

Breeding for Scab Resistant Hard Winter Wheat: The Thrill of Victory and the Agony of Defeat

P. Stephen Baenziger, Stephen N. Wegulo,
William Berzonsky, Guihua Bai,
Ali Bakhsh, and MengYuan Wang



Acknowledgements:

- HWWCP
 - Bill Bockus, Erick De Wolf, Bikram Gill, and Alan Fritz
 - Bob Bowden and Floyd Dowell
 - Jeff Stein
 - Joel Ransom and Frans Marais

ACKNOWLEDGEMENT

This material is based upon work supported by the U.S. Department of Agriculture – Agricultural Research Service through the U.S. Wheat & Barley Scab Initiative.



U.S. Wheat & Barley
Scab Initiative

Topics:

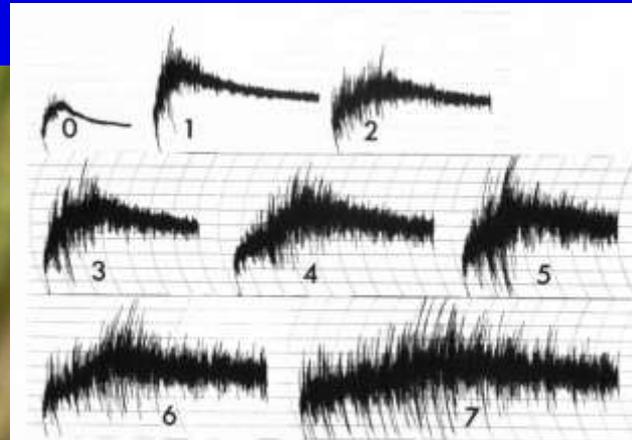
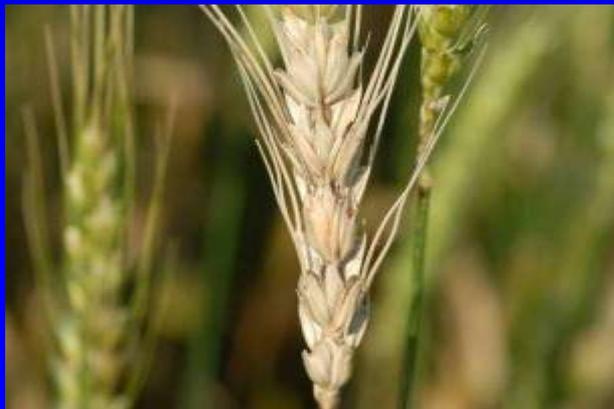
- The Nature of the Problem
- Our Strategy
- Our Successes
- What Remains to be Done
- Where do we go from here? The remaining challenges.

The Nature of the Problem:

- Scab is an episodic disease. The Great Plains region is prone to very erratic weather (extreme drought to extreme moisture).
- Corn is a major crop in much of Nebraska and many of our rotations are wheat, fallow, corn with minimum or no tillage. Residue is on the surface.
- The disease affected area is spreading.
- Long generation times in winter wheat and a difficult assay.
- Frustrating disease to work with, so you have to be opportunistic.

Our Strategy:

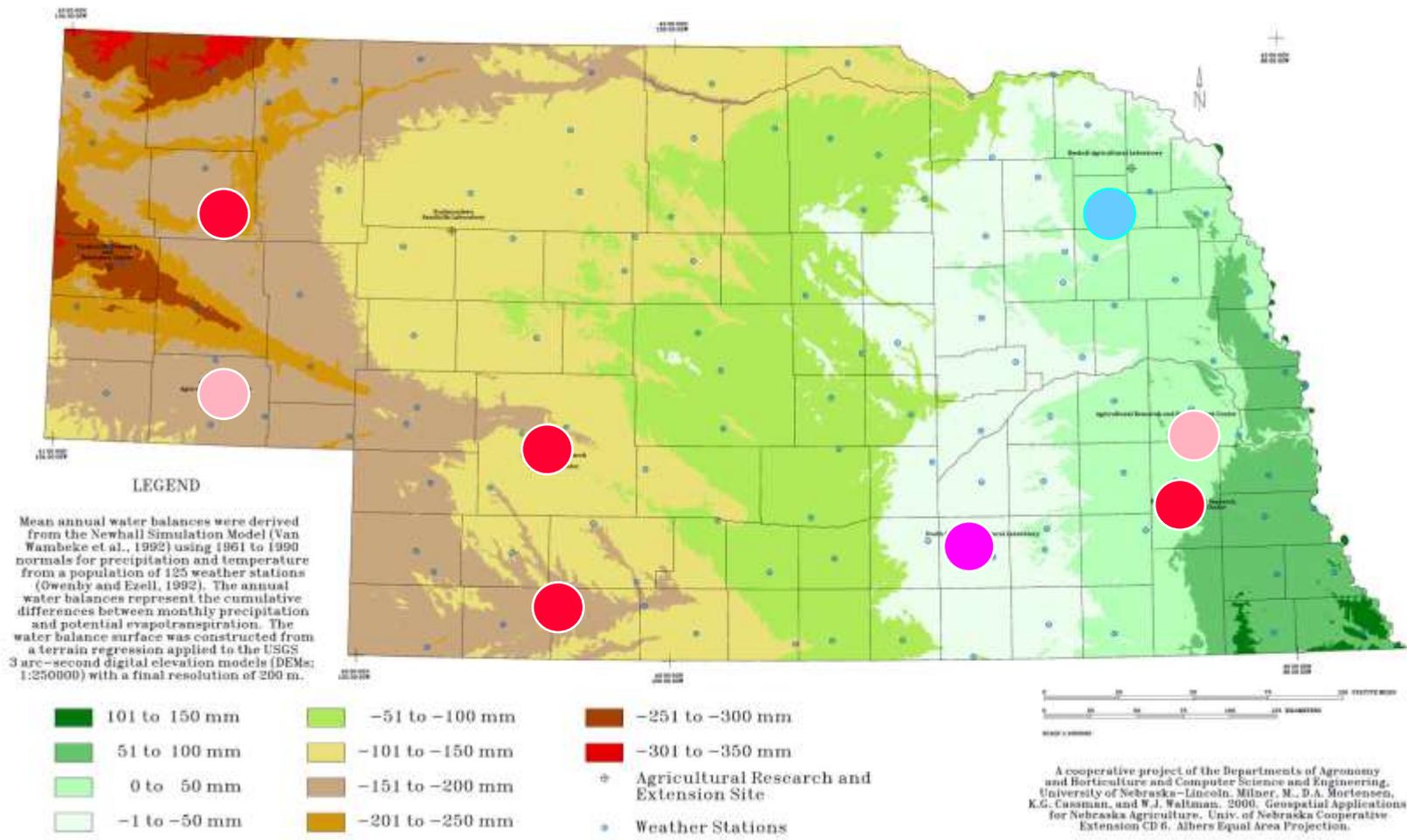
- Scab is one on many breeding objectives.
- The most effective strategy will couple genetic resistance with fungicide applications and sound management (organic market is growing).
- Breeders need defined targets.

