ITEMS FROM THE UNITED STATES OF AMERICA

COLORADO

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Wheat breeding and genetics — Production conditions, test sites, and cultivar distribution.

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Total winter wheat production in 2005 was estimated at 52.8 x 10^6 bushels, a 15 % increase from the 2004 crop but still 30 % lower than the 10-year average. Average grain yield, at 24.0 bushels/acre, was 11 % lower than in 2004 and 33 % lower than the 10-year average. The area harvested for grain was estimated at 2.2 x 10^6 acres, up from 1.7 x 10^6 acres in 2004.

In 2004–05, the breeding program conducted field trials at six main locations in eastern Colorado (Akron, Burlington, Dailey, Julesburg, Sheridan Lake, and Walsh) in addition to the main location at the ARDEC research facility near Fort Collins. As discussed in last year's report, the Dailey and Sheridan Lake locations were added as new locations in autumn 2004 in an effort to enhance our testing capability. Overall, environmental conditions experienced at these locations can be described as follows.

Akron – excellent autumn emergence and plant stand, very lush growth in early spring, severe drought stress in early May followed by damaging high temperatures at heading. Early June rains relieved drought stress to some degree. Severe stripe rust infection were found in wetter parts of the field, low levels of leaf rust infection. Two rains at maturity delayed harvest and lowered test weights.

Burlington – excellent autumn emergence and plant stand, very lush growth in early spring, severe drought stress in early May followed by damaging high temperatures at heading. Some hail damage prior to heading. Stripe rust present in early May prevented from developing by dry and hot conditions. Trials were quite variable.

Dailey – excellent autumn emergence, stand, growth going into winter and into the early spring. Significant drought and high temperature stress was observed before and at heading. Significant autumn leaf rust infection, some overwintered into the spring though dry conditions prevented further development. Stripe rust present in early May prevented from developing by dry and hot conditions. Rains and some hail at maturity delayed harvest, trials quite variable.

Julesburg – excellent autumn emergence, fall growth. Very lush in the spring, dry conditions as at other locations, though high temperatures at heading not as damaging as elsewhere. Stripe rust infection was fairly heavy. High temperatures during grain filling.

Sheridan Lake – excellent autumn emergence, growth. Very lush in the spring. Some damage from spring freeze event in late April. Very wet May brought on significant stripe rust pressure with trace levels of leaf rust. Small plots in a much wetter part of the field than the UVPT. Some RWA found at low levels.

Walsh – excellent autumn emergence, growth. Very lush in the spring, nice dark green color indicated adequate available soil nitrogen. Good spring moisture resulted in moderate stripe rust infection by late April which became severe by early May. Some damage from spring freeze event in late April. Some RWA found, both biotype 1 and biotype 2 based on differential variety response. Russian wheat aphid, mostly biotype 1, was observed throughout the nurseries. Trace levels of leaf rust found in mid-June. Very nice trials for this location.

Fort Collins (irrigated) – excellent stands and growth in the autumn, significant autumn stripe rust infection that did not overwinter into the spring. Excellent growth and tillering occurred in the spring. Severe stripe rust infection by early June, significantly reduced yields. High temperatures throughout grain filling also was a significant factor reducing yields. Little significant lodging observed. Some severe but localized damage from RWA.

Under the direction of CSU Extension Agronomist Dr. Jerry Johnson, the CSU Variety Testing Program evaluated check cultivars and experimental lines at seven other dryland trial locations (UVPT – Bennett, Cheyenne Wells, Genoa, Lamar, Orchard, Sheridan Lake, and Yuma) and two other irrigated trial locations (IVPT – Stratton and Rocky Ford). In addition to these dryland locations, experimental lines and a reduced set of check entries also were tested at two dryland locations (Hudson and Granada) that were added in autumn 2004 in response to the continued loss of so many variety trial sites. Overall, the various UVPT trial locations experienced a variety of stresses, with spring drought stress, high temperatures at heading and during grain filling, and stripe rust being the most damaging. In spite of all of the problems, 10 out of 11 UVPT locations were successfully harvested with only Orchard being abandoned due to severe effects of the spring drought. In addition to the Fort Collins IVPT, both Stratton and Rocky Ford were both successfully harvested though yields were reduced in some of these trials due to stripe rust and high temperatures. The most significant disease or insect problem in the trials in 2005 was the severe stripe rust infection that was present at many of the locations. This infection was typically heavy at some of the irrigated locations (Fort Collins, Stratton, and Rocky Ford) and higher yielding dryland locations (such as Genoa) but was uncharacteristically heavy in southeast Colorado (including Walsh, Lamar, and Sheridan Lake) where stripe rust has been a much lesser concern the last few years. In spite of the severity of the infection observed and the high degree of apparent susceptibility of some entries, differences were noted among test entries in the capacity to fill the grain from stem reserves after stripe rust killed the leaves. Although not a problem in most trials except for perhaps the UVPT at Julesburg, WSMV was a significant problem in some areas of the state due to the mild conditions experienced in late summer and autumn 2004 that provided ideal conditions for the wheat curl mite that transmits WSMV. A side from RWA, which were observed at several locations, no other significant insect (bird cherry-oat aphid or greenbug) problems were notes.

Planted acreage estimates for the 2005 crop were as follows: Akron – 20.1 %; TAM 107 – 10.5 %; Prowers/ Prowers 99 – 8.3 %; Prairie Red – 6.7 %; Trego – 6.3 %; Above – 6.1 %; Jagalene and Yumar – 4.4 %; Ankor – 4.1 %; Lamar – 3.3 %; Jagger – 2.9 %; Stanton – 1.8 %; and TAM 110 and Harry – 1.4 %.

Elite lines on increase.

CO00016 (CO940606/TAM107R-2) has been a top yielder in the Uniform Variety Performance Trial (UVPT) for 3 years now and will be advanced for Foundation Seed increase with the intent to release in autumn 2006. CO00016 is an early maturing line, like Prairie Red, which has been in the top group of lines in each of the last 3 years of testing (6 out of 66 in 2003, 2 out of 46 in 2004, and 3 out of 52 in 2005). Averaged across 21 dryland trial locations between 2003 and 2005, CO00016 has been the highest yielding entry in the trials, about 0.5 bu/acre higher than Bond CL, 1.7 bu/acre higher than Hatcher, 3.1 bu/acre higher than Above, 4.1 bu/acre higher than Avalanche, and 5.3 bu/acre higher than Jagalene. The principal deficiency of CO00016 is that it is quite susceptible to stripe rust, although it managed to maintain yield at some locations with severe stripe rust in 2005. Because the test weight of CO00016 is only average and its protein content is below average, CO00016 appears to have very good bread-baking quality characteristics.

New Russian wheat aphid biotype research.

With the identification of a new, virulent biotype of RWA in Colorado in 2003, and additional virulent biotypes in 2004, we have been actively involved in several different research areas to address this problem. These activities have focused on continued germ plasm screening, molecular marker identification for key resistance genes, and breeding line and population development. The following are the highlights of these activities. First, we completed the screening of 7,300 Iranian landrace selections from the NPGS for resistance to RWA biotype 2. Approximately 330 biotype 2-resistant accessions were then screened in spring 2005 for resistance to biotype 1 RWA. Approximately 155 accessions carry resistance to both biotypes; mapping populations are under development with at least five of these accessions. We are coordinating with the USDA–ARS Stillwater OK group to evaluate these lines with additional biotypes. Second, a set of five lines with biotype-2 resistance from triticale were evaluated in replicated trials at seven breeding locations. Two of these lines were very low yielding and were also shown to have problems with chromosomal stability (by Dr. Kabwe Nkongolo in Canada). Three lines showing reasonable performance and agronomic, and showing no chromosomal abnormalities, were advanced for testing to the 2006 UVPT. Third, a set of 27 line selections were made from backcross populations derived from crosses with 2414-11 and 2002 Altus-034 (a winter wheat line from Stillwater carrying the *Dn7* resistance gene). These selections were planted in a single-replication observation nursery at Fort Collins in autumn 2005. Finally, many new crosses and backcross populations have been developed using resistance sources identified.

Wheat antioxidant research.

Previous research, at CSU and elsewhere, has shown that antioxidants are present in wheat bran and that varieties differ for the amount of antioxidants in the bran. Several other studies, in wheat and other plant materials, have suggested that these antioxidants contribute to reduced risk from different types of cancers. In past research, our breeding program collaborated with a scientist (who has since left CSU) on these evaluations. Unfortunately, these tests were extremely costly and laborious, thus reducing our ability to evaluate large numbers of samples for genetic experiments or selection purposes. In collaboration with Dr. Cecil Stushnoff (Horticulture and Landscape Architecture Department, CSU), one of our research associates (John Stromberger) has developed modified standard laboratory protocols for measuring antioxidant properties to allow us to conduct more high-throughput analysis. Procedures for rapid measurement of two different antioxidant properties were developed for total phenolic content and ABTS-free radical scavenging capacity. Using these assays, John evaluated a group of common varieties from several locations in eastern Colorado in 2004 to determine the extent of genetic and environmental influence on the expression of the antioxidant tests. In addition to this work, John also worked with one of our other research associates (Joshua Butler) to develop whole-grain near-infrared reflectance (NIR) calibrations that would be particularly useful for mass sample screening. We hope to complete these studies using samples collected from several locations in 2005 and will then work to validate and hopefully implement the calibrations in subsequent years.

Preharvest sprouting tolerance evaluation.

Many hard white wheats have a predisposition to sprout in the head if wet conditions persist at harvest maturity. The severe sprouting that occurred in western KS and eastern CO in 2004 confirmed that we must pay attention to preharvest sprouting as part of our hard white wheat breeding effort. Since 2002, we have been using a technique for evaluating for preharvest sprouting tolerance of our most advanced hard white and hard red experimental lines. This technique involves sampling heads at physiological maturity in the field, drying the samples in the lab for a few days, threshing and freezing the seed samples, and then conducting controlled germination tests in a controlled-temperature incubator. In 2005, we evaluated 144 hard white samples from our breeding trials using this technique. To improve our ability to make selections based on preharvest sprouting, we modified a bread-baking proofing cabinet from our quality lab to enable sprout testing using a misting technique on intact heads. Using this procedure, we sampled about 20 heads at physiological maturity from each of 125 hard white lines that showed promise for advancement from our PYNs to the AYN. Following harvest and data analysis, we conducted the sprout tests in the mist chamber using head selections from 49 of the lines that were destined for advance. Although few of these lines showed a high level of tolerance as a group, sprout tolerant selections were identified within each of the lines, from just a few to several of the 20 head selections. These selections were advanced to the headrow reselection nursery in autumn 2005. We expect that we will continue to exploit this procedure in the future.

Graduate student research.

Several graduate student research projects are currently underway or were completed in 2004–05. Although we expect that these research projects will contribute vital information to help direct and focus breeding efforts, both the breeding project and the students benefit in many other ways though direct student involvement in the overall breeding program. Briefly, these include the following areas of research: 1) Assessment of the agronomic potential of the gibberellic acid-sensitive semidwarfing gene *Rht8* (Sally Clayshulte). Sally's research demonstrated that the molecular marker that is supposedly linked to *Rht8* (based largely on linkage analysis with European wheats) may not be linked with *Rht8* in Great Plains germ plasm. The second year of her field evaluation of a group of recombinant inbred lines from two populations was also completed. These studies showed that an allele at the *Rht8* marker locus, the WMS 261-210 allele, conferred taller plant height than the allele in most of our germ plasm (WMS261-165). Sally recently successfully defended her dissertation and has just accepted a position as a cotton breeder with Monsanto in Arizona. We thank Sally for all of her hard work and dedication over the years; she will definitely be missed. 2) Development and validation of near infrared reflectance (NIR) spectroscopy calibrations for whole-grain prediction of end-use quality characteristics (Joshua Butler). Josh began his Ph.D. dissertation studies (and his appointment as a research associate) in autumn 2004 and immediately focused on developing calibrations for test weight, kernel weight, and kernel diameter. These calibrations are extremely promising and we are nearing the point where we will use these calibrations for screening of headrow and other samples. Josh will continue to work in the coming year to refine these calibrations and also begin to develop calibrations for various measures of dough mixing strength and starch viscosity. 3) Validation of the BYDV resistance and high grain protein content traits introgressed to several elite background as part of the IFAFS molecular marker grant (Jennifer Roth, new student July 2005). Backcross populations segregating for either the BYDV resistance segment from *Ag. intermedium* or the high grain protein content segment from *T. turgidum* subsp. *dicoccoides* were planted in the spring at Fort Collins. Tissue samples were collected from over 2,000 plants and screened with molecular markers by the USDA–ARS Genotyping Center in Manhattan KS. Based on these assays, a subset of these lines will be increased in the greenhouse and Yuma AZ in winter 2005–06. Jennifer hopes to identify a subset of near-isogenic lines, homozygous for the presence or absence of the introgressed segment, that will be planted at several locations in fall 2006 to test for the direct and indirect effects of the introgressed segments. 4) RWA biotype-2 resistance gene mapping and gene transfer from *T. turgidum* subsp. *dicoccoides* (Ben Beyer, new student July 2005). Ben is currently developing several mapping populations developed using crosses with several RWA biotype-2 resistant Iranian landrace selections, in addition to some other sources. One of these populations will be used to identify a molecular marker linked with the resistance, which will then enable marker-assisted pyramiding of multiple RWA biotype 2 resistance genes into the same wheat variety. Ben also will be working to try to transfer RWA biotype 2 RWA resistance from a tetraploid wheat (*Triticum dicoccoides*) to common wheat.

IFAFS and CAPS Grants.

The IFAFS molecular marker grant expired in 2005. In collaboration with Dr. Nora Lapitan, we have been working with funding from this grant to transfer BYDV resistance, WSMV resistance, high grain protein content, and stripe rust resistance to several released varieties (Above, Avalanche, Ankor, Stanton, and Lakin) and experimental lines (CO970547-7). We are now working to develop NILs that differ for these introgressed segments or genes that will allow us to test for their direct and indirect effects in the field in Colorado.

Over the past year, we have been working with Dr. Jorge Dubcovsky at the University of California–Davis as the lead-PI on a continuation and extension of this project. Together with our breeding program and 16 other breeding programs across the U.S. Dr. Dubcovsky recently secured a 4-year, \$5 x 10^6 grant entitled “Wheat Applied Genomics” from the USDA-National Research Initiative-Coordinated Agricultural Project (CAP) grant program. The grant will fund about 75 % of a research associate, supplies, and student labor to conduct the research. Our involvement in the grant will focus on molecular marker mapping for various quality-related traits in one mapping population that Dr. Pat Byrne has constructed (Platte/CO940610). We also will collaborate with other programs in the region (Kansas State, Nebraska, Oklahoma State, Texas A&M) in evaluating their mapping populations in our environments, particularly focusing on those populations that will allow identification of markers linked to preharvest sprouting tolerance genes. As part of the grant, we will also be increasing our use of molecular MAS through collaboration with the USDA–ARS Genotyping Center in Manhattan KS.

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The 2005 Georgia winter wheat crop was grown on about 200,000 planted acres, a decrease of 6 % from the previous year. Yields of wheat grown by top producers were around 6,000 kg/ha on resistant cultivars. The growing season was characterized by mild weather and dry conditions during the winter and spring. A severe epidemic of stripe rust was observed in Georgia and the lower southeastern U.S. A major problem also occurred at harvest due to extreme wet conditions which resulted in a high incidence of sprouting.

Breeding.

AGS 2010 (GA 951079-2E31) is a new cultivar developed by the University of Georgia, derived from the cross 'GA 881130/Gore'. The pedigree of Gore is 'Stacy/Coker 797'; the pedigree of 881130 is 'KS8998/FR 81-10//Gore'. AGS 2010 is a early-medium maturing, white chaffed, medium-tall line that matures on average 3 days earlier than AGS 2000 in Georgia. AGS 2010 is resistant to currently biotypes of Hessian fly, especially Biotype L, and moderately resistant to races of powdery mildew, and resistant to leaf rust and stripe rust in Georgia. AGS 2010 also is resistant to WSBMV.

GA 951216-2E26 is a medium maturing, white chaffed, medium height line that matures, on average, 2 days later than AGS 2000 in Georgia. This line is resistant to current races of leaf rust and stripe rust in Georgia and has resistance to WSBMV. GA95121-2E26 is moderately resistant to current races of powdery mildew and moderately susceptible to biotypes of Hessian fly. The pedigree and history of GA 951216-2E26 is 'GA 87110*2/GA 8724'.

Scab. In the southeast region of the U.S., resistance to FHB in local adaptive SRWW is limited. Introduction of resistant genes from exotic sources could enhance the resistance of local adaptive germ plasm. A Virginia line AV01W-476 with the most widely used major QTL in chromosome 2A, 3B, and 5A for FHB resistance was used as donor in our program. A total of 47 double-haploid individuals were generated from backcross F_1 plants induced with maize pollen. Screening with SSR markers indicated the integration of novel FHB resistant QTL on 3BS and 5AL from donor parents and native adaptive gene pool of ASG2000 and its derivatives. Two double-haploid plants from backcross of VA01W-476/GA98186 and four double-haploid plants from backcross of 'VA01W-476/AGS2485' were identified to have VA01W-476/W14 type QTL on 3BS and 5A. Further evaluation for agronomic traits is under investigation.

Stripe rust. Stripe rust was very severe in 2005. We identified effective genes as *Yr17* (GA96229-3A41), *Yr18* in combination with other genes (PIO 26R61), and *Yr27*.

Entomology.

Recent studies in Georgia have found that full wheat yield could be achieved with modern adapted winter wheat cultivars while reducing seeding rates by 30 % or more. Insecticide seed treatments such as imidacloprid (Gaucho 480) can reduce aphid infestations and BYD incidence but this treatment generally is not cost effective at higher seeding rate. We conducted a study to evaluate the effect of Gaucho seed treatment at reduced seeding rates on aphid infestation, BYD incidence, wheat tillering and yield. Trials were conducted at Plains and Tifton GA over two seasons. Two cultivars, AGS 2000 and Roberts, were planted at four seed rates, 10, 20, 30, and 40 seeds/ft^2 (108, 215, 323, and 430 seeds/m^2) with and without Gaucho 480 at 1.5 fl oz/100 lbs seed (47 g ai/100 kg). These first-year results suggest that wheat seeding rates can be reduced without adversely affecting yield. Aphid infestations and presumably number of viruliferous aphids were not different among seeding rates but aphids/plant declined as seeding rate increased. Imidacloprid effectively controlled aphids at 30 days after planting. Conversely, BYD incidence as measured by symptomatic stems declined with increased seeding rate. Consequently, reduced seeding rates may not reduce yield potential but reduced plant populations may increase the risk of aphid infestation and BYD infection thereby making aphid control more critical.

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INDIANA

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Wheat production.

According to the USDA National Agricultural Statistics Service, Indiana farmers harvested 137,652 hectares (340,000 acres) of wheat in 2005, down from 440,000 acres in 2004 due to wet and rainy conditions during the wheat seeding season in the autuamn of 2004. Wheat yields in Indiana averaged 4,840 kg/ha (72 bu/acre) in 2005, a record, and up from 62 bu/acre in 2004. Like most winters in Indiana since 1996, temperatures averaged above normal and winterkill due to low temperatures was limited. Growing conditions for winter wheat in 2005 were excellent: ample soil moisture and cool temperatures continued to late June when much of the wheat crop was physiologically mature. Beginning in late June and through the harvest season to mid July, temperatures were elevated and soil moisture was limiting, providing ideal drying conditions during the harvest season, and resulting in high grain yields and high test weight. Due to generally favorable wheat market prices and especially favorable seeding conditions during the autumn of 2005, area seeded to winter wheat for the 2006 harvest season was 460,000 acres, up 28 percent from area seeded in autumn 2004.

Wheat disease summary.

Cool temperatures limited the incidence and spread of Fusarium head blight but favored development of stripe rust, which was moderately severe in some fields in limited areas and for which some producers applied fungicides to limit crop damage. Crop losses from other diseases, including powdery mildew, leaf rust, stem rust, Stagonospora glume blotch, and Septoria leaf blotch were limited or negligible.

Virus-induced gene silencing (VIGS).

Using VIGS to identify genes required in disease resistance pathways of wheat (Amanda Brandt, Cahid Cakir, Lauren Grieg, and Steve Scofield). We have developed a virus-induced gene silencing system, based on barley stripe mosaic virus, for the rapid analysis of gene function in hexaploid wheat. In VIGS, plants are infected with a virus that has been engineered to contain sequences from a plant gene of interest. The dsRNA produced as the virus replicates triggers the plant's sequence-specific RNA degradation mechanism, which targets all RNAs with homology to the viral genome for destruction. As the viral RNA contains transcribed plant sequence, any homologous host mRNAs also are targeted for destruction, resulting in silencing the expression of the plant gene of interest. This VIGS system has proven to be very effective in creating gene knockout phenotypes in hexaploid wheat and our lab is focusing on developing VIGS assays for the functional identification of genes required in a range of wheat disease resistance pathways.

During the past year, we published our work using VIGS to demonstrate the requirement of the *Lr21, RAR1, SGT1* and *HSP90*, genes for *Lr21*-mediated resistance to leaf rust (Scofield et al., 2005 Plant Physiol. 138: 2165-73). We have extended this analysis and are identifying other genes that are essential for *Lr21*-mediated resistance. Additionally, we have developed new VIGS assays that are being used to identify genes required for resistance to *M. graminicola* and *F. graminearum*.

Fusarium head blight.

Shortening the 7el$_2$ segment that has FHB resistance (Xiaorong Shen, Hari Sharma, Lingrang Kong, and Herb Ohm). Robertsonian translocation T7DS·7el$_2$L wheat line KS24-2 has FHB resistance gene(s) from *Th. ponticum*. The 7el$_2$L likely has agronomic undesirable genes. KS24-2 was crossed to the *ph1b* mutant to facilitate homoeologous recombination. Among the *ph1bph1b* F$_2$ plants, identified by marker WPG90, we selected translocation heterozygotes using dominant markers specific, respectively, for 7el$_2$ and 7D. Plants in subsequent generations of self pollination were phenotyped for FHB resistance and genotyped with markers to identify recombinants with a shortened 7el$_2$L segment. One F$_4$ plant, 275-4, lost two marker loci, *Xgwm333* and BE406148, but retained *Xpsr129*, BE445567 and *Xcfa2240* on the distal part of the 7el$_2$L segment. Thus, the amount of 7el$_2$L chromatin was reduced while retaining the FHB resistance. This wheat line should be useful in breeding wheat for FHB resistance. The search for additional useful wheat lines with shortened 7el$_2$L segment but that retain the FHB resistance is continuing.

Identifying virulence factors in *Fusarium graminearum* (Kyeyong Seong, Zhanming Hou, and Jin-Rong Xu). The REMI (Restriction-Enzyme Mediated Integration) approach was used to generate 11 pathogenicity mutants of *F. graminearum*, the causal agent of FHB (Seong et al. 2005b). Genetic analyses indicated that the defects in plant infection were tagged by the transforming vector in six of these mutants. In mutant M8, the transforming plasmid was integrated 110-bp upstream from the start codon of the cystathionine β-lyase gene (*CBL1*). Genes disrupted by the transforming DNA in M68, M7, and M75 encoded a putative NADH: ubiquinone oxidoreductase, a β-ZIP transcription factor, a transducin β-subunit-like protein, respectively. In mutant 222, the transforming vector was inserted at amino acid 269 of the hydroxymethyl-glutaryl CoA reductase gene (*HMR1*) that encodes a key enzyme in sterol and isoprenoid biosynthesis. Further characterization revealed that the N-terminal portion of the *HMR1* ORF has cryptic promoter activity (Seong et al. 2005a).

Yellow dwarf viruses.

Host Resistance (Hathaithip Wiangjun and Joseph Anderson). The mechanism of intermediate wheatgrass (*Th. intermedium*)-derived CYDV resistance (Wiangjun and Anderson 2004, Phytopath 94:1102-1106) has been further elucidated. This resistance is clearly due to the reduced ability of the aphid to deposit virus into the phloem and a concomitant block of virus movement from the infection site when the virus is deposited into the vascular system. Further analyses have shown that callose deposition is not responsible for the block in virus movement within the sieve tubes. This resistance has two quite distinct components, suggesting that it will be a durable resistance.

Gene expression analysis (Mahua Deb, Bovaraghan Balaji, and J.M. Anderson). The expression patterns of 20 candidate defense-response genes in a susceptible and a resistant wheat line were examined at eight time points after infestation with nonviruliferous and viruliferous (BYDV-PAV/CYDV-RPV). These results indicate that some of these genes are both aphid and virus responsive. The susceptible line also shows a more pronounced gene-induction pattern than the resistant line for most genes although there are a few whose response is either repressed or enhanced in the viruliferous aphid-infested resistant line. This pathosytem, which has three components (aphid–virus–plant), clearly has a complicated defense-response pattern.

Wheat–*Thinopyrum* mosaic chromosomes (Katie Card, Ligia Ayala, Nicole Thompson, and J.M. Anderson). Previously, F$_2$ progeny of two M$_4$ lines crossed to Chinese Spring were examined with PCR markers for the presence of *Th. intermedium* segregating fragments. These data showed that a set of recombinants was identified that were a mosaic of wheat and *Th. intermedium* chromatin segments. New data have been obtained that now correlate this marker analysis with the presence or absence of the *Bdv3* YDV resistance locus. These data have further identified several classes of recombinants in which the recombinant chromosome is primarily wheat yet the lines retain YDV resistance.

