ITEMS FROM THE UNITED KINGDOM

JOHN INNES CENTRE
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Homoeologous gene silencing in hexaploid wheat.

R. Koebner and G. Xia (Shandong University, PR China).

Many cDNA loci are triplicated in the wheat genome. However, the presence of three homoeologous genomic sequences (one/genome) does not necessarily imply that three independent mRNAs either are transcribed or successfully translated. We have been using single-strand confirmation polymorphism to distinguish the homoeologues of gDNA and cDNA (via RT-PCR) sequences from mapped, single-copy cDNA sequences and have been able to demonstrate that silencing of one of the three copies occurs at a significant frequency (Fig. 1). We aim to extend this approach to explore both the extent of, and the existence of any genomic patterning of homoeologous silencing in the hexaploid and tetraploid wheat genomes.

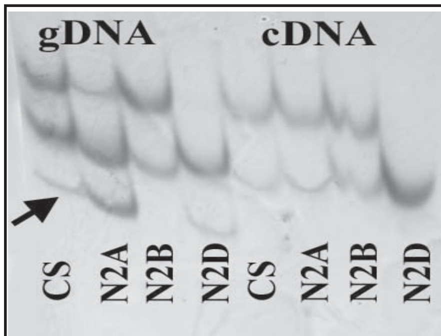

Fig 1. Single-strand confirmation polymorphism profiles of gDNA- and cDNA-derived amplicons from sequence PSR112. The arrow shows a 2B-encoded sequence that is absent (i.e., silenced) in all cDNA templates.

Facultative pathogens of cereals.

P. Nicholson, E. Chandler, N. Chapman, R. Draeger, D. Simpson, A. Steed, M. Thomsett, and A. Wilson.

We are continuing our studies of FHB and eyespot with emphasis on the former (not reflected in the publication list below). Resistance in wheat to FHB is being characterized in a number of sources (not Sumai 3) using a trait-dissection approach. Visual disease, yield loss, fungal biomass, and DON mycotoxin accumulation are being determined and data used in QTL studies to identify loci associated with each trait.

In addition, we are developing new diagnostic assays to improve our ability to detect the major *Fusarium* species involved in FHB in the U.K. and elsewhere. This work includes study of variation within *F. graminearum*, particularly with respect to lineage and chemotype. We have developed PCR assays that allow chemotypes of isolates to be determined without the need for costly mycotoxin analysis.

Work on eyespot is concentrating upon the identification of DNA markers to *Pch1* and *Pch2*. A cDNA-AFLP approach is being used to identify markers linked to these resistances and provide insight into potential mechanisms underlying the resistance.

Discovering genes for protein quantity and grain hardness by marker-mediated genetic analysis in U.K. winter wheat germ plasm.

R. Bradburne, A. Turner, L. Fish, and J. Snape.

In a project funded by the U.K. Home-Grown Cereals Authority (HGCA), we have been identifying and analyzing major genes and QTL-controlling attributes of end-use grain quality, in particular grain texture, protein content, and grain size and shape, using molecular marker-mediated methods of genetic analysis. Three populations were studied: a series of RSLs containing a chromosome 5A recombinant between Avalon (hard, high protein) and Hobbit Sib (soft, low protein) in a Hobbit Sib background, an analogous series of RSLs recombinant at chromosome 5D, and a set of 'Avalon/Hobbit Sib' RILs.

In the Hobbit Sib (Avalon 5D), markers significantly associated with grain hardness were found on the short arm, indicating segregation at the major hardness locus *Ha*. Additionally, this locus was found also to have a significant effect on grain-protein content, with hard lines having higher intrinsic protein, independent of the grain-texture effect. It is not clear if this is a pleiotropic effect of the *Ha* locus, but we think it is probably a linked locus. Interval mapping for grain protein content also revealed a significant QTL on the long arm of this chromosome, with Avalon contributing the increasing effect, somewhere near to the location of the vernalization gene *Vrn-D1*. Results from the Hobbit Sib (Avalon 5A) RSL population indicated that although loci influencing grain-protein concentration and grain hardness were consistent between both years of the study, their effect was not strong enough to give a statistical significance. However, the putative loci on 5A and 5D appear homoeologous.

Results from the 'Avalon/Hobbit Sib' RILs by interval mapping indicated statistically significant QTL for grain-protein content and grain hardness over and above the 5A and 5D effects previously detected using RSLs. QTL on chromosomes 2B and 6B were consistent over 2 years of field trials, with Avalon contributing the increasing effect in both cases. Single-year QTL also were significant on chromosomes 6A (2001 only) and 7A (2002 only), both with Hobbit Sib contributing the increasing effect. QTL mapping by multiple-marker regression indicated significant, year-by-year consistent QTL for hardness on chromosomes 1B (Avalon contributing the increasing effect) and also 5BS/7BS (Hobbit Sib contributing the increasing effect).

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ITEMS FROM THE UNITED STATES OF AMERICA

COLORADO

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Wheat Breeding and genetics.

S. Haley, J. Stromberger, B. Clifford, S. Clayschulte, T. Mulat, E. Ball, A. Brown, F. Pardina-Malbrán, M. Collins, and J. Butler.

Production conditions, test sites, and variety distribution. Total winter wheat production in 2002 was estimated at 36.3 x 10^6 bu, a 60 % decrease from the 2001 crop and 57 % lower than the 5-year average. Average grain yield, at 22 bu/acre, was 3 1 % lower than in 2001 and 38 % lower than the 5-year average. The area harvested for grain was estimated at 1.65 x 10^6 acres, down from 2.0 x 10^6 in 2001.

In 2001–02, the breeding program conducted field trials at four main locations in eastern Colorado (Akron, Burlington, Julesburg, and Walsh) in addition to the main location at the ARDEC research facility near Fort Collins. Overall, environmental conditions experienced at these locations were highly adverse for successful wheat test-plot research and selection. At Akron, timely planting with good soil moisture led to excellent stand establishment, autumn growth, and spring regrowth. Sustained high temperatures and drought stress during spring and summer reduced yield (to about 70 % of average) and limited the expression of yield differences among test entries. At Burlington, timely planting with good soil moisture led to good stand establishment and autumn growth. Dry soil conditions during the winter, and moderately cold air and soil temperatures, combined to induce a low level of winter injury, particularly in materials with marginal adaptation. High temperatures and a nearly complete lack of spring and summer precipitation led to abandonment of all trials prior to harvest. At Julesburg, later than normal planting (1 October) led to reduced establishment and autumn growth. Spring regrowth was accompanied by dry soil conditions that extended through to harvest and reduced yield (to about 75 % of average) and limited the expression of yield differences among test entries.

At Walsh, marginal soil moisture at planting (and extending through to harvest), combined with moderately cold soil temperatures during winter, led to poor stands, significant winter injury, excessive nongenetic field variation, and subsequent abandoning of most of the breeding trials (with the exception of the Dryland Variety Trial, UVPT) prior to harvest. At Fort Collins (irrigated location), timely planting and good soil moisture led to excellent establishment, autumn growth, and spring regrowth. Delayed spring irrigation (first irrigation 1 May), a severe spring freeze event (9 May), and a severe hailstorm 2 weeks prior to harvest collectively resulted in low and erratic yields.

In coöperation with the CSU Variety Testing Program under the direction of CSU Extension Agronomist Dr. Jerry Johnson, cultivars and experimental lines also were tested at six dryland trial locations (UVPT; Bennett, Briggsdale, Cheyenne Wells, Genoa, Lamar, and Sheridan Lake) and three irrigated trial locations in Colorado (IVPT; Haxtun, Rocky Ford, and Center in the San Luis Valley). Growing conditions at each of the UVPT locations were very much similar to the four main, dryland-breeding locations, with winter injury, spring freeze injury, high temperatures with dry winds, and severe drought stress complicating evaluation and selection. Only two of the six UVPT locations were harvested (Lamar and Bennett), although excessive nongenetic field variation at Lamar made the data of very questionable value for selection and cultivar recommendation. The Genoa location was not harvested because of a severe hailstorm prior to harvest, whereas the Briggsdale location was not harvested because of severe spring freeze injury. The Sheridan Lake and Cheyenne Wells locations were not harvested because of severe winter injury as a result of very dry soil conditions and moderately cold winter temperatures. Both the Rocky Ford and Haxtun IVPT locations were successfully harvested, although yields were reduced somewhat below optimum because of high temperatures and dry winds throughout spring and summer. The Center IVPT location, added in 2001–02 as an official IVPT testing location, was abandoned in the spring due to a high level of winter injury.

Very little or no virus (BYD or WSM) or insect (RWA, greenbug, or bird cherry-oat aphid) pressure was observed at any of the wheat trial locations. Common dryland root rot was observed at several dryland trial locations and adversely affected yield. A low level of stripe rust infection was observed at the Haxtun IVPT location, much lower than the epidemic observed in 2001. Leaf rust was observed at very low levels at both the Haxtun IVPT location and the Fort Collins-ARDEC irrigated location.

Planted acreage estimates for the 2002 crop were as follows: Akron – 25.3 %; Prairie Red – 13.9 %; TAM 107 – 13.6 %; Jagger – 6.7 %; Yumar – 4.8 %; Lamar – 3.6 %; Prowers – 3.5 %; Enhancer – 2.7 %; Halt – 2.6 %; Prowers 99 – 2.4 %; Trego – 2.4 %; Alliance – 2.3 %; TAM 110 – 2.3 %; and Yuma – 2.1 %.

New releases. In August 2002, one new winter wheat cultivar was formally released. The new cultivar, named **Ankor**, was derived from the crosses and backcrosses 'Akron/Halt//4*Akron' (about 94 % Akron parentage) made between 1994 and 1998. Halt and Akron are cultivars released by CSU in 1994. Halt has the *Dn4* gene, the source of RWA resistance in Ankor. Ankor is an awned, white-chaffed, medium-maturity, semidwarf HRWW. Ankor is medium maturing (144.8 days to heading from 1 January), about 3.5 days later than Prairie Red and similar to Akron. Plant height of Ankor is medium-short (30.1 inches), 1.7 inches taller than TAM 107 and similar to Akron. Coleoptile length of Ankor is slightly less than that of Prairie Red and similar to that of Akron. The straw strength of Ankor is good, slightly better than that of Akron based on limited evaluation and observation in the 2002 Irrigated Variety Performance Trial (IVPT). Ankor was tested in Colorado Dryland Variety Performance Trials (Colorado UVPT) during 2001 and 2002. Averaged over eight dryland trial locations in 2001, Ankor (41.6 bu/acre) yielded less than Akron (43.2 bu/acre) and greater than Prairie Red (40.7 bu/acre). Averaged over three dryland trial locations in 2002, Ankor (33.7 bu/acre) yielded more than Akron (33.2 bu/acre) and less than Prairie Red (34.6 bu/acre). Averaged over 11 locations in 2001 and 2002, Ankor (39.4 bu/acre) yielded more than Prairie Red (39.0 bu/acre) and less than Akron (40.4 bu/acre). Test weight averages from dryland trials in 2001 and 2002 show that Ankor (56.8 lb/bu) has similar test weight to both Akron (57.0 lb/bu) and Prairie Red (56.8 lb/bu). Ankor was tested in Colorado Irrigated Variety Performance Trials (Colorado IVPT) during 2002. Averaged over three irrigated trial locations in 2002, Ankor (78.9 bu/acre) yielded more than Akron (69.5 bu/acre), Prairie Red (73.2 bu/acre), and Yumar (74.6 bu/acre). Linear regression analysis of yield response from low-yielding dryland to high-yielding, irrigated conditions suggests that Ankor may have a more favorable yield response at higher dryland and irrigated yield levels than Akron. On the basis of field evaluations in Colorado and coöperative evaluations through the USDA Regional Testing Program, Ankor has a similar response to that of Akron to prevalent diseases and insects in the westcentral Great Plains. Ankor is moderately resistant to stem rust, susceptible to leaf rust, and susceptible to both WSMV and BYDV. Ankor is susceptible to the Great Plains biotype of Hessian fly, susceptible to greenbug, and resistant to RWA. Milling and bread baking quality of Ankor was evaluated from multi-location grain composite samples collected in 2000 and 2001 and four individual-location, grain samples collected in 2001. Relative to the recurrent parent Akron, Ankor had very similar average values for key milling and baking-quality traits. Based on summaries from the USDA Hard Winter Wheat Quality Database, Ankor appeared to have a slightly better baking quality than Akron.

In 2001–02, 31 advanced experimental lines were tested in the Dryland Variety Trial (UVPT). Of these lines, eight were Clearfield™ wheat lines, 11 were HWW lines with RWA resistance, and 10 were HRW lines either in their first or second year of statewide testing in the UVPT. Because of the overall lack of sound data from the UVPT and yield compression among entries where the UVPT was successfully harvested, decisions on experimental line retention and advance were extremely challenging. Selection intensity was relaxed slightly and more lines than normal were retained for further testing in the 2003 UVPT. Of the lines mentioned above, eight HRW lines, six Clearfield™ lines (all HRW types), and six HWW lines were retained and advanced (19 total).

Small-scale seed increases of each of the lines retained for further testing were planted in the autumn of 2002. The HRW lines are being increased under irrigation at Fort Collins while the Clearfield™ and HWW lines are being increased in Yuma, Arizona, largely because of isolation needs (particularly for the HWW lines) and capabilities in Yuma. Seed supply from any of these lines that perform well in 2003 should be adequate to enable Foundation Seed increase in 2003–04 (for earliest possible release in autumn 2004). In addition to continued yield testing, extensive milling and baking quality evaluations will be done on these materials during winter 2002–03 in the CSU Wheat Quality Lab, the USDA–ARS Quality Lab (Manhattan, KS), and by various private-industry collaborators.

