NCR-184 2000 ARKANSAS STATE REPORT

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WHEAT PRODUCTION

Arkansas growers harvested about 1,000,000 acres of soft red winter wheat with a record state average of 56 bu / acre. Growing conditions were excellent throughout the season. The major constraint to production was a stripe rust epidemic that was much more severe than any stripe rust epidemic in collective memories. About 300,000 acres were sprayed with Tilt fungicide to control stripe rust. Many more acres would have benefited from a Tilt application. Average yield likely would have exceeded 60 bu / acre if stripe rust did not occur.

FHB SITUATION

FHB was found in trace amounts in several fields and experimental plots in east-central Arkansas. The effects of FHB on yield, test weight, and DON appeared to be negligible.

CURRENT FHB PROJECTS

Robert Bacon's breeding program has several advanced lines that appear to have FHB resistance from early CIMMYT spring wheat selections and Chinese lines, and these will be screened more rigorously during the coming year. He has also made additional crosses with adapted Arkansas breeding lines and resistant soft red winter wheats and eastern European winter wheats.

Gene Milus has advanced lines from populations derived primarily from recent CIMMYT spring wheat cultivars and lines. These lines are in the process of being screened more rigorously for FHB resistance in the greenhouse and at several field locations. Steve Harrison, wheat breeder at Louisiana State University, is collaborating with this project by screening lines at two locations in Louisiana. Selections made in Louisiana and Arkansas have been exchanged each year. Additional sources of "durable" leaf rust, stripe rust, and leaf blotch resistances have been incorporated into the same two agronomic parents used for FHB resistance, and a recurrent selection program is planned to combine resistances.

Milus has planted the uniform winter wheat, southern winter wheat, and Bacon's scab nurseries in field screening nurseries and in the greenhouse for type 2 evaluations.

Scab occurs occasionally at low levels on rice in Arkansas. Former postdoc, Louis Prom, collected, identified, and stored many Fusarium isolates from rice in Arkansas. This project was discontinued after his departure, but Milus would be willing to provide cultures of these isolates to interested scientists.

NCR-184 MANAGEMENT OF HEAD SCAB IN SMALL GRAINS ILLINOIS REPORT - NOVEMBER, 2000

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ILLINOIS WHEAT PRODUCTION

The estimated wheat yield in Illinois in 2000 was 57 bushels per acre. This was three bushels per acre below last year's average of 60 bushels per acre, and four bushels per acre below the record state average of 61 bushels per acre set in 1997. Acreage harvested was about 920 thousand acres, down about 10 % from 1999, and the first time in many years that the harvested wheat acreage has dropped below one million acres. Wheat production in Illinois in 2000 was about 52.4 million bushels. This was a 13 % decrease from the 1999 production of 60.6 million bushels. In general, the winter was very mild in Illinois, and the crop developed rapidly in the spring. Wheat was harvested earlier than average in some of the southern regions, but rainy weather delayed harvest in some areas. One of the biggest problems for Illinois wheat producers in 2000 was getting the wheat harvested. Several widespread storms delayed harvest for many farmers and severely reduced test weights. Scab damage was spotty in 2000 with significant losses in some localized areas, but little damage due to scab overall. In spite of good yields for many farmers in 2000, the number of wheat acres planted for 2001 is projected to be significantly reduced.

UNIVERSITY OF ILLINOIS RESEARCH

Breeding for Scab Resistance in Soft Red Winter Wheat: Development of scab resistant germplasm and varieties is a major research emphasis in the wheat breeding program. The long-term objective is the development of soft red winter wheat genotypes with excellent resistance to scab combined with resistance to other diseases, high yield potential, and acceptable winter hardiness and milling and baking quality. Our short-term objectives are: 1) to combine genes for resistance to scab from diverse sources; 2) to evaluate the genotypes produced from crosses and identify those with resistance to scab; 3) to identify molecular markers associated with genes for resistance to scab; and 4) to work toward using molecular markers to assist in breeding for scab resistance.

Four Illinois breeding lines in the 2000 Cooperative Eastern Winter Wheat Fusarium Head Blight Screening Nursery were among the most scab resistant lines in the nursery. These lines have potential as parents, represent sources of resistance that are different from the Chinese sources of resistance, and are in soft red winter wheat backgrounds. These lines were made available to other breeders by entering them into the Cooperative Eastern Winter Wheat Fusarium Head Blight Screening Nursery.

About 680 breeding lines were evaluated in the misted, inoculated field nursery in 2000. Material evaluated included germplasm reported to be tolerant / resistant, current varieties, and experimental breeding lines. Individual heads were selected from 35 segregating

populations grown in the field nursery. About 3000 headrows resulting from these selections have been planted this season (2000-01). About 2220 individual plants from six segregating populations were evaluated in the greenhouse scab screening, and about 844 plants with Type II scab resistance equal to or better than Ernie were selected.

We are continuing to select lines from segregating populations, evaluate lines, and increase the number of lines selected from crosses with potential scab resistance using both greenhouse and field procedures with misting systems and inoculation. In summary, new lines with scab resistance were identified, and the agronomic performance of previously identified lines was evaluated.

Research on Molecular Markers: Using a population of lines from a cross of resistant and susceptible cultivars, we continued to conduct research on identification of molecular markers linked to scab resistance. Three microsatellite markers on the short arm of chromosome 3B were linked integrated into an AFLP linkage group containing a major QTL for scab resistance. The order of the three microsatellite markers from telomere to centromere is Xgwm389-Xgwm533-Xgwm493, and the genetic distances between Xgwm389 and Xgwm533, and between Xgwm533 and Xgwm493 are 5.3 cM and 4.8 cM, respectively. Based on single factor analysis of scab resistance data from evaluation of four generations, Xgwm533 is the microsatellite marker most closely associated with the major scab resistance QTL. Based on F_{10} scab resistance data, Xgwm389, Xgwm533, and Xgwm493 explained 36%, 44%, and 34% of the phenotypic variation for scab resistance, respectively. Combined with AFLP mapping data, an integrated linkage map with AFLP and microsatellite markers was constructed. Interval analysis based on the integrated map of AFLP and microsatellite markers showed that Xgwm389 and Xgwm493 flank the major scab resistance QTL for scab resistance. Mapping of the three microsatellite markers on eight 3BS deletion lines showed that Xgwm389 is located distally to breakpoint 3BS-3, and Xgwm533 and Xgwm493 are located between two breakpoints, 3BS-3 and 3BS-8. Thus, the chromosome region containing the major QTL is located distally to the breakpoint 3BS-8. PCR products amplified by the three microsatellite markers can be separated and detected clearly on standard agarose gel. They should be applicable in marker-assisted selection for scab resistance. This research is in cooperation with Guihua Bai, Oklahoma State University; Greg Shaner, Purdue University; and Les Domier, USDA-ARS at Urbana, Illinois.

PUBLICATIONS

Kolb, F. L., and N. J. Smith. 2000. Registration of 'Kaskaskia' wheat. Crop Sci. 40:1494-1495.

Kolb, F. L., G-H. Bai, G. J. Muehlbauer, J. A. Anderson, K. P. Smith, and G. Fedak. 2001. Host plant resistance genes for Fusarium head blight: Mapping and manipulation with molecular markers. Crop Sci. 40: (accepted).

MANAGEMENT OF SCAB OF SMALL GRAINS NCR-184 2000 INDIANA STATE REPORT

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Scab was sporadic and generally not severe in Indiana in 2000, although some rain fell during flowering. Where scab was found, incidence was generally low. Greatest intensity of disease appeared to be in the northern part of the state.

CURRENT RESEARCH PROGRAMS

As part of a collaborative study on epidemiology of scab of wheat, a study was conducted at the Purdue Agronomy Research Center in Tippecanoe County. Spores were recovered from the air and from wheat heads consistently during the time wheat was flowering. A report can be found in the Forum proceedings. (Shaner and Buechley)

Work was also formally initiated on some “new” sources of resistance to Fusarium head blight. Several accessions were previously screened and reselected lines for resistance. During the spring of 2000, crosses were made between these lines and susceptible cultivars, or between these lines and previously studied resistant cultivars (Sumai 3 and Ning 7840). Additional crosses are being made during the fall of 2000. Once F3 families and backcross F2 families have been developed, analysis of resistance will begin. (Shaner and Buechley).

