ROLE OF THE USDA REGIONAL GENOTYPING CENTERS

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ABSTRACT

The concept of USDA Regional Genotyping Center was original proposed by Van Sanford et al. (2001) to meet growing need of marker-assisted selection for scab resistant cultivars. With strong support from cereal crop researchers, three USDA regional genotyping centers have been recently established in Manhattan, KS, Fargo, ND and Raleigh, NC, respectively. Their missions include developing high throughput molecular markers for Fusarium head blight and other agronomically important traits of cereal crops, screening breeding materials and germplasm with molecular markers for breeding programs to perform marker-assisted breeding, and providing training and technical consultations on marker analysis to breeders and other researchers. Screening of breeding materials for the major FHB resistance QTL on 3BS will be the first service provided by the Centers. Protocols for sample handling, marker analysis, data analysis and data delivery will be proposed. Scopes of research and service in the Genotyping Centers will be discussed.

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PERCENTAGE SCABBY KERNELS IS CORRELATED WITH FUSARIUM HEAD BLIGHT INDEX FOR KANSAS WINTER WHEAT CULTIVARS

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ABSTRACT

Fusarium head blight (FHB) is a serious disease of wheat and barley that is best controlled by host resistance. Resistance to FHB can be expressed in several ways including a reduction in the percentage florets that are affected and a reduction in the percentage of scabby kernels in harvested grain. This research sought to determine if there is a correlation between the observed reaction of commercial Kansas winter wheat cultivars in the field and the percentage scabby kernels in harvested grain. Twenty (2000 and 2001) or 24 (2002 and 2003) common commercial wheat cultivars were screened over a 4-yr period in the field for reaction to FHB. Experimental design for each year was a randomized complete block with four replications. Corn grains colonized by *Fusarium graminearum* were applied to the soil surface in three applications about 2 wk apart beginning 5 wk prior to heading (93 g/m2 total applied). During heading and flowering, plots were sprinkler irrigated (3 min/hr) from 9:00 p.m. until 6:00 a.m. FHB index (percentage diseased spikelets) was determined for each plot of each cultivar between four and six times and averaged. At maturity, plots were harvested with a small-plot combine and the percentage scabby kernels visually estimated for the harvested grain. Analyses of variance (ANOVA) followed by LSD (P=0.05) were conducted for all cultivars for FHB index, grain yields, and percentage scabby kernels. Correlation coefficients were calculated for percentage scabby kernels in harvested grain with average FHB index and with grain yields (N=80 or 96 depending upon the year). There were 10 cultivars that were common to all four years. Significant differences (P=0.05) occurred among the cultivars for FHB index, percentage scabby kernels, and grain yields. Across all years, Hondo showed the lowest FHB index (8.0%) and Tomahawk the highest (52.7%). Within each year, significant correlations occurred between percentage scabby kernels and either FHB index or grain yields. For common Kansas commercial winter wheat cultivars, FHB index values are a significant predictor of the amount of scabby kernels in harvested grain; however, their predictive value is from 9% to 60%, depending upon the year. Similarly, grain yields of cultivars in a high-scab environment are a significant predictor of the amount of scabby kernels and their predictive value is 26-47%.

SCAB SCREENING OF SOFT RED WINTER WHEAT GENOTYPES IN MARYLAND

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ABSTRACT

The 2002/2003 wheat growing season presented very favorable environmental conditions for the development of a scab (*Fusarium graminearum*) epidemic in Maryland. Rainy, drizzly conditions predominated during the spring of 2003. These conditions led to a high level of scab incidence on Maryland's Eastern shore, the largest wheat growing area in Maryland. The official winter wheat state variety test was grown under field conditions in Queenstown (MD) and the level of scab severity, percentage of tombstones, and DON (Deoxynivalenol) were assessed. Forty genotypes were tested and the incidence of the disease was fairly uniform across the nursery. There were significant genotypic differences. The genotypes Vigoro Tribute, USG3350, Catoctin, McCormick, Coyote, USG3430, MV5-46, Neuse, 25R37, and Patton showed moderate levels of resistance to scab with low percentage of tombstones and low DON levels. On the other hand, the genotypes Southern States 522, Century II, GA931470E62, Coker 9835 and Florida 304 had very high levels of tombstones and DON. This ranking was consistent with other evaluations of resistance of currently grown soft red winter wheat cultivars. It is important to continue to screen currently grown cultivars of soft red winter wheat for even moderate scab resistance because this can be useful for future breeding as well as for immediate use by wheat growers.

COMPARATIVE EVALUATION OF THE UNIFORM REGIONAL SCAB NURSERY FOR SPRING WHEAT PARENTS UNDER DRYLAND AND MIST-IRRIGATED CONDITIONS

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OBJECTIVES

This study sought to compare the disease reactions of wheat entries in the 2003 Uniform Regional Scab Nursery for Spring Wheat Parents (URSN) at nursery locations that are mist-irrigated with locations where mist-irrigation was not used ("dryland screening"). Traditionally the URSN is grown at locations where mist-irrigation is utilized to facilitate the infection of plants by *Fusarium graminearum*. Disease severity in mist-irrigated nurseries is frequently very high, making identification of moderate variation for scab resistance among genotypes difficult due the narrow phenotypic range of disease reactions generally observed. Dry-land screening thus was evaluated in this study to see if useful information on the performance of wheat genotypes under lower disease pressure could augment the information obtained from mist-irrigated nurser-ies, while also demonstrating the utility of conducting Fusarium head blight (FHB) screening under dryland conditions.

INTRODUCTION

Fusarium head blight (FHB or scab) has occurred frequently since the early 1990's primarily in the upper Midwest and Northeastern U.S. The reemergence of FHB has resulted in severe economic losses to wheat producers, the wheat processing industry, and the associated rural communities in the affected regions (Windels, 2000). The severity and continued occurrence of the disease impelled wheat breeding programs to undertake a concerted effort to develop scab resistant varieties. The URSN was established in 1995 as a means of evaluating promising FHB-resistant germplasm, and to encourage open exchange of this germplasm among spring wheat breeding programs in the US. The URSN has traditionally been planted at multiple locations where mist-irrigation facilitates the development of FHB. The nursery provides a useful comparison of germplasm for reaction to scab over multiple locations (Campbell and Lipps, 1999; Groth et al., 1999) as well as a comparison among the locations for quality of data that is obtained. The develop-ment of methods which enable scab screening without the cost and time associated with maintaining a mist-irrigated location is now being examined, through the addition of two dryland locations in 2003 to the URSN, to augment the data obtained annually from the six mist-irrigated nursery locations.

MATERIALS AND METHODS

The 2003 URSN was planted at the standard set of misted and irrigated locations in Minnesota, North Dakota, South Dakota, and Canada. In addition, two dryland locations in Minnesota (St. Paul, Barnesville) were also planted. In 2003, the URSN consisted of 41 entries, of which 5 were checks, and 5 were durum wheats.

Dryland plots at St. Paul and Barnesville, MN were spray-inoculated with a suspension of macroconidia of *F. graminearum* when anthers were first observed on spikes within the plot. Plots were inoculated a second time three days after the first application. Inoculum was applied at a concentration of 1 x 10^5 macroconidia ml^{-1} sprayed at a rate of about 33 ml m^{-1} of row. Rows were sprayed at a rate of 3.3 sec m^{-1}. The CO_2-powered sprayer, fitted with an ss80015 TeeJet flat-fan orifice, was operated at 2.76 x 10^5 pascals dispensing inoculum at about 10 ml sec^{-1}. Inoculum was directed toward the spikes by keeping the tip of the orifice within 20-30 cm of the spikes. Plots were assessed for FHB incidence (percentage symptomatic spikes) and FHB severity (percentage symptomatic spikelets/symptomatic spike) about 14 days post-inoculation and at about 20 days post-inoculation at the St. Paul and Barnesville dryland sites, respectively.

The mist-irrigated nursery at St. Paul was inoculated with the same spray-inoculation methodology as the dryland plots about three days post-heading. Heading occurred when about 50% of the heads emerged from the primary tillers. Plots were mist-irrigated each night following the first application of inoculum until disease assessment. The mist-irrigation system delivered 14 irrigation events per night each event being about 5 min long. The combined volume of the misting events was about 4 mm per unit land area per night. Plots at Crookston were inoculated with sterilized corn kernels colonized with *F. graminearum*. Colonized grain was spread on the soil surface within the plots at a rate of 18.4 kg/ha at the five to six-leaf growth stage. Plots were mist-irrigated each night following inoculum dispersal to provide adequate moisture for perithecial development. At heading the mist-irrigation system was operated in a fashion to provide supplemental moisture on spikes each night, although excessive moisture was avoided by monitoring rainfall accumulations and duration of leaf wetness, using remote sensor instrumentation. Plots at Brookings, SD were inoculated with colonized corn and mist-irrigation was utilized.

For this study, disease data from three of the mist-irrigated URSN locations in Minnesota (St. Paul and Crookston) and South Dakota (Brookings) was used for analysis. Similarly, disease data was obtained for the two dryland locations (St. Paul and Barnesville). Data obtained at all locations included FHB incidence, FHB severity, and FHB index (product of FHB incidence and FHB severity), and visually scabby kernels (VSK or tombstones). Means, coefficients of variation, and data ranges were calculated for each location's dataset. Additionally, Pearson's correlation coefficients were calculated in a pairwise fashion for FHB index and VSK data from the locations included in the analysis.

RESULTS

A summary of the phenotypic data obtained for the URSN entries at three mist-irrigated locations and the two dryland locations is shown in Table 1. It is clear that mist irrigation following inoculation of wheat spikes with the pathogen increases both FHB incidence and severity relative to the values obtained at the dryland locations. Nonetheless, it is important to note that the range of values for FHB incidence is far greater in the dryland nurseries. The range of VSK ratings at the dryland locations is comparable to those obtained at two of the mist-irrigated locations. The results suggest that scab disease at both dryland locations was significant enough to result in a wide phenotypic range of measurements for the traits measured.

Table 1. Summary statistics (% values) for wheat entries in the 2003 URSN.

Mist-irrigated	FHB Incidence		FHB Severity		FHB Index		VSK	
Locations	Mean (cv)	Range	Mean (cv)	Range	Mean (cv)	Range	Mean (cv)	Range
St. Paul, MN	88.9 (12.7)	66.7-100	29.9 (36.8)	13.7-55.3	28.0 (42.2)	9.5-55.3	14.8 (41.0)	3.3-51.0
Brookings, SD	96.2 (6.8)	54.0-100	37.3 (25.2)	5.7-78.8	36.8 (26.6)	3.1-78.8	16.7 (39.6)	1.0-83.3
Crookston, MN	94.2 (8.3)	65.0-100	36.0 (34.4)	8.8-79.1	35.3 (28.3)	5.7-53.7	19.4 (28.3)	3.5-53.7
Dryland Locations								
St. Paul, MN, MN	52.2 (26.0)	15.0-93.8	12.5 (32.8)	5.2-27.5	7.8 (53.4)	1.1-24.5	7.9 (63.7)	1.0-58.8
Barnesville	74.6 (14.4)	27.5-100	20.1 (23.0)	8.5-58.6	16.6 (29.1)	2.4-58.6	8.7 (52.7)	1.0-57.5

It is of value to our study to determine if entries in the URSN were ranked similarly in both mist-irrigated and dryland locations. We compared the rankings of the five check varieties in the URSN across the locations to determine how similar they ranked in the dryland vs. mist-irrigated locations. These results are shown in Table 2. These results indicate that both the resistant and susceptible checks exhibit similar rankings between locations.

Table 2. Ranks of wheat check cultivars for FHB disease index (DX) and visually scabby kernels (VSK) at three mist-irrigated and two dryland sites.

Check	Brookings Irrig.		Crookston Irrig.		St. Paul Irrig.		St Paul Dryland		Barnesville Dryland	
cultivars	DX[1]	VSK	DX	VSK	DX	VSK	DX	VSK	DX	VSK
ND2710	1	2	1	1	2	2	5	18	2	1
Bacup	3	1	20	7	23	22	7	3	7	3
2375	23	18	27	28	18	9	2	11	14	20
Oslo	36	40	41	36	38	39	41	40	40	37
Wheaton	41	41	40	41	41	41	40	41	41	41

[1] Product of FHB incidence and FHB severity.

Further, to evaluate the relative similarity between data obtained at dryland vs. mist-irrigated locations, correlations were calculated in a pairwise fashion for FHB index and VSK. The results are shown in Tables 3 and 4. The correlation between the two dryland locations for disease index was positive and highly significant, and was the highest among all locations. The correlations between dryland locations and mist-irrigated locations were also highly significant in all instances.

Table 3. Pearson's correlation coefficients for means of FHB index of 41 wheat lines among selected locations participating in the Uniform Regional Scab Nursery (URSN) during the 2003 field season.

	Barnesville Dryland	St. Paul Dryland	St. Paul Irrig	Crookston Irrig
St. Paul, Dry	0.77***			
St. Paul, Irrig	0.70***	0.54***		
Crookston, Irrig	0.77***	0.70***	0.72***	
Brookings, Irrig	0.73***	0.54***	0.39**	0.62***

Asterisks represent significance of coefficients at the *P*=0.05 (*), *P*=0.01 (**), and *P*=0.001 (***).

Similarly, correlations for VSK between the two dryland locations was positive and highly significant (Table 4). In fact, all of the correlation coefficients between locations for VSK were positive and highly significant. Thus, it appears that even though the FHB index at the dryland locations was lower than the mist-irrigated locations, rankings for both FHB incidence and VSK were similar.

Table 4. Pearson's correlation coefficients for means of visually scabby kernels (VSK) of 41 wheat lines among selected locations participating in the Uniform Regional Scab Nursery (URSN) during the 2003 field season.

	Barnesville Dryland	St. Paul Dryland	St. Paul Irrig	Crookston Irrig
St. Paul, Dry	0.77***			
St. Paul, Irrig	0.75***	0.70***		
Crookston, Irrig	0.77***	0.52***	0.69***	
Brookings, Irrig	0.81***	0.76***	0.79***	0.72***

Asterisks represent significance of coefficients at the *P*=0.05 (*), *P*=0.01 (**), and $P \leq 0.001$ (***).

DISCUSSION

The URSN provides breeders with a mechanism to exchange and evaluate promising accessions with putative resistance to FHB. Traditionally the URSN was conducted only at locations with mist-irrigation and usually the intensity of disease limited the ability of cooperators to identify intermediate levels of scab resistance. Intermediate levels of scab resistance often are not detectable under severe scab intensity such as that often encountered in the misted URSN locations. This is unfortunate because often those genotypes with intermediate levels of resistance possess more desirable agronomic characteristics. Our results suggest that dryland screening provides a less severe disease intensity while still differentiating among resistant and susceptible genotypes. This provides an opportunity to identify those genotypes with improved agronomic characteristics with intermediate levels of resistance. Thus, the use of "dryland" nurseries may augment breeders' ability to identify germplasm to utilize in crosses aimed at improving FHB resistance while maintaining agronomic quality. The dryland screening also has the advantage of requiring fewer resources than traditional screening nurseries.

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ANDROGENIC ABILITY OF EIGHT FHB RESISTANT BARLEY ACCESSIONS

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ABSTRACT

Most Fusarium head blight (FHB) resistant barley (*Hordeum vulgare*) accessions are relatively poor from an agronomic point of view. Due to the complex inheritance of FHB resistance, introgression of this trait into well adapted local germplasm will likely require multiple generations of crossing and selection in order to combine resistance and agronomic performance, even with the use of doubled haploids. Unfortunately, little is know concerning the androgenic ability of genotypes providing FHB resistance and so it is not known which of these could prove interesting in the production of doubled haploid populations. The objective of a first experiment was to compare the androgenic ability of eight barley accessions, known to offer some resistance (Chevron, Gobernadora, Seijo II, Shyri, Svanhals, Zhedar I, F104-250-9 and C97-21-38-3), with three cultivars (ACCA and Léger and Cadette) whose androgenic response was already well characterized. In a second experiment, the androgenic ability of F_1 hybrids, involving some of these genotypes used as parents, was measured and compared to that of the parental genotypes. Very large and significant differences were observed in the number of green plants produced by the different accessions and F1s. In some cases, the androgenic potential proved so low that only a conventional approach, based on selfing to reach homozygosity, would seem justified.

RESOURCE ALLOCATION AND CULTIVAR STABILITY IN BREEDING FOR FUSARIUM HEAD BLIGHT RESISTANCE IN SPRING WHEAT

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OBJECTIVES

To characterize the stability of spring wheat cultivars for their Fusarium head blight (FHB) reaction and to obtain estimates of screening nursery requirements for an optimum resource allocation for FHB evaluation.

INTRODUCTION

Fusarium head blight, caused primarily by *Fusarium graminearum* Schwabe, is an important disease for spring wheat (*Triticum aestivum* L.) production. The use of disease-resistant cultivars represents the best method of control (Mesterházy, 1995; Parry et al., 1995; Campbell and Lipps, 1998; Groth et al., 1999). Resistance expression often differs among environments (Parry et al., 1995; Campbell and Lipps, 1998); consequently, developing cultivars with FHB resistance requires experimental designs and strategies that consistently discriminate among genotypes.

Fusarium head blight is incited by a highly variable pathogen, and development and evaluation of the response of wheat to FHB are complex and readily altered by environment. Infection incidence and disease severity measure the frequency and degree of colonization of the spike, respectively, and are common measures of disease (Parry et al., 1995). Disease-affected grain is often quantified as percent visually scabby kernels (VSK) and deoxynivalenol (DON) content (Tacke and Casper, 1996; Jones and Mirocha, 1999).

There is a lack of information on the stability of commercial cultivars and on the allocation of environments, replicates, and within plot sub-sampling for FHB evaluation. The objectives of this study were to characterize the stability of spring wheat cultivars for their FHB reaction and obtain estimates of screening nursery requirements for an optimum resource allocation for FHB evaluation.

MATERIALS AND METHODS

Plant Materials - Fourteen commercial wheat cultivars (Table 1), encompassing a broad range of cultivar response to FHB ranging from resistant to susceptible, were used in this study. These cultivars were grown in FHB nurseries at St. Paul and Crookston, MN from 1999 to 2002 in a RCBD with three replicates location^{-1} year^{-1}. Plots consisted of a single 2.4 m row seeded at a rate of 110 kg ha^{-1} with 0.3 m row spacing.

