ITEMS FROM THE UNITED KINGDOM

JOHN INNES CENTRE
Norwich Research Park, Colney Lane, Norwich NR4 7UH, United Kingdom

Genetics of resistance to Septoria tritici blotch.

James Brown, Lia Arraiano, Penny Brading, Clare Ellerbrook, Elaine Foster, and Tony Worland.

Septoria tritici blotch is currently the major foliar disease of wheat in most of Europe, North Africa, South America, and several other parts of the world. Until recently, little was known about the genetics of resistance to this disease in comparison to, for example, the better-studied rust diseases and mildew. New sources of resistance and improved knowledge about the genetics of resistance would be of great value to breeders in improving resistance to *Septoria tritici* blotch.

Specific interactions between wheat cultivars and isolates of *M. graminicola* have been known since 1973, but their relevance to field conditions has been controversial. In a series of trials, we found strong, specific resistance of wheat genotypes to *M. graminicola* isolates at the adult plant stage. We, and our collaborators in The Netherlands and Switzerland (G. Kema and H-R. Forrer, respectively), tested 71 cultivars and breeding lines, mostly from Europe, to six isolates of *M. graminicola*. The isolate-by-variety interactions were stable over six field trials, which were grown in diverse conditions of climate and soil. This study confirms that isolate-specific resistance is stable over environments. We also identified several lines with good quantitative resistance of an apparently isolate-nonspecific nature from seven European countries, Brazil, and the U.S.

Screening for disease resistance in glasshouse experiments is often laborious and expensive, whereas field disease testing can only be done once a year. We therefore developed a method of testing resistance and detecting isolate-by-cultivar interactions in detached seedling leaves, a method that is widely used by mildew workers. Isolate-by-cultivar interactions were expressed in a consistent manner in different experimental conditions. There was a good correlation between the results of detached leaf tests and those of tests on whole-seedlings and of field trials.

The existence of interactions such as these suggested the existence of a gene-for-gene relationship between wheat and *M. graminicola*. To test this, we crossed Flame and Hereward, which are resistant to the isolate IPO323, with each other and with the susceptible cultivar Longbow. In tests of the F_1, F_2, and F_3 generations, a single, semidominant resistance gene was identified as controlling resistance to IPO323 in Flame, whereas there was no recombination between genes for resistance to IPO323 in Flame and Hereward. The gene was mapped to the distal end of the short arm of chromosome 3A by linkage to microsatellite markers and is named *Stb6*. Tests on the pathogen have shown that a gene for avirulence in IPO323 is complementary to the resistance of both Flame and Hereward as well as several other wheat lines, representing the first demonstration of a gene-for-gene relationship in *S. tritici* blotch.

We have further shown that Dr. E. Sears' synthetic hexaploid wheat (*T. dicoccoides*/*Ae. tauschii*) is resistant to 12 of the 13 isolates of *M. graminicola* tested. We located this resistance to chromosome 7D of synthetic 6x in tests on intervarietal chromosome substitution lines of Synthetic 6x in Chinese Spring. A gene for resistance to isolate IPO94269 was mapped near the centromere of the short arm of chromosome 7D in a population of single homozygous chromosome recombinant lines and is named *Stb5*.

Research activities on yellow rust of wheat.

Lesley Boyd, Phil Smith, Peter Minchin, Tony Worland, Clare Ellenbrook, Jacqueline Garrood, and Robert Koebner.

Genetics of adult plant resistance to yellow rust in wheat. Adult plant resistance (APR) is being studied in wheat through an analysis of mutants showing enhanced field resistance to yellow rust. Mutants have been selected from mutant populations in the cultivars Hobbit 'sib' and Guardian. In the Hobbit 'sib' mutant I3-54, a single, dominant mutant locus segregates with enhanced yellow rust resistance, whereas in I3-48 at least two loci, one cosegregating with a deletion on chromosome 4DL, are associated with the altered yellow rust-resistant phenotype. Seven mutants have been selected from Guardian, four showing an increase in yellow rust resistance and three an increase in susceptibility. In mutant M66, a single, dominant locus confers the enhanced resistance. Mapping populations are being developed from these lines to find molecular markers for the mutant loci.

The genetics of yellow rust APR is also being examined in a number of wheat cultivars, many in collaboration with other research groups. Mapping populations of the Nickerson Seeds cultivars Claire and Buster are being made to map the QTLs controlling APR. A number of cultivars forming part of the Claire pedigree also are being studied. QTLs for yellow rust APR also are being identified in the South African cultivar Kariega (collaboration; Dr. RenJe Prins, Small Grains Institute, Bethlehem, and Prof. Sakkie Pretorius, University of the Free State, Bloemfontein, South Africa) and the Chinese cultivar Fan 6 (collaboration; Dr. Anmin Wan, Institute of Plant Protection, Beijing, PR China).

Development of markers for marker-assisted selection breeding. PCR-based molecular markers have been developed from cloned cosegregating AFLP bands for the wheat, yellow rust-resistance gene *Yr10*. Similar PCR-based markers also are being designed for *Yr5*. Little use has been made of either yellow rust-resistance gene in U.K.-wheat breeding and virulence to these resistance genes is unknown in the U.K. *P. striiformis* f. sp. *tritici* population. These markers have been developed so that *Yr5* and *Yr10* can be pyramided into new wheat cultivars.

Stem-based diseases of wheat.

Elizabeth Chandler, Richard Draeger, Nick Gosman, Martha Thomsett, Duncan Simpson, Andy Steed, Lorenzo Covarelli, and Paul Nicholson.

Fusarium research. The study of the genetic basis of FHB in wheat is continuing. Resistance of the cultivars Arina and RL4137 has been analyzed by spray inoculation of a DH population and RILs, respectively. Mapping and QTL analysis of resistance also is underway. The resistance of chromosome 4A of *T. macha* reported previously has been investigated further in single-chromosome recombinant DH lines. Resistance on this chromosome appears to be conferred by a single gene.

Molecular diagnostics. Molecular diagnostics (species-specific competitive PCR) are being used to study interactions between stem-base disease pathogens on cultivars differing in susceptibility to these diseases. In addition, the efficacy of the eyespot resistance genes *Pch1* and *Pch2* against stem-based diseases other than eyespot also is under investigation. The molecular diagnostics also are being used in studies to determine the effect of fungicides upon species involved in FHB and the consequences for accumulation of toxins in grain.

Progress towards characterizing the Ph1 locus on wheat chromosome 5B.

Simon Griffiths, Steve Reader, Tracie Foote, and Graham Moore.

The *Ph1* locus, on wheat chromosome 5B, is defined by its ability to affect chromosome pairing as scored at metaphase I. Two deletions of this locus have long been known, one in hexaploid wheat (*ph1b*) and the other in tetraploid wheat (*ph1c*). The deleted segment of the chromosome 5B in the *ph1b* line is 70 Mb. Comparative analysis with the gene content of the equivalent region of the rice genome (chromosome 9) suggests that at least 200 genes have been deleted. Recently, we reported the isolation of a set of new fast-neutron irradiation-induced deletions of the region encompassing the *Ph1* locus. Scoring the chromosome pairing of these lines at metaphase I and in wide hybrids with rye or *Ae. variabilis* has identified which have lost the *Ph1* locus. By locating the breakpoints of these deletions with respect to the ne order in the equivalent region of rice, the *Ph1* locus has now been delimited to a region defined by seven rice genes. Currently, a second round of screening for deletions will delimit the region further.

This work benefited from a collaboration with Scott Tingey (Dupont, Wilmington DE, USA).

Preharvest sprouting.

John Flintham, Manoel Bassoi, Rachel Adlam, and Mike Gale.

The map location for a novel major dormancy gene has been determined, close to the ancestral 4A/5A translocation point on the long arm of chromosome 4A. A fine-scale, genetic map and PCR markers for this locus are in development. In other work, QTL mapping has identified a number of dormancy genes that may be of use in combating preharvest sprouting in Brazilian germ plasm, in a Ph.D. program sponsored by EMBRAPA.

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ITEMS FROM THE UNITED STATES OF AMERICA

COLORADO

COLORADO STATE UNIVERSITY
Department of Soil and Crop Sciences, Ft. Collins, CO 80523, USA.

Wheat breeding and genetics.

S. Haley, J. Stromberger, B. Clifford, S. Clayschulte, T. Mulat, E. Ball, and A. Brown.

Production conditions, test sites, and variety distribution. Total winter wheat production in 2001 was estimated at 66 million bushels, a 3.2 % decrease from the 2000 crop. The average grain yield, at 33 bushels/acre, was 13.8 % higher than in 2000 but 6.2 % lower than the 5-year average. The area harvested for grain was estimated at 2 million acres, down from 2.35 million in 2000.

In 2000–01, the breeding program conducted field trials at four main locations in eastern Colorado (Walsh, Burlington, Akron, and Julesburg) in addition to the main site located at the ARDEC research facility near Fort Collins. Overall, environmental conditions experienced at these locations were highly variable, complicating both evaluation and selection. At Burlington, timely planting and good moisture led to excellent establishment and autumn growth, which, unfortunately, was followed by severe drought stress from jointing through harvest that significantly limited expression of yield differences. At Walsh, dry soil conditions in September delayed planting until late October (still in dry soil);

poor emergence and growth in the autumn, some of which occurred in the spring, resulted in a high level of variability within the nurseries. At Akron, 2 inches of rain immediately after planting led to soil crusting and very poor emergence in preliminary and advanced-generation breeding trials. At Julesburg, the variety trial (UVPT) was replanted in early October (following crusting after planting in mid September) and abnormally cold temperatures beginning in early November limited autumn growth. The Fort Collins breeding-trial location was the only successful location with very high yields achieved as a result of favorable environmental conditions and optimal irrigation.

In coöperation with the CSU Variety Testing Program under the direction of Dr. Jerry Johnson, varieties and experimental lines also were tested in Colorado at six dryland (Bennett, Briggsdale, Cheyenne Wells, Genoa, Lamar, and Sheridan Lake) and two irrigated-trial locations (Haxtun, Rocky Ford). Growing conditions at many of the sites was very similar to the four breeding locations, with problems caused by poor emergence and autumn growth contributing to high levels of variability within the trials and generally low yields. The plots at Bennett and Rocky Ford were not harvested because of severe hailstorms prior to harvest, whereas the Sheridan Lake location was not harvested because of very poor stands and soil blowing in the spring.

Virtually no virus (BYDV or WSMV) or insect (RWA, greenbug, or Bird cherry-oat aphid) problems were observed at any of the wheat-trial locations. A high level of stripe rust infection was observed by mid June at several locations (Akron, Fort Collins, Genoa, Haxtun, Julesburg, Lamar, and Walsh). Data were collected on stripe rust resistance of standard varieties and experimental breeding lines. In many materials that showed a very susceptible reaction, yields and test weights were adversely affected.

Planted acreage estimates for the 2001 crop were as follows: Tam 107 – 24.9 %; Akron – 24.4 %; Prairie Red – 11.5 %; Halt – 5.1 %; Yumar – 4.6 %; Lamar – 4.4 %; Yuma – 3.2 %; Prowers – 2.9 %; Jagger – 2.9 %; T-13 – 1.5 %; TAM 110 – 1.2 %, Prowers 99 – 1.1 %; and Alliance – 1.0 %.

New releases. In 2001, one new winter wheat germ plasm line and three new winter wheat cultivars were formally released. The germ plasm line, **CO960293-2** (PI 222668/TAM 107//CO850034 pedigree), was released for its combined resistance to WSMV and RWA. The source of these resistance genes is the PI 222668 parent. The RWA-resistance gene is different from those previously deployed in CSU cultivars and the recent Kansas State University release Stanton. Though distinct from the wheatgrass-derived WSMV resistance being deployed by several Great Plains breeding programs, it confers a high level of resistance (near-immunity) very similar to the wheatgrass source. We have used CO960293-2 extensively in recent crossing efforts to transfer the WSMV and RWA resistance to other backgrounds and combine its WSMV resistance with the wheatgrass WSMV-resistance source.

Two of the new cultivars released, **Above** and **AP502 CL**, are HRWW cultivars with nontransgenic tolerance to the new imidazolinone herbicide *BEYOND*™ from BASF Corporation. The first publicly developed *CLEARFIELD*™ winter wheat cultivars, Above and AP502 CL will allow selective control of winter annual grass (e.g., goatgrass, brome and cheat, and feral rye) and broadleaf weeds that are problematic in Colorado and other wheat-production areas. The genetic backgrounds of Above and AP502 CL are very similar, each coming from backcross introgression of imidazolinone tolerance into germ plasm adapted in the west central Great Plains.

Above is an awned, white-glumed, early maturing (1.8 days later than TAM 107 and 3.6 days earlier than Akron) semidwarf (0.5 inches taller than TAM 107 and 1.2 inches shorter than Akron) HRWW. Above was derived from the cross 'TAM 110*4/FS2' made in 1996 at Amarillo, TX. The wheat germ plasm line FS2 was developed by BASF Corporation (formerly American Cyanamid) through induced mutagenesis, with sodium azide and the French wheat cultivar Fidel, to obtain tolerance to the imidazolinone class of herbicides. Above was tested in the Colorado Dryland Variety Performance Trials in 2000 and 2001. Averaged over 15 trial locations (seven locations in 2000 and eight locations in 2001), Above (41.8 bu/acre) yielded less than Trego (45.1 bu/acre), the same as Jagger and Alliance, and greater than Akron (40.9 bu/acre), TAM 107 (39.9 bu/acre), and TAM 110 (39.0 bu/acre). Average test weight for Above (56.0 lb/bu) in these trials was less than those of Trego (59.0 lb/bu), TAM 107 (56.4 lb/bu), and Akron (56.3 lb/bu); the same as that of Jagger; and greater than that of TAM 110 (55.5 lb/bu). Above is resistant to stem rust, susceptible to leaf rust, and moderately susceptible to both WSMV and BYDV. Above is resistant to greenbug and susceptible to RWA and the Great Plains biotype of Hessian fly. Milling and bread-baking characteristics of Above were determined from composite grain samples from unreplicated yield trials in 1999 and the Colorado Dryland Variety Performance Trials in 2000. Relative to the broadly adapted check cultivar TAM 107, Above had higher grain volume weight, kernel weight, and flour yield, with lower flour protein content and higher ash content. In bread-baking tests, Above had lower bake water absorption, shorter mixograph mixing time, lower loaf volume, lower crumb grain and texture score, and the same mixograph-tolerance score compared to TAM 107. Ownership of Above was transferred from Colorado State University to the Colorado Wheat Research Foundation (CWRF).

The second the two *CLEARFIELD*™ wheats, **AP502 CL**, is an awned, red-glumed, early maturing (similar to TAM 107 and 5 days earlier than Akron) semidwarf (similar to TAM 107 and 1 inch shorter than Akron) HRWW. AP502 CL was derived from the cross 'TXGH12588-26*4/FS2' made in 1996 at Amarillo, TX. The wheat germ plasm line FS2 was developed by BASF Corporation (formerly American Cyanamid) through induced mutagenesis, with sodium azide and the French wheat cultivar Fidel, to obtain tolerance to the imidazolinone class of herbicides. TXGH12588-26, an unreleased experimental line from the Texas A&M University–Amarillo wheat-breeding program, is a sister line to TAM 110. AP502 CL was tested in Colorado Dryland Variety Performance Trials in 2000 and 2001. Averaged over 15 trial locations (seven locations in 2000 and eight locations in 2001), AP502 CL (40.1 bu/acre) yielded less than Trego (45.1 bu/acre), Jagger (42.4 bu/acre), Alliance (42.3 bu/acre), and Akron (40.9 bu/acre); similar to TAM 107 (39.9 bu/acre); and greater than TAM 110 (39.0 bu/acre). Average grain volume weight for AP502 CL (55.3 lb/bu) in these trials was less than those of Trego (59.0 lb/bu), TAM 107 (56.4 lb/bu), Akron (56.3 lb/bu), Jagger (56.1 lb/bu), and TAM 110 (55.5 lb/bu). AP502 CL is resistant to stem rust, susceptible to leaf rust, and moderately susceptible to both WSMV and BYDV. Above is resistant to greenbug and susceptible to RWA and the Great Plains biotype of Hessian fly. Milling and bread-baking characteristics of AP502 CL were determined from composite grain samples from unreplicated yield trials in 1999 and the Colorado Dryland Variety Performance Trials in 2000. Relative to the broadly adapted check cultivar TAM 107, AP502 CL had higher test weight, the same kernel weight, lower flour yield and flour protein content, and higher ash content. In bread baking tests, AP502 CL had lower bake-water absorption, shorter mixograph mixing time, lower loaf volume, lower crumb grain and texture score and the same mixograph-tolerance score compared to TAM 107. Ownership of AP502 CL was transferred from the CWRF to AgriPro Wheat.

The third cultivar released to seed producers, named **Avalanche**, is an awned, white-glumed, early maturing (4 days later than TAM 107, 1 day earlier than Akron, and 2 days earlier than Trego) semidwarf (1.1 inches taller than TAM 107 and similar to both Akron and Trego) HWWW. Avalanche was selected from the cross 'KS87H325/Rio Blanco' made in 1988 at Hays, KS, and is a sister selection to Trego. Avalanche was tested in Colorado Dryland Variety Performance Trials from 1998–2001. Averaged over 35 trial locations between 1998–2001, Avalanche (50.8 bu/acre) yielded less than Alliance (52.2 bu/acre), similar to Akron (51.0 bu/acre), and greater than TAM 107 (48.7 bu/acre). In comparison with other HWWW cultivars available in Colorado, Avalanche has yielded less than Trego (51.6 versus 49.5 bu/acre; 25 locations, 1999–2001) but greater than both Lakin (41.1 versus 38.9 bu/acre; 15 locations, 2000–01) and Nuplains (41.1 versus 37.6 bu/acre; 15 locations, 2000–01). Average test weight for Avalanche (58.7 lb/bu; 26 locations, 1999–2001) in these trials has been very high, slightly less than that of Trego (59.1 lb/bu) but greater than those of Akron (57.1 lb/bu) and TAM 107 (56.9 lb/bu). Avalanche is resistant to stem rust, moderately susceptible to leaf rust, and moderately susceptible to both WSMV and BYDV. Avalanche is susceptible to the Great Plains biotype of Hessian fly, greenbug, and RWA. Milling and bread-baking characteristics of Avalanche were determined from composite grain samples from eight subregional production zones from the 1999 and 2000 USDA Southern Regional Performance Nurseries and from the 1999 and 2000 Colorado Dryland Variety Performance Trials. Relative to the broadly adapted check cultivar TAM 107, Avalanche had higher test weight, kernel weight, and flour yield with similar flour protein and ash content. In bread-baking tests, Avalanche had better crumb grain and texture scores and slightly lower bake-water absorption than TAM 107. Mixograph mixing time, mixograph tolerance score, and loaf volume were similar for Avalanche and TAM 107. Ownership of Avalanche was transferred from Colorado State University to the CWRF.

In 2000–01, eight advanced experimental lines were on breeder seed increase and simultaneous RWA-resistance purification in Yuma, AZ. Five of these lines were RWA-resistant, backcross-derived versions of the popular variety Akron that were in their first year of testing in the UVPT. The other three lines (CO950043, CO970498, and CO970547) were RWA-resistant, experimental lines that had performed well in variety trials in previous years and showed promise as potential replacements for RWA-resistant cultivars currently in production. Based on yield performance in dryland (UVPT) and irrigated (IVPT) state variety trials, and various milling and baking quality evaluations, two of the RWA-Akron lines (CO99508 and CO99534) and one of the other lines (CO970547) were retained for further variety trial testing and seed increase. Of the other lines on increase, both CO950043 and CO970498 were dropped from further consideration. Although yield performance of CO950043 has been excellent in both dryland and irrigated trials, several independent baking quality evaluations (Wheat Quality Council, ConAgra Flour Milling, and the USDA–ARS) suggested that its overall baking quality was unacceptable. In addition to poor dryland yield performance in 2001, similar quality ratings for CO970498 were received.

Performance of the two RWA-resistant Akron lines, CO99508 and CO99534, was slightly less than that of Akron, although when disregarding dryland trials with less reliable data (e.g., Walsh and Lamar), the minor differences were not statistically significant. On the positive side, several independent milling and baking-quality evaluations (e.g., USDA–ARS, Bay States Milling, and ConAgra Flour Milling) also suggest that overall quality of these two lines is superior to that of Akron, a cultivar with a less than desirable baking-quality reputation. Both of these lines are currently on Foundation Seed Increase (18 acres each) in Colorado to enable the release of one line as an improved cultivar following testing (UVPT and IVPT) in 2002. Additional milling and baking quality evaluations are being done by the USDA–ARS quality laboratory during the winter 2001–02 using seed remnants from several locations in 2001.

The remaining line on breeder seed increase, CO970547 (Ike/Halt pedigree), again performed well statewide in dryland trials and was advanced for further testing. Based on a 2-year average in the UVPT, CO970547 has been the highest yielding entry in the central and northeast Colorado locations, 1.5 bu/acre better than Jagger and Enhancer and second only to Trego statewide. Although CO970547 has excellent RWA resistance and above-average milling- and baking-quality ratings, it did not perform as well in the southeast Colorado locations where RWA resistance is of greatest concern. In an attempt to identify types within CO970547 that may show different adaptation patterns or perhaps a yield advantage over CO970547, seven pure-line, headrow reselections were made from a headrow purification in Arizona. Seed harvested from the CO970547 headrow reselections was adequate to include each line in the replicated advanced yield trial (AYT) and a simultaneous strip-increase in Arizona for generation of breeder seed. If one or more of these reselections perform well in 2002, breeder seed quantities should be sufficient to increase in autumn 2002 for potential release in 2003. The ability to conduct a concerted headrow-reselection program, which exploits the phenomenal seed increase capabilities in Arizona, promises to be a significant benefit to the program in coming years.

In 2000–01, 26 other CSU hard red experimental lines were included in the UVPT. Three of these lines were wheat–maize DHs that combined resistance to RWA and BEYOND herbicide. One of these lines, CO99D726, yielded quite will in the UVPT but unfortunately exhibited unacceptable test-weight patterns and was dropped from further consideration, along with the other two CLEARFIELD DHs (CO99D679 and CO99D695) that were in the trial.

Five of the remaining experimental lines performed well in the UVPT, as well as the IVPT at Fort Collins and were advanced for a second year of testing in the UVPT and IVPT. These five lines (CO980376, CO980719, CO980630, CO980829, and CO980607) were sent to Arizona for headrow increases for generation of pure Breeder Seed and line reselection as was done with CO970547. The addition of Fort Collins as an official IVPT location in 2001, coupled with testing of lines that are concurrently tested in the dryland UVPT, should hopefully lead to identification of lines that show exceptional yield performance under irrigation. This strategy was further advanced with addition of a site in the San Luis Valley (Center, CO) as an official IVPT location with fall 2001 planting.

Research support projects and other activities.

In concert with the overall breeding effort, several other activities were undertaken or continued during 2000–01.

Graduate-student research. Several graduate-student research projects currently are underway. Briefly, these include determining the inheritance and chromosomal location of a new WSMV-resistance gene, assessing environmental influence and 'genotype x environment' interaction for key noodle-quality characteristics, and identifying advantages and disadvantages of semidwarfing genes (of European origin) that do not reduce coleoptile length. By summer 2002, three new graduate students will have joined the breeding program to work on other important areas of research. Although we expect that these student projects will contribute vital information to direct the breeding program, the students also benefit by receiving a strong graduate training opportunity.

Spring wheat breeding. A spring wheat breeding effort initiated in 1996 progressed to the selection of 12 spring wheat lines from advanced yield trials in 2001. These lines will be included in replicated, variety trials in eastern Colorado in 2002. Each of these lines was derived by intermating the RWA-resistant line from Montana State University (MTRWA116) with public and private wheat cultivars with primary adaptation in the northern Great Plains region.

USDA–IFAFS Project. A multi-institutional grant effort, coördinated through the University of California–Davis, to the USDA–IFAFS grant-funding agency was successful this past year. The focus of this grant, entitled Bringing Genomics to the Wheat Fields, proposes to utilize DNA-marker technology as a means to transfer desirable quality and pest resistance traits into released varieties and elite experimental lines. CSU is one of 12 public plant-breeding programs involved in this effort, with Nora Lapitan serving as our local collaborator. At CSU, we have chosen recently released varieties or advanced experimental lines (Avalanche, Above, RWA-Akron, CO970547, Stanton, and Lakin) as target parents to transfer or combine genes for WSMV and BYDV tolerance, high grain-protein content, and RWA resistance. The duration of the project is 4 years, with the release of several improved varieties and germ plasm anticipated at the end of the project.

Facilities and equipment improvements. In 2000–01, several facilities and equipment improvements were realized. These improvements include a new university greenhouse with improved climate control and increased space; a new plot planter with no-till openers, liquid starter-fertilizer setup, and automatic seed distribution; a new seed cleaner/conditioner to assist with sample preparation for planting; and a new ATV for alleyway spraying and maintenance in the field. We also recently purchased a new headrow planter that will be used for the first time in spring 2002. The Plant Science renovation is also underway, the primary benefit for our program being a renovated and expanded wheat quality laboratory that will house the bread-baking equipment from the Food Science Department. We are very excited about these important improvements and the positive impact that they promise to make to our program.

GEORGIA / FLORIDA

GEORGIA EXPERIMENT STATION / UNIVERSITY OF GEORGIA
Griffin, GA 30223-1197, USA.

J.W. Johnson, R.D. Barnett, B.M. Cunfer, and G.D. Buntin.

The 2001 Georgia winter wheat crop was grown on about 300,000 harvested acres. The crop production resulted in a state average yield of 53 bu/acre. Overall, the season was characterized by a mild and dry winter followed by a dry and hot spring. Cool and dry conditions prevailed through the grain-filling stage and helped reduce the infection from powdery mildew and leaf rust. Due to excessive rainfall at harvest, several thousands of acres were abandoned in the field and grain was severely sprouted.

Breeding.

92485E15 was released as an exclusively cultivar. Selected from the cross 'GA831276/GA861278 (Saluda/FL74265)/(Gore/FL302)', 92485E15 is a medium-maturing, white-chaffed, medium-height line with good straw strength. The cultivar matures an average of 1 day earlier than AGS 2000 in Georgia. 92485E15 is moderately resistant to the currently predominant races of powdery mildew, leaf rust, and biotypes of Hessian fly in Georgia.

Four SRWW germ plasm lines resistant to *St. nodorum* and other foliar pathogens were released. These lines also have good resistance to leaf rust, powdery mildew, and Hessian fly.

GA 84202 (Novisad138 /2/VPM/Moisson//FL74265),
GA85240 (Hunter/FL742765//IN71761/Coker 80-13),
GA85410 (Hunter/2*GA74-33 (Holley/McNair 701), and
GA861460 (Coker 9323/GA 100).

A wheat–rye translocation line (T2BS·2RL) has been developed for resistance to biotype L of Hessian fly. AFLP analysis using 64 primer pairs identified 2RL-specific polymorphisms between an NIL with 2RL and Hamlet. Nine primer combinations identified 12 reproducible polymorphic fragments in the NIL with 2RL. These 12 fragments were cloned and sequenced to converting AFLP markers into STSs. A comparison of the 12 sequences with nonredundant accessions in the NCBI database using the BLAST search option indicated that one fragment of approximately 200 bp (amplified using primer combination E+AAC / M+CTA) was highly homologous with the rye-specific, repetitive sequence 8173-1 and Wis-2-1A, a retrotransposon-like element in wheat. Two STS primers (SJ07 and SJ09) out of 12 STS primer sets enabled the detection of polymorphisms between NIL with 2RL. Our data suggest that primer set SJ07 amplifies a 2RL-specific fragment of diagnostic value.

Entomology.

Hessian fly populations in winter wheat were predominantly biotype L in northern Georgia, but O is the dominant biotype in the southern part of the state. The *H7H8* resistance genes remained effective in southern Georgia, but were only partly effective where biotype L was present. Advanced breeder lines containing *H13* and *H21* genes, which are effective against biotype L, were evaluated and screened for seed increase. An outbreak of true armyworm (*Pseudaletia unipuncta*) occurred throughout the southern U.S. in 2001. Armyworms defoliated wheat in Georgia during grain-filling but did not cause extensive grain-head clipping and apparent yield loss. Armyworms were controlled in heavily infested fields mostly using methyl parathion. Cereal leaf beetle (*Oulema melanopus*) populations continue to spread southward and increase in numbers in the upper coastal plain area of the state. Maize growing next to wheat fields was sometimes damaged as newly emerged adults moved from senescent wheat fields. Feeding damage by beetles usually was restricted to first 20 m of the field margin. Double-cropped cotton stands and yields were not adversely affect by planting into wheat stubble as compared with a fallow planting. Winter wheat stubble also did not increase insect numbers or disease incidence of cotton seedlings.

Pathology.

Foliar diseases caused little damage to wheat during 2001 because of a dry spring. Powdery mildew, leaf rust, and Stagonospora leaf and glume blotch caused minor losses on susceptible cultivars. Tan spot was found in a few fields planted with minimum tillage and following a period of heavy rains; the first documented case of tan spot in the state. Tan spot probably occurs in a complex with *St. nodorum*, which causes similar symptoms. In 2001, as observed in 2000, a single grower in Georgia experienced a near total crop loss due to stinking smut; always a result of saving seed three or more consecutive years with no application of seed treatment. These rare instances have occurred as some growers attempt to cut costs to a minimum despite educational programs to prevent these unnecessary losses. BYDV was variable but generally low due to the cold weather during the autumn and early winter, which reduced aphid activity during the critical period for transmission and infection. We had a significant increase in dryland foot rot caused by *Fusarium* spp. This disease is more common in the western U.S. where wheat is grown under low rainfall conditions. The extended drought in Georgia over the past several years has favored the development of this disease. A number of fields were extensively damaged resulting in reduced yield and test weights below 55 lb/bu.

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IDAHO

UNIVERSITY OF IDAHO
Moscow and Aberdeen, ID USA.

R. Zemetra, E. Souza, S. Guy, L. Robertson, B. Brown, N. Bosque-Perez, J. Hansen, K. O'Brien, M. Guttieri, D. Schotzko, Y. Wu, T. Koehler, L. Sorensen, and J. Clayton.

Production.

The 2001 Idaho winter wheat production was 51.8 million bushels, a 21 % decrease from 2000. The decrease in production was due in large part to a decrease in average yield/acre from 90 bu/acre in 2000 to 73 bu/acre in 2001. This is the lowest average yield in over 5 years. The decrease in yield can be attributed to a less than favorable spring and early summer, both for rainfall and temperature. There was adequate moisture in the autumn and minimal winter injury but less than adequate moisture and warmer than normal temperatures in the late spring and early summer had a negative effect yield. Lack of adequate irrigation water adversely affected production in some areas of southern Idaho. The climate was not conducive to foliar diseases so little was found in the field. Statistics for the Idaho winter wheat production for the last 5 years are in Table 1.

Table 1. Idaho winter wheat production for the last 5 years.

Year	Acres planted x 10^3	Acres harvested x 10^3	Yield bu/acre	Production bu x 10^3
1997	920	870	80	69,600
1998	820	770	82	63,140
1999	760	710	76	53,960
2000	780	730	90	65,700
2001	760	710	73	51,830

Personnel.

Marc Cortese joined the wheat breeding/genetics program in Moscow as a postdoctoral research associate with primary responsibility in the wheat lignin modification program. Maqsood Rehman joined the Moscow program as a graduate student with primary research responsibilities in the 'wheat x jointed goatgrass' hybrid biological risk program. At the wheat breeding program in Aberdeen, Cecile Becker, research technician, manages the coöperative research project with the Kraft/Nabisco corporation. IFAFS research on molecular markers in wheat is conducted by Brooke Doman. Two graduate students recently started with the Aberdeen wheat-breeding program, Humphrey Wanjugui, an M.S. student working on virus resistance, and David Bowen, a Ph.D. student working on the physiology of low phytic acid wheat.