In the breeding program, cultivars and advanced breeding lines with partial resistance to head blight have been crossed with other lines that show Type II resistance. Field selection is also continuing for lines with a low incidence of head blight. Selection is based on performance at multiple field sites. The most promising lines have been submitted to the Cooperative FHB Wheat Nursery for 2001. A mist irrigation system was established in a nursery at the Purdue Agronomy Research Center for head blight resistance screening. (Ohm, Shen, Drake, Sharma)

Several recombinant inbred populations, derived from crosses between wheat accessions with resistance to *F. graminearum* and susceptible cultivars, are under development. Analysis of these will begin in the spring of 2001. Once families have been reliably classified, by repeated testing, a search for molecular markers will begin. (Ohm)

A recombinant inbred population from a cross between ‘Goldfield’ and ‘Patterson’ is being developed to study the inheritance of low incidence resistance. In the field, Goldfield typically shows only one-fourth to one-fifth the head blight incidence that is observed in Patterson. (Ohm)

Several fungicides were evaluated for efficacy against head blight at two locations in Indiana. Although head blight was not severe, a few treatments reduced incidence of head blight and scabby kernels, and level of DON in grain, compared to the untreated controls. At the southern Indiana site, we observed that some strobilurin treatments increased DON levels compared to the control. A more complete report is provided in the Forum proceedings. (Shaner and Buechley)

Three cDNA libraries were constructed with RNAs isolated from different *Gibberella zeae* PH-1 cultures. Around 4000 random clones from these libraries have been sequenced as Expressed Sequence Tags (EST). Numerous genes that are potentially important for plant infection have been identified in these ESTs (www.genomics.purdue.edu/~jxu/Fgr). A 7x-coverage cosmid library was also constructed with the vector pMocosX, which contains the hygromycin resistance marker suitable for *G. zeae* transformation. In addition, we have accumulated 9000 BAC clones with an average insert size of 60 kb and are in the process of improving the quality of BAC clones. (Xu)

Cereal classes and acreage in Indiana

Indiana produces soft red winter wheat. In 2000, Indiana farmers harvested 510,000 acres, at an average yield of 69 bu/A, for a total production of 35.2 million bushels.

ANNUAL REPORT FOR 2000 NCR-184 – IOWA

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Wheat production and head blight in Iowa in 1999. Winter wheat acreage harvested for grain was very low in 2000, estimated at 18 thousand acres, down 13 thousand acres (42 percent) from 1999. The yield of 47 bushels per acre is up four bushels per acre from last year. Production at 846 thousand bushels is down 37 percent from one year ago. Weather in 2000 was characterized by extremely dry conditions during the flowering period. The result was that Fusarium head blight had a negligible effect on the wheat crop in Iowa this year. Early summer rains promoted scab development in spring wheat and barley, but Iowa's acreage of these crops is extremely low.

Fusarium head blight research. In 1999 we participated in the uniform scab nursery for spring wheat. Plots were planted in soybean stubble and no irrigation or inoculum was provided. Head blight severity reached about 30% in susceptible checks and was 2-3% in the best experimental lines. Deoxynivalenol concentrations ranged from 2.5 to 25.6 ppm, and there was a significant correlation between disease severity and DON. We also participated in the uniform fungicide trials with a winter wheat variety, but scab did not occur in the plots and there were no treatment effects. This fall we planted the uniform scab nursery for winter wheat. The Iowa State University Department of Agronomy has hired a new small grain breeder, Dr. Jean-Luc Jannink, but his emphasis is likely to be on oats.

NCR-184 STATE REPORT KANSAS 2000

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FHB SITUATION IN 2000 IN KANSAS

Kansas wheat generally had average yields and average disease levels in 2000. Barley yellow dwarf, leaf rust, and strawbreaker foot rot were major diseases. Stripe rust was the worst in many years. Fusarium head blight was not reported anywhere in the state.

Programs and personnel involved in FHB research

Breeding program and scab resistance screening: For the third year, a field screening nursery was operated at Manhattan by Bill Bockus, Mark Davis, and Bob Bowden. Plots were inoculated with corn kernels infested with one aggressive isolate of *Gibberella zeae*. Plots were irrigated with fine impact sprinklers for 3 minutes per hour each night starting at heading.

The Uniform Winter Wheat Fusarium Head Blight Nursery was rated at four dates. NY87048-7387, NY87048-7388, MO980525, IL97-2945, OH688, IL96-3073, and VA96W-329 looked the best in our plot this year.

In the Kansas cultivar screening test, Agripro Hondo, Clark's Cream, Heyne, and AP7510 had the best resistance. The newest KSU release, Trego, was identified as highly susceptible to scab. Fortunately, this white wheat variety is targeted to western Kansas where conditions are seldom conducive to scab. The new white noodle wheat, Lakin, had very good resistance to scab.

The Kansas Intrastate Nursery was screened and several highly susceptible lines were identified and will be discarded. Several new breeding lines had resistance comparable to our best cultivars.

We have been breeding for low polyphenol oxidase (ppo) in our white noodle wheat program to reduce noodle browning. Since ppo is thought to be a disease defense gene, André Rosa, a student in plant breeding, attempted to correlated scab resistance and ppo in several populations. Preliminary results suggest that there is no correlation.

Transgenic resistance: S. (Krishnan) Muthukrishnan (Biochemistry), Harold Trick (Plant Pathology), Bikram Gill (Plant Pathology), and George Liang (Agronomy) are cooperating on transgenic resistance. Transgenic plants had an increased level of resistance to scab. Spring wheat, 'Bobwhite', a scab-susceptible cultivar was transformed with pAHC20 vectors carrying the *bar* gene and the gene of interest under the control of maize ubiquitin promoter. Several transgenic lines containing single or pyramids of different combinations of PR-

proteins have been identified and are being propagated and tested for resistance to scab in the greenhouse.

Pathogen genetics and variability: Jim Jurgenson, Bob Bowden, and John Leslie finished work on a genetic map of a cross between a strain of *Gibberella zeae* from Kansas and a strain from Japan using AFLP markers. There were 441 unique AFLP loci arranged on nine linkage groups. One linkage group appears to have an intercalary inversion. This could be significant for introgression of genes between Asian and North American populations. Ron Plattner and Nancy Alexander (USDA mycotoxin unit at Peoria) provided data that toxin type (DON vs. NIV) and amount are segregating in this cross. These loci were independent. The toxin type co-segregated with a polymorphism for the *Tri5* gene. Therefore the DON/NIV switch is in the trichothecene cluster.

Kurt Zeller is doing a study comparing populations of *G. zeae* from the Corn Belt using AFLPs in cooperation with Bob Bowden and John Leslie. Populations from Illinois, Kansas, Minnesota, New York, North Dakota, Ohio, and Virginia had high genotypic diversity. However, all populations had very similar allele frequencies. Therefore it appears the population in the region is panmictic with little or no divergence with increasing distance. Kurt is also working with Dr. Yin-won Lee from Seoul National University to look at diversity in South Korean populations of *G. zeae.*

Ivette Vargas, an M.S. student with Bob Bowden, is initiating studies of South American populations of *G. zeae* and comparing them to North American populations. Populations from Uruguay and Brazil are in hand. Further populations are being sought from Paraguay and Argentina.

NCR-184 2000 KENTUCKY STATE REPORT

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FUSARIUM HEAD BLIGHT STATUS DURING 2000

Fusarium head blight (FHB) levels were very low throughout most of Kentucky during spring 2000. An occasional field was significantly affected because of timely rains, but these incidences were anomalies.

CURRENT RESEARCH PROJECTS

Field and Greenhouse Screening - Marla Hall, Brenda Kennedy, Liu Hua and David VanSanford

Numerous soft red wheat cultivars, breeding lines, entries in the Uniform Northern and Southern Scab Nurseries, and approximately 1400 exotic accessions were evaluated under mist irrigation in a field near Lexington, Kentucky. Autoclaved corn seed, artificially infested with *Fusarium graminearum,* was used to inoculate the nursery. Most of these lines were evaluated in the greenhouse for Type II resistance. 2000 data showed considerable variation; some breeding lines showed good Type II resistance as well as an apparent combining ability for this trait.

Inheritance Studies - Marla Hall, Liu Hua, and David VanSanford

A number of populations were synthesized from wheat parents with reportedly different sources of resistance to FHB. S_1 lines will be evaluated under mist irrigation in an inoculated nursery to elucidate inheritance of resistance. Two diallel series of crosses were made for Type II resistance and DON accumulation. These F_1's will be evaluated in the field and greenhouse.

Breeding Program - David VanSanford

Numerous crosses have been made to various sources of resistance, within and outside the soft red wheat market class.

Uniform FHB Fungicide Test - Donald Hershman and Scott VanSickle

Tests were performed at two locations in west Kentucky during 2000. One test was in south central Kentucky (Logan County) and one was in far west Kentucky (Fulton County). Both tests relied on natural inocula and neither test was irrigated. Six fungicides and a non-treated check were evaluated at both locations. An additional fungicidal treatment was evaluated at the Fulton County test. Due to very low disease pressure at both test sites, no differences were detected between any of the treatments in regard to disease control or

yield effects. Plans for 2001 are to evaluate treatments at single test site which is both artificially inoculated with *F. graminearum* and mist-irrigated.

