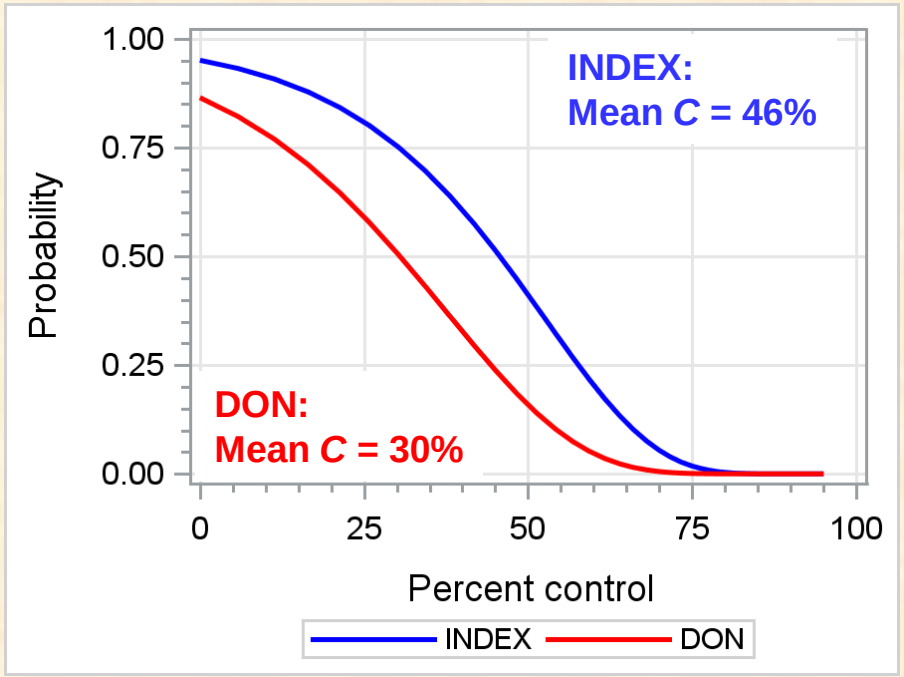


Probability of percent control in a randomly chosen future study (or field) exceeding specified values (e.g., Prob(*C* ≥ 50%))

Metconazole (Caramba) @ 10.5.1



Headline @ 9 + Prosaro @ 10.5.1



Conclusions

- "*Fusarium head blight is a difficult disease to manage*"
  - McMullen et al. (2012. *Plant Disease*)
- A single application of some DMI fungicides can result in significant reductions in mean INDEX and DON, and increases in mean yield and test weight (latter results not shown here)
- The greatest reduction in INDEX and DON is obtained with prothioconazole (Proline), metconazole (Caramba), or tebuconazole+prothioconazole (Prosaro) applied at anthesis
  - Other mixtures of DMI fungicides applied at anthesis may result in similar control
  - Earlier applications of fungicides result in substantially lower percent control
  - Application of some DMI fungicides shortly *after* anthesis may result in control similar to that found with application at anthesis
- Percent control exceeding 50-55% for INDEX and 40-45% for DON is *very* difficult to achieve with susceptible cultivars, overall
  - Management of FHB requires integration of multiple control tactics
- Strobilurin fungicides should be avoided for managing FHB
- Many additional analyses are still required to assess the effects of moderator variables, quantify distributions, and determine the economic effects of fungicides