Cultivar development.

Cultivar releases. In the past year, the University of Idaho approved two cultivars for release from the Aberdeen wheat breeding program, **DW (IDO513)** HRWW and **Gary** (IDO550) HWWW. Both are adapted to rain-fed production with resistance to dwarf bunt, snow mold, and stripe rust. DW has better bread quality than most recent winter wheats from the Aberdeen breeding programs. Gary is adapted for use both in the manufacture of bread and Asian-style noodles.

Two cultivars will be proposed for release in 2002, Alturas (IDO526) SWSW and Moreland (IDO517) HRWW. Alturas is broadly adapted to the Pacific Northwest for use in cookies, crackers, udon noodles, and Chinese steam breads. Moreland is specifically adapted to irrigated production and has relatively strong gluten strength at the high grain-yield levels associated with Pacific Northwest-irrigated production.

The SWWW breeding program in Moscow released the cultivar **Brundage 96**. Brundage 96 is a reselection from Brundage for improved resistance to stripe rust. Brundage 96 is a short, awnletted semidwarf winter wheat with excellent straw strength and superior end-use quality. The variety was tested under the line number ID-B-96. Brundage 96 is similar to Brundage in height, straw strength, winter hardiness, and end-use quality. Although early, it is slightly later in heading than Brundage and more similar to Stephens. Brundage 96 has improved stripe rust resistance compared to Brundage and has shown resistance similar to that found in Stephens. Yield potential of Brundage 96 is good to excellent, showing a slightly greater yield potential under dry land conditions than Brundage. Evaluated in the Pacific Northwest Wheat Quality Collaborative trial, Brundge 96 was found to have the desired quality for several end-uses.

Germ plasm releases. The Aberdeen wheat breeding program will make available to breeders two germ plasm lines. **IDO580** is a HWSW with seed-borne, polyphenyl oxidase enzyme activities that are similar to durums and **A93324S-76kbr**, a HRSW with resistance to Karnal bunt similar to Altar durum.

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<u>INDIANA</u>

PURDUE UNIVERSITY
Departments of Agronomy, Entomology, and Botany and Plant Pathology, and the USDA–ARS Crop Production and Pest Control Research Unit, Purdue University, West Lafayette, IN 47907, USA.

J.M. Anderson (USDA–ARS), H.W. Ohm, F.L. Patterson, H.C. Sharma, and J. Uphaus (Department of Agronomy); G. Buechley, S. Goodwin (USDA–ARS), D. Huber, and G. Shaner, and X.R. Xu (Department of Botany and Plant Pathology); R.H. Ratcliffe, R. Shukle, C.E. Williams, S. Cambron, C. Collier (USDA–ARS), and J. Stuart (Department of Entomology).

Wheat production.

Indiana farmers harvested 153,800 hectares (380,000 acres) of wheat in 2001, down 25 % from 2000. Most of the reduction in wheat acreage was accounted for by increased soybean acreage. Wheat yield in Indiana averaged 4,437 kg/ha (66 bu/acre) in 2001, 202 kg/ha (3 bu/acre) below the average yield in 2000. Farmers have seeded an estimated 142,000 ha (350,000 acres) of winter wheat in Indiana for the 2002 harvest season. Despite a steady decline in wheat production in Indiana, there are farmers who maintain an interest in producing high yields of high quality SRWW. Other farmers grow wheat because of a market for the straw. Livestock producers may grow wheat to provide land where animal manure can be spread during the summer. In the southern half of Indiana, double cropping with soybeans continues to be profitable.

New cultivars.

Three new SRWW cultivars named **INW0101**, **INW0102**, and **INW0123**, were licensed in 2001 for marketing. INW0101 and INW0102 are early, similar to the cultivar Clark, and should fit into a double-cropping system with soybeans. INW0123 is similar in maturity to Patterson. All three cultivars have *Lr37*, *Sr38*, and *Yr17* and resistance to local populations in Indiana of *B. graminis*. They also have resistance to *St. nodorum*, *S. tritici*, and WSBMV.

Wheat disease summary.

Diseases were not a serious problem in most Indiana wheat fields during 2001. The variable rainfall pattern throughout the state resulted in moderately severe leaf blotch in some areas but very little in others. Very little FHB, except in some local situations where wheat was planted into corn residue, but even there the incidence of was low. Stripe rust (yellow rust) was in several fields but was not severe. This rust usually is not seen in Indiana. Although weather in the spring seemed conducive to development of symptoms of infection by WSBMV or WSSMV, there was very little indication of either. The dry autumn of 2000 may have limited infection.

Fusarium head blight resistance sources (Shaner and Buechley). We have evaluated and reselected several wheat accessions for resistance to *F. graminearum*. We now have lines from the following accessions with a high degree and consistent expression of type-II resistance: Chokwang, CIMMYT 211, Futai 8944, Funo, Mentana, Paula VZ 434, and Oscar VY 5418

We crossed these resistant selections to susceptible cultivars (Sumai 3 or Ning 7840) and each other. We evaluated type-II resistance by inoculating a floret in the uppermost, well-developed spikelet of each plant when it was beginning to shed pollen. A 15-m droplet of spore suspension (10^4 conidia/ml) was used as inoculum. The inoculated spike was covered with a small, clear polyethylene bag for 48 h to provide moisture for infection. Blighted spikelets were counted 10 and 20 days after inoculation.

Based on this preliminary observation, genes for resistance in Mentana and Paula VZ 434 may differ from those in Sumai 3. CIMMYT 211, Futai 8944, and Y5418 probably share at least one resistance gene with Sumai 3. Several of these selections show a high degree of type-I and type-II resistance, but Victor V does not. When inoculated by the single-floret method, it is very resistant, but when the head is sprayed with a spore suspension, it is very susceptible.

Genes for resistance do not appear to be completely dominant. For example, when the F_1 of 'Futai 8944/Norm' was backcrossed to Futai 8944, progeny ranged from highly resistant to moderately susceptible. Likewise, when the F_1 of 'Futai 8944/Paula VZ 434' was backcrossed to Futai 8944, progeny ranged from highly resistant to moderately susceptible. When the F_1 of 'Futai 8944/Sumai 3' (or Ning 7840) was backcrossed to Futai 3, all progeny were resistant or moderately resistant, further suggesting that Futai 8944 has one or more genes in common with Sumai 3.

Distributions of the backcross of a 'Chokwang/Clark' F_1 to Clark and of the test cross of 'Chokwang/Clark' to Norm were trimodal. None of the progeny of the backcross to Chokwang were fully susceptible, but 62 % fell into an intermediate category.

Fungicides (Shaner and Buechley). We conducted fungicide trials at two locations in Indiana during 2001. The previous crop was corn at each location. Fungicides were applied prior to heading (Feekes 8 or 9) or during flowering (10.51 or 10.52). *Stagonospora* leaf blotch was the only foliar disease that developed at either location. Several fungicides reduced severity of leaf blotch compared to the untreated control, but two biological materials were ineffective. No scab developed at the north central location. Incidence of scab was low at SEPAC, but there were significant differences among treatments. No treatment had less head blight or number of scabby kernels in harvested grain than seen in the untreated control. Two treatments applied at flowering (Folicur and AMS 21619) did reduce DON contamination compared to the untreated control. Highly significant correlations between incidence of head blight in the field and number of scabby kernels (R = 0.87) and DON level (R = 0.87), and between number of scabby kernels and DON level (R = 0.90) were found.

Fusarium head blight resistance QTL (Drake and Ohm). RILs were developed by SSD, tested in the field and greenhouse by single floret inoculation at anthesis with *F. graminearum*, and genotyped with SSR markers. Two different QTLs on chromosome 3B were identified in the RILs developed from crosses of a susceptible backcross (BC_3F_5-derived) line (L1) by two resistant backcross (BC_3F_5-derived) lines (L1/L3 and L1/ L4) of FHB-resistant Chinese cultivar Ning 7840 and FHB-susceptible cultivar Clark (recurrent parent). Each population had a single unique QTL. Two QTLs, one near the centromere on chromosome 3B and another on chromosome 2B, were identified in a recombinant inbred population of FHB-resistant cultivar Freedom by the susceptible backcross derived line (L1). A single QTL on near the centromere of chromosome 3B, different than QFhs.ndsu-3B, was identified in a RIL population of the susceptible line L1 by FHB-resistant cultivar Patton.

***Septoria tritici* (Goodwin).** Current activities include the analysis of transposition events of a transposable element Dr. Goodwin discovered in the genome of the *S. tritici* leaf blotch pathogen of wheat, *M. graminicola*, revealed evidence for repeat-induced point mutation (RIP). This phenomenon had not been seen previously in relatives of *M. graminicola* and can explain the inactivation of active transposable elements. In other fungi, RIP causes point mutations in duplicated DNA sequences which can affect gene function by introducing stop codons in open reading frames. RIP is well studied in *Neurospora*, but was not known to occur in *Mycosphaerella* or other species in the same order. Occurrence of RIP could explain the inactivation of transposable elements and could provide a means for the fungus to protect itself from introduced DNA.

Analyses of the mating-type genes from the barley speckled leaf blotch pathogen, *Septoria passerinii*, identified two ideomorphs. Each ideomorph contained an uninterrupted open reading frame for one of the two mating-type genes. Both mating types occurred together on the same leaves in North Dakota, and every isolate tested had a unique genotype for molecular markers. Therefore, it seems highly likely that the mating-type genes are functional and that this pathogen has a sexual stage in nature that might complicate efforts to manage the disease. The mating-type genes of *S. passerinii* and *M. graminicola* appear to be evolving extremely rapidly, about ten times faster than the ITS region of the ribosomal DNA. This rapid evolution of mating types may facilitate the speciation process of cereal pathogens.

Phylogenetic analyses of the ITS and 18S regions of the ribosomal DNA from the barley scald pathogen *Rhynchosporium secalis* revealed that this fungus is closely related to *Tapesia yallundae*, the eyespot pathogen of wheat, and also is related to *Pyrenopeziza brassicae*, the cause of light leaf spot of *Brassica* species. Previously, the phylogenetic relationships of *R. secalis* were not known. From this, we predict that the sexual stage of *R. secalis*, if it exists, should be a small (1–2 mm), cup-shaped structure produced on dead stubble following periods of rainfall from 1–10 months after harvest. Anyone walking through old barley stubble following a rain should keep their eyes open for the possible sexual stage of *R. secalis*.

In wheat, we have identified four AFLP markers linked to the *Stb4* gene for resistance in the cultivar Tadinia. Work to convert those markers into a more useful form and to find the map location of the gene is continuing. Analysis of DH populations segregating for the *Stb2* and *Stb3* resistance genes received from Dr. Hugh Wallwork (South Australia) revealed an unknown gene in the Australian parent and two-gene segregations. Work on those populations is continuing and we expect to begin bulked-segregant analysis later this spring.

For more information see the Goodwin lab web site at: http://www.btny.purdue.edu/USDA-ARS/Goodwin_lab/Goodwin_Lab.html , and the USDA–ARS/Purdue University wheat genomics web site: http://www.btny.purdue.edu/usda-ars/wheatgen/ .

Hessian fly.

R. Ratcliffe, S. Cambron, R. Shukle, M. Yoshiyama, A. Johnson, C. Williams, C. Collier, J. Myers, and N. Sardesai.

Biotype determination (Ratcliffe and Cambron). Hessian fly populations from Alabama, Illinois, Louisiana, Maryland, Mississippi, North Carolina, and Virginia were collected and biotyped in 2000–01. This was the first report of the

Hessian fly from Louisiana and westcentral North Carolina. Biotype L was predominant (60–92 %) in all populations. The eastern Illinois samples were the first collected since the mid 1980s and substantiated that biotype L remains predominate in populations in this area of the state. Data from the central Alabama population indicates that the frequency of biotype L may be increasing in the southern two-thirds of the state. The high frequency of biotype L in the Louisiana and Mississippi populations may have resulted from movement of virulent biotypes into these areas via human activities (infested straw from areas where virulent biotypes are present) rather than from selection associated with exposure to resistance genes, since Hessian fly-resistant cultivars have not been deployed in these areas. Collections also were obtained from a single location in each state and may not be representative of populations throughout the area.

Evaluation of durum wheat genotypes for Hessian fly resistance (Ratcliffe, Ohm, Patterson, and Cambron). Twenty-six durum wheat genotypes were evaluated for resistance to Hessian fly biotypes D or L and four populations from the eastern U.S. soft winter wheat region. Resistance to laboratory biotypes D or L of the 26 genotypes was conditioned by one, two, or three genes, depending upon the line. Twenty-five of the genotypes were resistant to Hessian fly populations from the mid Atlantic and southeastern U.S.

Effectiveness of *H9* and *H13* resistance (Ratcliffe, Ohm, and Patterson). Elite wheat germ plasm lines or cultivars from the Purdue breeding program carrying *H9* and/or *H13* resistance to laboratory Hessian fly biotype L, were tested against fly populations collected in Alabama, Louisiana, Maryland, Mississippi, North Carolina, and Virginia in 2000 or 2001. The six fly populations ranged from 60–89 % biotype L based on laboratory biotype tests. The level of virulence in flies to genes *H9* and *H13* was similar for the six populations and highest in flies collected from central Alabama and northeastern Louisiana. Thirty to forty percent of the plants with *H9* and *H13* resistance genes were susceptible to the Alabama and Louisiana populations. The *H9* and *H13* sources were moderately to highly resistant to fly populations from Maryland, Mississippi, North Carolina, and Virginia. The samples collected from Alabama and Louisiana were limited to a very restricted area, therefore, results may not be representative of fly populations throughout these areas, and further studies will be required to ascertain the level of virulence to *H9* and *H13* in the southeastern U.S.

Expression of gene *Hfr-1* in response to attempted feeding by Hessian fly larvae (Williams, Meyer, Collier, and Sardesai). Although plant responses to microbial attack can be categorized according to induction of various defense-response pathways, little information is available about genes induced by herbivorous insects. We have identified a novel plant gene that responds to an incompatible interaction with an insect with a specific avirulence allele. The expression of *Hfr-1*, a low-copy gene, increases rapidly in response to attempted feeding by avirulent first-instar larvae. After cloning and sequencing, we determined that the gene encodes a protein related to defense-response genes and lectins, suggesting possible involvement in plant defense against insects.

We demonstrated that the *Hfr-1* gene responds specifically to Hessian fly and not to more generalized plant stress. This gene is unresponsive to desiccation and wounding and also is unaffected by inducers of certain defense-response pathways (methyl jasmonate and ABA). However, the gene is induced by salicylic acid and its analog BTH, which both induce systemic acquired resistance genes in several plant genera. In leaf blades, the *Hfr-1* gene is induced to the same level independent of the number of larvae per plant. Although the gene is systemically induced (up-regulated in leaves) during an incompatible interaction, induction levels are higher at the base of the plant in tissues surrounding the larval feeding sites. The *Hfr-1* gene was genetically mapped in the wheat genome and a second copy was identified. These map to loci *Xupw1(Hfr1)-4A* and *Xupw1(Hfr1)-7D*, respectively. Forty other partial cDNAs have been cloned that correspond to genes that respond to larval feeding. These sequences are currently under analysis.

Molecular biology of Hessian fly (Shukle, Yoshiyama, and Johnson). The primary focus of our laboratory is to obtain basic information that will expand the use of genetic resistance for control of Hessian fly. Specific objectives directed toward understanding Hessian fly genomics include developing genetic transformation to enhance molecular analysis through transposon tagging, enhancer trapping and gene validation; evaluating variation in mitochondrial and nuclear DNA sequences to reveal historical events, biogeographic patterns, population structure, and evolution of virulence; determining the structure and cytological location of cloned genes; and identifying transgenes to enhance resistance in wheat.

Recent results toward development of genetic transformation include use of microinjection for delivery of DNA into Hessian fly embryos and recovery of G1 individuals expressing the marker gene *EGFP*. Analysis of mtDNA sequence variation has revealed geographic patterns for mitochondrial haplotypes of Hessian fly in the U.S. and Canada. Analysis of additional populations from the Middle East, North Africa, and Europe will reveal information concerning historical events, biogeographical patterns, insight into population structure, and possible variation in selection pressures during dispersal and evolution of the fly in the Old World. A putative *white* gene has been cloned and characterized from Hessian fly. A *white* locus in Hessian fly is linked to three loci controlling virulence to resistance in wheat. Revealing the cytological location of the *white* gene will provide a chromosome landing for three loci controlling virulence. Efforts are being undertaken currently to develop collaboration for transformation of wheat with a putative transgene for resistance to Hessian fly to assess its biological activity.

Barley yellow dwarf virus resistance (Anderson, Sharma, and Ohm). Based on field trials of wheat lines containing group-7 *Th. intermedium* translocations, a translocation line, P98134, is being released as a SRWW germ plasm for BYDV/CYDV resistance. The line was derived from P29, a 7E(7D) chromosome substitution line.

Two BYDV-resistant addition lines with either a *Th. intermedium* group-1 or group-2 chromosome pair were previously crossed to the cultivar Patterson, and the seed irradiated with gamma rays. M_5 families with potential translocations induced from wheatgrass group-1 and -2 chromosomes that have additional resistance to BYDV were identified. These lines were screened cytologically to exclude families containing whole alien chromosome and to select those with 2n = 42 chromosomes and resistance to BYDV for further characterization and crossing to pyramid BYDV resistance. Molecular markers are being identified and utilized to determine if these lines do contain translocations and if so the size of the translocation.

Wheat Hybrids (Uphaus and Ohm). High-yielding, wheat parental lines can produce high-yielding wheat hybrids. However, heterosis in wheat is not reliably predictable based only on genetic unrelatedness of the parent lines. Effects of parental differences for yield components of kernel weight, number of kernels/spike, and number of spikes/meter row on grain yield heterosis were investigated. Eighteen single-cross hybrids were produced from combinations of 11 wheat cultivars and inbred lines contrasting for yield components. A CHA was used to sterilize the seed parents for hybrid seed production in 1998, at Lafayette, IN. Parents and hybrids were grown in replicated performance trials in two seasons, 1999 and 2000, at three locations in Indiana. Heterosis for grain yield, kernel weight, number of kernels/spike, number of spikes/meter row, plant height, heading date, straw strength, and seedling emergence were evaluated. Analysis of variance was performed within years and locations for each hybrid and its parents, hybrid compared to the mid-parent value, and for all parents and hybrids combined. AFLP markers were used to estimate the relatedness of the parental lines. High-parent grain yield heterosis ranged from –12.3 to 10.9 % and mid-parent heterosis ranged from –10.4 to 13.7 %. The highest yielding hybrids resulted from combinations of the highest yielding parent lines. Hybrids from genetically diverse parents with contrasting yield components were more likely to be heterotic for grain yield.

Research personnel.

Mehrdad Abassi finished a nine-month stay in Dr. Goodwin's laboratory studying the phylogenetics of rust fungi from wild grasses and other hosts in Iran, and returned home during July 2001. Dr. Tika Adhikari began a postdoctoral appointment in Dr. Goodwin's lab during March 2001. He will be working to identify molecular markers linked to the major genes for resistance to *S. tritici* leaf blotch and to look at the genomics of pest resistance in wheat. Jill Breeden joined the Goodwin lab as a Biological Science Research Technician during December 2001 and will run the greenhouse disease-screening project. Marcelo Giovanini, from Brazil, South America, initiated studies for the Ph.D. degree in Ohm's lab and will study the inheritance and mapping of resistance to Hessian fly from source lines PI134942 and PI192738. Jim Uphaus completed the M.S. degree and accepted the Small Grains Research Agronomist position in the Department of Agronomy.

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KANSAS

KANSAS AGRICULTURAL STATISTICS
Room 200, 632 S.W. van Buren, P.O. box 3534, Topeka, KS 66601-3534, USA.

Jagger still most popular. Jagger was the leading variety of wheat seeded in Kansas for the 2002 crop, according to Kansas Agricultural Statistics (Table 1). Accounting for 42.8 % of the wheat in the state, Jagger increased seven points from a year ago and was the most popular variety in seven of the nine districts. Jagger made the biggest gain in the southwest district. The KSU-maintained variety 2137 ranked second over all, with 15.5 % of the acreage. 2137 ranked first in two districts and second in the other seven. Karl and improved Karl moved up to third position and increased 0.3 points from last year. The OSU-maintained variety 2174 moved up to fourth place with 3.1 percent of the acreage. The fifth most popular variety was TAM 110 with 3.0 % of the acreage in the state. TAM 107 moved down to sixth place with 2.9 %. Ike moved down to seventh place, with 2.6 %. Dominator moved up to eighth place, with 2.0 %. The KSU-maintained variety 2163 remained in the top ten with 1.3 %. Back in the top ten is Vista, with 0.9 %. Acres planted with multiple varieties blended together were not included in the rankings by variety. Blends accounted for 11.4 % of the acres planted statewide and were used more extensively in the north central and central parts of the state. Out of the total state acres planted with blends, 96.5 % had Jagger in the blend and 75.8 % had 2137. All hard white varieties accounted for 1.1 % of the state's acreage. Trego was the leading hard white variety, accounting for 0.8 % of the wheat in the state. The majority of the white wheat was planted in the western third of Kansas.

Table 1. Top 10 wheat varieties grown in the state of Kansas for the 2002 crop and percent of seeded acreage.

1. Jagger	42.8	6. TAM 107	2.9
2. 2137	15.5	7. Ike	2.6
3. Karl/Karl 92	3.6	8. Dominator	2.0
4. 2174	3.1	9. 2163	1.3
5. TAM 110	3.0	10. Vista	0.9

Publications information.

Monthly crop. Wheat cultivars, percent of acreage devoted to each cultivar. Wheat quality, test weight, moisture, and protein content of current harvest. $10.00

Crop-weather. Issued on each Monday, March 1 through November 30 and monthly from December through February. Provides crop and weather information for previous week. $12.00

County Estimates. County data on wheat acreage seeded and harvested, yield, and production on summer fallow, irrigated, and continuous cropped land. December.

Wheat quality. County data on protein, test weight, moisture, grade, and dockage. Includes milling and baking tests, by cultivar, from a probability sample of Kansas wheat. September.

Each of the above reports is available on the Internet at the following address: http://www.nass.usda.gov/ks/

Reports available via E-mail and how to subscribe A list of all SSO reports that are available via E-mail can be found on the Internet at http://www.nass.usda.gov/sub-form.htm, which provides for automated subscribing. The reports are provided without charge. To subscribe to one or more of the reports listed follow the instructions on the automated form.

Table 2. Distribution of Kansas winter wheat varieties, 2002 crop.

	Agricultural Statistics Districts									
Variety	NW	WC	SW	NC	C	SC	NE	EC	SE	State
	percent of seeded acreage [1]									
Jagger	21.8	13.5	32.8	20.5	40.6	63.4	9.9	28.1	50.7	42.8
2137	15.5	18.2	12.2	18.3	20.3	10.8	43.3	34.8	27.7	15.5
Karl/Karl 92	1.9	3.0	0.3	14.7	4.0	1.4	25.6	13.4	4.6	3.6
2174	0.3	0.6	0.3	0.8	2.0	6.6	0.0	3.2	3.6	3.1
TAM 110	1.7	15.2	10.9	0.1	0.2	0.1	—	0.7	—	3.0
TAM 107	9.1	11.3	6.8	0.4	0.5	0.2	0.1	0.3	0.1	2.9
Ike	2.2	6.9	11.7	0.6	1.3	0.5	—	0.0	0.1	2.6
Dominator	0.1	0.1	—	6.4	5.8	0.4	3.4	4.1	0.0	2.0
2163	0.1	0.2	1.1	1.4	2.1	1.3	3.2	4.5	1.6	1.3
Vista	9.4	0.7	0.2	0.1	0.1	—	—	—	—	0.9
Larned	0.9	3.8	2.6	0.2	0.4	0.0	—	0.2	—	0.9
Trego (hard white)	3.4	2.4	0.8	0.7	0.3	0.1	—	0.0	0.0	0.8
T81	0.4	2.6	3.6	0.0	0.1	0.1	—	—	—	0.8
AgriPro Coronado	0.0	—	—	0.1	0.7	1.4	0.3	—	1.4	0.7
AgriPro Thunderbolt	2.1	0.9	1.6	0.7	0.2	0.1	—	—	—	0.6
AGSECO 7853	—	0.2	0.4	0.3	0.6	0.6	—	—	0.3	0.4
AgriPro Ogalala	0.8	1.5	1.3	0.2	0.2	0.0	—	—	—	0.4
Akron–HRW	1.2	1.8	0.8	—	—	—	—	—	0.0	0.4
Alliance–HRW	4.1	—	—	—	—	—	—	—	—	0.3
AgriPro Tomahawk	0.1	0.0	0.1	0.7	0.2	0.4	—	0.8	0.9	0.2
AgriPro Pecos	—	—	—	0.2	0.3	0.4	—	—	0.5	0.2
Niobrara	2.5	—	0.3	—	—	—	—	—	—	0.2
AgPro Big Dawg	0.1	0.0	—	0.0	0.5	0.3	—	0.2	1.3	0.2
Prairie Red	0.1	1.8	0.1	—	—	—	—	—	—	0.2
Eagle	0.0	0.5	0.8	—	0.2	0.0	—	0.1	—	0.2
AGSECO Onaga	0.5	—	0.0	0.2	0.1	0.2	0.3	—	1.4	0.2
Scout/Scout 66	0.1	0.2	1.0	0.1	0.0	0.0	—	—	—	0.2
Longhorn	0.7	0.2	0.8	—	0.0	0.0	—	—	0.0	0.2
Blends	9.7	6.0	3.6	29.4	15.8	8.9	6.3	4.2	1.7	11.4
Other Hard White Varieties	0.5	0.8	1.3	0.2	0.2	0.2	—	0.1	1.7	0.3
Other Hard Varieties	4.8	2.3	4.6	3.7	3.3	2.6	7.6	5.3	1.2	3.3
Other Soft Varieties	0.5	—	—	—	0.0	0.0	0.0	0.0	2.0	0.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[1] — = variety not reported in this district; 0 = < 1 %.

Table 3. Distribution of Kansas winter wheat varieties, specified years.

Variety	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
	percent of seeded acreage									
Jagger	—	—	—	1.0	6.4	20.2	29.2	34.0	35.8	42.8
2137	—	—	—	—	1.0	13.5	22.0	23.1	22.3	15.5
Karl/Karl 92	23.0	23.6	22.4	20.9	22.1	10.8	5.9	3.5	3.3	3.6
2174	—	—	—	—	—	—	—	1.1	3.0	3.1
TAM 110	—	—	—	—	—	—	0.5	1.3	2.8	3.0
TAM 107	19.8	19.0	20.6	17.1	17.0	12.6	8.3	6.3	5.3	2.9
Ike	—	—	0.9	7.2	10.5	7.0	5.5	4.1	3.6	2.6
Dominator	—	—	—	—	—	0.2	0.8	1.4	1.5	2.0
2163	9.0	13.8	17.1	19.8	15.4	10.4	3.4	2.3	2.0	1.3
Vista	—	—	0.3	0.8	1.2	1.1	0.9	0.9	1.0	0.9
Larned	8.3	8.3	7.6	4.8	3.6	2.4	1.9	1.2	1.0	0.9
Trigo (hard white)	—	—	—	—	—	—	—	—	0.3	0.8
T81	—	—	—	—	—	—	—	0.2	0.2	0.8
AgriPro Coronado	—	—	—	—	—	0.8	1.3	1.0	1.1	0.7
AgriPro Thunderbolt	—	—	—	—	—	—	—	—	0.2	0.6
AGSECO 7853	1.4	2.1	3.7	4.6	4.0	3.4	1.9	1.5	0.9	0.4
AgriPro Ogalala	—	—	0.2	1.5	1.3	0.8	0.7	0.8	0.4	0.4
Akron–HRW	—	—	—	—	—	0.4	0.8	1.0	0.4	0.4
Alliance–HRW	—	—	—	—	—	—	0.1	0.3	0.5	0.3
AgriPro Tomahawk	1.5	6.2	7.0	4.7	3.1	1.8	1.2	0.8	0.4	0.3
AgriPro Pecos	—	0.2	1.1	1.8	1.6	1.6	0.9	0.7	0.4	0.2
Niobrara	—	—	—	—	—	—	—	0.5	0.3	0.2
AgriPro Big Dawg	—	—	—	—	—	0.2	0.4	0.5	0.3	0.2
Prairie Red	—	—	—	—	—	—	—	—	0.1	0.2
Eagle	1.0	1.1	1.1	0.6	0.5	0.4	0.3	0.2	0.2	0.2
AGSECO Onaga	—	—	—	—	—	—	0.1	0.1	0.2	0.2
Scout/Scout 66	1.3	1.3	1.0	1..2	0.8	0.7	0.5	0.3	0.1	0.2
Longhorn	—	0.6	0.7	0.5	0.3	0.2	0.1	0.2	0.1	0.2
Blends	—	—	—	—	—	2.6	6.1	7.5	7.0	11.4
Hard White Varieties	—	—	—	—	—	—	—	0.2	0.8	0.3
Other Hard Varieties	32.4	22.0	15.5	12.7	10.3	9.0	7.0	4.7	3.8	8.3
Other Soft Varieties	—	—	—	—	—	—	0.0	2.0	0.0	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. Top wheat varieties planted in Kansas by district and percent of seeded acreage.

District 10 (Northwest)		District 40 (North central)		District 70 (Northeast)	
Jagger	27.2	Jagger	20.5	2137	43.3
2137	15.5	2137	18.3	Karl/Karl 92	25.6
Vista	9.4	Karl/Karl 92	14.7	Jagger	9.9
TAM 107	9.1	Dominator	6.4	Dominator	3.4
Alliance	4.1	2163	1.4	2163	3.2
District 20 (West central)		**District 50 (Central)**		**District 80 (East central)**	
Jagger	18.8	Jagger	401.6	2137	34.8
2137	18.2	2137	20.3	Jagger	28.1
TAM 110	15.2	Dominator	5.8	Karl/Karl 92	13.4
TAM 107	11.3	Karl/Karl 92	4.0	2163	4.5
Ike	6.9	2163	2.1	Dominator	4.1
District 30 (Southwest)		**District 60 (South central)**		**District 90 (Southeast)**	
Jagger	32.8	Jagger	63.4	Jagger	50.7
2137	12.2	2137	10.8	2137	27.7
Ike	11.7	2174	6.6	Karl/Karl 92	4.6
TAM 110	10.9	Karl/Karl 92	1.4	2174	3.6
TAM 107	6.8	AgriPro Coronado	1.4	2163	1.6

KANSAS STATE UNIVERSITY
Environmental Physics Group, Department of Agronomy, Kansas State University, Throckmorton Hall, Manhattan, KS 66506-5501, USA.

Heavy metals in soil at the Manhattan, KS, Biosolids Farm growing winter wheat.

M. Stanley Liphadzi and M.B. Kirkham.

Since 1976, all of the biosolids from the city of Manhattan, KS, have been injected into the soil to dispose of them and to use them as soil conditioners and fertilizers. Winter wheat has been grown at the Biosolids Farm during this time and continues to be grown at the farm. Long-term applications of biosolids to soil can result in an accumulation of heavy

Table 1. Concentrations of heavy metals in surface 30 cm of soil at the Manhattan, KS, Biosolids Farm, where winter wheat is grown. Mean and standard deviation are shown (n = 3 for the 25-year-application site; n = 6 for the control site). Mean and normal range for total concentrations of heavy metals in nonpolluted soils also are given.