Chromosome segment 7E from *Th. intermedium* carrying yellow dwarf viruses resistance (H. Sharma, K. Card, J.M. Anderson, and H. Ohm). Research is in progress to shorten the 7E segment of wheat germ plasm line P961341 (Ohm et al. 2005) that has *Bdv3* for resistance to yellow dwarf virus, via crossing P961341 to a *ph1b* mutant line and methods similar to those described above for $7el_2L$ carrying resistance to Fusarium head blight.

Hessian fly.

Hessian fly/gall midge Transcriptomics (Richard H Shukle, Omprakash Mittapalli, and Alisha Johnson). We are revealing the catalog of mRNAs expressed in tissues of the larval Hessian fly during interactions with wheat, which will allow identification of genes or cellular pathways selectively turned on or off in response to extrinsic factors or intrinsic genetic programs. Additionally, we are cataloging mRNAs expressed in the midgut and salivary glands of the orange wheat blossom midge and the Asian rice gall midge. Identification of gene responses and a comparison of genes expressed between the Hessian fly, the wheat midge and the rice gall midge will provide for molecular dissection of the interactions with their respective host plants.

Assessing the phylogenetics of the Hessian fly using mitochondrial and nuclear markers (R. Shukle and A. Johnson). The phylogenetics and phylogeographic relationships of Hessian fly populations from Southwest Asia, the Mediterranean basin, and North America have been assessed using the mitochondrial 12S rRNA gene and a nuclear intron sequence from a Hessian fly white gene. Results have revealed that genotypes present in populations from Israel show the greatest genetic distance from the other populations, suggesting these genotypes are either ancestral or are an incipient species with Hessian fly. Phylogenetic analyses from the present study support the previously proposed hypothesis that Hessian fly dispersal in the Mediterranean basin proceeded from the Middle East/fertile crescent toward the western rim of the Mediterranean basin. Historical record and phylogenetic analyses suggest the genotypes in North America trace their ancestry to those present in the western rim of the Mediterranean basin. Analysis of molecular variance has revealed insight into variation within and between populations. These results are revealing new insight into the ancestry of Hessian fly in North America and into genetic variation in populations with respect to the appearance of virulent genotypes of the pest capable of surviving on formerly resistant wheat.

Characterization of plant processes manipulated by virulent Hessian fly (Christie Williams, Jill Nemacheck, Subhashree Subramanyam, Marcelo Giovanini, and Kurt Saltzmann). We demonstrated that increased protein abundance correlates with increased mRNA levels. Through cloning into expression vectors, protein purification and immuno-detection, we demonstrated that two wheat genes responsive to Hessian fly feeding were more abundant in incompatible interactions. These are the first proteins demonstrated to contribute to the Hessian fly-resistance response. A mechanism of resistance is suggested: because these are lectins, they probably function as feeding deterrents or to block absorption of nutrients in larval midgut. These antibodies will allow us to target cellular and organelle location in the plant and the larval midgut, and quantify expression on western blots. This work will determine whether components of resistance and susceptibility are cell-autonomous or systemic responses.

Up-regulation of both SAMDC and aminopropyl transferase genes in susceptible plants implicates polyamine biosynthesis as a pathway manipulated by the Hessian fly to benefit its development. Up-regulation of a sorbitol transporter may supply a carbon source while suppression of a lipid transporter gene may sequester resources for use by developing larvae. These genes were also characterized in wheat challenged with virus, chewing and sucking insects, and abiotic stresses. This analysis distinguished genes specifically involved in susceptibility to insects from general stress response genes.

VIGS (virus induced gene silencing) verifies *Hfr-2* gene involvement in susceptibility. We demonstrated that the larvae on silenced plants grew at a slower rate than larvae on control plants, indicating that *Hfr-2* gene activity is beneficial to larval development. qRT-PCR confirmed that the gene was silenced. This gene (up-regulated 800-fold in compatible interactions) encodes a plant membrane pore-forming protein that probably allows delivery of nutrients to developing larvae. Blocking this gene may provide a novel form of resistance.

Developing Hessian fly larvae manipulate the amino acid content of wheat cells. Free amino acid analysis demonstrated increased plant production of five amino acids that cannot be synthesized by insects during compatible interactions. Most nonessential amino acids were not affected. This confirms our previous results showing that Round-up suppression of plant aromatic amino acids (essential to insect) resulted in larval death. This is the first evidence that Hf alters amino acid biosynthetic pathways of its host.

Development of microsatellite genetic markers in Hessian fly (Brandi Schemerhorn and Yan Ma Crane). Enriched microsatellite libraries were prepared from size-selected genomic DNA of Hessian fly. Approximately 81 % of the 52,224 recovered clones hybridized with microsatellite motif-specific probes. Of these, 8,256 clones were PCR screened, and 2,350 of them were successfully sequenced. Perfect microsatellites were contained in 55.8 % of the clones, and another 19.5 % contained at least one imperfect microsatellite. Polymorphism and reliability were tested in four Hessian fly biotypes, D, GP, O, and L, for 50 of the microsatellites in agarose gels. Twenty microsatellites were further tested with capillary electrophoresis. Of these, 17 behaved as a polymorphic single locus, two were invariant, and one represented a multiple locus. Preliminary results also indicate that there is no restriction in gene flow between the Hessian fly biotypes D, GP, O, and L.

Septoria tritici blotch.

Disease resistance (Jill Breeden, Ian Thompson, Emily Helliwell, and Stephen B. Goodwin). Real-time PCR was used to confirm differential expression of genes that probably are involved in the nonhost resistance response of barley to contact with the wheat pathogen *M. graminicola*. In previous experiments with the Affymetrix Barley1 genechip array, a large number of genes that were specifically up or down regulated in the non-host resistance response were identified. Real-time PCR confirmed the differential expression and also showed no change in control genes that did not change in the chip experiment. More than 30 of these genes had no useful annotations, yet appear to be involved in non-host resistance. Current work is involved with identifying putative functional domains within these genes.

In a collaborative project with Dr. Steve Scofield and his postdoc Cahid Cakir, we have been testing the effect of genes *Sgt1*, *Rar1*, and *Hsp90* on the expression of resistance genes *Stb2* and *Stb4* against *M. graminicola*. The VIGS technique that was developed in the Scofield lab was used to silence expression of the three genes listed above to test for a change in phenotype from resistant to susceptible. The initial experiments looked promising and a change in phenotype was seen for resistance gene *Stb4*. Those experiments are being repeated with increased replications to confirm whether the observed change is real.

Fungal genetics (Jessica Cavaletto and S.B. Goodwin). A project to sequence the genome of the septoria tritici blotch pathogen, *Mycosphaerella graminicola*, was begun in collaboration with Dr. Gert Kema and other scientists at Plant Research International in Wageningen, the Netherlands, through the Community Sequencing Program at the D.O.E.-Joint Genome Institute. The genome was sequenced to almost 9x coverage and the initial assembly was completed during November of 2005. The genome size is estimated to be 41.8 Mb, slightly larger than thought previously. In addition, a draft mitochondrial assembly of 43,962 bases is available. Over 500,000 sequence reads from the project have been deposited and are available through GenBank. Machine annotation of the genomic sequence is now in progress and plans for a community-wide annotation effort culminating in an annotation jamboree that will be open to all interested participants is anticipated for 2006.

Final work on the genetics of microsatellites in *M. graminicola* was completed and 23 loci were added to the existing genetic linkage map. These markers are highly polymorphic and are available for analyses of fungal genetic and population biology.

Research personnel.

Katie Card and Danielle Posch have joined the Anderson lab as Biological Science Research Technicians. Katie is in charge of developing and utilizing DNA markers linked to the yellow dwarf virus resistance locus, *Bdv3* and additional YDV resistance loci derived from *Thinopyrum*. Danielle is primarily responsible for developing oat DNA markers and will be constructing SSR enriched libraries for identifying polymorphic SSRs for mapping traits in oats. Emily Helliwell joined the Goodwin lab as a Masters student during the autumn of 2005. Emily is interested in marker-assisted selection and will be working on developing new markers that are linked to the *Stb2* gene for resistance to *M. graminicola* that is located on chromosome 3BS. Dr. Ian Thompson joined the Goodwin lab as a Biological Science Research Technician during the fall of 2006. Ian has a Ph.D. in Plant Pathology from Purdue University and is in charge of greenhouse testing and marker analysis. He has several ongoing projects, including backcrossing various STB resistance genes into common susceptible genetic backgrounds, introgressing a gene for resistance to STB from *Thinopyrum* into wheat, and developing improved methods for identifying and analyzing quantitative resistance to STB in wheat. Dr. Julie Zwiesler-Vollick joined the Goodwin lab as a postdoctoral associate during July of 2005. Julie received a Ph.D. in genetics from the DOE-Plant Research Laboratory at Michigan State University under the direction of Dr. Sheng-Yang He, and had two years of postdoctoral experience with Dr. Anne Osbourn at the Sainsbury Laboratory in Norwich, England, before coming to West Lafayette. She has funding from the National Science Foundation to work on non-model systems, and is analyzing secreted proteins from wheat and *Mycosphaerella graminicola* within apoplastic fluids to understand the molecular basis for host-pathogen interactions. She also has a side project to clone and analyze fungal mating-type sequences. Jill Breeden left the Goodwin lab and moved on to a position with the U.S. Forest Service. Brett Ochs joined the Ohm lab studying for the Ph.D. degree; his thesis research is focused on genetics and mapping of resistance to Stagonospora glume blotch resistance. Kristen Rinehart joined the Ohm lab studying for the MS degree; her thesis research is focused on genetics and mapping of a new source of resistance to Hessian fly. Paul Werner joined the Ohm lab studying for the Ph.D. degree; his thesis research is focused on genetics and mapping of resistance to yellow dwarf virus and slow crown rusting resistance in oat. Dr. Kurt Saltzmann joined the Williams lab early in 2006, after graduating from the Purdue department of Entomology. He is identifying and characterizing the expression of wheat genes that respond to avirulent Hessian fly larvae, and has identified wheat amino acids that become more abundant during compatible interactions. Dr. Nagesh Sardesai has moved across the street to the lab of Dr. Stan Gelvin where he is now working on Arabidopsis.

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KANSAS

KANSAS AGRICULTURAL STATISTICS
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Jagalene captures number one.

Jagalene became the leading cultivar of wheat seeded in Kansas for the 2006 crop. Jagger had held this position since 1998. Accounting for 27.2 percent of the state's wheat, Jagalene increased 6 points from a year ago and was the most popular cultivar in five of the nine districts (Table 1). Jagger moved down to second place, with 19.7 percent of the acreage. Jagger decreased 8.5 points but ranked in the tip five in eight of the nine districts. Overley came in third with the biggest increase from last year, up 13.1 points. The KSU-maintained cultivar 2137 moved down to fourth place, with 3.1 percent of

Table 1. Top 10 wheat cultivars grown in the state of Kansas for the 2006 crop and percent of seeded acreage.

1. Jagalene	27.2	6/7. TAM 111, TAM 110	2.2
2. Jagger	17.7	8. Cutter	1.6
3. Overley	15.3	9. 2145	1.2
4. 2137	3.1	10. Karl/Karl 92, Ike	
5. T81	2.6	Thunderbolt	1.1

the acreage. Back to the top ten is T81, after being out last year, ranking fifth with 2.6 percent. TAM 111, new to the top ten, tied for sixth place with TAM 110 at 2.2 percent. Cutter moved up to eights place with 1.6 percent of the acreage. The OSU-maintained cultivar 2174 moved down to ninth place with 1.2 percent of the state's acreage. Tied for tenth are Ike, Thunderbolt, Karl, and Karl 92, all with 1.1 percent. Acres planted with blended cultivars were not included in the rankings by cultivar. Blends accounted for 10.0 percent of the state's planted acres and were used more extensively in the north central, northeast, and central areas of the state. Out of the total acres planted with blends, 61.3 percent included Jagger in the blend, 46.3 percent had 2137 in the blend, and 42.2 included Jagalene. Hard white cultivars accounted for 36 percent of the state's white wheat. The majority of the white wheat was planted in the western third of the state. This wheat cultivar project is funded by the Kansas Wheat Commission.

Table 2. Top wheat cultivars planted in Kansas by district and percent of seeded acreage in 2006.

District 10 (Northwest)		**District 40 (North central)**		**District 70 (Northeast)**	
Jagalene	34.6	Jagalene	18.0	2137	18.3
Jagger	21.0	Jagger	16.9	2145	14.6
TAM 111	5.6	Overley	9.9	Jagalene	12.3
Thunderbolt	5.2	2137	7.2	Overley	7.5
NuHills–HWWW	2.8	Karl/Karl 92	5.9	Karl/Karl 92	7.1
District 20 (West central)		**District 50 (Central)**		**District 80 (East central)**	
Jagalene	32.6	Jagalene	24.8	Jagger	19.8
Jagger	15.6	Jagger	22.6	Overley	18.9
T81	9.8	Overley	22.0	2137	15.1
TAM 110	6.4	2137	4.9	Jagalene	10.5
TAM 111	5.3	Cutter	2.9	Dominator	5.1
District 30 (Southwest)		**District 60 (South central)**		**District 90 (Southeast)**	
Jagalene	35.1	Overley	29.6	Overley	23.8
Jagger	18.0	Jagalene	24.5	Jagger	16.7
TAM 110	9.9	Jagger	21.3	2137	13.5
T81	8.6	2174	2.9	2174	10.2
TAM 111	6.2	Cutter	1.9	Jagalene	9.9

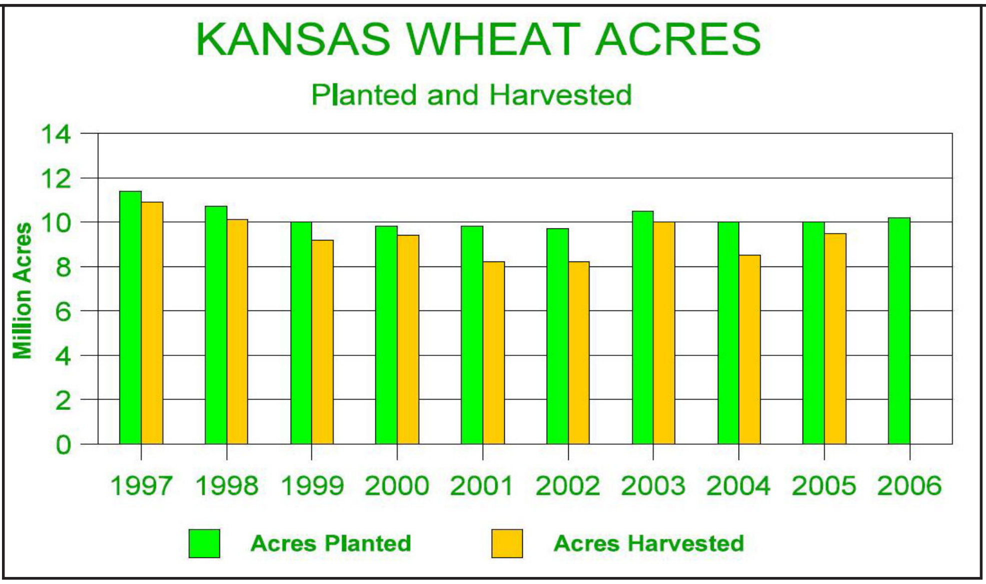

Table 3. Distribution of Kansas winter wheat cultivars, 2006 crop (— = cultivar not reported in this district; 0 = < 1 %).

	Agricultural Statistics Districts									
Cultivar	NW	WC	SW	NC	C	SC	NE	EC	SE	State
	percent of seeded acreage									
Jagalene	34.9	32.6	36.1	18.0	24.9	24.5	12.3	10.5	9.9	27.2
Jagger	21.0	15.6	19.0	16.9	22.6	21.3	6.9	19.6	16.7	19.7
Overley	0.6	0.8	0.1	9.9	22.0	29.6	7.5	18.9	23.8	15.3
2137	2.1	3.5	1.5	7.2	4.9	1.2	18.3	15.1	13.5	3.1
T81	2.2	9.8	9.9	0.0	0.0	—	—	—	—	2.6
TAM 110	0.1	6.4	9.9	0.0	0.0	—	—	—	—	2.2
TAM 111	5.6	5.3	6.2	0.0	—	0.0	—	—	—	2.2
Cutter	0.6	1.0	0.5	1.4	2.9	1.9	0.1	—	—	1.6
2174	—	0.0	—	0.5	0.4	2.9	—	2.4	10.2	1.2
Ike	0.9	1.9	4.3	0.5	0.6	0.2	—	—	—	1.1
Karl/Karl 92	0.5	0.4	—	4.9	1.2	0.7	7.1	2.9	1.0	1.1
Thunderbolt	5.2	2.0	1.1	1.1	0.1	0.1	—	—	—	1.1
2145	—	0.1	—	1.5	2.1	0.4	14.6	2.2	2.2	0.8
Dominator	0.1	—	—	2.5	2.7	0.2	1.4	5.1	—	0.8
Stanton	2.5	3.6	0.4	0.1	0.1	0.1	—	—	—	0.8
NuHills–HWWW	2.8	1.0	1.2	—	0.1	0.1	—	—	—	0.6
Coronado	—	0.3	—	—	0.1	1.1	0.2	—	—	0.4
NuFrontier–HWWW	2.3	0.2	1.0	—	—	0.0	—	—	—	0.4
TAM 107	0.7	1.4	0.9	0.0	0.0	—	—	—	—	0.4
Trego–HWWW	0.6	1.7	0.7	—	0.2	—	—	—	—	0.4
Onaga	—	—	—	0.1	0.0	0.8	0.1	3.6	3.5	0.3
Vista	1.7	0.7	—	0.0	—	—	—	—	—	0.3
Wesley	1.4	0.1	—	1.4	0.0	—	3.0	—	—	0.3
2163	—	—	0.3	0.3	0.6	0.1	0.0	0.6	0.6	0.2
Eagle	0.2	0.9	0.4	0.0	—	—	—	—	—	0.2
Larned	0.4	0.8	0.1	0.0	0.0	0.3	—	—	—	0.2
Protection	—	0.3	—	0.3	0.5	0.1	—	—	0.0	0.2
Santa Fe	—	—	—	0.2	0.5	0.3	1.5	0.0	0.2	0.2
Scout/Scout 66	0.5	0.3	0.8	0.0	—	0.0	—	—	—	0.2
Blends	8.1	3.8	4.3	28.9	10.2	9.0	23.4	10.8	3.2	10.0
Other HWWW Cultivars	0.5	0.5	0.7	0.1	—	0.1	0.0	—	0.0	0.3
Other HRWW Cultivars	4.8	5.0	4.0	4.1	3.1	4.9	3.6	8.3	9.8	4.5
All Soft Red Cultivars	—	—	—	0.0	0.0	0.0	0.0	0.0	5.4	0.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 4. Distribution of Kansas winter wheat cultivars, 1997–2006.

Cultivar	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
	percent of seeded acreage									
Jagalene	—	—	—	—	—	—	—	3.0	21.2	27.2
Jagger	6.4	20.2	29.2	34.0	35.8	42.8	45.2	40.9	28.2	19.7
Overley	—	—	—	—	—	—	—	0.1	2.2	16.3
2137	1.0	13.5	22.0	23.1	22.3	15.5	13.3	8.6	5.7	3.1
T81	—	—	—	0.2	0.2	0.8	0.6	1.8	1.6	2.6
TAM 110	—	—	0.5	1.3	2.8	3.0	3.8	4.2	3.3	2.2
TAM 111	—	—	—	—	—	—	—	—	1.5	2.2
Cutter	—	—	—	—	—	—	—	0.7	1.7	1.8
2174	—	—	—	1.1	3.0	3.1	3.1	2.8	3.0	1.2
Ike	10.5	7.0	5.5	4.1	3.6	2.6	2.1	2.0	1.4	1.1
Karl/Karl 92	22.1	10.8	5.9	3.5	3.3	3.6	3.2	2.3	1.5	1.1
Thunderbolt	—	—	—	—	0.2	0.6	0.8	1.4	1.7	1.1
2145	—	—	—	—	—	—	—	1.5	2.2	0.8
Dominator	—	0.2	0.8	1.4	1.5	2.0	2.2	1.5	1.1	0.8
Stanton	—	—	—	—	—	0.1	0.6	1.4	1.4	0.8
NuHills–HWWW	—	—	—	—	—	—	—	—	0.3	0.2
Coronado	—	0.8	1.3	1.0	1.1	0.7	0.8	0.5	0.4	0.4
NuFrontier–HWWW	—	—	—	—	—	0.1	0.3	0.6	0.2	0.4
TAM 107	17.0	12.6	8.3	6.3	5.3	2.9	2.3	1.3	1.0	0.4
Trego–HWWW	—	—	—	—	0.3	0.8	1.8	3.5	2.9	0.4
Onaga	—	—	0.1	0.1	0.2	0.2	0.2	0.1	0.1	0.3
Vista	1.2	1.1	0.9	0.9	1.0	0.9	0.3	0.2	0.3	0.3
Wesley	—	—	—	—	—	—	0.1	0.1	0.1	0.3
2163	15.4	10.4	3.4	2.3	2.0	1.3	0.8	0.3	0.2	0.2
Eagle	0.5	0.4	0.3	0.2	0.2	0.2	0.1	—	—	0.2
Larned	3.6	2.4	1.9	1.2	1.0	0.9	0.8	0.4	0.3	0.2
Protection	—	—	—	—	—	—	—	—	—	0.2
Santa Fe	—	—	—	—	—	—	—	—	—	0.2
Scout/Scout 66	0.8	0.7	0.5	0.3	0.1	0.2	0.2	0.2	0.1	0.2
Blends	—	2.6	6.1	7.5	7.0	11.4	12.8	15.2	11.3	10.0
Other HWWW Cultivars	—	—	—	0.2	0.8	0.3	0.2	0.1	0.5	0.3
Other HRWW Cultivars	21.1	17.3	13.3	11.3	8.6	5.9	3.9	4.6	5.8	4.5
All Soft Red Cultivars	0.3	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

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Heavy metals in drainage water from soil at the Manhattan, KS, Biosolids Farm.

Stanley Liphadzi and M.B. Kirkham

In 2003 we reported the concentrations of heavy metals in soil at the Manhattan, KS, Biosolids Farm, which has been receiving the city's sewage sludge (also called biosolids) since 1976. The farm is divided into four quadrants. Sludge is injected into one quadrant, one day per week, during a three-month period in a year. The three crops grown in rotation at the Biosolids Farm are winter wheat, sorghum, and corn. One quadrant is fallow at any one time. We observed that after 25 years of application of sludge to the farm, concentrations of seven heavy metals that we measured (Cd, Cu, Fe, Mn, Ni, Pb, Zn) have not increased in the soil, except for Cu, Pb, and Zn. Lead is the only toxic heavy metal, and we did not know the reason for its elevated level. Here we report concentrations of heavy metals in drainage water from the soil at the Biosolids Farm (Table 1). Details of the experiment are given in Liphadzi and Kirkham (2006d). The soil from the Biosolids Farm that had received sludge for 25 years was put in large columns (105 cm depth; 39 cm diameter) in a greenhouse. Data are from columns with no plants and no chelate added to solubilize the heavy metals (control soil). Days after the beginning of the experiment (11 Sept. 2001) are given in the table. At the beginning of the experiment, columns received 20 L water. Between 11 Sept. 2001 and 15 Jan. 2002, 4 L of water were irrigated onto the columns every 2 weeks. No water was added between 15 Jan. 2002 and 2 Feb. 2002. Between 2 Feb. 2002 and 15 May 2002, columns received 9 L of water every 2 weeks.

Table 1. Concentrations (mg/kg) of seven heavy metals in drainage water from columns containing soil from a 25-year-old sludge farm. Mean and standard deviation are shown (n = 2).

Time (days)	Cd	Cu	Fe	Mn	Ni	Pb	Zn
164	0.003±0.000	0.069±0.001	0±0	0.017±0.001	0.021±0.003	0.019±0.003	0.020±0.003
171	0.001±0.001	0.057±0.003	0±0	0.015 ±0.016	0.017±0.002	0.009±0.009	0.017±0.006
199	0.003±0.001	0.060±0.004	0±0	0.014±0.012	0.016±0.006	0.003±0.004	0.015±0.004
217	0.009±0.002	0.068±0.000	0±0	0.014±0.005	0.030±0.008	0.041±0.003	0.015±0.001
232	0.005±0.000	0.058±0.004	0±0	0.009±0.006	0.019±0.001	0.016±0.006	0.015±0.004
246	0.002±0.001	0.065±0.001	0±0	0.007±0.001	0.023±0.007	0.013±0.001	0.014±0.001
Mean	0.004±0.003	0.063±0.005	0±0	0.013±0.004	0.021±0.005	0.017±0.013	0.016±0.002

Drinking water standards are (in g/mL): Cd, 005; Cu, 1.3; Fe, 0.3; Mn, 0.05; Ni, none; Pb, 0.015; and Zn, 5.0. Concentrations of Pb in the drainage water were the only ones elevated above drinking water standards, except for Cd in the drainage water 217 days after the beginning of the experiment. The citizens of Manhattan, KS, use surface water for drinking water. Even though this study was done in a greenhouse with columns containing the soil from the Biosolids Farm and may not apply to field conditions, the results suggest that, when the soil is fallow, elevated levels of Pb can leach to the groundwater. Therefore, people using well water that drains from the Biosolids Farm might have slightly elevated levels of Pb in their water.