FHB Field Survey - Donald Hershman, Scott VanSickle and Philip Needham

2000 marked the third year of a state FHB survey. During the three years of the survey, 261 grower fields in Kentucy and several adjacent counties in Indiana, Illinois, Missouri and Tennessee were evaluated for FHB incidence and severity. These disease ratings were regressed against levels of corn residue left on the soil surface after planting the previous fall. In all three years, there was very poor and highly variable association detected between corn residue on the soil surface (measured in the fall) and FHB ratings. Data suggests that factors other than corn residue, such as weather, drive FHB epidemics. Widespread incidence of inocula of the FHB fungi probably exists in Kentucky due to the large number of widely-scattered corn fields which exist throughout wheat producing areas of the state. We hypothesize that this reality negates the in-field influence of corn residue on FHB inocula when environmental conditions favor FHB. In contrast, inocula sources are irrelevant in years when overall weather conditons do not favor FHB. The effect of in-field inocula on FHB epidemics may be greater in areas where FHB fungi are not widely distributed because of limited crop acreage of susceptible crops or do to certain crop rotations or cropping systems used.

Movement of *Fusarium graminearum* in Wheat Spikes Following Greenhouse Inoculation - Dennis TeKrony, David VanSanford, Jason Argyris, and Brenda Kennedy

The single floret inoculation system is commonly used to monitor visible infection of spikelets to determine the level of Type II resistance which exists in wheat. A preliminary investigation was conducted to relate visual spike and spikelet infection to actual presence of *F. graminearum* within components (rachis, glume, lemma, palea, and seed) of spikes and spikelets. Five genotypes were evaluated in the greenhouse following single floret inoculation with an isolate of *F. graminearum*. Results suggest that visual rating of inoculated spikes may be a poor indicator of actual levels of F. graminearum which exist in infected spikes and spikelets. Data also show that fungal movement in spikes occurs in three ways: 1) localization around the point of inoculation (PI); 2) movement up and down the spike from the PI; and 3) movement primarily downward from the PI. This research indicates that a potential weakness may exist in breeding programs which use visual FHB ratings to determine the level of Type II resistance following single floret inoculation. By providing for a better understanding of actual movement of *F. graminearum* within infected spikes and spikelets, it is hoped that a more precise method of measuring Type II resistance under greenhouse conditions might be developed. This, in turn, would improve the efficiency of breeding for FHB resistance.

2000 NCR-184 STATE REPORT MANAGEMENT OF HEAD SCAB OF SMALL GRAINS

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State situation: FHB occurred in Michigan in 2000. The incidence varied between less than 1% to greater than 40%. The occurrence was state wide, but with the higher incidence and severity in the western half of the state. DON was a significant problem with many end users of wheat who limited the DON content of the unfinished wheat to 1 ppm.

Research Reports

Variability of deoxynivalenol in individual fields of wheat. In a 1996 and 1998 statistical study on winter and spring wheats, a grain probe sampling protocol was developed to predict levels of deoxynivalenol (DON) in FHB infected grain. The variability was greater between probes in the 1998 study compared with the 1996 study. In the 1996 study, the DON average from four probe samples was within 1 ppm of the upper limit of the estimated truck average (95% confidence), or within 0.5 ppm on either side of the estimated truck average (95% confidence). Four probes from the 1998 study predicted the average within 3 ppm of the upper limit (95% confidence), or within 1.5 ppm on either side of the average (95% confidence), thus reflecting the increased variability of DON distribution in the trucks. Two of the five trucks from 1998 had DON means below 10 ppm (5.9 and 9.2 ppm), and four probes predicted the mean (95% confidence) within 2 ppm and 1 ppm, for the upper limit and for either side of the mean respectively.

An in field evaulation of the above sampling recommendations was conducted throughout Michigan in 2000. The DON analysis of the sampled grain has not been completed. In addition, a new study was implemented to estimate in field variability of DON in order to develop a simple but statistically reliable sampling recommendation for individual fields.

In planta expression of a peptide that mimics the binding of DON to DON specific antibody. The objective of this research project is to investigate the affect of DONPEP on resistance characteristics in Arabidopsis to the effects of deoxynivalenol, a virulence factor produced by *Gibberell zeae* (*Fusarium graminearum*) which is responsible for the disease in wheat know as Fusarium head blight (FHB). Our longer term goal is to develop transgenic wheat plants that exhibit resistance to G. zeae. This project is one part of a larger project that is investigating a broad range of alternatives to reduce the severity of this disease, including variety selection, planting multiple varieties, fungicides, tillage and biological control. It appears, however, that resistance is the only acceptable long-term approach.

To investigate the function of DONPEP.2 and its possible antagonistic interaction with DON in planta, we cloned DONPEP.2 into plant expression vectors by fusing with green fluorescent protein (GFP) using several strategies. First, DONPEP.2 was fused to the C-terminus of GFP under control of enhanced CaMV 35S promoter in the binary vector pCAMBIA. Sec-

ond, DONPEP.2 was fused to the N-terminus of GFP in the binary vector pEZT-NL. Third, two additional constructs were made to introduce PR1b signal peptide in front of DONPEP.2-GFP fusion in the binary vector pEZT-NL.

These constructs have been introduced into Arabidopsis (Columbia wild type) by Agrobacterium tumefaciens mediated transformation. These constructs will be transformed into wheat in collaboration with Dr. Patricia Okubara at the USDA-ARS, Western Regional Research Center, Albany, California. After transgenic plants are obtained, cell localization of DONPEP.2 will be observed, and its interaction with DON will also be investigated. Our rational for a two plant system approach is that regeneration of Arabidopsis is rapid compared to wheat, and should allow us to characterize the DON-DONPEPTIDE interaction, and come to a better understanding of how the DONPEP should be manipulated in planta to be most effective.

Fungicide trials on wheat to reduce FHB and DON levels.

Fungicide trials to evaluate effects on FHB development were conducted in 2000. Symptom development in the experimental plots was erratic and no conclusions concerning the effect of the fungicides in disease incidence, disease severity, or DON levels were obtained.

DON Diagnostic Services Laboratory

In 2000 over 3,000 samples have been analyzed by mid-November with approximately 1,000 samples remaining. These should be completed by the end of November. The number of sample submitted for analysis was about twice as many as in 1999, and the levels of DON appeared to be higher than in 1999. A newer Neogen ELISA was evaulated and used in place of the ELISA used in 1999. This test is called the 5/5 test, compared to the 10/10 test, and reduces both incubation times by five minutes.

USEFULNESS OF FINDINGS:

The year 2000 FHB epidemic was unusual in that the visual expression of symptoms, both incidenc and severity, would have predicted lower than detected levels of DON. A rudimentary FHB prediction system based on the amount of rain immediately preceding and during heading was fairly accurate at predicting where FHB would be the most severe. However, actual determination of FHB failed to predict the higher than expected DON levels. This suggested the importance of estimating DON in individual fields. This is important not only to growers and processors, but estimates of DON variability in research plots has not been reported or studied.

WORK PLANNED FOR NEXT YEAR:

The statistical study on sampling will be continued. Work will continue on the peptide mimic, including the development of transgenic plants, and a determination of the possible role the mimic may have in reducing the toxic effects of DON as a virulence factor in wheat and possibly barley. Work will also continue on the development of recombinant antibody to

DON, and identification of other peptide mimics that may be useful in elucidating the receptor ligands associated with DON toxicity.

PUBLICATIONS

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2000 NCR-184 MANAGEMENT OF FUSARIUM HEAD BLIGHT OF SMALL GRAINS - MINNESOTA STATE REPORT

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In 2000 Minnesota spring wheat production was similar to 1999 with production estimated at 2 million acres. Durum wheat was estimated at 2,000 acres, down 3,000 acres from 1999. Winter wheat acres were estimated at 20,000 acres. Minnesota's barley acreage increased to an estimated 240,000 acres, up 70,000 from a record low in 1999. The 2000, season was generally good for small grains production with state yields of barley averaging 64 bu/A and spring, durum and winter wheat averaging 49, 51, and 46 bu/A respectively.

A dry winter and early spring resulted in much of the Minnesota cereal crop being planted well ahead of the 5-year average. The early part of the growing season was generally cool and dry and afforded crops an excellent start with little disease development. Continued dry conditions posed concern to crops in southwest and southern Minnesota toward the end of May. Rainfall, shortly before anthesis, relieved dry soil conditions but raised concerns over the development of foliar diseases, particularly leaf rust and Fusarium head blight. While Fusarium level were generally low and yield losses minor, however levels of deoxynivalenol in harvested barley prevented much of the Minnesota crop from being sold as malt quality.

Septoria, powdery mildew, tan spot, and Fusarium head blight were observed on wheat but infections were generally low and yield losses were light. Leaf rust of wheat was also observed, but disease development was later and slower than last year and the resulting disease was not as widespread or severe as in 1999. Common root rot and crown rot were widespread and likely contributed to significant yield losses in some crops, root rots were especially prevalent in those fields that became waterlogged following heavy rainfall.

Aphid populations were much lower than last year and aphid damage was minimal. Army-worms became a problem in some fields late in the season and insecticide applications were required in some locations to check large populations in wheat and barley fields.