Fusarium Inoculation- At St. Paul, macroconidial inoculum was applied to the spikes at plant heading with a CO_2 powered backpack sprayer employing a single flat-fan nozzle. Plots were sprayed evenly at a rate of 30 ml m^{-1} of row, ca. 7×10^6 macroconidia $plot^{-1}$. At Crookston, the nursery was inoculated with Fusarium colonized wheat kernels spread uniformly on the soil surface at 100 kg ha^{-1} at about 25 d prior to average plant heading. The nurseries were misted about eight times during a daily cycle with an automatically controlled irrigation system providing about 12 mm of water per day.

Disease Evaluation - Visual disease scores (0 = no symptomatic spikelets to 5 = all spikelets symptomatic) were assigned to dominant spikes from 20 randomly selected plants $plot^{-1}$. The scores were used to calculate the following three variables for each plot: 1) disease incidence (INC) in % — frequency of symptomatic spikes (scores 1 to 5); 2) disease severity (SEV) in % — average score of spikes with scores from 1 to 5; and 3) disease index (DIS) — average score of spikes with scores from 0 to 5.

Spikes were assessed at late grain filling, when healthy spikes were still green and not senescent. Percent visually scabby kernels (VSK) was assessed according to Jones and Mirocha (1999). Samples from the three replications of each cultivar were bulked following VSK determination and DON analyses were conducted according to the methods of Tacke and Casper (1996) with some modifications.

Data Analysis - Analyses of variance and cultivars' means comparisons were conducted on INC, SEV, DIS, VSK, and DON. Pearson correlation and Spearman rank correlation coefficients were calculated to assess the relationships among heading date, INC, SEV, DIS, VSK, and DON. Two stability parameters of each cultivar: regression coefficient b_i and deviation from regression parameter δ_i^2 (Eberhart and Russell, 1966) were estimated for the different FHB parameters. Predicted $LSD_{0.05}$ for differing levels of sub-sampling, replications, and environments were calculated from estimates of cultivar × environment mean squares, $\sigma_\varepsilon^2 + r\sigma_{CE}^2$, where, σ_ε^2 is the plot error variance, r equals replicate number, and σ_{CE}^2 is the estimated cultivar × environment variance.

RESULTS AND DISCUSSION

Significant differences (at 0.05 probability level) among cultivars were found for the FHB parameters. Table 1 summarizes the mean cultivar values across eight environments for INC, SEV, DIS, VSK, and DON. Correlations between heading date and each of the FHB parameters were very low and non-significant, except for INC (r = 0.17**). Correlations among all FHB parameters were very high and significant (Table 2). SEV and DIS had the highest correlation coefficient among all parameters (r = 0.99***) and DON content of the grain had its highest correlation with VSK (Table 2). Yearly rankings of cultivars for their FHB response using SEV, DIS, VSK, and DON were highly repetitive. Cultivar rankings using VSK were the most repetitive, with overall mean values for Spearman rank correlation coefficients of 0.73***.

For DIS, VSK, INC, and SEV, results from stability analyses over eight environments revealed stability to FHB response in some resistant and some susceptible cultivars. For DIS, 'Forge', 'Roblin', and 'Verde' had low stability. Those varieties are intermediate for their FHB reactions. Thus, depending upon conditions, they will vary more than either varieties with better resistance or varieties with poorer resistance.

We predicted $LSD_{0.05}$ for DIS using spike numbers of 10 and 20 $plot^{-1}$, and replicate numbers of 2, 3, 4, 6, and 8 at 1, 2, 3, 4, 6, 8, and 10 environments (Table 3). We suggest that $LSD_{0.05}$ magnitudes ca. 33% or less of the observed range of values is sufficient for finding important differences. The difference between extreme cultivars for DIS, calculated from across environment means, was 2.4 (Table 1). Accordingly, a $LSD_{0.05}$ less than 0.8 is suggested. Two replicates with 20 spikes achieve this goal in three environments.

For our study, the greatest reduction in genotype standard error was obtained by going from 1 to 2 environments and from 1 to 3 environments, representing a 29 and a 42% reduction in genotype standard error, respectively.

CONCLUSIONS

Both colonized grain and conidial spray inoculation methods provide disease levels appropriate to differentiate resistant and susceptible cultivars. When breeding for FHB resistance, it is imperative to evaluate the material using resistant and susceptible check cultivars known to be stable in their FHB response. Stability of FHB reactions was not associated with levels of resistance in the cultivars tested. Increasing the number of environments has the greatest effect in reducing the genotype standard error and therefore increasing the probability of finding significant differences among genotypes evaluated. We recommend that wheat breeding programs testing a large number near homozygous-early generation lines (e.g. $F_4 – F_6$ derived), use one or two environments to identify and discard highly susceptible lines. The selected lines should continue to be evaluated in subsequent FHB trials to more accurately assess their response over more environments. A good assessment of cultivar FHB reaction can be obtained in three or four environments.

Table 1. Cultivar means for INC, SEV, DIS, VSK, and DON over eight environments.

Cultivar	INC	SEV	DIS	VSK	DON
BacUp	76	18	1.4	9.6	5.3
Ingot	84	24	1.9	11.7	6.6
Forge	81	25	1.9	18.9	7.2
P2375	89	25	2.0	16.5	8.6
Gunner	92	24	2.1	13.3	8.1
McVey	94	25	2.1	19.8	12.6
Russ	90	29	2.2	24.5	10.6
Verde	98	33	2.5	23.5	15.0
HJ98	96	38	2.7	25.4	9.8
Marshall	99	36	2.7	27.6	18.9
Oxen	98	41	2.9	28.8	10.9
Norm	99	47	3.1	44.1	36.5
Roblin	99	56	3.4	30.4	12.7
Wheaton	99	68	3.8	49.8	35.9
Mean	92	35	2.5	24.6	14.2
LSD	5	6	0.3	4.2	8.0

Table 2. Pearson correlation coefficients (above diagonal) and Spearman's rank correlation coefficients (below diagonal) among five parameters over cultivars, reps, and environ. (n=330).

	INC	SEV	DIS	VSK	DON
INC	-	0.43***	0.52***	0.43***	0.32***
SEV	0.58***	-	0.99***	0.56*	0.21*
DIS	0.65***	0.98***	-	0.58***	0.37***
VSK	0.52***	0.70***	0.72***	-	0.45***
DON	0.61***	0.63***	0.64***	0.73***	-

*, **, *** = significant at 0.05, 0.01, and 0.001, respectively.

Table 3. Predicted LSD's (P = 0.05) for disease index among 14 wheat cultivars under differing levels of sub-sampling plot^{-1} (spike number), replication within environments, and environments.

	No of reps with 10 spikelets plot^{-1}					No of reps with 20 spikelets plot^{-1}				
Env.	2	3	4	6	8	2	3	4	6	8
1	1.46	1.34	1.27	1.21	1.17	1.40	1.30	1.24	1.19	1.16
2	1.03	0.95	0.90	0.85	0.83	0.99	0.92	0.88	0.84	0.82
3	0.84	0.77	0.74	0.70	0.68	0.81	0.75	0.72	0.68	0.67
4	0.73	0.67	0.64	0.60	0.59	0.70	0.65	0.62	0.59	0.58
6	0.59	0.55	0.52	0.49	0.48	0.57	0.53	0.51	0.48	0.47
8	0.51	0.47	0.45	0.43	0.41	0.50	0.46	0.44	0.42	0.41
10	0.46	0.42	0.40	0.38	0.37	0.44	0.41	0.39	0.38	0.37

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FLOWERING CHARACTERISTICS AND INCIDENCE OF *FUSARIUM* INFECTION IN A RI POPULATION OF WHEAT

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ABSTRACT

The wheat cultivar Patterson develops a higher incidence of Fusarium head blight (FHB), caused by *Fusarium graminearum*, under field conditions than cv. Goldfield. The cleistogamous nature of Goldfield is likely responsible for its low incidence of FHB. To study the inheritance of flower opening width and duration in relation to incidence of FHB, Patterson and Goldfield were crossed to generate a recombinant inbred (RI) population consisting of 100 F_2-derived lines. The population was characterized for FHB incidence and heading date in eight field environments. Flower opening characteristics of the RI lines and the parents were characterized in three tests over time in a greenhouse and one test in the field, in 2003. An ANOVA revealed significant variation for both incidence and flower opening characteristics, with the ranking of lines typically consistent across environments. A scatter plot of FHB incidence vs. flower opening width suggests that the smaller the flower opening width, the lower the incidence. Research is in progress to identify DNA markers that are associated with cleistogamous flowering/low FHB incidence, which would be valuable in future breeding research to reduce crop production and grain quality losses in wheat due to FHB.

COMPARISON OF FHB DEVELOPMENT ON HARD WINTER WHEAT USING DIFFERENT PLANTING SCHEMES

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ABSTRACT

Fusarium head blight (FHB) is a destructive disease of wheat causing yield loss and poor grain quality. Winter wheat producers in South Dakota have adopted a reduced tillage cropping system and have increased production of winter wheat in traditional corn-soybean rotations. These practices could lead to an increase in FHB severity. The winter wheat breeding program at South Dakota State University has established a proactive effort to develop FHB-resistant hard winter wheat varieties. Transplanted hill nurseries have been screened since 1999 utilizing an established mist-irrigated field screening nursery designed to test cultivars, elite lines, and preliminary lines for FHB resistance. However, transplanting winter wheat is time consuming, involving vernalizing seedlings in cold chambers followed by hand planting. Also, the poorly established root system in transplanted wheat often leads to poor plant development. Furthermore, the laborious transplanting process does not follow the conventional direct seeding method followed by wheat producers. Therefore, we investigated planting schemes to determine if direct seeded row materials are affected differently than transplanted hill plots when they are inoculated with FHB. In October 2000, several multi-location field trials, including the South Dakota Crop Performance Trials (CPT), were directly seeded into the FHB nursery. The CPT trials were also vernalized and transplanted in May 2001. Significant correlations between the two types of planting techniques were observed for FHB severity and disease indices. However, the FHB incidence for the direct seeded rows was low and was not significantly correlated with the incidence levels in the transplanted hills. This was perhaps due to the early flowering of the direct seeded materials. Also, the cooler temperatures at anthesis may have inhibited FHB development. In 2002 and 2003, we investigated transplanted seedling performance in comparison to delayed seeded CPT lines. The CPT and several other trials were directly seeded on November 26, 2001 and October 25, 2002. The planting scheme helped delay flowering by approximately two to three weeks compared to conventional timely seeding. In May 2002 and 2003, the CPT trial was transplanted into the mist-irrigated field nursery. Significant correlations ($P < 0.01$) between the two types of planting techniques in 2002 and 2003 were observed for FHB disease index. Correlations between the direct planting techniques across years were also significant ($P < 0.05$). Correlation coefficients among transplanted hill nurseries across years were not significant, however. These results suggest that delayed direct seeding should replace transplanting for efficient scab screening in hard winter wheat. However, transplanted hills should be used if improper weather conditions prevent a successful direct seeded nursery.

USE OF ROMANIAN WINTER BREAD WHEAT LINE *FUNDULEA 201R* IN BREEDING FHB RESISTANCE

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ABSTRACT

Fusarium head blight (FHB, scab) is one of the main wheat diseases in Romania, because wheat-maize is a common rotation and because high humidity during flowering time is frequent in some areas and years. A winter breadwheat breeding program for resistance to FHB was started at Fundulea more than 20 years ago, in order to reduce yield losses produced by this disease.

Complex crosses between previously identified sources of moderate resistance to FHB and selection under artificial inoculation have produced several lines, that combine better FHB resistance with improved agronomic type and resistance to other diseases. Among them, resistance to FHB has been more documented in the advanced line *Fundulea 201R*.

The winter wheat line *F201R*, is a transgressive derivative of crosses between several sources of moderate resistance, not related to the Chinese resistant germplasm. It has shown high levels of resistance to FHB in several environments in Romania and in other countries, when various inoculation and assessment methods were used. Recently, investigation of quantitative trait loci (QTL) performed at Purdue University, U.S.A. revealed the presence of four interval regions located on chromosomes 1B, 3A, 3D and 5A, that together accounted for 43.0% of the genotypic variation in FHB resistance of *F201R*. In contrast to the Chinese resistant cultivar Sumai 3, *F 201R* is resistant to the main foliar diseases (powdery mildew, leaf and stripe rusts and septoriosis) and has good winterhardiness. However, like Sumai 3, this line has poor bread making quality. As a consequence, improving bread-making quality in FHB resistant germplasm became a major breeding objective. This proved to be a difficult task, because of the complex genetic control of FHB resistance and because one of the major QTLs for FHB resistance is located on the translocated chromosome 1B/1R of *F201R*.

However, after several cycles of breeding, using crosses between *F201R* and several donors for high breadmaking quality (Dropia, Delabrad, Boema from ARDI-Fundulea, Romania and Karl from KS, U.S.A.) we can report some progress.

Data are presented for 17 advanced lines derived from such crosses, in which the level of resistance was assessed under field artificial inoculation by point inoculation technique and breadmaking quality was estimated using the sedimentation value (sv).

Four of the 17 lines combined good levels of FHB resistance (AUDPC -% damaged spikelets- ranging between 180 and 271, when in *F201R* AUDPC was 122) with acceptable sedimentation values (sv=55-63, as compared to sv=42 in *F 201R*).

The investigation of response to FHB was also performed in doubled haploid (DH) lines derived from a cross between *F201R* (FHB resistant) and Boema (high bread making quality). Based on resistance defined as AUDPC and relative weight of grains (RW, as % of control), lines with reaction to FHB, similar to the resistant parent and bread making quality were identified.

Results indicate that combination of resistance to FHB with desired agronomic traits is a difficult but feasible breeding objective, in order to obtain new winter wheat cultivars more adapted for cultivation in conventional and organic farms.

AN ALTERNATIVE TO THE FHB INDEX: INCIDENCE, SEVERITY, KERNEL RATING (ISK) INDEX

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ABSTRACT

The FHB index is widely used by researchers working on Fusarium head blight (FHB) to express the resistance of breeding lines and cultivars. The FHB index is calculated by multiplying the incidence in percentage by the severity in percentage and dividing the product by 100 to express the FHB index on a scale of 0-100. We propose a new index that incorporates a third factor, the evaluation of harvested grain. We believe it is important to include the evaluation of the grain in an index to be used for selection of scab resistant breeding lines. The incidence, severity, kernel rating index (ISK index) is calculated as follows: 0.3 x (incidence in %) + 0.3 x (severity in %) + 0.4 x (FDK in %) or 4 x (kernel rating on 0-9 scale). The limits for the ISK index are 0-100 (or 0-96 if the kernel rating scale is used). Because the FHB index is calculated by multiplying the incidence and the severity, the variability of the FHB index is often greater than either the incidence or severity separately. Due to the variability associated with the FHB index, in many cases, FHB index means are significantly different only when they differ by large amounts. We have found that mean separation is better with the ISK index than with the FHB index. Susceptible and resistant breeding lines can be separated with either the FHB index or the ISK index; however, the ISK index is more effective for the separation of moderately resistant and very resistant breeding lines. Thus, the advantages of the ISK index over the FHB index are: 1) the ISK index incorporates a harvested grain evaluation, and 2) the ISK index provides better separation of means than the FHB index.

IDENTIFICATION OF QTLS IN THE HARRINGTON/MOREX BARLEY POPULATION FOR FHB REACTION, MATURITY, AND PLANT HEIGHT

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OBJECTIVES

To evaluate the Harrington/Morex (HM) doubled-haploid population for FHB reaction, heading date, and plant height in both long- and short-day environments and to estimate the number, genome location, and importance of quantitative trait loci (QTLs) associated with these traits.

INTRODUCTION

Development of spring barley, *Hordeum vulgare*, cultivars with resistance to Fusarium head blight (FHB), incited by *Fusarium graminearum*, is difficult because the inheritance of FHB resistance and its interactions with morphological traits are complex. These traits map near the six-rowed spike 1 (*vrs1*) locus in the proximal region of chromosome 2HL. Testing of doubled-haploid lines from the HM mapping population may reveal more information about the 2H associations. Harrington, a Canadian two-rowed cultivar, and Morex, a Midwest six-rowed cultivar, are recommended for malting in the US. Testing HM population in both long- and short-day environments could aid evaluation of plant height and maturity genes.

MATERIALS AND METHODS

The HM lines, their parents (Harrington and Morex), and the checks (CIho 4196, Bowman, and Conlon) were arranged in a randomized complete block design with two replicates, and grown in two environments in 2002: Langdon, ND (LA02) and Osnabrock, ND (OS02) and three environments in 2003: Hangzhou, China (CH03), Langdon, ND (LA03), and Osnabrock, ND (OS03). Plant height was measured in the CH03, LA03, and OS03 nurseries as centimeters from the soil surface to the tip of inflorescence excluding awns. Heading date was estimated in the CH03 and OS03 nurseries as the number of days from January 1 to when approximately 50% of the heads were half emerged from the boot. Fusarium inoculum was prepared according to Prom et al. (1996). Disease readings were taken at the soft dough stage. Counting the number of infected kernels and dividing by the total number of kernels per spike multiplied by 100 determined the severity of FHB. Assessments were made on 10 randomly selected spikes per plot. Analyses of variance for FHB severity, heading date, and plant height were conducted for each environment by means of GLM procedures of SAS (1990). Error mean squares across all the environments were not homogeneous as determined by Bartlett's chi-square test; thus, a combined ANOVA across environments was not conducted. Phenotypic data sets on HM lines from the five environments, and the published 107-marker linkage map for the HM population (Marquez-Cedillo et al., 2001) were used to perform QTL analyses with the software package NQTL. Both simple interval mapping (SIM) and simplified composite interval mapping (sCIM) techniques were used for QTL detection (Tinker and Mather, 1995). Each data set was analyzed with 1000 permutations, a 5-cM walking speed, and a Type-I error rate of 5%. Coincident peaks with both SIM and sCIM analysis above the significance threshold were used to declare the presence of QTL.