Time of biosolids application to soil	Cd	Cu	Fe	Mn	Ni	Pb	Zn
Years				mg/kg			
25	0.82 ± 0.15	16.7 ± 2.9	8,770 ± 1,400	167 ± 61	8.93 ± 1.94	27.2 ± 3.3	31.2 ± 2.5
0	0.88 ± 0.27	8.5 ± 3.1	12,000 ± 3,870	212 ± 74	12.4 ± 4.5	32.6 ± 6.9	20.7 ± 7.0
Mean	0.5	20	Not known	850	40	10	50
Normal range	0.01–0.7	2–100	200–100,000	100–4,000	5–5000	2–200	10–300

metals. However, the concentrations of heavy metals in the soil at the Biosolids Farm have not been monitored. We wanted to know if the soil contained abnormal levels of heavy metals. Soil samples were obtained from two sites at the Biosolids Farm. One site had received biosolids for 25 years (since 1976) and the other site had never received biosolids (control site). The samples were analyzed for total concentrations of Cd, Cu, Fe, Mn, Ni, Pb, and Zn. The results are shown in Table 1 (p. 217).

The results show that, after 25 years of application of biosolids to the farm, concentrations of heavy metals have not increased in the soil. The winter wheat at the Biosolids Farm is not being grown on soil contaminated with heavy metals.

We thank Dr. Abdu Durar, Assistant Director of Utilities, Wastewater, City of Manhattan, Kansas, for supplying the soil samples from the Biosolids Farm.

News.

Dr. Fernando Madrid, former postdoctoral student, has returned to Spain to accept the job as director of the analytical laboratory of the Spanish government's Institute of Natural Resources and Agrobiology in Seville.

Publications.

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THE WHEAT GENETICS RESOURCE CENTER
Department of Plant Pathology, Throckmorton Hall, Manhattan, KS 66506-5502, USA.
http://www.ksu.edu/wgrc

Chromosome healing by addition of telomeric repeats in wheat occurs during the first mitotic divisions of the sporophyte and is a gradual process.

B. Friebe, R.G. Kynast, P. Zhang, L. Qi, M. Dhar, and B.S. Gill.

Alien gametocidal chromosomes cause extensive chromosome breakage prior to the S-phase in the first mitotic division of gametophytes lacking the alien chromosome. The broken chromosomes may be healed either by the addition of telomeric repeats in the gametophyte or undergo fusions to form dicentric or translocation chromosomes. We showed that dicentric chromosomes undergo breakage-fusion-bridge (BFB) cycles in the first few mitotic division of the sporophyte, are partially healed before the germ line differentiation regimen, and are healed completely in the ensuing gametophytic stage. The gametocidal factor on chromosome $4M^g$ of *Ae. geniculata* was used to induce dicentrics involving the satellite chromosomes 1B and 6B of wheat, *T. aestivum*. The dicentrics T1BS·1BL-2AL·2AS and T6BS·6BL-T4BL·4BS initiated BFB cycles that ceased 2 to 4 weeks after seed germination. At the end of the BFB cycles, we observed deficient 1B and 6B chromosomes with breakpoints in proximal regions of the 1BL and 6BL arms. The process of chromosome healing was analyzed in root-tip meristems, at meiotic metaphase I, and in the derived progenies by fluorescence in situ hybridization analysis using a telomeric probe pAtT4. The results show that chromosome healing in wheat occurs during very early mitotic divisions in the sporophyte by de novo addition of telomeric repeats and is a gradual process. Broken chromosome ends have to pass through several cell divisions in the sporophyte to acquire the full telomeric repeat length.

High-resolution structural analysis of biolistic transgene integration into the genome of wheat.

S.A. Jackson, P. Zhang, W.P. Chen, R.L. Phillips, B. Friebe, S. Muthukrishnan, and B.S. Gill.

Transformation of plant genomes by biolistic methods has become routine over the past decade. However, relatively little is known about how transgenes are physically integrated into the host genome. Using a high-resolution physical mapping technique, fluorescence in situ hybridization on extended DNA fibers (fibre-FISH), 13 independent transgenic wheat lines were analyzed to determine the structural arrangement of stably inherited transgenes in host-plant chromosomes. Twelve transgenic lines were transformed with a single plasmid and one line was cotransformed with two separate plasmids, which cosegregated genetically. Three basic integration patterns were observed from the fiber-FISH experiments: Type I, large, tandemly repeated integration; Type II, large tandem integrations interspersed with unknown DNA; and Type III, small insertions, possibly interspersed with unknown DNA. Metaphase FISH showed that the integration of transgenes was in both hetero- and euchromatic, as well as proximal, interstitial, and distal regions of the chromosomes. In the transgenic plants, the type of promotor used, rather than the chromosomal site of the transgene integration, was most critical for transgene expression . The integration of the transgenes was not associated with detectable chromosomal rearrangements.

The colinearity of Sh2/A1 orthologous region in rice, sorghum and maize is interrupted and accompanied by genome expansion in the Triticeae.

W.L. Li and B.S. Gill.

The *Sh2/A1* orthologous region of maize, rice, and sorghum contains five genes in the order *Sh2*, *X1*, *X2*, and two *A1* homologues in tandem duplication. The *Sh2* and *A1* homologues are separated by ~20 kb in rice and sorghum, and by ~140 kb in maize. We analyzed the fate of the *Sh2/A1* region in large-genome species of the Triticeae (wheat, barley, and rye). In the Triticeae, synteny in the *Sh2/A1* region was interrupted with a break between *X1* and *X2* genes. *A1* and *X2* genes remained collinear in homoeologous chromosomes as in other grasses. The *Sh2* and *X1* orthologs remained collinear but were translocated to a non-homoeologous chromosome. *X1* gene was duplicated on two nonhomoeologous chromosomes, and surprisingly a paralog shared much higher homology than the orthologous copy to the *X1* gene of other grasses. No tandem duplication of *A1* homologues was detected but duplication of *A1* on a nonhomoeologous barley chromosome 6H was observed. Intergenic distances expanded greatly in wheat as compared to rice. Wheat and barley diverged from each other 12 million years ago and both showed similar changes in the *Sh2/A1* region suggesting that the break in colinearity as well as *X1* duplications and genome expansion occurred in a common ancestor of the Triticeae species.

Genome differentiation in Aegilops; evolution of the D-genome cluster.

E.D. Badaeva, A.V. Amosoma, O.V. Muravenko, T.E. Samatadze, N.N. Chikida, A.V. Zelenin, B. Friebe, and B.S. Gill.

Six polyploid *Aegilops* species containing the D genome were studied by C-banding and FISH using clones pTa71 (18S-5.8S-26S rDNA), pTa794 (5S rDNA), and pAs1 (noncoding repetitive DNA sequence) as probes. The C-banding and pAs1-FISH patterns of *Ae. cylindrica* chromosomes were identical to those of the parental species. However, inactivation of the NOR on chromosome 5D with a simultaneous decrease in the size of the pTa71-FISH site was observed. The N^v and D^v genomes of *Ae. ventricosa* were somewhat modified as compared with the N genome of *Ae. uniaristata* and the D genome of *Ae. tauschii*. Modifications included minor changes in the C-banding and pAs1-FISH patterns, complete deletion of the NOR on chromosome $5D^v$, and the loss of several minor 18S-5.8S-26S rDNA loci on N^v genome chromosomes. According to C-banding and FISH analyses, the D^{cr1} genome of *Ae. crassa* is more similar to the D^v genome of *Ae. ventricosa* than to the D genome of *Ae. tauschii*. Mapping of the 18S-5.8S-26S rDNA and 5S rDNA loci by multicolor FISH suggests that the second (X^{cr}) genome of tetraploid *Ae. crassa* is a derivative of the S genome (section Emarginata of the Sitopsis group). Both genomes of *Ae. crassa* were significantly modified as the result of chromosomal rearrangements and redistribution of highly repetitive DNA sequences. Hexaploid *Ae. crassa* and *Ae. vavilovii* arose from the hybridization of chromosomal type N of tetraploid *Ae. crassa* with *Ae. tauschii* and *Ae. searsii*, respectively. Chromosomal type T1 of tetraploid *Ae. crassa* and *Ae. umbellulata* was the ancestral form of *Ae. juvenalis*. The high level of genome modification in *Ae. juvenalis* indicates that it is the oldest hexaploid species in this group. The occurrence of hexaploid *Ae. crassa* was accompanied by a species-specific translocation between chromosomes $4D^{cr1}$ and $7X^{cr}$. No chromosome changes relative to the parental species were detected in *Ae. vavilovii*, however, its intraspecific diversity was accompanied by a translocation between chromosomes $3X^{cr}$ and $3D^{cr1}$.

Personnel.

Moha Ferrahi completed his Ph.D. degree in December, 2001, and has returned to Morocco. Li Huang completed her Ph.D. degree in May, 2002. She will remain at the WGRC as a postdoctoral research associate. Vasu Kuraparthy from India is a new Ph.D. student beginning in the autumn of 2001.

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USDA–ARS PLANT SCIENCE AND ENTOMOLOGY RESEARCH UNIT
Kansas State University, Throckmorton Hall, Manhattan, KS 66506, USA.

Collection and evaluation of wheat germ plasm from Tajikistan.

Gina Brown-Guedira, Safarali Naimov (Research Institute of Plant Physiology and Genetics, Academy of Sciences of the Republic of Tajikistan, Dushanbe, Tajikistan), and W.J. Raupp (Wheat Genetics Resource Center, Kansas State University, Manhattan, KS).

The territory of Tajikistan is indigenous to a wide variety of cultivated and wild cereal species. Although the territory was identified as a secondary center of diversity of the tribe Triticeae by N.I. Vavilov, collections of wheat germ plasm from Tajikistan are limited. Collections in the GRIN database of the USDA National Plant Germplasm System consist only of a small number of accessions of *T. aestivum* (12) and two collections of *T. spelta*, all of which were obtained from the Vavilov Institute. There are no collections of *Aegilops* species from Tajikistan in the USDA collection.

An ongoing collaboration between the Academy of Sciences of Tajikistan and the USDA–ARS Manhattan, KS, has led to the recent acquisition of 40 landraces of *T. aestivum* and 82 collections of wild *Aegilops* species, including 43 *Ae. tauschii*, 16 *Ae. cylindrica*, 16 *Ae. triuncialis*, and 7 *Ae. crassa*. Collections were made during August of 2001 by Dr. Safarali Naimov in the central part of Tajkistan, as well as the Hissar and Khanaka mountainous regions and parts of Kyrgystan and Uzbekistan (Table 1, p. 222-223). A portion of the collected seed was planted in the field at Dushanbe, Tajikistan, for seed increase and to evaluate the collection for tolerance of high salt concentration in the soil. Preliminary analyses identified a landrace collection of *T. aestivum* from central Tajikistan tolerant of soil salinity.

A sample of collected seed was sent to the Wheat Genetics Resource Center at Kansas State University. Collections were assigned accession (TA) numbers, and seed was planted for increase in the greenhouse at Manhattan, KS.

Seedlings were evaluated for reaction to PNMQ (avirulence/virulence formula 2a,11,16,17,26/1,2c,3a,3ka,9,10,18,24,30) and PRTUS6 (2a,3ka,9,61,18,24,26,30/1,2c,3a,10,11,17) isolates of *P. triticina* (Table 1). Leaf rust is a serious disease of wheat in many parts of the world, including most wheat-growing areas of the U.S. and central Asia. Six wheat landrace collections were resistant or heterogeneous to both isolates of *P. triticina* tested. Leaf rust reactions of *Ae. cylindrica* and *Ae. triuncialis* collections varied with the two isolates. With the exception of TA 10362, all collections of both species had resistant or heterogeneous reactions when tested with PRTUS 6. Six accessions of *Ae. cylindrica* were resistant or heterogeneous when inoculated with the PNMQ race of leaf rust. All of the *Ae. triuncialis* collections, except TA 10362, had resistant or heterogeneous reactions to PNMQ. All collections of *Ae. tauschii* and *Ae. crassa* were susceptible to the leaf rust isolates tested. Species designations of the collection are being verified and seeds will be sent to the USDA National Small Grains Collection. Small samples of seed may be requested from the Wheat Genetics Resource Center. This work is supported by the U.S. Civilian Research and Development Foundation for the Independent State of the Former Soviet Union.

Table 1. Collection site and seedling reaction [1] of *Triticum* and *Aegilops* collections to *Puccinia triticina* isolates PMNQ and PRTUS6.

TA #	Species	PNMQ	6	TA #	Species	PNMQ	6	TA#	Species	PNMQ	6
Tajikistan. Hissar district; central Tajikistan.											
10293	*tauschii*	3	3	10299	*tauschii*	3	3	10339	*crassa*	3	3
10294	*tauschii*	3	2+–3	10300	*tauschii*	3	3	10340	*crassa*	3	3
10295	*tauschii*	3	3	10301	*tauschii*	3	3	10341	*cylindrica*	3+	;–1C
10296	*tauschii*	3	3	10302	*tauschii*	3	3	10342	*cylindrica*	;C	;C
10297	*tauschii*	3	3	10303	*tauschii*	3	3	10360	*triuncialis*	;C	;C
10298	*tauschii*	3	3	10304	*tauschii*	3	3	10392	*aestivum*	3	—
Hissar valley; central Tajikistan.											
10385	*aestivum*	3	3	10397	*aestivum*	3	3+	10401	*aestivum*	3	3
10386	*aestivum*	3	3+	10398	*aestivum*	3	3+	10402	*aestivum*	3	;/2/3
10387	*aestivum*	3	3+	10399	*aestivum*	3	4	10403	*aestivum*	3	3+
10388	*aestivum*	3	3+	10400	*aestivum*	;C/;1C	;1C–2C	10404	*aestivum*	3	3+
In the Hissar Mountains of central Tajikistan; Tursunzade [Tursunzoda] district.											
10354	*cylindrica*	3+	;C								
South Hissar Mountains; central Tajikistan.											
10361	*triuncialis*	;C	;C	10362	*triuncialis*	3	3	10363	*triuncialis*	;C/3	;C/3
West Hissar Mountains; Tursunzoda district.											
10381	*aestivum*	;C/3	;C/3	10383	*aestivum*	;C/3	3/?	10384	*aestivum*	3	3
10382	*aestivum*	3	3								
Mountainous Khanaka; Hissar Mountains.											
10410	*aestivum*	3	3								
Sherkant area; Hissar Mountains.											
10411	*aestivum*	3	3	10412	*aestivum*	3	3	10413	*aestivum*	3	4
Qarm [Gharm] district; east central Tajikistan.											
10291	*tauschii*	3	3	10314	*tauschii*	3	3	10395	*aestivum*	3+	3+
10292	*tauschii*	3	3	10368	*triuncialis*	;C/3	;C/3				
Near mineral spring; Faizabad district; central Tajikistan.											
10305	*tauschii*	3	3	10307	*tauschii*	3	3	10353	*cylindrica*	3+	2
10306	*tauschii*	3	3								
Faizabad; central Tajikistan.											
10393	*aestivum*	—	;–;1C/3+	10394	*aestivum*	3	3+				
Faizabad District; central Tajikistan.											
10308	*tauschii*	3	3	10343	*cylindrica*	3	;/;C	10365	*triuncialis*	;C	;C
10309	*tauschii*	3	3	10344	*cylindrica*	3	;C	10366	*triuncialis*	;C	;C
10310	*tauschii*	3	3	10364	*triuncialis*	—	;C				
Dushanbe; Hissar Valley; central Tajikistan.											
10315	*tauschii*	3	3	10317	*tauschii*	3	3	10319	*tauschii*	3	3
10316	*tauschii*	3	3	10318	*tauschii*	3	3				

Table 1 (continued). Collection site and seedling reaction [1] of *Triticum* and *Aegilops* collections to *Puccinia triticina* isolates PMNQ and PRTUS6.

TA #	Species	PNMQ	6	TA #	Species	PNMQ	6	TA#	Species	PNMQ	6
Near Dushanbe; central Tajikistan.											
10357	*triuncialis*	;C	;C	10359	*triuncialis*	C	;C	10391	*aestivum*	3+	3
10358	*triuncialis*	;C	;								
In the Alay Mountains near Kyrgyzstan border; Dzirgatal' [Jirgital] district; northeast Tajikistan.											
10320	*tauschii*	3	3	10321	*tauschii*	3	3				
Darband district; eastcentral Tajikistan.											
10311	*tauschii*	3	3								
Tavil'dara district, eastcentral Tajikistan.											
10312	*tauschii*	3	3	10313	*tauschii*	3	3	10345	*cylindrica*	;/;C	;/;1C
Ganchi district; north Tajikistan.											
10334	*crassa*	3	3	10337	*crassa*	3	3	10349	*cylindrica*	;C	;C
10335	*crassa*	3	3	10338	*crassa*	3	3	10350	*cylindrica*	;C	;–;C
10336	*crassa*	3	3	10348	*cylindrica*	;C	;–;C				
Uroteppa [Ura-T'ube] district; north Tajikistan.											
10322	*tauschii*	3	3	10323	*tauschii*	3	3	10324	*tauschii*	3	3
Near Khodjent; north Tajikistan.											
10325	*tauschii*	3	3	10326	*tauschii*	3	3				
Uranium mine area in Karamazar Mountains near Khodjent; north Tajikistan.											
10327	*tauschii*	3	3	10370	*triuncialis*	;C	;C	10372	*triuncialis*	;C	;C
10328	*tauschii*	3	3	10371	*triuncialis*	;C	;C				
Khodjent district; north Tajikistan.											
10351	*cylindrica*	3+	;C	10352	*cylindrica*	3	;–;C				
Khatlon district; south Tajikistan.											
10346	*cylindrica*	3+	;C	10367	*triuncialis*	;C	;/;C/2C	10396	*aestivum*	3	3+
Estaravshan district; north Tajikistan.											
10347	cylindrica	;C	;C								
Sharinow district; west Tajikistan.											
10390	*aestivum*	3	3+	10406	*aestivum*	3	3+	10408	*aestivum*	3	3+
10405	*aestivum*	3	3+	10407	*aestivum*	3	3+	10409	*aestivum*	3	3+
Chudzand [Khujand].											
10389	*aestivum*	3	—								
Kyrgyzstan.											
Western Tian-Shan Mountains; east Kyrgyzstan.											
10329	*tauschii*	3	3	10330	*tauschii*	3	3				
Osh.											
10355	*cylindrica*	3	;C	10369	*triuncialis*	;C/3	;C/;1C	10380	*aestivum*	;C/3	2/3
10356	*cylindrica*	3+	;C								
Batkent district; east Kyrgyzstan.											
10378	*aestivum*	3	4								
Uzbekistan.											
Bekabod; north Tajikistan border.											
10331	*tauschii*	3	3	10333	*tauschii*	—	—	10353	*cylindrica*	3+	;–;C
10332	*tauschii*	—	—								
Village of Sukh.											
10374	*aestivum*	;C	3	10376	*aestivum*	3	3	10379	*aestivum*	3	3+
10375	*aestivum*	1C	;C–;1C	10377	*aestivum*	3	3+				

[1] The seedling infection types are: 0 = no uredinia or other microscopic sign of infection, ; = no uredinia but small hypersensitive necrotic or chlorotic flecks present, 1 = small uredinia surrounded by necrosis, 2 = small to medium uredinia surrounded by necrosis or chlorosis, 3 = medium uredinia with or without clorosis, 4 = large uredinia without chlorosis, X = heterogeneous (random distribution of variable-sized uredinia on a single leaf), C = more chlorosis than normal for the infection type, + = uredinia somewhat larger than normal for the infection type, — = no data.

GRAIN MARKETING AND PRODUCTION RESEARCH CENTER
U.S. Grain Marketing Research Laboratory, USDA, Agricultural Research Service, Manhattan, KS 66502, USA.

O.K. Chung, F.E. Dowell, S.R. Bean, G.L. Lookhart, J.B. Ohm, M. Tilley, L.M. Seitz, M.S. Ram, D.B. Bechtel, M.E. Casada, S.H. Park, J.D. Hubbard, B.W. Seabourn, M.S. Caley, J.D. Wilson, R.E. Dempster, J.M. Downing, J.E. Throne, J.E. Baker, and C.S. Chang.

Amyloplast formation and starch granule development in hard red winter wheat.

D.B. Bechtel and J.D. Wilson.

Plastids in the coenocytic endosperm of young wheat caryopses were mostly in the form of pleomorphic proplastids with a few of the plastids containing small starch granules. Following cellularization of the coenocytic cytoplasm, the endosperm outer layer or two became meristematic and continued to divide until about 14 days-after-flowering (DAF). During the first week of endosperm development, newly divided cells had plastids that were pleomorphic in shape, while subaleurone cells interior to the meristematic region contained amyloplasts that contained a single size class of starch granules (type A starch granules). The pleomorphic plastids exhibited protrusions that extended a considerable distance through the cytoplasm. Amyloplasts in the interior to the meristematic region did not exhibit the protrusions. Both subaleurone and central endosperm cells had amyloplasts that exhibited protrusions at 10-12 DAF, with some protrusions containing small starch granules. By 14 DAF, endosperm amyloplasts lacked protrusions and two sizes of starch, large type A and small type B granules, were present in the cells. Amyloplast protrusions were numerous again at 17 DAF in both subaleurone and central endosperm cells and by 21 DAF a third size class of small, type-C starch granules was present in the cytoplasm. Amyloplasts in the endosperm of wheat apparently divided and increased in number via protrusions, since binary fission typical of plastid division was never observed. Protrusions were observed in the coenocytic cytoplasm, in dividing cells, in subaleurone and central endosperm cells at 10-12 DAF, and in subaleurone and central endosperm cells at 17 DAF. The results suggest that there are three sizes of starch granules produced at specific times during wheat endosperm development.

Digital image analysis of isolated starch from wheats of different classes and application of correction factors to determine starch size distributions.

D.B. Bechtel and J.D. Wilson.

Starch is most abundant storage reserve in the wheat caryopsis yet little is known about its influence on end use properties. Starch was isolated from wheat grains of different classes and analyzed using digital image analysis coupled to a light microscope to determine starch size distributions. The image analysis data was converted into volume data. Starch granules with diameters greater than 5 μm were treated as oblate spheroids for calculating volume using the formula for an oblate spheroid. The measured equivalent diameter and an estimated starch granule thickness value were used for the major and minor axes in the oblate spheroid formula, respectively. Granules less than 5 μm in diameter were treated as spheres. Starch granules that had their perimeter touching the edge of field of view had their volumes corrected using correction formulae. Correction formulae were developed for each wheat class or starch size distribution class. Correction formulae were important because without them up to 50 % of the large type-A granules could be under counted. Data indicated that there can be a wide variation in the size distribution of starch depending on wheat class and environmental effects. Some wheats exhibited a trimodal distribution of starch while others only exhibited a bimodal distribution. This data will be used to help predict wheat quality.

Optimizing quantitative reproducibility in HPCE separations of cereal proteins.

S.R. Bean and G.L. Lookhart.

HPCE is capable of producing high-resolution, rapid separations of cereal proteins. Furthermore, HPCE has been shown to be highly reproducible in terms of migration time. However, little work has focused on the quantitative reproducibility of cereal protein separations. Several factors such as sample matrix, sample evaporation, voltage ramp-up time, sample injection time, and capillary end cut were evaluated for their involvement in quantitative reproducibility. These experiments showed that preventing sample evaporation, using optimum injection times, and insuring a clean, square cut on the capillary all improved the reproducibility of peak areas. Combining these factors together into an optimized procedure produced reproducibility with peak areas varying by < 1.76 % RSD. Migration time also was excellent under these conditions, varying only 0.45 % RSD. Other variables such as peak area %, peak height, and peak height % also showed good reproducibility with an RSD < 4%. Increasing the voltage ramp up time from 0.17 to 0.68 was found to increase peak efficiency by ~150 %. This factor had no effect on quantitative reproducibility, however. The gradual buildup of contaminants on the capillary walls was found to occur overtime and decreased both separation efficiency and reproducibility. Rinsing capillaries periodically with appropriate solvents delayed this effect. Peak efficiency was found to be a good marker for capillary performance and lifetime.

Factors influencing the characterization of gluten proteins by size-exclusion chromatography multiangle-laser light scattering (SEC-MALLS).

S.R. Bean and G.L. Lookhart.

The use of multiangle-laser light scattering (MALLS) in conjunction with size-exclusion chromatography (SEC) was investigated for characterizing wheat proteins. Four solvent systems including 50 % acetonitrile/0.1 % trifluoroacetic acid, 50 mM Na_2PO_4 pH 2.5, 500 mM acetic acid, and 50 mM Na_2PO_4 pH 7.0 + 1 % SDS were evaluated for protein extraction as well as for use as SEC mobile phases for MALLS analysis. The dn/dc values for wheat proteins were measured in each solvent. All mobile phases except for the SDS solvent showed dn/dc values between 0.16 and 0.20, which were similar to values reported for other proteins. The SDS solvent showed dn/dc values of 0.32, which was similar to that found for other proteins analyzed in the presence of SDS. Although all solvents showed similar resolution when used as mobile phases in SEC analysis, the SDS solvent extracted the most protein (approximately 82 %) in the unreduced form. This solvent system also displayed no concentration dependent or electrostatic effects during MALLS analysis. The SDS soluble and insoluble proteins were characterized by MALLS and Mw distributions ranging up to 1.4 x 10^7 Da were found for the insoluble proteins. The effect of the column-void volume also was examined as was the effect of sonication on the Mw distribution.

Incorporating a barley HVA1 gene to wheat for drought tolerance.

C. Detvisitsakun, W. Zhang, S. Muthukrishnan, G.L. Lookhart, and G.H. Liang.

To improve drought tolerance, a gene encoding a late embryogenesis abundant (LEA) protein, *HVA1*, from barley was introduced into a HRWW Jagger and a HWWW Lakin using biolistic bombardment. The gene construction, containing *HVA1* gene driven by the rice Act1 promoter and the selectable marker gene, *bar*, under the control of CaMV35S promoter, was delivered to embryogenic calli. One transgenic Jagger wheat plant was obtained. This plant survived in medium containing 5 mg/l ammonium glufosinate during the tissue culture processes and has normal morphology. The plant tested positive for the PCR analysis of *bar* gene and was resistant to 0.1 % (v/v) herbicide Liberty™. Southern hybridization analysis showed the integration of the *bar* and *HVA1* genes into the genome of this plant. The 27 kD of *HVA1* protein also was detected in this plant as shown by Western hybridization.

Screening of an Aegilops tauschii cDNA library for isolation of the genes encoding high-molecular-weight glutenin subunits.

M. Tilley, A. Dotson, M. Phillips, G. Liang, and G. Lookhart.

Aegilops tauschii is a valuable genetic resource for improvement of hexaploid wheat. Crosses of the cultivar Century with the *Ae. tauschii* accessions TA2450 and TA2460 exhibited shorter mixing times and improved milling and baking characteristics when compared to the parental hexaploid line. Novel HMW-glutenin subunits Dx43 and Dy44 were identified in these crosses and have been characterized at the protein and DNA level. A cDNA library was constructed in order to obtain HMW-glutenin subunits cDNA clones for plant transformation. Developing kernels of *Ae. tauschii* accessions TA2460 and TA2450 were removed from heads at 10-25 days post-anthesis (when glutenin proteins are synthesized and maximal levels of specific mRNA are present). The kernels were frozen in liquid nitrogen and frozen kernels were shipped to Life Technologies (Rockville, MD) for the construction of a cDNA library. The library was titered, plated, and screened using a nonradioactive method that employs a digoxygenin labeled probe. The probe was the 1.8-kb, internal-repeat fragment of the HMW-glutenin subunit Dx43 cloned from genomic DNA using PCR. Approximately 2,000 colonies were screened, and 89 demonstrated significant hybridization to the probe. Plasmid DNA was purified from tentative positives and analyzed by restriction analysis to determine insert size and restriction pattern compared to PCR amplified HMW-glutenin subunits. Several clones were identified and sequencing of cDNA ends verified that cDNAs contained the full coding region of HMW-glutenin subunits Dx 43 and Dy 44.

Analyses of tyrosine crosslinks in wheat and other grains.

K.A. Tilley, K.E. Bagorogoza, H. Kwen, and M. Tilley.

Formation of the three-dimensional protein network known as gluten during dough-mixing and bread-making processes is extremely complex. A specific subset of the proteins comprising the gluten complex, the glutenin subunits, directly affects bread-making quality. Glutenin subunits have not been shown to exhibit any definitive structural differences that can be directly correlated to their ability to aggregate into the gluten complex and affect bread-making quality. Evidence presented here indicates that tyrosine bonded species form in wheat doughs during the processes of mixing and baking and are major contributors to the structure of the gluten network. Various oxidizing and reducing agents that have been used in the baking industry directly affect tyrosine bonds. Tyrosine bonds between synthetic glutenin peptides form in vitro under baking conditions in the presence of potassium bromate and in the presence of water-soluble extract of flour. Bond structures and formation during the bread-making processes have been documented by HPLC, NMR, and mass spectroscopic analyses. Flours and doughs from other non-wheat grains have been examined for their abilities to form tyrosine crosslinks. Comparisons of tyrosine crosslinks in soft, hard, and durum wheats have been made and show dramatic differences. The formation of tyrosine crosslinks in developing wheat kernels has also been documented, shedding light on the biological mechanisms for tyrosine crosslink formation. The relevance of these data to wheat quality will be discussed.

Effects of bread making on wheat DNA: implications for detection of genetically modified materials in processed foods.

M. Tilley.

The use of GM materials in foods is increasing. Labeling of such products will be dependent upon methods capable of sensitive and accurate detection. Detection of transgenic events can be based upon the detection of the novel proteins or their specific activities, DNA encoding the specific proteins, or DNA flanking the coding region sequences (e.g., promoter, terminator). DNA-based analysis is the method of choice due to the fact that DNA is highly stable and PCR-based analyses provide very high sensitivity and specificity. Processing steps have a profound effect upon the properties of proteins and DNA present in the final product. This project was designed to examine the effects of the bread-making process on wheat DNA extracted from various steps in the process. Samples were taken from wheat kernels, milling fractions, flour, fully mixed dough, 1st punch, 2nd punch, moulding, pan stages, during bake (5, 10, and 15 min), and after bake (1, 3, and 5 days). Total DNA was purified, quantified spectrophotometrically, and integrity was evaluated on ethidium bromide stained agarose gels. DNA purified from kernels demonstrated intact high molecular weight DNA (> 12 kb), whereas that from flour exhibited a broad smear of DNA ranging from > 12 kb to < 0.3 kb. DNA purified from bread exhibited a smear with a maximal size of 0.4 kb with an average size of 0.2–0.3 kb. Samples were utilized in PCR reactions to amplify products representative of gene sequences present at different copy numbers within the wheat genome.

Hard winter wheats– past, present, and future.

O.K. Chung, M. Tilley, J.B. Ohm, M.S. Caley, and B.W. Seabourn.

Wheat is the major crop representing about one-third of the world grain production. The U.S. produces about 66.5 MMT (2.24 billion bushels) of which 43 % (28.8 MMT) enters the export market. The majority of the wheat is milled into flour for food uses, the remainder is used for animal feed, seed, and industrial uses. Nearly one-half of the wheat produced in the U.S. is HRWW, which is grown in the Great Plains Area. Turkey, was first HRWW grown in the Great Plains in 1873 and today's wheats differ in many ways. The number of HRWW varieties has increased from five in 1919 to 164 in 1984. Important traits selected in HRWW breeding are yield, test weight, kernel characteristics, disease resistance, stress tolerance, and agronomic appearance. Major end-use quality attributes of HRWW are milling and bread-making characteristics. Nearly 100 % of all released HRWW cultivars have been evaluated by the USDA–ARS Hard Winter Wheat Quality Laboratory (HWWQL). HRWW quality shows increasing trends in kernel weight and milling yield, but decreasing trends in protein content. The wheat industry is changing with the introduction of HWWW and additional products. HWWW can yield 1–2 % more flour with color properties that are desirable for Asian products. The HWWQL has contributed to the HWWW-breeding program by testing the milling and bread-making quality of HWWW varieties. Wheat use in the U.S. is changing from solely white bread to variety breads and nonbread products such as tortillas, pizza crust, and noodles. Future opportunities include wheats developed for niche markets and the role biotechnology will have in wheat improvement. As with white wheat, identification and segregation issues will need to be addressed.