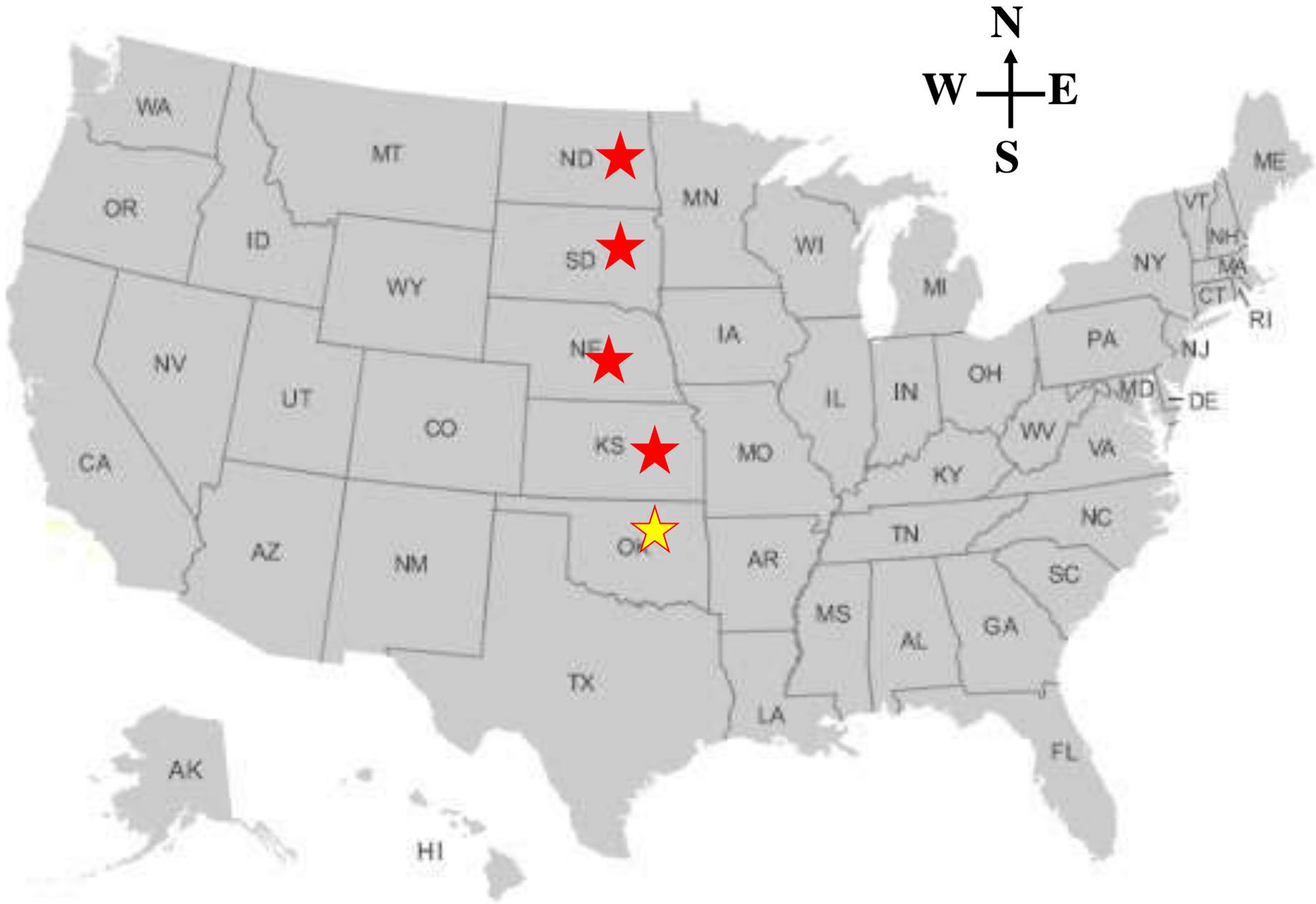


Our Target: By 2015

- 90% of the wheat grown in the affected areas will be resistant cultivars.
- The level of DON will 0.5 ppm (matching the European standard or the standard that is more stringent for the export market).
~50% of our wheat is exported
- The whole grain market is expanding so milling off the bran will not be an option for many of our products (1 ppm DON).

MEAN ANNUAL WATER BALANCE ACROSS NEBRASKA LANDSCAPES





Our Successes:

- Excellent cultivars with FHB tolerance available throughout the region.
- Cultivars were developed by public and private breeders—a necessary collaboration.
- None would have been found without funding from the Scab Initiative and the use of mist nurseries.
- None would have the data package on their resistance without the Scab Initiative.
- Set of FHB testing sites (for public and private testing) which span the region, but are very thin (4 sites).



Hard Red Winter Wheat

www.ScabSmart.org

The varieties listed for each state are adapted for production in that state and have the best available resistance to head Fusarium head blight (FHB=scab). These varieties are known to have moderate levels of resistance to head scab, and should reduce the risk of severe yield losses and DON contamination.