Minnesota's Fusarium head blight program was established in 1993 and has continued to expand. A brief outline of the current researchers and their projects follow:

Wheat - variety development, germplasm introduction, and biotechnology

J.A. Anderson (Agron. & Plant Genetics), R.H. Busch (USDA-ARS, retired), R. Dill-Macky (Plant Path.), J.A. Kolmer (USDA-ARS), G. Nelson (AES-WCROC), G.J. Muehlbauer (Agron. & Plant Genetics), J.J. Wiersma (AES-NWROC), J.V. Wiersma (AES-NWROC), W. Xie (Plant Path.)

Breeding high yielding hard red spring wheat varieties with resistance to FHB and acceptable agronomic and end-use characteristics is a primary focus of the Minnesota wheat breeding program. Approximately 1,000 lines are tested for FHB resistance using point inoculation in the greenhouse annually. Field screening for FHB resistance of approximately 11,000 rows (preliminary and advanced lines) was conducted this year in replicated inoculated and mist irrigated nurseries at three locations in Minnesota. Sources of resistance being utilized by the wheat breeding program include: Sumai 3, Wang-shui-bai, Ning 7840, Ning 8306, Ning 8331, Fujian 5114, Fujian 5125, Fujian 60096, Yumai 7, Yan-shi 9, and Er-mai 9. Recent releases from the program include HJ98 (1998) and McVey (1999). Dr Robert H. Busch wheat geneticist and spring wheat breeder retired this year. Dr. Busch can be credited for the release of 11 wheat varieties.

Barley - variety development, germplasm introduction, and biotechnology

K. Smith (Agron. & Plant Genetics), D.C. Rasmusson (Agron. & Plant Genetics, retired), R. Dill-Macky (Plant Path.), G. Nelson (AES-WCROC), G.J. Muehlbauer (Agron. & Plant Genetics), J.J. Wiersma (AES-NWROC), J.V. Wiersma (AES-NWROC), W. Xie (Plant Path.)

Developing barley varieties with resistance to *Fusarium* and reduced levels of deoxynivalenol with acceptable agronomic and malting quality characteristics have been the primary objectives of the Minnesota barley breeding program over the past five years. In 2000, over 7,500 rows of breeding lines were evaluated for resistance to *Fusarium* in field experiments conducted at three locations in Minnesota and additional 250 lines were screened in the greenhouse. Sources of resistance utilized in the barley breeding program include; AC Sterling, AC Oxbow, Atahuapla, Chevron, and Zhedar. DON testing of field evaluated materials is an important aspect of this program. MNBrite, released in 1998, has partial resistance to FHB but is not considered a malting variety by the brewing industry. Lacey, released in 1999, ranked first in yield comparisons with Robust, Stander, Foster, and MNBrite. Lacey appears to have a sound quality profile although industry scale testing has yet to determine the variety's malting status. Lacey appears to be similar to Robust with respect to resistance to Fusarium head blight. Donald C. Rasmusson retired from the University of Minnesota last month. Varieties including Morex, Excel, Robust, and Stander released from Don Rasmusson's program have dominated the barley acreage in the Upper Midwest.

Biotechnology - molecular studies of host response, germplasm enhancement, and genetics of pathogenicity

W.R. Bushnell (USDA-ARS), H.C. Kistler (USDA-ARS), G.J. Muehlbauer (Agron. & Plant Genetics), R.J. Zeyen (Plant Path.)

This diverse group of projects includes studies aimed at the isolation of resistance genes, mapping of resistance genes with molecular markers and the development of resistant wheat and barley varieties through genetic engineering. Transformation systems for wheat and barley have been developed and mapping of resistance genes in barley and wheat populations have been undertaken. Methods to expedite the selection of antifungal proteins

best suited for utilization in transformation are ongoing. Studies to examine the pathways of floret infection of *Fusarium* with experiments utilizing a green fluorescent protein (GFP) labeled *Fusarium* isolate which facilitates observation of fungal establishment in host tissues are continuing. The diversity of *Fusarium graminearum* is also being examined by testing the relative aggressiveness of isolates collected throughout the US and representative strains from the world collection.

Chemical and cultural control of Fusarium head blight

R. Dill-Macky (Plant Path), R.K. Jones (Plant Path), A.L. Sims (AES-NWROC)

Evaluation of candidate fungicides for efficacy in suppression of FHB have been undertaken as part of a multistate cooperative effort. To successfully integrate fungicide treatments, a quantitative PCR method for estimating inoculum potential is being tested. Studies to examine the relationship between residue decomposition and *Fusarium* survival and inoculum potential are continuing and studies to examine the effect of burning on the survival of *Fusarium* in residue have been initiated.

NCR-184 COMMITTEE- MANAGEMENT OF HEAD SCAB IN SMALL GRAINS 2000 MISSOURI REPORT

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Winter Wheat Production in Missouri and the 2000 FHB Situation in Missouri

Most of the Missouri wheat acreage is soft red winter wheat with a minimal number of hard red winter wheat acres. Fall seedings for the 2000 winter wheat crop in Missouri totaled 1 million acres, up 2 percent from the 1999 crop seeded acreage. Of the 1 million acres planted, 950,000 acres were harvested. Missouri wheat production in 2000 totaled 49,400 million bushels, up from last year's production of 44,160 million bushels. Missouri yields averaged 52 bushels per acre, up 4 bushels from last year's average yield of 48 bushels per acre.

1999 was an "interesting" year for wheat production and a fairly poor year for Fusarium head blight in most of Missouri. The winter of 1999-2000 was the eighth warmest winter on record (records going back to 1895). Most of Missouri was in a state of drought entering the year 2000. On January 1, 2000, topsoil moisture supply was rated as 24 percent very short, 42 percent short and 33 percent adequate for the state. Precipitation remained well below average until mid June. The wheat crop headed unusually early with 34 percent of the crop reported as heading for the week ending April 30. This was 9 days ahead of normal and the most advanced for that date since 1981. These unusually dry conditions as most of the state's wheat crop was flowering resulted in low levels of scab. Localized rainfall lead to scab problems in those areas but the incidence and severity of scab was minimal in Missouri in 2000.

The most serious disease problems on wheat during the 2000 season were virus diseases. Wheat spindle streak mosaic, wheat soilborne mosaic, barley yellow dwarf and wheat streak mosaic were all widespread and, in many fields, severe. Most samples tested by ELISA were positive for more than one of the viruses with wheat spindle streak mosaic and wheat streak mosaic being the most commonly found combination. Leaf rust and Septoria leaf blotch came in late in the season and did not move up to the flag leaves until well past heading. Stripe rust developed in higher than normal levels in southeastern Missouri and was found in low levels throughout the state. Losses from foliage diseases were low for most of Missouri. Missouri did have a Special Local Need Registration (Section 24c Registration) for Tilt which extended the time of application to Feeke's Growth Stage 10.5. However, because of the low level of foliage diseases few growers took advantage of the Tilt label change or the new federal label for Quadris on wheat.

The rains came just as much of the state was moving into wheat harvest. By June 18, 2000, farmers had harvested 40 percent of the crop which was about 11 days ahead of normal. Winter wheat harvesting was virtually complete by July 16, 6 days ahead of normal. How-

ever, the rain delays resulted in lowered test weights, decline in quality and weed problems in fields. There were some reports of wheat sprouting in the field and many reports of wheat heads or plants turning black in the field.

Quality of wheat seed tested by the Missouri Seed Improvement Association has been extremely variable this season. Lots coming in for germination tests look fairly normal. However, germination rates have dropped dramatically from bin germs to final germs. Lots with bin germs in the 90's had final germs in mid 50's to 70's. In one extreme case the germ of a lot dropped from a bin germ of 94 to a final germ of 14. When viewed with magnification it was possible to see that many kernels had sprouted and the sprout had been broken off. Dead seeds in the final germ tests were covered with various storage molds. The drop in germination rates appears to have been from sprouting and weathering (moisture and heat) in the field as harvest was delayed by wet conditions.

There are no official estimates of the number of acres planted to wheat this fall. Fall harvest was early. Rains have caused some delays in wheat seeding but as of November 5, 89 percent of the wheat acres had been planted.

Current Scab Research at the University of Missouri

Uniform Scab Fungicide Trial: The University of Missouri did participate in the Uniform Scab Fungicide Trial coordinated by Dr. Marcia McMullen, NDSU. Eight fungicide treatments were evaluated on Madison and Roane. FHB occurred in extremely low levels throughout the plot. There were no statistically significant differences in yield, ppm of DON, % incidence of FHB, % FHB severity or % field severity between the untreated control and any of the nine fungicide treatments. Results of this trial are given in more detail in the report for this initiative project.

Breeding Program: The University of Missouri's Wheat Breeding Program has a major emphasis on accelerating the development of scab resistant soft red winter wheat that was initiated in 1993 and significantly enhanced in the last 3 years with funds from the National Wheat and Barley Scab Initiative. Routine screening of all advanced lines in the breeding program has enabled the identification of numerous pedigrees with good to acceptable levels of scab resistance. Resistance is for reduced spread and incidence coupled with kernel retention. Once verified, lines will be entered into the Uniform Winter Wheat Scab Nursery and selected pedigrees, which differ from Ernie by descent, will be used in crossing programs to study the genetics of their resistance.