Quality characteristics of hard winter and spring wheats grown under a overwintering condition.

O.K. Chung, J.B. Ohm, G.L. Lookhart, and R.F. Bruns.

Twelve cultivars each of HWW and HSW were grown three crop years in a unique growing environment in California that allows for synchronous grain fill of all genotypes thus removing a normally strong environmental component and allowing a better investigation of the genetic component differences. Through the 3 years, the HSW showed significantly higher mean values of protein and gluten contents, kernel hardness, and loaf volume but lower gluten index than HWW. Specifically, wheat near-infrared reflectance hardness score (NIR-HS) overlapped very little among individual cultivars of the two classes. Therefore, differences in wheat hardness between HWW and HSW might be caused by genetic background. The HWW and HSW, grown side by side, could be clearly classified by canonical analysis, using wheat characteristics including single kernel parameters in addition to NIR-HS. Principal component regression analysis indicated that flour yields and loaf volumes could be estimated using wheat characteristics and/or single-kernel parameters, showing a good potential for screening early generation breeding lines.

Prediction of quality characteristics of hard winter wheats using single-kernel and mixograph parameters.

O.K. Chung, J.B. Ohm, M.S. Caley, and B.W. Seabourn.

Single kernel and mixograph parameters of hard winter wheats were gathered from federal regional nurseries from 1990 to 1999. Eight characteristics and 12 machine parameters obtained from Single Kernel Characterization System were used to develop a prediction model of flour yield by continuum regression. Flour yield showed mean values of 68.8 % and standard deviations of 6.6 and 3.5 for calibration (n = 1,200) and validation sets (n = 300), respectively. Prediction model of flour yield showed an R^2 of 0.696 for calibration set and 0.684 for validation set. Wheat protein content, single kernel characteristics, and objective computer-analyzed mixograph parameters also were used to develop prediction models of bread-making properties by continuum regression. Bread loaf volume showed mean values of 880 cm^3 and standard deviations of 96 and 86 for calibration and validation sets, respectively. Prediction model of bread loaf volume showed R^2 of 0.754 and 0.698 for calibration (n = 1,097) and validation (n = 319) sets, respectively. Prediction models of mixograph mixing tolerance and baking water absorption, mixing time, and specific loaf volume showed R^2 values of 0.713, 0.726, 0.865, and 0.814 for the calibration set and 0.676, 0.741, 0.835, and 0.779 for the validation set, respectively.

Effects of flour particle size on loaf volume and internal characteristics of experimental pup-loaf bread.

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

Flours with three different protein contents (PC) (9.8 %, 11.9 %, and 13.2 % on a 14 % mb) were used to study the effects of flour particle size (PS) on the experimental bread-making properties including loaf volume (LV) and internal characteristics such as crumb grain, fineness, and elongation ratio. Flour PS was manipulated by two ways: first, three flours were fractionated into three different fractions (< 53 mm, 53–75 mm, and > 75 mm) using sieving machine; and second approach was that three flours were further ground into four different levels of PS (7,000 rpm x 1, 14,000 rpm x 1, 14,000 rpm x 2, 14,000 rpm x 3) using Alpine Pin mill. Medium PS fraction flours (53–75 mm) showed the highest LV and small PS fraction flours (< 53 mm) showed the lowest LV probably because PC of each fraction played a major role. Crumb grain scores determined by baking expert and elongation ratio determined by CrumbScan V 3.0 (American Institute of Baking, Manhattan, KS) were higher for smaller PS fractions except low PC flour. Further ground flours, which could avoid the effect of different PC, showed increases in LV compared to original flours. Flours ground by 7000 rpm x 1 and 14000 rpm x 1 showed the highest elongation ratios and LV, respectively, for 11.9 % and 13.2 % protein flours. Flour PS distribution affected both LV and internal characteristics of experimentally baked pup-loaf breads.

Positive effects of growing environment on wheat protein content and bread-making quality.

F.M. Dupont, S.B. Altenbach, O.K. Chung, R. Chan, and R. Lopez.

The HRSW Butte 86 and the HRWWs Cheyenne and Arapahoe were grown in pots under controlled environmental conditions. All three cultivars have the same complement of HMW-glutenin subunits, including Dx5 and Dy 10, which contribute to good gluten quality. To understand the effects of environment on bread-making quality, wheat was grown under different regimens of fertilizer, water, and daytime and nighttime temperatures. Post-anthesis fertilizer increased wheat protein content per wheat grain whereas head and drought reduced the duration of starch deposition, and thus reduced kernel weight. In the absence of post-anthesis fertilizer and heat and drought increased flour protein content. Loaf volume and SDS-sedimentation volume were highly correlated with flour protein content, regardless of the environmental treatment. Some mixograph parameters also were correlated with protein content, regardless of environmental treatment. The results indicate that flour protein quality for these wheat cultivars were remarkably stable over a wide range of protein contents, whether achieved by varying fertilizer, temperature, or water during grain fill.

Free lipids in air-classified high-protein fractions of hard winter wheat flours and their effects on bread-making quality.

O.K. Chung, J.B. Ohm, A.M. Guo, C.W. Deyoe, G.L. Lookhart, and J.G. Ponte, Jr.

Free lipids (FL) were extracted from straight grade flours (SF) and their air-classified high-protein fractions (ACHPF) of nine hard winter wheats. The mean values of FL contents in 10-g (db) SF and ACHPF were, respectively, 92.8 and 178.5 mg for total FL, 74.1 and 141.9 mg for nonpolar lipids (NL), 12.8 and 20.9 mg for glycolipids (GL), and 4.9 and 12.0 mg for phospholipids (PL). FL compositions of SF and ACHPF showed nonsignificant difference in NL (80.7 and 81.1 % of the FL) but significant differences in GL (13.9 and 12.0% of the FL) and PL (5.4 and 6.9 % of the FL). Fortification of SF with ACHPF by blending to reach protein content to 13 % increased protein and gluten quantity and, thereby, loaf volume but decreased gluten index, loaf volume regression, and crumb grain scores. NL contents showed significant relationships with dry gluten contents (r = 0.79) and gluten index (r = –0.83) values, indicating that high NL content in ACHPF could decrease gluten quality of fortified flours. Thus, an optimum balance should be kept when fortification process is practiced.

The relationships of free lipids with quality factors in hard winter wheat flours.

J.B. Ohm and O.K. Chung.

Hard winter wheat flours (n = 72) were analyzed for free lipids (FL) and their relationships with quality parameters. The two main glycolipid (GL) classes showed contrary simple linear correlations (r) with quality parameters. Specifically, kernel hardness parameters, flour yields, and water absorptions had significant negative correlations with monogalactosyldiglycerides (MGDG) but positive correlations with digalactosyldiglycerides (DGDG). MGDG showed negative correlations with gluten content but positive correlations with gluten index. The percentages of DGDG in FL had significant positive correlations among cultivars (n = 12) with mixograph and bake mix times ($r = 0.71$, $P < 0.01$ and $r = 0.67$, $P < 0.05$, respectively), mixing tolerance ($r = 0.67$, $P < 0.05$), and bread-crumb grain score ($r = 0.71$, $P < 0.01$). These results suggest that increasing DGDG in FL could contribute to enhancing wheat quality attributes including milling, dough mixing and bread-making quality characteristics. FL content and composition (the ratio of MGDG or DGDG to GL) supplement flour protein content to develop prediction equations of mixograph mix time ($R^2 = 0.89$), bake mix time ($R^2 = 0.76$), and loaf volume ($R^2 = 0.72$).

Supercritical fluid extraction of total fat from breakfast cereals for nutritional labeling.

J.D. Hubbard, J.M. Downing, and O.K. Chung.

In recent years interest has shown in developing analytical methods for the extraction of lipids from various cereal grains using a Supercritical Fluid Extraction (SFE) system because of environmental, toxic exposure, and cost effects. The SFE methods are cost effective, less time consuming, and friendlier to the environment. Most recent interest is to apply SFE to extract total lipids from RTE Breakfast Cereals, instead of acid hydrolysis, for nutritional labeling purposes. We searched for a modifying solvent which would, in a binary supercritical mixture, successfully extract the total lipids including starch lipids. We used mixture of 1-propanol-water (3:1) 40 % by volume with carbon dioxide to form a binary supercritical fluid at 10,000 psi, 120°C, and 3 ml/min flow rate to extract the total lipids. The AACC standard method (58–19) for acid hydrolysis was used as a reference method. We extracted 5–10 % more total lipids by SFE than by acid hydrolysis depending on the sample matrix.

Analysis of chemical and sensory data for grain odor classification.

L.M. Seitz and M.S. Ram.

Chemical information for classifying grain odors was obtained by using dynamic headspace technology coupled with gas chromatography-mass spectroscopy to determine volatiles in a set of 745 samples consisting of corn, sorghum, soybeans, and wheat. Sensory data for each sample was obtained from at least two panels. Previous processing of the chemical and sensory data by multivariate analyses such as principal component analysis and partial least squares methods helped to determine what volatiles could be used to classify grain odors. In this study, we used artificial neural network methods to classify odors in the samples. Proper choice of samples and use of optimized variables (compounds indicating off-odors), as well as some preprocessing of raw data were necessary for training the networks. Properly trained, networks could classify samples into two odor categories (normal and off) or as many as five categories (normal, sour, musty, smoke, and insect) from analysis of chemical data concerning relative amounts of specific volatile compounds purged from each sample. Networks trained to classify into several specific categories could also identify mixed odors, i.e., having both musty and sour odors, in some samples. Panelists had given a consensus assignment of only a single odor with some samples, but neural network results and the corresponding presence of odor-indicating compounds suggested that more than one type of odor could have been assigned and may have been detected by some individual panelists.

Observations on the NaOH test for red and white wheat.

M.S. Ram, F. Dowell, and L. Seitz.

Soaking wheat kernels in an NaOH solution causes the difference in color to be enhanced. Red wheat turns a darker red and white wheat turns straw yellow upon soaking in NaOH solution. To understand the chemistry of this reaction, chromatographic and spectroscopic studies have been initiated. Acidified extracts have been analyzed by HPLC. Chromatograms from red and white wheat showed minor differences and were compared to those from scabby and rain-bleached wheat which appeared to have lost some pigmentation. Vibrational spectroscopic studies (FT-IR, FT-Raman, and IR-microscopy) of whole wheat and wheat bran are being continued.

Development of standard procedures for a simple, rapid test to determine wheat-color class.

M.S. Ram, L.M. Seitz, and F.E. Dowell.

An accurate, rapid, and simple means of determining wheat color class has been developed to aid in distinguishing between hard red and hard white varieties. Research by other scientists has shown that soaking kernels in dilute NaOH accentuates color differences resulting in a clear, objective differentiation between color classes. We optimized the procedure so that genetic color class can be determined at elevators in about 10 min. The test requires minimal training, is safe, and should cost only pennies per sample. This project was funded by the Kansas Wheat Commission and administered through a CRADA with the Grain Industry Alliance. Perten Instruments (Springfield, IL) has developed a commercial test kit for use in field locations. This technology will help keep white wheat segregated for use in new export markets.

Invisible coatings for wheat kernels.

M.S. Ram, L.M. Seitz, and F.E. Dowell.

It is occasionally necessary to tag wheat kernels without altering their appearance. Examples include tagging genetically modified grain, or grain with specific attributes of interest that need to be identity preserved. Tagging wheat kernels could be achieved using a coating of UV or NIR fluorescent chemical in combination with a binder, such as a lacquer or matte finish paint. Coatings could be superior to chemical derivatives, which alter the physical properties of surfaces. A number of chemicals were tested, but were discarded because of high carcinogenicity. Suitable materials were chosen and methods developed to suitably coat red and white wheat. UV fluorescence and NIR spectroscopy were applied to the kernels with and without coatings. Most recently, the invisible coating was used to tag Karnal bunt kernels used during calibration of high-speed sorting instruments.

High-speed detection and sorting to remove bunted kernels and purify white wheat stock.

F.E. Dowell, M. Pasikatan, T.N. Boratynski, R. Ykema, A.K. Dowdy, and R.T. Staten.

A high-speed, optical sorter was used to remove kernels infected with Karnal bunt from 1,800-g wheat samples. When the sorter removed about 8 % or more of the sample, the reject portion contained 100 % of the bunted kernels. Concentrating the bunted kernels in a smaller sample size will reduce sample inspection time and should reduce inspection errors. One high-speed sorter can process up to 8,800 kg/hr, thus, bunted kernels can be rapidly removed from samples or large lots. The instrument sorted each sample in less than 1 minute. This technology provides the wheat industry with a tool to rapidly inspect samples to aid in regulating Karnal bunt, and to remove bunt from seed wheat and wheat destined for food or feed use. This sorter is currently being used by APHIS as part of their routine Karnal bunt inspection procedures. The high-speed sorter also was used to remove red wheat from hard white wheat stock. The popularity of white wheat is increasing in the Midwest HRWW-growing area because of possible higher prices that may be realized through demands in Asian noodle markets. We have used the sorter to rapidly remove red wheat from early-generation white wheat breeder samples and to remove red wheat from large lots of commercial seed. Removing red seed from breeder samples reduces the amount of red wheat in subsequent generations, and removing red wheat from commercial seed helps insure the purity of harvested wheat.

Rapid, single-kernel sensing and sorting technology.

F.E. Dowell, M. Pasikatan, E. Maghirang, and D. Wang.

Some wheat-kernel attributes are not detectable by bulk-measuring devices. For example, defects that may be present in a small percentage of kernels, such as internal insects or fungal damage, may be detected only if each kernel is analyzed. Also, some types of blending, such as mixing high- and low-protein lots, may be detectable only by single-kernel analysis. In addition, for some applications such as purifying seed stock, it is desirable to not only detect the undesirable characteristic but to then also remove it. Technology includes 1) a low-cost NIR system for detecting and sorting single kernels at a rate of about 1 kernel/sec; 2) a Vis-NIR system (SKCS 4170, Perten Instruments) for detecting single-kernel attributes, including single-kernel hardness measurements, at about 1 kernel/sec; and 3) high speed Vis-NIR systems, such as those produced by Satake and Sortex, capable of sensing and sorting single kernels at a rate of hundreds of kernels/sec.

Sorting systems based on optical methods for detecting and removing seeds infested internally by insects or fungi: a review.

M.C. Pasikatan and F.E. Dowell.

Sorting systems based on optical methods have the potential to rapidly detect and physically remove seeds severely contaminated by fungi, or infested internally by insect larvae or pupae. Thus, the literature on sorting systems based on optical methods for detecting and sorting seeds with these attributes was reviewed. Sorting indices based on wavelengths useful for detecting these attributes were emphasized. Surface characteristics of seeds, like discoloration caused by fungi, are generally detectable in the visible range of the electromagnetic spectrum, whereas internal attributes are detectable in the near-infrared range. The spectral differences between sound and infested seeds are usually subtle, but full-spectrum and two-wavelength classification models have succeeded in detecting and classifying seeds based on these attributes. For high sorting accuracies, wavelength identification and proper selection of a sorting criterion are important. Chitin, ergosterol, or hydrolysis of triglycerides have been identified as indicators of seed fungal contamination whereas chitin, protein, phenolic compounds, or changes in starch have been useful indicators of internal insects in seeds.

Determining vitreous subclasses of hard red spring wheat by using near-infrared spectroscopy.

D. Wang, F.E. Dowell, and R. Dempster.

The content of dark hard vitreous (DHV) kernels in HRSW is an important grading factor that is associated with protein content, kernel hardness, milling properties, and cooking quality. The current visual method of determining DHV and nonDHV (NDHV) wheat kernels is time consuming, tedious, and subject to large errors. Our objective was to classify DHV and NDHV wheat kernels including kernels that are checked, cracked, sprouted, or bleached by using near-infrared (NIR) spectroscopy. Spectra from single DHV and NDHV kernels were collected using a diode-array NIR spectrometer. The dorsal and crease sides of the kernels were viewed. Three wavelength regions, 500-–750 nm, 750-–1,700 nm, and 500–1,700 nm, were compared. Spectra were analyzed by using partial least squares (PLS) regression. Results show that the major contributors to classifying DHV and NDHV kernels are protein content, kernel hardness, starch content, kernel color, and a scattering effect on the absorption spectrum. Bleached kernels were the most difficult to classify. The sample set with bleached kernels yielded lower classification accuracies of 91.1–97.1 % compared to 97.5–100 % for the sample set without bleached kernels. More than 75 % of misclassified kernels were bleached. Classification models that included the dorsal side gave the highest classification accuracies (99.6–100 %) for the testing sample set. Wavelengths in both the visible and NIR regions or the NIR region alone yielded better classification accuracies than these in the visible region only.

Assessment of heat-damaged wheat kernels using near-infrared spectroscopy.

D. Wang, F.E. Dowell, and D.S. Chung.

Heat damage is a serious problem frequently associated with wet harvests because of improper storage of damp grain or artificial drying at high temperature. Heat damage causes protein denaturation and reduces processing quality. The current visual method for assessing heat damage is subjective and based on color change. The denatured protein related to heat damage does not always cause change in kernel color. NIR spectroscopy is possible method to measure both physical (color) and chemical (protein denaturation) changes. A diode-NIR spectrometer, which measured reflectance spectra (Log(1/R)) from 400 to 1,700 nm, was used to differentiate single kernels of heat-damaged and undamaged wheats. Partial least squares (PLS) regression was used to develop classification models with three wavelength regions (400–750 nm, 400–1,700 nm, and 750–1,700 nm). Results showed that the major contributor to the spectral characteristics of heat-damaged kernels is protein denaturation, which changes the patterns of molecular absorption and shifts the peaks of the absorption spectrum. For PLS models, the highest classification accuracy of 100 % for both calibration and testing sample sets was obtained from the NIR wavelength region of 750–1,700 nm. The visible wavelength region (400–750 nm) gave the lowest classification accuracy.

Moisture absorption characteristics of wheat and barley.

M.E. Casada.

Moisture adsorption rates for stored grains are important for accurate modeling of drying and storage. Wheat and barley samples at initial moisture contents typical of grain storage were exposed to several levels of higher humidity at two temperatures to measure adsorption rates. The best fit to the data was achieved with the Page and cellular diffusion equations. The adsorption rates were lower than those of comparable desorption tests. The adsorption rates for barley were lower than for wheat, due to lower diffusion coefficients for the barley endosperm and germ as compared to wheat.

New scientists — welcome.

S.R. Bean and T.C. Pearson.

Grain Quality and Structure Research Unit. Dr. Scott Bean joined the Grain Quality and Structure Research Unit in October as a Research Chemist. Dr. Bean received his M.S. and Ph.D. degrees in Grain Science from the Department of Grain Science and Industry, Kansas State University. Dr. Bean has his expertise in cereal biochemistry and analytical methods for characterizing cereal proteins using instruments including capillary electrophoresis and liquid chromatography. In addition, Dr. Bean has experience in studying structure-function relationships of cereal biomolecules that relate to end-product quality. As lead scientist of the sorghum project, his responsibilities will include the biochemical characterization of grain sorghum for both human and feed uses, cultivar identification, their relationships to functional and nutritional quality, and providing information on quality biochemical determinants for sorghum breeders to improve lines suitable for traditional and novel uses. This is a new project created in response to efforts by the National Grain Sorghum Producers to enhance sorghum value in food and nonfood uses.

Engineering Research Unit. Dr. Tom Pearson joined the Engineering Research Unit in July to fill the position vacated by Dr. Inna Zayas. Dr. Pearson received his B.S. in mechanical engineering from California State University in Fresno, and his M.S. and Ph.D. in Agricultural Engineering from UC Davis. Dr. Pearson has experience as a project engineer/ senior research and development engineer with Wiebe Conveyance, Hollister, CA, and as a lead scientist at the Western Regional Research Center, Albany, CA. He has expertise in developing high-speed detection and sorting systems, machine vision, NIR, acoustics, and electronic circuitry. Dr. Pearson's responsibilities at the GMPRC will include developing sensing methods, techniques, equipment, and instrumentation for automating quality assessments of grain and grain products.

Guest scholars.

C.M. Rosell.

The Grain Science and Industry Department (Dr. Paul A. Seib), Kansas State University, and the USDA–ARS–GMPRC–Grain Quality and Structure Research Unit (Dr. George L. Lookhart) co-hosted, during the summer of 2001, Dr. Cristina Molina Rosell from the Laboratorio de Cereales, Instituto de Agroquímica y Tecnología de Alimentos in Valencia, Spain. Dr. Molina came to this laboratory to learn capillary electrophoresis in order to study the effects of insects and enzymes on wheat storage proteins.

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MINNESOTA

CEREAL DISEASE LABORATORY, USDA—ARS
University of Minnesota, 1551 Lindig St., St. Paul, MN 55108, USA .

D.L. Long, D.V. McVey, J.A. Kolmer, M.E. Hughes, and L.A. Wanschura.

The rusts of wheat in the United States in 2001.

Stem rust. In 2001, except for light infections in Texas, there were few reports of stem rust in wheat in the southern U.S. The first wheat stem rust report was in early May in central Texas, where light rust was reported in fields of Wintex and traces were reported in plots of McNair 701. In mid May, stem rust severities ranged from trace to 40 % in plots from northwestern Arkansas to northwestern Oklahoma. In wheat plots in north central Oklahoma, 20 % severities were observed on 10 % of the plants in plots of Chisholm, Lockett and Thunderbolt. Wheat stem rust developed later than normal and was light this year throughout the southern plains area of the U.S.

In late May, traces of stem rust were found in wheat fields in west central Missouri and east central Kansas. By the last week in June, stem rust was found in fields and plots in north central Kansas and southern Nebraska. Trace amounts of stem rust were observed in commercial fields, whereas 20 % severities were observed on susceptible lines in plots. The rusted wheat in these fields and plots provided inoculum for susceptible wheat further north.

In early June, severe wheat stem rust was found in a southern Louisiana nursery in plots, which were planted, much later than the normal, in late January.

In early July, traces of stem rust were observed on the winter wheat cultivar Norstar in east central North Dakota plots. In mid July, trace to 40 % stem rust severities were observed on the cultivar 2137 in plots throughout South Dakota. Stem rust also was observed on winter wheat cultivars Rose and Scout 66. Stem rust developed late in the season so losses were minimal.

In late June, traces of stem rust were found on the susceptible spring wheat Baart in southern and westcentral Minnesota rust detection plots. During mid July, 10–40 % wheat stem rust severities at 100 % prevalence were observed on Baart (at the full berry stage) in southern Minnesota disease detection plots. In west central Minnesota and east central South Dakota plots, trace–20 % stem rust severities were found on Baart at the one-quarter berry stage. No stem rust was found in the commonly grown spring wheat cultivars at these locations.

Stem rust infections were found in moderate amounts on susceptible spring wheat trap plots throughout North Dakota and northwestern Minnesota during the last week of July. No stem rust infections were observed on released wheat cultivars in either farm fields, or breeding plots.

In 2001, the number of stem rust samples received at the Cereal Disease Lab was twice the number in recent years, which continues the trends of increased sample numbers in 1999 and 2000. The increased severity of stem rust can be attributed to the increased amount of inoculum produced on susceptible winter wheat cultivars, e.g., 2137, in the Central Plains and to the temperatures and early moisture, which were ideal for stem rust infection in the Northern Plains this year. If current spring wheat cultivars were susceptible to stem rust, a serious epidemic with substantial yield losses may have occurred.

Stem rust race virulence. The preliminary results from the 2001 national wheat stem rust survey indicate the most commonly identified races in 2001 were QCCJ, QCMJ, QCMS, QFCS, QCCS, and QCMD (Table 1, p. 236). In 2000, these also were the most commonly identified races. Further testing is underway and the final results will be published in Plant Disease. From 1993 to 1997, race Pgt-TPMK was the most common wheat stem rust found in the U.S. and in 1999 it had dropped to the third most common. In 2000 and 2001 TPMK was not identified from samples received at the Cereal Disease Laboratory. Race QCCJ is virulent on barley cultivars with the *Rpg1* (T) resistance gene.

Wheat leaf rust. Southern Plains. By the third week in March, light amounts of wheat leaf rust were found on some wheat cultivars and lines in the Beeville nursery in southern Texas. Rust infections were noted on the lower leaves of the wheat plants, which indicates the rust may have overwintered in the nursery. In early April, in southern Texas wheat fields, traces of leaf rust were observed. By late April, rust was severe on susceptible lines and cultivars in southern Texas. In mid April, light leaf rust was found in central Texas plots. Throughout Texas, wheat was planted late and conditions were cooler than normal in late winter, which accounted for the slow development of leaf rust. By mid May, 40% severities were reported on flag leaves of susceptible cultivars in winter wheat plots in north central Texas and southern Oklahoma nurseries. During the last week in May, in plots of Jagger wheat in north central Oklahoma, 20 % severities were found whereas in fields of Jagger in south central Kansas, 5 % severities were observed on 1 % of the plants (Fig. 1, p. 237). In late May, 20 % severities were observed on *Ae. cylindrica* growing in the roadside in north central Oklahoma.

Central Plains. In early May, traces of wheat leaf rust were found in southern Kansas. During the last week in May, leaf rust was light in plots and only traces were found in fields from west central Kansas to west central Missouri. In south central Kansas wheat plots, 20 % severities were found on Jagger at the late berry stage compared to 80 % severities reported in 2000 on Jagger in the same nursery at the same plant growth stage. The cooler than normal temperatures and excessive moisture during the last part of May actually slowed leaf rust development in Kansas. During late June, leaf rust was found in fields and plots in north central Kansas and southern Nebraska. The loss to leaf rust in Kansas this

Table 1. Races of *Puccinia graminis* f. sp. *tritici* identified from wheat in 2001. Pgt race code after Roelfs and Martens (Phytopathology **78**:526-533). Set four consists of *Sr9a*, *9d*, *10*, and *Tmp*.

				Percentage of isolates of Pgt– race															
State	Source	Collections	Isolates	QCCJ	QCCS	QCMB	QCMD	QCMJ	QCMS	QCRS	QFCS	QKCJ	QKCS	RCCJ	RCCS	RCMJ	RCMS	RCRJ	RTRQ
AR	Nursery	1	3	67				33											
ID	Nursery	1	3	33							67								
KS	Field	6	17	12				29	18		6				12	6	18		
KS	Nursery	5	15	47				47				7							
LA	Nursery	1	3				67			33									
MN	Nursery	11	24	33	17		4	8	13		21		4						
MO	Field	1	2								100								
ND	Nursery	21	55	24	13		2	7	24		29					2			
NE	Nursery	4	11	9			9	9	45	9							18		
OK	Nursery	6	18	22			17	11	17	6				11	6		11		
SD	Nursery	18	50	32	6			38	10		2					6	6		
TX	Nursery	8	23	22	13	13	43	4	4										4
WA	Nursery	9	12	50	17						33								
WI	Field	1	3															100	
U.S.	Field	8	22	9				23	14		14				9	5	14	14	
	Nursery	85	217	29	9	1	8	17	14	1	13	0.5	0.5	1	1	2	3		0.5
	Total	93	239	27	8	1	8	18	14	1	13	0.4	0.4	1	1	2	4	1	0.4

year was 0.4 % (Table 4, p. 240), which was significantly less than the 2.9 % loss in 2000 and the 10-year average loss of 4.8 %. Twenty percent leaf rust severities were observed on lower leaves in wheat fields (at soft dough stage) in east central and southern Nebraska. This was a poor year for leaf rust development in the southern and central plains.

Northern Plains. In mid June, light leaf rust was observed on the flag leaves of hard red winter wheats in an east central South Dakota nursery. By late June, 20 % severities were common on lower leaves of winter wheats and traces on susceptible spring cultivars in southern Minnesota and east central South Dakota plots. In late June, trace–40 % severities were observed on winter wheats growing in east central North Dakota plots. By late June, leaf rust in the northern plains had developed slower and to a lesser extent than normal. This is due to the small amount of leaf rust inoculum arriving from the southern grain growing areas, cool wet spring weather, and the hot dry conditions in late June that were not favorable for rust development. Also, many of the flag leaves of the winter wheats that previously were free of rust were infected with wheat stripe rust, which normally was not found in this area. During mid July, 10 % severities were found on leaves of winter wheat growing in northeastern South Dakota and southeastern North Dakota fields at the late berry maturity stage.

In late June, traces of leaf rust were found in a spring wheat field in south central North Dakota and in plots in east central North Dakota. In mid July, 40 % wheat leaf rust severities were noted on susceptible spring wheat in southern Minnesota and east central South Dakota plots. Trace to 10 % severities were noted on a few of the commonly grown spring wheat cultivars. The hot, dry weather in late June slowed rust development, but July rains stimulated further rust increase. By the last week in July, leaf rust infections were found on spring wheat throughout North Dakota and Minnesota. Leaf rust was found on wheat in nearly every field and breeding plot that was surveyed in North Dakota and Minnesota. Heavy leaf rust infections were observed in plots and fields in central North Dakota near Carrington and Minot. Many wheat fields in this area had leaf rust severities of over 50 % at the late milk to soft dough stage, and flag leaves were starting senescence due to leaf rust.