Kansas

Art
Everest
Hitch
Overland

Nebraska

Art
Everest
Hitch
Lyman
Millenium
Overland

South Dakota

Arapahoe
Lyman
Overland

North Dakota

Lyman
Overland

Husker Genetics Brand Overland (NE01643)

- Most widely grown cultivar in Nebraska (~11% of our acreage) and growing.
- Licensed for sale in SD, ND, MN, KS, and CO.
- Excellent disease package for most of our diseases.
- Flaws: adequate end-use quality, Susceptible to WSMV and WSBMV.

The Agony of Defeat:

- Despite hundreds of crosses, few if any released lines with *Fhb1*. We rely on native resistance.
- We have identified lines with phenotypic tolerance to FHB, but accumulate DON which makes our phenotypic screens more difficult.

Why No Lines with *Fhb1*?

- Generation time?
- Is there a pleiotropic or linked effect of *Fhb1* that somehow affects selection or agronomic performance in Great Plains winter wheats?

Development of population (Ali Bakhsh)

Alsen x NE00403

FF

ff

Three way cross

F_1

x

NE02584

Ff

ff

Seed harvested in bulk

F_1

Ff

ff

F_2 Seeds
Bulked

F_2

$\frac{1}{4}$ FF : $\frac{1}{2}$ Ff : $\frac{1}{4}$ ff

ff

F_3 Seeds
Planted in
Families

F_3

$\frac{3}{8}$ FF : $\frac{1}{4}$ Ff : $\frac{3}{8}$ ff

ff

50%

50%

$\frac{3}{16} + \frac{1}{8}$

$\frac{3}{16} + \frac{8}{16}$

F_6

$\frac{5}{16}$ F-

$\frac{11}{16}$ ff

		F-	ff
Observed	o	44	71
Expected	e	35.93	79.06
	o-e	8.07	-8.06
	$(o-e)^2$	65.1249	64.9636
	$\frac{(o-e)^2}{e}$	1.8125	0.8216

$$\chi^2 = 1.8125 + 0.8216 = 2.634 \text{ NS}$$

$$X^2_{p0.05} = 3.84$$

Population was screened for *Fhb1* markers by using SSR markers GWM533, STS3B-256

Field evaluation at Lincoln in 2009 -10

After harvest, a population of 42 *Fhb1* lines and 3 Checks was developed for 2010 -11 experiments

20	Homozygous Resistant (confirmed with UMN10)
20	Homozygous Susceptible
1	Blend of 20 resistant
1	Blend of 20 susceptible
3	Checks

Experiment was planted at 6 locations with 3 reps using an incomplete block design with 9 incomplete blocks of 5 entries at each location

Lincoln	Mead
North Platte	Clay Center
Sidney	Alliance

**Combined Yield
For 5 locations**

POP1-----Susceptible (without *Fhb1*)

POP2-----Resistant (with *Fhb1*)

Blend1-----Susceptible blend (without *Fhb1*)

Blend2-----Resistant blend (with *Fhb1*)

Check----- NE00403, Camelot, Overland

**Type 3 Tests of
Fixed Effects**

Effect	Num DF	Den DF	Pr > F
winsur	1	319	0.001
Loc	4	10	<.0001
Trt	4	319	<.0001
ENTRY(Trt)	40	319	<.0001
Loc*Trt	16	319	<.0001
Loc*ENTRY(Trt)	160	319	<.0001

Contrasts

Label	Num DF	Den DF	Pr > F
Blend1 V Blend2	1	319	0.868
POP1 V POP2	1	319	<.0001
Check V POP1 & POP2	1	319	<.0001
Blend1 & Blend2 V POP1 & POP2	1	319	<.0001
Check V POP2	1	319	<.0001

**Least Squares
Means**

Least Squares Means		
Trt	Estimate	Standard Error
S Blend1	47.0101	1.3877
R Blend2	47.3048	1.3933
C Check	53.9654	0.9755
S POP1	41.2466	0.6069
R POP2	44.7001	0.5973

No effect on plant height, grain volume weight, or end-use quality.

Wesley Fhb1 Backcrosses

- Guihua backcrossed *Fhb1* into Wesley, Trego, and Harding.
- For Nebraska and much of South Dakota, Wesley is an excellent cultivar with good agronomics, disease resistance (with the exception of FHB), and end-use quality. It has been a good parent and is still grown in the FHB affected areas.
- (ND2928/Wesley//Wesley) F3/Wesley F3

Wesley Backcross lines tested in NE and SD in 2011:

	NE and SD		Flowering	Height	Test weight
	Grain Yeild	Rank	Julian		
Name	bu/a			(in)	lbs/bu
Overland	67.6	1	149.0	38.8	57.2
Lyman	61.2	2	146.0	38.8	57.6
WESLEY	58.9	3	145.7	33.7	56.9
ARAPAHOE	57.9	4	145.3	40.4	56.9
09WesleyBC40	57.1	5	145.7	37.0	56.8
09WesleyBC39	56.2	6	144.7	36.0	56.5
09WesleyBC88	55.6	7	145.3	36.4	56.3
09WesleyBC43	55.6	8	143.3	36.3	57.6
09WesleyBC6	55.2	9	146.3	36.7	57.1
09WesleyBC47	54.6	10	148.3	34.4	56.6
09WesleyBC23	54.6	11	146.3	36.5	57.3
09WesleyBC10	54.2	12	147.7	39.2	57.9
09WesleyBC107	54.1	13	145.7	34.4	56.5
09WesleyBC58	54.0	14	143.3	36.2	56.0
09WesleyBC12	53.8	15	146.0	36.5	52.8
09WesleyBC56	53.2	16	146.0	36.7	57.6
09WesleyBC19	52.9	17	145.7	36.4	55.6
09WesleyBC52	52.8	18	145.7	37.4	55.1
09WesleyBC95	52.4	19	145.3	38.9	56.6
09WesleyBC32	52.3	20	146.0	32.8	56.2
09WesleyBC41	51.8	21	145.7	37.7	56.2
09WesleyBC13	51.3	22	145.0	34.5	55.0
09WesleyBC59	50.6	23	147.7	40.3	57.5
09WesleyBC21	50.3	24	146.0	33.2	56.6
09WesleyBC46	49.8	25	147.0	37.4	56.8
GRAND MEAN	54.7		146.0	36.6	56.5