RESULTS AND DISCUSSION

FHB results **-** Only the results at specific sites are reported. Significant differences among HM lines were observed for all traits that were evaluated. The differentiation among lines for FHB reactions appeared best for the OS02, CN03, and LA03 nurseries (Table 1). Phenotypic correlation coefficient values for FHB severity among all environments were significant with a range of 0.40 to 0.69. The moderately resistant parent (Harrington) exhibited lower FHB severity than the moderately susceptible parent (Morex). Few HM lines had lower FHB scores than Harrington and several had higher FHB scores than Morex. With the exception of Chinese nursery, most lines were within the bounds of LSD (P=0.05) and were not transgressive segregates for increased FHB resistance. When averaged over locations, some HM lines appeared as resistant as the resistant check CIho 4196.

Table 1. Mean FHB severity, heading date, and plant height for Harrington/Morex lines, parents, and checks.

Line	Spike type	FHB %				Heading date days from Jan 1		Plant Height cm	
		2002	2003		Five Locations	2003		2003	
		Osnabrock	China	Langdon	Mean	China	Osnabrock	China	Langdon
Checks									
CIho 4196	2	8.7	0.1	22.1	12.0	115.4	201.5	109.1	114.0
Harrington	2	**10.3**	**20.3**	**30.5**	**16.7**	**108.0**	**206.5**	**93.1**	**92.5**
Bowman	2	11.0	32.5	32.9	27.3	102.2	198.0	91.8	87.0
Conlon	2		29.8	37.9		101.4	193.0	93.2	88.5
Morex	6	**25.2**	**37.1**	**40.9**	**35.4**	**97.2**	**195.0**	**110.2**	**96.0**
HM μ		21.1	26.4	39.7	29.1	105.3	200.2	104.2	96.7
σ		3.9	4.5	6.6		1.2	1.8	6.7	2.9
Less susceptible									
HM 124	2	6.6	8.8	26.0	11.4	107.3	206.0	116.7	110.5
HM 1	2	12.1	2.0	19.1	13.1	111.8	204.5	115.2	125.0
HM 244	2	4.4	6.6	22.5	15.0	107.1	199.5	114.7	108.0
HM 49	2	6.3	10.1	25.9	15.7	103.8	199.5	125.3	107.0
More susceptible									
HM 72	6	41.1	69.3	45.6	47.4	101.1	201.0	91.7	76.5
HM 33	6	35.2	66.3	60.1	47.5	103.9	196.0	88.4	81.5
HM 145	6	35.9	50.4	53.8	47.9	100.9	198.0	93.8	74.5
HM 73	6	46.3	70.1	78.7	52.9	106.3	202.0	85.1	77.5
LSD 0.05		10.9	12.5	18.5		3.2	5.1	18.5	8.0
CV		26.1	23.9	23.6		1.5	1.3	9.1	4.2

Heading date and plant height results **-** Harrington was later and shorter than Morex in all tests (Table 1). The frequency distributions in the HM population for all traits, except spike type, were continuous. A few transgressive segregates for plant height were noted, but not for heading date. Maturity was significantly and negatively correlated with FHB severity in two environments where days to heading were recorded. Maturity in both long- and short-day conditions was significantly and positively correlated. Plant height was significantly and negatively correlated with FHB severity. These data support previous findings about the general tendency of tall, late plants to be more FHB resistant.

Identification of QTLs -The largest QTL for FHB resistance was present in chromosome 2H and was detected in all five environments (Fig. 1A and 1B). A second, but smaller, QTL for FHB was found in 4H in all tests. The largest QTL for heading date was detected in 2H. At the short-day site, peaks in 4H and 7H were significant and peaks in chromosomes 1H and 5H approached significance (Fig. 1C). Two QTLs for plant height detected in 2H and 4H according to the coincident peaks of SIM and sCIM analyses (Fig. 1D). An additional plant height QTL in 7H was found in only two environments. Marquez-Cedillo et al. (2001) previously reported plant height and maturity QTLs in 2H in the HM population.

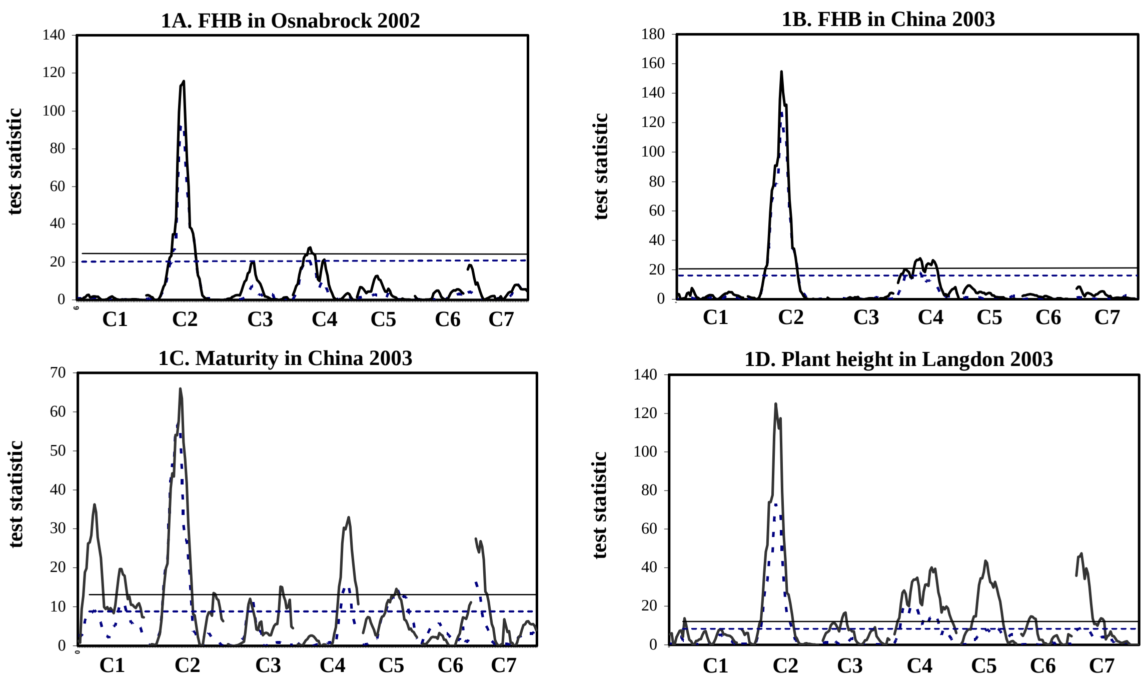

Figure 1. Scans of test statistics (Y-axis) for simple interval mapping (SIM, broken lines), simple composite interval mapping (sCIM, solid lines) for Harrington/Morex DH lines. Chromosomes 1 (7H), 2 (2H), 3 (3H), 4 (4H), 5 (1H), 6 (6H), and 7 (5H) are shown on the X-axis. Horizontal lines indicate corresponding thresholds for testing SIM and sCIM.

Trait relationships - Harrington contributed QTLs for FHB resistance, increased plant height, and late heading. The HM lines with lowest FHB readings were tall and two-rowed, while the lines with highest FHB readings were short and six-rowed (Table 1). Other studies placed at least two plant height genes (*hcm1* and *lin1*) and one heading date gene (*Eam6*) near the *vrs1* locus in 2H (Franckowiak and Lundqvist, 2002). These genes are present in Morex and can partially explain the observed trait associations in 2H. One previous suggested that the *Eam6* gene is expressed in short-day environments. Tohno-oka et al. (2000) reported that the QTL for short-day response in the Steptoe/Morex doubled-haploid population is located in 2H with minor factors in 1H, 4H, and 7H. None of the HM lines headed earlier than Morex in China. These results suggest that accumulating desirable factors for FHB resistance and associated morphological traits in cultivars adapted to the Upper Midwest will be difficult.

CONCLUSIONS

1. Lines with FHB reaction levels similar to those of CIho 4196, the resistant check, were observed in the Harrington/Morex DH population.

2. QTLs for FHB resistance were located primarily in chromosome 2H near major genes that control plant height and maturity.

3. Testing of the HM lines under short-day conditions revealed the presence of several QTLs that contribute to earliness in Morex.

4. Both adverse linkages and a number of minor genes for early heading have made development of early, FHB resistant barley cultivars difficult.

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DISCLAIMER

Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the view of the U.S. Department of Agriculture.

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SCREENING ELITE SOUTH DAKOTA WINTER WHEAT FOR SSR MARKERS LINKED TO FUSARIUM HEAD BLIGHT RESISTANCE

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ABSTRACT

Resistance to wheat (*Triticum aestivum* L.) Fusarium head blight (FHB) -caused by *Fusarium graminearum* Schwabe - is a very complicated quantitative trait. Marker assisted selection (MAS) could be a useful tool to enhance the efficiency of FHB resistance breeding. A major FHB resistance QTL, *Qfhs.ndsu-3BS*, has been identified in Spring wheat cultivar Sumai 3, and SSR markers *Xgwm389-135*, *Xgwm493-190*, *Xgwm533-98* and *Xgwm533-145* were found to be linked to this QTL. In this study, we screened 61 elite winter wheat lines for these four markers. The results indicated that 22 wheat lines had either *Xgwm533-98* or *Xgwm389-135* marker. However, none of the 61 winter lines had either *Xgwm493-190* or *Xgwm533-145*, the two SSR markers that are tightly linked to the *Qfhs.ndsu-3BS* FHB-resistance QTL. Of the four markers, *Xgwm389-135* was the most polymorphic. An *Xgwm533-120* allele, which was a diagnostic marker for stem rust resistance gene *Sr2,* was observed in 35 wheat lines.

RESISTANCE OF GENOTYPES OF THE UNIFORM SOFT RED WINTER WHEAT FHB NURSERY AND INTERNATIONAL GENOTYPES TO FHB

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OBJECTIVES

The main task of the experiment was to test of the uniform soft red winter wheat FHB nursery and its comparison with several advanced Hungarian and international genotypes.

MATERIALS AND METHODS

Each genotype was sown on a 5 m^2 plot at 19 October 2002. Germination was normal, in the second decade of December – 17-19 ^oC frost came without snow. The spring wheats were all killed, therefore Sumey-3 and Nobeoka Bozu could not have been tested. Several winter wheat genotypes suffered also, but mostly survived without problem the long winter. Inoculation was made at full flowering with 2 *F. graminearum* and two *F. culmorum* isolates (see Table 1) separately having different aggressiveness. Inoculation, evaluation of data followed Mesterhazy (1995, 2001) and Mesterhazy et al. (1999). Four evaluations of FHB were made rating the percentage of diseased spikelets. As the weather was hot and dry a fifth evaluation could not have been done, harvest was 14 days earlier than normal. At full ripening the infected groups of heads were harvested, ten heads were randomly separated, threshed carefully at low wind speed, weighted and rated for FDK. Two FDK ratings were made, in the first case the medium to severe FDK was rated, in the second only the severe. The genotypes B 980582 and B 011066 had white color grains, here the evaluation needed more care the contrast between normal a scabby grains was smaller than usual.

RESULTS AND DISCUSSION

Table 1 shows the data across the isolates, ranked by the severe FDK values. Mean of the FHB values is 33 %, for all FDK it is 59 and for severe 45 % and mean yield loss is 48 %. The variation width is very high, from very low to very high values all possibilities occur. Even the correlations between traits are close and highly significant, important genotypic deviations were recorded. There were several genotypes like B 011066 that had a susceptible head reaction, high FDK value for medium to severe infected grains, but rated much lower for severe FDK ratio. The opposite was Huba with relatively low FHB value, but its FDK was very high, 80 and 34 % for the severely infected grains. Normally the difference was much lower; in the most susceptible genotypes the difference was minor. Fundulea 201R had a better than medium FHB rating, but surprisingly very high FDK values above 70 %. Arina, the famous Swiss medium resistant cultivar made the same performance, relatively low FHB with very high FDK values. The most resistant genotypes had lower than 10 % FHB infection, up to 30 % medium and severe FDK, up to 23 % severe FDK and up to 30 % yield loss. Cooker 9835 was the most susceptible with nearly 80 % FHB, more than 80 % FDK and 80 % yield loss. Among Hungarian materials, not presented here, many such lines occur.

Even the resistance differences were considerable, full resistant material has not been found. However, the first four genotypes carry resistance from Nobeoka Bozu, the Japanese spring wheat resistance source. The

Sgv/NB//MM/Sumey3 line performed also well, presenting the lowest FHB value, but for FDK it was less strong. They are much more adapted than their spring wheat ancestors, but they are not yet suitable for a cultivar. However, crosses with these lines promise good lines for variety production.

Table 1. Resistance of American and several international wheat genotypes to FHB, 2003. Data: Means or four isolates.

Genotypes	FHB %	FDK(1) %	FDK (2) %	Yield loss %
81.60/NB//Ko	9.00	3.72	3.50	33.43
Zu//Ré/NB	4.98	28.75	9.63	44.97
RSt/NB	19.29	34.17	9.83	33.60
RSt/NB	7.90	29.58	12.83	35.24
Sgv/NB//MM/Sum3	1.25	20.00	13.00	20.00
ARGE 97-1033-3-5	3.15	25.83	16.00	17.47
Zu//Ré/NB	8.27	25.00	16.25	26.63
B 980582	14.71	25.83	18.33	44.81
ARGE 97 1047-4-2	8.19	29.17	22.25	30.39
ARGE 97 1038-3-5	15.33	31.67	22.33	41.02
NC 99-13296	28.10	35.00	27.08	41.58
B 011066	46.79	74.17	27.08	77.08
NC 98-26192	17.29	35.83	28.42	45.82
Huba	28.83	80.00	34.58	68.66
VA 00 W 566	46.88	40.83	37.08	66.40
B 980416	31.81	53.33	37.92	59.73
ERNIE	17.98	47.50	38.75	23.82
Saman	37.06	44.38	38.75	50.97
ARGE 97-1042-4-5	11.21	53.33	41.25	29.86
Mérő	29.54	71.25	41.25	58.84
AR 857-1-1	18.85	70.00	45.00	47.48
92.111466/Sum3/81.61//Ko	21.88	57.50	45.00	48.48
VA 02 W 713	50.52	46.25	46.25	56.75
ARGE 97 1048-3-6	33.50	62.50	46.67	61.34
VA 01 W 461	54.52	71.25	50.00	80.40
VAN 98 W 342	30.79	77.08	50.42	44.62
92.1117///RSt//MM/NB	30.10	60.00	51.88	60.91
NC 9913308	34.06	68.33	53.33	33.25
VA 00 W 562	35.98	63.33	55.42	47.63
AR 857-1-2	26.63	80.00	55.83	29.08
AR 93019-2-1	41.92	77.92	55.83	60.46
MV 15-42	36.52	65.83	56.25	54.02
B 011117	34.52	70.42	59.58	59.94
GA 931587 E 53	55.15	76.25	62.50	68.86
MV 5-46	39.33	75.00	64.58	53.38
MV 27-28	37.88	81.67	65.83	58.13
GA 931630 E 48	38.23	80.83	65.83	49.71
Ar 93035-4-1	68.10	89.17	68.33	79.46
VA 02 W 732	47.19	79.58	68.75	75.19
Fund.201R	37.65	77.50	71.25	61.61
GA 94261 E 7	62.13	92.92	72.92	83.02
Arina	33.90	95.25	78.75	52.90
GA 941208 E 35	64.73	91.67	79.67	65.48
GA 931233 A 24	78.33	87.92	82.00	82.49
COKER 9835	79.73	91.33	82.50	80.54
Mean	32.88	59.53	45.12	47.88
	2.14	6.82	7.98	2.36

Trait	FHB	FDK(1)	FDK (2)
FDK(1)	0.765212		
FDK (2)	0.806421	0.911796	
Yield loss	0.861387	0.693261	0.643818

All are significant at P = 0.1 %

Saman and Huba are new candidates for cultivars with good medium resistance and Saman has better parameters, especially for yield loss. Both are high yielding and have good baking quality.

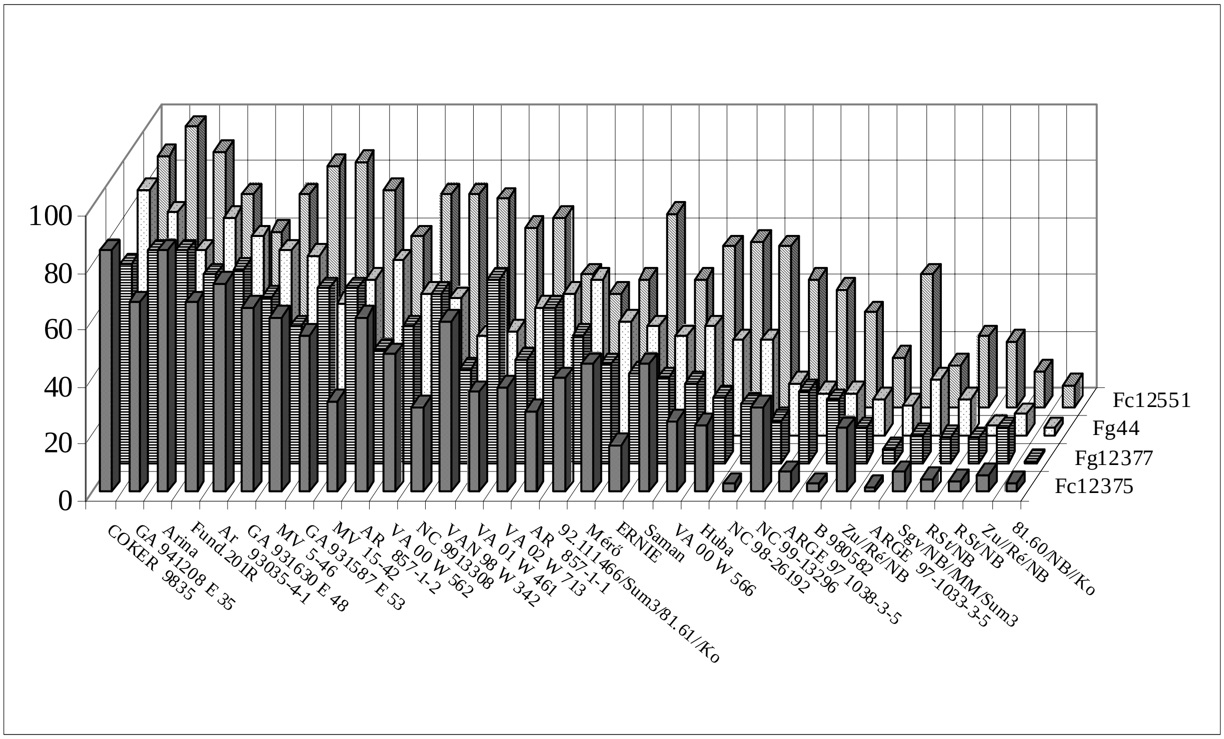

Figure 1. Resistance tests for FHB in wheat genotypes, severe FDK data of some entries according to the isolates used.