News.

James Kingston (Ken) McCarron, Visiting Scholar, has accepted a job with the U.S. Park Service in Charleston, South Carolina.

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B.S. Gill, B. Friebe, W.J. Raupp, W. Li, L. Qi, L. Huang, and D.L. Wilson.

Durable resistance to leaf rust.

In past years, the WGGRC has evaluated the seedling resistance to leaf rust of *Ae. tauschii* in the greenhouse after artificial inoculation in more than 550 accessions. From these studies, many resistance genes were found and several have been transferred to elite wheat backgrounds and released as germ plasm. At present, however, promising leaf rust genes in commercial cultivars seem to break down only a few years after a cultivar's release. Now, we hope to identify minor genes at the adult-plant stage that may not give an immune reaction to the leaf rust pathogen but allow the pathogen population to exist without reaching epidemic proportions or causing severe damage to the plant.

We selected a set of 328 lines previously identified as seedling susceptible to isolates PRTUS6 and PMNQ of the leaf rust pathogen. The lines were planted in the field at the Rocky Ford Research Area in Manhattan, KS. Two replications were made for each line. Plants were screened at anthesis for leaf rust infection. A total of 586 hills were planted, of which 12 were Chinese Spring wheat checks and eight were TA2460, a leaf rust-resistant *Ae. tauschii* line. Along with natural infection, the nursery was inoculated with leaf rust isolates PRTUS42, PRTUS45, and PRTUS50. Disease reaction was scored using the Cobb scale, which gives a percentage of the leaf area covered by pustules of the leaf rust fungus and a letter rating for the size of the pustules. For example, a score of 20MR would indicate 20 % of the leaf area covered with small pustules; a score of 40M would indicate 40 % of the leaf area covered with medium-sized pustules. The control Chinese Spring wheat plants scored a 60–70S, i.e., 60–70 % of the leaf surface was covered with very large pustules.

Of the accessions planted, only four differed significantly in their resistance scores between the replicates. These lines could possibly be segregating for resistance genes in the population or may have escaped some of the infection. Seventy-three lines had resistant (R, very small) type pustules. These lines ranged from 1–50 % coverage. Another 155 lines had moderately resistant (MR, small) type pustules. The spread of the disease in these lines was from 5–70 %. Of the remaining plants, 33 were considered to have medium-sized pustules (M, medium, 10–50 % coverage) and three were moderately susceptible (MS, large, 40–50 % coverage). Leaf rust reaction based on leaf area covered by disease was as follows: 1–5 %, 46 accessions; 10–20 %, 42 accessions; 30–40 %, 114 accessions; and 50–70 %, 62 accessions.

These accessions were all susceptible at the seedling stage however. Based on these results, 15 % of these lines contain one or more genes that can function in the adult plant and will provide another source of resistance genes for improving disease resistance in bread wheat. Selected lines are being grown in a field nursery for additional observations.

Development and characterization of wheat–Leymus racemosus translocation lines with resistance to Fusarium head blight.

Finding diverse sources of FHB resistance is critical for genetic diversity of resistance for wheat breeding programs. *L. racemosus* is a wild perennial relative of wheat and is highly resistant to FHB. Three wheat- *L. racemosus* disomic addition (DA) lines DA5Lr#1, DA7Lr#1, and DALr.7 resistant to FHB were used to develop wheat–*L. racemosus* translocation lines through irradiation and gametocidal gene-induced chromosome breakage. A total of nine wheat-alien translocation lines with wheat scab resistance were identified by chromosome C-banding, GISH, telosomic pairing, and RFLP analyses. The resistance level of the translocation lines with a single alien chromosome segment was higher than the susceptible wheat parent Chinese Spring but lower than the alien resistant parent *L. racemosus*. All the lines involve nonhomoeologous chromosomes and, thus, are of noncompensating type. We will use *ph1b*-induced homologous recombination in combination with molecular marker analysis to identify compensating recombinants that still retain the resistance genes.

This work was in coöperation with Drs. P.D. Chen and D.J. Liu, Nanjing Agricultural University, Nanjing, PR China.

Origin, structure, and behavior of a highly rearranged deletion chromosome, 1BS-4, in wheat.

Wheat deletion stocks are valuable tools for the physical mapping of molecular markers and genes to chromosome bins delineated by two adjacent deletion breakpoints. The cytogenetic and molecular marker analyses suggest that 1BS-4 resulted from two breakpoints in the 1BS arm and one breakpoint in the 1BL arm. The distal segment from 1BS, except for a small deleted part, is translocated to the long arm. Cytologically, chromosome 1BS-4 is highly stable, but shows a unique meiotic pairing behavior. The short arm of 1BS-4 fails to pair with a normal 1BS arm because of lack of homology at the distal ends. The long arm of 1BS-4 only pairs with a normal 1BS arm within the distal region translocated from 1BS. Therefore, using the 1BS-4 deletion stock for physical mapping will result in the false allocation of molecular markers and genes proximal to the breakpoint of 1BS-4.

Robertsonian translocations in wheat arise by centric misdivision of univalents at anaphase I and rejoining of broken centromeres during interkinesis of meiosis II.

Robertsonian translocations are an important step in the transfer of alien genetic variation into wheat. The mechanism of origin of Robertsonian translocations was investigated in plants monosomic for chromosome 1A of wheat and $1H^t$ of *E. trachycaulus* by GISH. Chromosomes 1A and $1H^t$ stayed univalent in all metaphase I cells analyzed, suggesting that Robertsonian translocations do not originate from meiotic recombination in centromeric regions with shared DNA sequence homology. At ana-/telophase I, the $1H^t$ and 1A univalents underwent either chromosome or chromatid segregation and misdivided in 6–7% of the pollen mother cells. None of the ana-/telophases I analyzed had Robertsonian translocations, which were only observed in 2% of the "half tetrads" at ana-/telophase II. The frequency of Robertsonian translocations observed at ana-/telophase II corresponds well with the number of Robertsonian translocations (1–4%) detected in progenies derived from plants monosomic for group-1 chromosomes of wheat (1A, 1B, and 1D) and $1H^t$ of *E. trachycaulus*. Our data suggest that Robertsonian translocations arise from centric misdivision of univalents at ana-/telophase I, followed by segregation of the derived telocentric chromosomes to the same nucleus, and fusion of the broken ends during the ensuing interkinesis. KS04WGRC45, incorporating leaf rust resistance from *E. trachycaulus*, was developed using this technology.

Development of a virus-induced gene-silencing system for hexaploid wheat and its use in functional analysis of the Lr21-mediated leaf rust resistance pathway.

Virus-induced gene silencing (VIGS) is an important tool for the analysis of gene function in plants. In VIGS, viruses engineered to carry sequences derived from plant gene transcripts activate the host's sequence-specific RNA degradation system. This mechanism targets the RNAs of the viral genome for degradation, and as the virus contains transcribed plant sequence, homologous host mRNAs are also targeted for destruction. Although routinely used in some dicots, no VIGS system was known for monocot plants until the recent report of silencing in barley-by-barley stripe mosaic virus (BSMV). We have developed protocols for use of BSMV to efficiently silence genes in hexaploid wheat. The VIGS system was first optimized in studies silencing phytoene desaturase expression. Next, we used it to assay genes functioning in leaf rust resistance mediated by *Lr21*, which encodes a nucleotide binding site-leucine-rich repeat class resistance gene product. We demonstrated that infection with BSMV constructs carrying a 150-bp fragment of *Lr21* caused conversion of incompatible interactions to compatible, whereas infection with a control construct or one that silences phytoene desaturase had no effect on resistance or susceptibility. Additionally, silencing the *RAR1*, *SGT1*, and *HSP90* genes, known to be required in many but not all nucleotide binding site-leucine-rich repeat resistance pathways in diverse plant species, resulted in conversion to compatibility, indicating that these genes are essential in *Lr21*-mediated resistance. These studies indicate that BSMV-VIGS is a powerful tool for dissecting the genetic pathways of disease resistance in hexaploid wheat.

This project is in coöperation with S.R. Scofield, Purdue University, W. Lafayette, IN.

Complex microcolinearity among wheat, rice, and barley revealed by fine mapping of the genomic region harboring a major QTL for resistance to Fusarium head blight in wheat.

A major QTL, *Qfhs.ndsu-3BS*, for resistance to Fusarium head blight in wheat has been identified and verified by several research groups. We constructed a fine genetic map of this QTL region and examined microcolinearity in the QTL region among wheat, rice, and barley. Two simple sequence repeat (SSR) markers (*Xgwm533* and *Xgwm493*) flanking this QTL were used to screen for recombinants in a population of 3,156 plants derived from a single F_7 plant heterozygous for the *Qfhs.ndsu-3BS* region. A total of 382 recombinants were identified, and they were genotyped with two more SSR markers and eight sequence-tagged site (STS) markers. A fine genetic map of the *Qfhs.ndsu-3BS* region was constructed and spanned 6.3 cM. Based on replicated evaluations of homozygous recombinant lines for Type II FHB resistance, *Qfhs.ndsu-3BS*, redesignated as *Fhb1*, was placed into a 1.2-cM marker interval flanked by STS3B-189 and STS3B-206. Primers of STS markers were designed from wheat expressed sequence tags homologous to each of six barley genes expected to be located near this QTL region. A comparison of the wheat fine genetic map and physical maps of rice and barley revealed inversions and insertions/deletions. This suggests a complex microcolinearity among wheat, rice, and barley in this QTL region.

The efficacy of Cot-based gene enrichment in wheat.

Cot filtration (CF) is effective in the characterization of the gene space of bread wheat, a large genome species (1C = 16 700 Mb). Using published Cot data as a guide, 2 genomic libraries for hexaploid wheat were constructed from the single-stranded DNA collected at Cot values > 1,188 and 1,639 M·s. Compared with sequences from a whole genome shotgun library from *Ae. tauschii* (the D genome donor of bread wheat), the CF libraries exhibited 13.7-fold enrichment in genes, 5.8-fold enrichment in unknown low-copy sequences, and a 3-fold reduction in repetitive DNA. CF is twice as efficient as methylation filtration at enriching wheat genes. This research suggests that, with improvements, CF will be a highly useful tool in sequencing the gene space of wheat

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GRAIN MARKETING AND PRODUCTION RESEARCH CENTER
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M. Tilley, F.E. Dowell, O.K Chung, S.H. Park, E.B. Maghirang, B.W. Seabourn, T.C. Pearson, F. Xie, H.P. Akdogan, M.E. Casada, J.D. Wilson, S.R. Bean, T.J. Schober, P.R. Armstrong, M.S. Caley, D.L. Brabec, S.Z. Xiao, L.M. Seitz, R.K. Lyne, J.E. Throne, F.H. Arthur, D.B. Bechtel, G.L. Lookhart, and M.S. Ram.

Nursery location clustering based on hard winter wheat regional quality evaluations.

S.R. Clayshulte, S.D. Haley, P.L. Chapman, B.W. Seabourn, and O.K. Chung.

Environmental conditions significantly affect wheat quality characteristics from year to year. Understanding the effects of environment on quality characteristics and the similarities of genotype response to testing locations is important for breeders selecting test sites and evaluating experimental lines. Six years of quality data from the U.S. Hard Winter Wheat Southern Regional Performance Nursery (SRPN) and the Northern Regional Performance Nursery (NRPN) were analyzed to divide test sites into groups similar in their response to the environment. Cluster analysis divided the SRPN into four clusters based on milling-related variables and three clusters based on rheology-related variables. Locations were consistently placed in the same cluster for the rheology-related variables but not for the milling-related variables. For the NRPN, clustering based either on rheology-related or milling-related variables produced one cluster that contained 58 % of the location-years. However, the remaining location-years were divided into two clusters based on milling-related variables and three clusters based on rheology-related variables. Principal component analysis of the SRPN data identified four principal components based on milling-related variables (explaining 78 % of the total variability) and three principal components based on rheology-related variables (explaining 93 % of the variability). Clustering based on these principal components revealed three clusters for the milling-related variables and four clusters in the rheology-related variables. Interpretation of the principal components allowed clusters to be characterized. Results from either clustering procedure indicate that only a few locations responded similarly to the environment from year to year.

Detecting insect fragments in flour.

J. Perez-Mendoza, J.E. Throne, E.B. Maghirang, F.E. Dowell, and J.E. Baker.

Primary pests of stored cereals that develop and feed inside grain kernels are the main source of insect fragments in wheat flour. The Food and Drug Administration (FDA) has set a defect action level of 75 or more insect fragments per 50 gram of flour. The current standard flotation method for detecting insect fragments in flour is very labor intensive and expensive. We investigated the potential of near-infrared spectroscopy (NIRS) to detect insect fragments in wheat flour at the FDA defect action level. Fragments counts with both the NIRS and the standard flotation methods correlated well with the actual number of fragments present in flour samples. However, the flotation method was more sensitive below the FDA defect action level than the NIRS method. Although the flotation method is very sensitive at the FDA action level, this technique is time consuming (almost 2 h/sample) and expensive. Although NIRS currently lacks the sensitivity of the flotation method, it is rapid, does not require sample preparation, and could be easily automated for a more sophisticated sampling protocol for large flour bulks. Therefore, this method should be reexamined in the future because NIRS technology is rapidly improving.

Monitoring grain quality using wireless data transmission.

P. Armstrong.

During grain storage the quality of grain can be subjected to adverse conditions of high grain moisture and insects. In both instances grain temperature is a good indication when these conditions are present. Most large grain storage facilities use elaborate grain temperature monitoring systems, which require multiple temperature sensors wired to a central computer. Smaller storages do not usually have these systems due to their cost or because the storage is only used for short periods. Wireless sensors, which use radio waves to transmit temperature, may provide a more convenient way to measure grain storage temperature in some cases and can be used for temporary storage or be permanently fixed in the larger storage structures as an alternative to wired sensors. Wireless sensors also have the potential to travel with the grain during distribution. A limiting factor for wireless data transmission is the ability to transmit radio waves through grain with a small, low-power, battery operated device. Tests were therefore conducted with a commercial wireless sensor development system to determine transmission range. These particular wireless sensors were about 2 x 0.5 x 1.5 inches in size. Results showed that data could be transmitted through grain over a 2-m distance at power levels that would allow about 3 years of operation, which is roughly the distance that adjacent wired sensors are placed at for commercial storage. The network ability of these sensors allows them to relay data from sensor to sensor and extend this range infinitely. Wireless sensors have the potential to improve the overall grain storage infrastructure by providing a system that would allow monitoring of storages, which would otherwise not be economically practical.

Summer aeration of stored wheat in Kansas.

H. Akdogan, F.H. Arthur, and M.E. Casada.

Insect pests often cause economic damage in stored grain, and cooling storage bins in autumn through aeration (using low-volume airflow rates of ambient air) can be an important component of integrated management plans for stored wheat. Model simulation studies show that a summer aeration cycle would cool stored wheat in Kansas and also reduce insect populations, but field studies have not been done to verify model predictions. We conducted a 3-year study in which summer aeration was included along with aeration in early and late autumn. Summer aeration reduced temperatures in stored wheat and generally reduced insect populations, but year-to-year variations in temperatures affected the level of control. Results warrant further research into the timing and optimization of summer aeration.

Automated NIR sorting technology commercialized.

F.E. Dowell, E. B. Maghirang, R.A.Graybosch, P.S. Baenziger, D.D. Baltensperger, and L.E. Hansen.

The single kernel sorting system developed to detect specific grain attributes was commercialized through a CRADA with Perten Instruments, Stockholm, Sweden. The system was demonstrated at several international conferences in 2005 and is being publicly marketed. The system automatically scans individual wheat kernels, and then sorts kernels based on specific attributes such as protein content, hardness, and amylose content. The system now is being used by breeders to select specific traits from early generation breeder samples and will significantly reduce the time and expense required to develop cultivars with specific end-use traits. The system is also being evaluated for use in detecting food safety attributes such as vomitoxin during routine grading. Although it was developed for wheat, it is also finding applications in sorghum and millet.

Relationships between cooked alkaline noodle texture and solvent retention capacity (SRC) SDS-sedimentation, mixograph and protein composition.

O.K. Chung, S.H. Park, S.R. Bean, and Z.S. Xiao.

Because of increasing uses of hard winter wheat in other than bread products, the HWWQL included Asian alkaline noodle-making in the quality evaluation of breeding program. Because the textural measurement of cooked noodle quality is too labor-intensive for thousands of breeding lines, we investigated relationships of texture profile analysis (TPA) values of cooked alkaline noodles of 34 HWW with quick tests generally used for bread quality estimation, i.e., SRC, SDS-sedimentation (Sed), computerized-mixograph (C-M), and protein content (PC) and composition. Some typical TPA values of cooked noodles included hardness, resilience, adhesiveness, and cohesiveness. The hardness values were negatively correlated with SDS-sedimentation, 5 % lactic acid (LA)-SRC, and insoluble polymeric protein content (IPP) ($r = -0.53$ to -0.75), and with PC ($r = -0.38$, $n = 34$, $P < 0.05$). Cohesiveness and resilience were positively correlated with SDS-Sed, 5 % LA-SRC, and IPP ($r = 0.61$ to 0.74 and 0.46 to 0.72). Both flour PC and IPP were positively correlated with resilience and adhesiveness ($r = 0.44$ to 0.58). Of many C-M parameters, the height at 8 and 6 min values of C-M showed similar correlations, shown by SDS-Sed. Cooking loss was negatively correlated to resilience and cohesiveness ($r = –0.78$ and $r = –0.80$, respectively). Prediction equations were developed by stepwise multiple regression using PC and C-M parameters, resulting in R^2 values of 0.67, 0.54, and 0.71 for cooked noodle hardness, resilience, and cohesiveness, respectively. The addition of SRC, SDS-Sed, and/or IPP data, the prediction improved the R^2 from 0.54 to 0.62 for only resilience, but for others marginally, indicating the potential use of flour PC and CM-height values for predicting cooked noodle textures for the HWW-breeding program.

Solvent retention capacity values in relation to hard winter wheat and flour properties and straight-dough bread-making quality.

Z.S. Xiao, S.H. Park, O.K. Chung, M.S. Caley, and P.A. Seib.

Solvent retention capacity (SRC) was investigated in assessing the end-use quality of hard winter wheat. The four SRC values of 116 HWW flours were determined using 5 % lactic acid, 50 % sucrose, 5 % sodium carbonate, and distilled water. The SRC values were greatly affected by wheat and flour protein contents and showed significant linear correlations with 1,000-kernel weight and single kernel weight, size, and hardness. The 5 % lactic acid SRC value showed the highest correlation ($r = 0.83$, $P < 0.0001$) with straight-dough bread volume, followed by 50 % sucrose, and least by distilled water. We found that the 5 % lactic acid SRC value differentiated the quality of protein relating to loaf volume. When we selected a set of flours that had a narrow range of protein content between 12–13 % ($n = 37$) from the 116 flours, flour protein content was not significantly correlated with loaf volume. The 5 % lactic acid SRC value, however, showed a significant correlation ($r = 0.84$, $P < 0.0001$) with loaf volume. The 5 % lactic acid SRC value was significantly correlated with SDS-sedimentation volume ($r = 0.83$, $P < 0.0001$). The SDS-sedimentation test showed a similar capability to 5 % lactic acid SRC, correlating significantly with loaf volume for flours with similar protein content ($r = 0.72$, $P < 0.0001$). Prediction models for loaf volume were derived from a series of wheat and flour quality parameters. The inclusion of 5 % lactic acid SRC values in the prediction model improved R^2 of 0.778 and root mean square error (RMSE) of 57.2 from R^2 of 0.609 and RMSE of 75.6, respectively, from the prediction model developed with single kernel characterization system and near-infrared reflectance spectroscopy data. The prediction models were tested with three validation sets having different protein ranges, and confirmed that 5 % lactic acid SRC test is valuable in predicting the loaf volume of bread from a HWW flour, especially for flours with similar protein contents.

Comparison of loaf-volume measuring methods: rapeseed displacement vs. laser sensor.

M.S. Caley, S.H. Park, and O.K. Chung.

Loaf volume (LV) is the principal component of bread quality evaluation of breeding lines and rapeseed displacement has been the method of choice for over 60 years at the HWWQL. A new computer-controlled LV measuring instrument, which employs laser sensor (LS), has become commercially available. The objective of our study was to investigate the potential use of the LS instrument for measuring LV of pup-straight-dough-bread (PUP: 100-g flour) and pound-sponge-&-dough-bread (POUND: 300-g flour). Using 43 flour samples (19 hard winter and 24 hard red spring wheat) from the Wheat Quality Council test samples, harvested in 2004, the LV values by rapeseed were generally higher than those by LS instrument. The overall average values of LV by rapeseed were 847 and 2,256 cc for PUP and POUND, whereas those by LS were 700 and 2,010 cc, respectively. The differences in LV values obtained between the two methods depend on the LV values of samples, i.e., a larger difference for a larger loaf of bread, especially for the PUP ($R^2 = 0.673$) and to lesser degree for the POUND ($R^2 = 0.154$, $P < 0.01$). The LV values were highly correlated between the two methods, irrespective of wheat classes, baking methods (straight-dough vs. sponge and dough) or sample size (100- or 300-g flour). The correlations between the two methods were highest for winter wheat of PUP and POUND ($R^2 = 0.997$) and lowest for spring wheat PUP ($r^2 = 0.840$). With all 86 data, R^2 value was 0.996. Rapeseed LV values could be predicted significantly ($R^2 =0.993$) using the LS instrument values such as LV, width, maximum depth, and area. Therefore, this new LS instrument has a potential to be used as an objective measurement instrument of LV for various bread products.

Computerized mixogram (C–M) parameters in relation to bread quality processed by straight-dough method: peak height versus time-x height (H-X).

Z.S. Xiao, S.H. Park, O.K. Chung, M.S. Caley, and P.A. Seib.

Computerized mixograph (C-M) has been available for awhile and provides numerous parameters. Due to excessive number of data provided by the software package in C-M, we continued to investigate, more in depth, some of C-M parameters, which would be highly correlated to final quality of straight-dough bread. With 116 hard winter wheat samples, widely ranging protein content (PC) (7–15 %), we analyzed data from C-M, physicochemical quality parameters, SDS sedimentation, and solvent retention capacity (SRC). The peak height is the height of C-M curve at optimum mix time (OMT) and the time-x height (H-x) is the height of C-M curve at 6 min for flours with OMT <6 min and at 8 min for flours with their OMT >6 min. The peak height was highly correlated with PC (r = 0.84) and loaf volume (LV) (r = 0.71, P < 0.0001), and the H-x was also highly correlated with PC (r = 0.71) and LV (r = 0.85). However, we found that the peak height was not able to differentiate the breadmaking performance of flours with a similar PC range, whereas the H-x could. With the set of 37 flours with a PC range of 12–13 %, the H-x was not significantly correlated with PC but highly correlated with LV (r = 0.78) and crumb grain score (r = 0.68, P < 0.001), whereas there were no significant correlations between peak height and PC or LV. We also found that height-x was highly correlated with 5 % lactic acid-SRC test (r = 0.82 and r = 0.83 for a PC range 7–15 % and 12–13 %, respectively, P < 0.001) irrespective of the PC ranges of flour sample set. Among the C-M parameters, H-x was the best parameter to correlate the pup-loaf bread quality (LV and crumb grain scores). Therefore, the H-x value of C-M should be a choice selection as one of the top quality evaluation parameters for hard winter wheat breeding program.

Improving the quality of white wheat through rapid sorting.

F.E. Dowell, E.B. Maghirang, T.C. Pearson, and D. Brabec.

White wheat is gaining acceptance throughout the Midwest as a class that can improve our competitiveness in export markets. All breeding programs in the Midwest are developing white wheat cultivars. We are able to improve the quality of white wheat cultivars being used in breeding programs by removing wheat of other classes, such as red wheat, from samples using high speed sorting procedures developed through a MOU with Satake, Inc. No other technology is available to remove these contaminating kernels. Almost all white wheat being developed in the Midwest and Pacific Northwest is now shipped to our research unit for purification through our sorter. Our sorting has reduced the development time for these new cultivars by several years, has saved the breeders hundreds of hours, and has salvaged some cultivars that would have been terminated if our technology was not available.

Levels of protein and protein composition in hard winter wheat flours and their relationships to breadmaking.

S.H. Park, S.R. Bean, O.K. Chung, and P.A. Seib.

Protein and protein fractions were measured in 49 hard winter wheat flours to investigate their relationship to breadmaking properties, particularly loaf volume which varied from 760 to 1,055 cm^3/100 g flour and crumb grain score of 1.0–5.0. Total soluble protein (SP) in 50 % 1-propanol was separated into albumins and globulins (AG), gliadins, and soluble polymeric proteins (SPP) using size exclusion high-performance liquid chromatography. Insoluble polymeric protein (IPP) was determined by combustion assay of the residue. Protein composition varied with flour protein content because SP and gliadin levels increased proportionally to increased protein content, but AG, SPP, and IPP levels did not. Flour protein content was positively correlated with loaf volume and bake water absorption (r = 0.80, P < 0.0001 and r = 0.45, P < 0.01, respectively). The percent SP based on flour showed the highest correlation with loaf volume (r = 0.85) and low but significant correlation with crumb grain score (r = 0.35, P < 0.05). Percent gliadins based on flour and on protein content were positively correlated to loaf volume (r = 0.73, P < 0.0001 and r = 0.46, P < 0.001, respectively). The percent IPP based on flour was the only protein fraction that was highly correlated (r = 0.62, P < 0.0001) with bake water absorption followed by AG in flour (r = 0.30, P < 0.05). Bake mix time was correlated positively with percent IPP based on protein (r = 0.86) but negatively with percent SPP based on protein (r = -0.56, P < 0.0001).