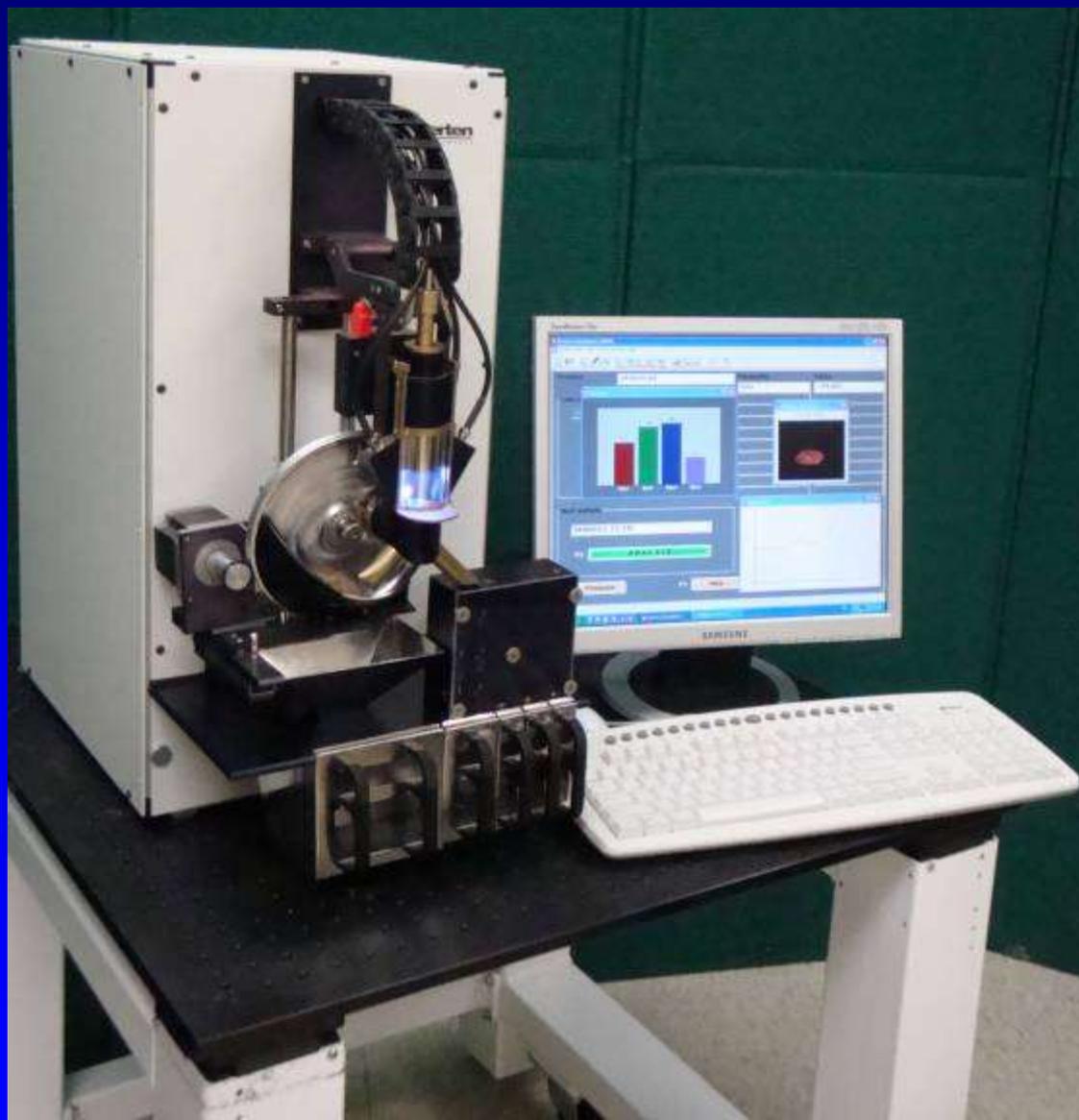
Conclusions:

- *Fhb1* does not appear to have any negative pleiotropic or linked effects.
- The lack of success in crossing was probably due to the diversity in the crosses (e.g. too much variation).
- Future efforts will be based upon BC derived lines, gene pyramiding, and markers with a strong base of native resistance (e.g. Overland *Fhb1* is under development).