Evaluating the resistance, yield response is also important. We need all four parameters in the positive range to have a stability of resistance.

Figure 1 shows the isolate specific data for FDK. It presents clearly that the response of the cultivars is not the same. In most cases as here also, the cultivar x isolate interaction is significant. When we use five inocula of the same isolate, we have the same picture. Therefore these data are not arguments for races. However it shows that a possible reliable evaluation of resistance needs the response as a mean of several aggressiveness level. So the data will not be only more reliable, but the resistance level can also be determined with a higher preciosity. Here we cannot have the case that by using a less aggressive isolate most of the material will be "resistant" and next year full of FHB at a severe epidemic.

We have now the problem, which level of resistance secures excellent field resistance. From these data it is not possible to set e limit value. When a natural epidemic occurs, such a set of cultivars will show according to their natural infection severities where is about the limit value. When we would not have more susceptible cultivars than the limit represented by Ernie it should be an acceptable value. In Hungary possibly less is enough like Saman. For practical reasons it is reasonable to select from the better half of the population tested.

We should stress that this is one year result. Comparing with the other location it seems that a good agreement is between data, even they were produced by different methods. Large differences can be identified well.

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DEVELOPING FHB-RESISTANT SOFT RED WINTER WHEAT VARIETIES FOR THE MID-SOUTH

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INTRODUCTION

Wheat varieties resistant to Fusarium head blight (FHB) are likely to be an important component of any integrated management strategy for FHB. In the Mid-South (Arkansas, Louisiana, Mississippi, and Tennessee), FHB resistance has not been as high of a priority for growers because FHB epidemics have occurred less frequently than diseases such as stripe rust, leaf rust, leaf blotch, and soilborne mosaic. Consequently, before FHB-resistant varieties will be accepted by growers, FHB resistance will need to be incorporated into agronomically suitable, high-yielding varieties with adequate resistance to other diseases. To achieve this goal, the Arkansas Breeding Program is developing resistant varieties as part of its on-going program, and the Arkansas Germplasm Enhancement Program evaluates all FHB winter wheat nurseries for resistance and is developing adapted breeding lines by transferring genes for resistance to FHB and other diseases into soft red winter wheat backgrounds.

MATERIALS AND METHODS

The Arkansas Breeding and Germplasm Enhancement Programs began making crosses specifically for FHB resistance in 1993 and 1997, respectively. Lines developed from these crosses have been selected each season for adaptation, yield, and resistance to FHB and other diseases. Evaluations of the most advanced lines are reported here as a progress report.

RESULTS AND DISCUSSION

Of the 32 entries evaluated in the Southern Winter Wheat FHB Nursery, several AR lines developed by the breeding program and ARGE lines developed by the germplasm enhancement program ranked among the top five entries for FHB incidence, severity, index, scabby seed, DON, and type 2 resistance in the greenhouse (Table 1). Several advanced lines have resistance to FHB as well as stripe rust and leaf blotch which are important diseases in the region (Table 2). ARGE lines were similar to checks for milling score, test weight, and flour protein, but most lines ranked below the checks for baking score, softness equivalent, and flour yield (Table 3). Fifteen advanced lines had yields that were not significantly different from the recently released variety, Pat (Table 4).

Arkansas began developing FHB-resistant soft red winter wheats before the US Wheat and Barley Scab Initiative existed. Funding from the Initiative has allowed the expansion of FHB activities, and the Arkansas program has made valuable contributions toward developing resistant varieties.

ACKNOWLEDGMENTS

We thank participants in the Southern Winter Wheat FHB Nursery for data across locations, Charles Gaines and the staff at the USDA, ARS Soft Wheat Quality Laboratory for the milling and baking data, and Steve Harrison for evaluating lines during the selection process.

Table 1. Performance of advanced lines from Arkansas averaged across all locations in the 2003 Southern Winter Wheat FHB Nursery.

Line[1]	FHB Incidence		FHB Severity		FHB Index		Scabby seed		Vomitoxin DON		Heading date		Plant height		Greenhouse severity	
	0-100	Rank	0-100	Rank	0-100	Rank	%	Rank	ppm	Rank	Julian	Rank	in.	Rank	0-100	Rank
ERNIE	49.6	5	23.5	13	13.9	9	27.6	8	6.5	17	129	2	31	8	15	2
COKER 9835	77.8	32	57.3	32	48.9	32	58	32	11.4	31	133	29	29	3	46	24
AR 857-1-1	58.2	11	16.9	3	11	5	32.1	14	4.4	7	132	25	38	31	31	14
AR 857-1-2	48.3	3	15.7	2	10	3	23.4	3	4.1	5	132	26	37	30	51	27
AR 93019-2-1	59.6	15	25	16	19.4	16	46.7	30	7.7	24	134	30	40	32	53	30
AR93035-4-1	65.7	21	26.7	18	23.3	21	49.6	31	7.2	22	132	27	34	20	33	18
ARGE 97-1042-4-5	44.4	2	19.2	9	10.2	4	30.2	10	3.3	2	130	9	35	22	23	3
ARGE 97-1033-3-5	44.3	1	10.7	1	4.5	1	25.2	4	4.1	6	132	23	37	28	14	1
ARGE 97-1048-3-6	51.5	7	17.7	7	14.6	11	27	6	4.5	8	132	22	37	29	23	5
ARGE 97-1038-3-5	54.7	10	20.4	11	12.2	7	27.3	7	3.3	3	130	8	35	24	35	22
ARGE 97-1047-4-2	50.7	6	17	5	9.8	2	31.9	12	3.1	1	129	1	36	26	44	23

[1]Ernie = resistant check, Coker 9835 = susceptible check, Ranks based on 32 total lines in the nursery.

Table 2. Disease ratings for advanced Arkansas lines in 2003.

Line	FHB % diseased florets			% Scabby grain	% Stripe Rust	% Leaf Blotch	% Green leaves
	Fayetteville[1]	Kibler[2]	Greenhouse[3]	Kibler	Fayetteville[4]		Kibler[5]
AR 93095-4-1	50	32	23	85	4	40	69
AR 93035-4-1	36	40	35	88	0	12	60
AR 93035-4-3	39	35	44	83	0	11	60
AR 93035-4-4	40	39	40	85	2	17	50
AR 93035-4-2	41	36	30	83	4	36	55
AR 93035-7-1	44	38	52	85	1	20	50
AR 93108-1-3	46	48	30	93	2	31	45
AR 93091-4-2	44	32	57	68	25	56	60
AR 93108-9-1	46	46	43	98	4	66	31
AR 93108-3-2	48	40	16	90	0	76	65
AR 93069-5-1	36	40	58	70	2	76	32
AR 93019-2-1	64	71	69	100	5	69	44
AR 93001-3-2	29	26	18	60	0	31	78
AR 878-2-1	28	28	19	68	4	59	45
AR 857-1-2	19	16	28	45	2	40	85
AR 857-1-1	22	21	62	64	2	45	78
AR 880-5-1	25	25	32	76	0	65	64
AR 922-5-1	36	19	13	48	2	81	69
ARGE 97-1022-5-1	34	39	40	88	0	20	81
ARGE 97-1042-4-5	30	38	9	88	0	18	50
ARGE 97-1043-6a-5	22	31	12	75	0	14	78
ARGE 97-1033-3-5	20	16	6	59	0	10	60
ARGE 97-1033-10-2	28	28	6	85	15	31	64
ARGE 97-1048-3-6	19	29	12	83	5	20	78
ARGE 97-1064-11-5	35	35	21	85	0	19	78
ARGE 97-1064-13-5	24	24	20	85	2	18	85
ARGE 97-1038-3-5	36	34	32	83	0	28	76
ARGE 97-1008-3-3	26	30	20	80	4	31	78

Table 2. Continued

Line	FHB % diseased florets			% Scabby grain	% Stripe Rust	% Leaf Blotch	% Green leaves
	Fayetteville[1]	Kibler[2]	Greenhouse[3]	Kibler	Fayetteville[4]		Kibler[5]
ARGE 97-1010-3-5	32	40	32	85	4	50	64
STANDARD[1]	41	34	38	65	0	17	76
ARGE 97-1047-4-2	28	24	35	68	0	35	83
Ernie	38	18	9	75	18	44	32
Agripro Patton	29	24	55	94	66	20	23
Agripro Mason	46	33	53	93	0	36	58
Pioneer 2684	58	46	13	90	5	83	42

[1]Mean of four replications rated on May 27 at soft dough stage

[2]Mean of four replications rated on May 19 at soft dough stage

[3]Center floret inoculation, mean of three replications with four to eight heads per replication

[4]Percentage of flag leaf diseased, mean of four replications rated on May 28

[5]Mean of four replications rated on May 12; leaf blotch and stripe rust were the principal diseases

Table 3. Milling and baking scores from the USDA, ARS Soft Wheat Quality Lab for ARGE FHB-resistant lines.

LINE	MILLING QUALITY SCORE		BAKING QUALITY SCORE		TEST WT. SCORE		SOFT. EQUIV. SCORE		MICRO T.W. LB/BU	SOFT. EQUIV. %		FLOUR YIELD %		FLOUR PROT. %	LACTIC ACID RET'N	COOKIE DIAM. CM.		TOP GR.
STANDARD[1]	64.0	C	65.3	C	72.3	B	60.5	C	61.7	54.6		71.1		9.59	113.1	18.11		2
97-1022-5-1	60.2	C	36.3	F	67.6	C	56.3	D	61.1	52.7		70.2	Q	10.42	113.5	16.95	Q	1
97-1042-4-5	65.9	C	-1.2	F	91.3	A	26.1	F	63.9	39.3	Q	71.6		10.38	116.6	15.45	Q	0
97-1043-6a-5	61.2	C	28.8	F	79.7	B	54.8	D	62.5	52.1		70.4		10.93	104.1	16.65	Q	1
97-1033-3-5	63.9	C	-3.0	F	84.4	A	21.2	F	63.1	37.1	Q	71.1		9.93	113.2	15.38	Q	0
97-1033-10-2	67.4	C	-6.2	F	84.6	A	22.4	F	63.1	37.6	Q	72.0		10.09	117.8	15.25	Q	0
97-1048-3-6	54.5	D	23.3	F	89.0	A	36.9	F	63.7	44.1	Q	68.7	Q	10.05	101.8	16.43	Q	1
97-1064-11-5	55.3	D	27.6	F	73.9	B	61.9	C	61.9	55.2		68.9	Q	9.64	139.0	16.60	Q	0
97-1064-13-5	58.7	D	36.3	F	68.0	C	66.5	C	61.2	57.3		69.8	*	10.72	114.3	16.95	Q	1
97-1038-3-5	57.0	D	37.6	F	63.7	C	46.4	E	60.6	48.3	Q	69.3	Q	9.38	109.6	17.00	Q	1
97-1008-3-3	56.1	D	52.0	D	83.2	A	51.4	D	63.0	50.5	*	69.1	Q	9.77	102.2	17.58	Q	2
97-1010-3-5	50.1	D	18.5	F	77.8	B	55.4	D	62.3	52.3		67.6	Q	10.74	105.1	16.24	Q	0
97-1060-5-5	61.6	C	29.8	F	82.5	A	57.5	D	62.9	53.3		70.5		10.03	108.5	16.69	Q	1
97-1047-4-2	58.0	D	38.6	F	75.0	B	54.5	D	62.0	51.9		69.6	*	9.58	110.6	17.04	Q	2
Agripro Mason	63.4	C	46.1	E	76.4	B	69.9	C	62.2	58.8		71.0		9.45	119.9	17.34	Q	1
Pioneer 2684	64.0	C	65.3	C	72.3	B	60.5	C	61.7	54.6		71.1		9.59	113.1	18.11		2
NK Coker9663	59.1	D	56.3	D	70.3	B	54.9	D	61.4	52.1		69.9	*	8.13	111.6	17.75	*	3

[1]Standard was Pioneer 2684

* = values was one LSD below the standard

Q = Values was two or more LSDs below the standard

Table 4. Performance of breeding lines and checks in the Scab Yield Nursery in 2003 across two locations in Arkansas (Stuttgart and Marianna).

Entry	Yield	Test weight	Lodging	Plt ht	Heading date	Maturity date	Leaf rust
	bu/A	lb/bu	%	in.			%
PAT	73.9	54.6	1	38	4/22	5/24	2
AR93108-3-2	71.1	54.2	3	35	4/16	5/17	0.7
AR93035-4-2	71.0	54.6	1	33	4/21	5/21	3.3
ARGE971043-6a-5	70.7	55.5	3	37	4/21	5/20	0.3
AR93035-4-1	70.7	55.4	0	35	4/23	5/22	2.7
AR93035-4-3	69.7	56.2	0	36	4/22	5/22	3
AR93035-4-4	69.2	54.4	0	35	4/21	5/23	3
ARGE97-1033-10-	69.0	54.9	13	40	4/22	5/23	1
AR93095-4-1	68.9	52.1	13	39	4/22	5/17	2
AR93108-1-3	68.0	53.1	12	32	4/18	5/20	2
ARGE97-1022-5-1	67.3	54.5	8	36	4/21	5/21	1.3
AR93001-3-2	66.9	56.3	16	37	4/16	5/19	2
AR93069-5-1	66.7	57.3	7	37	4/18	5/20	2
AR93035-7-1	66.6	54.7	0	34	4/20	5/21	3.3
AR93108-9-1	66.4	52.7	5	33	4/16	5/16	3.7
AR922-5-1	66.4	56.8	19	37	4/16	5/18	1.7
AR93019-2-1	66.1	52.1	0	33	4/21	5/21	2.3
AR857-1-2	64.4	55.3	8	41	4/15	5/16	.
AR857-1-1	63.7	55.7	6	40	4/15	5/16	.
ARGE97-1064-13-	62.9	52.6	13	41	4/20	5/23	0.7
ARGE97-1008-3-3	62.4	56.2	15	39	4/17	5/25	1.7
ARGE971064-11-5	62.2	52.8	16	39	4/20	5/23	2.7
AR880-5-1	62.1	53.9	13	37	4/18	5/19	2
ARGE971010-3-5	60.7	55.7	28	38	4/17	5/20	0
ERNIE	60.7	54.0	11	37	4/21	5/23	1.3
AR878-2-1	60.3	55.2	4	39	4/15	5/18	4
AR93091-4-2	59.7	54.9	6	37	4/21	5/24	0.3
ARGE97-1060-5-5	56.6	55.2	41	40	4/20	5/19	1
Mean	65.9	54.7	9.3	36.9	4/19	5/20	1.9
LSD05	7.5	1.4	13.3	4.2	3.2	4.1	1.6
CV%	10.0	2.3	125.6	5.6	0.4	0.4	52

THE DEVELOPMENT OF FUSARIUM HEAD BLIGHT TOLERANT VARIETIES OF WHEAT IN NEBRASKA FROM 2001 TO 2003

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ABSTRACT

Wheat germplasm that is tolerant to Fusarium head blight (FHB, scab) will be the basis for cultivar development in high rainfall and irrigated acreage, which is at high risk to FHB infection, in the Central Great Plains. The primary objective is to identify and develop elite winter wheat varieties that are tolerant to Fusarium head blight. The second objective was to field screen the elite hard winter wheat lines including those in the Regional Germplasm Observation Nursery (RGON). Eight hundred winter wheat experimental lines, which included the RGON were screened in the field against appropriate controls in 2003. Seventy two % of the lines have been screened in at least three mutually exclusive trials including an independent determination by South Dakota State University (SDSU). Inoculation was done, by spraying the heads at a rate of (70 000 *Fusarium graminearum* conidia of strain SD-4) / (1 ml distilled water), followed by misting in the field or bagging in the greenhouse. Six % of the RGON lines had significantly less than 35 % severity. Twenty one percent of the lines that were extensively screened, had significantly less than 46% severity. Thirteen percent of these extensively screened lines are derived from experimental breeding lines, and are very likely new sources of background FHB resistance. These very promising lines will be crossed with known major genes to enhance the tolerance their tolerance to FHB infection.

INTRODUCTION

Nebraska is second only to California for irrigated crop production. Hence FHB, though a periodic disease, can be an important disease greatly affecting approximately 35% of Nebraska's wheat acreage. As humans consume virtually all of this wheat and over one half is exported, safe, healthy grain is critical for maintaining the reputation of hard winter wheat in the domestic and export markets. All winter wheat lines to be released by the University of Nebraska shall be screened for FHB tolerance, and this information will be shared with producers.

The primary objective is to identify and develop elite winter wheat varieties that are tolerant to Fusarium head blight (FHB, scab), using conventional breeding methods. The second objective was to screen elite hard winter wheat lines including the Regional Germplasm Observation Nursery (RGON).

MATERIALS AND METHODS

Sources of FHB tolerant germplasm originating from our biotechnology efforts, spring and soft wheat germplasm, and exotic germplasm, were collected for crossing into our elite lines. In the field, seventy two transgenics and eight hundred winter wheat breeding lines, which included the RGON nursery were planted and screened, against appropriate controls, for tolerance to FHB, using a system similar to that of Campbell and Lipps (1998). Each variety was planted in a 10 ft^2 plot.

All lines screened in the field and greenhouse in Nebraska in 2003, were inoculated by spraying 70000 conidia of *F. graminearum* strain SD-4 / 1 mL distilled water, onto heads. Inoculum was applied in the field by spraying 50 mL of inoculum/plot using an electrical back pack sprayer, and in the greenhouse 5 mL of inoculum/head was applied using a hand held sprayer. After inoculation in the field the plants were misted for 5 minutes at 30 minute intervals, using a modified system similar to that employed by Zhang et al. (1999). Misting began when the plants were inoculated and continued until the first readings were taken. In the greenhouse inoculated heads were, tagged and then sealed in a 16 x 9.5 cm^2 snack size Ziploc bag for 72 hrs. Bordering the scab nursery with forage triticale provided an excellent buffer and greatly reduced wind in the misting nursery.