As mentioned previously, the Irrigated Variety Trial was planted at four locations but only Haxtun and Rocky Ford provided useful yield data. Although none of the experimental lines were at the top, as was the case in 2001 (particularly with CO980607 and CO980630), we will of course continue to focus breeding and germ plasm enhancement efforts toward irrigated wheat. Continued management of trials at ARDEC in Fort Collins for high yields and exploitation of high yielding germ plasm from other production areas (e.g., CIMMYT–Mexico and Pacific Northwest materials) should help to achieve these objectives.

Graduate student research.

Several graduate student research projects are currently underway or were completed in 2001–02. Althoguh we expect that these research projects will contribute vital information to direct breeding efforts, both the breeding project and the students benefit in many other ways though student involvement in the overall breeding program. Briefly, these include the following important areas of research:

- determination of inheritance and chromosomal location of a new WSMV-resistance gene (Erin Ball, completed May 2002),
- evaluation of environment and 'genotype x environment' interaction effects on Asian noodle quality characteristics (Aaron Brown),
- assessment of the breeding potential of gibberellic acid sensitive semidwarfing genes that do not reduce coleoptile length (Sally Clayshulte),
- development of GIS technology to improve variety recommendations and identify variety-specific production and quality zones (Federico Pardina-Malbrán),
- separation of the *Dn7* RWA-resistance gene from deleterious, rye-derived wheat quality factors (Meghan Collins), and
- characterization (inheritance, allelism, marker-tagging) of RWA resistance identified in Iranian landrace selections (Joshua Butler).

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 were included in replicated, variety trials in eastern Colorado in 2002. Each of these lines was derived by intercrossing a RWA-resistant line from Montana State University (MTRWA116) with public and private wheat cultivars with primary adaptation in the northern Great Plains region. Unfortunately, all of the trials in eastern Colorado were abandoned and no data were obtained. The trials and evaluations will be repeated in 2003 with the hopes of identifying a spring wheat line with potential for release. A new set of crosses was initiated in 2002 using the RWA-resistant lines and adapted lines from the HRSW region as parents. These populations will be advanced through several cycles of single-seed descent in the greenhouse.

USDA–IFAFS Project.

A multi-institutional grant effort, coördinated through the University of California–Davis, from the USDA–IFAFS grant-funding agency was awarded in April 2001. The focus of this grant, entitled 'Bringing Genomics to the Wheat Fields', is to utilize DNA-marker technology as a means to transfer desirable quality and pest-resistance traits into released cultivars and elite experimental lines. Our program at CSU is one of 12 public, plant-breeding programs involved in this effort, with Dr. Nora Lapitan serving as co-investigator in our effort at CSU. We have chosen recently released cultivars or advanced experimental lines (e.g., Avalanche, Above, Ankor, CO970547, Stanton, and Lakin) as target parents to transfer or combine genes for WSMV and BYDV tolerance (from wheatgrass), high grain-protein content (from wild durum wheats), and RWA resistance. In summer 2002, we completed our first cycle of MAS for the target traits and will be completing two more cycles in our autumn 2002 and spring 2003 greenhouse cycles. The duration of the project is 4 years, with the release of several improved cultivars and germ plasm lines anticipated at the end of the project.

Facilities and equipment improvements.

In 2001–02, several facilities and equipment improvements were realized, include

completing the installation of soil beds and movable benches in the new university greenhouse with improved climate control and increased space;

purchasing of a new, custom-built field plot planter with no-till openers, liquid starter fertilizer setup, and automatic seed distribution with a checkhead-cable system; a new Hege 1000 headrow tray planter with automatic seed distribution and a checkhead-cable system; a new trailer for hauling plot planters and plot combines; a new seed cleaner for small-lot seed conditioning; a new four-wheel ATV for field alleyway spraying and maintenance; and

installing a new linear/lateral-move sprinkler irrigation system at ARDEC in Fort Collins.

In addition to the above items, the Plant Science Building renovation is nearing completion (targeted for December 2002), the primary benefit for our program (in addition to air-conditioned office space for the project leader) is a renovated and expanded wheat quality laboratory that will house the bread-baking equipment from the Food Science Department. We are very excited about all of these important improvements and the positive impact that they promise to make to our program.

GEORGIA / FLORIDA

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

The 2002 Georgia winter wheat crop was grown on about 350,000 planted acres, an increase of 15 % over 2001. Oat acreage was 85,000 acres, 15 % less than in 2001. Acres planted to rye were 250,000, 17 % less than last year. The crop production for wheat resulted in a state average yield of 41 bu/acre. The autumn planting conditions were hot dry soils. Most of the planting was delayed by at least 2 weeks past optimum. Overall, the season was characterized by mild and dry winter conditions followed by a dry and hot spring. Lack of vernalization was a problem especially for late-maturing cultivars. A spring freeze occurred on 22–23 March with temperatures around 26°F. Dry conditions prevailed through the grain-filling stage and hastened harvest. Yield and test weight were reduced significantly due to the freeze damage.

Breeding.

Horizon 474 (FLX474-1) oat was released as an exclusive cultivar. A winter oat with excellent test weight, Horizon 474 has good crown rust resistance and early maturity. Horizon 474 was selected from the cross 'Coker85-18//Coker 78-28/Coker 79-26'. The cultivar is most similar to Florida 501 but has white seed.

Entomology.

Double cropping is an important practice in areas of the southern U.S. where length of growing season and adequate rainfall or irrigation permit timely stand emergence and development and maturity of a summer crop. The predominant double-crop sequence is winter wheat and soybean, although grain sorghum and cotton are sometimes grown as a double-crop with wheat. The advantages of double cropping are increased cash flow for producers, reduced soil erosion and water loss because of ground cover most of the year, and cost savings from a more intensive use of the land and better utilization of crop inputs, labor, and capital investments. However, double cropping essentially can result in continuous production of crops in the same field each year, which can cause a build up of damaging levels of pathogen, insect, and weed populations. Indeed, in the 1970s and 1980s, continuous double-crop production of winter wheat resulted in serious damage in many fields by take-all root and crown rot and by devastating outbreaks of the Hessian fly. Incorporating alternative crops that are culturally and biologically compatible with a soybean/wheat double-crop system could help reduce pest incidence and severity and also provide farmers with commodity marketing alternatives. Canola (*Brassica napus* L.) as an alternative, winter-grain crop and pearl millet (*Pennisetum glaucum* (L.) R. Br.) as a new, alternative summer crop may effective break pest cycles in double-cropped soybean and winter wheat.

We established a 5-year study in the Coastal Plain region of GA to examine the effects of incorporating canola and pearl millet in multiple-year rotational sequences on the agronomic performance and pest incidence and severity in a wheat-soybean double-crop system. The experiment was conducted on a Greenville sandy loam at the Southwest Branch Experiment Station near Plains, GA. Twelve crop sequence and rotational treatments were established in an RCB design with four replications. Rotations included winter wheat, winter canola, winter rye, or fallow and summer crops were soybean or pearl millet for grain production.

Winter wheat productivity was affected by the previous crop sequence and rotation history. A single year of canola production greatly reduced the severity of infection take-all root and crown rot in wheat. Wheat rotation with canola every few years was very effective in suppressing take-all stem and root rot. Canola as the previous winter crop reduced winter infestations and, to some extent, spring infestations of Hessian fly. Furthermore, the wheat-soybean rotation had lower winter infestation levels of the Hessian fly than a wheat-millet rotation. Reduced Hessian fly infestation in rotations with canola is understandable because of the lack of a host plant. The reason for increased infestation levels following millet compared with soybean is not clear. Possibly, the herbicide regime in millet did not control volunteer wheat in late summer and in soybean, thereby providing a bridging host for the first autumn generation of Hessian fly, which develops in volunteer wheat before planting of the winter wheat crop.

Canola grain yields were not affected by the previous summer and winter crop or the cropping sequence in any year. Pearl millet stands were lower following canola than wheat in 2 of 4 years. Stand loss was mainly the result of seedling feeding damage caused by false chinch bugs, (*Nysius raphanus* Howard) following canola. Soybean stands also were reduced consistently by 18–25 % following canola as compared with small grains in all years except 1998. Except for seedling damage by false chinch bugs, the sequence of the previous winter crop had little consistent effect on insect populations on soybean or grain millet or on soybean diseases.

These results show that continuous planting of a crop can enhance host-specific pests such as Hessian fly and take-all disease in wheat. Stands of soybean and grain millet usually were reduced when planted into canola stubble as compared to winter wheat, rye, or fallow. However, the previous cropping sequence did not reduce grain yields of pearl millet or soybean. Therefore, rotating canola with wheat to disrupt pest cycles in wheat can be done without detrimental, limiting effects on subsequent soybean or millet crops as long as plant populations are not near or below the minimum for a full stand.

Publications.

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

Production.

The 2002 Idaho winter wheat production was 54.5 x 10^6 bu, an 11 % increase from 2001. Although both acreage planted and acreage harvested decreased compared to 2001, the reduction in acreage was offset by an increase in average yield from 73 bu/acre to 79 bu/acre. Moisture was limiting in some areas in the late spring and summer resulting in lower test weight. Autumn and winter conditions were not conducive for root/crown diseases of winter wheat. In northern Idaho, the highest incidence of stripe rust in recent years was observed, especially in spring wheat. Statistics for the Idaho winter wheat production for the last 5 years are shown 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)
1998	820	770	82	63,140
1999	760	710	76	53,960
2000	780	730	90	65,700
2001	760	710	73	51,830
2002	730	690	79	54,510

Personnel.

Manish Kumar joined the wheat breeding/genetics program in Moscow as a graduate student in the wheat straw lignin modification program. Zhiwu Li completed his Ph.D. research on gene silencing in transgenic wheat. Bob Zemetra started his sabbatical at Oregon State University conducting research on the potential for gene migration from wheat to jointed goatgrass and developing molecular markers for resistance genes of diseases of wheat in the Pacific Northwest.

Cultivar development.

The SWWW advanced line 91-34302A from the Moscow program is being considered for release. The proposed name for 91-34302A is **Simon**. Line 91-34302A has good yield potential in both rainfed and irrigated regions of Idaho and is the first potential Idaho release with *Pch1*, a gene for resistance to Pseudocercosporella footrot.

Wheat molecular biology.

In the wheat straw, lignin-reduction project, four copies of the *CCR1* gene in the lignin biosynthesis pathway have been isolated from the cultivar Hubbard. The genes are currently being sequenced. An antisense form of *CCR1* has been introduced into spring and winter wheat cultivars using particle bombardment in an attempt to lower the percent lignin in wheat straw.

Zhiwu Li completed his Ph.D. research on silencing of transgenes coding for a WSMV coat-protein gene in wheat. He found that by germinating transgenic seed in 5-azacytidine, gene silencing was reversed and WSMV coat protein was again expressed in the treated wheat seedlings. The expression of the coat protein reduced virus titer of WSMV after inoculation. The effect of the 5-azacytidine ended after 12–15 days leading to silencing of the coat protein and increased virus titer. The ability to reverse gene silencing by 5-azacytidine indicated that methylation was the primary cause of gene silencing in these transgenic lines.

In an additional study, we found that the copy number of introduced genes in transgenic plants could be estimated more efficiently using RT-PCR compared to Southern analysis.

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INDIANA

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

Wheat production.

Indiana farmers harvested 133,540 ha (330,000 acres) of wheat in 2002, down 14 % from 2001, continuing the downward trend during the past several years. Most of the reduction in wheat acreage in Indiana is accounted for by increased soybean acreage. According to the USDA National Agricultural Statistics Service, wheat yield in Indiana averaged 3,562 kg/ha (53 bu/acre) in 2002, only 77 % of the average yield in 2000 and 80 % of the average yield in 2001. Farmers seeded an estimated 142,000 ha (350,000 acres) of winter wheat in Indiana for the 2002 harvest season, but harvested only 133,500 ha (330,000 acres). Little acreage was abandoned because of winter kill, but some acreage was abandoned from a combination of severe BYDV infection combined with spring flooding and fungal disease, largely glume blotch, in parts of southern Indiana. Probably because of strong wheat prices during autumn 2002, seeded acreage for the 2003 harvest season is estimated by the USDA National Agricultural Statistics Service at 450,000 acres in Indiana, 29 % higher than in 2001–02. Early maturing wheat cultivars in the central and northern areas of Indiana are of interest because of the continued profitability of double cropping; producing a crop of soybeans after wheat harvest in the same season.

New cultivars.

The new SRWW licensed cultivars, **INW0101**, **INW0102,** and **INW0123**, performed well and are being grown by farmers for the first time in 2002–03. INW0101 and INW0102 are early, like the cultivar Clark, and should fit into double cropping with soybeans. INW0123 is similar in maturity to the cultivar Patterson. All three cultivars have *Lr37*, *Sr38*, and *Yr17* resistance to populations of *B. graminis* in Indiana, and they have resistance to *St. nodorum*, *S. tritici*, and SBMV.

Wheat disease summary.

The most widespread and damaging disease on wheat in Indiana during 2002 was yellow dwarf, caused by either of two related viruses, BYDV or cereal yellow dwarf virus. The long, warm autumn of 2001 provided ample time for aphid vectors to infest wheat, reproduce, and move about in wheat fields, resulting in widespread and uniform infection. Aphids also can transmit these viruses in the spring, but autumn infections are more damaging. In statewide wheat performance trials, yellow dwarf was particularly severe at the southwest Indiana site, and there were considerable differences among entries in the percentage of plants that showed symptoms. Some entries were very susceptible, whereas others had only a low percentage of symptomatic plants. Although yellow dwarf was especially severe in southwestern Indiana, it occurred throughout the state.