Beyond screening, the incorporation of resistance genes identified through germplasm screening programs is essential to the continued improvement of Fusarium head blight resistance in winter wheat. We currently are incorporating genes from Sumai 3, Ning 7840, Frontana, and several CIMMYT sources. In addition, we routinely use soft red winter wheats sources including Ernie, Patton, Goldfield, Freedom and several of our own lines expressing good levels of resistance. Chinese and Yugoslavian accessions showing good levels of resistance have been added to our crossing block for 2000.

Germplasm Evaluation Center: Missouri was identified as a germplasm evaluation center for the National Wheat and Barley Scab Initiative with responsibility for identifying new sources of resistance in winter wheat. Screening of Asian accessions has been completed, results have been posted on the web, and seed will be available for distribution to interested scientists at the 2000 Scab Forum. Approximately 2000 accessions from the Balkans are being screened in 2000-2001. Resistances identified in the first group of 1006 are being verified during the fall of 2000 and data will be presented at the 2000 Scab Forum.

CIMMYT Germplasm Introduction Partnership: Approximately 75 wheat lines will be introduced into the US through the National Scab Initiative's partnership with CIMMYT. Lines will include 23 lines from China with diverse resistances, 7 lines from Romania and a number of lines from CIMMYT's bread wheat breeding and wide crossing programs. These lines will be quarantined in Missouri and then distributed to interested breeders in the spring of 2000.

Genetic Studies: Studies investigating the inheritance of resistance in Ernie are currently underway utilizing the Missouri breeding line MO 94-317, a widely adapted and highly inbred (F_{12}) line, as the susceptible parent. It has high yield and excellent milling and baking quality but is highly susceptible to scab with a FHBI of $\geq$ 0.9 and poor kernel quality under disease pressure.

Conventional Six Generation Means and Variance Analyses: A set of populations (F_1, reciprocal F_1, F_2, BC_1 and BC_2) from the cross Ernie x MO 94-317 is currently under development for conventional genetic analysis of the scab resistance in Ernie. Population development will be completed in 2000/2001 and genetic analyses will be conducted in 2001. Both Type II and Type III resistance data for each generation initially will be examined for goodness-of-fit (based on P^2 analysis) to simple Mendelian ratios. Where data collected fail to fit a simple dominant/recessive genetic model, generation means and variance analyses will be conducted.

Monosomic Analyses: Monosomic plants from each of the 21 Chinese Spring monosomics developed at the University of Missouri by Dr. E.R. Sears have been crossed with Ernie in an effort to identify critical chromosomes influencing scab resistance in Ernie. In addition, the results of this study will help focus molecular work aimed at identifying markers associated with genes for scab resistance in this cultivar.

Molecular Analysis: A set of F_3 derived F_9 recombinant inbred lines (RIL's) has been developed from the cross Ernie x MO 94-317 which will be used to map resistance genes in Ernie. Results from screening F_6 RIL's suggest that resistance in Ernie is heritable and relatively simply inherited. Mapping of gene(s) associated with resistance is expected to begin in January 2001 using RFLP, AFLP and SSR markers.

FUSARIUM HEAD BLIGHT IN 2000 NCR-184 NEBRASKA STATE REPORT

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Fusarium head blight incidence - John Watkins (Plant Pathology)

Fusarium head blight incidence in commercial wheat fields was very low in 2000 due to an extended drought throughout the growing season. Two thirds of Nebraska's winter wheat is grown in areas where drought is common i.e. the panhandle and the southwest, and Fusarium head blight is rare. There is some concern that irrigated wheat in these two areas could be affected by Fusarium blight if rains come at flowering because these fields are intensively managed and there is ample moisture to support the crop. As occurred in dry-land wheat, the incidence of Fusarium head blight in irrigated wheat was neglidgeable in 2000. Only one certified seed sample tested by the Nebraska Crop Improvement Association in 2000 tested positive for Fusarium head blight.

Enhance scab resistance in winter wheat germplasm by plant transformation - A.Mitra, Marty Dickman and Julie Schimelfenig (Plant Pathology), Tom Clemente and Shirley Sato (Biotechnology Center)

In this research the key goal was to increase the sources of resistance to Fusarium head blight (FHB) though the use of novel, highly biologically active genes from nontraditional sources by collecting a set of inhibitor of programmed cell death (PCD) or antiapoptotic genes (lead candidate genes: IAP and ced9) and antifungal genes (lead gene: lactoferrin). The objective was to transform Bobwhite with these genes using microprojectile or *Agrobacterium tumefaciens* mediated transformation, grow the progeny and screen them for resistance or tolerance to FHB. As these genes may not be effective, a second objective was to continue collecting genes that may be effective in reducing the devastating effects of FHB.

Using microprojectile and *Agrobacterium tumefaciens* mediated transformation, 24 events with IAP, 3 with ced9 and 24 with lactoferrin were made. The strategy in using antiapoptotic genes is to affect the infection process which requires testing at the whole plant level. The strategy in using lactoferrin is to express a known antifungal protein, which should affect FHB. Extracts from transgenic tobacco plants expressing lactoferrin (when compared to transgenic tobacco plants not expressing lactoferrin) were shown to inhibit FHB growth in petri dishes. The progeny from the IAP, ced9, and lactoferrin transgenic lines have been screened in the growth chamber. Preliminary results from our screen for FHB for IAP identified some families expressing a level of tolerance to FHB that merits further testing. The preliminary results for lactoferrin were also promising. Plants containing lactoferrin (57.6$\pm$ 8.8, mean $\pm$ standard error) had a lower level of FHB than plants, which did not contain lactoferrin (91.2$\pm$10.1). For both genes, transgenic families having the highest level of tolerance and appropriate controls (the best conventionally developed FHB susceptible and

resistance lines, and nontransgenic Bobwhite) are being retested to confirm these preliminary results. Additional genes (e.g. the antiapoptotic gene, Bcl-xl, and some derivatives) have been collected for and are being inserted into wheat.

To enhance variety development of scab resistant varieties - P. Stephen Baenziger (Agronomy) and Julie Schimelfenig (Plant Pathology)

The main objective was to develop germplasm that is tolerant to Fusarium head blight (FHB), which will be the future base for cultivar development for the high rainfall and irrigated acreage in the central Great Plains. To meet this goal, adapted and exotic germplasm was collected from throughout the world and crossed into adapted hard red and white winter wheat cultivars. Once the transgenic FHB tolerance is verified, those transgenes will be rapidly incorporated and pyramided into common wheat. Traditionally about one third of Nebraska=s wheat acreage is in the FHB risk area (between 600 to 700,000 acres) and the University of Nebraska wheat breeding program has developed cultivars grown on 80% of Nebraska, as well as being widely grown in the FHB risk areas in adjacent states in South Dakota and Kansas. In addition to collecting germplasm, a key need has been to develop effective screens to allow selection for FHB tolerance.

Elite germplasm has been collected from the northern Great Plains and eastern United States, as well as from China and evaluated for agronomic performance. The crossing continues as would be expected in any traditional breeding effort. An effective greenhouse screen has been developed, which will be used mainly for better parent identification. This screen has been used to evaluate transgenic materials. A field-screening nursery based on mist irrigation with appropriate controls to screen 1000 lines is being built and will be used in 2001.

The most significant accomplishments for 2000 were the continued incorporation and generation advance of FHB tolerant germplasm, the development of a FHB tolerance greenhouse screen, and the purchase of necessary equipment for a FHB tolerance field screen. NE94654, recommended for release in 2000-2001, appears to have low level of FHB tolerance. NE94654 is a line that seems well adapted to FHB risk areas of Nebraska.

NCR-184 STATE REPORT NEW YORK 2000

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FHB Situation in 2000 in New York

FHB was widespread across the soft winter wheat production area of New York in 2000, with disease incidience varying from field to field. Visual symptoms seemed to be delayed until about 3 weeks after flowering, possibly due to cool temperatures, especially at night, during grain formation. In general, the disease had only a modest impact on grain yields, but test weights were reduced. Vomitoxin contamination in the range of 1 to 4 ppm was common in commercial grain lots received at flour mills, thus many loads were rejected or discounted. Preharvest sprouting was also a severe problem in 2000 in New York wheat as was Stagonospora nodorum blotch. A cooperative survey between Cornell and the Star of the West Flour Mill in Churchville, NY is being conducted to assess associations among vomitoxin level, incidence of *Fusarium* infected grains, and geographic location of production fields in the 2000 crop.