FHB was rated by estimating the % head severity on 20 individual heads (Shaner and Buechley, 2001). Plot severity or the FHB index was calculated by averaging these 20 FHB ratings. Intensity was calculated by taking the count of the infected heads and dividing it by 20 (the total # of heads scored). It is not practical to record FHB index and incidence in the greenhouse, however % severity was recorded, by counting the # of infected spikelets relative to the total # of spikelets. The grain, from one of our three most advanced nurseries was analyzed for Deoxynivalenol (DON) by the Veterinary Diagnostic Service at North Dakota State University.

RESULTS AND DISCUSSION

The Nebraska breeding project has extensive field and greenhouse FHB tolerance data, from 9 independent trials conducted since 2001 in Nebraska and South Dakota. Seventy two % (i.e. 574 lines) of the eight hundred lines screened in 2003 have been screened in at least 3 mutually exclusive trials. However we were careful not to indiscriminately combine all the trials, because one should not base important decisions regarding line selection, upon experiments which may have unusual variability. Therefore we were careful to only compare lines, from experiments in which overall experimental variability was similar. Trials were considered similar if their variability differed by less than 5 fold in magnitude.

FHB severity was combined for 4 of the 9 greenhouse and field trails and incidence data was combined for 2 of the 4 field trials. Table 1 shows select lines including "Wesley" that were more tolerant to the spread of FHB infection than Millenium or NE99495. Wesley is a recently released widely grown line from our program. It appears to have a better than average level of FHB tolerance and a low DON level in our field tests which confirms our earlier greenhouse tests. Wesley is adapted to the primary regions where FHB is most common. Over half of these lines were derived from experimental breeding lines, and are very likely new sources of back-ground FHB resistance. These very promising lines will be crossed with known major genes to enhance the their tolerance to FHB infection.

FHB tolerance in winter wheat breeding nurseries was generally high. The most FHB tolerant transgenics will be crossed to varieties having some FHB tolerance, and to Wesley, The best lines for FHB tolerance and agronomic performance will be retested in 2004.

We have initiated a collaboration with Dr. Ismail Dweikat to test our lines with microsatellite markers to determine if they have the expected genes from the parents and to identify the marker diversity in known regions containing FHB quantitative trait loci.

In the 2003-2004 cycle, we will plant 80 out of 819 F_2 bulks and 33 out of 750 F_3 bulks that were deliberately made for FHB tolerance. Our most advanced lines from the FHB crosses are in the F6 generation. We will screen 420 lines from our elite germplasm (our three most advanced nurseries), 46 lines from the FHB screening nursery, 20 - 50 transgenic spring wheat lines (initially) from our biotechnology efforts, and 277 lines coming from the RGON in the field

Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the view of the U.S. Department of Agriculture.

Table 1: Pedigree of Extensively Tested Select FHB Lines Tolerance to FHB Severity Compared to More Susceptible Lines.

Line	Pedigree of the most FHB Tolerant Lines	LsMean Severity	Standard Error
NE99579	**TOMAHAWK/NE88584//NE89657**	22^{A}	14
CULVER	NE82419 X ARAPAHOE	26^{AB}	14
ARAPAHOE	BRULE/3/PKR4*/AGENT//BELOT198/LCR	28^{AB}	14
NE97465 (Goodstreak)	**SD3055/KS88H164//NE89646 (=COLT*2/PATRIZANKA)**	31^{AB}	14
ALLIANCE	ARKAN/COLT//CHISHOLMsib	31^{AB}	14
NIOBRARA	TAM105*4/AMIGO (TX80GH2679)//BRULE Fsel	31^{A}	14
N97V121	**N87V106/OK88767**	31^{A}	14
W91040		32	16
WESLEY	**KS831936-3//COLT/CODY**	31^{A}	14
CHEYENNE	CI8885	32^{B}	14
NE00544	**SD89180/KARL 92**	32^{B}	14
NE00403	**PRONGHORN/ARLIN//ABILENE**	33^{B}	14
NE96737	N95L421 N87V106/NE88582	33	14
PRONGHORN	CENTURA/DAWN//COLTsib	35	15
NE00679	NE93462 (=ARAPAHOE/NA HW-81-170)/NE90616 (=ARAPAHOE/COLT)	35	14
NE97689 (Harry)	NE90614 (=BRL/4/PKR*4/AGT//BEL.198/LCR/3/NWT/BRL) /NE87612 (=NWT//WRR*5/AGT/3/NE69441)	35	14
NE00479	IL85-3132-1/ARAPAHOE	35	14
NUPLAINS	ABILENE/KS831872	36	14
NE99656	TX89V4138/NE89657//KARL 92	36	14
NE00507	KS831936 - 3 / NE86501 / / TX86V1405 - 1	37	14
NE99464	NE86606/RAWHIDE//ABILENE	37	14
WAHOO	ARAPAHOE/Abilene//ARAPAHOE	37	14
NE99489	NE90625/NE91525//KARL 92	37	14
NE98632	NIOBRARA/NE91525	37	14
NE00658	NE93462 (=ARAPAHOE/NA HW-81-170)/NE92608 (=NE82413/COLT)	38	14
NI98439	NE90476/(10Ax88-1643)X10927 592-1-5	39	14
NE99543	ALLIANCE/KARL 92	40	14
NE98471	NE90461/NIOBRARA	40	14
NE98466	KS89H50-4/NE90518	40	14
NE00633	NE92614 (=CENTURA/RL8200003)/IKE	41	14
SCOUT66	CI73996	41	14
NE99445	RAWHIDE/TOMAHAWK//KARL 92	45	14
MILLENNIUM		46	14
NE00481	NE93462 (=ARAPAHOE/NA HW-81-170)/NE92608 (=NE82413/COLT)	46	14
NE99495	ALLIANCE/KARL 92	47	14
NE00435	WI87-018/2*ARAPAHOE	49	14
NE00429	WI87-018/2*ARAPAHOE	51	14
NE00564	T81/NE91635 (=NE82761/NE82599)	57	14

Lines with severity values followed by ^{A} or ^{B} respectively were significantly more tolerant than Millenium and NE99495 respectively.

ACKNOWLEDGEMENTS

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OBSERVATIONS FROM SRWW VARIETY DEVELOPMENT NURSERIES WITH SEVERE FHB PRESSURE

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OBJECTIVE

Screen soft red winter wheat (SRWW) germplasm for FHB resistance.

INTRODUCTION

Our 2002-03 soft red winter wheat nurseries in Ohio experienced severe disease pressure. The moderately resistant check Freedom had an average FHB index of 48 over 11 tests while the susceptible check Pioneer 2545 had an average FHB index of 79. This report summarizes results from screening breeding lines in our variety development program.

MATERIALS AND METHODS

We evaluated > 800 SRWW lines in a mist-irrigated field nursery inoculated with infested corn kernels. Spring was cool and wet which delayed anthesis and the onset of visual symptoms. Early heading lines were rated up to 37 days after anthesis, while later lines were rated about 20 days after anthesis. Some nurseries (YR1, YR2) were visually rated for % infected spikelets, for others we assessed disease incidence and severity on 20 heads per line per replication to calculate FHB index. We used three reps for all trials.

RESULTS AND DISCUSSION

First Year (YR1) of Testing: We tested 483 F4 derived lines from 69 crosses in the first year of replicated evaluation for eventual variety release. The lines were selected from the 2001-02 head row nursery based on agronomic value. The average FHB index of all lines was 53, slightly higher than Freedom (48) in the YR1 trial, and much lower than Pioneer 2545 (83). Heading was spread over 19 days with FHB rated 20 to 37 days after anthesis. FHB index was not correlated to heading date ($r = 0.01$) or days between anthesis and rating ($r = -0.02$).

Of the 483 lines, 141 had FHB index less than or equal to Freedom, 49 were significantly ($P<0.1$) more resistant than Freedom, and 454 were more resistant than Pioneer 2545. Eight lines were significantly more resistant than Freedom at the 0.05 probability level (Table 1). These eight lines were derived from eight different crosses and 15 different parents.

Comparing the range of family means within each cross to an $LSD_{0.05}$ of 17.4 indicated that significant segregation occurred in 72% of the populations with n is greater than or equal to 5 (Fig. 1). There was no association between population mean and range of FHB index. Even the population with the highest mean had one line that had an FHB index equal to that of Freedom (Fig. 1). The minimum family mean within a population was negatively associated with the range of FHB index values in the population (Fig. 2): families with the lowest FHB index came from populations with the greatest range of FHB values. All the lines in Figure 2 with means significantly (P<0.1) lower than Freedom came from crosses with significant segregation. The nine populations that produced lines with low means (Table 2) were derived from 17 parents.

Table 1. FHB index of eight breeding lines with FHB index significantly less (P<0.05) than Freedom (47.9) in the 2002-03 YR1 test of 483 F4 derived lines.

OSU Line	Heading Date	FHB Index (%)	Pedigree
OH02-3059	147	23.3	FREEDOM/OH618
OH02-15652	142	24	PATTERSON/HOPEWELL
OH02-8771	144	26.7	IN881064A12-3-3-1/OH552
OH02-5103	142	28.3	OH536/OH615
OH02-8183	146	30	GOLDFIELD/P89204A8-1-59
OH02-14111	141	30	IL87-1917-1/IN83127E1-24-5-2-1-31//FOSTER/P. 2548
OH02-10578	143	30	OH552/OH599
OH02-11675	144	30	OH618/OH552

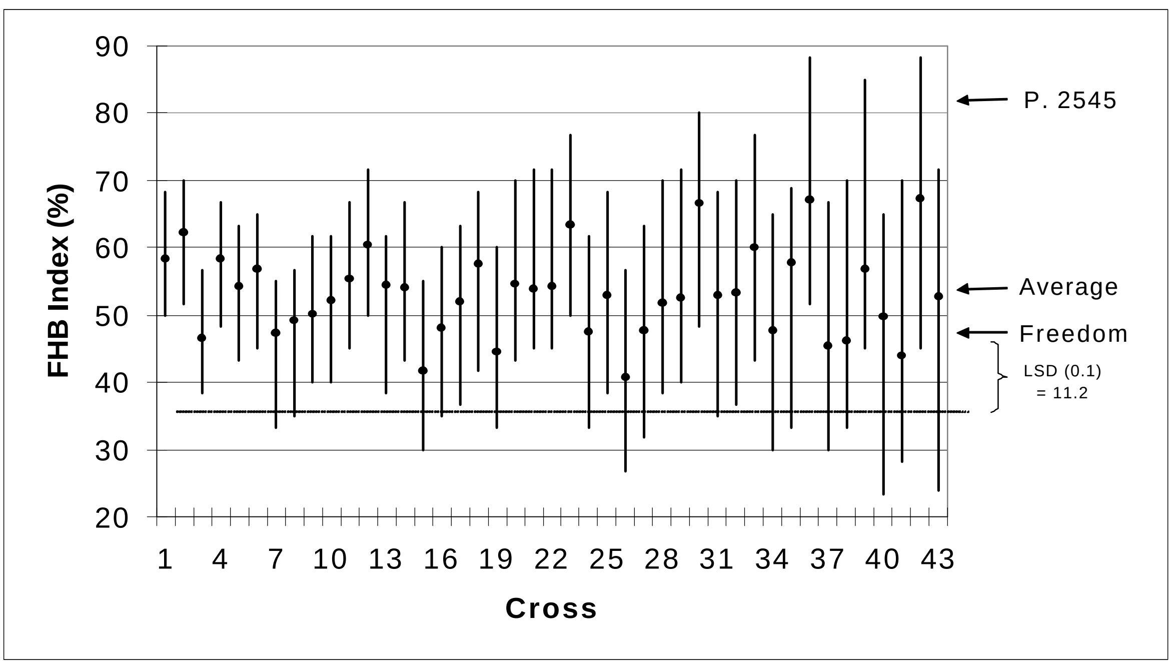

Figure 2. Association of the FHB index range of a population, and the minimum family mean of a population, for 43 populations (n is greater than or equal to 5) evaluated in the 2002-03 YR1 nursery.

<u>*Interpretation of YR1 results*</u>

- Many SRWW parent combinations generate genetic variation for FHB resistance
- Useful resistance (FHB index less than or equal to Freedom) is possible in many populations
- Segregation and recombination are needed to produce low FHB index
- Recurrent selection may be useful to create high levels of FHB resistance from the different FHB resistance alleles in SRWW.

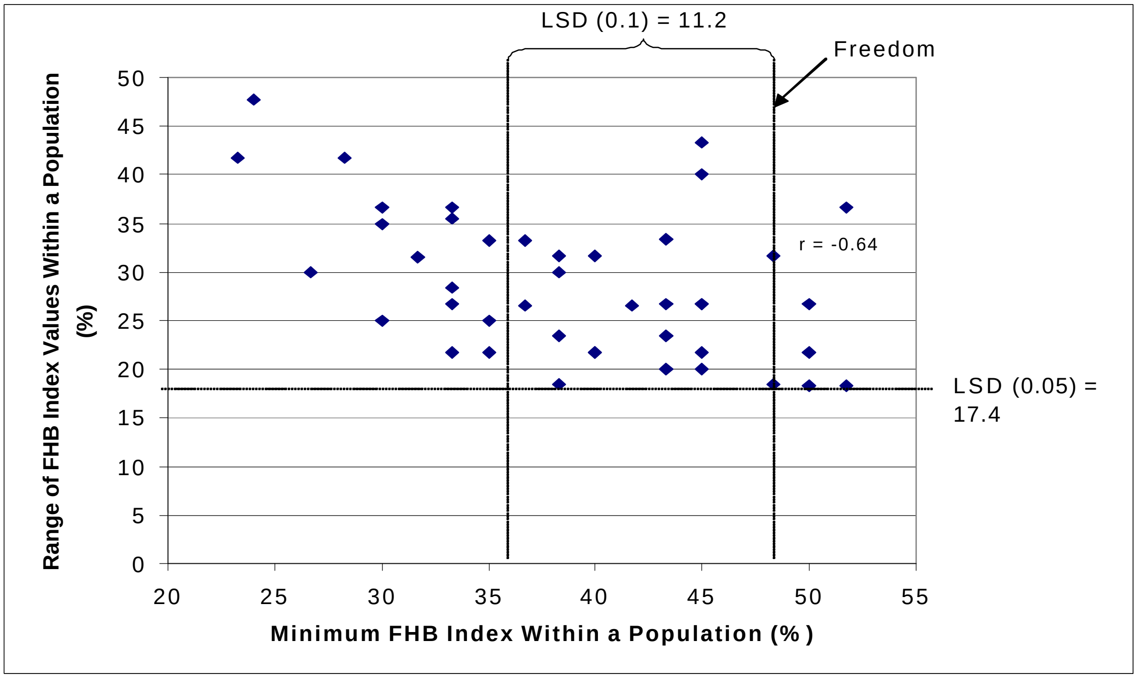

Figure 2. Association of the FHB index range of a population, and the minimum family mean of a population, for 43 populations (n is greater than or equal to 5) evaluated in the 2002-03 YR1 nursery.

Table 2. Mean, minimum, maximum, and range of populations (n>4) that produced lines with low FHB index values in the 2002-03 YR1 nursery.

Population	n	Average	Minimum	Maximum	Range
FREEDOM/OH618	10	49.8	23.3	65	41.7
PATTERSON/HOPEWELL	43	52.7	24	71.7	47.7
IN881064A12-3-3-1/OH552	15	40.8	26.7	56.7	30
OH536/OH615	11	43.9	28.3	70	41.7
IL87-1917-1/IN83127E1-24-5-2-1-31//FOSTER/P.	7	47.6	30	65	35
GOLDFIELD/OH546	8	47.7	31.7	63.3	31.6
PIONEER 2548/FREEDOM	7	46.2	33.3	70	36.7
OH581/IN83127E1-24-5-2-1-31//5088B-D-32-1/OH601	7	47.4	33.3	55	21.7
FREEDOM/PATTERSON	10	57.8	33.3	68.8	35.5

Second Year (YR2) of Testing: Disease pressure was light in the 2001-02 YR1 test of 316 breeding lines with checks averaging 76.5% less disease than in the 2003 YR1 test. We selected 117 lines and evaluated them in 2003 YR2 trials. The average FHB index of the selected lines (10.6) in the 2002 YR1 was 71% of the mean of all lines (15.1) and 34% of the mean of Pioneer 2545 (31.0). In the 2003 YR2 trial, the 117 lines had a mean FHB index of 58, which was 103% of the mean of Freedom (56.4) and 68% of the mean of Pioneer 2545 (85.0). The correlation of the YR1 and YR2 scores was 0.52. Several lines had low scores in both years (Table 3).

Interpretation of YR2 Results

- Resistance under light and severe disease pressure was associated.
- As in YR1 tests, useful resistance can be derived from many different crosses

Table 3. FHB index of the best lines selected from the 2002 (YR1) and 2003 (YR2) nurseries.

Line		Average	2003 (YR2)	2002 (YR1)
OH01-6467	OH534/12485-23-2//FREEDOM/R28785	19.3	37.5	1
OH01-1212	OH526/HOPEWELL	20.9	40	1.7
OH01-2642	OH534/12485-23-2//FREEDOM/OH572	21.3	36.7	6
OH01-1949	OH581/OH569	22.3	43.3	1.3
OH01-7658	HOPEWELL/OH601	23.6	43.3	4.3
OH01-3162	OH534/OH513//14884/VA91-54-219	23.7	41.7	5.7
OH01-2683	OH534/12485-23-2//FREEDOM/OH572	24.4	45	3.7
Freedom		30.5	56.4	4.6
Pioneer 2545		58	85	31

Advanced Testing: We evaluated 140 lines for incidence, severity and index in 2002-03 in five tests (FHB, YR3, YR4+, NUWWS, USFHB). Lines more resistant than the check were found in each trial. Lines with low index values (e.g .< 20) were derived from crosses with both exotic (ZM10782, Ning 7840) germplasm as well as adapted-only crosses.