Both *S. tritici* and *St. nodorum* leaf blotch were present in many fields, but did not reach the flag leaves of susceptible cultivars until late in the season. As usually observed in cultivar trials, the range of resistance between the most and the least resistant entries was small and mainly a matter of reduced severity on the flag leaf. Leaf rust was present in only trace amounts, but its annual presence indicates that fully susceptible cultivars would be at risk. Stripe rust developed well early in the season in a variety trial in southwest Indiana and was seen in other areas. Hot, dry weather that began in June halted spread of this disease.

Fusarium head blight developed to some extent around the state, but was not severe. Epidemiological studies suggest that cold weather for several weeks before and during the flowering period reduced production of inoculum.

Hessian fly.

Wheat genes responding to Hessian fly attack (Williams, Collier, Nemacheck, Sardesai, Subramanyam, and Puthoff). The expression of 20 pathogenesis-related genes was quantified by both Northern analysis and quantitative RT-PCR. Genes included in this study have been implicated in responses of dicotyledonous plants to microbial pathogens, but little was known about the responses of a similar set of genes in monocots to either pathogens or to insects. Only a few of the genes, such as *PAL* and *PR-1*, responded as predicted during incompatible interactions. Several of the genes, although responsive in resistant dicots, appeared to respond in both resistant and susceptible wheat. The majority of the genes showed little or no response to feeding by Hessian fly larvae. These data suggest that wheat defenses against the Hessian fly may be very different from the mechanisms of resistance utilized by monocots against pathogens.

Over 100 Hessian fly-responsive genes from wheat were identified by GeneCalling (Curagen Corp.). Approximately 20 % of the sequences had no match in the databases, ~ 17 % matched wheat genes of known function, and 11 % matched genes of known function from other plants. The remaining 52 % matched plant genes of unknown function. When compared to GeneCalling results from wheat/microbe interactions, the few genes that responded to Hessian fly also responded to the pathogens, indicating that undefined modes of resistance may protect wheat from the Hessian fly.

Hessian fly biotypes and evaluation of wheat germ plasm and barley lines for resistance (Cambron, Ratcliffe, and Shukle). We screened 4,675 wheat germ plasm lines and 262 barley lines for Hessian fly resistance against various laboratory-maintained biotypes. Germ plasm evaluated was received from four university breeding programs, three private companies, and three uniform nurseries that are distributed in eastern U.S. Of those, 1,226 wheat lines were screened against biotype O, which has recently been collected from the field and purified. Biotype O is avirulent to *H7H8*, which is still effective in the southern areas of Georgia and Alabama.

The Uniform Hessian fly Nursery was sent to 14 coöperators in the eastern U.S. with 13 nurseries returned for evaluation of Hessian fly infestation. These data are available in the 2001–02 Uniform Hessian fly Report.

Two Hessian fly populations, one virulent to *H9* and one virulent to *H13*, have been isolated and increased for use in genetics studies and germ plasm evaluation. A recent acquisition of a Hessian fly biotype from Israel is being increased for use in germ plasm evaluation. This biotype has virulence to all resistance genes that have been deployed in the U.S.

Hessian fly genetics (Stuart, Behura, and Valicente). An AFLP-based genetic map has been amended and improved to correspond with the Hessian fly polytene chromosomes. The DNA sequences of 52 AFLP markers were determined and used as probes to screen a Hessian fly BAC library. Selected BAC clones corresponding to each marker were then used as probes in FISH experiments to determine the corresponding position of each AFLP on the polytene chromosomes of the Hessian fly. These data have been used to establish the correspondence between chromosomes and linkage groups and to identify chromosome regions that show high rates of genetic recombination. The region with the greatest rate of recombination is associated with the tip of the small arm of chromosome X2 in proximity to *vH13*, the gene conditioning virulence and avirulence to Hessian fly resistance gene *H13* in wheat. A region of recombination suppression was discovered that includes and extends beyond the pericentromeric region of autosome 2, a region associated with *vH3* and *vH5*, the genes that condition avirulence to Hessian fly resistance genes *H3* and *H5*, respectively. *Chromosome maintenance* (*Cm*), a locus that controls paternal X chromosome elimination and sex determination in Hessian fly embryos, was positioned within 1 cM of markers on the genetic map and determined to reside near the tip of the long arm of Hessian fly autosome 1.

Nuclear and mitochondrial DNA sequence divergence in Hessian fly (Shukle, Zantoko, Yoshiyama, and Johnson). Analysis of sequence divergence in the Hessian fly mitochondrial 12S rRNA gene in populations from the United States and the Old World (southwest Asia, the Middle East, North Africa, and southern Spain) has been completed. The analyses have revealed patterns in the geographic distribution of mtDNA haplotypes in North America and in the Old World. Analysis of *Wolbachia* DNA in Hessian fly populations has shown that the biogeographic patterns observed for mtDNA haplotypes are not due to *Wolbachia* infection influencing inheritance of mtDNA variants. Several hypotheses for the biogeographic distribution of mtDNA haplotypes can be proposed for testing in future studies. The distribution of mtDNA haplotypes observed in the United States and Canada may reflect genealogical relationships among introduced populations and ancestral populations in Europe and Asia. Results can provide a basis for evaluation of evolutionary history and genetic variation in host-adapted alleles (virulence alleles) within and among populations in the United States.

The ribosomal DNA ITS2 region from Hessian fly has been cloned and intraspecific sequence variation documented. Sequence variation in introns from several nuclear genes also has been identified. Data from nuclear and mitochondrial genes can be used to develop an intraspecific phylogeny and combined with markers, such as microsatellites, to assess genetic structure and gene flow within and among Hessian fly populations in future studies.

Analysis of gene function in Hessian fly (Shukle and Yoshiyama). Microinjection has been used for delivery of DNA and dsRNA into Hessian fly embryos prior to formation of the blastoderm. A piggyBAC-based transformation vector has been used for transformation of Hessian fly with a GFP marker gene. Expression of GFP has been documented in G1 individuals but validation of transformation through genetic analysis or cytological detection of the GFP gene on polytene chromosomes *in situ* has not been done. Use of RNAi appears to hold promise for suppressing gene expression and generating loss-of-function phenotypes to reveal putative function. We have used RNAi to evaluate the role of a Hessian fly glutathione S-transferase (GST) gene during development of larvae on the host plant. Injection of dsRNA for the GST into embryos led to a failure of larvae developing from the embryos to survive the first instar on the host plant. Larvae developing from buffer-injected control embryos or embryos injected with a dsRNA control (dsRNA for the transposase of an endogenous Hessian fly *mariner* element) completed the first instar on the host plant in a normal manner. No effect from the GST dsRNA was observed on embryonic development or on the ability of hatchling larvae to infest the host plant. The deleterious effect of the GST dsRNA on larval development occurred after larvae infested the host plant. We propose that these results indicate a role for GSTs in the ability of Hessian fly larvae to deal with general defense responses of the host plant.

Expression of Hessian fly genes during interactions with wheat (Shukle, Johnson, and Yoshiyama). A program to identify Hessian fly genes differentially expressed during compatible interactions with wheat has been initiated. During the next year a pool of sequences differentially expressed in first-instar larvae during the compatible interaction will be developed. Homology searches (tBLASTx) will be used to identify known and unknown/novel sequences.

An ABC transporter gene, a glutathion S-transferase gene, and a vermilion gene from Hessian fly have been cloned and characterized. Expression of these genes during development has been documented by RT-PCR. Double-stranded RNA interference has been used to assess the role of GST expression in the interaction of Hessian flies with wheat. Results support a role for GSTs in the compatible interaction with wheat.

Septoria tritici blotch.

Markers for resistance genes (Goodwin). A bulked-segregant analysis with AFLP and microsatellite markers has lead to the mapping of five genes for resistance to *S. tritici* leaf blotch in wheat. The genes and their approximate chromosomal locations are *Stb1* (5BL), *Stb2* (3BS), *Stb3* (6DS), *Stb4* (7D) near the centromere, and *Stb8* (7BL). Each gene has at least one linked microsatellite marker and *Stb4* and *Stb8* also have linked AFLPs. *Stb8* is a new gene; the others were known previously but not mapped with microsatellites. The mapping populations were RIL or DH lines developed by collaborators including *Stb1* (RIL population developed by Greg Shaner and George Buechley at Purdue University). *Stb2* and *Stb3* (DH populations supplied by Hugh Wallwork, South Australian Research and Development Institute, Adelaide, South Australia), *Stb4* (RIL population provided by Jorge Dubcovsky, University of California-Davis), and *Stb8* (the standard ITMI RIL mapping population).

We currently are developing quantitative RT-PCR for identification of resistant and susceptible lines in wheat. Preliminary results look promising, and we anticipate that this will provide a method to discriminate resistant from susceptible lines within 7–10 days after inoculation, well before the usual expression of *Septoria tritici* blotch symptoms at 18–21 days after inoculation. Our tests could then be performed on seedlings and greatly increase the amount of material tested per year.

In a collaborative project with Dr. Joe Anderson, we have used quantitative RT-PCR to determine that the protein disulfide isomerase (PDI) may be associated with the resistance response in wheat. This is the first time that PDI has been implicated in resistance in plants, although it appears to be involved in signal-transduction events in animal systems. Several other pathogenesis-related genes also were tested and were shown to be more strongly induced in resistant plants following inoculation compared to uninoculated controls.

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/.

Fusarium head blight.

Resistance in wheat to *Fusarium graminearum* (Shaner and Buechley). We tested 49 wheat lines for resistance to FHB with both single-floret (point) and whole-spike (spray) inoculation. Disease was usually more severe with spray than with point inoculation, but a few lines showed the opposite pattern. Four lines were highly resistant after point inoculation but fully susceptible after spray inoculation, suggesting that they have a high degree of resistance to spread of the pathogen but no resistance to primary infection. We evaluated F_3 progeny from tested F_2 plants with point inoculation to evaluate the reliability of single-plant selection in early segregating generations. The correlation between the mean rating of the progeny and the rating of the parent plant was poor (r = 0.115, n = 243). Of the more than 2,200 heads inoculated, 48 % developed no blight symptoms. Many of these were progeny of apparently resistant plants, but some of these plants may have been escapes. Partially recessive resistance also could explain the poor correlation. We identified AFLP and microsatellite markers that are closely linked and flank a major QTL for FHB resistance on chromosome 3BS in an RIL population derived from cross 'Ning 7840/Clark'. Ning 7840 derives most of its resistance from Sumai 3. We identified additional QTL for FHB resistance on chromosomes 2BL and 2AS.

Epidemiology of Fusarium head blight. A brief warm spell in mid April was followed by 5 weeks of unusually cool weather. Although moisture was adequate for production of inoculum just before flowering, it was too cold. As temperatures rose, rainfall was insufficient for infection. We used a weather-based model developed from previous years' data to compare predicted with observed incidence of FHB. Model I, which uses weather for 7 days before anthesis, predicted less than a 25 % probability of an epidemic (defined as >10 % incidence) for all cultivar-planting date combinations. Model II, which includes both pre- and postanthesis weather, predicted less than a 20 % probability for a severe epidemic.

Fungicide research. In a fungicide trial, four treatments applied at early anthesis reduced incidence of FHB compared to the untreated control but did not eliminate the disease.

Mapping of Fusarium head blight resistance: Ning 894037 and Fundulea 201R (Shen and Ohm). QTL mapping was conducted in two wheat RIL populations derived from the crosses of the Chinese wheat line 'Ning 894037/Alondra' and 'Patterson/F201R'. Response to *F. graminearum* was evaluated for disease spread in greenhouse and field experiments after inoculation of a single floret in spikes. Using SSR markers and BSA, a major resistance QTL was identified in Ning 894037 on chromosome arm 3BS, in the region of markers *Xgwm493*, *Xbarc133*, and *Xgwm533*. A QTL with moderate effect also was identified in the moderately susceptible parental line Alondra on chromosome 2DS. These two QTL explained 42.5 % (3BS) and 12.1 % (2BS) of the phenotypic variation in the 'Ning 894037/Alondra' population. An Additional QTL with small effect was also suggested on 6B of Ning 894037. In the 'Patterson/F201R' population, four QTL were identified on chromosomes 1B, 3A, 5A, and 3D; three of which are from F201R. The QTL on 1B near *Xbarc8* and 3A near *Xgwm674* and *Xbarc67-3*, derived from F201R, account for 18.7 % and 13.0 % of the variation of resistance for FHB, respectively.

Huapei 57-2 and Bizel (Bourdoncle and Ohm). A population of RILs was developed by SSD from a cross 'Patterson/Chinese line Huapei 57-2'. RILs were evaluated for resistance to spread of the disease after inoculation of a single floret in spikes in one field experiment and two greenhouse tests. A major QTL was identified on chromosome 3BS that is flanked by markers *Xgwm493* and *Xgwm533* and cosegregates closely with *Xbarc133* and *Xbarc147*. Additional QTL of smaller effects also were identified on chromosomes 3A, 3BL, and 5B. The QTL on 3BS is likely the same as the one already identified using lines derived from Sumai 3. Given its stability across populations and environments, we concluded that MAS for this QTL will be efficient.

The wheat cultivar Bizel is resistant to FHB. Given its pedigree, Blé Bohémien/rye//Oro/3/variant of Hauters, it was characterized using telomeric and dispersed rye-specific repetitive DNA sequences. We have shown conclusively that Bizel does not contain rye chromatin. Therefore, FHB resistance in Bizel is not derived from its rye progenitor. In addition, SSR markers designed for wheat and mapped across the entire genome can be used for gene tagging of FHB resistance QTL in Bizel.