Programs and Personnel Involved in FHB Research

Winter wheat cultivar evaluation

One site of the winter wheat cooperative scab nursery is located at Ithaca, NY. Conditions were conducive for scab development, which was promoted with irrigation and the provision of grain spawn inoculum in the plots. See the report by Lipps and Engle for a summary of results at all locations. Two New York lines, NY87047W-7387 and NY87047W-7388, were among the top five entries for reduced FHB severity and lowered DON content. In addition to the standard 29 cooperative lines, an additional 50 regionally-adapted varieties and lines are also being evaluated. Also, scab reaction of over 75 lines derived from crosses of New York-adapted winter wheat cultivars with Chinese sources of resistance is being assessed.

Personnel: Mark Sorrells and David Benscher (CU Plant Breeding); Gary Bergstrom and Stan Kawamoto (CU Plant Pathology)

Fungicide Evaluation

One site of the uniform fungicide trial is located at Aurora, NY. See the summary report by McMullen and Milus in this volume. Fungicides and biocontrols were applied by foliar spray utilizing the dual (forward-backward) flat fan nozzle system configured by North Dakota researchers. Grain spawn inoculum was spread in the border areas and the plots were irrigated following anthesis. Rainfall was also frequent from heading through grain formation, conditions conducive for scab. Leaf blights were not significant at this location. No treatment resulted in a significant increase in yield, though plots treated with Folicur had the highest yields (Table 1). Various treatments induced moderate reductions in scab incidence,

Fusarium damaged kernels, DON contamination, and improvement of test weight, but not to the extent required for economic feasibility. Overall, the most promising treatment for scab and DON reduction was the combined application of the bioprotectant Trigo Cor 1448 with 4 fl oz of Folicur. Personnel: Stanley Kawamoto, Christine Stockwell, Gary Bergstrom (CU Plant Pathology); William Cox and Dilwyn Otis (CU Crop and Soil Sciences)

Biological Control

Microbial antagonists of Fusarium graminearum are being isolated and characterized for potential application to wheat spikes, seed, and crop residue. See the report by Stockwell et al in this volume.

Personnel: Christine Stockwell, Stanley Kawamoto, Gary Bergstrom (CU Plant Pathology); Wilmar da Luz (Embrapa Trigo, Passo Fundo, Brazil)

Aerobiology/Epidemiology

Research is continuing with the use of remote piloted aircraft to study the aerobiology of *Gibberella zeae* ascospores in the lower atmosphere in order to better understand the potential of regional dispersal of airborne inoculum. Efficient recovery of isolates aloft with the same AFLP pattern as a clonal isolate released on the ground in grain spawn strongly indicates that ground level inocula gain access to the planetary boundary layer. Also under investigation are the effects of environmental conditions on the discharge of mature ascospores from perithecia. Research is being conducted in laboratory chambers and under field conditions. Maldonado-Ramirez *et al* in this volume report on initial results in examining the temporal patterns of ascospore release from a corn stalk substrate under natural conditions. Three papers by Shah *et al* in this volume report on spatial aspects of FHB and epidemiological considerations associated with seed infection incidence.

Personnel: Sandra Maldonado-Ramirez, Gary Bergstrom (CU Plant Pathology); Elson Shields (CU Entomology); David Gadoury (CU Plant Pathology, Geneva campus); Don Aylor (Connecticut Ag Experiment Station); Robert Bowden, Kurt Zeller (Kansas State University)

Table 1. Effect of foliar treatment at anthesis on scab incidence, Fusarium-damaged kernels, yield, test weight, and DON contamination in Caledonia winter wheat in Aurora, NY in 2000.

Treatment and amount	Scab (spike) incidence on 26 Jun (%)	*Fusarium* damaged kernels (%)	Test weight @ 13.5% moisture (lb/bu)	Yield @13.5% moisture (bu/A)	DON ppm
Nontreated	14.1	8	56.1	74	10.7
AMS 21616	na	7.1	56.7	77.4	12.6
BAS 500F (12.3 fl oz/A) + Agridex COC (1% v/v)	11.7	6.7	56.7	73.5	14.3
BAS 500F (6.2 fl oz/A) + Agridex COC (1% v/v) + Folicur 3.6F (2 fl oz/A)	14	9.9	56.4	80.1	15.1
Folicur 3.6F (4 fl oz/A) + Induce (0.125% v/v)	11.1	6.7	57	82.4	9
Folicur 3.6F (6 fl oz) + Induce (0.125% v/v)	na	5.6	58	80.4	10.5
HI 2036 (5 lb/A)	23.5	9.1	54.5	76.7	13.7
Quadris 2.08SC (9.2 fl oz/A) + Benlate 50WP (0.25lb/A)	16.2	6.8	56	76.2	11.2
Stratego E (14 fl oz/A) + Induce (0.125% v/v)	11.6	8.8	56.6	74.1	12.9
Tilt (4 fl oz/A)	10.5	6.2	56.8	74.1	9.6
TrigoCor 1448 biocontrol	11.7	7.5	56.6	74.2	8.2
TrigoCor 1448 biocontrol + Folicur 3.6F (4 fl oz/A) + Induce (0.125% v/v)	8.7	5.2	58.3	80.1	8
TrigoCor 4712 biocontrol	11.9	7.1	56.6	77.3	9.4
TrigoCor 9790 biocontrol	17	8.2	56.5	77.2	14.4
LSD (*P* =0.05)	0.6	0.2	1.1	NS	3.8
CV (%)	14	12.4	0.1	12.1	23.5

NCR-184 REPORT 2000 - NORTH DAKOTA

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The FHB situation in North Dakota in 2000 and its impact on small grain crops. Results provided by Marcia McMullen, extension plant pathologist, who conducted a survey of 1200 grain crops across ND in 2000. Statewide, Fusarium Head Blight (FHB) was about twice as severe in 2000 than in 1999. Individual severely affected fields of spring wheat and barley could be found in parts of central ND and in fields of durum in north central, west central and northwest ND. There were many late planted durum crops which may have increased the problem. Several of the worst-affected counties were in more western locations which have not seen severe FHB in the past. Overall, wheat losses to FHB in 2000 were moderate, about 6% statewide, but averaging over 11% in the durum region. Yield loss in barley was less than 2% statewide but DON levels were often above 0.5 ppm in affected fields.

Overview of present research programs. The FHB research effort at NDSU continued to be a large one in 2000. Six NDSU departments, three NDSU Research & Extension Centers, and the USDA-ARS Northern Crop Sciences Laboratory located on the NDSU campus, all were involved in research on FHB. Many of the projects received funding from the scab initiative and reports from those investigators are included in the forum proceedings. Several of the projects are cooperative efforts between state and federal scientists.

While the principal research emphasis at North Dakota State Univ. continues to be on breeding for resistance to FHB, and classical and molecular genetics of resistance, there is active research in several other areas including epidemiology, soil microbial ecology, physiology and biochemistry, grain quality, food science, disease survey, and chemical control.

FHB resistance is being sought in breeding programs for spring wheat, spring wheat, durum wheat, and barley. Methods to obtain resistant varieties include both conventional and molecular plant breeding methods. These efforts utilize inoculated-irrigated field nurseries and greenhouse testing. Sources of resistance for spring wheat being used include lines from China, Japan, Hungary, and Brazil. Sources for durum include world collection materials and accessions from ICARDA. Similar diverse sources are being evaluated for barley.

The highlight of the year was the release of ‘Alsen’, a hard red spring wheat combining moderately high resistance to FHB with excellent grain quality and good agronomics. This release is fortuitous as certain other varieties with partial FHB resistance or yield tolerance to FHB are being lost because of race changes in wheat leaf rust.

Units involved in FHB Research.

NDSU:
Dept. of Plant Pathology
Dept. of Plant Sciences.
Dept. of Soil Science.
Dept. of Cereal and Food Sciences.
Dept. of Agricultural Engineering.
Dept. of Veterinary Science and Microbiology.
NDSU Extension Service
NDAES Research-Extension Centers at Langdon, ND, Carrington, ND, Minot, ND.

USDA
USDA-ARS Northern Crop Sciences Laboratory, Fargo

NCR-184 MANAGEMENT OF HEAD SCAB OF SMALL GRAINS: 2000 OHIO REPORT

Patrick E. Lipps[1]*, Erick D. Dewolf[1], Laurence V. Madden[1], Anju Gupta[2] and Jessica S. Engle[1]

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One million, five thousand acres of soft red winter wheat were planted in Ohio in the fall of 1999 for harvest in 2000. Highly favorable weather conditions for winter survival and spring growth lead to a record state average yield of 72 bu/A. There was very little damage from head scab, although most fields had trace levels of disease. Fields with the highest level of scab did not exceed 5-10% incidence. Yield losses probably range from 0 to 3%, but state wide the average yield loss was less than 0.1%. Cool temperatures during and after anthesis probably limited scab development because precipitation for the period was adequate to favor infection.

Research

Research efforts at OSU were focused on: disease forecasting, screening germ plasm, breeding for disease resistance, and evaluation of fungicide efficacy.