Prediction of alkaline noodle color and polyphenol oxidase activity using near-infrared reflectance spectroscopy of wheat grain, meal, and flour.

S.H. Park, B.W. Seabourn, F. Xie, and O.K. Chung.

Noodle color is an important quality trait to wheat breeders as well as consumers. This study investigated the potential of NIR spectroscopy to predict noodle color and polyphenol oxidase (PPO) content directly from whole grain, meal, and flour. A total of 585 hard winter wheat samples (375 for calibration and 210 for validation) harvested in 2002 and 2003 were used. Reflectance measurements were collected over a wavelength range of 400–2,498 nm. Alkaline noodle dough was made, and color was determined at 0 and 24 hr. PPO activity was also determined from the whole grain, meal, and flour. Unscrambler (v8.0.5), a program for multivariate statistical analysis, was then used to process the spectral data and to develop NIR partial least squares calibration models from the spectra and laboratory data. Calibration models were developed for predicting noodle color (L*, a*, and b* at 0 and 24 hr) and PPO content from grain, meal, and flour. Calibration model R^2 for PPO content were generally and unacceptably lower than those for noodle color. For noodle color, the highest R^2 value was for L* at 24 hr from flour (0.84 and 0.68 for calibration and validation, respectively), with an RPD of 2.46. Other calibration models for noodle color at 0 and 24 hr from whole grain and meal also showed very comparable R^2 values with an even higher RPD. The highest R^2 for a* and b* at 24 hr were 0.82 and 0.84 for calibration, and 0.78 and 0.70 for validation with RPD values of 3.23 and 2.98, respectively. The data suggest that there is a good potential for predicting noodle color using NIR spectra from such basic materials as grain, meal, and flour.

Glucose oxidase effects on wheat flour albumins and gliadins.

M. Tilley.

Chemical oxidants are routinely added to flour to modify rheological properties (shorten mixing time, improve gas retention, lower energy requirement for dough mixing) and enhance bread-making performance (increase loaf volume and improve crumb structure). The elimination of potassium bromate, and possibly other chemical oxidant additives, presents a challenge to the baking industry. Alternative oxidation methods need to be found since industrial baking has been standardized with bromate. Substitution of chemical oxidants with enzymes is a desirable approach because enzymatic reactions are very specific, with little or no reactivity outside of the substrate. Oxidoreducing enzymes such as glucose oxidase (GOX) have been proposed as improvers for the baking industry. The mechanism of improvements caused by GOX is not understood. Following mixing wheat flour with and without the addition of GOX the different protein classes were extracted and analyzed by electrophoresis and size-exclusion HPLC. The most significant effects were observed to occur in the albumin (water-soluble) and gliadin (alcohol-soluble) protein groups. A significant increase in protein concentration and molecular weight distribution was observed in the albumin fraction by SE-HPLC. Further analysis revealed that this is due to changes in gliadin solubility. Gliadins are generally not soluble in water, however the inclusion of GOX in mixing renders the gliadins more water-soluble. The biochemical interactions responsible for this behavior and the possible effects on end-use properties are currently under investigation.

Description of a wheat endosperm peroxidase with potential to catalyze dityrosine formation during dough processing.

M. Tilley, V. Pierucci, and K.A. Tilley.

The water-soluble extract from wheat flour was fractionated using preparative isoelectric focusing and the fractions were tested for the ability to synthesize dityrosine from tyrosine in vitro. The fraction that catalyzed dityrosine also possessed a high level of peroxidase activity. The major protein was purified and the N-terminal amino acid sequence was determined. The sequence was similar to barley endosperm peroxidase BP1. An oligonucleotide probe based on this sequence was used to screen cDNA libraries from developing kernels of wheat and the progenitor *Ae. tauschii*. Resulting cDNAs were identical at the amino acid level and had a high similarity to BP1. These findings support data on the nature of endogenous wheat peroxidase and the potential of peroxidase to catalyze dityrosine formation in dough.

Effects of different emulsifiers on the textural properties and shelf-stability of 100 % whole wheat flour tortillas.

H.P. Akdogan, M. Tilley, and O.K. Chung.

100 % whole wheat (WW) products offer many health benefits by being naturally rich in fiber and bran as well as in B and E vitamins, iron, phytochemicals, and phytoestrogens. 100% WW tortillas have their own sizable market and like other tortilla types their shelf-life and texture play vital importance in consumer acceptance. The literature on 100% WW tortillas is scarce, therefore, this study was performed to evaluate the influence of three different types of emulsifying agents, sodium stearyl lactylate, lecithin, and glyceryl monostearate, on tortilla staling. All samples were subjected to extensibility (tear) tests by using a TA-XT2 Texture Analyzer at days 0, 2, 4, 8, 12, 16, and 20 days of storage. A completely randomized statistical design was chosen. One-way ANOVA was used to analyze the data. No significant difference was found among the means of color attributes of tortillas (L, a, b) or the means of tortilla diameters. The maximum force to tear and gradient (modulus of deformation) were highly correlated to tortilla rollability scores (a scale of 0 to 5 was used, 5 being the most acceptable). Although all emulsifiers improved the shelf-life, lecithin at 2 % resulted in the lowest maximum force to tear at day 0 (softest) and the highest rollability score (3.5/5) at the end of day 20. The control tortillas were the most stretchable (longest distance to tear) at day 0 compared with the tortillas made with emulsifiers. However, at day 20, the control and emulsifier added tortillas did not exhibit a significant difference regarding the distance to tear. Among all three emulsifiers used, lecithin at 2 % level was the most effective to improve the shelf-life and texture of 100 % WW tortillas.

Prediction of polymeric protein content in wheat flour by NIR.

B.W. Seabourn, S.R. Bean, G.L. Lookhart, and O.K. Chung.

Insoluble polymeric proteins (IPP), which are primarily glutenins, are regarded to play an important role in breadmaking, particularly dough strength. A number of studies confirm that IPP are directly related to dough strength. One hundred hard winter wheat flours were provided by the USDA–ARS Hard Winter Wheat Quality Laboratory (HWWQL), Manhattan, KS. They were from wheats harvested at two federal regional performance nurseries (RPN) during the 1993-1995 crop years. The flours were selected using the HWWQL-RPN Relational Database based upon their aggregate milling and baking scores, and then analyzed by high performance liquid chromatography for their gliadin and soluble polymeric protein contents, and by Leco Nitrogen Analyzer for IPP content. Using near-infrared reflectance spectroscopy spectral (NIRS) data and multivariate modeling techniques, gliadin and IPP fractions could be predicted with accuracies acceptable for screening purposes ($R^2 = 0.79$). For IPP, the standard error of cross-validation for the model was sufficiently high ($R^2 = 0.83$) for NIRS to be used as an alternative method for measuring IPP content in flour. Results indicate that NIR analysis of flour for IPP (insoluble glutenin) may be very useful in plant breeding programs and quality laboratories where rapid screening of large numbers of flour samples is needed.

Determination of secondary structural changes in gluten proteins during mixing using FT–HATR spectroscopy.

B.W. Seabourn, O.K. Chung, P.A. Seib, and P.R. Mathewson.

An infrared spectroscopic method was developed to examine changes in the secondary structure of gluten proteins in a flour-water dough system during mixing. Fourier transform horizontal attenuated total reflectance (FT–HATR) mid-infrared spectra of mixed doughs revealed changes in four bands in the amide III region typically associated with secondary structure of proteins: 1,317 (α-helix), 1,285 (β-turn), 1,265 (random coil), and 1,242/cm (β-sheet). The largest band, which also showed the greatest change in second derivative band area (SDBA) during mixing (increasing over time), was at 1,242/cm. The bands at 1,317 and 1,285 also showed an increase in SDBA over time. Conversely, the band at 1,265/cm showed a corresponding decrease over time as the doughs were mixed. All bands reached an optimum (or minimum) corresponding to the proper development of the dough as determined by the mixograph. Increases in α-helical, β-turn, and β-sheet secondary structures during mixing suggest that the dough proteins assume a more ordered conformation, and the decrease of SDBA at 1,265/cm suggests this occurs at the expense of the random coil structural components. These results demonstrate that it is possible, using infrared spectroscopic techniques, to relate the rheological behavior of developing dough directly to changes in the structure of the gluten protein system.

An objective and rapid method to determine dough optimum mixing time for early generation breeding lines using FT–HATR mid-infrared spectroscopy.

B.W. Seabourn, F. Xie, and O.K. Chung.

The traditional method in the U.S. for screening hard winter wheat breeding lines is based upon optimum mixing time (MT) obtained from the mixograph (MIXO), which is an important rheological property of a wheat flour-water (dough) systems. This method is largely time-consuming and somewhat subjective in its interpretation, especially with regard to mixing tolerance. The objective of this study was to investigate the potential of FT–HATR mid-infrared (IR) spectroscopy to objectively predict optimum MT in a flour/water dough from a short duration mixing cycle (1 min). Fifty-five HRWW flours with varying protein contents (8.7–14.2 %) and MT (1.63–7.38 min) were scanned with three replicates for each sample in the amide III region of the mid-IR (4,000–700/cm) by FT–HATR immediately after being mixed with a MIXO for 1 min. The ratio of the second derivative band areas at 1,335/cm (α-helix) and 1,242/cm (β-sheet) was highly correlated to optimum MT as determined by the MIXO ($R^2 = 0.81$). Results obtained from this study indicated that the FT–HATR technique was able to predict optimum MT very early in the mixing process based upon changes in the secondary structure of the dough protein. This method could be the basis for new technology to rapidly and accurately screen wheat samples in early generation breeding lines, and thus save breeders considerable time and expense in the development of new cultivars.

Study of wheat gluten secondary structure conformational changes in frozen dough using FT-HATR mid-infrared spectroscopy.

F. Xie, B.W. Seabourn, O.K. Chung, and P.A. Seib.

Bread-making quality of frozen dough is usually inferior to that of freshly mixed dough. A change in gluten structure during freezing and thawing might be one of the reasons that frozen dough has a poorer end-use performance than fresh dough. We investigated changes in wheat gluten secondary structure resulting from freezing and thawing of flour-water 'model' doughs optimally mixed, using six HRWW flours of varying protein content and optimum mix time. Doughs were scanned in the mid-infrared region of the electromagnetic spectrum using Fourier transform horizontal attenuated total reflectance mid-infrared spectroscopy. Frozen storage time was 0 min, 24 hr, 1 and 2 weeks, and the thawing time was 45 min for all frozen doughs. The protein secondary structures such as β-sheet (1,242/cm), β-turn (1,285/cm), and α-helix (1,317/cm) decreased, whereas random coil (1,265/cm) and α-helix (1,336/cm) increased, in general, with frozen storage time. The greatest changes for all of the secondary structures occurred within the first 24 hr of frozen storage. For each sample, the most significant change occurred with a decrease in beta-sheet structure. Secondary structure changes in gluten after freezing and thawing cycles were opposite from the changes in secondary structure observed during the dough-mixing and development processes. At present, we do not know if the alteration of secondary structure of gluten resulted from the process of freezing, dough relaxation during thawing or a combination of both. Secondary structural characteristics of gluten protein in frozen and thawed doughs were similar to secondary structural characteristics of an undermixed or undeveloped dough.

Measurement of wheat starch granule size distribution using image analysis and laser diffraction technology.

J.D. Wilson, D.B. Bechtel, T. Todd, and P.A. Seib.

Starch was isolated from flour of four wheats representing hard red winter (Karl), hard red spring (Gunner), durum (Belfield 3), and spelt (WK 86035-8) wheat classes. Digital image analysis (IA) coupled to light microscopy was used to determine starch size distributions where the volume of granules were calculated as spherical particles or oblate spheroids. Starch granules were classified into three size ranges, A-type granules (> 15 µm), B-type granules (5–15 µm), and C-type granules (< 5 µm). An error was noted in using digital image analysis because the perimeter of some granules touch the edge (PTE) of the field being analyzed. PTE granules are traditionally treated in IA by eliminating them, and ignoring the errors, or by eliminating half the PTE particles in the calculations. The error is highest for the largest granules and the distribution is skewed towards the smaller sized granules. To correct for this error the PTE granules were manually replaced into the field by measuring their diameters and entering them into the database. The results showed differences in the starch-size distributions between the classes of wheat evaluated, as well as the method of analysis. Another factor found to affect the distribution data was the total number of granules counted per analysis, the 'concentration' effect. In general, the IA of 5,000 versus 1,000 granules increased the proportion of A-type granules in a distribution. Four laser diffraction sizing instruments were used to measure granule distributions of the four classes of wheat. The minimum sized granules detected in volume % distribution curves were between 0.4 and 1.2 µm, whereas the largest granules detected were 44 to 62 µm, dependent on the instrument and variety of wheat starch. Laser diffraction sizing compared to IA resulted in a ~40 % underestimation of the A-type granule diameter and ~50 % underestimation of the B-type granule diameter. A correction factor (adjustment) was developed from IA data to correct laser diffraction size analysis. Laser diffraction data correlations before adjustments to image analysis data, ranged from R^2 = 0.02 (power of ns) to 0.55 (power of ***). After adjustment, these correlations improved to a range of R^2 = 0.72 (power ***) to 0.93 (power of ***) depending on the class of wheat starch evaluated.

Laser diffraction sizing: studying wheat flour and starch particle sizes.

J.D. Wilson and D.E. Bechtel.

Laser diffraction sizing (LDS) was used to measure particle size distributions of wheat flour and isolated starch to determine if the method could be used as a component for predicting end-use quality. Five hard red winter and five soft red winter wheats were milled into flour from which starch was isolated. Flour particle size distributions were measured dry as well as flour suspended in isopropanol (AACC Method 55-40). Analysis using isopropanol as a suspension fluid caused smaller particles (<8 µm in diameter) to be released from flour. Use of isopropanol caused a shift to larger particle sizes between 8 and 400 µm/m in comparison to dry analysis. Isopropanol also caused clumping with spurious particles found between 250–400 µm. LDS of isolated starch showed a separation of A- and B-type granules between 9.8 and 10.8 µm for the soft wheats and between 8.2 and 9.8 µm for hard wheats. Hard wheats had a larger volume of starch in the A-type fraction, whereas the soft wheats had more starch in B- and C-type fractions. A demarcation between the B- and C-type starch granules was only observed for the soft wheats and that was when data was presented as percent surface area. Flour and starch differences were observed between wheat classes as well as among wheats within a class, LDS may prove to be a valuable tool in helping predict wheat end-use quality, an important goal of the grain industry.

Rapid isolation of sorghum and other cereal starches using sonication.

S.H. Park, S.R. Bean, J.D. Wilson, and T.J. Schober.

High intensity ultrasound (sonication) was investigated as a method to rapidly purify starch from sorghum and other cereal grains. To improve the process, buffers were optimized to solubilize sorghum proteins in combination with the sonication. Protein content and starch color were determined to evaluate the efficiency of the extraction process. Sonication times, SDS concentration, different types and concentrations of reducing agents (sodium metabisulfite, dithiothreitol, and mercaptoethanol), and centrifugation speeds of the starch washing procedure were tested. Protein content of isolated sorghum starch was reduced to 0–0.14 % (db) after a 2-min sonication (using any of the reducing agents tested). Sodium metabisulfite was chosen as the preferred reducing agent because of its lower toxicity and odor compared to other reducing agents tested. The optimum conditions for producing high purity sorghum starches (0.06% protein) were obtained using the following conditions: 2 min sonication time with 12.5 mM sodium borate buffer, pH 10 containing 0.5 % SDS (w/v), and 0.5 % sodium metabisulfite (w/v) using 1,500 rpm centrifugation speed during starch washing. Starches separated by this method showed significantly less protein content and b values (yellowness) compared with starches separated by enzymatic methods or methods using NaCl solutions and protein extraction buffers with multiple washing steps, both of which take several hours to complete. Differential scanning colorimetry thermogram values for starches isolated by three different methods showed similar patterns except starches obtained with the enzymatic method had slightly higher values of To, Tp, and change of H. Other cereal starches from whole wheat meal, wheat flour, corn, rice, and barley also were rapidly obtained using sonication.

Investigation of conditions for rapid cereal starch isolation using sonication.

S.H. Park, S.R. Bean, and J.D. Wilson.

Cereal starches have been isolated by hand-washing, wet-milling, or enzymatic methods (EM). However, these procedures are often tedious and time-consuming. Therefore, the objectives of this study were to develop new, rapid and reproducible starch isolation methods using sonication. Decorticated sorghum flour was sonicated in a pH 10.0 buffer with 2 % SDS and 2 % reducing agent at a solvent to sample ratio of 20:1, followed by water-washing. Sonication times (2, 4, 6, 8, and 10 min) and different reducing agents (ME, DTT, and sodium metabisulfite) were tested. Protein content of starch was only 0.35–0.45 % (db) after a 2-min sonication (using any reducing agent) and was reduced further to 0.15–0.30 % (db) using longer times. The sonicated starch was comparable to starch obtained by the EM which takes several hours to complete. Starch yield (db) and protein content (db) were 74 and 0.83 %, respectively, for the EM starch, and 74 and 0.42%, respectively, for the sonicated starch. The color of starch obtained by sonication showed a similar L (brightness) value, (93.9 versus 93.8) and lower b (yellow) value (2.99 versus 3.80) than the EM starch. Physicochemical properties of starches from different types of sorghum (hard versus soft, normal versus waxy) and the purification of starch from other cereals will be presented. Wheat, corn, rice, and barley starches also were rapidly isolated using this procedure.

Protein composition and fundamental rheological properties of spelt cultivars as a model of gluten quality.

T.J. Schober, S.R. Bean, and M. Kuhn.

Spelt is an ancient relative of modern bread wheat. Recently, many spelt cultivars have been bred by crossing spelt and modern wheat cultivars. Consequently, a wide range of gluten properties exist in spelt, from very primitive to similar to modern bread wheat. This wide quality range makes spelt an interesting research object for the examination of the influence of protein composition on fundamental rheological gluten properties. Studies were conducted using 25 European spelt cultivars grown at two locations. Proteins were fractionated into insoluble/soluble polymeric proteins and gliadins by a combination of selective extraction, size exclusion HPLC, and nitrogen combustion. Wet glutens were isolated and characterized by fundamental rheological methods including dynamic oscillatory measurements and creep tests. The ranges were 1.6–3.9 kPa, 30.9–40.4 degrees, 6.1–30.5 10^{-3}/Pa, and 41.7–67.0 % for complex modulus, phase angle, creep compliance, and relative recovery, respectively. Moisture content of the wet glutens, wet-gluten content, and SDS-sedimentation volume also were determined and ranged 61.7–66.0%, 21.4–57.1%, and 9–68, respectively. Rheological properties were dependant on cultivar as well as on environment. Cluster analysis performed with the gluten quality data across environments resulted in three groups of spelt cultivars (1. gluten properties similar to modern bread wheat; 2. typical spelt; and 3. poor gluten quality). Significant correlations between the protein fractions and fundamental rheological properties were found. Overall, spelt is a good model system for an in depth understanding of gluten.

Combination of fundamental rheology and size-exclusion high-performance liquid chromatography in the study of gluten proteins from spelt wheat cultivars.

T.J. Schober, S.R. Bean, and M. Kuhn.

The aim of this study was to understand protein chemistry behind gluten quality of spelt, classify European spelt cultivars based on gluten quality, and compare their protein composition to modern wheat. Gluten quality of two sets of 25 spelt cultivars was studied by fundamental rheology (dynamic oscillatory and creep tests), SDS sedimentation test, moisture content of the wet gluten, and wet-gluten content. These data were compared to the results of size-exclusion HPLC analyses. Significant correlations indicated that the amount of insoluble polymeric proteins (IPP) contributed resistance to deformation in creep tests, elasticity in oscillatory and creep tests, and swelling capacity of the gluten. Gliadins had the opposite effects, whereas the contribution of soluble polymeric proteins (SPP) depended on the type of test. In creep tests, (strain 0.3–1.5) SPP acted similar to gliadins, in oscillation (strain 0.001) they tended to increase elasticity. Spelt, in comparison to HRWWs, was characterized by lower IPP, but higher SPP and gliadins, resulting in softer and less elastic glutens. A wide variation in gluten quality was found within spelt and three groups could be identified by cluster analysis (closer to modern wheat, typical spelt and poor quality).

Detecting insect fragments in flour.

J. Perez-Mendoza, J.E. Throne, E.B. Maghirang, F.E. Dowell, and J.E. Baker.

Primary pests of stored cereals that develop and feed inside grain kernels are the main source of insect fragments in wheat flour. The Food and Drug Administration (FDA) has set a defect action level of 75 or more insect fragments per 50 gram of flour. The current standard flotation method for detecting insect fragments in flour is very labor intensive and expensive. We investigated the potential of near-infrared spectroscopy (NIRS) to detect insect fragments in wheat flour at the FDA defect action level. Fragments counts with both the NIRS and the standard flotation methods correlated well with the actual number of fragments present in flour samples. However, the flotation method was more sensitive below the FDA defect action level than the NIRS method. Although the flotation method is very sensitive at the FDA action level, this technique is time consuming (almost 2 h/sample) and expensive. Although NIRS currently lacks the sensitivity of the flotation method, it is rapid, does not require sample preparation, and could be easily automated for a more sophisticated sampling protocol for large flour bulks. Therefore, this method should be reexamined in the future because NIRS technology is rapidly improving.

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Wheat rusts in the United States in 2005.

Wheat stem rust (*Puccinia graminis f. sp. tritici*). The first reports of wheat stem rust were in late April, when trace levels of infection were found in plots of susceptible wheat at Giddings in central Texas. The next report of wheat stem rust was in late May, in plots of susceptible wheat at Castroville in south Texas that had high severity levels.

In early July, susceptible winter wheat plots had trace to 10 % severities at the soft dough stage in east central Minnesota. In mid-July, trace levels of stem rust were found on the susceptible spring wheat cultivar Baart in south central Minnesota and in an east central South Dakota plot of the susceptible cultivar Morocco. In late July, wheat stem rust was found in plots of Baart at Crookston in northwestern Minnesota. Stem rust was not found on any of the commonly grown cultivars in the spring wheat region. All current spring wheat cultivars grown in the region are resistant to the predominant stem rust race.

Stem rust on barberry. Aecial infections on common barberry in southeastern Minnesota in 2005 were heavy, similar to the level of infections in 2003 and 2004. Light aecial infections were found on barberry in Wisconsin. Aecial infections from Minnesota and Wisconsin were mostly due to *P. graminis* f. sp. *secalis* (the form attaching rye) as *P. graminis* f. sp. *tritici* (the form attacking wheat) or *P. graminis* f. sp. *avenae* (attacking oats) was not identified from the barberry samples. Common barberry plants with aecial infections were also found in the state of New York, but isolates did not infect wheat, rye or oat.

Virulence of wheat stem rust. Relatively few collections of wheat stem rust were made in 2005 due to the rarity of stem rust infections, which may indicate that many of the winter and spring wheat cultivars possess effective resistance to the predominant race. Race QFCS was the predominant race, identified on 21 of the 24 collections. One collection from Texas was race TTTT. Race QCCS, previously identified from collections in Washington, was found in Idaho (Table 1).

Table 1. Races of *Puccinia graminis* f. sp. *tritici* identified from wheat in 2003. Pgt race code after Roelfs and Martens (Phytopathology **78**:526-533). Race QCCS virulent to *Sr5, 9a, 9d, 9g, 10, 17,* and *21*; QFCS virulent to *Sr5, 8a, 9a, 9d, 9g, 10, 17,* and *21*; and TTTT virulent to *Sr5, 6, 7b, 8a, 9a, 9b, 9d, 9e, 9g, 10, 11, 17, 21, 30, 36,* and *Tmp*. Set four consists of *Sr9a*, *Sr9d*, *Sr10*, and *SrTmp*.

State	Collections	Isolates	Percentage of isolates of race Pgt QCCS	QFCS	TTTT
TX	10	10		9	1
SD	1	1		1	
MN	11	11		11	
ID	2	2	2		
U.S. Total	24	24	2	21	1

Wheat leaf rust (*Puccinia triticina*).

Southern Plains. In late January, leaf rust infections were found in central Texas plots. The most severe rust was reported on the cultivars TAM 110 and Cutter. Warm temperatures and wet weather in February allowed for good leaf rust development. In mid-February, cultivars such as Jagger in southern and central Texas varietal plots had 80 % severities. By late February, leaf rust was widespread across central Texas in fields of cultivars Coronado, Cutter, and Jagalene. Some of the fields in central Texas were sprayed for rust control (Fig 1). In early March, leaf rust was increasing rapidly in south Texas plots at Castroville, and cultivars like Cutter, Jagalene, and TAM 107 had 40–60 % severity ratings. Thunderbolt, Overley, both with *Lr41*, had little rust. In early March, leaf rust was at high severity levels in a nursery at McGregor in central Texas. At the same location, plots of Cutter that were planted in early September had completely brown leaves due to leaf rust. In mid-March leaf rust was the major disease of wheat in central Texas. Temperatures and rain were ideal for leaf rust development throughout Texas in March.

