Breeding Fusarium Head Blight-Resistant Winter Wheat

Principal Investigators:

Steve Kalsbech, Research Associate, Winter Wheat Breeding, SDSU, Brookings
Sue Blodgett, Dept. Head, Plant Science Dept., SDSU, Brookings, SD

Collaborators:

Jeff Stein, Assistant Professor, Small Grains Pathology, SDSU, Brookings
Yang-Yen, Assoc. Professor, Biology-Microbiology & Plant Science, SDSU.

Project objectives:
The long term objective is use traditional breeding techniques, aided by molecular marker selection (MAS), to develop and release Fusarium Head Blight (FHB)-resistant hard winter wheat varieties and germplasm with superior agronomic performance and end-use quality characteristics, excellent winter survival ability, and resistance to diseases prevalent in South Dakota and the northern Great Plains.

Specific objectives:
1) use elite, FHB-resistant germplasm with tagged quantitative trait loci (QTLs), in addition to indigenous native resistant sources, in developing populations segregating for FHB resistance and desirable agronomic traits,
2) screen segregating populations, advanced lines, and established varieties in our mist-irrigated nursery and greenhouse for the purposes of line advancement and release while providing growers with accurate FHB ratings on commonly grown varieties,
3) use MAS as a complementary tool to select FHB-resistant lines, and
4) enter promising resistant lines into regional nurseries to facilitate development of varieties with broad adaptation in collaboration with the University of Nebraska and Kansas State University.

Project justification:
FHB related losses in hard winter wheat in 2005 in South Dakota were estimated at about 20 million US dollars (Table 1). Very devastating yield losses occurred in the southeastern part of the state where an average of 60 percent FHB index was estimated. Yield losses as high as 90 percent occurred in some fields in this area. Losses were less severe in fields planted to the cultivars "Harding," "Arapahoe," and "Expedition" compared to fields planted to "Jagalene" and "Wesley." Resistant varieties will continue to be the main component of an integrated strategy to control FHB.

Table 1. 2005 South Dakota Wheat FHB and Loss Estimates - By Crop and Region

					Estimated Losses Due to FHB		
Crop	**Total Acreage**	**Avg Yield**	**Avg Price[§]**	**Est. State Index[¶]**	**Acres (#)**	**Yield (#)**	**$ Lost**
Spring	1,600,000	47	$3.68	3.20%	51,200	2,406,400	$8,855,552
Winter	1,650,000	45	$3.39	8.00%	132,000	5,940,000	$20,136,600
Combined	3,250,000	46	$3.54	5.64%	183,200	8,346,400	$28,992,152

[§]Prices estimated using monthly state averages
[¶] Disease Index weighted by acreages within each region

Recent changes in winter wheat production practices in South Dakota have lead to the significant increase in FHB in hard winter wheat. These changes include:
1. high adoption of minimum tillage by producers,
2. sowing of winter wheat into spring wheat residue to provide protection from cold injury, and
3. increased production of winter wheat in traditional corn – soybean rotations in eastern South Dakota.

The current situation of FHB in South Dakota requires continuing the efforts of developing resistant varieties and timely application of fungicides. We have an ongoing and aggressive effort to develop resistant lines that combine the Sumai3 and Tokai66 type of resistance with our indigenous resistance. Evaluation of promising lines in our mist-irrigated nursery is critical. In addition, broad testing of advanced lines in the aforementioned Tri-State FHB-Screening Nursery is highly warranted.

Progress:
The best evaluation of the progress of the breeding program at SDSU can be found in the data received from a field experiment conducted in 2007 near Manhattan, KS. Experimental design was a randomized complete block comprising the Hard Winter Wheat Fusarium Head Blight Nursery with 48 entries from Kansas, Nebraska, and South Dakota breeding programs. Six of the top seven lines in the experiment are from the South Dakota program. SD00111-9 was the top variety in the statewide CPT yield trial in 2007. Foundation Seed has a 40 acre increase with intent for release in fall of 2008.

Severe FHB developed as evidenced by disease ratings from the susceptible check Overley. All entries, except NE05403, KS000183-3-1, KS000183-3-2, KS010514-6-11, KS980512-11-24, KS990152-3-26, KS04WKS-24, and KS010525-1-1 had significantly lower mean FHB ratings compared with Overley. The line SD07359 had the lowest mean rating, although three other entries were statistically similar including the resistant check cultivar Hondo.