Fig. 1. Leaf rust severities in wheat fields

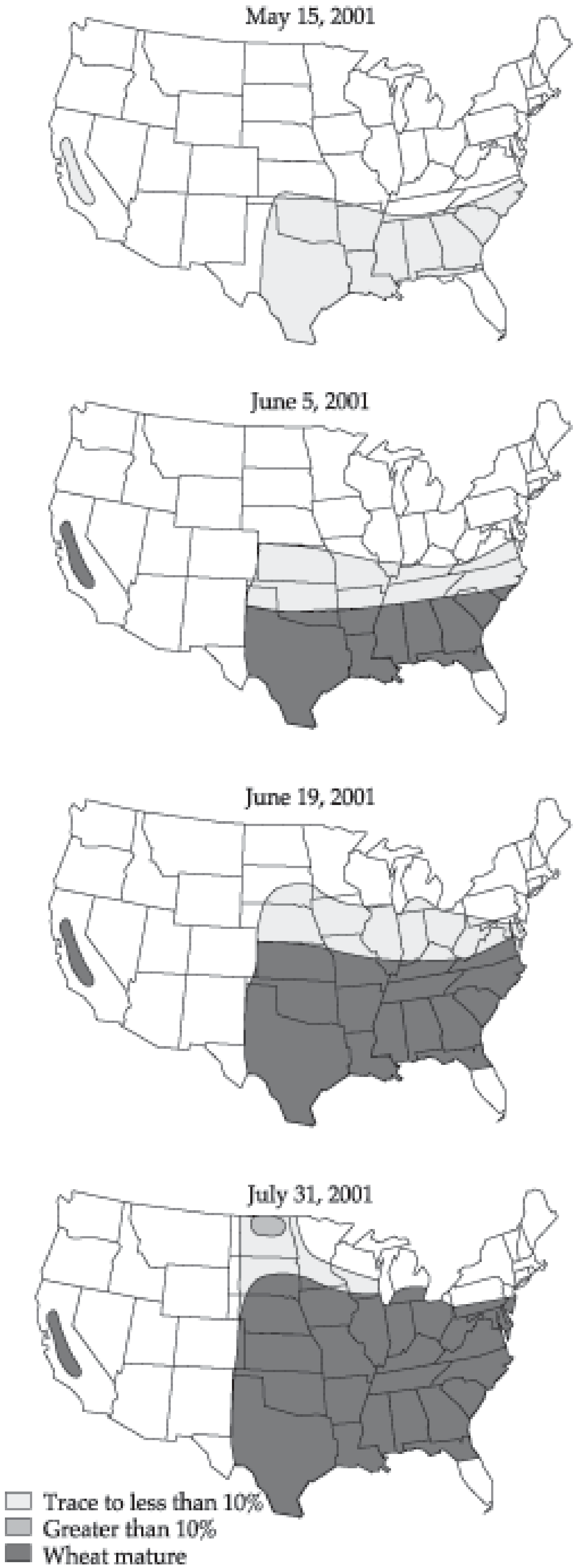

Fig. 2. Stripe rust severities in wheat fields

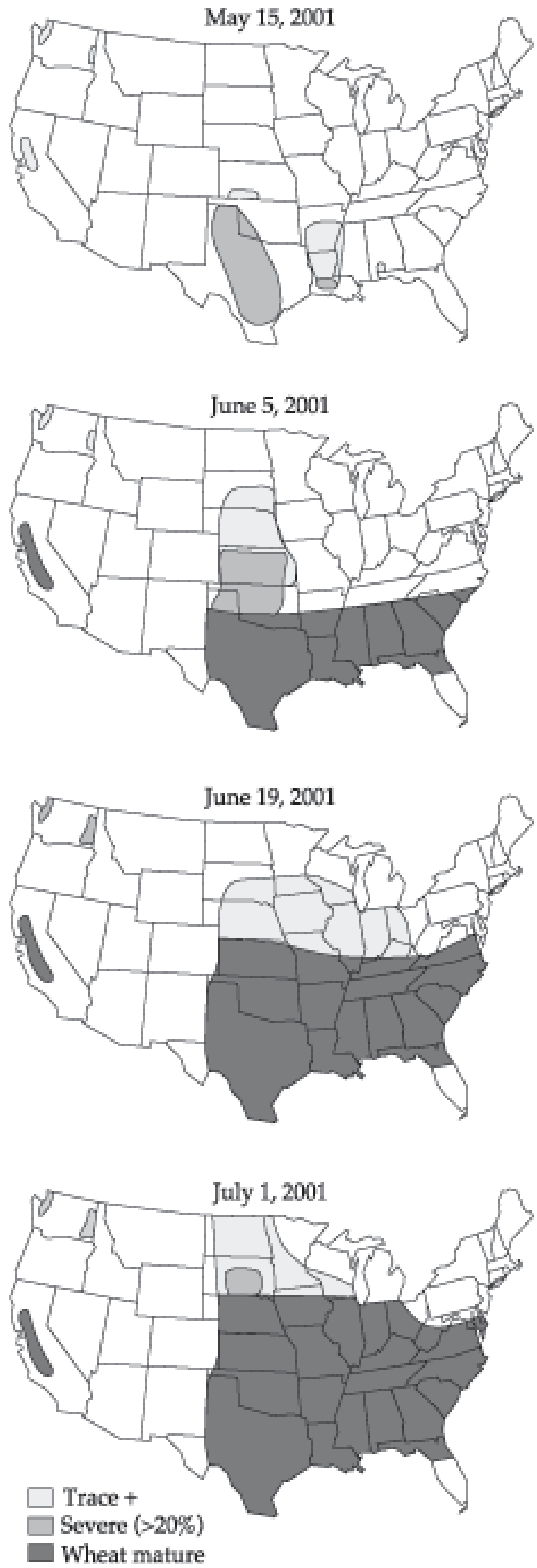

Table 2. Wheat leaf rust code and corresponding virulence formula for collections made in 2001.

Race code [1]	Virulence formula [2]	Race code [1]	Virulence formula [2]
BBBD	14a	NBGT	1, 2c, 10, 11, 14a, 18, B
CBBD	3, 14a	PCRQ	1, 2c, 3, 3ka, 10, 11, 26, 30, B
CLLM	3, 3ka, 9, 18, B	PLMR	1, 2c, 3, 3ka, 9, 10, 18, 30, B
FCMT	2c, 3, 3ka, 10, 14a, 18, 26, 30, B	PNMR	1, 2c, 3, 3ka, 9, 10, 18, 24, 30, B
FGBJ	2c, 3, 10, 14a, 16	TBBS	1, 2a, 2c, 3, 10, 14a, B
FLLL	2c, 3, 3ka, 9, B	TBRJ	1, 2a, 2c, 3, 3ka, 10, 11, 14a, 30
LBBG	1, 10	TCBJ	1, 2a, 2c, 3, 10, 14a, 26
LOST	1, 3ka, 10, 11, 14a, 17, 18, B	TCJS	1, 2a, 2c, 3, 10, 11, 14a, 17, 26, B
MBBJ	1, 3, 10, 14a	TCRJ	1, 2a, 2c, 3, 3ka, 10, 11, 14a, 26, 30
MBDS	1, 3, 10, 14a, 17, B	TDBJ	1, 2a, 2c, 3, 10, 14a, 24
MBGJ	1, 3, 10, 11, 14a	TDDS	1, 2a, 2c, 3, 10, 14a, 17, 24, B
MBJJ	1, 3, 10, 11, 14a, 17	TFBJ	1, 2a, 2c, 3, 10, 14a, 24, 26
MBRJ	1, 3, 3ka, 10, 11, 14a, 30	TGBJ	1, 2a, 2c, 3, 10, 14a, 16
MBRK	1, 3, 3ka, 10, 11, 14a, 18, 30	THBJ	1, 2a, 2c, 3, 10, 14a, 16, 26
MCDS	1, 3, 10, 14a, 17, 26, B	TKBJ	1, 2a, 2c, 3, 10, 14a, 16, 24, 26
MCRJ	1, 3, 3ka, 10, 11, 14a, 26, 30	TLGF	1, 2a, 2c, 3, 9, 11, 14a, 18
MCRK	1, 3, 3ka, 10, 11, 14a, 18, 26, 30	TLGJ	1, 2a, 2c, 3, 9, 10, 11, 14a
MCRS	1, 3, 3ka, 10, 11, 14a, 26, 30, B	TLGS	1, 2a, 2c, 3, 9, 10, 11, 14a, B
MDBG	1, 3, 10, 24	TLHS	1, 2a, 2c, 3, 9, 10, 11, 14a, 30, B
MDBJ	1, 3, 10, 14a, 24	TLRJ	1, 2a, 2c, 3, 3ka, 9, 10, 11, 14a, 30
MDRJ	1, 3, 3ka, 10, 11, 14a, 24, 30	TNMJ	1, 2a, 2c, 3, 3ka, 9, 10, 14a, 24, 30
MFBJ	1, 3, 10, 14a, 24, 26	TNRJ	1, 2a, 2c, 3, 3ka, 9, 10, 11, 14a, 24, 30
MGBJ	1, 3, 10, 14a, 16		

[1] Race code plus additional fourth set containing *Lr10*, *Lr14a*, *Lr18*, and *LrB* near-isogenic supplementals, after Long and Kolmer, Phytopathology **79**:525-529.
[2] Resistances evaluated for formula: *Lr1, 2a, 2c, 3, 9, 16, 24, 26, 3ka, 11, 17, 30, 10, 18, 14a* and *B*.

Most wheat cultivars in the demonstration plots at Carrington and Minot had leaf rust severities of over 20 %. A significant yield loss due to leaf rust would normally be expected with this level of rust severity, however the extreme temperatures of over 90°F in the last week of July and first week of August increased leaf senescence, reducing the effects due to leaf rust (Table 5, p. 241). The high rust severities of the cultivars in the nursery plots indicates that many spring wheat cultivars do not have good levels of resistance to leaf rust. Leaf rust infections were generally lighter in the Red River Valley area of North Dakota and Minnesota. Leaf rust severity ratings of spring wheat cultivars in Minnesota and North Dakota in 2001 is available on the Cereal Disease Laboratory website (http://www.cdl.umn.edu/germplasm/survey/MN_ND2001.html).

In early July, leaf rust was present on susceptible winter wheat cultivars across much of southern Wisconsin. By mid-July, light levels of leaf rust were observed in winter wheat plots and fields in northeastern Wisconsin.

Southeast and east. In mid April, light leaf rust was found in plots in southern Georgia, southern Alabama, and southern Louisiana. This was the lightest and latest in the year leaf rust that has been observed in this southern region in many years. In late April, leaf rust was light in plots in southern and central Georgia and Alabama and central Louisiana. In plots at Tallassee in central Alabama a 40 % severity was reported on 20 % of the plants of the cultivar Jackson and in a few of the other entries only 1–2 % severities were observed. In early May, traces of wheat leaf rust were found in eastern Arkansas and southern South Carolina fields. By the second week of May, light leaf rust was found in fields in eastern Arkansas. In late May, 20–40 % severities were observed on plots of Thatcher wheat at Plymouth, North

Table 3. Races of *Puccinia triticina* identified from wheat collections in 2001. States grouped according to agroecological area (1–8), see Plant Dis 86:15-19.

Percent of isolates per state

	1						2		3				4		5			6				7	8	
Code	AL	AR	FL	GA	LA	NC	NY	VA	IN	KY	MO	OH	OK	TX	IA	KS	NE	MN	MT	ND	SD	CA	WA	USA
BBBD							9		8										23	3				1.9
CBBD																			8					0.2
CLLM									8															0.2
FCMT	4																							0.2
FGBJ																				1				0.2
FLLL																				1				0.2
LBBG	9																							0.4
MBBJ					5									4										0.4
MBDS									15			33	60	57	67	73	89	44	15	7	32	15		24.9
MBGJ								20	8	17								13				46		5.2
MBJJ																						10		0.8
MBRJ	26			17				20	31							3								3.1
MBRK	22		33	17			82								17									5.9
MCDS					14				23	33			40	23		9		13		2	4	28		10.7
MCRJ														4										0.4
MCRK	4							40		25					17					2				2.3
MCRS																				1				0.2
MDBG							4																100	1.5
MDRJ														4			6				4			0.8
MFBJ																6								0.4
MGBJ														2		3		6		1	4			1.1
NBGT										8														0.2
PCRQ																				1				0.2
PLMR																				1				0.2
PNMR										8														0.2
TBBS																				1				0.2
TBRJ		100			10	10					67													1.9
TCBJ									8		33									1	9			1.5
TCJS																				4				0.8
TCRJ										8										3	4			1.1
TDBJ																			8					0.2
TDDS																6								0.4
TFBJ														4						4	20			2.1
TGBJ																			8	1				0.4
THBJ																		19	38	66	23			17.9
TKBJ																	6			1				0.4
TLGF	17			33				20																2.1
TLGJ	17		67	33	24	20								2				6		1				4.6
TLGS					19	10																		1.1
TLHS						60																		1.3
TLRJ					10																			0.4
TNMJ					19																			0.8
TNRJ							4					67												0.6
No. isol	23	2	6	12	21	10	22	10	13	12	6	3	25	47	6	33	18	16	13	111	22	39	7	477

Table 4. Estimated losses in winter wheat due to rust in 2001 (T = trace).

State	1,000 acres harvested	Yield in bushels per acre	Production, 1,000 bushels	Losses due to: Stem rust Percent	Stem rust 1,000 bushels	Leaf rust Percent	Leaf rust 1,000 bushels	Stripe rust Percent	Stripe rust 1,000 bushels
AL	70	48.0	3,3360	0.0	0.0	T	T	0	0
AR	970	52.0	50,440	0.0	0.0	T	T	T	T
CA	380	70.0	26,600	0.0	0.0	3.0	840.0	2.0	560.0
CO	2,000	33.0	66,000	0.0	0.0	T	T	8.0	5,739.1
FL	9	41.0	369	0.0	0.0	T	T		
GA	200	53.0	10,600	0.0	0.0	T	T	0	0
ID	710	73.0	51,830	0.0	0.0	0.0	0.0	0	0
IL	720	61.0	43,920	0.0	0.0	T	T	T	T
IN	380	66.0	28,080	0.0	0.0	T	T	T	T
IA	18	54.0	972	0.0	0.0	T	T		
KS	8,200	40.0	328,000	T	T	0.4	1,421.5	7.3	25,941.5
KY	360	66.0	23,760	0.0	0.0	1.0	240.0	T	T
LA	160	50.0	8,000	0.0	0.0	0.5	40.4	0.5	40.4
MI	560	64.0	35,840	0.0	0.0	T	T	T	T
MN	13	29.0	377	0.0	0.0	T	T		
MS	225	52.0	11,700	0.0	0.0	1.0	118.2	T	T
MO	760	54.0	41,040	T	T	1.0	414.5	T	T
MT	870	22.0	19,140	0.0	0.0	0.0	0.0	0.0	0.0
NE	1,600	37.0	59,200	0.0	0.0	T	T	0.5	297.5
NM	240	34.0	8,160	0.0	0.0	0.0	0.0		
NY	120	53.0	6,360	0.0	0.0	T	T	0.0	0.0
NC	470	39.0	18,330	0.0	0.0	T	T	0.0	0.0
ND	80	40.0	3,200	T	T	T	T	T	T
OH	900	67.0	60,300	0.0	0.0	0.1	60.4	T	T
OK	3,700	33.0	122,100	T	T	T	T	3.0	3,776.3
OR	700	40.0	28,000	0.0	0.0	0.1	28.0	T	T
PA	160	52.0	8,320	0.0	0.0	T	T	0.0	0.0
SC	210	43.0	9,030	0.0	0.0	0.0	0.0	0.0	0.0
SD	370	32.0	11,840	T	T	2.0	244.1	1.0	122.1
TN	340	54.0	18,360	0.0	0.0	0.5	92.3	0.0	0.0
TX	3,200	34.0	108,800	T	T	T	T	1.5	1,656.0
VA	170	60.0	10,200	0.0	0.0	T	T	0.0	0.0
WA	1,750	61.0	106,750	T	T	0.2	216.1	1.0	1,080.5
WV	8	58.0	464	0.0	0.0	T	T	0.0	0.0
WI	160	65.0	10,400	0.0	0.0	T	T	T	T
WY	120	24.0	2,880	0.0	0.0	0.0	0.0		
Total	30,903	43.3	1,339,722		T		3,715.5		39,214.3
U.S. % loss				T		0.27		2.84	
U.S. Total	31,295	43.5	1,361,479						

Table 5. Estimated losses in spring wheat due to rust in 2001 (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	44	72.0	3,168	0.0	0.0	T	T	T	T
ID	490	68.0	33,320	0.0	0.0	0.0	0.0	0.0	0.0
MN	1,800	44.0	79,200	0.0	0.0	1.0	800.0	0.0	0.0
MT	2,850	23.0	65,550	0.0	0.0	T	T	0.0	0.0
ND	6,900	34.0	234,600	0.0	0.0	2.0	4,787.8	0.0	0.0
OR	175	30.0	5,250	0.0	0.0	0.1	5.3	0.2	10.6
SD	1,650	39.0	64,350	0.0	0.0	3.0	1,990.0	T	T
UT	16	49.0	784	0.0	0.0	0.0	0.0		
WA	630	41.0	25,830	T	T	0.2	52.8	2.0	528.2
WI	7	44.0	380	0.0	0.0	T	T	0.0	0.0
WY	6	28.0	168	0.0	0.0	0.0	0.0		
Total	14,569	35.2	512,608		T		7,636.1		538.8
U.S. % loss				T		1.46		0.10	
U.S. Total	14,569	35.2	512,608						

Table 6. Estimated losses in durum wheat due to rust in 2001 (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	87	91.0	7,917	0.0	0.0				
CA	81	105.0	8,505	0.0	0.0	0.0	0.0	T	T
MN	2	39.0	78	0.0	0.0	0.0	0.0	0.0	0.0
MT	495	24.0	11,880	0.0	0.0	0.0	0.0	0.0	0.0
ND	2,100	26.0	54,600	0.0	0.0	0.0	0.0	0.0	0.0
SD	24	24.0	576	0.0	0.0	0.0	0.0	0.0	0.0
Total	2,789	30.0	83,556		0.0		0.0		T
U.S. % loss				0.0		0.0		T	
U.S. Total	2,789	30.0	83,556						

Carolina. Leaf rust incidence and severity on winter wheats in North Carolina was very light in 2001 compared to previous years. Some rust was observed on Coker 9663 and Foster in plots. Late planting of the crop in the fall, colder than normal winter in January and February and dry conditions in April all contributed to the light rust development in the southern U.S.

By the last week in May, 10–70 % leaf rust severities were observed on susceptible cultivars in a nursery in east central Virginia.

During the second week in June, trace–10 % leaf rust severities were reported in plots and traces in fields of soft red winter wheat cultivars from northeastern Missouri to northwestern Ohio (Fig. 1, p. 237). The cooler than normal temperatures during the last part of May and first part of June actually slowed leaf rust development.

By the last week in June, 5–20 % severities were reported on winter wheat fields in northwestern New York at the late milk growth stage.

California. During the second week of May, light leaf rust was found in fields in the San Joaquin and Sacramento Valleys of California. During the fourth week of May, 60 % wheat leaf rust severities were common in plots of susceptible varieties and in commercial fields throughout the Central Valley of California.

Washington. During the second week in June, 10 % leaf rust severities were found on susceptible winter wheat cultivars at the milk growth stage in southeastern Washington. By early July, only light amounts of leaf rust were found on wheat throughout Washington.

Leaf rust development was abnormally light throughout most of the U.S. and losses to leaf rust were minimal (Tables 4, p. 240, and 5, p. 241).

Canada. In late June, high levels of leaf rust were observed on susceptible winter wheat varieties in southwestern Ontario, Canada. In early July in winter wheat fields (anthesis stage) in southern Manitoba, 1 % severities and 10 % prevalences of leaf rust were observed. Light losses were expected on winter wheats because of the low rust levels and the advanced growth stage.

Leaf rust on durum. Leaf rust resistance in some commercial durum cultivars in northwestern Mexico broke down this year. In some fields farmers applied fungicides.

Wheat leaf rust virulence. The 2001 leaf rust race identifications from collections made in the U.S. are presented in Table 2. From the central and southern plains rust collections the most common races were M-races (virulent to *Lr1*, *Lr3*, *Lr10*, *Lr17*, +) (Table 3, p. 239). Many of the MBDS and MCDS races were identified from rust collections made from Jagger, which is grown on significant acreage in the southern and central Plains states. Race MBRK was the race most commonly identified from collections from North Carolina and also was the most widely found race from that area of the country in 2000. Race MBGJ was the predominant race found in California and has been for the past 10 years. There also has been an increase in the number of T-races (virulent to *Lr1*, *Lr2a*, *Lr2c*, *Lr3*, +), particularly, an increase in T-races with virulence to *Lr9* and *Lr10* in the southern SRWW area. The *Lr9* and 10 combination was found in significant amounts in the race survey for the first time in 2001. Virulence to *Lr16* was found in over 50 % of the isolates from the northern plains. Since *Lr16* is present in some spring wheats this helps to account for the increased leaf rust severity on spring wheats in 2001.

Wheat stripe rust. Southern Plains. In mid March, wheat stripe rust was severe in the Beeville, Texas nursery and in a few southern Texas fields. Commercial wheat in this area was at the heading stage. This is the most stripe rust observed in this nursery in the past 20 years. Prevalences were rated at 15–20 % with 20 % severities within the foci. Primary infections were noted on the upper leaves and were 3-4 weeks old. This indicates the initial stripe rust spore shower may have come from infected areas further south, i.e., Mexico, in early to mid February. During the third week in March in a SRWW field near College Station in central Texas light stripe rust was observed on the middle and lower leaves of wheat plants. By the third week in March, farmers were spraying wheat fields for stripe rust in the San Angelo area in westcentral Texas. Throughout Texas in 2001, the winter crops were planted later than normal and moisture conditions were above normal. The cool temperatures in late winter were especially favorable for stripe rust development throughout southern Texas. In early April, wheat stripe rust was found in wheat fields in southern Texas and in south central

Texas. Disease severities ranged from trace amounts to 80 % infection. At high severities, stripe rust significantly reduces yields and test weight. In early April, stripe rust caused complete losses in many of the entries in nurseries in south Texas. Jagger and TAM 201 were the two cultivars that showed the best stripe rust resistance in the Uvalde, southern Texas nursery. In 2000, no stripe rust was observed in southern Texas, but was found farther north and east in Texas. In 2001, south Texas provided inoculum for susceptible wheat in the northern wheat growing area.

By mid-April, stripe rust was reported in central and north Texas. Rust was severe in a few central Texas fields that were planted early and in McCulloch county plots rust was light on the lower and middle leaves. Cool spring temperatures and unusually cool nights allowed for more stripe rust development in early April. In Texas by mid April, wheat stripe rust had slowed with the onset of hot dry weather. In central Texas rust was severe in a few fields. In late April, in north central Texas, stripe rust was severe on highly susceptible lines but undetectable in fields. In northeast Texas, stripe rust was not detected in either fields or nurseries. In early May, in west central Texas, stripe rust was moderate on susceptible cultivars, but because of the drought conditions and hot weather further rust development was limited. During the second week in May, severe stripe rust was found in fields of 2137, 2174, and Custer in southwestern Oklahoma (Fig. 2, p. 237).

Central Plains. During the first week in May, wheat stripe rust was found on susceptible cultivars in a south central Kansas nursery and in fields of susceptible cultivars in southern Kansas. The plants were in the late boot maturity stage. By the second week in May, stripe rust had nearly defoliated susceptible varieties at the late milk stage across southern Kansas. In late May, severe stripe rust was reported in northern Kansas. Despite expectations that the epidemic would be halted by warm weather in mid-May, unusually cool conditions prevailed and allowed it to stay active through the first week of June. Three main factors apparently came together to generate the stripe rust problem in Kansas. First, unusually cool, wet weather in Texas in March and April were favorable for rust development. Second, very strong southerly winds transported a heavy spore shower to Kansas in mid April. Third, unusually cool wet weather in Kansas in May allowed the epidemic to prosper. Economic losses were significant in many fields of susceptible varieties across a large portion of the state. The loss to stripe rust this year in Kansas was 7.3 %, which is the most stripe rust loss on record for the state.

During the last week in June, stripe rust was the most common rust found on wheat throughout southern and eastern Nebraska. Stripe rust on susceptible winter wheat cultivars ranged from 20–80 % on the flag leaves at late anthesis to soft dough.

In early June, stripe rust was severe in irrigated wheat, but light in dryland wheat in northeastern Colorado. In late June, stripe rust was severe on the flag leaves of irrigated white wheat (e.g., Platte) in the Front Range of the Rocky Mountains in Colorado.

Northern Plains. On 8 and 9 June, light infections of wheat stripe rust were found in SRWW plots at Rosemount, and St. Paul, Minnesota, respectively. In contrast to last year, stripe rust and leaf rust were not found together on the same leaves, which probably indicates they did not develop from the same spore shower. By mid June, wheat stripe rust development was extensive in east central and northern South Dakota and severities ranged from trace–80 % on flag leaves of winter wheats. Much of the stripe rust development originated from spores produced farther south in Texas, Oklahoma, Kansas or adjacent states. During late June, stripe rust was found in winter wheat plots in east central North Dakota. Hot temperatures that followed the initial rust sighting in the Minnesota and the Dakotas set back the rust development, but cool and moist weather in mid-June resulted in further development. In mid July, stripe rust was still evident on some winter wheat cultivars, (especially the cv. Foster which has *Yr*9 resistance) despite hot, dry weather in northeastern North Dakota.

In late June, traces of stripe rust were observed on lower leaves of susceptible spring wheat in the disease observation nurseries in east central South Dakota and in a field in south central North Dakota. Stripe rust in spring wheats was limited because most spring wheats have *Yr18*/*Lr34* resistance and there are no reports of stripe rust isolates that have virulence to the resistance conditioned by *Yr18*. Also, with the onset of the hot dry temperatures in late June and early July, stripe rust development essentially ceased in spring wheats.

The past 2 years have seen the most widely dispersed stripe rust development observed throughout the northern winter wheat area in at least 40 years.

Louisiana and Arkansas. During the second week in March, wheat stripe rust was found in fields in the Evangeline parish of southern Louisiana. By this date in 2000, stripe rust was already found in northeastern Louisiana. By early April, wheat stripe rust was severe in a few fields at the one-quarter berry- maturity stage in southern Louisiana. The fields in this area had centers (foci) with 40–50 % severities, whereas throughout the rest of the field there was light infection. The rust infection centers probably developed from rust spores that arrived in early March. Stripe rust losses were significant in a few southern Louisiana fields. The hot, dry weather in April slowed stripe rust development in Louisiana. By late April, only light amounts of stripe rust were found in central Louisiana wheat plots at the one-half berry stage and none had been reported in fields. In late April, the only report of stripe rust in Arkansas was in an infection center 2 feet in diameter in the east central part of the state. In 2000, stripe rust was severe by this date throughout the state of Arkansas. By mid May, reports of stripe rust in Arkansas were limited to only a few areas in the east central and west central parts of the state. Losses to stripe rust were light in Louisiana and Arkansas in 2001.

Mideast. By mid-June, wheat stripe rust was found in northeastern Indiana plots and severities ranged from traces to 80 % on flag leaves. Light stripe rust was observed in fields in northern Indiana and northeastern Ohio. Losses to stripe rust were light.

California. In early April, wheat stripe rust was found in Central Valley, California plots. In the Davis, California nursery susceptible entries had 5–40 % severities. In mid-April, the moist cool conditions were ideal for increase of rust in the Davis nursery. By mid April, wheat stripe rust had reached 70–100 % severities in plots of susceptible entries in the Davis, California nursery. By early May, wheat stripe rust was found on susceptible cultivars growing in fields in the Sacramento Valley of California. The cool moist conditions were ideal for rust development.

Washington. In late April, as usual, stripe rust was severe in the cereal disease nurseries at Mt. Vernon in the Skagit Valley in northwestern Washington. Severities of 40–60 % were reported on susceptible wheat entries, whereas in commercial fields traces of rust were observed. In late April, in a few eastern Washington fields, traces of stripe rust were found. In mid May, wheat stripe rust was increasing in western Washington and traces were found on winter wheat in eastern Washington. The rains and cool temperatures provided ideal conditions for stripe rust increase in most of the Pacific Northwest. By late May, wheat stripe rust was increasing on susceptible winter wheat cultivars in the Pacific Northwest. In mid June, 100 % severities of wheat stripe rust were reported on susceptible winter wheat cultivars in plots in western Washington. In eastern Washington 40 % severities were observed in some fields of susceptible varieties. In early July, wheat stripe rust was present in eastern Washington but severity levels generally were low because most cultivars are resistant except for a few fields of susceptible cultivars such as WestBred 470. Stripe rust did not cause much damage on winter wheats in the Pacific Northwest this year. Because most spring wheats have good resistance to stripe rust, losses were minimal.

Canada. By late June, stripe rust was found in several locations across southwestern Ontario in plots of several cultivars of winter wheat. Infections were generally localized, but spreading rapidly. Grain filling was in the early stages, so yields were affected in some plots. In southern Manitoba, in early July, in winter wheat fields (anthesis stage), 1 % severities and 10 % prevalences of stripe rust were observed. Light losses are expected because of the low rust levels and the advanced growth stage. In late July, wheat stripe rust was widespread in southwestern Ontario, Canada, but severity was low and it was very spotty in many commercial fields and in plots no cultivar was more susceptible or resistant than the rest.

Results of stripe rust race identification show that the group of new races virulent on *Yr*8, *Yr*9, and Express, that were identified in 2000 were prevalent again in 2001 in California and Texas.

NEBRASKA

UNIVERSITY OF NEBRASKA–LINCOLN AND USDA–ARS, WHEAT, SORGHUM & FORAGES UNIT
Lincoln, NE, 68583, USA.

Personnel.

Dr. Brian Beecher joined the staff of the University of Nebraska Department of Agronomy and Horticulture. Dr. Beecher will conduct research in molecular biochemistry and will supervise activities in the Wheat Quality Laboratory. Mr. Yuan Ganan and Mr. Sahin Dere joined the project as visiting scientists. Mr. Ritesh Mishra completed his M.S. degree and returned to India to work in private industry. Dr. Mustafa Erayman completed his Ph.D. was hired as a post doctoral scientist.

Wheat production.

The 2001 Nebraska Wheat Crop was estimated at 59,200,000 bu, which represented a 37.0 bu/acre state average yield on 1,600,000 harvested acres. The area planted to winter wheat was 1,750,000 acres. The 2001 crop was similar to the 2000 crop (59,400,000 bu harvested from 1,650,000 acres with a 36.0 bu/a state average yield). Stripe rust was the major disease, though leaf and stem rust also were present. Stripe rust is rare in Nebraska (only seen once before in the previous 16 years) because it requires cool temperatures, freestanding moisture, and a source of inoculum. In most years, one of more of these factors is missing (usually cool temperatures and the source of inoculum). Russian wheat aphid damage was small and required little spraying. Despite continued genetic improvement, the main determinant in wheat production seems to be acres harvested and weather (which also affects disease pressure). Alliance (16.0 % of the state) replaced Arapahoe (13.4 %) as the most popular variety in Nebraska. Pronghorn is the third most widely grown variety followed by 2137 and Niobrara. Cultivars developed by the cooperative USDA University of Nebraska wheat improvement program occupied 73 % of the state acreage. Other public varieties occupied 17 % and private varieties occupied 10 % of the state acreage. One area of concern is the increasing production of stem rust susceptible wheats. Currently, the popular 2137, Karl/Karl 92, and Buckskin are susceptible to stem rust and cumulatively occupy 19.2 % of Nebraska's acreage.

New cultivars and experimental lines.

In 2001, the HWWW **Nuplains** was released. Wahoo was released in 2000. Five lines were advanced to small-scale increases at the Nebraska Foundation Seed Division. They are

NE97426	Brigantina/2*Arapahoe
NE97465	SD3055/KS88H164//NE89646 (=Colt*2/Patrizanka)
NE97638	NE90614 (=BRL/4/PKR*4/AGT//BEL.198/LCR/3/NWT/BRL)/NE87612 (=NWT//WRR*5/AGT/3/NE69441)
NE97669	VISTA/KS87H6//Arlin
NE97689	NE90614 (=BRL/4/PKR*4/AGT//BEL.198/LCR/3/NWT/BRL)/NE87612 (=NWT//WRR*5/AGT/3/NE69441)

All of these lines have good winter hadiness, stem rust resistance, agronomic performance and in our trials acceptable end-use quality. NE97426 is an awnless, semidwarf wheat that may have potential in grazing/haying and grain systems. NE97465 is a long-coleoptile, tall wheat that would have potential in western Nebraska and Wyoming where tall wheat varieties are needed (the Buckskin, Centura, and Pronghorn regions of these two states). This line has extraordinary yielding ability (nearly 8 MT/ha in Indiana), but the key criterion for release will be if it can do well in our tough environments (1.7 to 2.7 MT/ha). If it competes again well this year, NE97465 will be released as there are few tall wheat varieties being produced. NE97638 and NE97689 are sister lines that are semidwarf and tend to be genetically lower in test weight. Of the two lines NE97689 has a slightly better yield record and would be considered the more likely to be released. NE97669 is a good-yielding, semidwarf wheat, but will need an additional year of testing before we will know if it competes with NE97689 and NE97638.

Winter triticale nursery.