In mid-January, leaf rust was found in southern Oklahoma and conditions were conducive for sporulation, spread and development of the disease. In mid-February pustules were observed on lower leaves of susceptible varieties, which indicated that leaf rust had survived the winter in much of Oklahoma. By the first week in March, pustules were observed in the wheat varietal plot at Stillwater, Oklahoma.

In late March in southern, central, and northern Texas, low to moderate levels of leaf rust infections were found in most commercial wheat fields. High severities (80 %) of leaf rust were observed on susceptible cultivars in nursery plots and trace-20 % severity levels were found in wheat fields. In late March, in southern Oklahoma, fields had high severity levels of leaf rust, but severity levels were much lower in north central Oklahoma.

In mid-April, leaf rust was found in the Great Plains from Texas to Nebraska (Fig..1, p. 155). During the first week in April, leaf rust was found on the mid and upper canopy leaves of susceptible cultivars in central and southern Oklahoma. In early April, high levels of leaf rust were found in variety trails and fields in the panhandle of Oklahoma, which is unusual since low moisture conditions in this area usually are not conducive for rust to develop.

In late April, plots of susceptible wheat cultivars had leaf rust severities up to 80 % in the area from central Texas to the Florida panhandle. In late April in central Texas, susceptible cultivars had moderate to severe rust infections, while in northern Texas wheat at milk stage had light to moderate leaf rust infection (Fig. 1, p. 155). By the last week in April, 100 % leaf rust severities were observed on flag leaves of *Ae. cylindrica* (common goatgrass) growing in roadside ditches in north central Texas. In central Texas and east central Louisiana, fields that had been sprayed with fungicides had 40 % leaf rust severities. By late April, leaf rust was increasing throughout Oklahoma. Cultivars such as 2174, Jagger (*Lr17*), and Jagalene (*Lr24*) were heavily rusted and there was some yield reduction. During the second week in May, moderate levels of leaf rust were reported in central Texas and low levels in the Panhandle area (Fig. 1, p. 155). In north central Texas, stripe rust was more common at the boot and heading growth stages, but leaf rust was more prevalent at the dough stage.

In early May, plots and fields of susceptible wheat in Oklahoma had 60–90 % severities. In mid-May, flag leaves of *Ae. cylindrica* growing in roadside ditches in north central Oklahoma had 60 % leaf rust severities.

In mid-May, leaf rust in the southern Great Plains was not as severe as last year, because the cooler temperatures in late April and early May slowed leaf rust development.

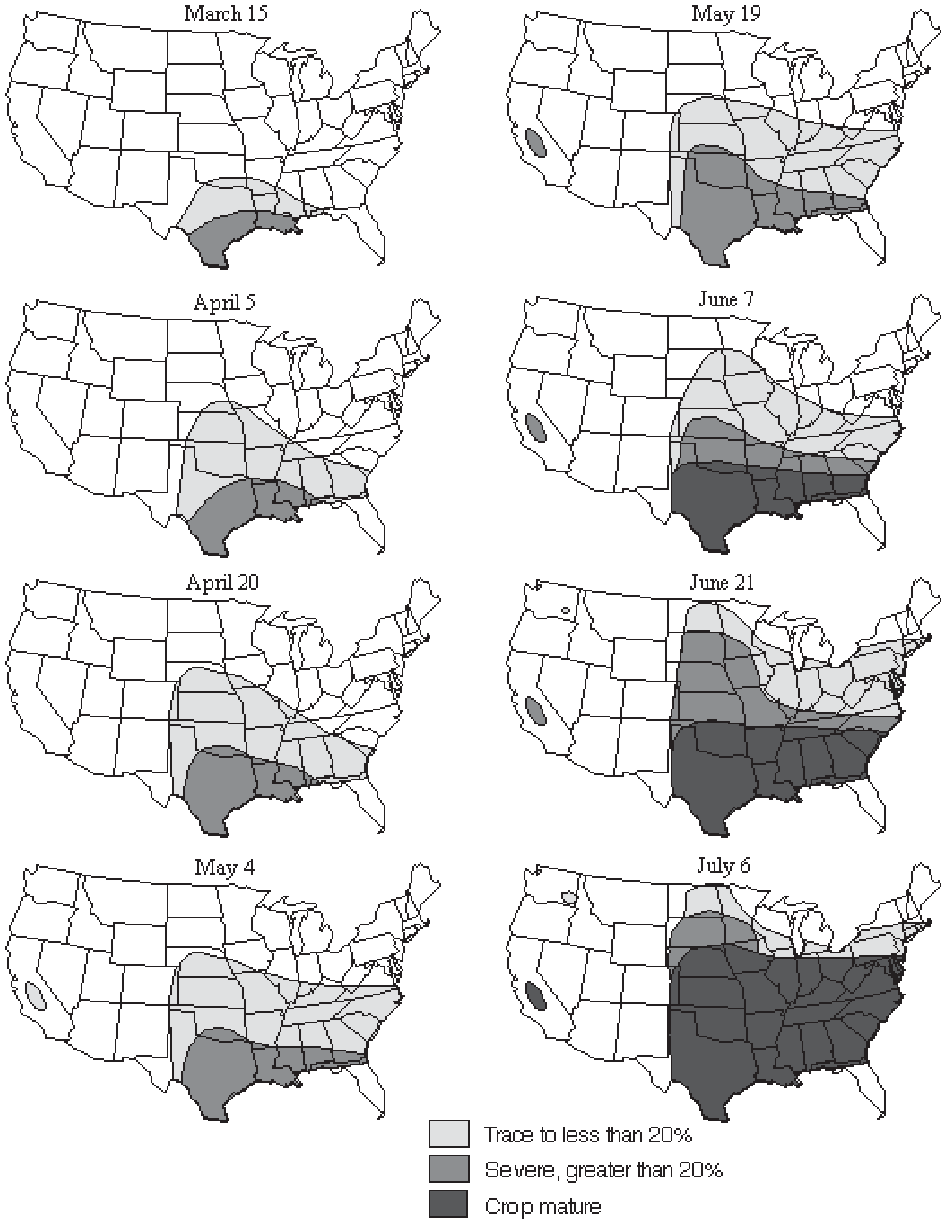

Fig. 1. Leaf rust severities in wheat fields in 2005.

Central Plains. In late March, over wintering leaf rust infections were observed on lower leaves in southern Nebraska. Leaf rust over wintered in Colorado throughout the eastern half of the state, but dry conditions in the spring slowed leaf rust development.

In mid-April, trace levels of leaf rust were found across south central to southwest Kansas. In mid-May, plots and fields of susceptible wheat in south central Kansas had 40 % severities while in central Kansas fields 5 % severities were observed. In south central Kansas wheat plots, 40 % rust severities were observed on Jagger, Jagalene, Cutter, and Karl 92 cultivars. No leaf rust was observed on Overley, Deliver, and Santa Fe. In late May, leaf rust was found on susceptible cultivars in fields in northern Kansas. Hot dry weather slowed the rust development in Kansas and Oklahoma in late May**.** A two percent loss due to wheat leaf rust was estimated for Kansas in 2005 (Table 4, p. 179).

In early June, traces of leaf rust were found in wheat fields in southern Nebraska. In mid-June wheat leaf rust was found in winter wheat fields from southern Nebraska to North Dakota (Fig. 1). Rust severities on flag leaves in fields ranged from 20 % in Nebraska to trace levels in North Dakota fields. In late June, susceptible winter cultivars such as Jagalene in western Nebraska had 60 % rust severities.

Northern Plains. On 11 May, leaf rust infections that had over wintered were found on the lowest leaves of winter wheat plants of the susceptible cultivar Cheyenne at the Rosemount Experiment Station in east central Minnesota. In early June, leaf rust was increasing in winter wheat in southern Minnesota; susceptible cultivars had severities of 20–60 % on lower leaves and 5–10 % on flag leaves. The spring wheat crop had trace to 10 % levels of leaf rust infections on lower leaves. In early June, rain and warm temperatures were ideal for the increase and spread of leaf rust in the north central region.

Trace amounts of leaf rust were found on winter wheat lines in plots at Brookings in east central South Dakota in early June. Trace levels of leaf rust infections were also found in spring wheat in the Red River Valley of Minnesota in early June.

In late June in susceptible winter cultivars such as Jagalene, in east central Minnesota and central South Dakota had 60 % rust severities, but the resistant cultivars had only trace levels of infections on the flag leaves (Fig. 1, p. 171). In late June, susceptible spring wheat cultivars in southern Minnesota plots had 60 % rust severities with most infections on the lower leaves.

In early July, flag leaves of winter wheat in southeastern North Dakota fields had leaf rust severities up to 90 %. In mid-July, flag leaves of spring wheat cultivars in fields from north central South Dakota to west central Minnesota had trace–60 % leaf rust severities. Many wheat fields were sprayed with fungicide to prevent losses due to rust and scab. In 2005, 2–4 % losses to wheat leaf rust were common in the northern spring wheat states (Table 4, p. 179).

In mid July wheat leaf rust was widespread throughout North Dakota and northwest Minnesota. Susceptible spring wheat cultivars such as Oxen, Ingot, Hanna, and Reeder, had leaf rust severities of 60 % or greater in southeast and central North Dakota. The heavy leaf rust infections combined with high temperatures killed the flag leaves of these cultivars. Alsen, the most commonly grown cultivar in North Dakota, had good to moderate resistance to leaf rust, and the cultivars Knudson, Steele, and Glenn were highly resistant. Leaf rust was at lower levels in northeast North Dakota and northwest Minnesota, being mostly found on the lower leaves of susceptible cultivars. By the end of July susceptible wheat cultivars in northwest Minnesota had leaf rust severities of 80–100 %.

This year leaf rust was widespread in the upper Midwest in spring and winter wheat. Rust inoculum arrived from the south in mid-May through mid-June with rain showers. Many of the wheat fields in the spring wheat region were treated with fungicide, which prevented losses due to leaf and stripe rust. However, in unsprayed fields of susceptible cultivars leaf rust losses were significant.

Southeast. In late January, heavy leaf rust (> 5 %) was observed in varietal plots in a nursery at Baton Rouge. By mid-February, leaf rust was severe on susceptible cultivars throughout the state in plots and fields. Temperature and moisture conditions in February and March were ideal for rust development throughout the southern red winter wheat region.

In late February, leaf rust was severe in fields of susceptible varieties in southwest Arkansas and some fields were sprayed for rust control. By mid-March, leaf rust infections were more severe and widespread than usual in southwestern Arkansas. In late March, susceptible cultivars in Baton Rouge, Louisiana, plots had 50 % leaf rust severities. Some of the fields infected with rust were sprayed for rust control in the southeastern U.S.

In early April from central Louisiana through Alabama to Georgia, moderate levels of leaf rust infections were observed in research plots and fields. Susceptible cultivars in south central Louisiana and southern Alabama nurseries had up to 60% severities. In late April, southeastern Alabama varietal plots had 80 % leaf rust severities, whereas 100 miles to the north only trace amounts of leaf rust were observed on the same varieties. In late April in east central Arkansas plots of susceptible cultivars, trace levels of leaf rust were on lower leaves while upper leaves did not have any leaf rust. By late May, 100 % rust severities were reported in plots of susceptible cultivars in central and southwestern Georgia.

East. In late April, traces of leaf rust were found in nursery plots in eastern Virginia at Warsaw and in fields in northeastern North Carolina. During the second week in May, traces of leaf rust were found in fields in north central Tennessee. In late May, 15 % leaf rust severities were observed on flag leaves of Saluda and McCormick cultivars in northeastern North Carolina research plots. Soft red winter wheat cultivars in eastern Virginia in late May had trace to 90 % severities.

In early June, leaf rust severities were low across the state of Virginia. However, a severe leaf rust epidemic occurred in a nursery at Warsaw, Virginia with multiple races that had virulence to *Lr24* and *Lr26*. Cultivars with *Lr26*, e.g., USG 3209 and Sisson, had high leaf rust severities.

In mid-June, trace levels of leaf rust were found in south central New York plots. In early July, light levels of wheat leaf rust were found in western New York.

Mideast. In early June**,** leaf rust was found in fields from southern Illinois at 20 % severity to trace levels on flag leaves in northwestern Ohio, northwestern Indiana, and south central Wisconsin. In much of the Ohio Valley and Wisconsin, dry conditions in May and June slowed rust development.

California. In late April, traces of leaf rust were detected in yield trials in the Central Valley of California. In mid-May, susceptible cultivars in the San Joaquin Valley nurseries in California had 60 to 100 % severities. In late May, 70 % leaf rust severities were observed in a field of the cultivar Blanca Grande in Kern County, California.

Pacific Northwest. In early June, low levels of leaf rust was found in winter wheat in south central Washington. In mid- June, wheat leaf rust was at high levels in nurseries near Mt. Vernon in northwestern Washington and was increasing in central Washington, mainly in seed-production fields under irrigation. In early July, low levels of wheat leaf rust were found in southwestern Idaho and east central Washington.

Mexico. In the second week in March, leaf rust was present in low amounts on durum wheat and bread wheat throughout the Yaqui Valley. Plots of Morocco had light (5 %) levels of leaf rust. Isolated areas of high leaf rust infection were found on durum wheat.

Wheat leaf rust virulence. In 2005, 72 races of wheat leaf rust were found in the U.S. Races with virulence to *Lr24* increased in frequency throughout all wheat growing regions of the U.S, except for Washington state. Virulence to *Lr24* was highest throughout the Great Plains region, where a number of winter wheat cultivars have *Lr24*. Races with virulence to *Lr9* were found in all regions except for California and Washington State. Virulence to *Lr9* was highest in Texas and Oklahoma. Virulence to *Lr26* occurred in all regions of the U.S. and was highest in the northeast region. Virulence to *Lr16* occurred in all regions except for the northeast and was highest in the spring wheat region of Minnesota and North and South Dakota. Virulence to *Lr17* was found in all regions of the U.S., with the highest frequency in the Northeast region. Virulence to *Lr18* occurred in all regions, except California and was highest in the southeast region where a number of SRWWs have this gene. Virulence to *Lr21* was not found in any region, whereas virulence to *Lr41* was found in all regions except the Ohio Valley and California. Virulence to *Lr42* was found in all regions except California.

In the southeast, the most common race, TCRKG (10.8 %), had virulence to *Lr2a, Lr26,* and *Lr18.* In the Northeast, the most common race MCDSB (41.7 %) had virulence to *Lr26* and *Lr17*. In the Ohio Valley, the most common race TDBGG (14.8 %) had virulence to *Lr2a* and *Lr24*. In Texas and Oklahoma, the most common race TDBGH (14.5 %) had virulence to *Lr2a, Lr24,* and *Lr42*. In Kansas and Nebraska, the most common race MCDSB (13.2 %) had virulence to *Lr26* and *Lr17*. In Minnesota, South Dakota, and North Dakota, the most common race TJDGH (11.8 %) had virulence to *Lr2a, Lr16, Lr24, Lr17,* and *Lr42*. In California, the most common race MBDSB (35 %) had virulence to *Lr17*. In Washington state, the most common race MBJJG (50 %) had virulence to *Lr11* and *Lr17*.

Since 2003, races that are avirulent to *Lr14a* and virulent to *Lr1, Lr2a, Lr2c, Lr3,* and *Lr24* have increased in frequency throughout the U.S. Previous to the detection of these races, virulence to *Lr14a* had been near 100 % in all regions of the U.S. for over 20 years. These races also are unique since they are avirulent to a second, previously undetected, gene in the Thatcher line with *Lr1*. Some of these races are also virulent to *Lr16*, *Lr17*, and *Lr26*. Virulence to *Lr41* was most common in races that were also virulent to *Lr9* and *Lr24*. These races were found mostly in Texas and Oklahoma.

Wheat stripe rust (*Puccinia striiformis* f. sp. *tritici*).

Southern Plains. During the second week in February, low levels of stripe rust were found scattered throughout the varietal plot in central Texas at College Station. Weather conditions were ideal for stripe rust development. In mid-February in south Texas at Castroville, stripe rust was severe on susceptible cutlivars, whereas more resistant cultivars had low levels of rust. In early March, stripe rust was increasing rapidly and was widespread throughout the nursery at Castroville (Fig. 2, p. 174). Most infections sites were on lower leaves, with a few on the upper leaves. In south Texas fields were sprayed for rust control.

In late March, wheat stripe rust infections were at low to moderate severities in wheat fields in southern and central Texas. Stripe rust severities ranged from trace levels to 80 % severity in plots. This year, stripe rust was found at more locations and the weather conditions were more favorable for rust development than last year in Texas. However, in late March, higher day and night temperatures had slowed stripe rust development in southern and central Texas plots and fields.

During the third week in March, moderate levels of stripe rust were found throughout southern Oklahoma.

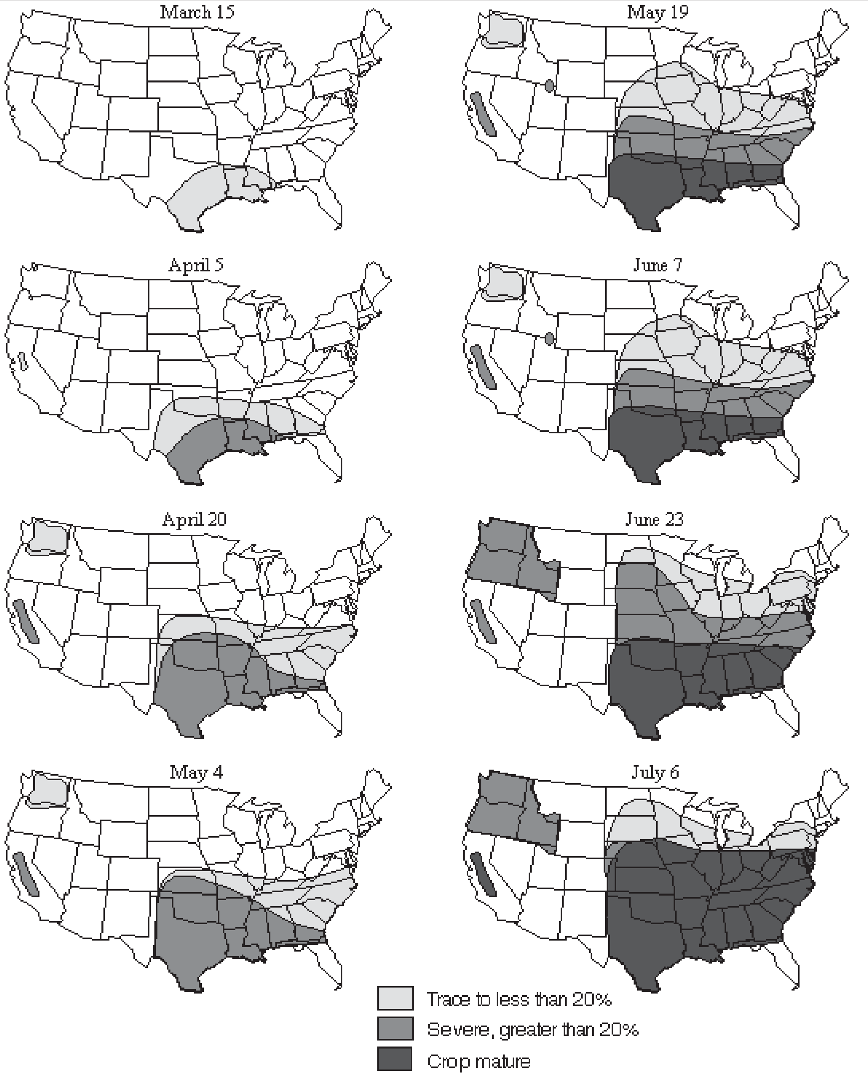

Fig. 2. Stripe rust severities in wheat fields in 2005.

In early April, stripe rust was reported from central Texas, Louisiana, and Arkansas to southern Alabama (Fig. 2). In the first week of April, susceptible entries had severity levels of 100 % in stripe rust-monitoring and breeding nurseries throughout Louisiana and central Texas. In early April, in southern Oklahoma, fields of 2174 and OK 102 had severe stripe rust and were sprayed for rust.

In mid-April, stripe rust was increasing throughout the Texas Panhandle (Fig. 2) and by late April most plots of susceptible cultivars had rust severities over 80 % on flag leaves. In north central and central Texas, stripe rust was most common in April but by mid-May the warmer temperatures had caused stripe rust development to cease.

In late April, stripe rust was at moderate to severe levels in north central Texas and Oklahoma plots and fields. On 30 April, in a wheat-breeding nursery at Lahoma, in north central Oklahoma, the cultivars Custer, OK101, and 2137 had 80 % stripe rust severities. In the same nursery, Jagger and Jagalene had trace to 5 % stripe rust severities. In late April, Jagger and Jagalene in north central Texas had 30–40 % stripe rust severities.

In Oklahoma by mid-May, dry and warm weather had slowed stripe rust development throughout the state. Stripe rust did cause yield reductions in much of the wheat producing areas of Oklahoma (Table 4, p. 179).

This year, stripe rust infections in the southern U.S. were more severe and extensive than last year due to more initial inoculum sources of infection and cooler than normal temperatures in early spring.

Central Plains. In mid-April in Kansas, trace levels of stripe rust were found in south central and southwestern regions. In early May, a field of Jagger at heading stage in south central Kansas had 30–40 % stripe rust severity. This was among the first reports of increased stripe rust severity levels on Jagger, Jagalene, and Cutter. In mid-May, wheat stripe rust was prevalent in much of Kansas at varying degrees of severity. Stripe rust was most severe in the southern and western areas of the state. Resistant cultivars such as Overley, Cutter, and

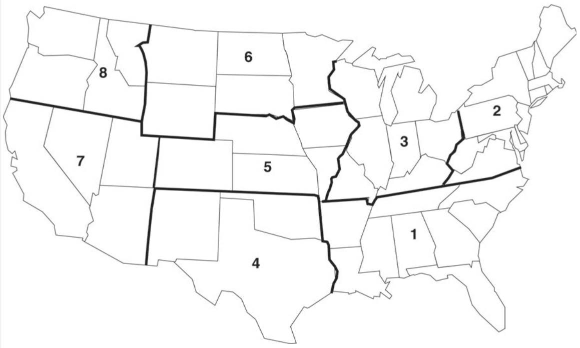

Fig. 3. Agroecological areas for *Puccinia tricina*.

TAM 111 were still resistant. In some areas of Kansas, the more susceptible cultivars such as 2137, OK102, and Trego had high levels of stripe rust. In 2005, the estimated overall loss to wheat stripe rust in Kansas was 8.0 %, which relates to a 34 x 10^6 bushel loss (Table 4, p. 179).

In mid-May, wheat stripe rust was severe in central Nebraska plots and light in east central Nebraska plots. In early June, stripe rust was widespread from northern Kansas and across Nebraska and many fields were sprayed to

Table 2. Races of *Puccinia triticina* in the U.S. in 2005 determined by virulence to 20 near-isogenic lines of Thatcher wheat with leaf rust-resistance genes. Differentials used were 1a, 2c, 3, 9, 16, 24, 26, 3ka, 11, 17, 30, B, 10, 14a, 18, 21, 28, 41, 42. An * indicates less than 0.6 %. For area designations, see Fig. 3 (p. 174).

Race	Virulence combination (ineffective *Lr* genes)	SE		NE		OH Valley		TX–OK		KS–NE		MN SD ND		CA		WA		U.S. Total	
		#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
BBBDB	14a	1	*	0	0	0	0	0	0	0	0	1	*	0	0	0	0	2	0.3
MBBJG	1,3,10,14a,28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	25	2	0.3
MBDSB	1,3,17,B,10,14a	6	4	2	8	3	11	9	4	1	2	6	2	7	35	1	13	35	4.4
MBJJG	1,3,11,17,10,14a,28	1	*	0	0	0	0	0	0	0	0	0	0	0	0	4	50	5	0.6
MBRKG	1,3,3ka,11,30,10,14a,18,28	12	8	0	0	0	0	0	0	2	3	0	0	0	0	0	0	14	1.8
MBSJB	1,3,3ka,11,17,10,14a	0	0	0	0	0	0	0	0	0	0	0	0	2	10	0	0	2	0.3
MBTSB	1,3,3ka,11,17,30,B,10,14a	1	*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.1
MCDSB	1,3,26,17,B,10,14a	15	10	10	42	0	0	25	11	9	13	8	3	1	5	0	0	68	8.5
MCDSG	1,3,26,17,B,10,14a,28	0	0	0	0	0	0	2	1	0	0	1	*	2	10	1	13	6	0.8
MCPSC	1,3,26,3ka,17,30,B,10,14a,42	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0.3
MCRKG	1,3,26,3ka,11,30,10,14a,18,28	30	19	0	0	0	0	1	*	0	0	1	*	0	0	0	0	32	4.0
MCTSG	1,3,26,3ka,11,17,30,B,10,14a,28	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	2	0.3
MDDSB	1,3,24,17,B,10,14a	0	0	0	0	0	0	2	1	0	0	1	0*	0	0	0	0	3	0.4
MDGJH	1,3,24,11,10,14a,28,42	0	0	2	8	0	0	0	0	0	0	0	0	0	0	0	0	2	0.3
MDNSB	1,3,24,3ka,17,B,10,14a	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	2	0.3
MFBJG	1,3,24,26,10,14a,28	0	0	2	8	2	7	0	0	0	0	0	0	0	0	0	0	4	0.5
MFDSB	1,3,24,26,17,B,10,14a	0	0	0	0	0	0	8	4	0	0	0	0	0	0	0	0	8	1.0
MFGJG	1,3,24,26,11,10,14a,28	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0.5
MFGJH	1,3,24,26,11,10,14a,28,42	8	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	1.0
MFPSB	1,3,24,26,3ka,17,30,B,10,14a	2	1	0	0	0	0	2	1	0	0	0	0	0	0	0	0	4	0.5
MFPSC	1,3,24,26,3ka,17,30,B,10,14a,42	2	1	0	0	3	11	24	11	5	7	27	10	4	20	0	0	65	8.2
MFPSH	1,3,24,26,3ka,17,30,B,10,14a, 28,42	0	0	0	0	0	0	3	1	0	0	0	0	0	0	0	0	3	0.4
MHDSB	1,3,16,26,17,B,10,14a	0	0	0	0	0	0	0	0	0	0	0	0	4	20	0	0	4	0.5
MJBJH	1,3,16,24,10,14a,28,42	0	0	0	0	0	0	0	0	0	0	1	*	0	0	0	0	1	0.1
MLDSB	1,3,9,17,B,10,14a	4	3	0	0	2	7	8	4	4	6	6	2	0	0	0	0	24	3.0
SBDBG	1,2a,2c,17,28	0	0	0	0	0	0	4	2	0	0	0	0	0	0	0	0	4	0.5
SBDDB	1,2a,2c,17,14a	0	0	0	0	0	0	1	*	2	3	1	*	0	0	0	0	4	0.5
TBBGG	1,2a,2c,3,10,28	6	4	0	0	0	0	0	0	0	0	2	1	0	0	0	0	8	1.0
TBBJG	1,2a,2c,3,10,14a,28	1	*	0	0	0	0	4	1	3	4	9	3	0	0	0	0	17	2.1
TBDGH	1,2a,2c,3,17,10,28,42	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	2	0.3

control the disease. In mid-June, susceptible cultivars in winter wheat plots and fields in the panhandle of Nebraska had 60 % rust severities, but hot temperatures at the end of June stopped further rust development.