Yellow dwarf viruses.

Resistance to yellow dwarf viruses (Ohm, Sharma, Ayala, Balaji, and Anderson). The severe natural epidemic of yellow dwarf virus in Indiana in 2002, the most severe since 1976, enabled us to identify several advanced soft winter wheat lines that have excellent resistance to yellow dwarf transferred from wheatgrass (*Th. intermedium*). In field plots, the resistant lines were scored 0.5 and wheat lines without the wheatgrass-derived resistance were typically scored 3–6 (0 = no symptoms to 9 = severe plant stunting and leaf discoloration) in nurseries at Lafayette, IN. Yellow dwarf symptoms were most severe in our head-row nurseries, which were seeded 10 days earlier than the yield trials the previous autumn, our typical practice to maximize disease establishment, including yellow dwarf viruses, in head-row nurseries. In our head-row nurseries at Lafayette, lines with wheatgrass-derived resistance were scored 0.5–0.7 and wheat lines without wheatgrass resistance scored 4–8. One of the advanced wheat lines with wheatgrass resistance was in performance trials in 2001, a season in which yellow dwarf viruses infection was negligible, and its grain yield averaged 6,586 kg/ha compared to that of Patterson at 6,250 kg/ha, ($LSD_{0.05}$ = 530 kg/ha). In 2002, the yield of the yellow dwarf viruses-resistant line averaged 6,498 kg/ha compared to 5,772 kg/ha for Patterson ($LSD_{.05}$ = 376). Yellow dwarf viruses symptom scores for the resistant line and Patterson in 2002 averaged 0.5 and 5, respectively. We initiated seed increase of yellow dwarf viruses-resistant lines in 2002–03 for possible cultivar release.

A quantitative, reverse-transcriptase RT-PCR technique was used to detect the coat protein genes of BYDV-PAV and CYDV-RPV and examine the level of virus accumulation following infection in a yellow dwarf viruses-resistant wheatgrass, a yellow dwarf viruses-resistant wheat line, a susceptible wheat line, and a susceptible oat line. BYDV-PAV and CYDV-RPV was detected as early as 2 and 6 hrs, respectively, in susceptible oat compared to detection by ELISA at 4 and 10 days post infestation. BYDV-PAV RNA accumulated more rapidly and to a higher level than CYDV-RPV in both oat and wheat, which may account for PAV being a more prevalent, and more severe viral disease then CYDV. This technique is reproducible, sensitive, and has the potential to be used for examining susceptibility and resistance and as a rapid diagnostic tool for yellow dwarf viruses.

Several types of markers have been used to characterize *Th. intermedium* translocations in wheat backgrounds. Morphological markers, when available, allow the selection of individuals with foreign heterochromatin (Banks et al 1995, Genome 38:395-405) but do not delineate their genetic constitution. SSRs, although greatly facilitating the study of traits in wheat, are genome specific. When using wheat-derived SSRs, the absence of a particular wheat band has been interpreted as presence of *Th. intermedium* DNA. However, this means that we cannot identify heterozygous individuals. Most wheat maps have been developed using RFLPs because of their consistency. These maps have become the framework of choice for incorporating new markers. However, RFLPs typically identify just one or two polymorphisms, are laborious and time consuming. Consequently they are not the best choice when testing large numbers of individuals. In contrast, AFLPs are reproducible, reveal a number of polymorphisms in a single gel but do not readily identify the map position of such polymorphisms. To take advantage of both marker systems, we are testing a technique to develop specific markers based on AFLP using primers designed from previously mapped RFLP probes. This technique is allowing us to direct our search for polymorphisms to previously mapped sites known to contain polymorphic zones and to design specific PCR primers to use in large-scale screening.

Research personnel.

Dr. Steve Scofield joined the small grains group in the USDA–ARS position of biochemical geneticist and is adjunct associate professor in the Department of Agronomy. His research involves a genomics approach to host-pathogen interactions. Dr. Charles Crane joined the small grains group in the USDA–ARS position of bioinformatics specialist. Dr. Roger Ratcliffe retired and continues to reside in the Lafayette, IN, area (we certainly hope he continues to stay involved). Dr. Brandon Schemerhorn, a recent graduate of the University of Notre Dame, plans to join the Hessian fly research group as a research entomologist, USDA–ARS. She plans to utilize molecular techniques to investigate topics including population genetics and the evolution of virulence in the Hessian fly. William Smith is working with D. Huber and D. Schulze on the effect of crop sequence on Mn-transition states in various soil types and disease incidence.

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KANSAS

KANSAS AGRICULTURAL STATISTICS
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Jagger remains number one cultivar.

Table 1. Top 10 wheat cultivars grown in the state of Kansas for the 2003 crop and percent of seeded acreage.

1. Jagger	45.2	6. TAM 107	2.3
2. 2137	13.3	7. Dominator	2.2
3. TAM 110	3.8	8. Ike	2.1
4. Karl/Karl 92	3.2	9. Trego	1.8
5. 2174	3.1	10. 2163	0.8

Jagger was the leading cultivar of wheat seeded in Kansas for the 2003 crop (Table 1). Accounting for 45.2 % of the state's wheat, Jagger increased 2.4 points from a year ago and was the most popular cultivar in seven of the nine districts. Jagger made the biggest gain in the southcentral district. The KSU-maintained cultivar 2137 ranked second over all, with 13.3 % of the acreage. 2137 ranked first in one district and second in five. TAM 110 moved up to third position, and increased 0.8 points from last year. Karl and improved Karl moved down to fourth place with 3.2 % of the acreage. The OSU maintained cultivar 2174 moved down to fifth place with 3.1 % of the state's acreage. TAM 107 held onto sixth place with 2.3 %. Dominator moved up to seventh place, with 2.2 %. Ike moved down to eighth place, with 2.1 %. New to the top ten is Trego, a HWWW, ranking ninth with 1.8 %. The KSU-maintained cultivar 2163 remained in the top ten with 0.8 %. Acres planted with multiple cultivar blends were not included in the rankings by cultivar. Blends accounted for 12.8 % of the acres planted statewide and were used more extensively in the northcentral and central parts of the state. Out of the total state acres planted with blends, 98.6 % had Jagger in the blend and 77.0 % had 2137 in the blend. All HWWWs accounted for 2.7 % of the state's acreage. Trego was the leading HWWW, accounting for 67 percent of the state's white wheat. The majority of the white wheat was planted in the western third of the state. This project is funded by the Kansas Wheat Commission.

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.

Table 2. Distribution of Kansas winter wheat cultivars, 2003 crop.

	Agricultural Statistics Districts									
Cultivar	NW	WC	SW	NC	C	SC	NE	EC	SE	State
	percent of seeded acreage [1]									
Jagger	23.0	12.2	27.0	23.6	40.6	69.8	11.7	36.5	49.7	45.2
2137	12.9	11.5	11.6	16.0	18.9	8.6	32.3	33.1	24.9	13.3
TAM 110	0.9	21.1	20.4	—	0.2	0.2	—	1.9	0.2	3.8
Karl/Karl 92	0.8	2.0	—	12.2	3.9	1.3	22.7	8.3	2.1	3.2
2174	—	0.1	0.4	0.3	1.3	6.6	0.7	2.8	7.8	3.1
TAM 107	13.5	9.1	6.3	0.1	0.3	0.0	0.0	0.1	0.0	2.3
Dominator	0.1	0.2	—	6.5	5.7	0.0	7.2	2.4	0.2	2.2
Ike	2.2	7.7	9.0	0.1	1.3	0.5	—	0.2	0.7	2.1
Trego–HWWW	7.5	9.6	2.2	0.3	0.9	0.3	0.3	1.5	—	1.8
2163	0.3	0.3	—	1.5	0.9	0.9	6.5	3.7	0.7	0.8
Larned	2.3	3.2	3.1	—	0.4	—	0.5	—	—	0.8
AgriPro Thunderbolt	4.3	2.5	1.0	0.6	0.4	0.1	—	0.0	—	0.8
AgriPro Coronado	—	0.0	—	0.2	0.7	1.4	—	—	2.6	0.8
Stanton	1.7	3.9	1.4	0.1	0.2	—	—	0.3	—	0.6
T81	0.1	1.7	4.1	0.1	0.1	0.0	—	0.4	—	0.6
Vista	3.8	0.1	0.4	—	0.1	0.0	—	—	—	0.3
AGSECO 7853	—	—	0.6	0.1	0.5	0.2	—	0.3	0.7	0.3
NuFrontier–HWWW	2.2	0.5	0.8	0.1	—	0.0	—	—	—	0.3
NuHorizon–HRW	0.0	0.6	1.8	0.1	—	—	—	—	—	0.2
AgPro Big Dawg	—	0.2	—	0.0	0.4	0.2	—	0.2	2.0	0.2
Scout/Scout 66	0.1	—	2.1	—	0.0	—	—	—	—	0.2
Akron	0.8	0.3	0.7	0.4	0.0	—	—	—	—	0.2
AGSECO Onaga	—	—	—	0.0	0.0	0.4	0.2	0.1	1.1	0.2
Ogallala	0.8	0.2	0.3	0.1	0.2	0.0	—	—	—	0.2
Lakin–HWWW	0.3	0.2	1.4	—	0.0	0.0	—	—	—	0.2
T83	0.1	1.0	—	—	0.1	0.1	—	—	—	0.2
Blends	11.2	6.3	3.2	32.8	19.9	7.3	10.8	1.1	2.4	12.8
Other HWWW Cultivars	0.1	0.9	0.2	0.1	0.1	0.2	0.5	1.0	0.0	0.2
Other Hard Cultivars	11.0	4.6	2.0	4.5	2.9	1.9	6.2	6.1	4.0	3.0
Other Soft Cultivars	—	0.0	—	0.2	—	0.0	0.4	—	0.9	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 %.

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/

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

Cultivar	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
	percent of seeded acreage									
Jagger	—	—	1.0	6.4	20.2	29.2	34.0	35.8	42.8	45.2
2137	—	—	—	1.0	13.5	22.0	23.1	22.3	15.5	13.3
TAM 110	—	—	—	—	—	0.5	1.3	2.8	3.0	3.8
Karl/Karl 92	23.6	22.4	20.9	22.1	10.8	5.9	3.5	3.3	3.6	3.2
2174	—	—	—	—	—	—	1.1	3.0	3.1	3.1
TAM 107	19.0	20.6	17.1	17.0	12.6	8.3	6.3	5.3	2.9	2.3
Dominator	—	—	—	—	0.2	0.8	1.4	1.5	2.0	2.2
Ike	—	0.9	7.2	10.5	7.0	5.5	4.1	3.6	2.6	2.1
Trigo–HWWW	—	—	—	—	—	—	—	0.3	0.8	1.8
2163	13.8	17.1	19.8	15.4	10.4	3.4	2.3	2.0	1.3	0.8
Larned	8.3	7.6	4.8	3.6	2.4	1.9	1.2	1.0	0.9	0.8
AgriPro Thunderbolt	—	—	—	—	—	—	—	0.2	0.6	0.8
AgriPro Coronado	—	—	—	—	0.8	1.3	1.0	1.1	0.7	0.8
Stanton	—	—	—	—	—	—	—	—	0.1	0.6
T81	—	—	—	—	—	—	0.2	0.2	0.8	0.6
Vista	—	0.3	0.8	1.2	1.1	0.9	0.9	1.0	0.9	0.3
AGSECO 7853	2.1	3.7	4.6	4.0	3.4	1.9	1.5	0.9	0.4	0.3
NuFrontier–HWWW	—	—	—	—	—	—	—	—	0.1	0.3
NuHorizon–HWWW	—	—	—	—	—	—	—	—	—	0.2
AgriPro Big Dawg	—	—	—	—	0.2	0.4	0.5	0.3	0.2	0.2
Scout/Scout 66	1.3	1.0	1..2	0.8	0.7	0.5	0.3	0.1	0.2	0.2
Akron–HRWW	—	—	—	—	0.4	0.8	1.0	0.4	0.4	0.2
AGSECO Onaga	—	—	—	—	—	0.1	0.1	0.2	0.2	0.2
AgriPro Ogalala	—	0.2	1.5	1.3	0.8	0.7	0.8	0.4	0.4	0.2
Lakin–HWWW	—	—	—	—	—	—	—	—	0.1	0.2
T83	—	—	—	—	—	—	0.1	0.2	0.1	0.2
Blends	—	—	—	—	2.6	6.1	7.5	7.0	11.4	12.8
Other HWWW Cultivars	—	—	—	—	—	—	0.2	0.8	0.3	0.2
Other Hard Cultivars	22.0	15.5	12.7	10.3	9.0	7.0	4.7	3.8	8.3	3.0
Other Soft Cultivars	—	—	—	—	—	0.0	2.0	0.0	0.1	0.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 4. Top wheat cultivars planted in Kansas by district and percent of seeded acreage.