Single-kernel near-infrared (SKNIR) system

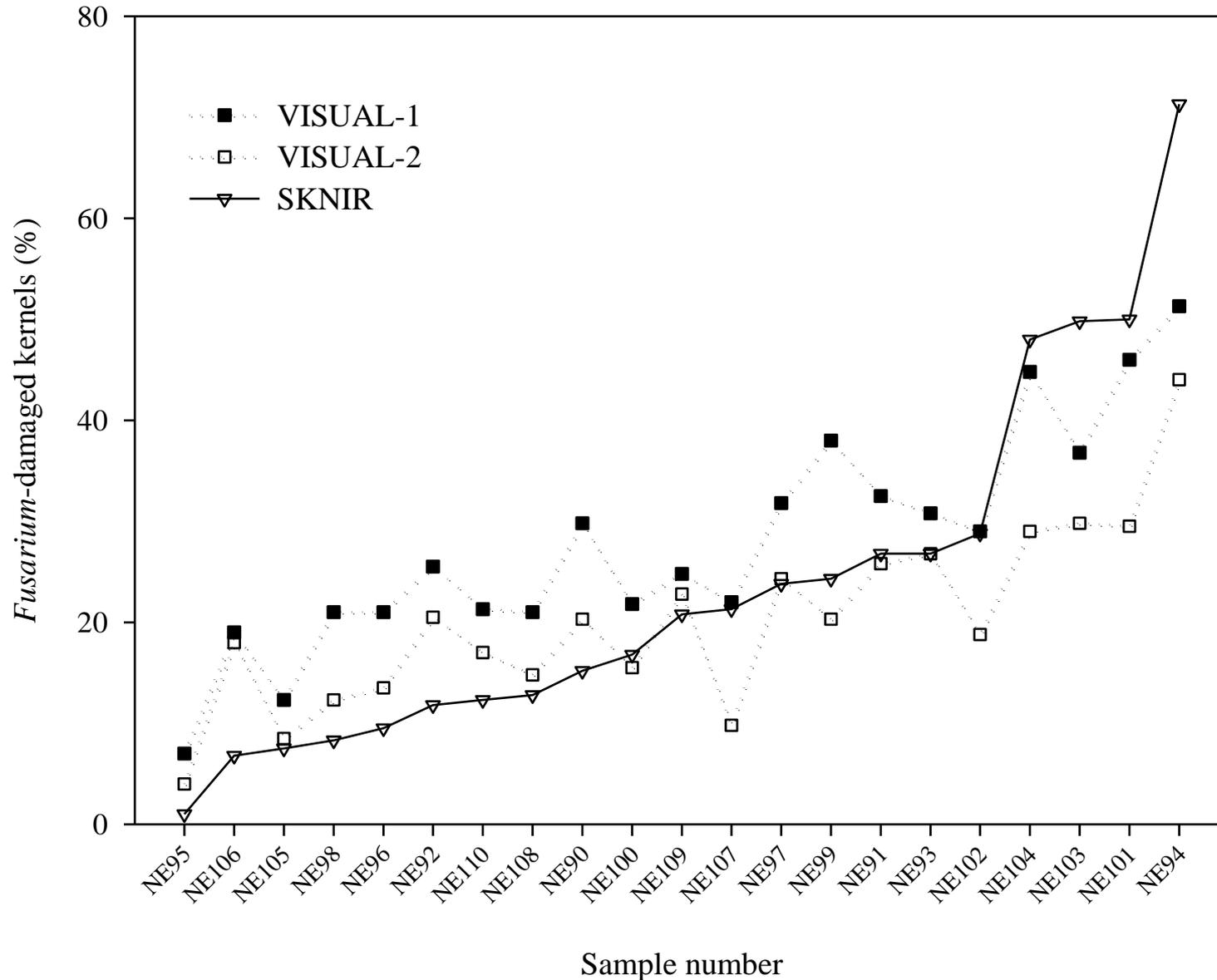
Developed by
Dr. Floyd Dowell,
an engineer at
USDA-ARS
Manhattan, KS.

Wegulo and Dowell





Over- and underestimation of FDK by visual raters compared to the SKNIR system



Conclusions: near-infrared versus visual sorting of *Fusarium*-damaged wheat kernels

- **The SKNIR system sorted FDK as well as human raters**
- **The SKNIR system was more consistent in sorting FDK than human raters**
- **Compared to the SKNIR system, human raters overestimated low FDK and under-estimated high FDK**

Wegulo and Dowell

**Differential accumulation of
deoxynivalenol (DON) in two winter
wheat cultivars
(2007, 2008, 2009)**

**Hernandez-Nopsa et al.,
submitted**

Differential accumulation of DON...

Cultivars:

- **Harry, moderately resistant to FHB**
- **2137, susceptible to FHB**

Disease assessment

- **Disease severity categories:**
0%, 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50% (2007 and 2009)
- **Disease severity categories:**
20%, 25%, 30%, 35%, 40%, 45%, 50%, 70%, and 90% (2008)
- 20 heads in each severity category were tagged per plot

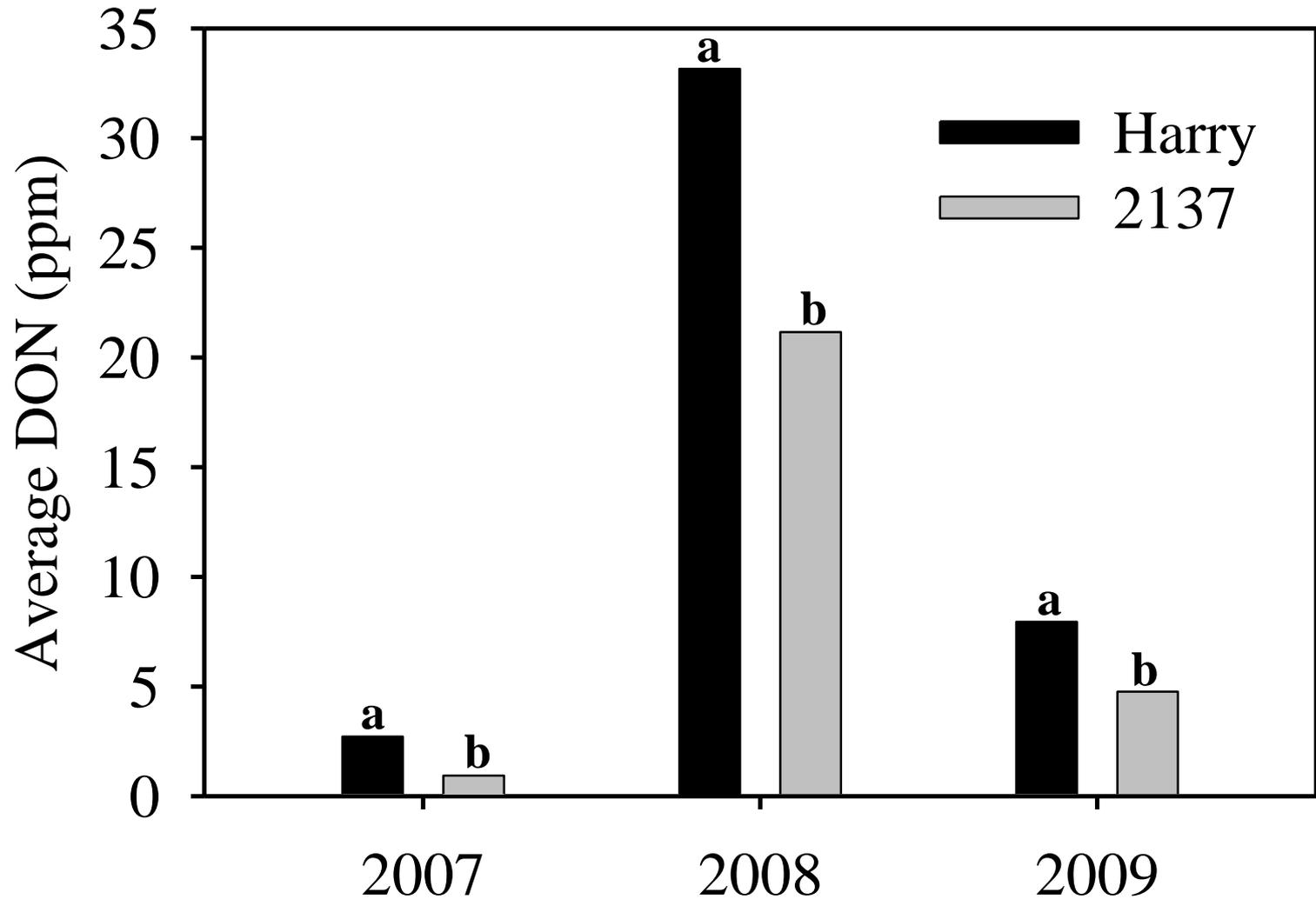
DON analysis:

**Gas chromatography, North Dakota
Veterinary Diagnostic Lab, NDSU,
Fargo, ND**

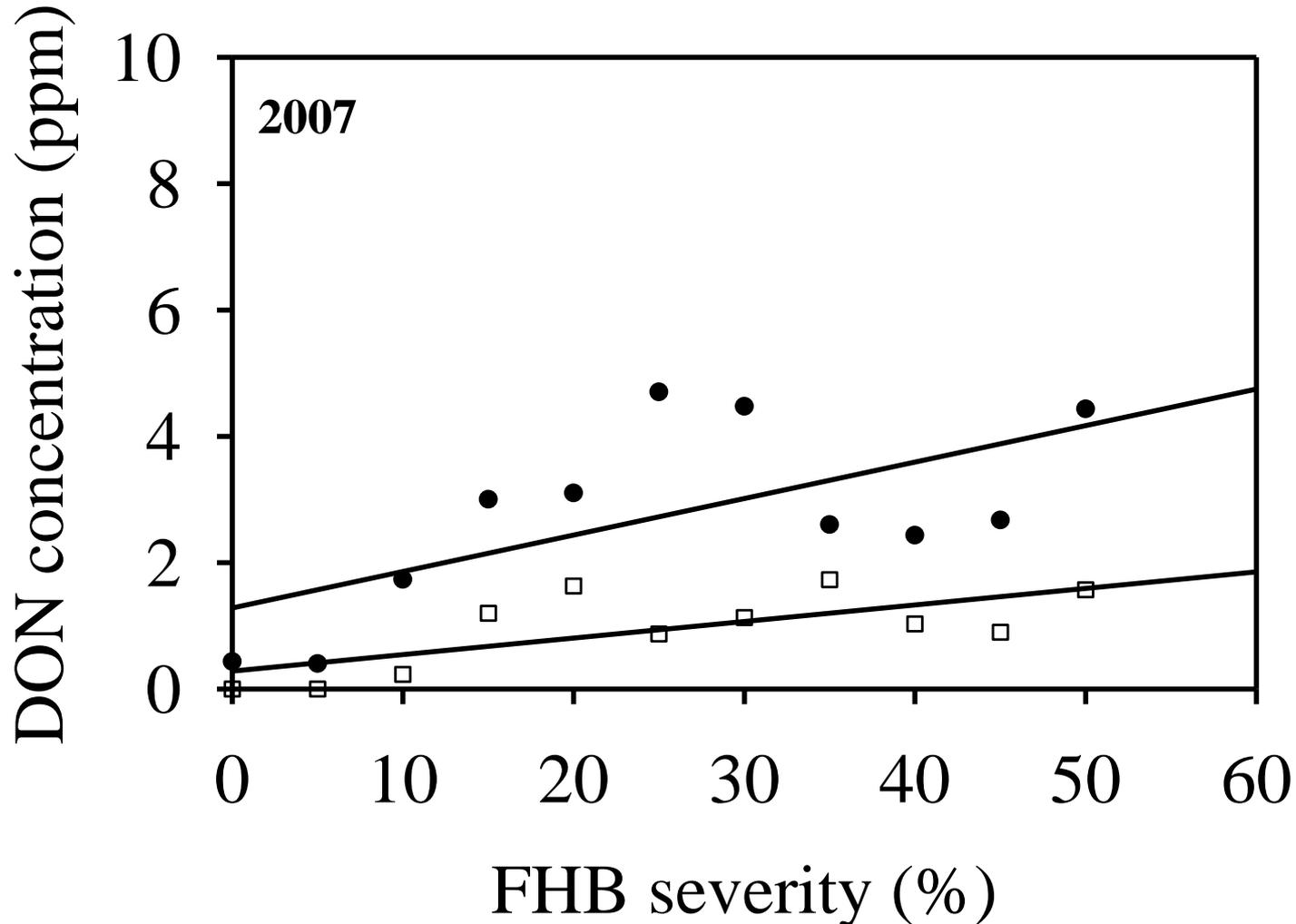
FDK analysis:

**SKNIR system, USDA-ARS,
Manhattan, KS**

DON accumulation in Harry & 2137

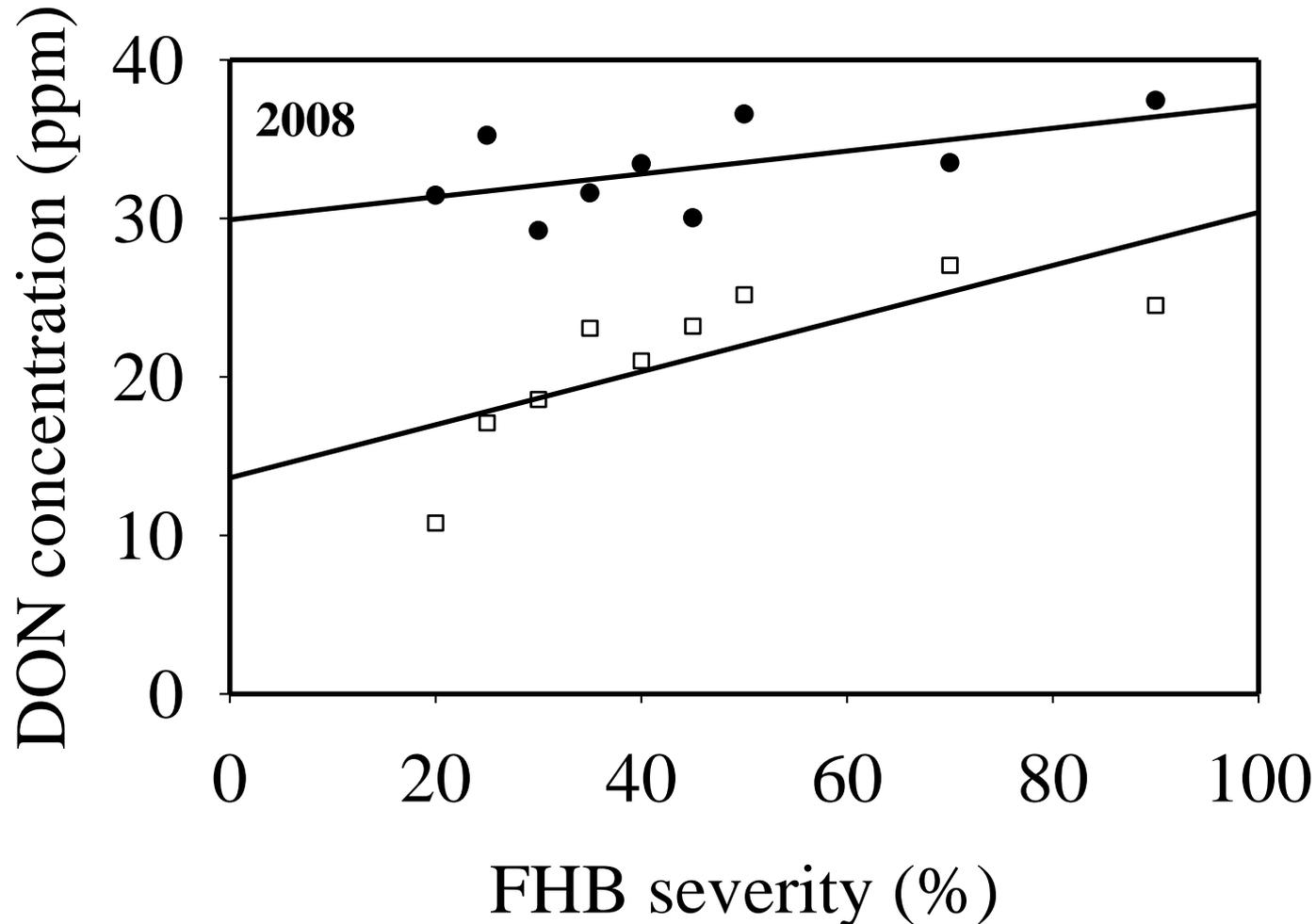


Regression of DON on FHB severity, 2007



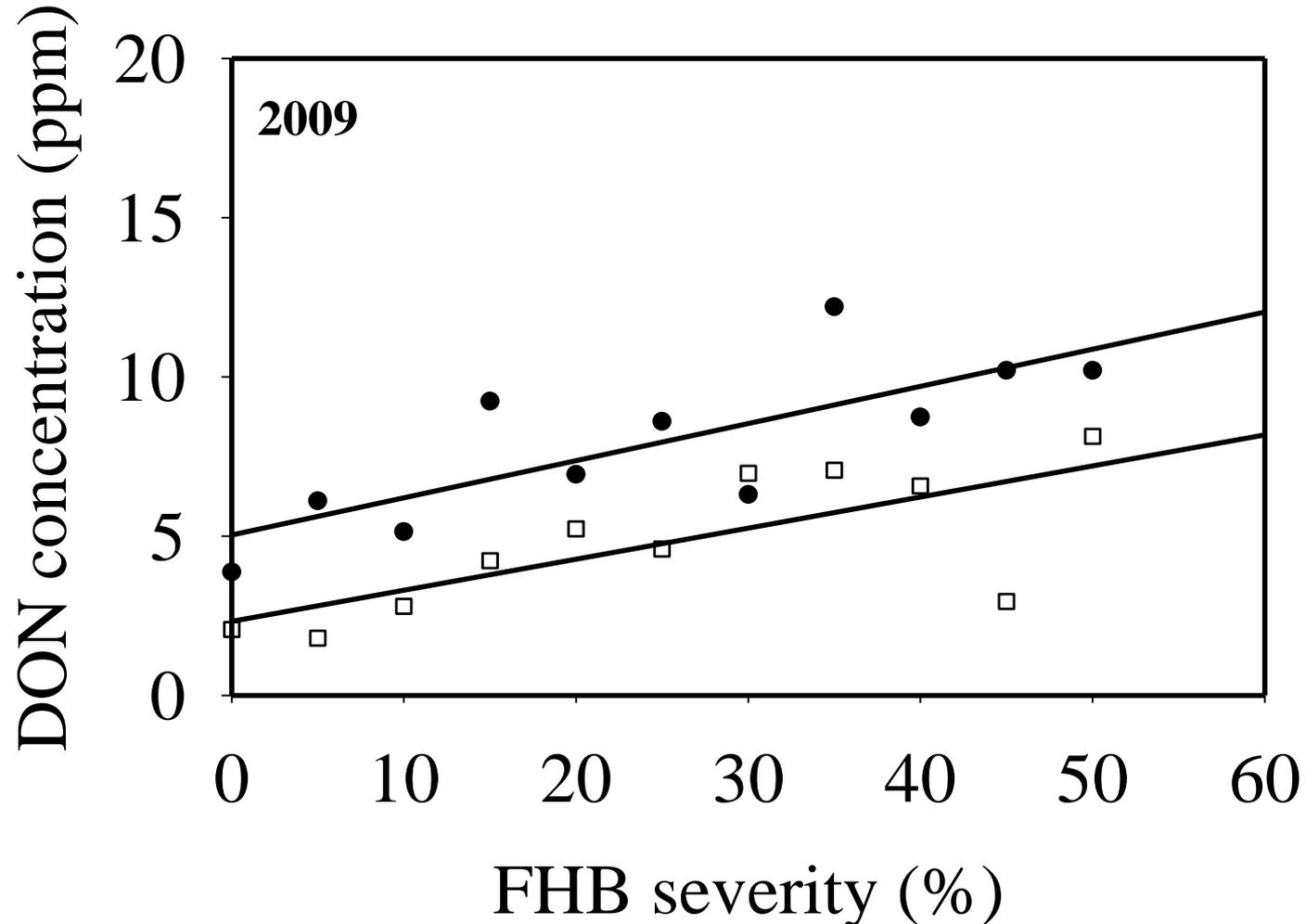
- **Harry: $Y = 1.28 + 0.06X$; $R^2 = 0.42$, $P = 0.0311$**
- **2137: $Y = 0.41 + 0.02X$; $R^2 = 0.36$, $P = 0.0687$**