Northern Plains. In late May, traces of wheat stripe rust were found in winter wheat plots in east central Minnesota and south central South Dakota. Infections were mostly on the lower leaves. In early June, stripe rust infections were found in east central Minnesota winter wheat plots on flag leaves. In early June, trace amounts of stripe rust were found in spring wheat fields throughout North Dakota and in spring wheat plots in south central Minnesota. Soft red winter

Table 2 (continued). Races of *Puccinia triticina* in the U.S. in 2005 determined by virulence to 20 near-isogenic lines of Thatcher wheat with leaf rust-resistance genes. Differentials used were 1a, 2c, 3, 9, 16, 24, 26, 3ka, 11, 17, 30, B, 10, 14a, 18, 21, 28, 41, 42. An * indicates less than 0.6 %. For area designations, see Fig. 3 (p. 174).

Race	Virulence combination (ineffective *Lr* genes)	SE		NE		OH Valley		TX–OK		KS–NE		MN SD ND		CA		WA		U.S. Total	
		#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
TBDJG	1,2a,2c,3,17,10,14a,28	0	0	0	0	0	0	0	0	2	3	4	2	0	0	0	0	6	0.8
TBDSB	1,2a,2c,3,17,B,10,14a	3	2	0	0	0	0	3	1	0	0	1	*	0	0	0	0	7	0.9
TBDSG	1,2a,2c,3,17,B,10,14a,28	0	0	0	0	0	0	0	0	0	0	1	*	0	0	0	0	1	0.1
TBRKG	1,2a,2c,3,3ka,11,30,10,14a,18,28	12	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	1.5
TCBJG	1,2a,2c,3,26,10,14a,28	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	2	0.3
TCRKG	1,2a,2c,3,26,3ka,11,30,10,14a,18,28	17	11	2	8	2	7	2	1	0	0	2	1	0	0	0	0	25	3.1
TCTDB	1,2a,2c,3,26,3ka,11,17,30,14a	0	0	0	0	0	0	1	*	0	0	0	0	0	0	0	0	1	0.1
TDBGG	1,2a,2c,3,24,10,28	2	1	0	0	4	15	10	5	8	12	10	4	0	0	0	0	34	4.3
TDBGH	1,2a,2c,3,24,10,28,42	4	3	0	0	0	0	32	15	17	25	30	11	0	0	0	0	83	10.4
TDBJG	1,2a,2c,3,24,10,14a,28	0	0	0	0	2	7	7	3	2	3	2	1	0	0	0	0	13	1.6
TDBJH	1,2a,2c,3,24,10,14a,28,42	0	0	0	0	2	7	0	0	0	0	0	0	0	0	0	0	2	0.3
TDDGH	1,2a,2c,3,24,17,10,28,42	0	0	0	0	0	0	0	0	0	0	9	3	0	0	0	0	9	1.1
TDDJH	1,2a,2c,3,24,17,10,14a,28,42	0	0	0	0	0	0	0	0	0	0	9	3	0	0	0	0	9	1.1
TDMJG	1,2a,2c,3,24,3ka,30,10,14a,28	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	2	0.3
TFBGH	1,2a,2c,3,24,26,10,28,42	0	0	0	0	2	7	5	2	0	0	3	1	0	0	0	0	10	1.3
TFBJG	1,2a,2c,3,24,26,10,14a,28	0	0	2	8	1	4	7	3	0	0	0	0	0	0	0	0	10	1.3
TFDJH	1,2a,2c,3,24,26,17,10,14a,28,42	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0.3
TFDSB	1,2a,2c,3,24,26,17,B,10,14a	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	2	0.3
TGBGH	1,2a,2c,3,16,10,28,42	0	0	0	0	0	0	0	0	0	0	3	1	0	0	0	0	3	0.4
TGBJG	1,2a,2c,3,16,10,14a,28	0	0	0	0	0	0	0	0	0	0	13	5	0	0	0	0	13	1.6
TGDGG	1,2a,2c,3,16,17,10,28	0	0	0	0	0	0	0	0	0	0	11	4	0	0	0	0	11	1.4
TGDJG	1,2a,2c,3,16,17,10,14a,28	0	0	0	0	0	0	0	0	0	0	1	*	0	0	0	0	1	0.1
TGDSB	1,2a,2c,3,16,17,B,10,14a	0	0	0	0	2	7	0	0	0	0	1	*	0	0	0	0	3	0.4
TGDSG	1,2a,2c,3,16,17,B,10,14a,28	0	0	0	0	0	0	0	0	0	0	8	3	0	0	0	0	8	1.0
TGLJG	1,2a,2c,3,16,3ka,10,14a,28	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0.5
THBJG	1,2a,2c,3,16,26,10,14a,28	0	0	0	0	0	0	0	0	2	3	2	1	0	0	0	0	4	0.5
TJBGG	1,2a,2c,3,16,24,10,28	0	0	0	0	0	0	0	0	0	0	16	6	0	0	0	0	16	2.0
TJBGH	1,2a,2c,3,16,24,10,28,42	2	1	0	0	0	0	0	0	0	0	12	4	0	0	0	0	14	1.8
TJBJH	1,2a,2c,3,16,24,10,14a,28,42	0	0	0	0	0	0	1	*	3	4	5	2	0	0	0	0	9	1.1

cultivars with *Yr9* stripe rust-resistance gene, which is on the T1B·1R wheat-rye translocation that also has *Lr26/Sr31*, had 80 % severities in plots in east central Minnesota in mid-June. By mid-June, stripe rust had passed peak development in southern Minnesota and slowed down due to warmer weather and host resistance the spring wheat cultivars.

In late June, very hot weather slowed or stopped stripe rust development throughout the northern Great Plains. In late June, stripe rust severity levels were up to 20 % in east central South Dakota spring wheat plots (Fig. 2, p. 174). Most of the commonly grown spring wheats have good resistance to stripe rust. In mid-July, hot temperatures stopped development of stripe rust on spring wheat in the far northern Great Plains.

Table 2 (continued). Races of *Puccinia triticina* in the U.S. in 2005 determined by virulence to 20 near-isogenic lines of Thatcher wheat with leaf rust-resistance genes. Differentials used were 1a, 2c, 3, 9, 16, 24, 26, 3ka, 11, 17, 30, B, 10, 14a, 18, 21, 28, 41, 42. An * indicates less than 0.6 %. For area designations, see Fig. 3 (p. 174).

Race	Virulence combination (ineffective *Lr* genes)	SE		NE		OH Valley		TX–OK		KS–NE		MN SD ND		CA		WA		U.S. Total	
		#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
TJDGG	1,2a,2c,3,16,24,17,10,28	0	0	0	0	0	0	0	0	0	0	1	*	0	0	0	0	1	0.1
TJDGH	1,2a,2c,3,16,24,17,10,28,42	0	0	0	0	0	0	0	0	0	0	32	12	0	0	0	0	32	4.0
TKBGG	1,2a,2c,3,16,24,26,10,28	0	0	0	0	0	0	0	0	0	0	1	*	0	0	0	0	1	0.1
TKBGH	1,2a,2c,3,16,24,26,10,28,42	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	2	0.3
TKBJG	1,2a,2c,3,16,24,26,10,14a,28	0	0	0	0	0	0	0	0	0	0	4	2	0	0	0	0	4	0.5
TKBJH	1,2a,2c,3,16,24,26,10,14a,28,42	0	0	0	0	0	0	1	*	0	0	2	1	0	0	0	0	3	0.4
TKDJG	1,2a,2c,3,16,24,26,17,10,14a,28	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	2	0.3
TLBDG	1,2a,2c,3,9,14a,28	0	0	0	0	2	7	0	0	0	0	0	0	0	0	0	0	2	0.3
TLGJG	1,2a,2c,3,9,11,10,14a,28	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0.5
TLRJG	1,2a,2c,3,9,3ka,11,30,10,14a,28	2	1	0	0	0	0	0	0	3	4	0	0	0	0	0	0	5	0.6
TMGJG	1,2a,2c,3,9,26,11,10,14a,28	0	0	0	0	0	0	3	1	0	0	1	*	0	0	0	0	4	0.5
TNRJJ	1,2a,2c,3,9,24,3ka,11,30,10,14a,28,41	9	6	4	17	0	0	17	8	4	6	2	1	0	0	0	0	36	4.5
TNRJK	1,2a,2c,3,9,24,3ka,11,30,10,14a,28,41,42	2	1	0	0	0	0	30	13.6	1	2	14	5	0	0	0	0	47	5.9
Total		158		24		27		220		68		272		20		8		797	

Lower Mississippi Valley. In early February, severe levels of stripe rust was observed in some varietal plots at Baton Rouge. During the third week in February, fields were sprayed for stripe rust control in central Louisiana.

In early March, in southwestern Arkansas plots, susceptible wheat cultivars averaged 30 % rust severity, whereas other cultivars had 0 to 5 % severities. In late March, stripe rust was active in Louisiana and some fields were sprayed for rust control. In wheat plots in south central Louisiana, 80 % stripe rust severities were recorded. Higher day and night temperatures during the last week of March slowed stripe rust development. In late March, stripe rust was severe in fields throughout Arkansas and fungicide application was recommended.

In mid-April, wheat stripe rust severities of 100 % were observed on susceptible entries in nurseries in southwestern Arkansas. By the third week in April, stripe rust was found throughout Arkansas. In late April, wheat plots with 90 % severities were observed at Marianna (east central Arkansas) and cool temperatures were still favorable for infection, but insufficient moisture was limiting spread. In mid-May, stripe rust development had slowed in Arkansas.

East. In mid-March, stripe rust over wintering foci were observed in plots in south central Georgia. Stripe rust had expanded outward from the foci and many of the cultivars in the nursery were infected. In late April, plots of susceptible cultivars had trace–80 % severities in the panhandle of

Florida, southwestern Georgia, and southern Alabama. By late April, stripe rust was reported as far north as southeastern Virginia.

In early May, wheat stripe rust was found across the Atlantic coastal plain from Georgia to Virginia. North central Tennessee wheat fields had 15 % stripe rust severities. In mid-May stripe rust was found on Virginia's Eastern Shore and significant stripe rust was found in border rows in nurseries in Painter, Virginia.

In late May, severe stripe rust was found in a field in Washington county in central coastal North Carolina.

In mid-June traces of stripe rust were found in plots in south central New York.

Mideast. In early June, low levels of wheat stripe rust was found in a plot of Becker (older cultivar) in plots at Wooster Ohio. This was only the fourth time in 25 years that stripe rust was seen in the plots at Wooster.

In early June, fields and plots from northwestern Missouri to east central Indiana had 60 % severities (Fig. 2, p. 174). Traces of wheat stripe rust were found in nurseries in northwestern Ohio and central Michigan in early June.

In early June, stripe rust foci with 10 % severity were found in winter wheat plots and fields in northern Indiana and south central Wisconsin. In much of the Ohio Valley and Wisconsin, dry and hot conditions in June slowed rust development.

California. Stripe rust on wheat was first detected on 25 February in the nursery at UC Davis in border rows of the highly susceptible variety D6301. On 11 March, trace levels of stripe rust were detected in the Sacramento Valley and in the Sacramento/San Joaquin Delta nursery. Severity levels and incidence were less than last year on the same date. In early April, susceptible entries in nurseries in the Davis area of the Sacramento Valley had 60 % stripe rust severities. Cool and wet weather in late April were ideal for stripe rust infection, but rust levels remained low to moderate on most of the wheat acreage (dominated by resistant cultivars Summit and Blanc Grande). In late April in the Central Valley,

Table 3. Virulence frequencies (%) of *Puccinia triticina* in the U.S. in 2005 to 20 differential lines of Thatcher wheat with leaf rust-resistance genes. Areas are described in Fig. 3.

Resistance gene	SE		NE		OH Valley		TX–OK		KS–NE		MN SD ND		CA		WA		U.S. Total	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
Lr1	157	99.5	24	100.0	27	100.0	220	100.0	68	100.0	271	99.5	20	100.0	8	100.0	551	69.1
Lr2a	70	44.3	8	33.3	17	63.0	134	60.9	47	69.1	218	80.1	0	0.0	0	0.0	494	62.0
Lr2c	70	44.3	8	33.3	17	63.0	134	60.9	47	69.1	218	80.1	0	0.0	0	0.0	494	62.0
Lr3	157	99.4	24	100.0	27	100.0	215	97.7	66	97.1	270	99.3	20	100.0	8	100.0	787	98.7
Lr9	21	13.3	4	16.7	4	14.8	58	26.4	12	17.6	23	8.5	0	0.0	0	0.0	122	15.3
Lr16	6	3.8	0	0.0	2	7.4	2	0.9	5	7.4	117	43.0	4	20.0	0	0.0	136	17.1
Lr24	37	23.4	10	41.7	16	59.3	155	70.5	40	58.8	185	68.0	4	20.0	0	0.0	447	56.1
Lr26	82	51.9	16	66.7	10	37.0	88	40.0	16	23.5	58	21.3	11	55.0	1	12.5	282	35.4
Lr3ka	95	60.1	6	25.0	5	18.5	84	38.2	15	22.1	48	17.6	6	30.0	0	0.0	259	32.5
Lr11	102	64.6	8	33.3	2	7.4	54	24.5	10	14.7	22	8.1	2	10.0	4	50.0	204	25.6
Lr17	38	24.1	12	50.0	10	37.0	96	43.6	23	33.8	134	49.3	20	100.0	6	75.0	339	42.5
Lr30	91	57.6	6	25.0	5	18.5	82	37.3	15	22.1	48	17.6	4	20.0	0	0.0	251	31.5
LrB	35	22.2	12	50.0	10	37.0	90	40.9	19	27.9	62	22.8	18	90.0	2	25.0	248	31.1
Lr10	157	99.4	24	100.0	25	92.6	214	97.3	66	97.1	268	98.5	20	100.0	8	100.0	782	98.1
Lr14a	144	91.1	24	100.0	21	77.8	169	76.8	43	63.2	140	51.5	20	100.0	8	100.0	569	71.4
Lr18	71	44.9	2	8.3	2	7.4	3	1.4	2	2.9	3	1.1	0	0.0	0	0.0	83	10.4
Lr21	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lr28	122	77.2	12	50.0	17	63.0	133	60.5	47	69.1	220	80.9	2	10.0	7	87.5	560	70.3
Lr41	11	7.0	4	16.7	0	0.0	47	21.4	5	7.4	16	5.9	0	0.0	0	0.0	83	10.4
Lr42	22	13.9	2	8.3	7	25.9	96	43.6	26	38.2	151	55.5	4	20.0	0	0.0	308	38.6
Total	158		24		27		220		68		272		20		8		797	

Table 4. Estimated losses in winter wheat due to rust in 2005 (T = trace).

State	1,000 acres harvested	Yield in bushels per acre	Production, 1,000 bushels	Losses due to Stem rust		Losses due to Leaf rust		Losses due to Stripe rust	
				Percent	1,000 bushels	Percent	1,000 bushels	Percent	1,000 bushels
AL	45	50.0	2,250	0.0	0.0	*T	T	T	T
AR	160	52.0	8,320	0.0	0.0	T	T	5.0	437.9
CA	300	72.0	21,600	0.0	0.0	2.0	464.5	5.0	1,161.3
CO	2,200	24.0	52,800	0.0	0.0	T	T	1.0	533.3
DE	51	70.0	3,570	0.0	0.0	T	T	0.0	0.0
FL	8	45.0	360	0.0	0.0	T	T	T	T
GA	140	53.0	7,280	0.0	0.0	T	T	1.0	73.5
ID	730	91.0	66,430	0.0	0.0	0.1	68.5	3.0	2,056.7
IL	600	61.0	36,600	0.0	0.0	T	T	T	T
IN	340	72.0	24,480	0.0	0.0	1.0	2,469.5	T	T
IA	15	50.0	750	0.0	0.0	T	T	T	T
KS	9,500	40.0	380,000	0.0	0.0	2.0	8,444.4	8.0	33,777.8
KY	300	68.0	20,400	0.0	0.0	0.1	20.5	0.2	40.9
LA	100	48.0	4,800	0.0	0.0	1.0	51.1	5.0	255.3
MD	140	66.0	9,240	0.0	0.0	T	T	0.0	0.0
MI	590	66.0	38,940	0.0	0.0	T	T	T	T
MN	15	36.0	540	0.0	0.0	1.0	5.5	T	T
MS	65	50.0	3,250	0.0	0.0	1.0	33.2	1.0	33.2
MO	540	54.0	29,160	0.0	0.0	1.0	300.6	2.0	601.2
MT	2,100	45.0	94,500	0.0	0.0	T	T	T	T
NE	1,760	39.0	68,640	0.0	0.0	1.0	722.5	4.0	2,890.1
NJ	23	53.0	1,219	0.0	0.0	T	T	0.0	0.0
NM	270	36.0	9,720	0.0	0.0	0.0	0.0	0.0	0.0
NY	95	54.0	5,130	0.0	0.0	T	T	0.0	0.0
NC	435	57.0	24,795	0.0	0.0	T	T	T	T
ND	285	39.0	11,115	0.0	0.0	2.0	226.8	T	T
OH	830	71.0	58,930	0.0	0.0	1.0	595.3	T	T
OK	4,000	32.0	128,000	0.0	0.0	1.0	1,361.7	5.0	6,808.5
OR	780	61.0	47,580	0.0	0.0	0.1	49.6	4.0	1,984.6
PA	145	54.0	7,830	0.0	0.0	T	T	0.0	0.0
SC	165	52.0	8,580	0.0	0.0	T	T	T	T
SD	1,490	44.0	65,560	0.0	0.0	2.0	1,338.0	T	T
TN	150	56.0	8,400	0.0	0.0	T	T	0.5	42.2
TX	3,000	32.0	96,000	0.0	0.0	3.7	4,337.0	15.2	17,816.8
UT	135	47.0	6,345	0.0	0.0	T	T	5.0	333.9
VA	160	63.0	10,080	0.0	0.0	T	T	T	T
WA	1,800	67.0	120,600	0.0	0.0	0.1	123.2	2.0	2,463.7
WV	5	60.0	300	0.0	0.0	T	T	T	T
WI	175	57.0	9,975	0.0	0.0	1.0	100.8	T	T
WY	145	30.0	4,350	0.0	0.0	T	T	T	T
Total	33,787	44.4	1,498,419		0.0		20,713.4		71,348.0
U.S.% Loss				0.00		1.30		4.49	
U.S. Total	33,794	44.4	1,499,129						

plots of susceptible cultivars had severe stripe rust and severe rust was found in the screening nursery at UC Davis. In early May, stripe rust was increasing in fields and nurseries in the Sacramento Valley.

Pacific Northwest. In early February, stripe rust was found in experimental plots near Corvallis, Oregon. On 10 March, susceptible checks in winter wheat plots at Mount Vernon in northwestern Washington had 20 % severities. The winter was warmer than normal in the Pacific Northwest, and therefore, stripe rust started sporulating earlier than normal in western PNW.

Table 5. Estimated losses in spring wheat due to rust in 2005 (T = trace).

				Losses due to					
				Stem rust		Leaf rust		Stripe rust	
State	1,000 acres harvested	Yield in bushels per acre	Production, 1,000 bushels	Percent	1,000 bushels	Percent	1,000 bushels	Percent	1,000 bushels
CO	19	65.0	1,235	0.0	0.0	0.0	0.0	0.0	0.0
ID	450	72.0	32,400	0.0	0.0	0.1	0.0	2.0	661.2
MN	1,730	41.0	70,930	0.0	0.0	4.0	2,955.4	T	T
MT	2,550	32.0	81,600	0.0	0.0	T	T	T	T
NV	3	85.0	255	0.0	0.0	0.0	0.0	0.0	0.0
ND	6,600	34.0	224,000	0.0	0.0	2.0	4,571.4	T	T
OR	115	52.0	5,980	0.0	0.0	0.0	0.0	8.0	478.4
SD	1,690	40.0	67,600	0.0	0.0	2.0	1,379.6	T	T
UT	13	58.0	754	0.0	0.0	T	T	5.0	39.7
WA	425	44.0	18,700	0.0	0.0	0.1	19.1	4.0	770.6
WI	7	41.0	287	0.0	0.0	T	T	T	T
WY	7	45.0	315	0.0	0.0	0.0	0.0	0.0	0.0
Total from above									
	13,609	37.1	504,456		0.0		0.0		345.0
U.S. % loss				0.0		0.0		0.3	
U.S. total									
	13,609	37.1	504,456						

Table 6. Estimated losses in durum wheat due to rust in 2005 (T = trace).

				Losses due to					
				Stem rust		Leaf rust		Stripe rust	
State	1,000 acres harvested	Yield in bushels per acre	Production, 1,000 bushels	Percent	1,000 bushels	Percent	1,000 bushels	Percent	1,000 bushels
AZ	79	100.0	7,900	0.0	0.0	0.0	0.0	0.0	0.0
CA	69	95.0	6,555	0.0	0.0	0.0	0.0	5.0	345.0
ID	20	88.0	1,760	0.0	0.0	0.0	0.0	0.0	0.0
MT	585	28.0	16,380	0.0	0.0	0.0	0.0	0.0	0.0
ND	1,950	35.0	68,250	0.0	0.0	0.0	0.0	0.0	0.0
SD	13	20.0	260	0.0	0.0	0.0	0.0	0.0	0.0
Total from above									
	2,716	37.2	101,105		0.0		0.0		345.0
U.S. % loss				0.00		0.00		0.3	
U.S. Total									
	2,716	37.2	101,105						

In early April, wheat stripe rust continued to increase in western Oregon and northwestern Washington. During the first week of April, wheat stripe rust was found on susceptible winter wheat entries in south central Washington nurseries. In mid-April, traces of stripe rust were found in winter wheat nurseries near Pullman in southeastern Washington. An early appearance of stripe rust in the Palouse region was expected according to the forecast based on the higher than normal temperatures in December and January. The wet weather in April was favorable for stripe rust infection.

During the third week in April wheat stripe rust was developing rapidly in the Pacific Northwest, because of moist weather, which was favorable for rust development. In northwestern Washington, wheat fields with 20 % rust severities were reported.

By early May, stripe rust was present throughout the Pacific Northwest and caused yield losses in susceptible winter wheat crops in northwestern Oregon and south central Washington. Fungicides were sprayed to control stripe rust in Washington wheat fields in an area that had the most stripe rust in the last 20 years. In early May, in east central Washington and northern Idaho, susceptible winter wheat experimental fields had 60 % stripe rust severities. In both Oregon and Washington nurseries stripe rust severities ranged from 0 to 60 % in winter wheat cultivars.

In mid-May, stripe rust was widespread throughout the Pacific Northwest. Susceptible entries in southeast Washington winter wheat nurseries had 100 % severities and susceptible entries in the spring wheat nurseries had 40 % severities. In eastern Washington, winter wheat fields with 5 % rust severities were sprayed with fungicides. Stripe rust was common in spring wheat fields with less than 2 % severity on the lowest leaves. The wet and cool weather in mid-May, were ideal for stripe rust infection in the Washington.

In early June, fields in northern Utah and southern Idaho had severe rust. In mid-July, significant levels of stripe rust were found on wheat in fields and plots in south central Idaho. Losses to wheat stripe rust were expected in southern Idaho.