The cultivar Karl 92 had the lowest DON levels although nine other entries were statistically similar. There was a significant negative correlation between heading and mean FHB index ($n = 192$, $r = -0.5702$, $P < 0.0001$) indicating late maturing entries tended to have less FHB. However, there was a positive correlation between heading and DON levels ($n = 192$, $r = 0.4308$, $P < 0.0001$). There was a significant negative correlation between mean FHB index and yield ($n = 192$, $r = -0.2281$, $P = 0.0015$), a significant positive correlation between FHB index and Fusarium Damaged Kernels (FDK) ($n = 192$, $r = 0.5066$, $P < 0.0001$), and a positive correlation between FDK and DON ($n = 192$, $r = 0.1708$, $P = 0.0179$). Interestingly, there was a significant negative correlation between mean FHB index and DON levels ($n = 192$, $r = -0.2129$, $P = 0.0030$).

Entry[z]	FHB (% infected spikelets)					Heading	Yield	FDK	DON	
	28 May	31 May	4 Jun	7 Jun	14 Jun	Mean[y]	(Julian)	(oz/plot)	(%)[x]	(ppm)[w]
SD07359	1.0	6.0	13.0	27.5	52.5	20.0	139.5	1.08	28.8	30.8
SD00111-9	1.0	7.8	14.8	25.0	61.3	22.0	137.5	3.75	25.0	19.0
Hondo	1.5	9.3	18.5	31.3	57.5	23.6	136.5	1.90	31.3	24.5
SD05133	2.0	8.0	22.5	33.8	52.5	23.8	139.0	1.84	33.8	30.4
SD05048	1.5	8.0	21.3	35.0	62.5	25.7	138.3	2.28	26.3	18.4
Harding	2.0	12.3	23.8	35.0	65.0	27.6	139.3	1.26	43.8	33.9
Darrell	3.0	8.8	22.5	37.5	68.8	28.1	137.5	1.52	42.5	19.0
Goodstreak	1.5	11.0	27.5	47.5	62.5	30.0	136.5	2.22	50.0	24.6
SD02480	1.5	11.0	27.5	47.5	62.5	30.0	139.5	1.17	40.0	32.4
KS980512-2-2	2.0	7.8	21.3	43.8	76.3	30.2	135.8	4.14	20.0	21.0
SD05267	2.5	10.5	31.3	38.8	70.0	30.6	134.0	2.22	43.8	26.9
NE05537	4.8	14.8	25.0	40.0	72.5	31.4	135.5	1.83	31.3	17.3
SD05250	2.5	14.3	27.5	37.5	76.3	31.6	136.0	1.62	46.3	29.0
NW03666	2.5	14.8	30.0	56.3	55.0	31.7	136.3	1.13	52.5	31.3
SD07288	4.0	12.5	27.5	38.8	77.5	32.1	136.3	1.43	21.3	15.5
NW03654	4.8	13.0	25.0	50.0	72.5	33.1	133.8	1.74	50.0	27.1
KS04WKS-13	4.0	16.3	35.0	47.5	72.5	35.1	135.3	0.73	48.8	38.8
Expedition	7.0	15.0	26.3	55.0	72.5	35.2	133.5	1.67	21.3	23.1
NE05418	5.5	16.0	25.0	48.8	82.5	35.6	131.3	3.19	22.5	14.2
NI04427	6.5	16.0	27.5	47.5	82.5	36.0	133.5	3.19	35.0	17.9
SD05156	2.0	12.3	30.0	63.8	75.0	36.6	139.3	0.83	55.0	25.5
NE03488	5.8	17.5	31.3	53.8	76.3	36.9	135.5	2.06	28.8	18.0
KS06PYN2-21	9.8	22.5	33.8	42.5	81.3	38.0	133.0	1.60	28.8	17.3
SD05W012	4.5	14.0	32.5	53.8	85.0	38.0	135.5	2.14	42.5	19.7
KS990002-2-4	7.0	18.8	35.0	50.0	80.0	38.2	134.3	2.09	28.8	13.8
NE06497	3.5	18.8	32.5	60.0	80.0	39.0	135.0	1.42	55.0	17.5
NE05523	3.5	15.0	38.8	57.5	88.8	40.7	135.5	1.59	63.8	23.2
NE05496	5.5	16.0	36.3	61.3	85.0	40.8	134.8	1.19	60.0	25.9
Karl 92	9.3	23.8	36.3	61.3	77.5	41.6	131.5	1.71	45.0	10.3
NE05453	5.5	22.5	33.8	72.5	77.5	42.4	134.5	2.26	56.3	23.7
NI04411	3.5	15.0	36.3	72.5	85.0	42.5	136.0	2.45	40.0	13.2
SD01058	4.5	21.3	38.8	67.5	81.3	42.7	137.0	0.86	52.5	23.4
NE04449	10.3	24.3	38.8	58.8	82.5	42.9	134.0	1.88	33.8	15.2
KS990002-2-13	13.0	28.0	40.0	51.3	86.3	43.7	133.8	1.62	51.3	15.2
KS010525-1-3	4.5	18.8	46.3	65.0	83.8	43.7	135.3	2.20	42.5	24.1
SD07338	3.5	21.3	45.0	75.0	76.3	44.2	139.0	0.48	52.5	38.7
KS980512-11-22	10.3	21.3	42.5	66.3	88.8	45.8	133.8	1.43	50.0	18.5
KS010520-5-3	7.0	23.8	40.0	77.5	82.5	46.2	132.8	1.32	58.8	29.1
NE04490	14.8	28.8	41.3	65.0	81.3	46.2	132.3	1.60	65.0	17.1
NE05403	16.8	28.3	42.5	68.8	86.3	48.5	133.0	1.55	35.0	15.4
KS000183-3-1	8.0	21.8	46.3	72.5	96.3	49.0	134.3	2.50	81.3	22.9
KS000183-3-2	5.5	20.0	51.3	78.8	91.3	49.4	134.8	1.74	60.0	32.2
KS010514-6-11	10.5	28.8	52.5	77.5	91.3	52.1	133.3	0.78	48.8	17.9
KS980512-11-24	15.5	31.3	48.8	76.3	92.5	52.9	132.8	1.34	67.5	22.9
Overley	16.8	28.8	55.0	76.3	88.8	53.1	134.8	0.54	66.3	24.6