Regression of DON on FHB severity, 2008



- **Harry: $Y = 29.9 + 0.07X$; $R^2 = 0.32$, $P = 0.1092$**
- **2137: $Y = 13.6 + 0.17X$; $R^2 = 0.57$, $P = 0.0192$**

Regression of DON on FHB severity, 2009



- Harry: $Y = 5.04 + 0.12X$; $R^2 = 0.60$, $P = 0.0053$
- 2137: $Y = 2.33 + 0.10X$; $R^2 = 0.54$, $P = 0.0101$

Conclusion/summary

Differential accumulation of DON...

The cultivar Harry with a moderately resistant FHB phenotype consistently accumulated more DON than the FHB-susceptible cultivar 2137

This suggests that in some cultivars, regulation of DON accumulation may be independent of phenotypic FHB reaction

What Remains to be Done:

- Backcrossing as a prelude to forward breeding.
- Gene pyramiding and looking for better resistance genes.
- Integrated FHB management (cultivars, fungicides, and cropping system).

Where Do We Go From Here:

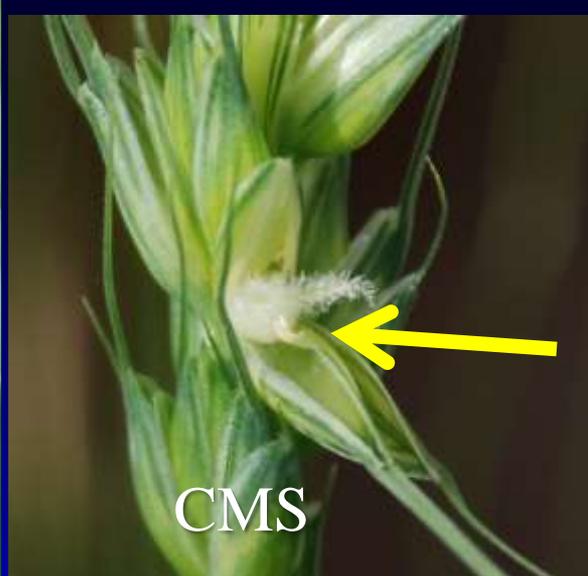
- Continue with proven methods, but with a tight timeline. A sense of urgency in cultivar development, integrated management, and outreach. Management is critical.
- Exploratory research:
 - Kernel sorting
 - NIR DON assays
 - CMS as a method of FHB control

CMS as a Way of Controlling FHB:

- Premise: If anthers and the filament are the infection route for FHB, can you reduce the disease by having atrophied anthers (e.g. male sterile wheat)
- Mixtures of CMS and fertile lines have been commercialized (Trio Seeds, now owned by Limagrain) with good grain yields. Note the male can be lower yielding and have pyramided Fhb resistance genes. The female can be very high yielding.



CMS



CMS



Fertile

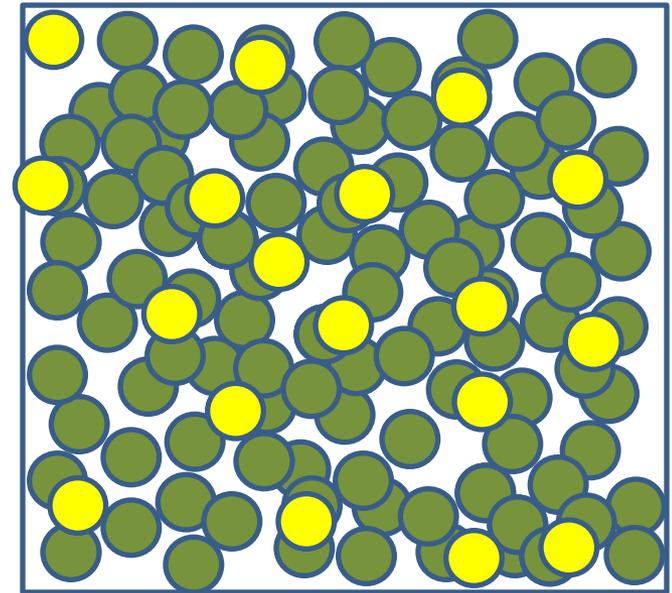


Fertile

Results of FHB Infection: MengYuan Wang

Mechanical Mixture

	Severity	STD
CMS 77(2)	0.84	1.2
77(2)	21.9	16.9
CMS Yanshi No. 9	0.24	0.47
Yanshi No. 9	9.8	3.6
R- Line	8.5	3.6



Experiment is being repeated. There is possible confounding cytoplasmic effects, wounding (the CMS lines' florets were cut open prior to pollination)

- CMS high yielding female line
- Male fertile line with lots of Fhb resistance genes.

*If you want to go fast, go alone.
If you want to go far, go together.*

African proverb

**We have 10 Billio  People to feed
and**

We all need to work together!