In 2001, two forage triticale varieties were released for commercial sale (NE422T (formerly NE96T422)) through Nupride Genetics Network and Gro-Green Plus (formerly NE96T441) through Star Seed Inc. of Kansas. NE422T is a forage winter triticale (*X Triticosecale rimpaui*) cultivar developed cooperatively by the Nebraska Agricultural Experiment Station and the USDA–ARS (Dr. Ken Vogel). Jointly released in 2001 by the developing institutions, NE422T was selected from the cross 'Trical/UB-UW26' where Trical is most likely Trical 100 (a forage triticale developed by Resource Seed Inc., a subsidiary of Goldsmith Seed Company, Gilroy, CA) and UB-UW26 is an unknown winter triticale germ plasm line given to the breeding program in the 1980s. NE422T is an F_3-derived F_4 line that was released primarily for its superior forage production in rainfed winter cereal production systems in Nebraska.

NE422T was performance tested as NE96T422 in Nebraska grain yield nurseries starting in 1997 and in forage yield trials in 1997 and 1998. In 2 years of forage testing in Nebraska cultivar performance trials, NE422T has performed extremely well throughout most of Nebraska in rainfed production systems. The average Nebraska rainfed forage yield cut at the R2 (fully headed but the peduncle not fully emerged) to R4 (anthesis, Nebraska scale) stage of NE422T (six environments) was 9,070 kg/ha dry matter; with an average in vitro dry matter digestibility of 63.9 % and an average protein content of 9.0 %. These data compare favorably with Newcale (a grain triticale: 8,730 kg/ha, 67.9 %, and 8.5 %) and Trical 100 (8,530 kg/ha; 63.5 %, and 9.0 %). For further comparison, the forage yields of NE422T were higher than two commonly grown wheat cultivars Arapahoe (7,200 kg/ha, 67.7 %, and 8.5 %) and Pronghorn (7,930 kg/ah, 67.0 %, and 8.6 %). The wheat cultivars are earlier than NE422T and were cut at the R4 to S0 (caryopsis visible, Nebraska scale). NE422T has a good grain yield (10 environments; 2,790 kg/ha) for a forage triticale. The grain yield was higher than Trical 100 (2,040 kg/ha), but lower than grain triticale cultivars (Presto, 3,620 kg/ha; Newcale, 3,120 kg/ha). For comparison, the grain yield of Arapahoe was 3,050 kg/ha, which is lower than the grain triticale yields and might be explained by triticale yield nurseries generally be planted near, but earlier than the wheat yield trials. The main advantages of NE422T when compared to most other forage triticale cultivars, within its area of adaptation, is its high forage yield coupled with a good grain yield (needed for efficient seed production) and its broad adaptation in rainfed production systems.

Other measurements of performance from comparison trials show that NE422T is late in maturity, about 7 days later than Newcale, 6 days later than Presto, 5 days later than Arapahoe, and 1 day earlier than Trical 100. The mature plant height of NE422T, a tall triticale (58 in; 148 cm) is 3 in (7.5 cm) taller than Trical 100, 12 in (31 cm) taller than Presto and Newcale, and 19 in (49 cm) taller than Arapahoe. NE422T has moderate straw strength for a tall, forage triticale. NE422T is slightly better than Trical 100 lodging, but worse than Presto, Newcale, and Arapahoe. The winter hardiness of NE422T would be consider as good, similar to Trical 100, which is one of the most winter-hardy triticale cultivars currently available to grower, and comparable to an average winter wheat for this trait.

Based on field observations, NE422T is moderately resistant to the currently prevalent races of stem rust (most likely containing *Sr31*) and leaf rust. Like most ryes and triticale varieties, NE422T is moderately resistant to WSMV. Ergot has not been found in the cultivar when the disease was present in the other triticale varieties under similar growing conditions. NE422T has an average grain volume weight for triticale.

In positioning NE422T, based on performance data to date, it should be well adapted to most rainfed winter annual forage production systems, with high forage yield potential in most of Nebraska. NE422T should also perform well as a second crop in irrigated productions, where it is planted following a harvested summer annual crop and the forage is harvested the following year before planting another annual summer crop. In these cropping systems, water would not be limiting and three crops could be harvested in 2 years. NE422T should perform well in similar growing areas in adjacent states.

The Nebraska Foundation Seed Division, Department of Agronomy, University of Nebraska-Lincoln, Lincoln, NE 68583 had NE422T foundation seed available to qualified certified seed enterprises in 2000. The U.S. Department of Agriculture will not have seed for distribution. The seed classes will be Breeder, Foundation, Registered, and Certified. The Registered seed class will be a nonsalable seed class. NE422T will be submitted for registration and plant variety protection under P. L. 10577 with the certification option. A research and development fee will be assessed on certified seed sales of NE422T and Gro-Green Plus.

Wheat transformation and tissue culture studies.

T. Clemente, S. Sato, M. Dickman, A. Mitra, S. Mitra, J. Watkins, J. Schimelfenig, and S. Baenziger.

Wheat transformation continues to be a key strategic effort in the wheat improvement overall effort. In our current research, we are emphasizing trying to develop wheat lines with improved FHB resistance as part of the U.S. Wheat and Barely Scab Initiative. So far, we have concentrated on transferring the following genes: a) inhibitors of apoptosis (programmed cell death); b) lactoferrin and a related derived protein, lactoferricin; and c) related antifungal proteins that have been derived based on similar protein structures. We have created over 10 events for these genes and are increasing the seed of them now. We have lines from the T_1 to T_5 and are screening those for FHB tolerance. We continue to see levels of FHB tolerance in the transgenic lines. However a concern remains that the assay is very difficult and false positives and negatives are possible.

Chromosome substitution lines.

H. Budak, T. Campbell, M. Erayman, Y. Mater, K. Gill, S. Baenziger, K. Eskridge, I. Dweikat, S. Dere, R. Graybosch, and A. Lukaskewski.

Dr. Mustafa Erayman, a postdoc, is assigning bins to the known probes for chromosome 3A using the Chinese Spring deletion stocks developed at Kansas State University. His research is helping us understand the recombinational map and the physical map for chromosome 3A. Todd Campbell and Hikmet Budak are graduate students who actively filling in the gaps in our genetic map and to determine the critical chromosome regions contains the genes that control agronomic traits. We currently have about 20 polymorphic markers on chromosome 3A. Todd has just completed his evaluation of 98 recombinant inbred chromosome lines (RICLs) for Cheyenne (CNN) Wichita (WI) chromosome 3A lines (e.g., CNN(RICLs3A)) in replicated trials in seven environments which will be the basis for identifying QTLs and measuring 'QTL x E'. He has found two QTL loci that affect grain yield. In a separate effort, Mr. Yehia Mater is developing a new T1A·1R chromosome in which he hopes to combine the best attributes of T1A·1R from Amigo with T1B·1R from Kavkaz. This research is possible due to the elegant cytogenetic manipulations of Dr. Adam Lukaszewski (Univ. of California–Riverside) who created the T1A·1R lines where the 1R was previously on 1B in Kavkaz.

White wheat.

Bob Graybosch, USDA–ARS and Steve Baenziger continue the orderly transfer of white wheat germ plasm to the state wheat breeding. Promising experimental lines were identified. NW97S182 finished 7th in the 2001 Nebraska State Variety Trial, and NW97S278 did very well in the Colorado irrigated trials (data can be found via a link on L. Nelson's on-line report). Both will be in the Nebraska State Variety Trial for 2002, and we will make a decision on their fate next summer. Efforts continue to develop pure white wheat so there will less concern about mixed white and red seed and grain in the marketing channels. As with the creation of most new markets, marketing remains an issue.

Wheat quality: genetics and germ plasm enhancement.

R. Graybosch, S. Baenziger, D. Baltensperger, and B. Beecher.

Three HWWWs, NW97S182, NW97S218 and NW97S278, were advanced to preliminary seed increase, with final release decisions scheduled to be made in the summer of 2002. Release of three additional sets of germ plasm lines are in process, pending approval by USDA–ARS. These include 1) a set of spring waxy (amylose-free) wheats (PI 619354 – PI619375); 2) N96L9970 (PI 619231, GRS1201/TAM202), which carries resistance to greenbug biotypes B, C, E, G, and I, and a T1AL·1RS wheat-rye chromosomal translocation, as well as improved agronomic performance over its greenbug resistant parent GRS1201; and 3) two T1BL·1RS wheat-rye translocation lines (PI 617064 and PI 617066) with markedly improved gluten strength relative to typical T1BL·1RS lines. We also have been examining the phenotypic stability of functional properties of waxy wheat flours. A set of waxy (amylose-free) experimental spring wheats of diverse parentage were grown, along with four nonwaxy check cultivars, at various North American cultural environments. Grain yield and functional attributes of derived flours were determined. Average grain yield of the waxy lines did not differ significantly from the average yield of the check cultivars, but significant differences were observed amongst the waxy lines. Grain hardness varied significantly amongst the waxy lines, and both hard and soft textured waxy lines were identified. Analysis of flour quality traits showed few differences between waxy lines and check cultivars for traits primarily related to protein concentration or protein quality, but many significant differences between properties primarily dependent upon starch structure, or related to milling behavior. Protein-related quality attributes of waxy wheats demonstrated environmental and genotypic variances similar to those typical of non-waxy wheats. Starch-related quality attributes of waxy wheats showed remarkable stability across environments, but some significant genetic variation was observed. End-users interested in employing waxy wheats should be able to select desired waxy lines and feel confident that the starch-related functional properties will be environmentally consistent.

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NORTH DAKOTA

USDA–ARS CEREAL CROPS RESEARCH UNIT
Northern Crop Science Laboratory, Fargo, ND, USA.

Justin Faris, James Miller, Daryl Klindworth, Leonard Joppa, Phil Meyer, Mary Johnshoy, David Birdsall, Karri Haen, Kristin Simons, and Erik Doehler.

Genomic targeting of the Tsn1 locus in wheat.

Karri M. Haen and Justin D. Faris.

Sensitivity to the tan spot necrosis toxin (Ptr ToxA) is conferred by a single dominant gene (*Tsn1*) located on the long arm of wheat chromosome 5B. Because chromosome walking is laborious and time-consuming, especially in large and genetically complex genomes like that of wheat, chromosome landing via high-density and high-resolution mapping may be a more feasible approach to map-based cloning. We have combined the techniques of AFLP and cDNA-AFLP with bulked-segregant analysis to target markers to the *Tsn1* region. Bulked DNAs derived from 'CS/CS-DIC 5B' and 'LDN/LDN-DIC 5B' RSLs were analyzed to identify polymorphic fragments within the *Tsn1* region. Positive fragments were converted into RFLP markers and mapped in segregating RSL populations. Over 400 primer combinations have been screened resulting in the identification of 33 positive fragments. So far, 21 of the 33 fragments have been cloned and mapped resulting in three markers tightly linked to *Tsn1*. A population of ~2,000 F_2s has been constructed for high-resolution mapping. Other research suggests the bp/cM ratio within this region is approximately 200 kb/cM. Therefore, our goal is to identify markers within 0.5 cM of *Tsn1* before screening BAC libraries to identify clones spanning the locus.

Genomic targeting, high-resolution mapping, and chromosome walking at the Q locus in wheat.

Justin D. Faris, John P. Fellers, Steve Brooks, and Bikram S. Gill.

The *Q* gene is largely responsible for the domestication of bread wheat because it confers the free-threshing character of the spike. The *Q* gene has also been shown to influence many other agronomic characters depending on the genetic background. Thus, *Q* is likely a major regulatory gene. High-density and high-resolution mapping are the first steps toward positional cloning. The *Q* gene has been physically mapped on the long arm of chromosome 5A between the chromosomal breakpoints of deletion lines 5AL-7 and 5AL-23. To target markers to this genomic region, we compared the two deletion lines using RFLP, AFLP, and mRNA differential-display analysis. The use of these techniques resulted in the identification of 18 markers within the deletion interval. A population of 465 F_2 plants was used for high-resolution mapping. The resulting genetic linkage map of the region was 20 cM, indicating that the *Q* locus lies within a recombination hot spot. Markers within 0.8 cM of the *Q* gene were identified and used to screen a *T. monococcum* BAC library. A chromosome walk has been initiated and a partial BAC contig constructed. To date, we have sequenced about 250 kb spanning 0.6 cM and currently have markers within 0.1 cM of the *Q* gene.

Genomic analysis of segregation distortion and recombination on durum chromosome 5B.

Justin D. Faris, Karri M. Haen, and Bikram S. Gill.

Distorted segregation ratios of genetic markers are often observed in progeny of inter- and intraspecific hybrids and may result from competition among gametes or abortion of the gamete or zygote. Homoeologous group-5 chromosomes of the Triticeae are known to possess segregation distortion factors, and detailed analysis of *Ae. tauschii* chromosome 5D indicated that it possessed at least three different segregation-distortion loci that conferred gametophytic competition among pollen when an F_1 plant was used as a male parent. In this study, we developed genetic linkage maps of chromosome 5B in male and female populations derived from Langdon (LDN) durum and

Langdon/*T. turgidum* subsp. *dicoccoides* 5B disomic chromosome substitution (LDN-DIC 5B). Genetic markers in the female population had expected segregation ratios, and the recombination frequencies were similar to those found along chromosome 5B in other wheat and durum populations. However, segregation ratios of markers in the male population were highly skewed in favor of LDN alleles, and recombination frequencies were severely suppressed. At least two distorter loci appear to be present along chromosome 5B of durum, and they are likely homoeoalleles of those identified in *Ae. tauschii*. This research agrees with previous research in that segregation distortion is likely the result of gametophytic competition for preferential fertilization in a heterogeneous pollen population, and suggests that this phenomenon may lead to reduced recombination frequencies.

Identification and characterization of a durum/Ae. speltoides chromosome translocation conferring resistance to stem rust.

Erik Doehler, Justin Faris, James Miller, and Leonard Joppa.

Homozygous, durum/*Ae. speltoides* translocation lines were produced by homoeologous recombination and tested for reaction to the stem rust pathogen. The durum parent is a universal susceptible line, but the *Ae. speltoides* chromosome translocation conditions seedling resistance to at least nine races of stem rust. RFLP analysis indicates that the translocation chromosome involved is durum chromosome 2B, and it consists of the long arm and a portion of the short arm derived from *Ae. speltoides*. Experiments are underway to identify the *Ae. speltoides* chromosome involved in the translocation, to determine if the gene(s) on the translocated segment confer resistance to all races of stem rust, and to determine if this gene(s) is the same or different from *Sr32* and *Sr39* which were also derived from *Ae. speltoides* by translocations to hexaploid wheat chromosome 2B.

Development of Fusarium head blight-resistant durum wheat germ plasm.

James D. Miller, Leonard R. Joppa, and Robert W. Stack.

Substitution of individual chromosomes from each of two FHB resistant accessions of *T. turgidum* subsp. *dicoccoides* into Langdon durum have been completed for 10 of the 14 chromosomes. The disomic substitutions were grown in replicated greenhouse tests, inoculated using the single spikelet method, and scored for type-II resistance to identify the chromosomes having genes for FHB resistance from *T. turgidum* subsp. *dicoccoides*. Of the disomic substitution lines showing average severities of 33 percent or less, we have found that genes in chromosomes 3A, 7A, 5B, and 7B appear to be contributing resistance to FHB.

Nine F_2 families from a cross between the FHB resistant, *T. turgidum* subsp. *dicoccoides* disomic 7A chromosome substitution line and a susceptible cultivar Ben were inoculated with the scab fungus. A total of 1,046 plants were scored for type-II resistance (severities of 20 % or less) with 24 % appearing to contribute resistance to FHB. Attempts will be made to determine the inheritance of resistance and gluten strength in the F_3 derived lines.

We also evaluated five BC_1F_2 families from a cross between a FHB-resistant accession of *T. turgidum* subsp. *dicoccoides* and the susceptible durum cultivar Ben, which were grown and inoculated in a FHB hill plot nursery. We selected and harvested 403 heads having scab severities of only 7 %, and the derived F_3 lines are being evaluated in the greenhouse.

F_4-derived F_5 lines from two crosses between Ben and a FHB-resistant, *T. turgidum* subsp. *dicoccoides* accession continue to be evaluated and selected. In greenhouse tests, the selected F_5 lines showed average severities of 10–15 % infection.

Selection of a durum wheat that is universally susceptible to stem rust.

Daryl L. Klindworth and James D. Miller.

The most widely used set of durum aneuploids used in North America is the Langdon D-genome disomic substitutions. Studies of stem rust resistance in durum wheat are complicated because Langdon has at least three stem rust-resistance genes. As a result, aneuploid analyses can only be conducted when the stem rust race used is virulent on Langdon and avirulent on the genotype carrying the gene of interest. Studies of stem rust resistance in durum wheat would be facilitated by use of aneuploids based on a universal susceptible durum. Marruecos 9623 was identified many years ago as having only a single gene that confers resistance to only a few weakly virulent races of stem rust, most notably race 111. However, Marruecos 9623 has a poor ideotype and poor fertility. Therefore, we have crossed Marruecos 9623 to Langdon aneuploids and selected euploid progeny in an attempt to improve plant ideotype and fertility, and to select for susceptibility to race 111. We have identified a line, which is presently designated 47-1R1 which has these attributes. We presently are backcrossing 47-1R1 to the Langdon D-genome disomic substitutions to produce a stem rust-susceptible set of durum aneuploids.

Chromosomal location of genetic male sterility genes in four mutants of hexaploid wheat.

Daryl L. Klindworth, Noman D. Williams, and S. S. Maan.

In 1978, Sasakuma et al. (Crop Sci **18**:850-853) reported on the inheritance of several male-sterile mutants of wheat. The mutants FS2, FS3, FS20, and FS24 were conditioned by a recessive gene, with three of the mutants being allelic to each other. We wanted to determine the allelic relationship of these genes to *ms1*, which is the only mapped recessive male-sterile mutation in wheat. We crossed the mutants to Cornerstone (*ms1c*) to determine allelic relationships. We found that mutants FS2, FS3 and FS24 were allelic to *ms1*, and, therefore, the mutations in these lines must be located in chromosome arm 4BS. A monosomic study of the FS20 mutant was conducted and the mutated gene was located to chromosome 3A. From a telosomic analysis of the FS20 gene, we found the the mutated gene in FS20 was located in chromosome arm 3AL. A linkage chi-square test indicated that the FS20 gene was not linked to the centromere of chromosome 3A. The gene symbol *ms5* was assigned to the mutated gene in FS20, and gene symbols *ms1d*, *ms1e*, and *ms1f* were assigned to the mutations in FS2, FS3, and FS24, respectively. The *ms5* gene may be useful for mapped based cloning of a male-sterility gene from wheat

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OKLAHOMA

OKLAHOMA STATE UNIVERSITY
Department of Plant and Soil Sciences, 368 Ag Hall, Stillwater, OK 74078-6028, USA.

Variety development.

B.F. Carver.

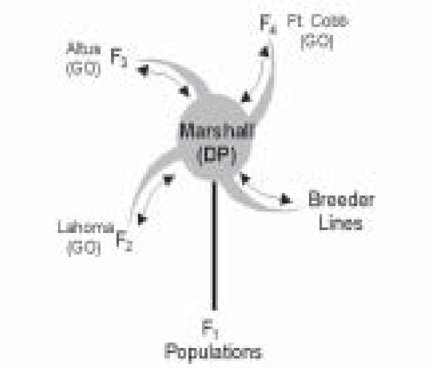

Fig. 1. A 3-year selection system for plant selection and seed production of breeding populations.

The 2000–01 crop season marked the first year in which the parent bulk populations of all head rows ($F_{4:5}$) were shuttled through a 3-yr selection system that can best be pictured as a pinwheel (Fig. 1). At the center of the pinwheel is the process of plant selection and seed production of breeding populations for 3 consecutive years under a dual-purpose (DP) grazing system at Marshall, OK. Simultaneously, these breeding populations are evaluated (and eliminated, if inferior) under a grain-only (GO) system in north central Oklahoma in the F_2 generation, in southwest Oklahoma in the F_3, and in central Oklahoma in the F_4. Each year, a new set of about 30,000 breeder lines are extracted from 200–250 breeding populations, after having cycled through this 'pinwheel' for 3 years. This selection and testing program leads to breeder lines with improved adaptation to a dual-purpose production system, but only from those populations with highest yield potential in a grain-only production system. There is one caveat, however. We learned for the first time in 2001 that selection strictly for adaptation to grazing may lead to a plant type that, ironically, is less conducive to high forage production. That may be the plant's way of conserving its energy for reproductive development and grain production. Consequently, selection in succeeding generations is needed to restore forage growth patterns to which wheat producers in the southern Great Plains are accustomed.

The Oklahoma Agricultural Experiment Station and USDA–ARS will jointly announce in May 2002 the release of **Ok102** HRWW. Tested under the experimental name, OK97508, its pedigree is '2174/Cimarron'. Ok102 is widely adapted to Oklahoma and should mimic the adaptation range of one its parents, 2174. This cultivar should be most competitive in areas with i) a history of WSBMV, ii) the likelihood of leaf rust infection in adult-plant stages, or iii) moderate soil acidity and aluminum toxicity. Severe soil acidity (pH near 4.0) and/or soils with high aluminum saturation (near 30 %) will restrict its forage and grain performance. Ok102 also is adapted for the High Plains, with or without irrigation. Ok102 has no known defects in physical grain quality or in milling and baking quality, regardless of production site. Moreover, it has consistently demonstrated moderately high protein levels and good protein strength and, therefore, constitutes a desirable grain source for leavened bread products. The test weight of Ok102 is very good, with moderately high kernel size.

With regard to grain yield and quality, Ok102 may be used in dual-purpose and grain-only management systems, but its temperature-sensitive seed dormancy will cause it to be a 'slow starter' if planted extremely early under hot soil conditions. Thus, Ok102 is not recommended for a forage-only management system where planting date is earliest and emphasis on fall forage production is highest. An avoidance for premature plant dormancy release should allow extended grazing without sacrificing grain yield, provided grazing termination precedes first-hollow-stem stage. A more erect vegetative growth habit makes it potentially less likely to fully recover from intensive grazing than prostrate genotypes, though yield depression in a dual-purpose management system has not been extensively quantified.

Ok102 is highly resistant reaction to WSBMV, and it shows a susceptible seedling reaction (*Lr3* and *Lr24*) but a resistant adult-plant reaction to leaf rust. The reaction to stripe rust is intermediate. An intermediate reaction to BYDV places Ok102 in a class unlike most HRWW varieties that tend to be more susceptible.

Identification of Ok102 as a candidate cultivar was accomplished through OSUs Wheat Improvement Team, which includes Brett Carver (lead scientist), Gene Krenzer, Art Klatt, Arron Guenzi, Guihua Bai, and Bjorn Martin, Department of Plant and Soil Sciences; Bob Hunger and Jeanmarie Verchot, Department of Entomology and Plant Pathology; Patricia Rayas-Duarte, Department of Biochemistry and Molecular Biology; and David Porter, USDA–ARS Plant Science Research Laboratory, Stillwater.

Molecular genetics and breeding for stress tolerance.

G. Bai and B.F. Carver.

Leaf rust is an important disease in the southern Great Plains. Molecular markers linked to genes for rust resistance can facilitate pyramiding of those genes with resistance to different races of the pathogen. Two series of NILs contrasting in *Lr41* and *Lr42* from *Ae. tauschii* in a Century background were screened with AFLP markers. *Pst*I and *Mse*I enzymes and matching adapters and primers were used for DNA preparation and PCR amplifications. Bulked resistant and susceptible NILs and the three parents were screened with 400 sets of primers. Nine markers closely linked to the two genes were identified. Among them, five markers were linked to *Lr42* and three to *Lr41*. Conversion of the AFLP markers into STS markers is underway.

Wheat scab is a destructive disease of wheat. Conversion of AFLP markers into STS markers can generate breeder-friendly markers for MAS and make full use of AFLP markers developed for the major scab-resistance QTL on 3BS. We used *Pst*I–AFLP markers to further saturate the original AFLP map on the 3BS QTL region and identified five markers that were significantly associated with the QTL. One of the markers explained up to 50 % of the phenotypic variation for scab resistance. Successful conversion of the 222-bp fragment yielded a codominant STS marker that explained about 50 % of the phenotypic variation for scab resistance in an F_7 recombinant population derived from 'Ning 7840/Clark'. The STS was validated in 14 other cultivars and the banding pattern perfectly matched their pedigrees. This is the first STS marker for a scab resistance QTL converted from an AFLP marker. Application of this marker in breeding programs may accelerate breeding procedures to enhance wheat scab resistance in wheat.

Genome-wide analysis of gene expression patterns in response to scab infection may lead to gene discovery and provide insight into further understanding genetic mechanisms of resistance. To enrich differentially ESTs for scab resistance, cDNA subtraction libraries were generated from *F. graminearum*-infected spikes of two bulked RILs differing in scab resistance using the suppression-subtractive hybridization (SSH) method. The bulked RILs were formed by pooling infected spikes from five $F_{8:12}$ scab-resistant and five susceptible RILs based on their type-II resistance from four greenhouse tests. The RILs were derived from the cross between the resistant cultivar Ning 7840 and the susceptible cultivar Clark. The selected RILs were grown in the growth chamber and inoculated with a conidiospore suspension of *F. graminearum* by single-floret inoculation at the early flowering stage. The infected spikes were harvested for mRNA extraction at 6, 36, and 72 hours after inoculation. About 1,000 cDNA clones were isolated from the three libraries. Eighty-six clones were randomly selected from the libraries and sequenced; most of them (92 %) were singletons. Sequence homology search using the BLAST program from NCBI showed some of them were similar to those genes involved in stress or defense responses and signal regulation. The clones from the libraries will be used for temporal gene expression analysis with microarrays.

Aluminum toxicity is a major constraint for wheat production in the southern Great Plains. To enrich differentially ESTs for Al tolerance, cDNA subtraction libraries were generated from Al-stressed roots of two wheat NILs differing in an Al-tolerance gene from Atlas 66, using SSH. Expression patterns of the ESTs were investigated with macroarrays of 1,311 cDNA clones from the subtraction libraries. Gene-expression profiles exhibited about one-fourth of ESTs with significantly altered levels of expression in both tolerant and susceptible lines in response to different durations of Al stress. Furthermore, several ESTs showed consistently increased expression only in the tolerant NIL after Al treatment, indicating that those ESTs may play a significant role in enhancing wheat Al tolerance. Those highly expressed clones were sequenced, and some of them showed high similarity with genes involved in signal transduction, membrane transport, oxidative stress, and cell defense and rescue processes. Therefore, wheat response to Al stress may involve complicated defense-related signaling and metabolic pathways.

To identify molecular markers linked to aluminum-tolerance genes, an F_2 mapping population was derived from the cross 'Atlas 66/Century'. The F_2 population was evaluated for Al tolerance by hematoxylin staining and measuring lengths of roots after two days Al treatment. This population will be further phenotyped in F_3 families and putative markers previously derived from NILs will be further verified.

Wheat germ plasm enhancement.

A.K. Klatt.

The variability enhancement/germ plasm development program at Oklahoma State University continued to give priority to transferring durable leaf rust resistance from CIMMYT spring wheats to winter wheats adapted to the southern and central Great Plains. An extensive crossing program with new synthetics and synthetic derivatives developed by CIMMYT is also in progress. These crosses have multiple objectives including new sources of leaf rust resistance, improved kernel size, enhanced stay green characteristics, and improved biomass and yield potential.

During the 2000–01 cycle, more than 1,800 additional winter and spring wheat materials were introduced (primarily from CIMMYT) and cleared through quarantine procedures. These materials are currently being evaluated for multiple disease resistance and agronomic performance. The best materials will be utilized as parents to introduce new genetic variability into the program. For information regarding this program, contact Art Klatt, Department of Plant & Soil Sciences, 274 Ag Hall, Stillwater, OK 74078.

Department of Entomology & Plant Pathology, 127 Noble Research Center, Stillwater, OK 74078, USA.

Barley yellow dwarf virus.

Bob Hunger, Brian Olson, and Mark Payton.

Aphids, and subsequent BYDV infections were not a major disease in Oklahoma for the 2000–01 wheat crop. Although trials were conducted in several locations to evaluate the effectiveness of insecticide seed treatments to control aphids and subsequent BYDV, limited results were obtained because of the low incidence of aphids during the crop season. This low incidence most likely resulted from an extremely dry autumn, which resulted in later planting of wheat over much of the state. This was followed by a severe period of abnormally cold weather during late November through early January, which not only slowed wheat development, but also was unfavorable for insect and disease development.

In growth chamber studies, the effects of aviruliferous bird cherry-oat (BCO) aphids (*Rhopalosiphum padi*) on HRWW seedlings were investigated. Caged wheat seedlings were grown hydroponically at 16.5°C with a 16:8 photoperiod. Ten-day-old seedlings were infested with 0, 10, 20, or 30 aviruliferous BCO aphids for 2, 4, 6, 8, or 10 days. Nymphs were removed daily. At 20 days after planting, length of roots and shoots was quantified using Rootedge software. Seedlings were transplanted into clay pots, vernalized, and grown to maturity in a greenhouse. Results indicated that low population levels of aviruliferous BCO aphids adversely affected root and shoot length of seedling wheat. Increasing aphid density decreased number of heads, number of seeds, and grain weight.

Eyespot (strawbreaker, footrot).

Bob Hunger and Larry Singleton, Gene Krenzer and Ray Sidwell (Department of Plant & Soil Sciences), and Mark Payton.

Eyespot causes sporadic losses in Oklahoma, but was severe in many fields during the 1998–99 and 1999–2000 seasons. Severe lodging caused by eyespot was observed in a wheat field located at the North Central Experiment Station near Lahoma, OK, so a replicated trial was conducted in this field during the 1999–2000 season. This study examined the affect of planting date (early = 20 September, 2000; late = 22 November, 2000), tillage (disking or moldboard plowing after harvest), and burning or not burning the residue. Results indicated that only planting date affected the severity of eyespot, with early planted wheat showing significantly more severe eyespot and more severe lodging (Table 1). Later planted wheat was less severely affected by eyespot and showed no lodging. However, the reduced disease in the later planted wheat did not translate into increased yields because of the lateness of the late planting date (1–15 October is optimum) and because of the extremely cold weather that occurred after the late planting date that prevented normal development in these plots. Results do confirm conclusions from studies on this disease in the Pacific Northwest that indicate an effect of planting date, but not of burning or tillage, on the incidence and severity of eyespot.

Table 1. The effect of planting date, tillage, and burning of residue on severity of eyespot, lodging, and yield.

Agronomic practice	Eyespot severity (1–5) [1]	Lodging (1–5) [2]	Yield (Lb)
Early planted	4.43*	1.92*	40.2*
Late planted	2.55	1.00	29.3
Disked	3.53	1.63	35.2
Moldboarded	3.45	1.29	34.2
Burned	3.28	1.25	35.0
Not burned	3.70	1.67	34.4

[1] Eyespot severity is the mean of the rating given to 15 lowest internodes of 15 stems collected at random from each plot. Internodes were rated on a scale of 1–5, where 1 = 0–25 % discoloration; 2 ≥ 25–50 % discoloration; 3 ≥ 50–75 % discoloration; 4 ≥ 75–100 % discoloration; and 5 = dead or eyespot lesions present.
[2] Lodging was rated in each plot in the field on a scale of 1–5, where 1 = no lodging; 2 ≤ 10 % of tillers in the plot were lodged; 3 = 10–25 % of tillers in the plot were lodged.
* Indicates significant difference between the pair of values at P = 0.05.

Breeding for disease resistance: soilborne wheat mosaic virus and wheat foliar diseases.

Bob Hunger and Jeanmarie Verchot.

Many regional nurseries, including the Southern Regional Performance Nursery, the Northern Regional Performance Nursery, and the Regional Germplasm Observation Nursery, were tested for reaction to WSBMV (field) and leaf rust (seedling and greenhouse). Results from these and other trials conducted on winter wheats are summarized at *http://www.ianr.unl.edu/arslincoln/wheat/default.htm*. For a description of releases from the wheat breeding program at Oklahoma State University, see the annual summary in this newsletter from the Plant & Soil Science Department at Oklahoma State University.