Table 4. FHB incidence (INC), severity (SEV), and index (IND, also given as % resistant check [I%C]) for best lines and resistant checks from the 2003 advanced tests.

Test	**Name**	**Pedigree**	**INC**	**SEV**	**IND**	**I%C**
FHB	OH904	ZM10782/Free.//305/VA91-54-219	90	7.9	7.1	33%
FHB	OH903	Ning 7840/Glory//OH526	97	7.6	7.4	35%
FHB	Freedom		92	21.8	21.4	
YR4+	OH740	L89060/OH529	100	29.1	29.1	53%
YR4+	OH753	Catoctin/OH536	100	31.2	31.2	57%
YR4+	OH736	OH462/Ckr 9663	100	34.5	34.5	63%
YR4+	Freedom		100	55.2	55.2	
YR3	OH806	Freedom/OH530	100	14.8	14.8	49%
YR3	OH886	Freedom/OH530	100	22.6	22.6	75%
YR3	Freedom		100	30.2	30.2	
NUWWS	RCATL33	R/FR#1/ACRon//25R18/ACRon	100	16.2	16.2	53%
NUWWS	P.981233A1-10	Freedom//Goldfield/X117	100	17.6	17.6	58%
NUWWS	IL97-6755	IL90-4813//IL85-3132-1/Ning 7840	100	17.9	17.9	59%
NUWWS	Freedom		100	30.5	30.5	
USFHB	ARGE97-1033-3-5	Freedom/Catbird	100	14.1	14.1	24%
USFHB	AR857-1-1	Madison/YMI6	93	18.9	17.6	30%
USFHB	B011117	YMI6/Ckr 9877	92	19.7	18.8	32%
USFHB	Ernie		100	58.1	58.1	

REPORT ON THE 2002-03 NORTHERN UNIFORM WINTER WHEAT SCAB NURSERY (NUWWSN)

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OBJECTIVE

Evaluate soft winter wheat lines for resistance to FHB in a multi-site uniform nursery.

INTRODUCTION

Each year the USWBSI funds coordination of a uniform nursery to assess FHB resistance in soft winter what lines adapted to the northern US.

MATERIALS AND METHODS

The 2002-03 NUWWSN evaluated 51 breeding lines from 10 breeding programs (Table 2). Data was collected from 10 field trials and five greenhouse tests. The field trials used various methods of inoculation and rating, though most use mist irrigation and Fusarium infected corn kernels as inoculum. Most cooperators reported incidence (INC) and severity (SEV) collected on 20 heads per replication. INC and SEV were used to calculate index (IND=INC*SEV/100). Some also collected data on percent scabby seed (%SS) based on seed weight and DON. The greenhouse tests were conducted using single floret inoculation and all reported severity (GHSEV). For this report, data is averaged over all locations and the genotype x location interaction was used as the error to calculate an LSD (0.05). For each trait, each entry was compared to the entry with the lowest mean, and the entry with the highest mean using the $LSD_{0.05}$.

RESULTS AND DISCUSSION

A summary of the full NUWWSN report is presented here. The full version of the 2002-03 NUWWSN report will be available at the 2003 USWBSI forum and at the USWBSI web site (http://www.scabusa.org/). Based on proportion of total sum of squares (TSS) accounted for by genotype by environment interaction (GEI) effects, GEI was an important source of variation for SEV (40% of TSS), INC (23%), GHSEV (22%), and DON (21%). The data summarized over all locations for the best and worst lines is summarized in Table 1 while the data for all lines is presented in Table 3.

Table 1. Mean over all locations for all traits for the best and worst entries in the 2002-03 NUWWSN. Entries with a mean that is not significantly different than the highest mean in that column are designated with an "h", while the entries with a mean that is not significantly different than the lowest mean in that column are designated with an "l"

	SEV n=7		INC 9		IND 9		%SS 4		DON 2		GHSEV 5		# LOW TRAITS	# HIGH TRAITS
P.981359C1-4	16.5	l	49.3	l	10.7	l	23	l	13.9		34.7	l	**5**	0
MO980829	21.6	l	41.9	l	11.4	l	35.7	l	12.4		24.9	l	**5**	0
MO011174	16	l	43	l	11.8	l	32.3	l	13.2		24.3	l	**5**	0
VA02W708	15	l	44.3	l	11.9	l	25.7	l	16.3	h	31.5	l	**5**	1
IL96-24851-1	16.3	l	47.7	l	12.8	l	43		9.5	l	27.1	l	**5**	0
IL97-6755	15.7	l	43.3	l	13.1	l	30.7	l	16	h	30.4	l	**5**	1
IL99-27048	14.4	l	42.8	l	13.1	l	28.2	l	13		37.2	l	**5**	0
MO981020	17.9	l	45.1	l	15.5	l	34.3	l	11.9		26.1	l	**5**	0
MO011175	21.4	l	46.1	l	15.8	l	32.2	l	8.3	l	41.6		**5**	0
VA02W709	16.5	l	49.3	l	16.6	l	52.9	h	11.4	l	29.8	l	**5**	1
P.981238A1-1	17.4	l	49	l	18	l	49.5		8.7	l	35	l	**5**	0
E0009	20.9	l	52.7	l	18	l	36.2	l	11.7		36.6	l	**5**	0
ERNIE	17	l	45.7	l	19	l	36.3	l	8.6	l	27.6	l	**6**	0
P.97397E1-11	21.1	l	49.7	l	20.5		45.5		9.4	l	23.4	l	**4**	0
MO010708	20.7	l	55.7		18	l	33.4	l	12.7		34.6	l	**4**	0
RCATL33	15.3	l	39.9	l	14.6	l	39.3		6.9	l	46.2		**4**	0
PIONEER 2545	30.7	h	71.4	h	34.4	h	58.6	h	10.7	l	43.5		1	**4**
KY93C-1238-34-1	36.2	h	64.7	h	34.4	h	52	h	13.2		46.8		0	**4**
F0008	27.5	h	66.3	h	34.6	h	55.3	h	5.7	l	50.5		1	**4**
VA01W448	30.8	h	57.3		35.1	h	55.3	h	19.1	h	47.9		0	**4**
RCATL13	31.1	h	65.3	h	36	h	51.5	h	15.5	h	65.9	h	0	**6**
OH738	31.8	h	66.9	h	37.3	h	57.2	h	15.4	h	45.3		0	**5**
RCATTF17/34	36.6	h	60.8	h	39.3	h	53.8	h	11.9		61.2	h	0	**5**
VA02W734	36.1	h	64.7	h	41.3	h	49		7	l	55	h	1	**4**
AVERAGE	24.3		54.6		23.4		44.6		11.3		43.9			
R2	0.6		0.84		0.77		0.95		0.79		0.78			
CV	45.1		25.4		41.5		22		30.2		34.3			
LSD	11.5		12.8		9		13.7		6.8		18.7			

Table 2. List of entries in the 2002-03 Northern Uniform Winter Wheat Scab Nursery (NUWWSN)

Source	Entry	Name	Pedigree
Ohm	1	P.97397E1-11	96204//Gfd/INW9824
Ohm	2	P.981227A1-1	Gfd/9824//96204/3/x117/4/9853
Ohm	3	P.981233A1-10	Fdm//Gfd/X117
Ohm	4	P.981238A1-1	Ernie//91193D1/X117
Ohm	5	P.981359C1-4	Acc3130/Patterson
Ohm	6	P.99646C2-7	961331/9811//283-1/Fdm
Sorrels	7	NY89064SP-7139*	88029(84061(6120-15/F29-76)/Augusta)/Harus
Sorrels	8	NY89052SP-9232	88119(Geneva/84004/6-1MR)/Geneva
Sorrels	9	CALEDONIARESEL-VT	Caledonia offtype
Sorrels	10	NY88046-8138	Susquehanna/Harus
Sorrels	11	NY89052-7142	88119(Geneva/84004/6-1MR)/Geneva

Table 2 (Continued)

Source	Entry	Name	Pedigree
Ohm	1	P.97397E1-11	96204//Gfd/INW9824
Ohm	2	P.981227A1-1	Gfd/9824//96204/3/x117/4/9853
Ohm	3	P.981233A1-10	Fdm//Gfd/X117
Ohm	4	P.981238A1-1	Ernie//91193D1/X117
Ohm	5	P.981359C1-4	Acc3130/Patterson
Ohm	6	P.99646C2-7	961331/9811//283-1/Fdm
Sorrels	7	NY89064SP-7139*	88029(84061(6120-15/F29-76)/Augusta)/Harus
Sorrels	8	NY89052SP-9232	88119(Geneva/84004/6-1MR)/Geneva
Sorrels	9	CALEDONIARESEL-VT	Caledonia offtype
Sorrels	10	NY88046-8138	Susquehanna/Harus
Sorrels	11	NY89052-7142	88119(Geneva/84004/6-1MR)/Geneva
Kolb	12	IL97-6755	IL90-4813//IL85-3132-1/Ning 7840
Kolb	13	IL99-13436	IL91-14163/IL93-1517
Kolb	14	IL99-27048	IL90-6364/Pioneer brand 2571
Kolb	15	IL97-4915	IL87-2834-1/OH470//MO9965-52/IL90-6364
Kolb	16	IL96-24851-1	IL90-6364//IL90-9464/Ning 7840
Baenziger	17	ARAPAHOE	BRULE/3/PKR4*/AGENT//BELOT198/LCR
Baenziger	18	NE97V121	N87V106/OK88767
Baenziger	19	NE99445	RAWHIDE/TOMAHAWK//KARL 92
Baenziger	20	NE98466	KS89H50-4/NE90518
Vansanford	21	KY94C-0094-11-2	L880119/2684//2510
Vansanford	22	KY93C-0403-23-1	VA88-52-69/KY83C-004//2510
Vansanford	23	KY93C-1238-34-1	VA87-54-558/ KY83C-004//2510
McKendry	24	MO980829	MO 11769/Madison
McKendry	25	MO981020	MO 11769/Madison
McKendry	26	MO011175	MO 91-19/Pioneer 2552
McKendry	27	MO011174	MO 980521 reselection. (MO 11769/Madison)
McKendry	28	MO010708	MO 94-182/VA 91-54-219
McKendry	29	MO010719	MO 12278/Pioneer 2552
Sneller	30	OH738	L890690/T814
Sneller	31	OH743	OH529/OH506
Sneller	32	OH750	OH536/OH506
Sneller	33	OH751	10584-0801/COKER 9663
Sneller	34	OH753	CATOCTIN/OH536
Sneller	35	OH736	OH462/COKER 9663
Schafsmaa	36	RCATL33	R/FR#1/AC RON//25R18/ACRON
Schafsmaa	37	RCATL10	BALKAN//AC RON/SUP72017-17-5-10-1
Schafsmaa	38	RCATL13	2737W/25R57//R/FR#1/2737W
Schafsmaa	39	RCATTF19/26	EX9806/AC RON
Schafsmaa	40	RCATTF2/4	2737W/EX9806
Schafsmaa	41	RCATTF17/34	2737W/25R57
Griffey	42	VA01W448	PC-11(SHANGHAI4/CHILL"S":SCAB-RES) /3/92-51-39(IN71761A4-31-5-48//71-54-147 /MCN1813)//FFR555W/RCT/4/COKER9803, F8
Griffey	43	VA02W694	96-54-250(CK9803/FREEDOM)/P92823A1-1-2-3-5(CLARK*4/NING 7840), F6
Griffey	44	VA02W708	NING 7840/PION2684//96-54-244 (CK9803/FREEDOM), F6
Griffey	45	VA02W709	NING 7840/PION2684//96-54-244 (CK9803/FREEDOM), F6

Table 2. (Continued)

Source	Entry	Name	Pedigree
Griffey	46	VA02W729	PC-11(SHANGHAI4/CHILL"S":SCAB-RES) /3/92-51-39(IN71761A4-31-5-48//71-54-147 /MCN1813) //FFR555W/RCT/4/93-52-23&24 (MSY//HUNTER/WLR), F8
Griffey	47	VA02W734	PC-7(CHILL"S"/YM16:SCAB-RES)/3/92-51-39(IN71761A4-31-4-48//71-54-147 /MCN1813)//CK9803/RCT/4/93-52-55 (MSY*3/BALKAN//SAL), F8
Ward	48	D6234	(X1291,I3118/FRANKENMUTH//FRANKENMUTH)/3/(C5107,B2218/B2142//B5250)
Ward	49	E0009	NY82-105-2 / NY262-37-422
Ward	50	E0010	NY82-105-2 / NY262-37-422
Ward	51	F0008	(D2217,C4680/AUG//AUG)/3/(PIONEER_2555,PNR_W3017/PNR_W521)
CHECKS	52	ERNIE	
CHECKS	53	PIONEER 2545	
CHECKS	54	FREEDOM	

Table 3. Mean over all locations for all traits for all entries in the 2002-03 NUWWSN. Entries with a mean that is not significantly different than the highest mean in that column are designated with an "h", while the entries with a mean that is not significantly different than the lowest mean in that column are designated with an "l"

	SEV n=7		INC 9		IND 9		%SS 4		DON 2		GHSEV 5		# LOW TRAITS	# HIGH TRAITS
P.97397E1-11	21.1	l	49.7	l	20.5		45.5		9.4	l	23.4	l	4	0
P.981227A1-1	27.5	h	56.5		27.6		47.1		14.5		43.9		0	1
P.981233A1-10	22.9	l	57.8		20.4		50.5	h	14.2		21.9	l	2	1
P.981238A1-1	17.4	l	49	l	18	l	49.5		8.7	l	35	l	5	0
P.981359C1-4	16.5	l	49.3	l	10.7	l	23	l	13.9		34.7	l	5	0
P.99646C2-7	29.5	h	62.7	h	28.1		46		10.8	l	64.1	h	1	3
NY89064SP-7139*	22.1	l	55.6		18.7	l	49.8		21.5	h	39.2	l	3	1
NY89052SP-9232	22.2	l	53.5		20.6		39.6		11	l	59.1	h	2	1
CALEDONIARESEL-VT	23.4	l	47.1	l	18.9	l	52.3	h	6.5	l	58.8	h	4	2
NY88046-8138	26.6		54.9		29.7		43.1		8	l	43		1	0
NY89052-7142	29.8	h	57		25.5		39.7		4.7	l	57.9	h	1	2
IL97-6755	15.7	l	43.3	l	13.1	l	30.7	l	16	h	30.4	l	5	1
IL99-13436	27.8	h	58.2		25.5		48.5		8.8	l	49.8		1	1
IL99-27048	14.4	l	42.8	l	13.1	l	28.2	l	13		37.2	l	5	0
IL97-4915	28.5	h	52.5	l	20.7		39.3		8.2	l	47		2	1
IL96-24851-1	16.3	l	47.7	l	12.8	l	43		9.5	l	27.1	l	5	0
ARAPAHOE	19.9	l	55.1		18.7	l	42.9		9.7	l	53.4	h	3	1
NE97V121	33.1	h	66	h	32		59.1	h	13.9		49.7		0	3
NE99445	38.4	h	57.8		36.3	h	49.7		8.5	l	59.7	h	1	3
NE98466	29.9	h	54.5		22.8		41.9		10.5	l	47.7		1	1

Table 3 (Continued)

	SEV n=7		INC 9		IND 9		%SS 4		DON 2		GHSEV 5		# LOW TRAITS	# HIGH TRAITS
KY94C-0094-11-2	21.1	l	57.3		23.5		43.7		6.7	l	43		2	0
KY93C-0403-23-1	26.5		59.4	h	31.3		63.6	h	8	l	71.4	h	1	3
KY93C-1238-34-1	36.2	h	64.7	h	34.4	h	52	h	13.2		46.8		0	4
MO980829	21.6	l	41.9	l	11.4	l	35.7	l	12.4		24.9	l	5	0
MO981020	17.9	l	45.1	l	15.5	l	34.3	l	11.9		26.1	l	5	0
MO011175	21.4	l	46.1	l	15.8	l	32.2	l	8.3	l	41.6		5	0
MO011174	16	l	43	l	11.8	l	32.3	l	13.2		24.3	l	5	0
MO010708	20.7	l	55.7		18	l	33.4	l	12.7		34.6	l	4	0
MO010719	22.9	l	48.1	l	18	l	37.5		15.3	h	41.1		3	1
OH738	31.8	h	66.9	h	37.3	h	57.2	h	15.4	h	45.3		0	5
OH743	22.2	l	57.2		24.8		48		15.7	h	33.8	l	2	1
OH750	23.5	l	56.8		21.2		50.7	h	12.2		51.2		1	1
OH751	21.9	l	55.7		22.5		41.2		9	l	37	l	3	0
OH753	23.1	l	56		24.7		48.6		10.1	l	48.6		2	0
OH736	26		57.2		22		43.4		7.7	l	50.4		1	0
RCATL33	15.3	l	39.9	l	14.6	l	39.3		6.9	l	46.2		4	0
RCATL10	29.8	h	61.5	h	27.6		48.9		7.8	l	34.7	l	2	2
RCATL13	31.1	h	65.3	h	36	h	51.5	h	15.5	h	65.9	h	0	6
RCATTF19/26	27.2	h	56.2		25.4		50.4	h	6.4	l	51.9		1	2
RCATTF2/4	22.3	l	48.9	l	19.3	l	49.1		7.3	l	56.2	h	4	1
RCATTF17/34	36.6	h	60.8	h	39.3	h	53.8	h	11.9		61.2	h	0	5
VA01W448	30.8	h	57.3		35.1	h	55.3	h	19.1	h	47.9		0	4
VA02W694	22.5	l	45.6	l	25.2		40		16.3	h	61.5	h	2	2
VA02W708	15	l	44.3	l	11.9	l	25.7	l	16.3	h	31.5	l	5	1
VA02W709	16.5	l	49.3	l	16.6	l	52.9	h	11.4	l	29.8	l	5	1
VA02W729	22.2	l	58		22		43.8		20.1	h	44.9		1	1
VA02W734	36.1	h	64.7	h	41.3	h	49		7	l	55	h	1	4
D6234	24.8	l	57.2		27.1		41.2		15	h	45.8		1	1
E0009	20.9	l	52.7	l	18	l	36.2	l	11.7		36.6	l	5	0
E0010	26		61.1	h	26.2		48.4		8.1	l	36.8	l	2	1
F0008	27.5	h	66.3	h	34.6	h	55.3	h	5.7	l	50.5		1	4
ERNIE	17	l	45.7	l	19	l	36.3	l	8.6	l	27.6	l	6	0
PIONEER 2545	30.7	h	71.4	h	34.4	h	58.6	h	10.7	l	43.5		1	4
FREEDOM	21.5	l	58		21.6		49.9	h	11.1	l	37.8	l	3	1
AVERAGE	24.3		54.6		23.4		44.6		11.3		43.9			
R^2	0.6		0.84		0.77		0.95		0.79		0.78			
CV %	45.1		25.4		41.5		22		30.2		34.3			
LSD(0.05)	11.5		12.8		9		13.7		6.8		18.7			

BREEDING FOR SCAB RESISTANCE IN SOFT RED WINTER WHEAT

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ABSTRACT

Fusarium head blight (FHB) caused significant damage to the Kentucky wheat crop in 2003. Many producers had grain rejected from wheat millers due to high levels of dexoynivalenol (DON). This problem is not new. Each year FHB affects producers in the state by causing economic damage. The yearly impact from FHB infection and resulting DON accumulation demonstrates the need of screening wheat for FHB resistance. In 2001 approximately 80 breeding lines were selected from the breeding program to be tested in the scab nursery. The lines were dividing into two tests, the Magnum and Mondo. The breeding lines were developed from parents that had some level of scab resistance. For the past two years the Magnum and Mondo have been evaluated in the greenhouse and two locations, Lexington and Princeton, KY. Evaluations of the Magnum and Mondo have resulted in several lines with good resistance. The selected breeding lines are being evaluated for the third year in the scab nursery. Plots outside of the scab nursery are being used to increase seed for the selected lines. We anticipate including several of the lines in the 2005 Northern Uniform Winter Wheat Scab Nursery. The selected lines are also being evaluated in elite tests for agronomic traits. Several of the breeding lines with low severity also were above average in yield. Dependent on further testing, we would like to release the breeding lines as scab tolerant culitvars or germplasm. The scab nursery in Lexington 2003 was evaluated for FHB severity over time using area under disease progress curve (AUDPC). The goal of collecting this data is to determine the amount of disease pressure each year and to pinpoint when symptom development begins. By using this data, disease pressure can be quantified to compare the scab nursery over years and locations. A 7-day interval (post-anthesis) was used for severity evaluation. Fifteen rows within the scab nursery and fifteen rows in the border of the nursery were evaluated for severity. The data collected from the AUDPC along with the data from culitvar checks will be a useful tool in determining the uniformity of FHB in the scab nursery.