Disease forecasting: De Wolf, Madden, Lipps

A) We are participating in a cooperative program with North Dakota, South Dakota, Indiana, and Manitoba to monitor inoculum levels, environmental parameters and disease severity in replicated plots. Information from multiple sites is being used to develop a disease forcasting system. The cooperative effort is necessary to assess the effect of regional variation in cropping practices, tillage and climate on inoculum levels and subsequent disease level across the wheat producing regions. Volumetric air sampling and a wheat head bioassay are being used to monitor fluctuations in the levels of inoculum reaching heads. Automated environmental monitoring instrumentation is used to measure temperature, relative humidity, precipitaion, solar radiation, wind speed, and moisture status of the crop. This is the second year of our monitoring project.

B) Erick De Wolf and Larry Madden have developed a scab risk assessment model based on historical weather information and scab severities. The model was constructed from hourly temperature, relative humidity and precipitation data from 50 location years from Ohio, North Dakota, Kansas and Missouri. Stepwise regression identified two time periods in which three environmental parameters were critical to reasonably accurate prediction: 1) duration of precipitation and duration of temperature between 15 and 30C for 7 days prior to crop anthesis and 2) duration of temperature between 15 and 30C and corresponding relative humidity above 90% for the 10 days post anthesis. This model has had 84% prediction accuracy in classifying epidemics with greater than 10% scab severity.

C) Erick De Wolf is examining the effect of temperature and moisture content of crop residues on development of perithecia by *Gibberella zeae*. He has adapted a sensor to monitor the moisture content of corn residues over time. Experiments are in progress using enclosed moisture chambers in growth chambers to accurately control temperature and moisture content of the residues. Preliminary results indicate that temperature and moisture have a profound influence on perithecial development. Moisture sensors were used in corn residues in the field during the 2000 growing season to document fluctuations in moisture content in corn residues and examine perithecial development under a wheat crop canopy.

Breeding for scab resistance: Lipps, Gupta, Engle

A) The departments of Hort and Crop Science and Plant Pathology are cooperating to develop varieties with resistance to head scab. Four avenues of research are being followed; 1) evaluation of varieties and advanced lines for resistance, 2) evaluate and select lines with combined resistance to FHB and Stagonospora blotch, 3) incorporate resistance from sources identified within the breeding program into elite lines and 4) increase the level of resistance above current levels by incorporating new genes and gene combinations from diverse germplasm sources. During the year the following germ plasm were screened for resistance in field nurseries: 200 Advanced breeding lines, 128 resistant by susceptible crosses, 101 resistant by resistant crosses, 443 scab resistant by Stagonospora resistant crosses, and 1428 early generation head row selections. In addition the resistant by susceptible crosses were evaluated in the greenhouse.

B) Anju Gupta screened a population fo 189 Yugoslavian lines obtained from the National Plant Germpalsm System to identify new sources of resistance that could be incorporated into the breeding program. These lines were evaluated in the greenhouse and the field for two years. Results of the project are being presented the Fusarium Head Blight Forum (December 2000).

C) Anju Gupta has been identifying quantitative trait loci associated with resistance to FHB by screening two different populations using microsatellite markers. The populations being evaluated are a resistant by susceptible cross (Ning 7840 x OH 542) and a resistant by resistant cross (Ning 7840 x Freedom). This project will be complete in 2001.

Fungicide efficacy and dissemination of information: Lipps, De Wolf

We are participating in the cooperative effort of the Chemical and Biological Control section headed by M. McMullen and G. Bergstrom. Five fungicides and two biologicals were evaluated in 2000 using procedures and rates outlined by the project leaders. Measurable precipitation occurred 4 of the 7 days of anthesis, but average daily temperatures below 15 C limited disease development. Continued rain favored Stagonospora glume blotch. The biological agents (TrigoCor 1448 and 9790) did not limit glume blotch development. BAS 500 and Tilt reduced the level of disease to less than 50% of the untreated control. BAS 500 (56.7 bu/A) and Folicur (50.1 bu/A) treated plots had significantly higher yield (LSD 5 bu/A) than the untreated control (42.3 bu/A). Weather observations were used to predict the risk of head scab during the critical anthesis period. Weekly reports were provided to wheat growers through the Ohio State University Extension electronic newsletter Crop Observation and Recommendation Network (C.O.R.N.).

NCR-184, MANAGMENT OF HEAD SCAB OF SMALL GRAINS 2000 SOUTH DAKOTA STATE REPORT

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2000 SCAB DEVELOPMENT IN SOUTH DAKOTA

Minimal scab was observed across the state in South Dakota in 2000 although some fields in north and eastern part of the state had a higher incidence. Scab index (statewide average) was estimated at 2%. (M. Draper and Y. Jin).

CURRENT RESEARCH PROJECTS

Germplasm introduction and evaluation. The overall project goal is to identify new sources of scab resistance in spring wheat and to introgress the resistances into adapted materials. Spring wheat accessions from targeted regions of the world and relatives of wheat were evaluated in inoculated field nurseries and in the greenhouse. A scheme of three-nursery system was implemented in the germplasm evaluation process. Accessions were evaluated in the Preliminary Screening Nursery (PSN) initially. Selections from PSN were re-evaluated in the greenhouse to derive entries for Elite Germplasm Nursery (EGN). Most elite selections from EGN were entered into the Uniform Regional Scab Nursery for spring wheat for testing at multiple environments and for direct access by researchers. Elite selections were used for crossing to introgress the resistance into adapted germplasm. (Y. Jin)

Epidemiology. Ongoing research on several aspects of scab epidemiology includes effects of soil moisture/wetness on inoculum development, ascospore survival and accumulation on plant surface, and monitoring inoculum and environments. A sensor was developed to monitor moisture at the soil/air interface and integrated into an automated weather station. This sensor may help to understand the effects of soil surface wetness on the inoculum development. South Dakota continues to serve as one of the testing sites in a collaborative project, collecting data on environmental conditions, inoculum dynamics and disease development during the crop season in an attempt to develop a disease forecasting system. (Y. Jin)

Breeding for scab resistance in spring wheat. Greenhouse and field screening nurseries are used to evaluate early generation and advanced lines for scab resistance. All entries in the advanced yield trials are at least moderately resistant to scab. This is dramatically different from a few years ago when the spring wheat breeding program first began to evaluate for resistance to scab. We continue to see an increase in the number of lines that have good agronomic performance and good scab resistance. Eighteen lines in our 2000 advanced yield trials had scab resistance equal to Sumai 3. Ten of the eighteen lines had superior grain yield under heavy scab pressure compared to our best yielding commercial cultivars

(Russ and Oxen). Six of the eighteen lines had grain yield equal to Russ and Oxen in replicated yield trials grown under natural conditions. (J. Rudd)

Breeding for scab resistance in winter wheat. The first step in developing scab resistant hard winter wheat varieties is to assess the genetic variability for resistance in existing cultivars and advanced breeding lines. Scab resistance sources in the winter crossing block included adapted spring wheats from the SDSU breeding program, Sumai 3 derived spring wheat lines, eastern European winter wheat lines, entries from the 1998 regional winter wheat scab nursery, and adapted hard red and hard white breeding lines. Approximately 200 crosses with scab resistant sources were made and the segregating populations will be evaluated in 2000. Approximately 6000 plants were evaluated for scab resistance during the 1999 season and selections were planted into the field this fall. The following nurseries were screened for scab resistance in 2000: Northern Regional Performance Nursery; Winter Wheat Regional Scab Nursery; South Dakota Crop Performance Trials; SDSU Advanced Hard Red and Hard White Yield Trials; SDSU Preliminary Hard Red and Hard White Yield Trials. (A. Ibrahim)

Fungicide efficacy studies. South Dakota participated in the uniform fungicide trial for scab suppression. Two hard red spring wheat cultivars were planted at three locations each and treated at anthesis with the seven core treatments. The treatments were also applied to two hard red winter wheat cultivars planted at a single location. The winter wheat location was lost due to poor stand associated with root rotting diseases and cheat grass pressure. Plots were evaluated for protection of the flag leaf against diseases as well as for average incidence of scab infected heads, average head severity of scab, average plot severity of scab, Fusarium damaged kernels (FDK), deoxynivalenol (DON) content in the harvested grain, grain yield, protein and test weight of harvested grain. Under ambient conditions, scab was not severe. The greatest scab occurred at the South Shore, SD location. All treatments significantly reduced diseased leaf area ($P_{0.05}$) on spring wheat at the Groton location. Scab was not reduced significantly at any location. The most severe scab observed was at South Shore, SD with 3.9% scab index in the untreated plots. Scab was present at less that 1% disease index at the other two locations. Folicur (4 fl. oz./A), BAS 500 (12.3 fl. oz./A), and BAS 500 (6.2 fl. oz./A) tank mixed with Folicur (2 fl. oz./A) were the most effective treatments numerically. In other treatments, Folicur applied at the 6 fl. oz./A rate numerically outperformed the 4 fl. oz./A rate for scab index at South Shore. Metconazole and Folicur at 6 fl. oz./A were the most effective treatments tested. When scab or leaf diseases were reduced numerically by a fungicide, no significant increase in yield was realized. A mist irrigation system was completed late in the summer at the Brookings site that will be used to ensure moisture at anthesis in 2001 studies. (M. Draper)