In mid-June, wheat stripe rust occurred throughout the wheat areas of the Pacific Northwest. The disease passed peak development on winter wheat and was developing on spring wheat. By late June, stripe rust was severe in virtually every location wheat was grown in the Pacific Northwest, extending as far east as Bozeman (Fig. 2, p. 174). Most fields of moderately susceptible or susceptible winter and spring wheat cultivars were sprayed with fungicides.

Because the rust started very early in the season, and the weather was extremely favorable to the disease (cool and wet), and the inoculum load was heavy, cultivars with low to moderate levels of high-temperature adult-plant (HTAP) resistance, which is generally adequate in years of normal weather, showed heavy infection. This year wheat stripe rust losses were expected to be higher than average in the Pacific Northwest.

Mexico. Stripe rust was at moderate to high infection levels on a few bread wheat cultivars throughout the Yaqui Valley. Some fields were sprayed to prevent yield loss.

NEBRASKA

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The 2005 Nebraska Wheat Crop was estimated at 68,600,000 bu, which represented a 39 bu/acre state average yield on 1,760,000 harvested acres. The 2005 crop was 12 % higher than the 2004 crop (61,100,00 bu, which represented a 37 bu/a state average yield on 1,650,000 harvested acres). Despite continued genetic improvement, the main determinant in wheat production seems to be acres harvested, government programs, and weather (which also affects disease pressure and sprouting).

Hard red wheat development.

P.S. Baenziger, R.A. Graybosch, B. Beecher, M. Shipman, D. Baltensperger, and L. Nelson with cooperation of Jim Krall and Amir Ibrahim.

In 2005, two new cultivars (**Hallam** and **Infinity CL**) were formally released. These cultivars were recommended for release in 2004 and have been described in the 2004 report. The release statements can be found at:

Hallam: http://agronomy.unl.edu/grain/hallam.PDF
Infinity CL: http://agronomy.unl.edu/grain/infinity.PDF

One experimental line **NE99495**, which has exceptional end-use quality, has been licensed to the Kansas Organic Producers. The license is part of our effort to ensure that the germ plasm developed at the University of Nebraska for the public good is broadly available to interested parties. NE99495 is a HRWW with the pedigree Alliance/Karl 92. The cross was made in 1993. NE99495 is an F_3-derived line that was selected in the F_4 generation. The F_1 generation was grown in the greenhouse in 1993-94. The F_2 and F_3 generations were grown in bulk at the Agricultural Research and Development Center at Ithaca, Nebraska in 1995 and 1996, respectively. Random heads were chosen from the F_3 bulk and planted as head rows, which were harvested in 1997. The F_3-derived F_5 family was harvested as a single observation plot in 1998. NE99495 was identified in 1999 and was grown at six unreplicated locations in 1997. The line has been tested in replicated trials at six to seven locations per year from 2000 to present. In addition, NE99495 was tested in the Northern Regional Performance Nursery in 2002 and 2003, and in Nebraska cultivar performance trials in 2003 and 2004. NE99495 is semidwarf wheat with medium plant height for a semidwarf cultivar and acceptable winterhardiness for production in Nebraska. NE99495 is slightly later than Alliance and slightly earlier than Millennium for flowering date. This line is susceptible to WSMV, WSBMV, and stripe rust; moderately resistant to Hessian fly and stem rust; and moderately susceptible to moderately resistant to leaf rust. NE99495 has good yield potential and has genetically lower test weight.

Based on last year's results and our recent releases, we have decided to increase one line, **NE01643** for possible release in 2006. NE01643 is a HRWW with the pedigree 'Millennium sib/ND8974'; where ND8974 is Seward/Archer (hence the full pedigree would be Millennium sib//Seward/Archer). The cross was made in 1995. NE01643 is an F_3-derived line that was selected in the F_4 generation. The F_1 generation was grown in the greenhouse in 1995–96. The F_2 and F_3 generations were grown in bulk at the Agricultural Research and Development Center at Ithaca, Nebraska in 1997 and 1998, respectively. Random heads were chosen from the F_3 bulk and planted as head rows, which were harvested in 1999. The F_3-derived F_5 family was harvested as a single observation plot in 2000. NE01643 was identified in 2001 and was grown at six unreplicated locations in 2001. INE01643 has been tested in replicated trials at six to seven locations per year from 2002 to present. In addition, NE01643 was tested in the Northern Regional Performance Nursery in 2004 and 2005, and in Nebraska cultivar performance trials in 2004 and 2005. NE01643 is semidwarf wheat with medium plant height for a semidwarf cultivar and acceptable winterhardiness for production in Nebraska. The line is later than Alliance and Millennium and slightly later than Harry for flowering date. NE01643 has excellent grain yield (topped the NRPN in 2004, data being analyzed for 2005; topped the state cultivar in 2005 and best 2-year average for 2004 and 2005). In addition, it has very good test weight and is moderately resistant to leaf and stem rust, and to Hessian fly. NE01643 is moderately susceptible to Fusarium head blight and powdery mildew and susceptible to stripe rust and soilborne/spindle streak mosaic virus. The end-use quality is minimally acceptable (not a star). See also: http://agronomy.unl.edu/grain/NE01643.PDF

Hard white wheat development.

R.A. Graybosch, P.S. Baenziger, B. Beecher, D. Baltensperger, and L. Nelson.

The following hard white wheats are entered in the 2006 Nebraska Statewide Small Grains Variety trial for testing and possible release: NW98S097 and NW03Y2016. NW98S097 consistently has demonstrated low levels of grain PPO, and now is under preliminary increase for possible cultivar release. NW03Y2016 carries the *Wsm-1* gene for resistance to wheat streak mosaic virus.

Hard spring wheat development.

D.D. Baltensperger, P.S. Baenziger, and Karl Glover.

Nebraska has expanded the coöperative spring wheat effort with South Dakota and several lines are being evaluated for potential joint release. These lines carry improved production under heat stress and improved scab tolerance. We are incorporating double imi-tolerance into well-adapted material.

Winter waxy wheat breeding.

R.A. Graybosch and P.S. Baenziger.

Approximately 25 winter waxy wheats were advanced to either their second or third year of yield testing, with replicated trials seeded both in Nebraska and Kansas. In addition, 100+ new winter waxy wheats were selected at Mead, NE, largely on the basis of resistance to stripe rust, and advanced to a preliminary yield trial in Nebraska. NX02Y4481, a fully waxy wheat derived from 'BaiHuo/Kanto107//Ike/3/SD94217W', was entered in the USDA–ARS coördinated Northern Regional Performance Nursery, a replicated trial grown across a six state region in the northern Great Plains.

Wheat streak mosaic virus resistant germ plasm.

R.A. Graybosch, P.S. Baenziger, G.L. Hein, and D.D. Baltensperger in cooperation with P. Heslop-Harrison and T. Schwarzacher, University of Leicester.

We have been selecting winter wheat lines carrying *Wsm-1*, a gene from *Th. intermedium* conditioning resistance to wheat streak mosaic virus. Several wheats of interest have been identified, all with acceptable agronomic performance. N02Y5117, a hard red winter wheat, has been placed under preliminary seed increase for possible cultivar release. Three hard white wheats, NW03Y2016, NW03Y2022 and NW03Y2023 have been entered in the 2006 Southern Regional or Northern Regional Performance Nurseries. Genomic *in situ* hybridization suggests each carries *Wsm-1* on the 4DL.4AiS translocated chromosome derived from CI 17884. All test positive in PCR for *Wsm-1* markers described by Talbert et al. (TAG 93: 463), and show a strong positive reaction with primers 2P1 and 2P2, used by Li et al. (TAG 111:932) to detect *Thinopyrum* DNA in wheat backgrounds.

Single-kernel, near-infrared analysis of waxy and partial waxy tetraploid (durum) wheat.

S.R. Delwiche (USDA–ARS, Beltsville, MD), R.A. Graybosch, L.E. Hansen, E. Souza (USDA–ARS, Wooster, OH), and F.E. Dowell (USDA–ARS, Manhattan, KS).

Essential to development of a market for partial waxy and waxy wheats are means to rapidly and, ideally, nondestructively identify the waxy condition will need to be developed that can be used at the point of sale. The study described herein evaluated the effectiveness of near-infrared reflectance single-kernel spectroscopy for classification of durum wheat into its four possible waxiness genotypes, these being wild type, waxy, and the two intermediate states in which a null allele occurs at either the two homologous genes (*Wx-1A* and *Wx-1B*) that encode for the production of the enzyme, granule bound starch synthase, that controls amylose synthesis. Two years of breeders samples, corresponding to 47 unique lines subdivided approximately equally into the four waxiness states, were scanned in reflectance (1,000–1,700 nm) on an individual kernel basis. Linear discriminant analysis models were developed using the best set of four wavelengths, best four wavelength differences, and best four principal components. Each model consistently demonstrated the high ability (typically greater than 95 % of the time) to classify the fully waxy genotype. However, correct classification among the three other genotypes (wild type, wx-A1 null, and wx-B1 null) was generally not possible.

Winter triticale breeding.

P. S. Baenziger, Lekgari A. Lekgari, and Ken Vogel with the coöperation of Lance Gibson and Jean-Luc Jannink.

No new triticale cultivars were released but a number of lines were advanced for grain and forage yield. Germ plasm remains a major limitation in triticale improvement and we welcome sharing germ plasm with others developing triticale germ plasm and cultivars.

Personnel.

Dr. John Watkins retired from the Department of Plant Pathology after many excellent years of service to the wheat industry. Dr. Stephen N. Wegulo joined the Department of Plant Pathology as John's successor. Dr. Drake Stenger will be leaving the USDA-ARS group at Lincoln to assume a position as Research Leader at the USDA-ARS San Joaquin Valley Agricultural Sciences Center in Parlier, California. Mr. Jerry Bohlmann accepted a position with Monsanto and we wish him well. Dr. Chatuporn Kuleung successfully completed her Ph.D. degree and returned to her university in Thailand. New students are Mr. Neway Mengistu, from Ethiopia and with partial support from Pioneer Hibred Inc. and Ms. Anyamanee Auvuchamon, from Thailand with funding from her government, began their Ph.D. programs; and Mr. Javed Sidiqi, from Afghanistan with funding from the Fulbright program, began his M.S. degree.

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SOUTH DAKOTA

SOUTH DAKOTA STATE UNIVERSITY AND THE USDA–ARS NORTHERN GRAIN INSECT RESEARCH LABORATORY (NGIRL).
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A.M.H. Ibrahim, S.A. Kalsbeck, R.S. Little, S. Malla, E. Babiker, M. Langham, T. Cheesbrough, Howard J. Woodard, Anthony Bly, and Brian Pavel (South Dakota State University) and L. Hesler, W. Riedell, and S. Osborne (USDA–ARS–NGIRL).

Winter wheat breeding and genetics.

A.M.H. Ibrahim, S.A. Kalsbeck, R. S. Little, S. Malla, and E. Babiker.

Crop report and testing sites. Winter wheat production in South Dakota in 2005 was estimated at 63.4 x 10^6 bushels from 1.44 million harvested acres (1.5 million planted acres), for an average of 44 bushels/acre. In 2005, the winter wheat breeding program tested at eight sites throughout South Dakota. These environments included Aurora and Brookings (Brookings Co.), Platte (Douglas Co.), Highmore (Hyde Co.), Selby (Walworth Co.), Winner (Tripp Co.), Wall (Pennington Co.), the Northeast Research Farm near Watertown (Codington Co.), Kennebec (Lyman Co.), and both irrigated and dry land environments at the Dakota Lakes Research Farm east of Pierre (Hughes Co.). Crop performance testing also was conducted at five sites west of the Missouri River in cooperation with John Rickertsen and Bruce Swan (SDSU West River Agricultural Research and Extension Center, Rapid City). The crop was planted 11 September, 2004, at Selby and the Northeast Research Farm; 17 September at Dakota Lakes Research Farm and Highmore; 20 September at Winner, Wall, and Platte; and 4 October at Brookings. When autumn stand counts were taken at all locations, the crop was at the four leaf stage with very good crown development and as many as four tillers or more per plant. Above average temperatures in February and March led the South Dakota Field Office of USDA's National Agricultural Statistics Service to rate the winter wheat crop as 81 percent good to excellent the first week of April. A continuation of great growing conditions in May resulted in major disease development. Temperature and moisture conditions in late May resulted in the development of powdery mildew (a condition normally only seen in the greenhouse) at Dakota Lakes. Fusarium had blight and tan spot were both severe in some parts of the state. The severity of disease occurrences (stripe rust, FHB, tan spot, stem rust, powdery mildew, take-all, and WSMV) allowed for data collection and evaluation in many sites in the breeding program. The nursery at Selby was abandoned. The winter wheat seedlings were suppressed because of extreme pressure from volunteer spring wheat regrowth in that site. The spring wheat stubble nursery at Dakota Lakes was not harvested because of severe lodging and poor quality of seed samples.

Foundation seed increase. Foundation seed of two lines (SD97W609 and SD98102) is being increased for potential release in 2006. SD97W609 was developed from the cross 'Abilene/Karl' and is a semidwarf, early maturing (similar to Wendy) HWWW with good winter survival ability and excellent yield potential. SD97W609 has excellent baking quality in predictive testing and in large-scale testing in the 2005 Wheat Quality Council. This line has high test weight, intermediate levels of polyphenoloxidase enzyme, average protein, very short coleoptile, and good sprouting resistance. SD97W609 is moderately resistant to stem rust and WSMV and is moderately susceptible to leaf rust.

SD98102 was developed from the cross '2076-W12-11/Karl 92//NE89526'. This line has very good yield performance, good milling, and average baking quality attributes. SD98102 is moderately resistant to stem rust and moderately susceptible to leaf rust and WSMV. A third line (SD97059-2) is being increased for Foundation Seed with potential release in 2007. SD97059-2 was developed from the cross ND8889/NE90574. SD97059-2 had very good yield performance over the last 3 years; excellent resistance to stem, leaf, and stripe rusts; good resistance to scab; strong straw; and good milling and baking quality. This line will be targeted as a replacement to Arapahoe wheat across South Dakota.

Research. Our research continues to focus on line development, characterization, and applied studies in areas with potential to contribute to variety release. Crossing and germ plasm enhancement efforts continue to address high yield potential, end-use quality, and important biotic and abiotic constraints facing producers in South Dakota and the Northern Great Plains.

Basic research support projects included: end-use quality enhancements and inheritance and mapping studies on resistance to *Fusarium* head blight, stem rust, and freeze survival.

Eight hundred and forty lines have been screened in our mist-irrigated nursery in 2005 including the Northern Regional Performance Nursery (NRPN), Regional Germplasm Observation Nursery (RGON), and Southern Regional Performance Nursery (SRPN), in addition to South Dakota Crop Performance Trials (CPT), Advanced Yield Trial (AYT), Preliminary Yield Trials (PYT), and Early Yield Trial (EYT). Expedition hard red winter wheat, released by our program in 2002 showed better resistance to FHB than Wesley and Jagalene in producers' fields in eastern and central South Dakota in 2005. Two experimental lines, SD98102 and SD97059-2, have been increased with intention to release in 2006 and 2007, respectively. Both lines have good FHB resistance in addition to excellent leaf and stem rust resistance. They also had good performance and stability in the NRPN which is essential for adaptation in the northern Great Plains. Seven lines with promising FHB resistance were included in the 2006 AYT, 16 in the 2006 PYT, and 58 in the 2006 EYT. Our program relied on indigenous local resistance in the past. However, with the spread of FHB epidemics in winter wheat in South Dakota, use of highly resistant sources became paramount. In the 2005–06 season, we planted 151 out of 535 F_3s and 134 out of 593 F_2s with promising FHB resistance. Sixty-six of the F_3s and eight of the F_2s included resistance sources from Sumai 3, Ning7840, and their derivatives. About 7,000 head-rows with Sumai 3 type sources were planted in 2005. The best lines out of the head-row nursery will be included in the EYT in 2006. FHB-resistant advanced lines from these populations will be entered into regional nurseries to facilitate development of varieties with broad adaptation to the northern Great Plains.

A six parent diallel showed highly significant ($P < 0.01$) general combining ability in both greenhouse and field environments, but significant specific combining ability ($P < 0.05$) only in an F_2 greenhouse environment for resistance to FHB. The ratio of combining ability variance components ranged from 0.66 to 0.89 indicating the importance of additive gene effects.

Cereal aphids, other arthropod pests, and arthropod-borne viral plant disease.

L. Hesler, W. Riedell, and S. Osborne (USDA–ARS–NGIRL, Brookings) and M. Langham and T. Cheesbrough (South Dakota State University).

Meaningful sources of plant resistance are needed against the bird cherry-oat aphid, a widespread pest of wheat. We found moderate levels of resistance to this aphid in several lines of triticale and low levels of resistance in two wheat cultivars. Transformed wheat lines did not manifest resistance to bird cherry-oat aphid. Three papers that summarize our results have been published, and another series of tests with triticale are nearly completed. Follow-up studies are underway to test for resistance to bird cherry-oat aphid in crosses between a widely planted wheat variety and a resistant triticale line.

Alteration of planting date is one potential method to limit infestations bird cherry-oat aphid, other cereal aphids, and various arthropods and reduce the incidence of some arthropod-borne viral plant diseases. We conducted a study in which winter wheat was planted over three dates (early, middle, and late; generally from late August to late September) to determine the effect on abundance of insect pests, incidence of plant damage, incidence of viral plant disease, and grain yield. The study was conducted simultaneously at two sites in South Dakota over three consecutive cropping seasons for a total of 6 site yrs. Cereal aphids were abundant in 3 site yrs. Bird cherry-oat aphid was the most abundant cereal aphid at the Brookings site, whereas greenbug predominated at Highmore. Aphid-days were greater in early versus late plantings. Aphid abundance in middle plantings depended on aphid species and site, but usually did not differ from that in early plantings. Incidence of *Barley yellow dwarf virus* (BYDV) declined with later planting and was correlated with autumnal abundance of cereal aphids. Incidence of BYDV ranged from 24 to 81% among 1999 plantings, and was less than 8% in other years. Damage to seedling wheat by chewing insects varied for two site-years, with greater incidence in early and middle plantings. *Wheat streak mosaic virus*, spring infestations of cereal aphids, wheat stem maggot, and grasshoppers were insignificant. Yield at Brookings was negatively correlated with BYDV incidence but not cereal-aphid abundance, whereas yield at Highmore was negatively correlated with aphid abundance but not BYDV incidence. Planting on September 20 or later reduced damage from chewing insects, and reduced cereal aphid infestations and resulting BYDV incidence.

The role of spring wheat in crop rotations.

Howard J. Woodard, Anthony Bly, and Brian Pavel.

Field plots (30’ x 30’) were established at a site near Brookings for planting corn/soybean, spring wheat/soybean and corn/soybean/spring wheat. No-till and Conventional tillage blocks were established for each crop rotation. Residue management plots were included in the plot design for each crop rotation and tillage system as either completely removing all loose residues (residue removal) or leaving the residues in place (residue maintenance). In the residue removal plots all of the loose residues across the whole plot were removed. The plot design is a strip-split-split randomized complete block with four replications. Briggs HRSW was seeded at 1.2 x 10^6 pure live seeds/acre. Adequate levels of N and Cl was broadcast applied to the wheat plots. Weeds were controlled with appropriate herbicides.

No single source of variation significantly influencing grain yield, protein, or residue weight (Table 1). The only significant SOV interaction was tillage-rotation-residue for grain protein and possibly explained with ANOVA of protein by residue maintenance. ANOVA by tillage system showed a significant response for no-till residue weight. Treatment plots with residue maintained had significantly higher residue weights and probably a result of undecayed plant residues from prior years which were evidently seen in the residue samples. This difference was not measured or seen with conventional tillage since residues from prior crops were incorporated with tillage. ANOVA by residue maintenance showed a significant difference in grain protein between tillage systems when residues were maintained. Conventional

Table 1. Spring wheat grain yield and protein as influenced by crop rotation, tillage method, and residue management at Brookings, SD, in 2005. till = conventional or no-till; res = crop residues removed or maintained; NS = not significant; and LSD = least significant difference.

	Grain @ 13 % moisture		
Source of variation	Yield	Protein	Residue weight dry basis
Pr > F			
tillage method (till)	0.119	0.541	0.953
residue maintenance (res)	0.425	0.289	0.235
crop rotation (rot)	0.401	0.935	0.163
till * res	0.073	0.068	0.157
till * rot	0.158	0.401	0.507
res * rot	0.123	0.602	0.270
till * rot * res	0.315	0.029	0.726
Tillage Method			
No-till	59.6	15.4	3,624
Conventional	64.4	15.5	3,601
LSD $_{(.05)}$	NS	NS	NS
Residue Management			
Removed	62.6	15.5	3,368
Maintained	61.4	15.4	3,857
LSD $_{(.05)}$	NS	NS	NS
Crop Rotation			
Soybean / Wheat	60.7	15.5	3,213
Corn / Soybean / Wheat	63.3	15.5	4,012
LSD $_{(.05)}$	NS	NS	NS
ANOVA by tillage method			
	bu/acre	%	lbs/acre
Conventional tillage			
Residue Removed	62.8	15.3	3,615
Residue Maintained	65.9	15.8	3,587
Pr>F	0.139	0.073	0.965
LSD $_{(.05)}$	NS	NS	NS
No-till			
Residue Removed	62.3	15.7	3,122
Residue Maintained	56.8	15.1	4,127
Pr>F	0.111	0.083	0.014
LSD $_{(.05)}$	NS	NS	610
ANOVA by residue maintenance			
	bu/acre	%	lbs/acre
Residue removed			
No-till	62.3	15.7	3,122
Conventional	62.8	15.3	3,615
Pr>F	0.606	0.321	0.129
LSD $_{(.05)}$	NS	NS	NS
Residue maintained			
No-till	56.8	15.1	4,127
Conventional	65.9	15.8	3,587
Pr>F	0.093	0.050	0.433
LSD $_{(.05)}$	NS	0.6	NS

tillage had significantly higher grain protein and probably a result of more available N from mineralization caused by tillage. Spring wheat grain yields were very good.

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VIRGINIA

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J.J. Paling, C.A. Griffey, W.E. Thomason, E.L. Stromberg, J. Chen, D.M. Tucker, T.H. Pridgen, and E.G. Rucker.

2005 wheat production in the Commonwealth of Virginia.

J.J. Paling, C.A. Griffey, and W.E. Thomason.

Growing conditions. Weather conditions in 2005 were favorable for planting and growing wheat. Warm temperatures and near normal rainfall occurred through October and November during planting time. Temperatures then became colder and precipitation was slightly below normal for much of the Commonwealth during the winter. Cold temperatures in eastern and southern Virginia during the winter months impeded tillering and resulted in some winter injury. In contrast to 2004 where abnormally high temperatures and dry conditions in May had a deleterious impact on grain fill, yield and test weight, an extended period of cool temperatures during spring 2005 resulted in a longer than average grain fill period, high grain yields, and record test weights in wheat harvested timely. However, delayed senescence and grain dry down in some varieties resulted in later harvest, which was further hindered by persistent rain showers at many locations in eastern Virginia.

Disease and insect incidence and severity. Stripe rust, which rarely had been identified and only in isolated sites in Virginia, was widespread in 2005 and fungicide control was needed in susceptible varieties in some locations. Incidence was moderate to severe in susceptible cultivars at Painter on the Eastern Shore and at Warsaw in Eastern Virginia. Susceptible lines were also infected at Blacksburg in the southwestern part of the state. Disease severity ratings and disease reaction type (resistant to susceptible) were obtained on all released cultivars and experimental lines in test plots grown at Painter in 2005. Powdery mildew incidence was lower than usual for the second consecutive year in the Eastern Shore and Coastal Plain region. Leaf rust infection was moderate on susceptible cultivars grown in research yield trials at Blacksburg and moderate to high at Warsaw in eastern Virginia. Cultivars such as Sisson and USG3209 having gene *Lr*26 and McCormick having gene *Lr*24 were susceptible to leaf rust. The incidence of scab was low in 2005. Aphids were present in plots at several regions during the autumn, whereas cereal leaf beetle populations were relatively low during the spring. Barley yellow dwarf virus infection was moderate at four of the testing locations, and results from DNA tissue analysis conducted by USDA–ARS at Purdue University indicated presence of only the MAV strain.

Production. The NASS Agricultural Statistics Service reported in January 2006 that Virginia wheat producers harvested 160,000 acres (64,800 ha) of winter wheat for grain in 2005. This was slightly less than the 180,000 acres harvested in

2004. However, grain yields averaged 63.0 bu/acre (4,230 kg/ha) in 2005, 8 bu/acre (540 kg/ha) more than in 2004 and much more than the very low 46 bu/acre (3,090 kg/ha) in the 2003 FHB epidemic year. Total wheat production in 2005 for the Commonwealth was 10.08 x 10^6 bushels (274,000 metric tons), 180,000 bu (4,900 metric tons) higher than in 2004.

State cultivar tests. A total of 71 entries were evaluated at seven locations across the Commonwealth in 2005. Included in this total were 34 released cultivars and 37 experimental lines (31 developed at Virginia Tech). Average grain yields ranged from 61 to 80 bu/acre (4,100–5,375 kg/ha) with an over location test average of 72 bu/acre (4,840 kg/ha). Wheat cultivars with yields significantly above the test average were SS MPV 57, SS 560, Renwood 3260, USG 3209, Featherstone 176, 3706, Pioneer 26R24, SS 520, and V9412. Fourteen experimental lines, all from Virginia, also yielded significantly higher than the seven-location test average. Yields from these highest producing cultivars and experimental lines ranged from 75 to 80 bu/acre (5,040–5.375 kg/ha). Average test weights of wheat lines ranged from 57.5 lb/bu (740 kg/m^3) to 60.3 lb/bu (775 kg/m^3) with a test average of 59.0 lb/bu (760 kg/m^3). Average test weights of most of wheat lines entered in 2005 were similar to the overall average. Indeed, only three entries (one cultivar and two experimentals) produced wheat with test weights significantly higher than the average.