District 10 (Northwest)		District 40 (North central)		District 70 (Northeast)	
Jagger	23.0	Jagger	23.6	2137	32.3
TAM 107	13.5	2137	16.0	Karl/Karl 92	22.7
2137	12.9	Karl/Karl 92	12.2	Jagger	11.7
Trego-HWWW	7.5	Dominator	6.5	Dominator	7.2
AgriPro Thunderbolt	4.3	2163	1.5	2163	6.5
District 20 (West central)		**District 50 (Central)**		**District 80 (East central)**	
TAM 110	21.1	Jagger	40.6	Jagger	36.5
Jagger	12.2	2137	18.9	2137	33.1
2137	11.5	Dominator	5.7	Karl/Karl 92	8.3
Trego-HWWW	9.6	Karl/Karl 92	3.9	2163	3.7
TAM 107	9.1	Ike	1.3	2174	2.8
District 30 (Southwest)		**District 60 (South central)**		**District 90 (Southeast)**	
Jagger	27.0	Jagger	69.8	Jagger	49.7
TAM 110	20.4	2137	8.6	2137	24.9
2137	11.6	2174	6.6	2174	7.8
Ike	9.0	AgriPro Coronado	1.4	AgriPro Coronado	2.6
TAM 107	6.3	Karl/Karl 92	1.3	Karl/Karl 92	2.1

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Update on heavy metals in soil at the Manhattan, KS, Biosolids Farm growing winter wheat.

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Last year, we reported concentrations of heavy metals in soil at the Manhattan, KS, Biosolids Farm, which grows winter wheat on the sludge-injected soil. However, the samples that we reported as ‘controls’ were not labelled correctly. These samples came from a new part of the farm that had received sludge during the summer of 2000. This area is labelled ‘Area XIV’ on the map of the sludge farm. The sludge came from a lagoon that had held the aerobically digested sludge (2 % solids or less) since 1978. The lagoon was 0.33 ha in area and 5.18 m in depth. All of this liquid was applied during the early summer of 2000 at a rate of 14.9 metric tons/ha to a field, which then grew soybeans that summer. The soil was sampled on 30 November, 2000, by personnel at the Manhattan, KS, Wastewater Treatment Plant. The soil that had received sludge yearly for 25 years and that grew winter wheat, in the old area of the farm, was sampled by the personnel on 13 March, 2001. This old area is labelled ‘Area IV’ on the map of the sludge farm, which was established in 1976. In the early years of the sludge farm (1976–92), 32 t/ha dry sludge were applied yearly. On 25 November, 1992, the EPA published regulations limiting land disposal of sludge (known as the 40 Code of Federal Regulations Part 503) and rates of sludge application now must be based on agronomically acceptable practices, which depend on the type of crop grown and its nitrogen requirements. Because we had no control samples, on 8 June, 2002, we sampled soil adjacent to Area IV. This area was fenced-off and holds the shed that houses the sludge injector when it is not in use. We now report the concentration of metals in the three different areas (Table 1).

In general, our conclusions from last year hold. That is, the results show that, after 25 years of application of biosolids to the farm, concentrations of heavy metals have not increased in the soil, except for Cu, Pb, and Zn. Lead is the only toxic heavy metal, and the reason for its elevated level is not known.

Table 1. Total concentrations (mg/kg) of heavy metals in the 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 (Area IV at the Farm); n = 6 for the site where liquid sludge (biosolids) in a 22-year old lagoon was emptied during the early summer of 2000 (Area XIV); and n = 2 for the control site, which was adjacent to Area IV, but had received no biosolids.

Time of biosolids application to soil (years)	Cd	Cu	Fe	Mn	Ni	Pb	Zn
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
One summer	0.88 ± 0.27	8.5 ± 3.1	12,000 ± 3,870	212 ± 74	12.4 ± 4.50	32.6 ± 6.9	20.7 ± 7.0
Control	0.75 ± 0.04	8.8 ± 0.2	6,910 ± 667	130 ± 2	9.0 ± 1.00	18.6 ± 0.5	22.0 ± 0.1

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

News.

Dr. Stanley Liphadzi received his Ph.D. at graduation ceremonies at Kansas State University on 13 December, 2002.

Publications.

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The WGRC Gene Bank.

The working collection of wild wheat species maintained by WGRC consists of 3,098 accessions comprising annual *Triticum* and *Aegilops* species (Table 1). This collection is a composite, as distinguished from core collections established by pioneering plant explorers. The entries in the germ plasm collection are from expeditions by the University of Kyoto (Japan) in 1955, 1959, 1966, and 1970; Johnson and coworkers (University of Riverside, CA, USA) 1966, 1972, and 1973; E. Nevo and colleagues (University of Haifa, Israel); and R.J. Metzger (University of Oregon, Corvallis, USA), J. Hoffman (USDA–ARS), G. Kimber (University of Missouri, Columbia, USA), S. Jana (University of Saskatchewan, Canada), and A. Sencor, M. Kanbertay, and C. Tüten (Agean Agricultural Research Institute, Manemen, Izmir, Turkey), 1979, 1984, and 1985. Additional accessions from major gene banks of the world include ICARDA (Aleppo, Syria), the USDA Small Grains Collection (Aberdeen, ID, USA), the N.I. Vavilov Institute (St. Petersburg, Russia), and the Institute for Genetics and Crop Plant Research (Gatersleben, Germany).

Table 1. Current composition of the wild species collection of the Wheat Genetics Resource Center Gene Bank, December 2002 (Genome symbols in parentheses).

Species	No. of accessions
Diploid (2n = 14) species.	
T. monococcum (A^m)	685
T. urartu (A)	182
Ae. bicornis (S^b)	12
Ae. caudata (C)	18
Ae. comosa (M)	21
Ae. longissima (S^l)	9
Ae. searsii (S^s)	213
Ae. sharonensis (S^{sh})	7
Ae. speltoides (S)	97
Ae. tauschii (D)	509
Ae. umbellulata (U)	45
Ae. uniaristata (N)	21
Am. mutica (T)	19
H. villosa (H^v)	92
Polyploid tetraploid (2n = 28) and hexaploid (2n = 42) *Triticum* and *Aegilops* species.	
T. timopheevii (A^tG)	283
T. turgidum (AB)	489
Ae. biuncialis (UM)	36
Ae. columnaris (UM)	12
Ae. crassa (4x (DX), 6x (DDX))	34
Ae. cylindrica (DC)	43
Ae. geniculata (MU)	141
Ae. juvenalis (DMU)	9
Ae. kotschyi (SU)	18
Ae. neglecta (UM and UMN)	67
Ae. peregrina (SU)	29
Ae. trunicialis (UC)	183
Ae. ventricosa (DN)	16
TOTAL	3,098

The world collection of *Triticum* and *Aegilops* consists of approximately 17,500 accessions distributed in a dozen or so gene banks worldwide. To access this extensive material to our germ plasm collection or making arrangements for its availability, we have made a survey of global wheat genetic resources and documented accessions and diversity. Data previously available only in the literature, through gene bank records, or by personal communication can now be accessed via the World Wide Web and other computer interfaces. In the future, the WGRC hopes to further distribute information by coöperating with other gene banks and database coördinators. Additionally, dissemination of data via the internet (the WGRC home page is http://www.ksu.edu/wgrc/) will be increasingly useful to scientists requesting germ plasm and other genetic stocks.

New acquisitions for the germ plasm collection include several mapping populations of Karnal bunt-resistant material from Dr. Indu Sharma (Punjab Agricultural University, Ludhiana, India), a collection of *Ae. tauschii*, *Ae. crassa*, and *Ae. triuncialis* and *T. aestivum* landraces from Dr. Safarali Namoor (Research Institute of Plant Physiology and Genetics, Dushanbe, Tajikistan), and *Haynaldia villosa* accessions from the Gatersleben Gene Bank, the Prague Gene Bank, and the USDA Small Grains Collection.

Genetic and cytogenetic stocks.

New amphiploids. Rapid genetic changes in new hybrids and amphiploids have been reported recently. For this purpose, we have initiated production of new hybrids involving extracted tetraploids from the cultivars Chinese Spring, Canthatch, and Thatcher with various accessions of *Ae. tauschii*. The F_1 embryos were rescued and placed on tissue-culture medium and will be treated with colchicine to produce amphiploids next year.

Table 2. Current composition of the genetic stocks collection of the Wheat Genetics Resource Center Gene Bank, December 2002.

Genetic stock	No. of accessions
Ae. tauschii synthetic and parental lines	311
Alien addition	356
Alien substitution	238
Alloplasmic	8
Amphiploid	127
Aneuploid	359
Cultivar	221
Deletion/duplication/deficiency	490
Germ plasm	68
Mutant/Marker	292
Mapping and RIL populations (44 populations)	5,551
Substitution	149
Translocation	135
TOTAL	8,305

New addition lines. We are in the process of developing a set of wheat–*Ae. biuncialis* (2n = 4x = 28, $U^bU^bM^bM^b$) chromosome-addition lines. To date, six disomic *Ae. biuncialis* additions have been identified. Previously, we reported on the development of a complete set of chromosome addition lines from the closely related species *Ae. geniculata* (2n = 4x = 28, $U^gU^gM^gM^g$) (Friebe et al. 1999; Genome **42**:374-380). Once the set of *Ae. biuncialis* additions have been completed; a detailed analysis of the evolutionary relationships of the U^b/U^g and M^b/M^g chromosomes can be made.

Recently we reported on the development of a complete set of wheat-*Ae. speltoides* chromosome addition lines (Friebe et al. 2000; Theor Appl Genet **101**:51-58). This set of addition lines is especially interesting because the S genome of *Ae. speltoides* is considered as the most closely related genome in the Sitopsis group to the B genome of *T. aestivum*. By crossing the addition lines with the appropriate B-genome monosomic stocks we have produced five S(B) chromosome substitution lines. Once this set has been completed these stocks will allow to determine the sporophytic and gametophytic compensation ability of the S-genome chromosomes (Friebe et al. 1993; Genome **35**:731-742).

We also have developed eight disomic $4S^{sh}$ chromosome addition and three disomic substitution lines from different *Ae. sharonensis* accession that all have a functional *Gc2* gene. These lines were screened for marker polymorphism and regular meiotic pairing in the $4S^{sh}L$ arm against the original $4S^{sh}$ 'cuckoo' chromosome. Two lines had high levels of polymorphism and regular meiotic-pairing behavior, and these lines were used to produce mapping populations that will allow fine mapping of the *Gc2* gene. This is the first step towards the cloning of this gene, which will allow us to analyze the molecular mechanism/s underlying *Gc* function.

Tolerance to heat stress.

Sudden, high temperatures during grain filling are a major impediment to high wheat crop yields in the Great Plains. Stable photosynthesis in some genotypes and high reserve content in others were associated with low susceptibility to stress and provided for high grain yield. A minimum of 1.4 genes with both additive and dominance effects were determined from crosses between a heat-tolerant (Ventnor) and a heat-sensitive (Jagger) genotype. Two microsatellite markers are linked to quantitative trait loci for grain-filling duration during heat stress.

These results indicated that heat tolerance in common wheat is controlled by multiple genes and suggests that marker-assisted selection with microsatellite primers might be useful for developing improved cultivars. We also tested 30 synthetic hexaploid wheats (*T. durum*/*Ae. tauschii*) and amphiploid derivatives from different grasses for their heat tolerance, although the value of the octaploid amphiploids is questionable because of low kernel number in lines with a low heat stress index. Three papers were published from this research (see publications list Yang et al. 2002a, 2002b, 2002c).

Rust resistance.

A potentially durable and highly effective leaf rust-resistance gene in wheat, an *Lr21* allele (previously designated as *Lr40*) was introgressed from a different accession (TA1649) into the wheat cultivar Wichita to develop leaf rust-resistant germ plasm lines WGRC2 and WGRC7. A strategy was developed and used for map-based cloning of *Lr21* from wheat. Cloning of *Lr21* was confirmed by genetic transformation and a stably inherited, resistant phenotype was recovered in transgenic plants. Molecular characterization of *Lr21* indicated that the gene spans 4,318-bp genomic DNA and encodes a 1,080 amino-acid protein containing a conserved nucleotide-binding site (NBS) domain, 13 imperfect leucine-rich repeats (LRR), and a unique 151 amino-acid sequence missing from known NBS-LRR proteins at the N-terminal region. With the cloning and successful genetic transformation of *Lr21*, we can now use a molecular approach for breeding wheat for durable rust resistance.

Personnel.

New graduate research assistants in the laboratories of the WGRC include Michael Pumphrey (M.S. University of Minnesota), Jamie Wilson (B.S. University of Northern Iowa), and Shalpa Kuraparthy from India. Peng Zhang completed her Ph.D. dissertation 'Analysis of the wheat genome by BAC-FISH' and currently is a research associate with Bernd Friebe.

Visitors to the WGRC laboratories in 2002 included Dr. Gulzar Singh Chahal, Punjab Agricultural University, Ludhiana, India, July–December; Dr. Peidu Chen, Nanjing Agricultural University, China, March; Didier Lamouroux, INRA (National Institute for Agronomic Research), Clermont-Ferrand, France, October–December; Robert A. McIntosh, University of Sydney, Australia, June; Dr. Safarali Namoor, Research Institute of Plant Physiology and Genetics, Dushanbe, Tajikistan, May–June; Dr. Tomás Naranjo, Universidad Compultense Madrid, Spain, September; and Dr. Indu Sharma, Punjab Agricultural University, Ludhiana, India, October.

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GRAIN MARKETING AND PRODUCTION RESEARCH CENTER
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Cereal research in North America.

O.K. Chung, M. Tilley, and J.E. Dexter.