BREEDING FOR FUSARIUM HEAD BLIGHT RESISTANCE: AN INTERNATIONAL APPROACH

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INTRODUCTION

The International Maize and Wheat Improvement Center (CIMMYT) begun research on Fusarium head blight (FHB), initially denoted as 'scab', in the mid 1980's. The center's roots trace back to 1943/44, when a bilateral program between Mexico and the Rockefeller Foundation was established to develop modern wheat varieties for irrigated production in Mexico, with barley added in 1970 (later under ICARDA/CIMMYT). When these high-yielding rust resistant lines were sown globally, it became obvious that in rainfed areas additional traits needed to be introgressed: first resistance to *Septoria tritici* resistance in the 70's and later *Fusarium spp.* in the 80's. Another motivating factor emphasizing FHB was CIMMYT's increasing relationship with China, the largest producer, consumer and importer of wheat, from the mid 1980's onwards. FHB, stripe rust, powdery mildew and BYDV were the most important diseases in China. Adapted germplasm from China was used to combine high yield, slow rusting, and FHB resistance, with spin-offs expected to the FHB-prone regions of Africa and Latin America. In barley just 23 lines out of 5000 tested formed the basis for FHB resistance breeding, resulting in the widely grown Chinese variety Gobernadora (Zhenmai-1) in which resistance QTLs were mapped in collaboration with Oregon State University.

MATERIALS AND METHODS

After several years of experimentation in Toluca (800 mm rainfall per crop cycle) begun by Girma Bekele in the mid 80's, the methodology settled on sprinkler-enhanced screening of a 0.5-1 ha field. Resistance was characterized in terms of reduced fungal spread throughout the spike (Type II) and good grainfill (Type IV and V), later augmented with resistance to infection (Type I) and recently with low toxin levels (Type III) in both wheat and barley (Miller and Arnison, 1986; Mezterhazy, 1995; Schroeder and Christensen, 1963; Vivar, 1996). On barley 14 *Fusarium* species were found; *F. avenaceum* was the most frequent (25.5 – 32.0 %) in field conditions, followed by *F. graminearum* (20.0 – 23.5 %). In barley Type I resistance appears most important, particularly under Midwest (US) conditions (Capettini, 1999). Lucy Gilchrist was the main researcher for the past 10-plus years on this topic in collaboration with the breeders. An international Scab Resistance Screening Nursery (SRSN) was started in the late 1980's and distributed on an *ad hoc* basis (data was received from: Argentina, Brazil, Canada, China, France, Germany, Guatemala, India, Iran, Korea, Pakistan, Paraguay, Peru, Poland, Tanzania, Ukraine, and Uruguay). After CIMMYT joined the USWBSI in 2000, the SRSN was assembled annually and all entries shared with USWBSI. Toxin levels of seed sent from FHB hotspots in China were also tested: these include Wuchang, Hubei Province, Nanjing, Jiangsu Province, Putian and Jianyang, and Fujian Province). The breeding/selection methodology aims to combine resistance mechanisms by accumulating distinct alleles (Singh and van Ginkel, 1997; van Ginkel and Gilchrist, 2002; See table 1 for two examples)

Table 1. Complementary parental combinations 1x2 and 3x4 to accumulate FHB resistance Types in wheat. (bold font = FHB resistant; normal font = FHB susceptible)

		RESISTANCE TYPE				
		I	II	III	IV	V
Entry	Cross	Damage (%)	Damage (%)	Toxin (ppm)	Grain losses (%)	Grain (1-5)
1	Milan/Sha7	**0.00**	6.07	**0.14**	13.29	2
2	Bcn*2//Croc_1/Ae. squarrosa (886)	11.56	**4.82**	0.38	**1.68**	**1***
3	Mayoor//Tk Sn1081/Ae. squarrosa (222)	**0.86**	7.26	0.49	**1.3**	**1***
4	Gov/Az//Mus/3/Dodo/4/Bow (= Gondo)	2.51	**2.66**	**0**	21.16	2

The inheritance of resistance in key FHB resistant wheat parents (e.g. Sumai#3 and derivatives, Frontana), later also gaining favor with USWBSI, was studied and published (Singh and Rajaram, 1995; Van Ginkel *et al*. 1996). Table 2 lists key resistance sources in barley, based on data from cooperation between Mexico, the US, Canada, China, Ecuador, Brazil and Uruguay, shared with USWBSI. Molecular studies in progress will look at genetic diversity, aiming to combine resistance with yield and malting quality.

Table 2. Effective barley sources of Type I and Type II resistance (ICARDA/CIMMYT).

Cross	Head Type		Cross	Head Type
Atahualpa	**2**		Gobernadora	**2**
Azafrán (Misc. Cal. 21)	**2**		Humai 10	**2**
Chamico	**6**		PFC 88209	**6**
Chevron	**2**		Shyri	**2**
CIho 4196	**2**		Svanhals	**2**
Fredrickson	**2**		Zhedar 1	**2**

When the molecular position of some FHB resistance genes and associated markers was published, also the genetic diversity in CIMMYT wheats began to be studied (Anonymous, 2003; Sixin Liu and Anderson, 2003; this paper). Three doubled haploid populations involving three resistant parents (Gondo; Bcn*2//Croc_1/Ae. squarrosa (886); Sha3/Cbrd) crossed to a susceptible line (Flycatcher) are being studied using BSA to identify linked markers (Table 6). Resistance from 11 CIMMYT synthetic hexaploid spring wheat derivatives was back-crossed into five wheats nominated by the USWBSI: Ivan, Reeder, Russell, Verde, and Wheaton.

RESULTS

In the past three years, following the association with USWBSI 50,000 – 150,000 spikes of 5,000-10,000 of wheat and barley lines are inoculated annually. These materials include global introductions (from e.g. Argentina, Austria, Brazil, Bulgaria, Canada, Chile, China, France, Germany, Japan, Hungary, Romania, South Africa, Turkey, UK, Uruguay, and USA), and breeding products, and were inoculated and evaluated/characterized for the five types of resistance. The most resistant 50-200 spring and winter entries are sent to the USWBSI annually (Table 3).

Table 3. Types of germplasm materials sent to USWBSI since inception of agreement.

Type of material	2000	2001	2002	2003
Bread wheat, spring, advanced lines	15	55	6	117
Bread wheat, spring, alien derivatives	21	1	2	20
Bread wheat, spring, introductions	19	116	29	186
Bread wheat, winter, advanced lines	-	-	-	2
Bread wheat, winter, alien derivatives	-	-	15	2
Bread wheat, winter, introductions	-	-	18	34
Durum wheat	5	-	-	14
Barley	9	27	-	166
Triticale	-	-	-	7

Table 4 lists the globally most resistant SRSN spring bread wheat entries.

Table 4. Top Type II resistant wheat entries in global testing of Scab Resistance Screening Nursery (equal or better than Sumai#3 and Frontana; most resistant first)

1st SRSN	2nd SRSN	3rd SRSN	4th SRSN	5th/6th SRSN	7th SRSN
Shanghai #3	Ng82149/Kauz	Wuhan #3	Ng8675/Ng8645	Sha5/Weaver	Catbird
CMH78A.544	Ng8201/Kauz	China #7	Mayoor	Catbird	Gondo
Fan #1	Sha#3/Kauz	Ning7840	Ng8675/Cbrd	Chum18//Jup/Bjy	Shanghai
Ning7840		Shanghai #3	Lu 95	Gondo	Ng8675/Cbrd
Yangmai #6		F3.71/Trm//3383.20			Sha3/Cbrd
		Suzhoe #6			
		Ng82149			

The following SRSN lines expressed the lowest toxin content after heavy FHB epidemics in China (including Jianyang and Fujian Provinces, where levels reached 17-21 ppm in some entries): Sha#3/Cbrd, Ng8675/Cbrd, Milan/Sha7, Shanghai, and Mayoor//Tk Sn1081/Ae. squarrosa (222), toxin levels ranging from 0.35 to 1.65 ppm.

When barley genotypes from different programs from the US, Mexico and Latin America were evaluated in the Mexican highlands for Type I and Type II resistance to artificially inoculated *F. graminearum* and *F. avenaceum*, genotype x *Fusarium* species interaction was found (Marchand, 2003). The most resistant barleys were also tested in China and Canada (see Table 5), and will enter into the national nursery NABSEN.

Table 5. Top ICARDA/CIMMYT barley germplasm evaluated in Canada and China.

	Brandon, Canada 2001			Hangzhou, China, 2001-02		
Cross	**Row**	**Rating (1-5)**	**DON**	**Diseased spike**	**Diseased index**	**Diseased seed**
Canela/Zhedar#2	2	2	21.4	45.2	13.7	5.2
Zhedar#1/4/Shyri//Gloria-Bar/Copal/3/Shyri 2000/5/Arupo/K8755//Mora	2	2	46.3	45.2	11.3	6.0
Canela/Zhedar#2	2	2	28.7	35.5	8.9	7.3
Guayaba	2	3	44.0	53.3	20.8	8.8
Atah92/Gob	2	3	29.7	35.3	13.2	13.3
Atah92/Gob	2	2	21.6	45.8	15.6	16.4
Chevron, Robust, Stander (susceptible checks)	*6*	*5*	*92.0*	*77.4-96.8*	*29.0-55.6*	*25.4-45-7*
Zhedar 1, CI 4196 (resistant checks)	*2*	*-*	*-*	*6.6-10.0*	*1.9-2.8*	*0.6-3.1*

Some synthetic wheats show great promise, with 15 expressing multiple resistance: these are also being studied for marker identification. Wheat/*Thinopyrum bessarabicum* addition lines are being converted into translocation lines using the ph-system, FISH, C-banding, DHs and markers. To improve durum wheats *T. monococcum*, *T. urartu*, *T. boeoticum* and *Ae. speltoides* are being crossed, but success is not guaranteed. Some of the newly identified resistant parents were intercrossed allowing determination of four possibly new genes (Gilchrist *et al*., 2002; Table 6). The resistant and susceptible tails of the three distributions are now being studied for marker identification.

Table 6. Gene postulations of three crosses among three FHB resistant lines.

#	Parent 1	Parent 2	#	Postulation P1	Postulation
1	Bau/Milan	Gondo	2	AABBCCDD	aabbCCDD
2	Bau/Milan	Catbird	2	AABBCCDD	AABBccdd
3	Catbird	Gondo	4	AABBccdd	aabbCCDD

A total of 186 F7, F6, and BC1F4 populations, in which synthetic resistance Type II was back-crossed into five US commercial varieties, most confirmed twice to be resistant, were sent to USWBSI. They are also resistant to the most virulent Mexican races of stem, leaf and stripe rust. In collaboration with Busch Agricultural Resources Inc., FHB resistance is being crossed into US commercial barley varieties. Multiple disease resistant lines are now available (Table 5), also to the USWBSI.

In recent molecular studies at CIMMYT about one third of an elite group of CIMMYT wheats were shown to carry resistance distinct from the full Sumai#3 haplotype. See Figure 1.

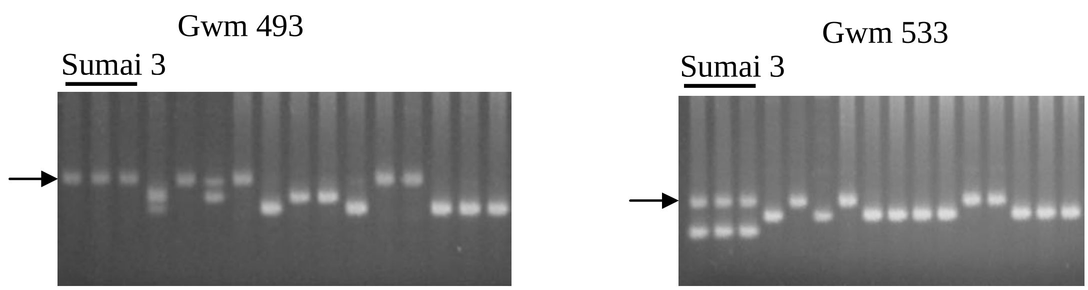

Figure 1. Allelic variations among a subset of CIMMYT bread wheat germplasm for SSR markers *Xgwm 493* and *Xgwm 533* associated with chromosome 3BS region. Sumai 3 alleles are indicated by an arrow.

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BREEDING FOR FUSARIUM HEAD BLIGHT RESISTANCE: PHENOTYPIC VS. MARKED-BASED SCREENING IN EARLY GENERATIONS

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ABSTRACT

Fusarium head blight (FHB) caused by *Fusarium graminearum* (Schwabe) causes significant losses in the soft red winter wheat crop in Kentucky and in small grain crops in many regions of North America. FHB epidemics result in significant yield losses, and can cause serious reductions in grain quality. Phenotypic screening for FHB resistance is expensive and time consuming. Use of markers linked to FHB resistance genes may increase efficiency of the breeding process. For this purpose, three $F_{2:4}$ populations of 40 lines each were evaluated during 2001 in one location (Lexington, KY) and 2003 in two locations (Lexington and Princeton, KY). Screening for the Type II resistance QTL located on the chromosome 3BS was done using the SSR markers GWM493 and GWM533. Pedigree information led us to expect that all three populations would be segregating for these alleles. However, marked-based screening showed that only 19 lines of population 2 had the Sumai 3 alleles associated with markers GWM493 and GWM533. Broad sense heritabilities were calculated for severity in the three populations. Estimates were (0.83, 0.63 and 0.66) based on one location and (0.31, 0.60 and 0.59) based on two locations, suggesting that considerable progress could be made through selection. Some non-Sumai 3 resistance is evidently present in populations 1 and 3. Field results showed that severities ranged from 30 to 32 % and incidence from 43 to 50% in the three populations. Respective differences between lines in population 2 with marker and without were : severity - 28 vs 32%; incidence - 47 vs 53%; scabby kernels - 9.41 to 11.27%; and DON - 9.7 vs 10.64 ppm. These lines will continue to be analyzed for their FHB resistance phenotype and agronomic performance in FHB nurseries at Lexington and Princeton.

SUCCESS OF ALTERNATIVE BREEDING METHODS IN TRANSFERRING FUSARIUM HEAD BLIGHT RESISTANCE TO SOFT RED WINTER WHEAT

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OBJECTIVE

Accelerate development of FHB-resistant soft red winter wheat varieties using breeding methods other than traditional topcrossing.

INTRODUCTION

The Mid-Atlantic region has suffered significant economic losses in recent years, including 2003, from Fusarium head blight epidemics (Griffey et. al., 1999). This has reinforced the need to accelerate development of FHB-resistant varieties suited to our area. The Virginia Tech Small Grains Program has been involved in developing scab-resistant soft red winter wheat varieties using both traditional and alternative breeding methods. Traditional methods include topcrossing elite parents to obtain an improved variety with disease resistance. This method has proven to be successful in developing the scab-resistant Virginia Tech varieties Roane, McCormick, and Tribute. Alternative breeding methods include the transfer of FHB resistance from unadapted germplasm to adapted elite varieties via backcrossing and the acceleration of breeding progress using the wheat ´This paper evaluates progress made to date using such alternative breeding methods.

MATERIALS AND METHODS

Backcrossing. The first crosses between unadapted, scab-resistant lines and adapted elite varieties were initiated in 1998. Following these initial crosses, a series of one to five backcrosses were made to elite (recurrent) parents. During each of these cycles, the backcrosses were evaluated for scab resistance in a mist-irrigated greenhouse using the single floret inoculation technique. At various stages of the backcrossing process, populations were developed from selected individuals and planted at Mt. Holly, VA under mist-irrigated, scab-inoculated conditions. FHB-infected maize seed was the primary inoculum applied to these populations each year. Scab-resistant populations were bulk-selected in early generations and advanced; head-selections were made in later generations and evaluated in headrows.