A new technique was developed that allows for uniform inoculation of wheat plants with WSBMV. In this technique, an artist's tool called a NIB is employed. Use of the NIB to inoculate WSBMV eliminates the wound-induced necrosis normally associated with rub inoculating virus to wheat leaves. This new inoculation technique was used along with inoculation by growing seedlings hydroponically and in *Polymyxa graminis*-infested soil to analyze the resistance of one WSBMV-susceptible and three WSBMV-resistant cultivars to WSBMV. Results indicate that resistance to WSBMV likely functions in the roots to block virus infection.

In other studies, experiments were conducted to determine the path for WSBMV transport from roots to leaves. Results of immunogold labeling suggest that WSBMV enters and moves long distances through the xylem. WSBMV may enter primary xylem elements before cell death occurs, and then move upward in the plant after the xylem has matured into hollow vessels. There is also evidence for lateral movement between adjacent xylem vessels.

As in 2000, wheat stripe rust was the most common foliar disease observed in Oklahoma in 2001. The areas most affected were southwestern Oklahoma northward to Kansas. Although stripe rust was severe in some fields and on certain varieties, yield reductions were not severely affected. As in 2000, this higher incidence of stripe rust was attributed to a mild and moist winter followed by a cool and moist spring, which provided conditions favorable for stripe rust from Texas to become established in Oklahoma. Losses due to stripe rust were significantly higher in Kansas, where the cool moist the cool moist conditions in the spring provided a longer optimum environment to facilitate the spread and development of stripe rust.

Other foliar diseases observed in Oklahoma included leaf and glume blotch, tan spot, and powdery mildew. No significant losses from these diseases were observed.

Karnal bunt testing.

Bob Hunger and Larry Singleton.

Commercial wheat produced in Oklahoma in 2001 was examined for the presence of teliospores of *T. indica*. Testing was conducted using methods and following protocols approved by the Animal and Plant Health Inspection Service (APHIS). In 2001, 70 samples collected from elevators representing 39 counties were tested, which satisfied APHIS's National Karnal Bunt Testing Program. Testing has been conducted every year since 1996 in Oklahoma, with no positive samples being found.

Departmental and personnel changes.

Mr. Brian Olson completed a Master of Science degree in May, 2001, under the direction of Dr. Bob Hunger. The title of Brian's thesis was 'Effect of the bird cherry-oat aphid (*Rhopalosiphum padi*) on wheat and control of the aphid/barley yellow dwarf complex with Gaucho (Imidacloprid) insecticide.' Brian currently is working at Oklahoma State University as the Plant Disease Diagnostician in the Department of Entomology & Plant Pathology.

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SOUTH DAKOTA

SOUTH DAKOTA STATE UNIVERSITY AND THE USDA–ARS NORTHERN GRAIN INSECT RESEARCH LABORATORY (NGIRL).
Plant Science Department, Brookings, SD 57007 U.S.A.

Winter wheat breeding and genetics.

A.M.H. Ibrahim, M.A.C. Langham, S.A. Kalsbeck, R.S. Little, F. Hakizimana, and D. Gustafson.

Personnel changes. Dr. Amir Ibrahim joined the Faculty of Plant Science Department as the winter wheat breeder and assistant professor of plant science in June 2000. His master's degree in crop production came from the American University of Beirut, Lebanon, and his doctorate in plant breeding and genetics from Colorado State University, Fort

Collins. Following graduate studies, he remained at CSU as a postdoctoral fellow, breeding drought-resistant spring wheat. His research efforts at SDSU focus toward the development of improved cultivars adapted for production in South Dakota and the northern Plains along with other aspects of winter wheat breeding and genetics research.

Crop report. Winter wheat production in 2001 was estimated at 11.8 million bushels from 0.37 million harvested acres (1.3 million planted acres), for an average of 32 bushels/acre, an 80 % reduction compared to 1998. Overall, colder than normal temperatures, very dry autumn planting conditions, loss of snow cover during the winter, and cold late spring resulted in significant acreage loss. The nurseries at Dakota Lakes, in addition to the Crop Performance Trial at Platte, were abandoned.

Breeding program. In 2001, the winter wheat breeding program conducted testing at 11 sites throughout South Dakota. These environments included both Aurora and Brookings (Brookings Co.), Britton (Marshall Co.), Platte (Douglas Co.), Highmore (Hyde Co.), (Selby (Walworth Co.), Winner (Tripp Co.), Wall (Pennington Co.), the Northeast Research Farm near Watertown (Codington Co.), and both irrigated and dryland environments at the Dakota Lakes Research Farm east of Pierre (Hughes Co.). Crop performance testing also was conducted at an additional eight sites west of the Missouri River in coöperation with Clair Stymiest and John Rickertson (SDSU West River Agricultural Research and Extension Center, Rapid City). Crossing and germ plasm enhancement efforts continue to address HRWW and HWWW, end-use quality, and important constraints facing producers in the northern Great Plains (FHB, WSMV, leaf and stem rust, leaf spotting diseases, and winter hardiness). Ongoing research support projects include screening for resistance or tolerance to Fusarium head blight, WSMV, and genetic studies of WSMV inheritance.

Foundation seed increases. Two advanced experimental lines are under foundation seed increase. These lines, SD97457 (Tomahawk/Bennett) and SD97W604 (SD89333 (Gent/Siouxland)//Abilene) are being increased for possible release in autumn 2002 and 2003, respectively. Two lines were placed under small-scale increase for the autumn of 2001 planting season. These lines SD92107-5 (Brule//Bennett/Chisholm/3/Arapahoe) and SD97W609 (Abilene/Karl) have shown promise in regional and statewide trials for the last 2 years.

Inheritance of resistance to WSMV in OK65C93-8 winter wheat line (Hakizimana, Langham, and Ibrahim). Frederic Hakizimana has completed last third of his research studies on WSMV. The main goal of this study was to determine the mode of inheritance and the type of gene action of WSMV resistance in three crosses involving two susceptible and one resistant winter wheat lines. Results indicated that one major single recessive gene and one single dominant gene control the resistance to WSMV in OK65C93-8 winter wheat line. Additive, dominance, and epistatic effects were all found to be involved in the inheritance of WSMV resistance. Narrow-sense and broad-sense habitability estimates were intermediate to high.

Fusarium head blight (Ibrahim and Gustafson). We have established a proactive effort to develop scab-resistant hard winter wheat varieties. Recent changes in winter wheat production practices could lead to an increase in scab (increase in reduced tillage and changes in cropping systems). A mist-irrigated scab evaluation nursery will be used to evaluate elite breeding lines, regional nurseries, commercial varieties, and segregating populations. The winter wheat breeding program at South Dakota State University has screened transplanted hill nurseries for scab resistance since 1999 utilizing an established mist-irrigated field screening nursery designed to test cultivars, elite lines and preliminary lines for resistance to FHB. In 2001, we investigated planting schemes to determine if direct seeded row materials are affected differently than transplanted hill plots when they are inoculated with FHB. Preliminary results suggested that there were indeed significant correlations between the two methods. We will continue to investigate planting schemes in future studies as well as to begin evaluating winter wheat lines and varieties for scab tolerance under greenhouse conditions in 2002.

White wheat (Ibrahim, Little, and Kalsbeck). For the past 5 years, our breeding efforts for HWWW have centered on making crosses between adapted red lines and unadapted white germ plasm. We have been successful at incorporating resistance to prevalent races of stem rust and increasing the winter-hardiness of the hybrid material. We are ready to pursue the more difficult challenges of increasing coleoptile length, decreasing preharvest sprouting susceptibility, and decreasing PPO activity (a predictive measure of noodle-making quality) without sacrificing bread-making qualities.

The new challenges will require efforts at germ plasm development which have heretofore been outside the scope of the SDSU Winter Wheat Breeding Project. We have screened coleoptile length, but have had few successes in increasing the length. Screening for sprouting susceptibility has been conducted for a couple of years with questionable results. Preharvest sprouting resistance is undoubtedly our biggest challenge and will command our most intense efforts at both screening and germ plasm development. In the coming year, we will outline a plan for germ plasm development to meet these challenges.

We are currently focusing on understanding the results of our PPO activity tests and are developing a screening regime for PPO activity. For PPO activity screening, several breeding programs use adaptations of the L DOPA whole-seed or L-DOPA flour tests described by Anderson and Morris (2001). We have used a visual adaptation of the whole-seed test, but have kept selection intensity low because of questions concerning the repeatability of this method. We are now comparing the results of tests for PPO activity in meal, flour and whole seed samples. We also are evaluating the repeatability of a new protocol that combines a meal PPO test with the meal sedimentation test, (a predictive measure of bread-baking quality). Screening during the month between harvest and planting has not been implemented in previous years because of the time crunch. A combined meal and PPO test will enable us to do a limited amount of screening at harvest time with a maximum effect. Screening for high PPO activity prior to planting will perhaps eliminate 40 EYT white lines, 50 PYT white lines and 15 AYT white lines. Screening for sedimentation prior to planting will perhaps eliminate 100 EYT lines, 150 PYT lines, and 8 AYT lines.

Molecular pathogen-wheat interactions and DNA marker development.

Yang Yen, Denghui Xing, Lanfang Bai, Lieceng Zhu, and Yue Jin.

In the year of 2001, our research efforts were focused on 1) identification of pathogen and host genes that play key roles in scab pathogenesis; 2) cloning the *Sr25* gene; and 3) implementation of DNA MAS in SD wheat improvement programs. So far, seven ESTs have been observed to be specific to the FHB-inoculated, Sumai 3 spikes in our repeated experiments. These ESTs were cloned and sequenced. A blast search of GenBank with these ESTs as query sequences has revealed no homologue with any known R or PR gene. Northern and Southern hybridizations revealed that two of the cloned ESTs belong to pathogen *F. graminearum* and the rest are wheat. We are currently cloning the full-length cDNA of the corresponding genes. Eleven ESTs have been identified as being specifically expressed in *P. graminis*-inoculated wheat line '*Sr25*/9*LMPG'. These ESTs are the most promising and the possible ones that are specifically related to stem rust resistance gene *Sr25*. Our data indicated that *Sr25* seems to be expressed about 2 hours after invading wheat tissues. As the first step toward our goal to implement DNA MAS, we screened 78 elite breeding materials from SD spring wheat breeding program and 87 elite selections from USWBSI spring wheat germ plasm program for SSR markers with primer sets gwm533, gwm493, and gwm389. Sumai 3 and Wheaton were used as the controls. The results showed that 38 of the 78 elite breeding lines screened have the Qfhs.ndsu-3BS-gwm493 marker identified by Anderson et al. (2001) but only five also have the Qfhs.ndsu-3BS-gwm533 marker. Of the 87 elite germ plasm selections screened, 27 lines have the Qfhs.ndsu-3BS-Xgwm493 markers, 31 lines have the Qfhs.ndsu-3BS-*Xgwm533* marker, and 26 lines have the Qfhs.ndsu-3BS-*Xgwm389* marker. The *Xgwm533-120bp*, *Xgwm493-140bp*, and *Xgwm493-160bp* markers observed in our elite-breeding lines also were observed among the elite germ plasm selections. In addition, new markers *Xgwm389-130bp*, *Xdwm533-300bp*, and *Xgwm533-165bp* also were observed among the selections.

Soil N fertility management.

Howard J. Woodard, Anthony Bly, and Dwayne Winther.

The yield and crude protein levels of three varieties of HRSW were tested after the application of 0. 90, 170, and 240 kg N/ha as dry fertilizer. As N rate increased from the control to the highest rate, yield only increased by 250 kg/ha. However, crude protein increased 2.2 % to the 170 kg/ha rate over the control and leveled off thereafter. In another experiment, a foliar application rate of 33 kg/ha was applied to a single HRSW variety at planting (on bare soil), tillering, jointing, and the boot stage. The rate was a supplement to the N rate applied to attain a 3,300 kg/ha yield goal. Crude protein increased by 0.5 % at each application stage compared to the control (no foliar application) , but increased to 1.0 % over the control at the boot stage. There was no yield increase to the foliar application at any application stage.

Cereal aphids, other arthropods, and diseases.

L. Hesler and W. Riedell (USDA–ARS–NGIRL).

Research continues on ways to limit infestations of cereal aphids, other arthropod pests, and diseases in wheat. We are determining the mechanisms and levels of resistance to bird cherry-oat aphids among wheat and related grasses. We also are coöperating with Dr. Marie Langham (SDSU, plant virologist) to determine any effects of staggered dates of planting on insect infestations, incidence of viral diseases, and plant growth and yield of winter and spring wheat at two locations in South Dakota. We are surveying for the multicolored Asian ladybird beetle, which recently arrived in eastern South Dakota, to determine whether it will have any significant impact on cereal aphid populations in small-grain crops. We also are collaborating with Dr. S. Dean Kindler (USDA–ARS–PSWCRL, Stillwater, OK) to develop rearing methods, determine host plant suitability, and characterize plant damage by the rice root aphid, another member of the cereal aphid complex and vector of barley yellow dwarf virus. Dr. Mike Catangui (SDSU, extension entomologist) and Dr. Hesler also have participated in a regional survey for army and pale western cutworms in South Dakota and several other western states. The levels of these cutworms have generally remained low in South Dakota, although some individual fields have had significant infestations in recent years. Finally, Dr. Riedell is cooperating with Drs. Shannon Osborne (USDA–ARS–NGIRL) and Yue Jin (SDSU, wheat pathologist) in evaluating remote sensing technology for detection of rust and tan spot diseases in greenhouse experiments. Field experiments on remote detection of these diseases and others are also being conducted.

Dosage effect of wheat streak mosaic virus on agronomic characteristics of winter wheat lines.

Cynthia I. Bergman and Marie A.C. Langham.

Ten lines of winter wheat were evaluated over 2 years for their reaction to dilutions of WSMV. Plants were mechanically inoculated with inoculum dilutions of 1:5, 1:10, and 1:20 (ratio of infected tissue to extraction buffer). Dilution (inoculum dosage) was found to significantly affect the agronomic characteristics of plant height (P = 0.0018), kernel protein analysis (P = 0.0200), spike length (0.0265), kernel number (P = 0.0152), kernel weight (P = 0.0130), and 100-kernel weight (P = 0.0346). These results prove the viral disease resistance expression in winter wheat varieties is affected by dilution (dosage level of inoculum).

Introduction. WSMV, of the family Potyviridae in the genus *Tritimovirus*, causes a worldwide, economically

Table 1. Average reduction in plant height due to WSMV in 10 winter wheat lines over the 2-year study. Values are differences in centimeters between controls and infected at heading date for dilution-by-variety. A * indicates significant difference at P = 0.05 or less and ** indicates a significant difference at P = 0.01 or less.

Winter wheat line	1:05 dilution	1:10 dilution	1:20 dilution
Arapahoe	17.2 **	22.5 **	21.9 **
Dawn	13.5 **	24.2 **	25.9 **
Harding	17.8 **	19.5 **	25.9 **
Jagger	6.3 **	14.9 **	15.1 **
KS95H102	3.6	5.1 *	3.2
KS96HW10-1	7.2 **	5.1 *	5.9 **
SD93267	11.3 **	14.9 **	19.1 **
Sage	9.9 **	14.1 **	19.1 **
TAM107	7.6 **	18.6 **	19.3 **
Vista	6.5 **	12.9 **	10.5 **

Table 2. Average increase in protein analysis due to WSMV in 10 winter wheat lines over a 2-year study. Values are differences in percent protein content between controls and infected at harvest for dilution-by-variety. A * indicates significant difference at P = 0.05 or less and ** indicates a significant difference at P = 0.01 or less.

Winter wheat line	1:05 dilution	1:10 dilution	1:20 dilution
Arapahoe	0.96 *	0.71	0.61
Dawn	1.83 **	1.24 **	1.15 **
Harding	1.50 **	1.21 **	1.33 **
Jagger	1.34 **	1.00	0.86 *
KS95H102	0.28	0.26	0.44
KS96HW10-1	0.29	0.26	0.36
SD93267	0.91 *	1.38 **	0.48
Sage	2.13 **	0.98 *	0.77
TAM 107	1.64 **	1.51 **	0.50
Vista	1.00 *	0.53	0.19

important wheat disease. Yield losses are estimated to be about 5 % annually with up to 100 % loss in localized areas. Leaf symptoms of the disease move progressively from a faint light green mottle (mosaic), dots, or dashes to a yellow (chlorotic) mottling, then broken streaking, and finally into long, linear streaking. In advanced or severe cases, the leaf streaking becomes severely chlorotic, then necrotic, until the leaves and ultimately the plant dies. Other symptoms are stunted roots, reduced plant height, failure to produce heads, and poor grain. Heads often contain shriveled kernels, which lower kernel size and weight as well as the number of kernels per head. Test weights and yield are both reduced. The inoculum dilutions used by researchers to infect test plots of wheat have varied widely, ranging from 1:1 to 1:50. This experiment was designed to test if the dosage level used in screening nurseries affected their level of resistance to WSMV.

Materials and methods. The 10 winter wheat lines utilized were Arapahoe (PI 518591), Dawn (CI17801), Jagger (PI593688), Harding (PI608049), KS95-H102, KS96HW10-1, Sage (CI17277), SD93267, TAM 107(PI495594), and Vista (PI562653). The inoculum for this experiment was a WSMV originally collected from infected wheat plants in South Dakota. Presence of virus in all inoculated plots was verified with serological methods.

Table 3. Average reduction in spike (head) length due to WSMV in 10winter wheat varieties over 2-year study. Values are differences in cm between controls and infected immediately prior to harvesting at dilution-by-variety. A * indicates significant difference at P = 0.05 or less and ** indicates a significant difference at P = 0.01 or less.

Winter wheat line	1:05 dilution	1:10 dilution	1:20 dilution
Arapahoe	0.34	0.71 **	–0.08
Dawn	0.44	0.37	0.16
Harding	0.69 *	0.24	0.20
Jagger	0.84 **	0.64 *	0.45
KS95H102	0.41	0.43	0.16
KS96HW10-1	0.42	0.49 *	0.06
SD93267	0.53 *	1.12 **	0.00
Sage	0.17	0.23	0.01
TAM 107	0.56	0.68 **	0.50 *
Vista	0.53	0.09	0.47

Table 4. Average reduction in the number of kernels/head due to WSMV in 10 winter wheat lines over the 2-year study. Values are differences between controls and infected immediately prior to harvesting at dilution-by-variety. A * indicates significant difference at P = 0.05 or less and ** indicates a significant difference at P = 0.01 or less.

Winter sheat line	1:05 dilution	1:10 dilution	1:20 dilution
Arapahoe	46.4 **	49.1 **	25.6
Dawn	15.7	7.5	–18.0
Harding	49.5 **	18.6	24.7
Jagger	68.7 **	62.2 **	18.5
KS95H102	43.8 *	21.7	–11.5
KS96HW10-1	23.7	46.5 **	16.0
SD93267	27.1	36.4 *	10.4
Sage	27.7	14.1	6.8
TAM 107	24.0	28.5	-4.8
Vista	19.2	0.7	25.5

Results. Dilution had a significant effect on the agronomic characteristics of plant height (0.002), protein (0.02), head length (0.03), kernel number (0.02), kernel weight (0.01), and 100-kernel weight (0.03). In all six tables, significant differences (0.05 or less) are marked with an asterisk (*), and highly significant differences (0.01 or less) are marked (**).

Summary. Inoculum dilution affects virus resistance through the plant's disease expression. These results prove WSMV inoculum dilution rates affect disease resistance ratings. Variations in the means of the lines used indicates that dosage had varying effects on characteristics; because of this reaction to dilution, classifying varieties as resistant based solely on yield, stunting, or viral content is likely to miss resistance genes present in lines strong in other characteristics. For wheat breeders, this means low levels of resistance to WSMV may be found in previously overlooked wheat lines by screening with several different inoculum dilutions before labeling a plant with a simple yes or no for resistance.

Acknowledgments. Agricultural Experiment Station at South Dakota State University, South Dakota State University Wheat Breeding Program, South Dakota Crop Improvement Association, and South Dakota Wheat Commission.

Table 5. Average reduction in weight of seeds due to WSMV in 10 winter wheat lines over the 2-year study. Values are differences in grams between control and infected immediately prior to harvest for dilution-by-variety. All seed-count reductions were highly significant (P = 0.01 or less) except where noted. A * indicates a significant difference at P = 0.05 or less and NS is not significant at P = 0.0793 or higher.

Winter wheat line	1:05 dilution	1:10 dilution	1:20 dilution
Arapahoe	3.72	3.11	2.97
Dawn	3.45	2.82	2.08
Harding	3.84	2.67	2.49
Jagger	3.8	3.46	2.2
KS95H102	1.81	1.27	0.52 NS
KS96HW10-1	1.76	1.57	0.82 NS
SD93267	2.03	2.39	1.3 *
Sage	2.13	0.07 NS	1.06 NS
TAM 107	2.61	2.92	1.69
Vista	2.36	1.6	1.66

Table 6. Average reduction in weight of one hundred seeds due to WSMV in 10 winter wheat lines over the 2-year study. Values are differences in grams between controls and infected immediately prior to harvesting for dilution-by-variety. A * indicates a significant difference at P = 0.05 or less and ** indicates a significant difference at P = 0.01 or less.

Winter Wheat Line	1:05 dilution	1:10dilution	1:20 dilution
Arapahoe	1.22 **	0.74 **	0.98 **
Dawn	1.40 **	1.15 **	1.04 **
Harding	1.25 **	1.04 **	0.85 **
Jagger	0.80 **	0.48 **	0.62 **
KS95H102	0.23	0.30 *	0.51 **
KS96HW10-1	0.80 **	0.26	0.27
SD93267	0.76 **	0.61 **	0.45 **
Sage	0.68 **	–0.24	0.50 **
TAM107	0.90 **	1.23 **	1.06 **
Vista	0.92 **	0.93 **	0.39 **

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VIRGINIA

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
Department of Crop and Soil Environmental Sciences, Blacksburg, VA 24061, U.S.A.

2001 Wheat Production in the Commonwealth of Virginia.

W.L. Rohrer, C.A. Griffey, and D.E. Brann.

Growing conditions. The 2000–01 growing season was relatively dry with temperatures fluctuating but generally cooler, especially during December, as compared to the exceptionally warm winters of 1999 and 2000. Little precipitation fell during the winter months. A late cold spell in April resulted in significant freeze injury to wheat nurseries at

Table 1. Virulence/avirulence of 38 powdery mildew isolates (across the top) derived from cleistothecia collected in Warsaw, Virginia, in 2001.

	CG1	CG3	CG4	CG5	CG6	CG7	CG8	CG9	CG10	CG11	CG12	CG13	CG14	CG16
Axminster *Pm1*	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Ulka *Pm2*	M	R	S	R	RM	S	RM	S	S	R	S	R	R	S
Asosan *Pm3a*	M	S	S	M	M	S	M	S	S	S	S	S	S	S
Chul *Pm3b*	RM	S	R	R	R	R	RS	S	R	S	R	R	R	M
Sonora *Pm3c*	RM	S	M	M	M	S	RS	S	S	S	S	S	R	RM
Yuma *Pm4a*	R	S	S	M	M	M	M	S	S	R	S	R	R	R
Ronos *Pm4b*	R	M	R	RM	R	RM	R	M	R	R	R	R	R	RS
Hope *Pm5*	M	S	S	S	S	S	S	S	S	S	S	S	RM	S
C747 *Pm6*	RM	S	S	S	M	S	S	S	S	S	S	S	S	S
Transec *Pm7*	M	S	S	S	S	S	S	S	S	S	S	S	S	S
Kavkaz *Pm8*	S	S	RM	M	S	S	M	S	RS	S	S	RS	RM	S
Amigo *Pm17*	R	RM	R	R	RM	R	M	R	RS	R	R	RM	R	R
MI Amber	M	S	S	S	S	S	S	S	S	RM	S	S	RM	S
Chancellor	M	S	S	S	S	S	S	S	S	S	S	S	RM	S

	CG17	CG18	CG19	CG20	CG21	CG22	CG23	CG24	CG25	CG26	CG27	CG28	CG29	CG30
Axminster *Pm1*	R	R	R	R	R	R	R	RM	R	R	R	R	R	R
Ulka *Pm2*	S	R	S	S	S	M	S	S	R	RM	S	S	RM	M
Asosan *Pm3a*	S	S	S	S	S	S	S	S	S	S	S	R	S	S
Chul *Pm3b*	S	M	R	R	R	R	R	R	S	S	S	S	S	S
Sonora *Pm3c*	S	S	S	M	M	M	M	S	S	S	S	R	S	S
Yuma *Pm4a*	M	S	M	M	M	M	S	S	S	S	S	S	S	R
Ronos *Pm4b*	R	R	R	R	R	R	R	RM	R	R	M	RS	R	M
Hope *Pm5*	S	M	S	M	S	M	S	S	S	S	S	R	S	S
C747 *Pm6*	S	M	S	S	S	S	S	S	S	M	S	S	S	S
Transec *Pm7*	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Kavkaz *Pm8*	S	RM	S	RM	S	M	M	S	S	M	S	S	S	S
Amigo *Pm17*	R	R	R	R	RM	RM	RM	RM	R	R	R	R	R	R
MI Amber	S	M	S	S	S	M	S	S	S	S	S	RS	S	S
Chancellor	S	S	S	S	RS	S	S	S	S	S	S	S	S	S

	CG31	CG33	CG34	CG35	CG36	CG37	CG38	CG39	CG40	CG42
Axminster *Pm1*	R	R	R	R	R	R	R	R	RM	R
Ulka *Pm2*	M	R	R	S	S	S	RM	R	R	R
Asosan *Pm3a*	S	R	R	S	S	S	S	S	S	S
Chul *Pm3b*	M	R	R	R	R	R	S	S	S	S
Sonora *Pm3c*	S	S	S	S	S	S	S	S	S	S
Yuma *Pm4a*	R	S	R	S	S	S	M	S	S	S
Ronos *Pm4b*	R	R	R	R	R	RM	RM	R	R	RM
Hope *Pm5*	S	S	S	S	S	S	S	S	S	S
C747 *Pm6*	S	S	S	S	S	S	S	S	S	S
Transec *Pm7*	S	S	S	S	S	S	S	S	S	S
Kavkaz *Pm8*	S	S	S	S	S	S	S	S	RS	S
Amigo *Pm17*	R	R	R	RS	R	R	R	R	R	R
MI Amber	S	S	S	S	S	S	S	S	S	S
Chancellor	RM	S	S	S	S	S	S	S	S	S

Blacksburg. Subsequently, warm temperatures and dry conditions prevailed through most of the season. Both the Blacksburg and Warsaw areas remained very dry throughout most of the spring. Because of the relatively dry conditions, disease prevalence and severity, with the exception of powdery mildew, generally remained low in most areas. Crop lodging also was generally low due to lack of heavy precipitation late in the growing season.

Disease incidence and severity. Leaf rust and powdery mildew were the most prevalent diseases of wheat in Virginia in 2001. Powdery mildew was prevalent in most wheat-production areas of the state and was most severe in the coastal plain and eastern shore regions. Although leaf rust was observed in several regions of the state, it generally developed late in the season and disease severity was low. However, significant leaf rust infection of wheat was observed on the eastern shore of Virginia. The incidence of FHB generally was low or nil; although isolated foci were observed. Stripe rust was found in Virginia for the first time in 2000 near Blacksburg in the western part of the Commonwealth. In 2001, a stripe rust foci was found in the coastal plain region near Warsaw, Virginia.

Production. According to Virginia Agricultural Statistics Service 200,000 acres (81,000 ha) of winter wheat were planted in the Commonwealth in the autumn of 2000. This figure is down from 240,000 acres (97,200 ha) planted in the autumn of 1999 and 280,000 acres (113,400 ha) planted in the autumn of 1998. Of the 200,000 acres seeded in the autumn, Virginia producers harvested 175,000 acres (70,875 ha) of SRWW for grain in spring 2001. Grain yields across the state averaged 57.0 bu/acre (3,830 kg/ha). This figure is 10 bu/acre (672 kg/ha) lower than the state yield-record set in 1997 and is 6 bu/acre (403 kg/ha) lower than in 2000. Total grain production for the Commonwealth in 2001 was 10 million bushels (272,109 metric tons).

Virginia Wheat Yield Contests. Participation in the both the conventional-till and no-till wheat yield contests was down in 2001 though yields were characteristically high. Richard Sanford of Westmoreland County was the sole entrant in the 2001 Virginia Conventional-Till Wheat Yield Contest. Mr. Sanford entered two different cultivars and took first place with a yield of 100.7 bu/acre (6,766 kg/ha) over a minimum area of 3 acres (1.2 ha). Two producers representing two counties participated in the No-till Wheat Yield Contest. In first place was the team of Louis and Randolph Aigner of Henrico County with a yield of 108.5 bu/acre (7,290 kg/ha) over a minimum area of 3 acres (1.2 ha). Second place went to William C. Crossman of Westmoreland County with a yield of 79.1 bu/acre (5,315 kg/ha).

State cultivar tests. A total of 71 entries were evaluated at seven locations across Virginia in 2001. Included in the tests were 46 experimental lines (including two white-seeded lines and four lines of triticale), 23 released cultivars, and one triticale cultivar. Average grain yields ranged from 63–94 bu/acre (4,233–6,316 kg/ha) with an overall test average of 77 bu/acre (5,174 kg/ha). Wheat genotypes with yields significantly above the test average included Trical 498, three experimental triticale lines, Raxil-Thiram-treated USG 3209 and Sisson, Baytan-treated Pioneer 26R24, Dividend-treated Century II; untreated SS 550, SS 520, and an experimental Pioneer line. In addition, 11 experimental Virginia lines (including one white-seeded line) had yields significantly higher than the test average. Yields among genotypes in this group ranged from 81–94 bu/acre (5,442–6,316 kg/ha). Tests conducted in the Coastal Plain Region yielded an average of 76 bu/acre (5,106 kg/ha), whereas tests conducted in the Piedmont and Blue Ridge Region yielded an average of 79 bu/acre (5,308 kg/ha). Test weights for wheat (excluding triticale) obtained across the seven test sites ranged from 55.8 lbs/bu (718.1 kg/m^3) to 60.3 lbs/bu (776.1 kg/m^3) with a test average of 57.3 lbs/bu (737.5 kg/m^3). Of the 15 entries with test weights significantly higher than the test average, 11 were experimental lines (seven from Virginia) and four were released cultivars. Six entries (a Pioneer experimental line and five Virginia experimental lines) had both grain yields and test weights that were significantly higher than the test average.

Virulence spectra of the powdery mildew population in Virginia.

C.A. Griffey and W.L. Rohrer (Virginia Tech), and Lynda Whitcher (USDA–ARS, Raleigh, NC).

Virulence spectra of 38 isolates of *Blumeria graminis* f. sp. *tritici* was determined by Lynda Whitcher, USDA–ARS, Department of Plant Pathology, NCSU. Single-pustule isolates were derived from cleistothecia collected in Warsaw, VA, in 2001. The 38 powdery mildew isolates were screened for virulence/avirulence on 13 wheat differentials with known genes for mildew resistance and the susceptible cultivar Chancellor (Table 1, p. 262). Among the 38 isolates, virulence was found for all resistant genes except for *Pm1*, *Pm4b*, and *Pm17*. The 38 isolates possessed virulence for 1 to 10 resistance genes; however, 27 isolates (71 %) possessed virulence for 7–10 genes. Among the 38 isolates, 24 had different virulence spectra. Among the 38 isolates, 26 to 37 had virulence for genes *Pm3a, Pm3c, Pm5, Pm6, Pm7, Pm8,* and Michigan Amber. Virulence for genes *Pm*2, *Pm3b*, and *Pm4a* was observed in 17, 9, and 20 isolates, respectively.