In the U.S.A., agricultural research (AR) is conducted by public (federal and state agencies) and private (industry) sectors. U.S. AR is funded mainly by federal departments (USDA and others) state agencies and to a lesser extent by other nonfederal and nonstate agencies. In the year 2000, the total funds for U.S. AR were nearly 3.5 billion dollars, of which 48 % ($1.67 billion) was from federal funds (USDA–ARS, CSREES, and other departments), 35.6 % ($1.23 billion) from state appropriations, and 16.4 % ($567.2 million) from nonfederal and nonstate sources. About 23 % of total AR is conducted by the USDA agencies and the remaining 77 % by the nonfederal agencies including 50 state agricultural experiment stations (one/state). Nationwide this represents a total of 16,998 AR projects and 9,368 scientists' years (SYs) of which 2,098 projects with 2,036 SYs were conducted by USDA–ARS. A small portion of the total U.S. AR is conducted in the area of cereal grain research. Approximately 800 SYs (8.4 % of total SYs in AR) are engaged in about 3,000 projects (17 % of total AR projects) with a budget amounting to nearly $300 million. Among the cereal grains, corn (maize) research is most active with 270 SYs working on over 1,000 projects funded with over $107 million. This is followed by wheat research with 258 SYs working on 973 projects with a budget of $94 million. Other grains in order of funding include rice, grain sorghum, and rye. In Canada, government institutions, mainly the Agriculture and Agri-Food Canada (AAFC), conduct the majority of AR. In addition, the Canadian Food Inspection Agency, the National Research Council, the Canadian Grain Commission-Grain Research Laboratory, and nongovernment agencies such as the Canadian International Grains Institute and universities of Manitoba, Guelph, and Saskatchewan are all important agencies/institutions for Canadian AR. The five Research Centers in the eastern Canada place the most emphasis on programs in the area of cereal research (wheat, oats, maize, etc.). Because cereal grains dominate agriculture in western Canada, there are major cereal programs at the three Centers in Winnipeg, Swift Current, and Lethbridge. Programs in western Canada include crop and soil management, breeding, gene mapping, development of quality screening protocols, research on cereal component structure, and cereal processing studies.

Cereal research in the USA.

O.K. Chung and M. Tilley.

The goals of agricultural research in the U.S. are to enhance the economic viability and competitiveness of the U.S. by maintaining the quality of harvested agricultural commodities or otherwise enhancing their marketability, meeting consumer needs, developing environmentally friendly and efficient processing concepts, and expanding market opportunities through the development of value-added food and nonfood products and processes. Research is conducted by public (federal and state agencies) and private (industry) sectors. In the public sectors, including the U.S. Department of Agriculture, State Agricultural Experiment Stations located in land-grant universities, other universities, and also other cooperating institutions. Research is funded mainly by federal departments (USDA and others), state agencies, and to a lesser extent by other non-federal and non-state agencies. In the year 2000, the total funds for agricultural research were nearly 3.5 billion dollars, of which 48 % ($1.67 billion) was from federal funds, 35.6 % ($1.23 billion) from state appropriations, and 16.4 % ($567.2 million) from nonfederal and nonstate support. Cereal grain research accounts for a small portion of the total U.S. agricultural research. Among the cereal grains, corn (maize) research is most active followed by wheat research. Other grains in order of funding include rice, grain sorghum, and lastly rye. Cereal grains research is supported slightly more by federal than by non-federal funds. However, rice, grain sorghum, and grain crops research projects were funded slightly more by nonfederal sources. The U.S. supports the use of biotechnology for the development of enhanced agricultural products and has a rigorous system involving three federal agencies that regulates and monitors agricultural biotechnology including the evaluation of genetically modified crops that may be used for human and animal consumption at all levels of production.

The study of wheat starch size distribution using image analysis and laser-diffraction technology.

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

Starch was isolated from wheats of four different classes and analyzed using digital image analysis (IA) coupled to a light microscope and several laser diffraction sizing instruments (LDS). The IA data was converted into volume data in order to compare to LDS data. LDS analysis tended to underestimate both A and B starch granule populations when compared to IA. Linear correlations comparing IA to LDS instruments ranged from $r = 0.17599$ ($p > 0.1$) to $r = 0.73956$ ($p < 0.001$) depending on the LDS instrument used. A correction factor was developed to convert LDS starch size distribution data to that obtained using IA. The corrections were validated to four classes of wheat; spelt, HRW, HRS, and durum. R^2 values of the corrected starch size distribution general linear regression model were as follows: spelt, 0.86; HRW, 0.77; HRS, 0.79; and durum, 0.89. The corrections will be used to develop a standard method of analysis for measuring wheat starch size distributions quickly and accurately.

The effect of various wavelengths in the quantitation of wheat proteins with SE-HPLC.

H.A. Naeem, F. MacRitchie, and G.L. Lookhart.

The total polymeric proteins from more than 100 wheat flour samples were analyzed via SE–HPLC using a system with a diode array detector. The chromatograms were recorded at five different wavelengths; 200, 210, 214, 250, and 270 nm. The chromatograms of the samples, recorded at different wavelengths, were different from each other in absorption intensity and total area. However, the percentage area under each peak of the chromatograms was similar for all wavelengths investigated. Highly significant correlations were observed when comparing the percent areas of each peak recorded at different wavelength. Although the overall percentage areas were the same, minor differences were noted in the chromatograms recorded at 200 nm. This study shows that wheat proteins may be quantitated by SEC–HPLC at any of the 5 wavelengths described.

The effect of high temperature stress on accumulation of storage proteins: quantitation of polymeric proteins during grain development in near-isogenic wheat lines expressing HMW-GS (2 + 12) or Glu-1D1 (5 + 10).

H. A. Naeem, F. MacRitchie, and G. L. Lookhart.

Effect of elevated temperatures on accumulation of storage proteins during grain development was investigated in wheat near-isogenic lines expressing HMW-GS *Glu-D1a* (2+12) or *Glu-D1d* (5+10). Plants were exposed to six separate temperature regimes. The intensity, duration and the developmental stage of plants (days-after-anthesis) were varied over the different treatments. Grains were collected starting 16 days-after-anthesis until maturity, at 3-day intervals. Total and unextractable polymeric protein (UPP) per grain were determined by SEC-HPLC. UPP was found to provide a clear differentiation between the near-isogenic lines in accumulation patterns of polymeric proteins. The heat treatment reduced the time, up to 6 days, to initiate the accumulation of UPP. Lines expressing HMW-GS 5+10 began to increase UPP 3 to 6 days earlier than 2+12 lines and maintained that difference until maturity.

Effect of Aelia spp. and Eurygaster spp. damage on wheat proteins.

C.M. Rosell, S. Aja, S. Bean, and G.L. Lookhart.

The effect of *Aelia* spp. and *Eurygaster* spp. wheat bugs on the protein fractions of different wheat cultivars has been studied by SE–HPLC and free-zone capillary electrophoresis (FZCE). Those methods were used to quantify and characterize the extent of protein modification. A decrease in the amount of alcohol insoluble polymeric proteins along with an increase in the alcohol soluble polymeric proteins and gliadins were observed in damaged wheat. The HMW- and LMW-glutenin fractions were barely detected in the incubated damaged wheat from some cultivars, which indicated hydrolysis of those proteins by the bug proteinases. In damaged wheats both incubated and unincubated, gliadin electrophoregrams revealed the presence of some new peaks with mobilities similar to the ω gliadins. The overall results suggest that the bug proteinases are potent enzymes, which appear to be nonspecific because they hydrolyze all gluten proteins.

Relationship of insoluble polymeric proteins to mixing requirements for flours from commercial mills and individual cultivars.

G.L. Lookhart, S. Bean, R. Lyne, O.K. Chung, S. Chandra, J.-B Ohm, M. Stearns, and S. Piland.

This project was designed to examine the potential of predicting the mixing properties of commercial flours (CF). Mixing properties of individual cultivars are related to the amount of insoluble polymeric protein (IPP). The IPP of each sample was determined by extracting the soluble proteins and combusting the dried remaining sample for protein content. The CF samples were obtained from three commercial mills on a weekly basis for 3 years. The individual cultivars were hard winter wheats from the 95–98 Wheat Quality Council (WQC). The mixing properties of the CF were evaluated by the Labtron, whereas those of the individual cultivars (WQC samples) were evaluated by the Mixograph. The average % IPP for the two sets were the same, 0.40, with a sd of 0.03. The % IPP of the WQC samples correlated with the mixing time with r values ranging from 0.60 to 0.85 over 4 crop years. In the CF, the % IPP versus Labtron mixing time r values were nearly zero. The range of % IPP values in the CF was narrower than the WQC samples; 0.35 to 0.47 for the CF versus 0.28 to 0.55 for the WQC samples. The lack of variation in the CF supports the conclusion that the three CF mills selected and blended their wheats to produce consistent flours.

HPLC of gluten monomeric proteins.

G.L. Lookhart, S.R. Bean, and J.A. Bietz.

HPLC is an analytical method that uses a liquid pumping system to accurately deliver solvents through a column or columns each packed with particles of a specific size (1.5 to 10 μ) and with specific bonded phases. The end result is the ability to separate complex mixtures in minutes. HPLC is a superb tool as it is complimentary and often superior to previous methods for characterization of complex cereal proteins.

Separation of gluten proteins by high-performance capillary electrophoresis.

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

HPCE is an analytical method that uses a voltage differential to accurately move solvents and solutes through a capillary. HPCE is a relative newcomer to the field of cereal chemistry, utilizing small inner diameter capillaries as an anti-convective medium in place of slab gels. Because of the small inner diameter of those capillaries (typically 50 to 100 μ) high voltages can be used, resulting in rapid, high resolution separations. Combining the high voltages (up to 30 kV) with isoelectric buffers and buffers varying in ionic strength, complex mixtures can be separated in minutes. Like traditional slab-gel electrophoresis, HPCE can operate in several modes. HPCE is a superb tool as it is complementary and often superior to previous methods for characterization of complex cereal proteins.

Separation of water soluble proteins from cereals by free-zone capillary electrophoresis (FZCE).

S.R. Bean and M. Tilley.

Most research concerning grain proteins has concentrated upon the gluten storage proteins. The albumins and globulins are the water and salt soluble proteins that contain biologically active enzymes and enzyme inhibitors. A free-zone capillary electrophoresis method was developed to separate these proteins. Optimization included sample extraction method, capillary temperature, buffer composition, and additives. The optimal conditions for separation of these proteins was found to be 50 μ i.d. x 27 cm (20 cm L_D) capillary at 10 kV (with a 0.17 min ramp up time) and 25°C. The optimum buffer was 50 mM sodium phosphate, pH 2.5 + 20 % acetonitrile (v/v) (ACN) + 0.05 % (w/v) hydroxypropylmethyl-cellulose (HPMC) + 50 mM hexane sulfonic acid (HSA). Sample stability was an issue that was addressed by lyophilizing fresh extracts and redissolving in aqueous 50 % ethylene glycol and 10 % separation buffer. This method was successfully used in both wheat flour and whole meal samples. Comparisons were made of several wheats of different classes as well as several cereal grains. This methodology could be useful in screening cereal grains for important enzymes and their impact on end-use quality such as food functionality, food coloration, and malting quality.

Identification of active components from the water-soluble extract of wheat flour that catalyze dityrosine formation.

M. Tilley and K.A. Tilley.

The ability of a given wheat flour to form gluten determines its utilization quality. One of the most important aspects is the manner in which gluten proteins interact to form a cohesive, viscoelastic dough. Recently, dityrosine crosslinks were shown to be involved in dough formation and the water-soluble extract (WSE) of wheat flour was shown to catalyze their formation in vitro. The objective of this project was to identify the active component(s) of the WSE that are involved in catalyzing dityrosine. The WSE of flour (cultivar Bronze Chief) was fractionated and tested for dityrosine forming activity. Initial fractionation of the WSE involved separation of components by the use of preparative isoelectric focusing. The resulting 20 fractions were collected and tested in a single blind assay for dityrosine formation with appropriate controls. The fraction causing the greatest formation of the crosslink was further fractionated into single components. The identification of components that catalyze crosslinking and determination of activity may provide an analytical scheme for the use of crosslink formation as a means of predicting breadmaking quality.

Identification of novel structures in wheat dough: impact on structure and function of gluten.

K.A. Tilley and M. Tilley.

Formation of the 3-dimensional protein network known as gluten during dough mixing and breadmaking processes is extremely complex. A specific subset of the proteins comprising the gluten complex, the glutenin subunits, directly affect 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 breadmaking 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 breadmaking processes have been documented by HPLC, NMR, and mass spectroscopic analyses. Flours and doughs from other nonwheat 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 also has been documented, shedding light on the biological mechanisms for tyrosine crosslink formation.

PCR amplification of wheat sequences from DNA extracted during milling and baking.

M. Tilley.

Processing steps have a profound effect upon the proteins and DNA present in the final product. DNA-based analysis has several advantages over protein-based methods due to the fact that DNA is highly thermostable and DNA-based analyses are highly sensitive and specific. This project examined the effects of breadmaking on wheat DNA extracted from various steps in the baking process. Samples were taken from wheat kernels, milling fractions, flour, and at steps during and after the baking process. Kernel DNA contained high molecular weight DNA (>12,000 bp), whereas that from flour exhibited a broad smear (>12,000 bp to <300 bp). PCR was used to amplify sequences present at different copy numbers within the wheat genome. PCR successfully amplified products of both high and low copy number, however, successful amplification requires that the maximum size be no more than the average molecular weight of the DNA recovered from the source. The data also demonstrated the ability to detect the presence of a minor ingredient (yeast).

Segregation of hard winter wheats according to baking and milling properties using wheat quality parameters.