Doubled Haploid. Use of the wheat × maize doubled haploid (DH) system was initiated in 2000 with nine 3-way crosses comprised of diverse scab-resistant parents. Emasculated wheat heads were hand-pollinated with maize pollen and immersed in 100 mg/L 2,4-D solution 1 to 2 days later. Embryos were excised 12-16 days post-pollination and cultured in test tubes containing nutrient agar medium. The resulting seedlings were then immersed in 0.1% colchicine solution, rinsed, transplanted into soil, and vernalized for up to 8 weeks. This process was repeated in 2001 with ten additional 3-way crosses.

RESULTS AND DISCUSSION

Backcrosses. In 2002, 29 BC_1F_4 and 3 BC_2F_4 headrows were selected and subsequently evaluated in observation yield tests at two locations and in a FHB nursery in 2003. Of these, 12 lines were selected and advanced for testing in replicated preliminary yield tests at three locations in 2004 (Table 1). Five of these lines are also being tested in the 2004 Uniform Scab Nurseries. Most of these lines had higher yield and lower FHB incidence than Roane, and 4 lines had FHB incidence levels lower than Ernie. FHB severity and index values followed a similar pattern.

In 2003, 124 backcross lines (28 BC_1F_5, 15 BC_2F_5, 59 BC_2F_4, 3 BC_3F_4, 18 BC_4F_3 and 1 BC_5F_3) were selected as headrows and advanced for evaluation in observation yield tests at two locations and in a FHB screening nursery in 2004. Field and greenhouse FHB screening data for the most advanced backcross lines are presented in Table 2. Most of the backcross lines were more resistant to scab than their respective recurrent parents in the field test. In the 2002 greenhouse screening, all of the backcross lines were more resistant than their recurrent parent. Other scab-resistant parents used in developing backcross lines being evaluated in 2004 observation yield tests but not included in Tables 1 and 2 include Er-Mai 9 and Yan-Ahi 9. The recurrent parent Jackson was also used in developing backcross lines.

Doubled Haploids. In 2003, 135 H_3 doubled haploid lines were evaluated in inoculated, mist-irrigated greenhouse and field tests. Of these lines, 30 were selected for further evaluation in observation yield tests at two locations and in a FHB screening nursery during the 2003-04 season. Twelve of the19 original 3-way crosses are represented among these selections. Field and greenhouse FHB screening data on the DH lines are presented in Table 3. For most of the lines, scab incidence and severity percentages are 30 or less, and Type II resistance ratings are within the resistant to moderately resistant range. A few DH lines with higher disease severities were selected due to outstanding agronomic characteristics, but in general, most lines performed very well in the presence of FHB.

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Table 1. Performance of Backcross Lines Selected for Advancement to the 2003-04 Virginia Tech Preliminary Yield Test.

		2003 Observation Data			
Line	**Pedigree**	**Yield (bu/a)**	**INC %**	**SEV %**	**IND**
ERNIE	RESISTANT CHECK	52.7	9.7	11.9	0.3
ROANE	RESISTANT CHECK	52.1	26.7	13.7	0.4
PION 2545	SUSCEPTIBLE CHECK	n/a	40.0	24.3	1.2
VA03W-633	VR95B717 / 2*Sisson"S"	61.5	15.0	12.6	0.3
VA03W-635	VR95B717 / 2*Sisson"S"	65.6	21.3	15.5	0.7
VA03W-646	Ning9016 / 2*Sisson"S"	73.2	18.3	13.0	0.5
VA03W-643	W14 / 2*Roane	53.9	4.3	7.4	0.1
VA03W-644	W14 / 2*Roane	55.9	16.7	11.3	0.3
VA03W-647	Shaan85-15 / 2*GA891283LE18	60.2	11.0	6.4	0.1
VA03W-651	Yumai 7 / 2*Pioneer2684	65.7	20.0	16.7	0.6
VA03W-652	Ning9016 / 3*Pioneer2684	64.0	28.3	17.0	0.8
VA03W-655	VR95B717 / 2*Ernie	61.1	16.7	9.3	0.2
VA03W-661	Ning7840 / 2*Ernie	46.3	4.3	5.4	0.1
VA03W-662	Ning9016 / 2*Ernie	51.4	3.7	4.0	0.1
VA03W-664	Ning9016 / 2*Ernie	50.8	7.0	8.6	0.2

Table 2. Reaction of FHB-Resistant Backcross Lines Versus Recurrent Parents in the 2003-04 Virginia Tech Scab Observation Test.

		Field Screening (2003)			Greenhouse Screening (2002)	
Entry	**Pedigree**	**INC %**	**SEV %**	**IND**	**SEV %**	**Type II Reading (1-5)**
Recurrent Parent	**Renwood 3260**	**55**	**60**	**33**	**47.8**	**3.9**
VA04W-163	W14 / 5*Renwood 3260, BC4F3	10	18	1.8	17.2	3.3
VA04W-164	W14 / 5*Renwood 3260, BC4F3	15	25	3.8	27.6	3.6
VA04W-165	W14 / 5*Renwood 3260, BC4F3	25	29	7.3	20.7	3.4
VA04W-166	W14 / 5*Renwood 3260, BC4F3	15	23	3.5	21.4	3.4
VA04W-167	W14 / 5*Renwood 3260, BC4F3	10	21	2.1	17.9	3.3
Recurrent Parent	**Roane**	**30**	**19**	**5.7**	**39.7**	**3.9**
VA04W-218	W14 / 5*Roane, BC4F3	30	27	8.1	11.1	2.7
Recurrent Parent	**Madison**	**75**	**61**	**46**	**31.9**	**3.7**
VA04W-231	Futai8944 / 5*Madison,BC4F3	55	69	38	30.0	3.7
VA04W-232	Futai8944 / 5*Madison,BC4F3	50	34	17	30.0	3.7
VA04W-234	Futai8944 / 5*Madison,BC4F3	55	52	29	17.1	3.4
Recurrent Parent	**Agripro Mason**	**35**	**36**	**13**	**48.2**	**4.0**
VA04W-239	Shaan85-15 / 6*Agripro Mason,BC5F3	50	45	23	29.4	3.7
Recurrent Parent	**Ernie**	**5**	**23**	**1.2**	**44.5**	**4.0**
VA04W-257	Shaan85-2 / 5*Ernie, BC4F3	4	13.3	0.5	22.2	2.9
VA04W-260	VR95B717 / 5*Ernie, BC4F3	20	39	7.8	20.7	3.4
VA04W-265	W14 / 5*Ernie,BC4F3	5	20	1	28.1	3.7
VA04W-266	W14 / 5*Ernie,BC4F3	5	18	0.9	20.8	3.3
VA04W-274	Futai8944 / 5*Ernie,BC4F3	4	18	0.7	21.7	2.8
VA04W-275	Futai8944 / 5*Ernie,BC4F3	10	21	2.1	22.9	3.0
VA04W-276	Futai8944 / 5*Ernie,BC4F3	4	15.7	0.6	20.7	3.4
VA04W-277	Futai8944 / 5*Ernie,BC4F3	20	34	6.8	28.0	3.5

Table 3. Field and Greenhouse Reaction of FHB Doubled Haploid Lines in the 2003-04 Virginia Tech Scab Observation Test.

		Field Screening (2003)			Greenhouse Screening (2002)	
Line	**Pedigree**	**INC %**	**SEV %**	**IND**	**SEV %**	**Type II Score: 1-5**
Ernie	**Resistant Check**	5	23	1.2	44.5	4.0
Roane	**Resistant Check**	30	19	5.7	39.7	3.9
Renwood 3260	**Moderately Susceptible Check**	55	60	33	47.8	3.9
Madison	**Susceptible Check**	75	61	46	31.9	3.7
VA04W-118	Ning7840/Ernie//Tribute,H3	40	52.0	21.0	23.3	3.2
VA04W-119	Roane/Freedom//Ernie,H3	25	24.0	6.0	6.3	2.0
VA04W-120	Roane/Freedom//Ernie,H3	5	17.8	0.9	5.2	1.5
VA04W-121	Roane/Freedom//Ernie,H3	20	13.0	2.6	9.1	2.5
VA04W-122	Roane//W14/Coker9134,H3	20	19.0	3.8	6.8	2.0
VA04W-123	Roane//W14/Coker9134,H3	5	11.7	0.6	7.2	2.4
VA04W-124	Roane//W14/Coker9134,H3	4	0.0	0.0	4.7	2.1
VA04W-125	Roane//W14/Coker9134,H3	4	14.3	0.6	8.9	2.4
VA04W-127	Renwood 3260//Freedom/Ernie,H3	20	33.0	3.3	11.1	2.0
VA04W-128	Renwood 3260//Freedom/Ernie,H3	4	21.7	0.9	27.5	3.6
VA04W-129	Renwood 3260//Freedom/Ernie,H3	15	28.0	4.2	8.0	2.7
VA04W-130	Renwood 3260//Freedom/Ernie,H3	4	13.0	0.5	26.5	3.3
VA04W-131	Renwood 3260//Shaan85-2/Ernie,H3	4	10.0	0.4	6.9	2.8
VA04W-132	Renwood 3260//Shaan85-2/Ernie,H3	40	30.0	12.0	8.6	2.7
VA04W-133	Renwood 3260//Shaan85-2/Ernie,H3	4	16.7	0.7	4.7	2.0
VA04W-134	VR95B717/Roane//Pioneer26R24,H3	4	15.0	0.6	14.4	2.9
VA04W-135	VR95B717/Roane//Pioneer26R24,H3	4	11.7	0.5	12.3	3.3
VA04W-136	Ernie//INW 9824/McCormick,H3	4	10.0	0.4	7.0	2.7
VA04W-137	IL4162//INW 9824/McCormick,H3	5	22.0	1.1	14.1	2.9
VA04W-138	INW 9824/VA375WS//Pioneer25W33,H3	5	17.0	0.9	7.5	2.4
VA04W-139	INW 9824/VA375WS//Pioneer25W33,H3	20	22.0	4.4	25.3	3.6
VA04W-140	INW 9824/VA375WS//Pioneer25W33,H3	35	31.0	11.0	13.6	2.7
VA04W-141	Roane//IL89-6489/AGS 2000,H3	30	27.0	8.1	29.5	3.8
VA04W-142	Roane//IL89-6489/AGS 2000,H3	20	24.0	4.8	27.5	3.0
VA04W-143	Roane//IL89-6489/AGS 2000,H3	15	15.0	2.3	11.7	2.5
VA04W-144	Roane//IL89-6489/AGS 2000,H3	15	15.0	2.3	13.0	3.2
VA04W-145	Roane//INW 9824/AGS 2000,H3	15	18.0	2.7	11.0	2.3
VA04W-146	Roane/AGS 2000//Agripro Gibson,H3	10	15.0	1.5	14.3	3.0
VA04W-148	Roane/AGS 2000//Agripro Gibson,H3	35	38.0	13.0	18.5	2.7
VA04W-149	Roane/AGS 2000//Agripro Gibson,H3	20	15.0	3.0	5.9	1.8

MARKER-ASSISTED BACKCROSSING SELECTION OF NEAR-ISOGENIC LINES FOR A 3BS FUSARIUM HEAD BLIGHT RESISTANCE QTL IN *TRITICUM AESTIVUM*

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OBJECTIVE

Our objective was to develop near-isogenic lines for the 3BS Fusarium head blight resistance QTL using marker-assisted backcrossing.

INTRODUCTION

Near-isogenic lines (NILs) differing in disease resistance quantitative trait loci (QTL) are valuable materials for the study of the genetic basis of quantitative resistance. A major QTL on the distal part of chromosome 3BS known to have an effect on Type II Fusarium head blight (FHB) resistance in hexplaoid wheat was used in a marker-assisted backcross program. This QTL explained up to 60% of the phenotypic variation in several mapping populations (Bai et al., 1999; Zhou et al., 2000, 2002; Buerstmayr et al., 2002). A number of research groups have reported that this QTL has the largest effect on FHB resistance among all FHB resistance QTL identified to date (Bai et al., 1999; Anderson et al., 2001; Ban and Watanabe 2001; Zhou et al., 2000, 2002; Sneller et al., 2001; Buerstmayr et al., 2002; Shen et al., 2003). This 3BS QTL was also verified in two breeding populations and used successfully in marker-assisted selection for FHB resistance (Zhou et al., 2003).

MATERIALS AND METHODS

A marker-assisted backcrossing selection program was begun in 1999 to develop NILs for the 3BS Fusarium head blight resistance QTL. A recombinant inbred line, RIL90, was selected from among 133 RILs derived from Ning7840×Clark as the donor parent of the 3BS QTL. RIL90 was selected based on AFLP mapping results and FHB screening tests. Based on 617 AFLP markers mapped on 133 RILs, the genetic similarity between Clark and RIL90 was 65%. RIL90 was backcrossed with Clark and the F_1 was further backcrossed with Clark. Five BC_1F_1 plants were selfed, and fifty BC_2F_2 plants were genotyped with SSR markers Xgwm389, Xgwm533 and Xbarc147 during the seedling vernalization period and evaluated for Type II scab resistance after flowering in the greenhouse. Two plants which were homozygous for marker alleles from Ning7840 for Xgwm533 and Xbarc147 with moderate resistance were selected to backcross with Clark for two additional generations. Five BC_4F_1 plants derived from the two BC_2F_2 plants were selfed, and 56 and 64 BC_4F_2 plants derived from these two BC_2F_2 plants were genotyped and Type II scab resistance was evaluated. NILs for the major scab resistance QTL were identified, and 15 $BC_4F_{2:3}$ plants derived each line were evaluated for Type II scab resistance conferred by the 3BS QTL.

Genetic similarity between Clark and NILs was calculated by means of simple matching coefficients (SMC), $S_{ij} = (a + d)/(a + b + c + d)$, where a = number of fragments in common between genotypes; d = number of fragments absent in both genotypes, and *b* and *c* = number of fragments not in common between two genotypes (Sokal and Michener, 1958).

RESULTS AND DISCUSSION

The average percentage of scabbed spikelets (PSS) values of RIL90 over four FHB screening tests was 47%. Based on AFLP markers linked to the 3BS major QTL, RIL90 carries the resistant allele from Ning7840. With the development and application of simple sequence repeat (SSR) markers in wheat genome mapping, 121 polymorphic SSR markers (out of 728 SSR markers analyzed) were mapped on the 133 RILs. All of these SSR markers were integrated with 617 AFLP markers mapped on the same population. Six SSR markers and one STS marker (Guo et al., 2003) linked to the 3BS QTL were identified (Figure 1.). During the process of developing NILs, the genome region containing the scab resistance QTL in backcross plants was retained through SSR marker analysis. NILs differing in Type II FHB resistance and alleles from Ning7840 and Clark were identified in BC_4F_2 populations. Greenhouse evaluation of FHB resistance of single BC_4F_2 plants and a progeny test and SSR analysis confirmed the identification of RILs with the 3BS QTL. Frequency distribution of PSS values for BC_4F_2 plants is shown in Figure 2.

NILs were selected from 120 BC_4F_2 plants based on SSR and STS marker genotypes and FHB phenotypic data. Genetic similarity between NILs and Clark was tested based on all SSR markers polymorphic between Ning7840 and Clark. Plants obtained after the fourth generation of backcrossing resembled the recurrent susceptible parent based on phenotypic and genotypic evaluation. NILs had genetic similarity with Clark of more than 98%, but retained the major FHB resistance QTL from Ning 7840 and a 3BS region from Ning 7840 of less than 8 cM in length. These NILs will be useful for further molecular characterization of the major QTL on 3BS.

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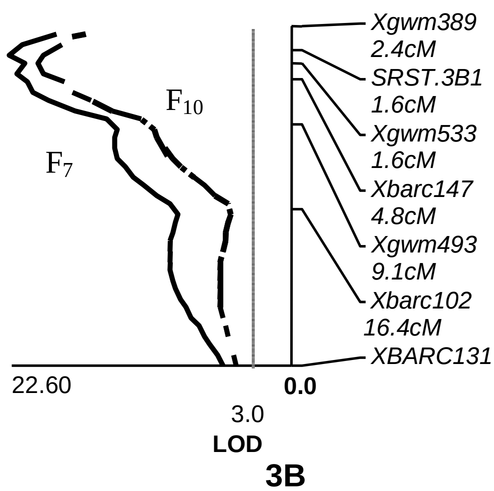

Figure 1. Linkage and interval analysis of SSR and STS markers linked to the major Type II FHB resistance QTL on chromosome 3BS in a set of 133 recombinant inbred lines from a cross of Ning7840 ×Clark. Phenotypic data was collected in F7 and F10 RILs, respectively.

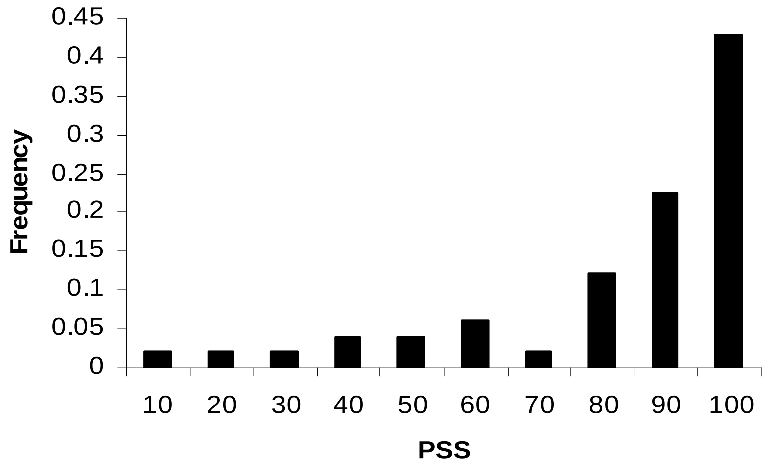

Figure 2. Frequency distribution of PSS values of 120 BC_4F_2 plants derived from backcrossing RIL90 with recurrent susceptible line, Clark. RIL90 is a F_{11} recombinant inbred line derived from a cross between Ning7840 and Clark.