Of the seven test sites in 2005, the conventional tillage tests grown at Warsaw and Orange produced the highest average yields and test weights (Table 1). Both yield and test weights were reduced at Painter because of stripe rust and harvest delayed nearly 2 weeks due to rain showers after maturity. Excellent yields also were obtained at Blacksburg, however, test weights were reduced as a result of harvest delayed 1 week due to rain.

Table 1. Average yield and test weight of the 71 wheat entries for each location in the 2005 Virginia State Tests.

	Yield		Test weight	
Location	bu/acre	kg/ha	lb/bu	kg/m^3
Blacksburg – Kentland Farm Southwest VA	86	5,780	58.6	755
Blackstone – Southern Piedmont AREC	49	3,290	60.5	780
Holland – Tidewater AREC	60	4,030	56.3	725
Orange – Northern Piedmont AREC	90	6,050	60.7	780
Painter – Eastern Shore AREC	77	5,170	54.5	700
Shenandoah Valley	54	3,630	60.1	775
Warsaw – Eastern Virginia AREC	88	5,910	62.7	805
Seven location average	72	4,840	59.0	760

Warsaw no-till wheat test. An excellent stand was obtained in the autumn of 2004. Tillering was lower than normal going into early spring, but rebounded later with the favorable growing conditions. Grain yields averaged 90 bu/acre (6,050 kg/ha) with an average test weight of 62.1 lb/bu (799 kg/m^3). Ten entries, five cultivars, and five Virginia experimental lines yielded significantly higher than the test average. Yields of these ten entries ranged from 98 to 104 bu/acre (6,585–6,990 kg/ha). Released cultivars yielding higher than the test average were SS MPV 57, 3706, SS 560, Chesapeake, and SS 520. In general, wheat grown in the no-till test at Warsaw performed very well in 2005 despite the occurrence of epidemic levels of both leaf rust and stripe rust in this nursery.

Virginia wheat yield contests. Nine entries were in the 2005 Virginia wheat yield contests. Seven of the entries were grown no-till and two using conventional tillage. Four of the five highest yields were obtained from entries grown in Charles City County, and the seven no-till entries resulted in the highest yields. Average yield of no-till entries was 20 percent higher than in 2004. All of the contestants planted certified seed after a previous corn crop.

The highest yield of all entries was obtained by Archer H. Ruffin Jr. of Charles City County, who produced 123 bu/acre (8,265 kg/ha) of 'Tribute' wheat. The other entries from Charles City county were; Timothy Ruffin, 110 bu/acre (7,390 kg/ha) of Pioneer 26R15; David Black, 108 bu/acre (7,255 kg/ha) of Tribute; Darrell Harold, 102 bu/acre (6,855 kg/ha) of Renwood 3260; and Renwood Farms Inc., 96 nu/acre (6,450 kg/ha) of USG 3137. Roger Calhoun of King and Queen County produced 97 bu/acre (6,520 kg/ha) of Tribute and David Hula of James City County grew 92 bu/acre (6,180 kg/ha) of Renwood 3260. In the conventional till fields, Clifton Brann of Northumberland County harvested 84 bu/acre (5,645 kg/ha) of McCormick and John Jenkins of Westmoreland County harvested 81 bu/acre (5,440 kg/ha) of

Tribute. Congratulations to all contestants in the Virginia Wheat Yield Contest for growing wheat crops with grain yields well above the commonwealth average.

Specialty wheat breeding and genetics research.

Winter durum wheat. The Virginia Tech small grains breeding and genetics program has been working on developing winter durum wheat lines since 1998. In 2004, 49 experimental lines of winter durum wheat developed at Virginia Tech were planted in an observation yield nursery at Warsaw, VA. These lines were evaluated for yield, test weight, winter survival, and disease resistance in the field trial and in greenhouse disease screening tests. Overall, test weights of the experimental lines averaged 61.6 lb/bu (793 kg/m^3), ranging from 58.9 to 64.3 lb/bu (758 to 828 kg/m^3). Average test weight of the winter durum check cultivars in this observation nursery was 60.7 lb/bu (781 kg/m^3). Seventeen of the 49 experimental durum lines having good winter hardiness and overall field performance were advanced and planted in replicated yield tests at two locations in Virginia and one location in Kansas during autumn 2005. The average test weight of these 17 selected lines was 62.6 lb/bu (806 kg/m^3) and ranged from 60.0 to 64.3 lb/bu (772 to 828 kg/m^3). Their average grain protein concentration was 15.6 %, with a range from 14.4 to 16.9 %.

Hard red and hard white winter wheat breeding and research. Virginia Tech's Small Grains Breeding and Genetics program has been evaluating and developing hard red and hard white winter wheat for several years. Select elite bread wheat cultivars and experimental lines from other breeding programs were tested in replicated yield trials and lines developed at Virginia Tech were evaluated in non-replicated nurseries in 2005. Fifty-two elite bread wheat lines were tested at Blacksburg, Warsaw, and Painter Virginia in 2005. Average yield of these entries was 70.8 bu/acre (4,757 kg/ha) and ranged from 51.9 to 80.0 bu/acre (3,487–5,375 kg/ha). Average test weight was 59.3 lb/bu (763 kg/m^3) and ranged from 55.6 to 61.7 lb/bu (716 to 794 kg/m^3). Of the 52 entries harvested in 2005, grain from 24 cultivars and experimental elite lines harvested at Warsaw in eastern Virginia were sent for milling and baking quality analysis.

In 2004–05, a nonreplicated observation yield nursery (73 experimental lines and 7 checks) of bread wheat lines, many developed at Virginia Tech, was planted and harvested at two locations (Blacksburg and Warsaw). Lines were evaluated for agronomic performance including yield, winter survival, test weight, disease resistance, and grain quality. The average yield over the two locations for the experimental lines was 60.9 bu/acre (4,092 kg/ha) and ranged from 39.1 to 78.5 bu/acre (2,627 to 5,274 kg/ha). Average test weight was 60.4 lb/bu (777 kg/m^3) and ranged from 57.8 to 62.6 lb/bu (744 to 806 kg/m^3). The average yield and test weight of the hard winter wheat check cultivars was 50.9 bu/acre (3,420 kg/ha) and 60.7 lb/bu (781 kg/m^3). Sixteen experimental lines were selected and planted in replicated yield nurseries in Blacksburg and Warsaw in the fall of 2005. Yields of these 16 lines averaged 70.7 bu/acre (4,750 kg/acre) and ranged from 45.8 to 82.4 bu/acre (3,077–5,536 kg/ha) with an average test weight of 60.6 lb/bu (780 kg/m^3), ranging from 56.3 to 64.5 lb/bu (725 to 830 kg/m^3). These 16 lines also were evaluated for milling and baking quality.

Bread wheat breeding and research in 2006. A bread wheat elite test with 32 entries was planted at three locations in the autumn of 2005. The experimental bread wheat lines selected from the 2005 observation nursery were planted in replicated nurseries at Blacksburg and Warsaw. Bread wheat observation yield nurseries, 142 total plots with more than 100 experimental lines developed and/or selected at Virginia Tech, were planted at Warsaw and Blacksburg during autumn 2005. In addition, 50 elite hard winter wheat lines from Colorado State University and 42 lines included in Kansas State University's Advanced Yield Nursery were planted in separate replicated yield nurseries at Warsaw, Virginia. Entries in the USDA–ARS Uniform Bread Wheat Nursery also will be evaluated in replicated tests at two locations in Virginia.

Bread wheat cultivar response to disease incidence and effects on grain yield and quality characteristics.

W. E. Thomason and E. L. Stromberg.

Hard wheat and certain strong gluten soft wheat are suitable for use in making bread and dough products. Because the market exists for bread wheat and because it is usually of higher value than soft wheat ($0.40 or more per bushel), growers are interested in using adapted varieties and developing agronomic techniques to grow bread wheat in the mid-Atlantic region.

Two trials were established using five promising bread wheat cultivars: Karl 92 (a Kansas HRWW cultivar), Amelio (a French bread wheat whose marketing rights in this region are owned by the Virginia Identity Preserved Grains group), Tam 110 (a HRWW developed in Texas), Lakin (a Kansas HWWW cultivar), and Renwood 3260 (a SRWW developed in Virginia). These cultivars were chosen to represent the breadth of diversity of potential bread wheat genetics and diverse patterns of disease resistance. Experimental locations were at the Eastern Virginia Agricultural Research and Extension Center, Warsaw, VA, and at the Eastern Shore Agricultural Research and Extension Center, Painter, VA, in 2004-05. Seeding rates were 375 seeds/m^2 based on research for SRWW cultivars. A split-plot experimental design was employed such that Baytan 30® (triademenol) seed treatment at 94 g/kg of seed was applied to one-half of the planted plots, resulting in one block of varieties protected from autumn infection of powdery mildew and another block with only genetic resistance. Quilt® (azoxystrobin + propiconazole) was applied at 203 g/ha to one-half of all plots at GS 37 (flag-leaf emergence) to assess the efficacy of chemical control of powdery mildew, both with and without previous seed treatment. In 2005, disease pressure was low and the growing environment was favorable for high yields and test weights. Seed treatment had no effect on spring disease levels. Application of a fungicide did lower disease scores, but did not affect grain yield or test weight at either location. Further information is available on the web at: http://www.grains.cses.vt.edu/grains/Research/BW_disease_05.htm.

Personnel.

Two individuals on the small grains breeding project completed advanced degrees at Virginia Tech in 2005 and a new Research Associate joins the program in March 2006.

Dr. Jianli Chen received her Ph.D. degree in Crop and Soil Environmental Sciences with a specialty in Plant Genetics and Breeding in December 2005. Her dissertation title was "Validation and Marker-Assisted Selection of Two Major Quantitative Trait Loci Conditioning Fusarium Head Blight Resistance in Wheat". One of dissertation derived papers "Validation of Two Major Quantitative Trait Loci for Fusarium Head Blight Resistance in Chinese Wheat Line W14" has been published in the Journal of Plant Breeding 125: 99-101, 2006. Jianli has been a Research Associate and co-principal investigator in the Fusarium head blight (FHB) project of the Small Grains Breeding and Genetics Program at Virginia Tech since 1997. Jianli coordinates the FHB research program, and has been working on breeding, selection and development of FHB resistant wheat and barley cultivars. Dr. Chen is continuing her career at Virginia Tech where she will continue to lead the program's FHB breeding project, including mapping and marker-assisted selection (MAS) for FHB resistance.

Dominic Tucker completed his M.S. program in May 2005. His thesis title was "Validation, Saturation, and Marker-Assisted Selection of Quantitative Trait Loci Conferring Adult Plant Resistance to Powdery Mildew in an Elite Wheat Breeding Population". The major objective of his research was to identify molecular markers associated with partial resistance or adult plant resistance in the cultivar 'USG 3209'. Dominic has a paper titled "Potential for Effective Marker-Assisted Selection of Three Quantitative Trait Loci Conferring Adult Plant Resistance to Powdery Mildew in Elite Wheat Breeding Populations" in press in the Journal of Plant Breeding.

Dominic is continuing his education towards a Ph.D. at Virginia Tech. He is working on a collaborative project with Iowa State University, The Ohio State University, and Virginia Polytechnic Institute and State University on mapping and cloning *Phytophthora sojae* genes in soybean under the direction of Dr. M.A. Saghai Maroof, Professor, Department of Crop and Soil Environmental Sciences at Virginia Tech.

Patricia Gundrum joins the Virginia Tech small grains breeding and genetics program as a Research Associate in March. She will be working with plant diseases, particularly the fungal pathogens affecting small grains. Patricia received a B.S. degree in Plant Sciences from West Virginia University in 1989 and a M.S. in Plant Pathology from West Virginia University in 1999, Thesis title "A Biological Comparison of *Discula destructiva* Isolates from Four Geographic Locations". Patricia was with the USDA Forest Service from 1991 to 1998. She was with the Appalachian Integrated Pest Management from 1991-92 and in State and Private Forestry from 1992 to 1998. From 1998 to the present she has been a Plant Pathologist at the USDA-ARS Appalachian Fruit Research Station at Kearneysville, West Virginia.

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WASHINGTON

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Epidemiology and Control of Wheat Stripe Rust in the United States, 2005.

Xianming Chen, David A. Wood, Laura Penman, Paul Ling, Meinan Wang, and Feng Lin.

Monitoring rusts, predicting epidemics, assessing yield losses and implementing disease control. In 2005, stripe rust, leaf rust, stem rust, and other foliar diseases of wheat were closely monitored throughout the Pacific Northwest (PNW) through field surveys and disease nurseries. Early prediction of wheat stripe rust epidemic was made using rust forecasting models based on temperatures in December 2004 and January 2005. The warmer-than-normal winter allowed more survival of the stripe rust fungus in infected leaf tissues, resulting in early occurrence and quick development of stripe rust in the PNW. Based on the forecast, a stripe rust alert was sent to wheat workers and growers as early as in February 2005, which allowed growers to be prepared for control of stripe rust by planting resistant spring wheat cultivars and using fungicides. In March 2005, field surveys were conducted periodically and rust updates on distribution and severity were provided to growers based on real-time rust situations. The early occurrence of stripe rust due to the warm winter and fast development due to the disease-favorable weather conditions (cool and frequent precipitations) in the late spring and early summer made the disease pressure unusually high. Advice on whether or not to use fungicides on specific cultivars and timely use of fungicides were provided to growers for minimizing yield losses and fungicide usage and maximizing profit under the severe stripe rust epidemic. The effective control of stripe rust saved the PNW wheat growers millions of dollars that could have been lost without the timely control of the disease. Based on acreages of planted resistant and susceptible cultivars and fungicide applications in the commercial fields, and data of our experimental plots, the yield losses caused by stripe rust were reduced to 2 % for the winter crop and 4 % for the spring crop in the state of Washington. Without fungicide application, the winter wheat crop could have suffered 5–10 % yield losses and the spring wheat crop could have suffered 15–20 % yield losses, and individual fields grown with susceptible cultivars could have had 40–60 % yield losses.

Through coöperators in many other states, wheat stripe rust was monitored throughout the United States. In 2005, wheat stripe rust occurred in at least 35 states, which was the most widespread of the disease in the recorded U.S. history. Severe epidemics occurred in California, Texas, Louisiana, Arkansas, Oklahoma, Colorado, Nebraska, Kansas, Alabama, Indiana, Missouri, and some other states in the southeast and Great Plains, and the PNW including southern Idaho, where stripe rust epidemic did not occur from 2000 to 2004.

In 2005, leaf rust, which was severe in the eastern and Great Plains states, occurred severely in our experimental plots in western Washington and in some irrigated fields in eastern Washington. The wide application of fungicides for controlling stripe rust also reduced the risk of leaf rust. Stem rust was found in limited field spots in the late growth stage in eastern Washington, and it did not cause significant damage.

The epidemic impact and benefit of fungicide control were assessed based on our experimental data and disease surveys. In 2005, we evaluated yield reduction by stripe rust and yield increase by fungicide application with 24 winter wheat and 16 spring wheat cultivars in field experiments of a randomized split-block design with 4 replications. Yield losses caused by stripe rust were more than 70 % on highly susceptible winter wheat and more than 60 % on highly susceptible spring wheat. Fungicide spray increased yield by 2.9 times for susceptible winter cultivars and by 1.6 times for susceptible spring wheat cultivars.

Identifying races of *Puccinia striiformis* f. sp *tritici.* Because the most widespread of stripe rust, we collected and received 518 samples from 28 states for identification of stripe rust races in 2005. Of the samples that were collected from wheat, barley, triticale, and grasses, 477 were wheat stripe rust. The stripe rust samples were tested on a set of 20 wheat differential cultivars to identify races of the pathogen. A total of 29 races were detected, of which seven were first identified in 2005. Previously identified races counted for 94 % and new races counted for 6 % of the isolates. The new group of races, which have virulences on resistance genes *Yr8* and *Yr9* and were first detected in the US in 2000, counted for 96 %, whereas the old group of races, which are avirulent on *Yr8* and *Yr9*, counted for only 4 % of the isolates. The three most predominant races in the U.S. in 2005 were PST-100 (33 %), PST-102 (27 %), and PST-115 (14 %). PST-100 has virulences on Lemhi, Heines VII, Produra, Yamhill, Stephens, Lee, Fielder, Express, *Yr8*, *Yr9*, Clement, and Compair of the 20 differential cultivars. PST-102, which was first detected in 2003, has all virulences of PST-100 plus virulence on Tres. PST-115, which was first detected in 2004, has all virulences of PST-102 plus virulence on Paha. Some new races had even wider spectra of virulence. For example, PST-116, which was limited to the PNW in 2005, had all virulences of PST-115 plus virulences on Moro. The increases of these races in frequency and appearance of new races circumvented the all-stage (also called seedling) resistance in winter wheat cultivars such as Eltan and Hiller and several spring wheat cultivars such as Hank, WPB 926, Tara, IDO377s, and Jefferson. These races will likely cause problems in the near future. Cultivars with race nonspecific high-temperature, adult-plant resistance continued to be the best.

Genomic study of *P. striiformis* and its relationships to other cereal rusts. To identify stripe rust genes, we constructed a bacterial artificial chromosomal (BAC) library and a full-length cDNA library from spores of race PST-78 of the wheat stripe rust pathogen. This race represents the group of new races that were first identified in the year 2000 and have caused the widespread epidemics in the U.S. since 2000. The full-length cDNA library consisted of 42,240 clones with an average cDNA insert of 1.5 kb. A total of 167 randomly picked full-length cDNA clones were sequenced, of which 126 had complete sequences and 41 had partial sequences. The BLAST (Basic Local Alignment Search Tool) program was used to compare the sequences to the fungal gene sequence database in NCBI (the National Center for Biotechnology Information). Functions of 36 genes were identified based on their significantly high homologies with genes having clear identified functions in other fungi. These genes included the elongation factor, mitogen-activated protein kinase (MAPK), deacetylase, calnexin, transaldolase, TATA binding protein, UDP-glucose dehydrogenase, β–tubulin, diacylglycerol acyltransferase, retinoblastoma binding protein, GTPase Rac1, serine/threonine kinase receptor, iron-sulfur cluster Isu1-like protein, and enolase. A total of 128 ORFs were identified from the sequences of the 167 cDNA clones. The longest ORF had 951 bp, and the shortest ORF had 93 bp. The genes for elongation factor, TATA-box binding protein, β-tubulin, nucleoside diphosphate kinase (NDK), and mitogen-activated protein kinase were used to determine evolutionary relationships of the stripe rust pathogen to other fungi. The wheat stripe rust pathogen was more related to the wheat stem rust pathogen based on the elongation factor genes than to any other fungal species. Fungal species in Basidiomycetes were more related to each other than to fungi in other groups.

To use the identified genes of the wheat stripe rust pathogen in study of the pathogen population structures and variations, a total of 18 specific DNA primers were designed based on the DNA sequences of 16 selected genes with clear functions. Primers based on genes encoding for the differentiation-related protein (Pstc30M9), spore formation protein (Pstc10I12), MAPK (Pstc55B10) and deacetylase (Pstc10C3) were used to identify polymorphisms among seven cereal rust species or formae speciales: the wheat stripe rust, barley stripe rust, bluegrass stripe rust, orchard grass stripe rust, wheat stem rust, wheat leaf rust, and barley leaf rust pathogens. The primers for the MAPK gene (Pstc55B10F/R) and deacetylase gene (Pstc10C3) amplified the same size of DNA fragments from the genomic DNAs of the wheat stripe rust and barley stripe rust isolates, but did not amplify any fragment from other stripe rust forms and other rust species, indicating that these primers are useful in separating the wheat and barley stripe rusts from other rusts, and that both wheat and barley stripe rust forms are more closely related to each other than to other stripe rust forms and other rust pathogens. Some of the EST primers were able to separate different formae speciales of *P. striiformis* and isolates of *P. striiformis* f. sp. *tritici*.

Evaluation of wheat germ plasm and screening breeding lines for resistance to stripe rust and other foliar diseases. In 2005, we evaluated more than 6,900 winter wheat and 9,100 spring wheat entries for resistance to stripe rust and other foliar diseases. The entries included germplasm, genetic populations, and breeding lines from the National Germplasm Collection Center, and public and private breeding programs. All nurseries were evaluated at both Pullman and Mt. Vernon locations under natural stripe rust infection. The wheat entries also were evaluated for resistance to leaf rust, powdery mildew, and physiological leaf spot at the Mt. Vernon field plots, where these diseases occurred. Some of the nurseries were also tested in the greenhouse with selected five races of stripe rust covering all identified virulences for further characterization of resistance. Disease data of regional nurseries were provided to all breeding and extension programs of that region, while data of individual breeders' nurseries were provided to the individual breeders. Through our testing, new wheat cultivars such as Bauermeister (WA7939), MDM (WA7936), Concept (89*88D), George (GMG-Q-1), Rjames (GMG-Q2), Eddy (BZ9W96-788-E), and Sola (DA900-229) have been or are being released.

Through germ plasm screening, we have established a core collection of wheat germ plasm with stripe rust resistance. The current collection has more than 5,000 entries, which will be valuable sources of stripe rust resistance for further characterization of resistance, identified new effective resistance genes, and for development of wheat cultivars with superior resistance.

Genetic study of resistance, molecular mapping, and cloning stripe rust resistance genes. To identify genes for resistance and develop molecular markers for the resistance genes, we made crosses among Alpowa, Express, IDO377s, and Zak and Avocet Susceptible (AVS). In 2005, F_5 progeny and parents of these crosses were evaluated in the field for resistance to stripe rust. Parents and F_1, F_2, and F_3 progeny from the AVS/Express cross were tested in the greenhouse with selected races of the wheat stripe rust pathogen. The results showed that Express had a dominant gene for all-stage resistance to stripe rust. Using the resistance gene-analog polymorphism (RGAP) technique and the field data of the 'AVS/Alpowa' cross, a linkage group was constructed for a quantitative trait locus conferring high-temperature, adult-plant resistance in Alpowa. Through collaboration with Dubcovsky at UC Davis, we identified a new gene and named it *Yr36* from *T. turgidum* subsp. *dicoccoides* controlling HTAP resistance. We have made significant progress in cloning *Yr5*, a resistance gene effective against all wheat stripe rust races identified so far in the U.S., using the BAC library we have recently constructed. We have identified positive BAC clones and subclones using the molecular markers we identified for *Yr5*.

Determine effectiveness and use of fungicides for rust control. A total of 10 fungicide treatments were evaluated for controlling stripe rust in experimental fields near Pullman, WA. Susceptible winter wheat cultivar PS 279 was planted on 14 October, 2004, and susceptible spring wheat cultivar Fielder and moderately susceptible Eden were planted on 19 April, 2005, using a completely randomized block design with four replications. The fungicide treatments were compared with non-treatment check. Fungicides were sprayed on 21 May in the winter wheat plots when the plants were at the late jointing stage with 20–40 % stripe rust severity, and on 20 June in the spring wheat plots when the plants also were at the late jointing stage with 20–40 % stripe rust severity. Severities of stripe rust were recorded five times for the winter plots and four times for the spring plots at and after fungicide application. Area under disease progress curve (AUDPC) was calculated for each treatment and the check from the multiple sets of rust severity data, and also used for comparison of rust severities over the time period. Test weight and yield were recorded for each plot at the time of harvesting. All fungicide treatments significantly reduced rust severity and increased yield compared to the untreated check. All treatments also increased test weight, but only treatments of two applications of Quilt, Absolute, Sparta, and Folicur significantly increased test weight of PS 279; only Sparta, Quilt, Absolute, and Folicur significantly increased test weight of Fielder; and all treatments but Absolute significantly increased test weight of Eden. These treatments varied in duration of effectiveness, which was correlated with relative stripe rust AUDPC and yield. Based on rust AUDPC data, the best treatments were two applications of Quilt, Absolute, and Folicur for winter wheat PS 279; Absolute, Folicur, Sparta, Quilt, Flutriafol, and Tilt for spring wheat Fielder; and all treatments were not significantly different from each other for the moderately susceptible cultivar, Eden. Based on yield data, Absolute, Sparta, two applications of Quilt, and Folicur were the best in the tests with PS 279; Sparta, Quit, Absolute, Folicur, and Stratego were the best in the test with Fielder; and all fungicide treatments were not significantly different from each other in the tests with moderately susceptible Eden.

Compared to the disease and yield data of 2004, the 2005 data validated two applications of fungicides under the circumstances of early starting and prolonged epidemics like in 2005. In 2004, stripe rust severity was only 1 % on PS 279 on 6 June when fungicides were applied at the boot stage. Untreated plot produced 66 bu/acre and the best controlled plot (with two applications of Quilt) produced 110 bu/acre. In contrast, in 2005 stripe rust severity had already reached 40 % on 21 May when fungicides were used at the late jointing stage. The untreated plot of PS 279 produced only 13 bu/acre and the same treatment (two applications of Quilt) produced 45 bu/acre.

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