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

Predicting milling and baking quality of wheat from the properties of the kernels is highly desirable. Starting with 1,845 hard winter wheats grown in federal nurseries between 1990–2000, both the flour-milling yield and their pup-loaf volume were assigned to high, medium, and low categories, giving a total of nine quality permutations. Excellent (poor) wheats gave a combination of >68 % (<65 %) flour yield and >940 cm^3 (<850 cm^3) loaf volume. There were 141 excellent and 130 poor wheats in the total of 1,845 wheats. Wheat and single kernel parameters (total of 14) of the 1,845 wheats were then used to develop canonical classification models for quality segregation. The model successfully identified 58 % of the excellent wheats and 37 % of the poor wheats. No excellent wheat was predicted to be poor, or vice versa. A model based on single kernel parameters showed 49 % accuracy for the excellent classification but one excellent wheat was classified falsely with the poor wheats.

Effects of varying the weight ratio of large and small wheat starch granules on experimental pup-loaf bread.

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

One commercial bread wheat flour (11.3 % protein content on 14 % mb) was fractionated into three fractions (starch, gluten, and water-solubles) by hand-washing. The starch fraction was further separated into large and small granules (LG and SG) by repeated sedimentation. Sizes of large (10-40 μ in diameter) and small (1-15 μ in diameter) starch fractions were examined by a MicroTrack S3000 (Wyomissing, PA). Flour fractions were reconstituted to their original levels in the flour but the weight percent of SG was varied at 0, 17, 30, 60, and 100 % of total starch. A modified pup straight-dough method was used in an experimental baking test. Loaf size (698–729 cc) and external appearance of breads were not affected by varying the weight ratio of starch granular sizes. However, the crumb appearance and softness were affected. The bread made from flour with starch of 30 % SG and 70 % LG had the highest crumb grain score (4.0; subjective method) and fineness (1029; CrumbScan, AIB) and the second highest elongation ratio (1.55; CrumbScan, AIB). Inferior crumb grain scores, low fineness and elongation ratios were observed in breads made from flours with starch fractions at 100 % SG or 100 % LG. The higher the proportion of SG in the flour, the softer the bread texture during storage.

Lipid extraction from wheat flour using supercritical fluid extraction.

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

Environmental concerns, the disposal cost of hazardous waste, and the time required for extraction encouraged us to look for a method to extract lipids from wheat flour that would be faster, less costly, and more environmentally acceptable. Supercritical Fluid Extraction (SFE) with CO_2 plus ethanol as a modifier has provided that medium. The method is fully automatic. Extraction of nonstarch free lipids (FL) or crude fats from wheat flour (about 5 g) by SFE using CO_2 plus 11.7 mole % ethanol (12.2 % by volume) as modifier, at 7,500 psi (51.7 Mpa) and 80°C, was compared to the AACC Approved Method of Soxhlet extraction using petroleum ether. The precision of the FL extraction by SFE was comparable to that of Soxhlet with a 14.6 to 1 reduction in the overall analysis cost ($0.33 vs. $4.80/sample), including a 14 to 1 reduction in the cost of organic solvent and a 20 to 1 reduction for solvent disposal cost, and a possible six-fold reduction in analysis time.

Wheat lipids: what do they do to quality?

O.K. Chung, J.B. Ohm, and S.H. Park.

Wheat lipids, a minor constituent, play major roles in wheat production, storage, processing, products, nutrition, and consumer acceptance of finished goods. Quantitative and qualitative differences in lipids in various structural parts of grains are responsible for multifaceted functions. In germination, nonpolar lipids (NL) are energy sources and polar lipids (PoL) are structural components of cellular membranes. Lipids are only 4–5 % of wheat kernel weight and are unevenly distributed in wheat structural parts, including 50–60 % in germ and outer parts and 40–50 % in endosperm (20–31 % nonstarch lipids (NSL) and 16–22 % starch lipids (SL)). Wheat lipids are broadly divided into free lipids (FL, easily extractable with ether or hexane) and bound lipids (BL, extractable with aqueous alcohol and at an elevated temperature for the SL). Lipids are most rapidly changing during grain/flour storage, especially under adverse conditions: an increase in fat acidity is an index of measuring storage conditions. Because of high concentration of lipids, germs are easily separated from flour during the milling process. Flour is less dusty because of the presence of FL; the removal of FL increased the dust index by 100 times. The large difference between steryl esters in bread wheat (3–58 mg/100-g wheat) from durum wheat (0–1.5 mg/100-g wheat) allows for detection of the contamination of durum semolina with bread wheat farina. Defatting and reconstituting studies demonstrated the beneficial effects of PoL (especially glycolipids, GL) but detrimental effects of NL on loaf volume, crumb grain, and texture of breads; positive effects of FL on size and internal structures of Arabic flat bread, Chinese steam bread, both cookie size and top-grain structures; a full restoration of cookie size by PoL but only partial restoration on top-grains by either PoL or NL; FL effects on both size and fine cell structures of pan-cake; the beneficial effects of FL on yellow color and decreases in surface stickiness and also cooking loss of spaghetti; positive effects of FL, especially NL, on keeping the surface firmness of cooked Asian noodles; and the role of FL to limit excessive expansion of extrudates. The U.S., Canadian, or Greek wheat showed genetic variations in FL composition (GL content, NL/POL or NL/GL ratios) to be significantly correlated with baking parameters, but only partially responsible. Thus, FL content/composition cannot be the sole bread quality determinant but a good supplementary one, especially for a wheat-breeding program.

Wheat lipids: a supplementary quality determinant.

O.K. Chung, J.B. Ohm, and S.H. Park.

Wheat lipids, a minor constituent, play major roles in wheat processing and consumer acceptance of finished goods. Lipids are only 4–5 % of wheat kernel weight and 40–50 % is in starchy endosperm (20–31 % nonstarch lipids (NSL) and 16–22 % starch lipids (SL)). Two broadly divided wheat flour lipids are free lipids (FL, easily extractable with ether or hexane) and bound lipids (BL, extractable with aqueous alcohol and at an elevated temperature for the SL). The NSL consist of 60% FL and 40% BL, whereas the SL are all in tightly bound form. Defatting and reconstituting studies demonstrated the beneficial effects of polar lipids (PoL, glycolipids, GL) but detrimental effects of nonpolar lipids (NL) on loaf volume (LV) and bread structures. NL is beneficial for cookies or cakes internal structures, spaghetti's bright yellow color, and firmness of cooked Asian noodles. Varietal variations in FL composition (GL, NL/PoL or NL/GL ratios) were significantly correlated with LV, as reported by various researchers. Based on our recent studies, the two main GL classes, monogalactosyldiglycerides (MGDG) and digalactosyldiglycerides (DGDG), showed opposite relationships with quality parameters. Kernel hardness parameters, flour yields, and water absorptions were correlated negatively with MGDG but positively with DGDG. MGDG contents were correlated with gluten contents negatively but with gluten index values positively. Flour FL content and composition (MGDG/GL or DGDG/GL ratios) supplemented flour protein content to develop prediction equations of mixograph mix time (MT, $R^2 = 0.89$), bake MT ($R^2 = 0.76$), and LV ($R^2 = 0.72$). Lipids were only partially responsible for variations in end-use quality. Therefore, wheat lipids cannot be the sole quality determinant, but a good supplementary one, especially for screening wheat breeding lines at early generations.

Analysis of flavor compounds from microwave popcorn using supercritical fluid CO_2 followed by dynamic/static headspace techniques.

R. Rengarajan and L.M. Seitz.

Dynamic-headspace purge (DHP) analysis was used to observe volatile compounds from freshly popped commercial flavored and non-flavored microwave popcorn. The obtained results were compared with supercritical fluid extraction (SFE) followed by DHP. The sensitivity of the latter method (SFE–DHP), in general, was several fold higher than DHP itself. Previously reported high FD compounds like 2-acetyl-tetrahydropyridine, 4-vinylguaiacol, 2-phenylacetaldehyde and 2-acetyl-1-pyrroline were found by both methods in this study, not only with very little sample quantity but also with relatively little sample preparation time. Except for 2-methylpyrazine, all observed pyrazines were 2-6 fold higher with the SFE-DHP than the DHP method. In a separate experiment, the supercritical fluid (SF) extract from popcorn was a) exposed to a SPME fiber (SFE-SPME), and b) injected directly into the gas chromatograph. SFE-SPME showed highest sensitivity towards pyrazines. Furaneol, vanillin, sulfurol, maltoxaine, and nonalactone were detected best by direct injection of the SF extract.

Metabolites of lesser grain borer in grains.

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

Lesser grain borer (LGB, *Rhyzopertha dominica*) is an insect that causes major physical and off-odor damage to grain in storage. Metabolites of LGB were identified to obtain information needed for understanding and detecting the off-odor, and providing alternative means for detecting LGB infestation. Volatiles from grains, mostly whole wheat, at 80°C were collected on Tenax absorbent, thermally desorbed, and analyzed by gas chromatography using infrared and mass detectors for component identification. A solid-phase-micro-extraction technique also was used in analyzing grain samples and in a synthesis process required to identify ester metabolites. Predominant compounds in LGB-infested grains were 2-pentanol and its esters of 2-methyl-2-pentenoic (A) and 2,4-dimethyl-2-pentenoic (B) acids which are known aggregation pheromones, dominicalures 1 and 2. 2-Pentanol esters of saturated A, beta-keto- and beta-hydroxy derivatives of A and B, and 1,2-carbon homologues of A and B were found. Other 5–7 carbon straight- and branched-chain secondary alcohols and their esters were also observed. Some of these metabolites, especially 2-pentanol, were associated with insect odor in grain samples obtained from grain inspectors. Advanced LGB infestation was indicated by presence of the minor ester and alcohol metabolites. These metabolites are of interest to scientists investigating insect metabolism and behavior.

Characterization of volatile organic compounds in airborne dust.

E.B. Razote R.G. Maghirang L.M. Seitz, and I.J. Jeon.

Three methods of extracting volatile, organic compounds (VOCs) adsorbed on the airborne dust in a swine finishing building were investigated. Airborne dust was collected in prebaked glass fiber filters (GFFs) and the compounds were extracted by solvent extraction using dichloromethane, solid-phase microextraction (SPME) using carboxen/polydimethylsiloxane (CAR/PDMS) and PDMS fibers, and purge and trap methods. Solvent extraction was not sensitive enough to extract detectable amounts of compounds, except for some high-boiling-point, fatty acids. The SPME and purge and trap methods were effective in extracting the more volatile compounds adsorbed in the airborne dust. The SPME CAR/PDMS fiber extracted the low to mid boiling point compounds like the fatty acids, phenols and indoles, whereas the PDMS fiber extracted more of the mid boiling point compounds, specifically the aliphatic hydrocarbons. Purge and trap method extracted compounds with low to mid boiling points. Most of these compounds are also present in the air of swine buildings. The major compounds identified were carboxylic acids, aldehydes, alcohols, ketones, hydrocarbons, phenols, indoles, phthalates, and esters.

FT-Raman spectra of unsoaked and NaOH-soaked wheat kernels, bran, and ferulic acid.

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

The NaOH test for determining wheat color class depends on the observation that upon soaking in NaOH, red wheat turns a darker red and white wheat turns straw yellow. To understand the mechanism of this test, Raman spectra of wheat bran, wheat starch, ferulic acid, and whole kernels of wheat, before and after NaOH soak, were studied. The major observable components in the whole kernel were that of starch, protein, and ferulic acid, perhaps esterified to arabinoxylan and sterols. When kernels are soaked in NaOH, spectral bands due to ferulic acid shift to lower energy and show a slightly-reduced intensity which is consistent with deprotonation of the phenolic group and extraction of a portion of the ferulic acid into solution. Other phenolic acids, alkyl resorcinols, and flavonoids found in the NaOH extracts of wheat by high performance liquid-chromatography were not observed in the Raman spectra. Wheat bran accounts for most of the ferulic acid in the whole kernel, as indicated by the increased intensity of the doublet at 1,631 and 1,600/cm in the bran. The intense starch band at 480/cm found in the whole kernel of wheat was nearly absent in the wheat bran.

Use of optical sorting to detect wheat kernels infected with Tilletia indica.

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

Tilletia indica is subject to international regulation by 78 countries, and U.S. economic losses could exceed $1 billion if *T. indica* was found throughout major wheat producing regions causing wheat exports to be halted. Currently, samples are inspected manually for the presence of kernels with Karnal bunt as part of routine survey methods. However, this visual procedure of inspecting all seeds in a sample can result in harvest delays due to long inspection times, and missed kernels due to inspector fatigue. A high-speed sorter was tested to determine if infected kernels could be rapidly removed 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. Each sample was sorted 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 bunted grains from seed wheat and wheat destined for food or feed use.

Detecting single wheat kernels containing live or dead insects using near-infrared reflectance spectroscopy.

E.B. Maghirang, F.E. Dowell, J.E. Baker, and J.E. Throne.

An automated NIR system was used over a two-month storage period to detect single wheat kernels that contained live or dead internal rice weevils at various stages of growth. Correct classification of sound kernels and kernels containing live pupae, large larvae, medium-sized larvae, and small larvae averaged 94, 92, 84, and 62 %, respectively. Wheat kernels containing either live or dead insects were used to develop pupae + large larvae calibrations for detecting both live and dead insects in wheat. Validation results showed correct classifications ranging from 86 to 96 % over the 2-month storage period. The important wavelengths for detecting internal insects across the 2-month storage period included 990 nm (starch); 1,135 and 1,670 nm (rice weevil cuticular lipids); 1,425 nm (insect moisture); and 1,210, 1,325, 1,370, 1,395, and 1,610 nm (C–H first and second overtones and C–H combination bond vibrations). The data provided evidence that the physical or biochemical differences detected by NIR for live insects are generally the same factors detected by NIR for dead insects over a two-month storage period. These findings showed that NIR calibrations for internal insect detection can be done using kernels containing either live or dead insects; this will impact how calibration samples can be handled. Immediate sample processing may no longer be necessary; internal insects can be killed and calibrations can be created at a later time without sacrificing accuracy. Additionally, these same calibration samples can be shared across locations or laboratories resulting in savings in time and resources.