Among the 13 resistance genes, *Pm1*, *Pm2*, *Pm3a*, *Pm3b*, *Pm4a*, *Pm4b*, *Pm5*, *Pm6*, *Pm8*, and *Pm17* have been commonly deployed in commercial SRWW cultivars, so it is not surprising that virulence for most of these genes was observed. Virulence for gene *Pm17* was not found, which is not surprising since this gene has been deployed only recently and only a few commercial cultivars are known to possess this gene. Surprisingly, virulence for genes *Pm1* and *Pm4b* was not identified in the mildew population. Upon evaluation of powdery mildew data from field tests conducted in Virginia from 1990 to 2001 (Table 2), it is apparent that virulence for gene *Pm4a* increased following release of the cultivar Roane in 1998, which possesses this gene. However, it is not clear why virulence for gene *Pm4b*, which the cultivar Pocahontas is proposed to possess, was not identified in the mildew population since susceptibility of Pocahontas to powdery mildew increased after its release in 1997. Verification of the presence of gene *Pm4b* in Pocahontas is needed in order to understand this phenomenon. On the contrary Wakefield, possessing gene *Pm1*, was susceptible to powdery mildew throughout most of Virginia at the time of its release in 1990, and was not widely grown commercially in Virginia. In 1991, Wakefield had a powdery mildew rating of 2.8. In subsequent years (1992–97), its mildew ratings declined dramatically to a low of 0.0 in 1995 and 1997, after which Wakefield was no longer tested in Virginia's official variety trials. Although virulence to gene *Pm1* occurred at a high frequency when cultivars such as Wakefield and Coker 9733 were in commercial production, it was soon eliminated from the pathogen population once these cultivars became obsolete. Resistance conferred by gene *Pm1* is easily overcome apparently, yet virulence to this gene must be disadvantageous to the pathogen population as it is quickly eliminated once it is no longer needed by the pathogen population. Therefore, we doubt that recycling of this gene alone would give durable resistance.

Table 2. Powdery mildew ratings for Wakefield, Pocahontas, and Roane wheat at Warsaw, VA, 1991–2001. Ratings are 0–9, where 0 = no disease present and 9 = total canopy leaf area infected.

Line	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Wakefield	2.8	2.5	2.0	2.0	0.0	1.0	0.0				
Pocahontas				0.0	0.0	0.5	0.0	0.0	2.7	3.3	8.3
Roane				0.3	0.0	1.5	0.3	1.8	0.0	3.0	6.3

Identification and characterization of marker QTLs for scab resistance in common wheat.

J. Chen, C.A. Griffey, M.A. Saghai Maroof, W. Zhao, J. Wilson and D. Nabati.

The overall goal of the current research is to accelerate development of scab resistant wheat varieties and germ plasm using MAS. A population of 82 F_2 individuals derived from the cross 'Pioneer 2684 (susceptible)/W14 (resistant)' was used as the initial mapping population. Percentages of infected spikelets (severity), scab-colonized seeds, and DON content (ppm) were characterized in greenhouse tests using floret inoculation method. SSR markers were used to identify QTLs associated with scab resistance. DNA polymorphism between parents was significant and was observed for 76 % of SSR primers (152 out of 200). Among 36 pairs of primers used, a total of 45 loci have been mapped to five chromosomal regions in this population. A major QTL, in addition to the 3BS QTL, has been identified on chromosome 2BS. Fifteen markers from these chromosome regions were significantly ($p < 0.05$) associated with scab resistance and explained 23 %, 28 %, 21 %, and 36 % of the total variation in percentage of scabby seeds, DON content, severity in 82 F_2 individuals, and severity in 82 corresponding $F_{2:3}$ families, respectively. Additional markers are being identified to saturate these chromosome regions in F_2 and a DH populations of 'Pioneer2684/W14'. SSR markers *Xgwm533/493* (on 3BS) and *Xgwm410/BARC18* (on 2BS) are being used to tag resistance gene(s) in the development of near-isogenic backcross lines and in the evaluation of advanced breeding lines in our program.

Eight DNA markers from the five chromosome regions were used to genotype six putatively diverse resistance sources (Funo, Sumai 3, Shaan 85, W14, Ernie, and VR95B717). DNA polymorphism was found among these resistance sources for marker loci associated with postulated resistance genes. Differences observed among some of these sources for marker loci indicate that some lines may possess different resistance genes that could be useful in pyramiding resistance and, thereby, improve the level of scab resistance. W14 may possess a gene or allele different from that of Sumai 3 in the 2BS-QTL region, and Ernie may possess resistance genes different from other type-II resistance sources in both the 2BS and 3BS QTLs regions.

Selective breeding for Fusarium head blight resistance in soft red winter wheat.

C.A. Griffey, J. Wilson, D. Nabati, J. Chen, T. Pridgen, W. Rohrer, and B. Robinson.

A major objective of our breeding program is to transfer type-II resistance from unadapted sources, primarily of spring habit, into SRWW backgrounds to develop scab-resistant germ plasm and varieties with high yield potential and resistance to other prevalent diseases including powdery mildew, leaf rust, and glume blotch. Strategies being used to accelerate development of scab-resistant wheat genotypes include 1) incorporating and pyramiding of type-II and other types of resistance into adapted SRWW backgrounds via selection of progeny from topcross, backcross, and DH populations; 2) screening and selecting for type-II and other types of resistance in inoculated mist-irrigated greenhouse and field tests and; 3) simultaneously evaluating progeny for resistance to other diseases and agronomic traits.

Thirty-six scab-resistant sources (21 Chinese, two French, one Japanese, two Canadian, and 10 SRWWs) have been used as parents in the breeding program, and over 500 populations have been developed. In 2001, 68 of 234 (29 %) populations were advanced on the basis of scab incidence and severity. In headrow tests, 2,960 F_5 lines, derived from populations previously screened for scab resistance, were evaluated for agronomic traits and resistance to diseases other than FHB at Warsaw, VA. From these headrows, 47 topcross derived lines and three DH lines were selected for further testing in our scab nursery at Blacksburg, VA, and in Observation Yield Tests at two locations. Twenty-three advanced F_6 lines and 13 DH lines were evaluated simultaneously for scab resistance in a mist-irrigated nursery at Blacksburg, VA, and for other agronomic traits in a noninoculated observation yield test at Warsaw, VA. Nine of the F_6 lines and two of the DH lines were advanced for testing in Preliminary Wheat Trials. Three elite lines were evaluated in Preliminary Yield Trials; one of these lines was selected for further testing in our Advanced Yield Trial and another will be evaluated in Virginia's Official Variety Trial. Seven lines were tested in the Uniform Winter Wheat FHB Nurseries, and two adapted lines, VA98W-591 and VA98W-593, slated for release were shown to possess moderate resistance to FHB.

Progress in transferring type-II resistance into SRWW genotypes has been accelerated via use of the wheat by maize DH system. To date, 165 DH lines have been derived from three-way crosses, comprised of diverse scab-resistant parents, and will be evaluated for FHB resistance in an inoculated, mist-irrigated greenhouse test in spring 2002. Type-II resistance derived from six different sources has been backcrossed into seven SRWW backgrounds, of which two (Ernie and Roane) are adapted sources with other types of resistance. Ninety backcrosses between resistant progeny, derived from 5 BC_4F_1 and 83 BC_3F_1 populations, and their recurrent parents will be screened for FHB resistance and evaluated for similarity to the recurrent parent in a greenhouse test in spring 2002. Molecular markers (*Xgwm533* and *Xgwm493*) have been implemented in selection of backcross progeny possessing the 3BS QTL. Of 12 BC_3F_1 lines evaluated thus far, one possessed both marker loci, and five possessed a single marker locus (*Xgwm533* in all cases). The relatively low frequency of 3BS markers identified among the resistant progeny indicates putative presence of resistance genes derived from other chromosomal regions yet to be identified. Ultimately, adapted SRWW NILs with type-II resistance will be developed and will facilitate pyramiding of different types of resistance.

WASHINGTON

USDA–ARS, WHEAT GENETICS, QUALITY, PHYSIOLOGY AND DISEASE RESEARCH UNIT AND WASHINGTON STATE UNIVERSITY
Departments of Crop and Soil Sciences, Food Science and Human Nutrition, and Plant Pathology, Pullman, WA 99164-6420, U.S.A.

Conversion of winter growth habit cultivars to spring growth habit.

R.E. Allan (USDA–ARS).

Development has been completed on four sets of backcross-derived NILs for winter and spring growth habit governed by four vernalization response genes. The genes are *Vrn1* (*Vrn-A1*), *Vrn2* (*Vrn-B1*), *Vrn3* (*Vrn-D1*), and *Vrn4* (*Vrn-B4*). Recurrent parents were semidwarf SWWW Daws and Stephens, nonsemidwarf SWWW Brevor; and nonsemidwarf HRWW Wanser. The nonrecurrent parents contributing the *Vrn* genes were the Triple Dirk lines developed by A.T. Pugsley. All NILs are BC_6-derived $F_{5:8}$ lines selected for winter or spring growth habit.

Several spring-growth habit lines of each *Vrn* gene and cultivar set were evaluated in spring-sown tests at Pullman during 2000 and 2001. Differences among NILs of the four *Vrn* genes occurred within each cultivar set for heading date, grain yield, test weight, and plant height. Interactions occurred between *Vrn* genes and cultivars for these traits. All of the spring habit *Vrn* NILs had later heading (5–16 d) than spring check cultivars Calorwa and Alpowa. Heading dates varied by 4, 5, 7, and 10 d among NILs of the four *Vrn* genes for Wanser, Brevor, Stephens, and Daws, respectively. NILs with *Vrn1* were usually earlier than NILs of the other *Vrn* genes. An exception was Stephens *Vrn4* which was 3 d earlier than Stephens *Vrn1*. NILs with *Vrn2* were the latest heading in three cultivar sets but Daws *Vrn4* was extremely late and headed 4 d later than Daws *Vrn2*.

Grain yields among the four *Vrn* NILs of each cultivar set differed by 20–115 %. Ranges in grain yield (g/m^2) of the four *Vrn* gene NILs were 330–400 (Brevor), 435–530 (Wanser), 325–455 (Stephens), and 210–455 (Daws). Except for Brevor, the *Vrn1* NILs were among the highest for grain yield. NILs of Brevor *Vrn3* , Stephens *Vrn3*, and Stephens *Vrn4* also were high yielding. NILs having *Vrn2* generally had low yields. The *Vrn4* NILs were the most variable with high and low yields occurring for Daws and Stephens, respectively. Wanser *Vrn3* NILs had low yield potential while other *Vrn3* NILs had medium to high yields. Several of the spring growth habit *Vrn* NILs had grain yields equal to or greater than those of Calorwa and Alpowa. Daws *Vrn1*, Stephens *Vrn4*, Wanser *Vrn1*, and Wanser *Vrn3* yielded 10–30 % more than the checks.

Test weights of spring habit *Vrn* NILs of Daws and Stephens were low varying from 712–737 and 688–719 g/l, respectively. The test weights of Brevor and Wanser NILs were adequate ranging from 771–785 and 781–798 g/l, respectively. In general *Vrn1* NILs had the highest test weights, whereas the *Vrn2* NILs had the lowest test weights. Both *Vrn1* and *Vrn2* NILs of Brevor had low test weights, however. It seems likely that the very late heading of some Daws and Stephens *Vrn* NILs contributed to their low yields and test weights.

Plant height differences occurred among spring habit NILs of the four *Vrn* genes in all cultivar sets. The Brevor and Stephens *Vrn* NILs only varied 5 % for plant height, whereas *Vrn* NILs of Daws and Wanser differed by 10 to 15 %. The *Vrn1* and *Vrn2* NILs usually had tall and short heights, respectively. Across the cultivar sets, the *Vrn3* and *Vrn4* genes had variable effects on plant height.

Limited data is available from autumn plantings of both the winter (*vrn*) and spring (*Vrn*) sibs of the four *Vrn* gene and four cultivar sets. Differences in heading date occurred for seven of the 16 comparison between spring versus winter sib pairs. The spring sibs were 2 to 3 d later than their winter sibs in six comparisons. Yield differences occurred between spring and winter members in six of 16 comparisons. In every instance, the winter sib out yielded its spring counterpart. Most of the time, the winter sib had better winter survival or spring recovery than its spring sib. The winter *Vrn1* sibs had less winter injury than their spring *Vrn1* sibs in all cultivar sets, whereas no differences occurred between the winter and spring *Vrn2* sibs of any cultivar set.

Vrn1, *Vrn2*, and *Vrn3* are believed to be an orthologous set of genes. Hence the numerous agronomic differences that occurred among NILs of the four genes was unexpected. Apparently, *Vrn* genes behave differently when placed in different genetic backgrounds. Adaptative differences between winter and spring wheats must not be completely due to their allelic makeup for vernalization response. All spring habit NILs of the four *Vrn* genes had delayed heading, suggesting that spring and winter wheats probably differ for other genes affecting heading such as those mediated by photoperiod or temperature. Testing of these genetic stocks is continuing; once evaluation is complete they will be released as USDA–ARS germ plasm and made available to others.

Control of wheat rusts in the western United States, 2001.

Xianming Chen, David A. Wood, Mary K. Moore, Guiping Yan, and Roland F. Line.

Wheat stripe rust, leaf rust, and stem rust were monitored throughout the PNW using trap plots and field survey in 2001. The diseases were accurately predicted for the PNW using monitoring data and predictive models based on resistance of wheat cultivars and environmental factors such as temperature and precipitation. Through coöperators in many other states, wheat stripe rust was monitored throughout the United States. Similar to the year 2000, wheat stripe rust occurred from California and the PNW to Georgia and Virginia and from Louisiana and Texas to North Dakota and Minnesota. Severe yield losses caused by stripe rust occurred in fields of susceptible wheat in the PNW, California, Colorado, Texas, and especially Kansas. The severe epidemics in the Great Plains were due to the weather conditions, new races of the stripe rust pathogen, and widely grown susceptible cultivars. The spring weather was cooler than normal, favoring stripe rust development. The most severe yield losses caused by stripe rust occurred in Kansas (7.3 %) and Colorado (8 %). Wheat yield losses caused by stripe rust were estimated over 39.5 million bushels in the United States, which may be the biggest losses in 20 years.

In the PNW, wheat stripe rust widely occurred, but yield losses were the minimum in 2001 because the most wheat fields were grown with resistant cultivars. The winter of 2000–01 was mild, favoring stripe rust overwintering. Severities of over 90 % were observed on susceptible varieties in the stripe rust nurseries and on susceptible cultivars such as Westbred 470 in commercial fields. Resistant cultivars that were widely grown in the PNW provided effective control of wheat stripe rust. The durable, high-temperature, adult-plant resistance that is in most SWWW, HRWW, and spring wheats and the multiline cultivar Rely of club wheat with many seedling-resistance genes prevented stripe rust epidemics.

In 2001, wheat leaf rust occurred in some locations in the PNW but generally in lower levels because of unfavorable conditions. Yield losses due to leaf rust were negligible. Only race MDBJ (virulence on *Lr1*, *Lr3a*, *Lr10*, *Lr14a*, and *Lr24*) was detected in Washington. Wheat stem rust occurred in the later growing season in the PNW and caused significant losses in some fields. Madsen, the number one SWWW cultivar grown in the state of Washington, had moderate level of stem rust.

Hundreds of stripe rust collections from 19 states were evaluated to determine their virulence. These samples were increased on susceptible cultivars and tested on a set of 20 wheat genotypes that are used to differentiate races of *P. striiformis* f. sp. *tritici* in the United States. In 2001, the most prevalent races in the PNW were those attacking Lemhi, Fielder, Produra, Moro, Paha, and seedlings of Druchamp and Stephens. The most prevalent races in California were Express-attacking races and races attacking Express, Lee, Fielder, and varieties with stripe rust resistance genes *Yr8* and *Yr9*. The predominant races east of the Rocky Mountains were those attacking varieties with *Yr8*, *Yr9*, plus Express, Lee, Fielder, and Produra. The Express-attacking races, which were first detected in California in 1998, were in all regions. The races attacking *Yr8* and *Yr9*, which were first detected in the United States in 2000, were widely distributed in 2001. Races with new combinations of virulences were identified in 2001.

In 2001, more than 5,700 entries of wheat germ plasm and breeding lines from the National Germplasm Collection Center and wheat breeders in the western U.S. were evaluated for stripe rust resistance in fields under natural infections and in the greenhouse with selected races to cover all possible virulences. Germ plasm and breeding lines with stripe rust resistance were identified. High-temperature, adult-plant (HTAP) resistance continues to be the most effective and durable type of stripe rust resistance. More than 95 % of the wheat cultivars in Washington state have stripe rust resistance, and all newly released cultivars have HTAP resistance.

To develop molecular markers for *Yr5*, a wheat gene conferring resistance to all races of *P. striiformis* f. sp. *tritici* in the U.S., a BC_7F_3 population was developed by backcrossing the *Yr5* donor *T. spelta album* (TSA) with the recurrent parent Avocet Susceptible (AVS). Seedlings of the *Yr5* NIL (AVS/6**Yr5*, developed in the Plant Breeding Institute, University of Sydney, Australia), AVS, TSA, and the BC_7F_3 lines were tested separately with two races PST-29 and PST-43 of *P. striiformis* f. sp. *tritici* under controlled greenhouse conditions. The single gene was confirmed by a 1:2:1 segregation ratio for homozygous resistant, heterozygous, and homozygous susceptible BC_7F_3 lines. Genomic DNA was extracted from the parents and 202 BC_7F_3 lines. The resistance gene analog polymorphism (RGAP) technique was used to identify molecular markers. The parents (the *Yr5* NIL and AVS) and the homozygous resistant and homozygous susceptible BC_7F_3 bulks were used to identify putative RGAP markers for *Yr5*. Association of the markers with *Yr5* was determined using cosegregating analysis with DNA from the individual BC_7F_3 lines. Of 16 RGAP markers confirmed by cosegregating analysis with 109 BC_7F_3 progenies, five positive and four negative markers were coincident with the *Yr5* locus, and the other seven markers were closely linked to *Yr5* with a genetic distance between 0.5 and 7.3 cM. Of nine markers verified further with additional 93 BC_7F_3 lines, two positive markers and three negative markers still cosegregated with the *Yr5* locus and the other four markers were tightly linked to the locus with a genetic distance from 0.2 to 1.2 cM. Analysis of a set of Chinese Spring nulli-tetrasomic lines with three negative markers (*Xwgp-18*, *Xwgp-20*, and *Xwgp-23*) confirmed that the *Yr5* locus is on chromosome 2B. Five RGAP markers that were cloned and sequenced, the codominant markers *Xwgp-17* (546 bp) and *Xwgp-18* (540 bp) had 98 % homology in both DNA and translated amino-acid sequences. The two markers had as high as 97 % homology with a resistance gene like sequence from *Ae. ventricosa* and had significant homology with many known plant resistance genes such as Mi, I2C, RPM1, RPP8, and RPP13, as well as ESTs from wheat and other plant species. The markers also have high homology with the NB-ARC domain that is in several plant resistance genes, nematode cell death genes, and human genes involving apoptosis. To develop user-friendly STS markers for *Yr5*, specific primers were designed based on the sequences of *Xwgp-17* and *Xwgp-18*, the codominant markers completely co-segregating with *Yr5*. The primers were used to amplify genomic DNA of the resistant (the *Yr5* NIL) and susceptible (AVS) parents, TSA, and the resistant and susceptible bulks of BC_7F_3 lines. Almost all STS primer pairs produced expected polymorphic bands in the bulk segregant analysis. The cosegregation of the STS markers with *Yr5* was analyzed using 114 BC_7F_3 lines. Among the three primer pairs that were analyzed with 114 BC_7F_3 lines, one produced a dominant marker and two produced codominant markers that were completely associated with the *Yr5* locus. The codominant markers were more specific and easier to score than the original RGAP markers. RGAP markers either tightly linked or coincident with *Yr15*, another wheat gene conferring resistance to all races of *P. striiformis* f. sp. *tritici*, also were identified. These markers should be useful for transferring the resistance genes into commercial cultivars and for combining them with other genes for durable and superior resistance.

Foliar fungicides were evaluated for control of the rusts in winter and spring wheat plots near Mount Vernon and Pullman, WA. Foliar applications of Folicur, Stratego, Tilt, Quadris, or combinations of Tilt and Quadris at boot to heading stages either completely or almost completely controlled stripe rust. Applications of the fungicides increased wheat yield by 9–69 % compared to untreated checks depending upon cultivar and location.

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ITEMS FROM YUGOSLAVIA

AGRICULTURAL RESEARCH INSTITUTE "SERBIA", CENTER FOR SMALL GRAINS
Save Kovacevic 31, Kragujevac 34000, Yugoslavia.

Yield and quality of Ana Morava wheat cultivar.

Desimir Knezevic, Veselinka Zecevic, Nevena Djukic (Biological Faculty of Kragujevac, Yugoslavia), Danica Micanovic, Dusan Urosevic, and Biljana Dimitrijevic.

Ana Morava is new winter wheat cultivar created in Center for Small Grains. Selected as line Kg 3130 developed from the cross combination of cultivars Morava and Una, Ana Morava botanically belongs to *T. aestivum* subsp. *vulgare* var. *lutescens*. The cultivar expressed high grain yield production and good bread-making quality. The productive potential of grain yield is 10 t/ha. The bread-making quality is good and the cultivar is B1 according to Farinograph and in the 2nd quality group according to protein content and sedimentation volume.

Introduction. To increase the grain yield of cultivars that have already been exposed to an intense selection pressure for this character (e.g., bread wheat) it is necessary to use knowledge of the genetic basis of major morphological and physiological characteristics with the aim of developing new selection criteria. The aim of breeding is developing new wheats highly adapted to growing conditions. The yield potential of a wheat cultivar can be assessed on the basis of morphological and physiological characteristics that maximize expression (Borojevic 1986). Adaptability may be estimated according to yield potential of a cultivar that was grown in a different environment with limiting nutrients or water or when pests, diseases, and other stresses are not effectively controlled. The yields achieved in Yugoslav cultivars are on the level of European wheat cultivars (Bedö et al. 2001). At Kragujevac, we aim to select cultivars with high grain yield and good bread-making quality.

Material and methods. Ana Morava cultivar was selected as line KG-3130 derived from the cross 'Morava/Una'. Morava is a Kragujevac winter wheat cultivar with a stable grain yield and good bread-making quality. Una was created in the Novi Sad breeding center and has a high yield potential (10 t/ha) and very good technological quality (Misic et al. 1986). Parents of Ana Morava were highly resistant to low temperature. The good bread-making quality of Ana Morava was inherited from parents. Una has *Glu-D1d*, which correlates positively with good bread-making quality (Knezevic et. al. 1993) and could be donor of it gene.

Crosses were made in 1987. The hybrids were grown using the pedigree method of plant selection. Phenotypically similar lines in the F_4 were selected. Those lines were tested during 3–4 years in microtrials on the experimental fields of the Center for Small Grains in Kragujevac. The best lines were selected for further testing in different environments.

During 1997–98 and 1999–00, wheat line Kg-3031 (now Ana Morava) was included and tested in microtrials of Yugoslav Federal Commission of plant cultivar approvement. Ana Morava was tested at five locations differing in ecology. Ana Morava and other lines were compared with check cultivars Partizanka and Pobeda. The resistance to pest and diseases was tested on the field and by artificial inoculation. The resistance to low temperature was tested in controlled conditions in freezing chambers by successively decreasing the temperature from 0–15°C during a 24 h period. Quality analyses of grain, flour, dough, and bread were made at the Technological Faculty of Novi Sad using standard laboratory methods. Data were obtained during testing at the Federal Commission of plant cultivar approvement.

Results and discussion. Productive traits. Grain yield is a very complex trait that depends on both genetic and environmental factors. Wheat breeding for this trait is tedious work. Genetic variability of yield components (number of spike/m^2, number of kernels/spike, and grain mass) are very important. Resistance to pest and diseases, low temperature, and lodging and shattering are associated with grain yield. Tolerance to stress (water deficiency and soil salinity) also are associated with grain yield. After the examination of cultivars during several years in different environments, we can assess a cultivar's adaptability and plasticity. The average of grain yield of Ana Morava was 7.88 t/ha, higher than average yield of the Pobeda check and statistically was significantly higher than the average yield of Partizanka (Table 1). The maximum grain yield of Ana Morava at Novi Sad location in 1998–99 was 10 t/ha and indicated a grain-yield potential over 10.0 t/ha.

Table 1. Grain yield of wheat cultivar Ana Morava and check cultivars between 1997–2000.

Cultivar	Average grain yield (kg/ha)	% compared to better check	Maximum grain yield (kg/ha)	% compared to better check
Ana Morava	7,882.0	100.57	10,000.0	98.42
Pobeda (check)	7,837.0	100.00	10,160.0	100.00
Partizanka (check)	6,858.0	87.50	8,652.0	85.15
LSD 0.05	170.0			
LSD 0.01	236.0			

Morphophysiological traits. Ana Morava has white spike and a red kernel color, is awnless, and botanically belongs to *T. aestivum* subsp. *vulgare* var. *lutescens*. The average height for all years and locations was 96.1 cm (Table 2). The cultivar expressed the high level of resistance to lodging as in both parents. According to heading data, Ana Morava is a medium-to-early cultivar. Heading time of Ana Morava averages 1.75 days earlier than Pobeda and 0.75 day earlier than Partizanka. Resistance to low temperature was equal to that of Partizanka and higher (6.6 %) than that of the Pobeda check (Table 2). A test of resistance to low temperature showed that 100 % of the plants of Ana Morava survived. The ability of plants to survive below-freezing temperatures without damage at the seedling stage and in later stages of growth and development indicates good frost resistance. This trait is an extremely complex physiological trait that is both genetically and environmentally determined. A number of biochemical changes have been detected during cold acclimatization, for example, increasing content of sugar, soluble protein, proline, and other organic acids; appearance of new isozymes; and alterations in lipid compositions (Steponkus and Lynch 1989). Except for biochemical, biophysical, and physiological changes, cold acclimatization may involve changes in gene expression, i.e., cold-regulated genes (COR, Cattivelli and Bartels 1990). Ana Morava was characterized by good resistance to leaf rust, stem rust, and powdery mildew (Table 2).

Table 2. Morphological and physiological traits of Ana Morava and the check cultivars Pobeda and Partizanka.

	Cultivars			Difference compared to check	
Trait	Ana Morava	Pobeda	Partizanka	Pobeda	Partizanka
Plant height (cm)	96.1	92.6	92.9	+ 3.5	+ 3.2
Heading (days)				– 1.75	– 0.75
Resistance to lodging (0–9)	0.91	1.36	1.18		
Resistance to low temperature (%)	100.00	93.33	100.00	+ 6.66	0.00
Resistance to diseases (0–99)					
Puccinia graminis tritici	12.5	35.0	30.0		
Puccinia triticina	50.0	46.0	26.0		
Erysiphe graminis tritici	35.0	35.0	45.0		

Technological traits. The average 1,000-kernel weight of Ana Morava was 42.1 g; similar to that of Partizanka and 1.9 g less than that of Pobeda (Table 3, p. 271). Hectoliter grain mass is an indicator of grain quality. A high hectoliter mass

Table 3. Characteristics of grain quality, flour and bread quality of Ana Morava and the check cultivars Pobeda and Partizanka.

	Cultivars			Difference compared to check	
Trait	Ana Morava	Pobeda	Partizanka	Pobeda	Partizanka
1,000-kernel weight (g)	42.1	44.0	42.8	– 1.9	– 0.7
Hectoliter mass (kg)	88.00	87.50	89.10	+ 0.50	– 1.10
Protein content (%)	12.2	12.5	14.0	– 0.3	– 1.8
Sedimentation value (ml)	32.0	44.0	49.0	– 12.0	– 17.0
Percent of flour (%)	78.9	80.6	80.7	– 1.7	–1.8
Water absorption (%)	63.7	64.0	62.9	– 0.3	+ 1.8
Quality number	68.7	78.8	71.0		
Quality group	B1	A2	A2		
Extensogram energy (cm^2)	40	70	84	– 30	– 44
Ratio of resistance to flexibility	1.76	2.33	2.04	– 0.54	– 0.28
Yield of bread (g/100 g flour)	138.8	140.3	140.0	– 1.5	– 1.2
Bread volume (ml/100 g flour)	554.0	532.0	558.0	+ 22	– 4.0
Crumb number	6.4	6.1	6.3	+ 1.5	+ 1.2
Yield of flour (kg/ha)	6,218.0	6,316.0	5,534.0	– 98	+ 684
Yield of bread (kg/ha)	10,940.0	10,995.0	9,601.0	– 55	+ 339

can be reliable indicator of high grain quality, the biological plasticity of the cultivar, and better resistance to high temperatures during the grain filling. Hectoliter mass in Ana Morava was higher than that of Pobeda and slightly lower than that of Partizanka on average. Sedimentation volume was lower than that of both check cultivars. A high sedimentation volume is correlated with gluten content and quality (Knezevic et al. 1993). Protein content in Ana Morava was similar to that of Pobeda but less (1.8 %) than that of Partizanka. However, protein content can vary depending on environmental factors and fertilizer dosage and regimes. Changes in protein content can cause changes in quality group classification and have an important role in the quality properties of grain, flour, and dough.

Water absorption depends on gluten quantity and quality. In Ana Morava, 63.7 % water absorption was similar to that of Pobeda (64.0 %) and higher than that of Partizanka (62.9 %). The quality number in Ana Morava was slightly lesser than either of the check cultivars. On the basis of farinograph analyses, Ana Morava belongs to the B1 quality group; Pobeda and Partizanka belong to the A1 quality group. Extensogram energy and the ratio of resistance to flexibility are indicators of gluten and dough quality (Saric et al. 1997). These parameters in Ana Morava are lower than those of the check cultivars Pobeda and Partizanka.

Grain quality of wheat depends mainly on the physiochemical characteristics of proteins. Gluten consists of a complex of gliadin and glutenins proteins with a strong physiochemical interaction. Altering the ratios of these proteins changes the protein properties. By increasing the gliadin content, the extensibility of gluten is increased, and by increasing the amount of glutenins, gluten is strengthened and is, therefore, less extensible (Finney et al. 1987; Knezevic et al. 1994). Bread yield, loaf volume, and crumb value are very important parameters to assess bread-making quality (Kovacev-Djolai et al. 1987). These parameters in Ana Morava were similar to those in the check cultivars. Ana Morava has excellent crumb quality.

Conclusions. During 1997–98 and 1999–00, wheat line Kg-3031 was included and tested in microtrials of Yugoslav Federal Commission of cultivar approvement. On the basis of value of expressed traits, the Yugoslav Federal Commission of cultivar approvement, approved this line as the cultivar Ana Morava in 2001. The breeders of cultivar are Drs. Desimir Knezevic and Veselinka Zecevic. Ana Morava botanically belongs to *T. aestivum* subsp. *vulgare* var. *lutescens*. The cultivar is characterized by white, awnless spikes and red grain with an average height of ~ 96.1 cm; high resistance to low temperatures and lodging; good resistance to leaf and stem rust and powdery mildew; and a high grain yield potential (> 10.0 t/ha). During the testing period, the average of grain yield was 7.88 t/ha, higher than the average yield of both check cultivars and significantly greater than that of the Partizanka check. The 1,000-kernel weight is 42.1 g, and the hectoliter grain mass is 88.0 kg. The bread-making quality is good and belongs to the B1 group according to Farinograph and the 2nd quality group according to protein content and sedimentation volume.

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