KS990152-3-26.....	18.0	37.5	50.0	70.0	93.8	53.9	130.3	2.52	63.8	12.0
KS04WKS-24.....	20.0	40.0	58.8	83.8	92.5	59.0	131.5	1.69	60.0	20.2
KS010525-1-1.....	13.0	37.5	67.5	86.3	92.5	59.4	133.8	1.89	52.5	21.8
Average.....	6.5	18.5	34.9	56.0	77.8	38.7	135.1	1.77	45.0	22.4
LSD (*P*=0.05).....	5.8	8.7	7.7	12.6	9.8	5.6	1.5	0.80	18.7	6.9
R^2	0.7	0.7	0.9	0.8	0.8	0.9	0.9	0.70	0.6	0.7
CV.....	63.3	33.5	15.7	16.0	9.0	10.3	0.8	32.10	29.7	22.0

[z] Sorted by data in "Mean" column.

[y] Average for rating dates 28 May, 31 May, 4 Jun, 7 Jun, and 14 Jun.

[x] Fusarium damaged kernels.

[w] Deoxynivalenol.

Research methods:

We are continuously including lines with superior FHB resistance in our crossing blocks for germplasm and variety development purposes. A mist-irrigated FHB evaluation nursery has been used to evaluate elite breeding lines and new putative resistant sources, regional nurseries, commercial varieties, and segregating populations since 1999. The following nurseries were screened for scab resistance in 2000, 2001, 2002, 2003, 2004, 2005, and 2006: Northern Regional Performance Nursery (NRPN), Regional Germplasm Observation Nursery (RGON), Southern Regional Performance Nursery (SRPN), South Dakota Crop Performance Trials (CPT), SDSU Advanced Yield Trial (AYT), SDSU Preliminary Yield Trials (PYT), and SDSU Early Yield Trial (EYT).

Our F_2 and F_3 populations are grown as bulks under normal winter wheat production practices. This provides natural selection for survival traits, especially winter survival ability. Individual F_3 plants are evaluated for FHB reaction by millet inoculation. This point inoculation method induces disease even in marginal environmental conditions. $F_{3:4}$ progeny rows are planted under normal winter wheat production practices and selected for agronomic performance. In year 4, $F_{3:5}$ yield trials (EYT) [1 rep, 2 locations] are grown and corresponding $F_{3:5}$ rows are grown in the mist-irrigated FHB nursery and also evaluated in the greenhouse using needle inoculation. Entries with good yield data and FHB reaction are planted in year 5 in $F_{3:6}$ PYT (2 rep, 5 locations), in the FHB nursery, and are also screened in the greenhouse for Type II resistance. Promising lines from the EYT are also included in the Tri-State FHB-Screening Nursery planted in South Dakota, Nebraska, and Kansas, as well as in RGON. Winners from year-five are entered into Advanced Yield Trials in year-six in 10 locations in South Dakota, and one each in North Dakota, Nebraska, and Colorado. Lines from year-five with good FHB resistance as well as good yielding ability and adaptation are also included in the NRPN. Winners from the AYT nursery will be evaluated for at least two years in the CPT in 14 locations in South Dakota prior to line increase and release.

We will utilize every opportunity available during growers' meetings, field days, and through our web page (http://plantsci.sdstate.edu/triticum/index.htm) to increase growers' awareness about FHB. We will also recommend use of fungicides when the risk of FHB is high, talk about suitable crop rotations for the management of FHB, and avoidance of susceptible hard winter wheat varieties in these rotations.