Molecular biology and DNA markers for scab resistance. One of big obstacles in fighting scab epidemics is that little is known about the nature of scab resistance, particularly at molecular level. Our research aims at addressing this problem and getting insight into the molecular mechanism of *F. graminearum*-wheat interaction. Our current objectives were to identify, clone, sequence and analyze ESTs related to scab resistance by comparing the DDPCR revealed EST profiles of spring wheat cultivars Sumai 3 (resistant) and Wheaton (susceptible) before and after inoculation with *F. graminerum*. A total of 144 primer combinations were tested. Several gene expression patterns were observed: 1) constitutively ex-

pressed in Sumai 3; 2) constitutively expressed in Wheaton; 3) induced expression in inoculated Sumai 3 and Wheaton only; 4) induced expression in inoculated Wheaton only; and 5) induced expression in inoculated Sumai 3 only. ESTs of the last category are most likely related to scab resistance genes. Three such ESTs, *EST12G*, *EST15AU* and *EST15AD*, were cloned with PCR-Trap cloning kit (GenHunter Corporation, Nashville, TN) and sequenced using ABI automatic sequencer. A sequence similarity-search of GeneBank database revealed that *EST15AU* is 94% similar to part of a wheat mRNA for polypeptide elongation factor 1 beta'; *EST15AD* has three homologous regions (with 86% identity) with an EST sequence from a pathogen induced sorghum bicolor cDNA; *EST12G* is almost identical (with 99% identity) to a part of minus strand of a wheat gene for chloroplast ATP synthase CF-O subunit I and III. Confirmation of the accurate relationship of these three ESTs with scab resistance by genetic analysis is in progress. (Y. Yen)

Biological control studies. South Dakota began screening biological control agents in the field in 1999. During the summer of 2000 the project was expanded with six agents evaluated as whole cell treatments. A mist irrigation system was completed too late in the year to provide moisture during anthesis. As a result, scab index values were quite low in 2000. Nonetheless, the results appear promising. Two of the agents screened were from the SDSU collection that had been selected based on suppression of tan spot in greenhouse tests and *Fusarium graminearum* in culture plate tests appeared to have some activity in the field. The other four isolates had been selected elsewhere for antimicrobial activity. Suppression of scab at the very low levels of severity was similar to Folicur. None of the agents reduced leaf disease. At the low levels of disease present in the field an evaluation is not reliable, but the agents tested do appear to have promise for continued testing. (B. Bleakley and M. Draper)

PERSONNEL INVOLVED IN SCAB RESEARCH

Researchers/Project: Y. Jin/Small Grain Pathology; M. Draper/Extension Plant Pathology; J. Rudd/Spring Wheat Breeding; A. Ibriham/WinterWheat Breeding; B. Bleakley/Soil Microbiology; Y. Yen/Cytogenetics-Molecular Biology.

Supporting staff: X. Zhang (Research Associate, Pathology); L. Osborne (Research Associate, Pathology); T. Hall (Research Assistant, Pathology); R. Rudd (Research Assistant, Pathology/Breeding); Key Ruden (Research/Extension Assistant, Pathology).

NCR 184: VIRGINIA 2000 SSTATE REPORT ON *FUSARIUM* HEAD BLIGHT

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PRODUCTION AND SCAB DEVELOPMENT

In Virginia, 205,000 acres of soft red winter (SRW) wheat were harvested in 2000, with a state average yield of 60 Bu/A. The harvested acreage has declined by 40,000 acres since 1998, when scab epidemics devastated the crop. The incidence of *Fusarium* Head Blight (FHB) was sparse in the 1999-2000 season due to dry conditions prevailing throughout much of the flowering stage.

FUNGICIDE EFFICACY STUDIES

Research aimed at developing a means to control FHB in wheat with the application of a single fungicide, multiple fungicides, or a biological agent on wheat heads prior to or during anthesis was conducted this past year. Effectiveness of fungicide treatments on the control of FHB could not be assessed this past year due to the absence of FHB development, despite no-till planting of plots into chopped corn stubble.

ASSESSMENT OF SCAB RESISTANCE IN SRW WHEAT

One of the major objectives of our program has been to assess the variation among SRW wheat genotypes for resistance or susceptibility to FHB. Thirty SRW wheat genotypes, including many commercial cultivars, were evaluated in irrigated nurseries for reaction to FHB at two locations in inoculated and non-inoculated plots. At Blacksburg, inoculum was applied as a spore suspension to each genotype at flowering and again seven days post-anthesis. At Warsaw, colonized corn was spread in plots two weeks prior to anthesis.

Among the 30 genotypes evaluated in year 2000, FHB Index varied from 9 to 69 at Blacksburg and from 8 to 81 at Warsaw. Yield losses varied from 9 to 49% at Blacksburg and from 0 to 36% at Warsaw. Reductions in test weight varied from 4 to 23% at Blacksburg and from 0 to 14% at Warsaw. Percentage of scabby seeds varied from 24 to 90% at Blacksburg and from 10 to 85% at Warsaw. DON concentration varied from 0.5 to 15.9 PPM at Blacksburg and from 3.0 to 57.9 PPM at Warsaw. In tests conducted over the past 3 years, disease severity and yield loss often were significantly lower in cultivars Ernie, Freedom, Roane and INW9824 than others. Other genotypes exhibiting resistance included AgriPro Patton, AgriPro Foster, IL94-1909, IL94-1549, and NY87048W-7388.

BREEDING FOR SCAB RESISTANCE

Thirty-six scab resistant sources (21 Chinese, 2 French, 1 Japanese, 2 Canadian and 10 SRW wheat lines) have been used as parents in the breeding program to incorporate and/or combine Type II and other types of resistance. This year, 89 F_3, 101 F_2, 162 F_1, and 42 BC_2F_1 populations will be advanced. Scab resistance of 50 advanced lines and 532 doubled haploid and F_6 lines, selected from 2460 F_5 lines evaluated at Warsaw last year, will be evaluated for scab resistance in an inoculated nursery at Blacksburg and for other agronomic traits in trials at Warsaw in 2001. In addition, agronomic performance of 2960 F_5 lines, selected from inoculated tests of 53 F_4 populations, will be evaluated in a head-row nursery at Warsaw.

Type II resistance derived from nine different sources is being backcrossed into11 different SRW wheat backgrounds, of which three possess other types of scab resistance. Four BC_3F_1, 15 BC_2F_1 and 3 BC_1F_1 populations will be crossed with their respective recurrent parent this year. Subsequently, this will result in the development of near-isogenic lines with type II resistance incorporated into adapted SRW wheat backgrounds and facilitate pyramiding of different types of resistance.

Approximately 240 doubled haploid lines derived from 12 crosses were evaluated for scab resistance and other agronomic traits this past year, and nearly 450 additional haploid plants derived from nine crosses were produced. In the coming year, the maize x wheat hybridization method will be used to produce doubled-haploid progeny in ten multi-parent F_1 populations comprised of adapted resistance sources. Development of resistant lines using the comprehensive breeding techniques proposed above will provide the fundamental basis for pyramiding and improving scab resistance in SRW wheat varieties.

INHERITANCE AND MAPPING STUDIES

Three scab resistance sources, W14, Shaan 85 and Ernie, were crossed with the susceptible SRW wheat cultivar Madison and/or Pioneer 2684, and their F_2 progeny were evaluated for resistance using a single floret inoculation method in greenhouse tests. Two complementary genes with major effects were found to confer scab resistance in W14 and Shaan 85 based on similar segregation patterns of F_2 populations for type II, III and IV resistance characterized by scab severity, DON content and percentage of infected kernels, respectively. One to two genes were found to confer resistance in SRW wheat Ernie. The $F_{2:3}$ families of mapping populations Pioneer2684 x W14 and Madison x W14 will be characterized for severity, DON content and scabby seeds in greenhouse tests this coming year to confirm genetic segregation data obtained from F_2 populations last year.

To date, 62 SSR markers have been characterized in the parents and F_2 bulks of the two mapping populations; twenty-one (34%) of the 62 markers were polymorphic in both populations. Preliminary mapping data indicate that marker GMS533 located on chromosome 3BS (Anderson et al. 1998; 2001) likely is associated with resistance in W14. A second putative marker GMS410 identified in the susceptible parent Pioneer 2684 also was associated with resistance. These results will be verified in the coming year. Additional markers, SSR and other types, will be evaluated in the two mapping populations to search for additional puta-

tive QTLs associated with resistance, saturate chromosome regions associated with resistance, and develop a skeletal map. This research has the potential to identify new QTL associated with scab resistance, provide additional markers linked to previously reported QTLs, and to identify markers that are effective across genetic backgrounds; all of which are essential for successful exploitation of marker-assisted selection.