Automated detection of hidden internal insect infestations in wheat kernels using electrical conductance.

T.C. Pearson and D. Brabec.

The wheat industry is in need of an automated, economical, and rapid means to detect whole wheat kernels internally infested with insects. The feasibility of the Perten single-kernel characterization system (SKCS) to detect internal insect infestations was studied. The SKCS monitors compression force and electrical conductance as individual kernels are being crushed. Samples of HRWW and SRWW infested with rice weevil and lesser grain borer were run through the SKCS and the conductance/crush signals saved for post-run processing. We found that a discontinuity is often present in the conductance signal of an insect-infested kernel. An algorithm was developed to classify kernels as infested, based on features of the conductance signal. Average classification accuracies for all wheat samples were 24.5 % for small-sized larvae, 62.2 % for medium-sized larvae, 87.5 % for large-sized larvae, and 88.6 % for pupae. There were no false positives (sound kernels classified as infested). The classification algorithm is robust for a wide range of moisture contents. Classification accuracy was somewhat better for kernels infested with rice weevils than for lesser grain borer, and classification accuracy was better for HRWW than for SRWW.

Controlled aeration.

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

Controlled aeration is an improved technique for cooling stored grain and preventing deterioration from molds and insects. By automating control of the fans with a simple reliable control system, fan operation is much easier for the operator and the aeration process will be more efficient and effective than can be achieved by manual operation. However, controlled aeration is only part of an effective storage management plan. Controlled aeration and other important aspects of grain storage management are required to maintain stored grain quality.

Temperature monitoring and aeration strategies for stored wheat in the central plains.

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

Two aeration strategies were compared to no aeration in field tests of stored wheat in Kansas. An additional summer aeration cycle before the usual two autumn cycles produced better temperatures for insect control in the grain. Both aeration strategies yielded much better temperatures for insect control than did the naturally cooled, unaerated bin (~ 3,500 bu/bin). In 2 years of tests with wheat aerated with low airflow rates in summer immediately after harvest, there were sufficient hours with air temperatures below 24°C (75°F) to cool the grain with an airflow rate of 0.11 m^3/min-t (0.1 cfm/bu). However, during one year, high humidities during these nighttime periods of low temperatures resulted in final temperatures higher than 24°C because of the heating effect when the grain was slightly rewetted by the high humidity air. These results demonstrate the importance of looking at both temperature and humidity together to evaluate weather conditions for adequate cooling potential, especially during summer aeration when air temperatures are near the upper acceptable limit.

Accuracy and feasibility of measuring characteristics of single kernels using near-infrared spectroscopy.

F.E. Dowell and E.B. Maghirang.

Single-kernel near-infrared spectroscopy has been used to measure many grain attributes such as protein, oil, internal insects, transgenic traits, and fungal damage. Analysis of single kernels instead of bulk samples has the advantage of detecting attributes that may only be present in a few kernels in a sample and also can give the distribution of measured attributes.

Evaluation of a high-speed color sorter for segregation of red and white wheat.

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

A high-speed color sorter has the potential to help wheat breeders purify their white wheat breeding lines and white wheat exporters meet purity requirements of end users. For this reason, a commercial color sorter was evaluated for sorting mixed red and white wheat. Ten wheat blends containing 95 % white and 5 % red wheat by mass were produced by mixing common cultivars of hard white and hard red winter wheat. The sorter was set to accept white wheat and reject red wheat in single pass when viewed by either a green or red filter. Percentages of red and white wheat in the accept and reject portions were determined by soaking in sodium hydroxide, a definitive method for determining if a wheat kernel is red or white. In order to reject most of the red wheat in a single pass through the sorter, at least 15 % of the original wheat mass needed to be rejected. F or wheat blends with white wheat of consistent color that contrasted considerably with the red wheat contaminant, this rejection would reduce red wheat mass in the accept portion to <1 %. This reduction could be achieved for most other blends when rejecting 20–25 % of the mass or through resorting the accept portion. The red filter resulted in more red kernels rejected than the green filter.

Determining wheat vitreousness using image processing and a neural network.

N. Wang, F.E. Dowell, and N. Zhang.

The GrainCheck 310 is a real-time, image-based wheat quality inspection machine that can replace tedious visual inspections for purity, color, and size characteristics of grains. This machine also has the potential for measuring the vitreousness of durum wheat. Different neural-network calibration models were developed to classify vitreous and nonvitreous kernels and evaluated using samples from GIPSA and from fields in North Dakota. Model transferability between different inspection machines was also tested.

Single-kernel protein variance structure in commercial fields in western Kansas.

T. Bramble, T.J. Herrman, T. Loughin, and F.E. Dowell.

Research was undertaken to quantify the structure of protein variation in a commercial HRWW production system. This information will augment our knowledge and practices of sampling, segregation, marketing, and varietal development to improve uniformity and end-use quality of HRWW. The allocation of kernel-protein variance to specific components in southwestern Kansas was performed using a hierarchical sampling design. The variance structure included fields, plots within fields, rows within plots, plants within rows, heads on a single plant, spikelet position on a single head, and kernels within a spikelet. Individual kernels (10,150) were collected from 47 fields planted to one of the following four cultivars: Jagger, 2137, Ike, or TAM 107. Kernels were evaluated for protein concentration using a single kernel characterization system equipped with a diode array NIR spectrometer (SKCS 4170). For the cultivars Jagger, 2137, and Ike, all sources of variability except kernels within a spikelet were statistically significant ($P < 0.05$). For TAM 107, variation attributed to fields and plants within fields were not significant; however, the remaining sources of variability were significant ($P < 0.05$). Field and plot sources of variability contributed the greatest amount of variance within the hierarchy for Jagger, 2137, and Ike. For TAM 107, plot was the greatest source of variability. The least squares means were calculated for the fixed effect spikelet position on a head. Jagger, Ike, and 2137 showed a significant protein gradient in which the highest protein concentration occurred at the base of the head and the lowest protein content at the top. For TAM 107, the greatest protein content was found at the base; however, the middle spikelet contained the lowest protein content followed by the top most spikelet.

Accuracy and repeatability of protein content measurements for wheat during storage.

M.E. Casada and K. O’Brien.

Producers with wheat stored on-farm for a few months are concerned about unexpected decreases in protein content measurements obtained from commercial laboratories. These differences can adversely affect the price when the wheat is sold. This study evaluated the contribution of measurement errors in giving a false indication of protein change during storage. Eleven bins of wheat were sampled at three in-bin positions during one storage season and five of these bins were refilled and sampled during the second season to evaluate differences in protein measurements. Samples were analyzed for protein content using four measurement instruments. Additional wheat was stored in the laboratory and evaluated over two years with two instruments. Data showed that the variation between protein measuring instruments was significant with an expected variation of ± 0.74 % protein content (95 % confidence interval) during the field tests. The variation over time for measurements with the FGIS instrument was ± 0.3 % protein for an 8-month period, when measuring successive samples taken from the same positions. Measurements from the other three instruments varied by ± 0.8 % protein or more during the same time. Variation with in-bin position was not significantly different ($a = 0.05$) than the variation between instruments. The greater consistency for the FGIS instrument was likely due to the rigorous standardization and maintenance procedures employed by FGIS for their NIR protein instruments, indicating that a similar rigorous system is needed to obtain the same consistency for other instruments used in the wheat marketing system.

New scientists–welcome.

P.A. Armstrong, E.B. Maghirang, and M.S. Ram.

Engineering Research Unit. Dr. Paul Armstrong joined the Engineering Research Unit of GMPRC in July. Paul was originally from South Dakota and his family moved to Australia where he received a bachelor's degree in engineering from the University of Southern Queensland. In 1982, he received a master's degree in agricultural engineering from Oklahoma State University and in 1989, he received his Ph.D. in agricultural engineering from Michigan State University. Before joining GMPRC, Paul was the proprietor of Bioworks, Inc. in Stillwater, Oklahoma, where he developed instrumentation to measure the firmness and size of small fruit such as cherries. His research program at GMPRC will focus on grain quality instrument sensors. He is particularly interested in investigating sensors for grain quality trait analysis and in-storage networked sensors for grain quality monitoring.

Engineering Research Unit. Elizabeth Bonifacio-Maghirang joined the Engineering Research Unit in November, 2002, as an agricultural engineer. She received her B.S. and M.S. in agricultural engineering from the University of the Philippines at Los Baños and completed her 2-year postgraduate research in Agricultural Engineering at the University of Illinois at Urbana-Champaign. She also received training from the Universiti Putra Malaysia (formerly Universiti Pertanian Malaysia) on economics for agricultural engineers. Elizabeth has experience as a researcher with the University of the Philippines, International Rice Research Institute, University of Illinois at Urbana-Champaign, and Kansas State University. Her research experience is in the area of grain quality for various commodities such as wheat, rice, corn, sorghum, soybeans, and guar splits. She has expertise in grain quality assessment, grain quality detection and sorting systems using NIR and machine vision, crop processing, economics of grain quality, and research management and coordination. Her responsibilities at the GMPRC include developing quality measurement procedures and instrumentation for grains, oilseeds, and grain and oilseed products, and research management and coördination.

Grain Quality and Structure Research Unit. Dr. M. S. Ram joined the Grain Quality and Structure Research Unit in January, 2003 as a chemist. Dr. Ram received his Ph. D. in chemistry in 1983 from Kent State University (Kent, OH) and was a postdoctoral researcher at Rice University (Houston, Texas), Iowa State University (Ames, IA), Northwestern University (Evanston, IL), Kansas State University, and Grain Marketing and Production Research Center (Manhattan, KS). His recent contributions include the use of an auto-sampler for purge and trap analysis of grain volatiles by GC-IR/MS, development of a standard procedure for NaOH test for wheat color class determination, Raman, and fluorescence spectra of red and white wheat. He will be working with Dr. Okky Chung on super-critical extraction and analysis of lipids from wheat flour and other cereal foods.

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MINNESOTA

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The rusts of wheat in the United States in 2002.

Stem rust. In 2002, the only reports of wheat stem rust in the southern Great Plains were in late April, when light amounts were found in plots in south Texas and southwestern Louisiana. In late May, traces of stem rust were found on wheat in a field and plot of the cultivar 2137 in central Kansas.

In the last week in June, traces of stem rust were observed on susceptible winter wheat cultivars in central and eastcentral South Dakota and southeastern North Dakota plots. In much of the northern Great Plains, high temperatures and dry conditions limited stem rust development.

In the third week in July, the susceptible spring wheat cultivars Baart and Max had trace–20 % stem rust severities in southern Minnesota, eastcentral South Dakota, and southeastern North Dakota plots. At the end of July HRWW fields had traces of stem rust in westcentral Wisconsin and northeastern South Dakota. In late July, susceptible spring wheat plots and fields in central North Dakota had 30 % severities.

Much of the early stem rust development in the northern plains was due to spores deposited with rains in mid-June. The stem rust infections can be attributed to inoculum produced on winter wheat cultivars in the southern Great Plains and to the warm temperatures and high moisture conditions, which were ideal for stem rust infection in some areas of the northern plains. If current spring wheat cultivars were susceptible to stem rust, a serious epidemic with substantial yield losses would have occurred.

In late July, traces of wheat stem rust were found in fields and disease nurseries in western Washington.

Stem rust race virulence. Race QCCJ (Table 1) is the most common stem rust race identified from collections made in the U.S. in 2002. This race is virulent on barley cultivars with the *Rpg1* (T) gene for resistance. QCCJ and most of the other stem rust races identified in 2002 are avirulent to most wheat cultivars. However, a single isolate of TPMK and two isolates of TTTT were collected from susceptible wheat plots in Minnesota. These races have more virulence to rust resistance genes in wheat. TPMK and TTTT races have survived at low levels in the U.S.

Wheat leaf rust. Southern Plains. In early January, traces of leaf rust were found in a nursery in central Texas and by the second week in February 80–100 % severities were on lower leaves and 30 % severities on upper leaves. Freezing temperatures in early March damaged leaves and destroyed rust infected leaf tissue. Drier and cooler weather in March slowed leaf rust development throughout the southern U.S.

In early April, leaf rust was light in fields but severe on susceptible cultivars in nursery plots from central Texas to Georgia. In early April, sufficient moisture in central and southern Texas allowed leaf rust to increase to 70 % severity on flag leaves in plots at College Station and McGregor. At both locations in Texas, cultivars that have *Lr9* (Lockett) or *Lr41* (Thunderbolt) had 70 % leaf rust severities. In drier areas of west Texas, only 5–10 % severities were on lower leaves.

In mid-April, leaf rust was found in fields in trace to light amounts and was severe on susceptible cultivars in plots from central Texas to South Carolina. In early May fields in central Texas, had 60 % rust severities, but the crop rapidly matured, which limited any additional infections. In early May, leaf rust was light in north Texas fields.

Table 1. Races of *Puccinia graminis* f. sp. *tritici* identified from wheat in 2002. Pgt race code after Roelfs and Martens (Phytopathology **78**:526-533). Set four consists of *Sr9a*, *Sr9d*, *Sr10*, and *SrTmp*.

State	Source	Collections	Isolates	Percentage of isolates of Pgt– race															
				QCCJ	QCCQ	QCCS	QCMJ	QCMS	QFCS	QKCJ	QKCS	RCCJ	RCCS	RCMJ	RCMS	TPMK	TTTT
KS	Nursery	1	3	100													
LA	Nursery	1	3		100												
MN	Nursery	6	17	59		18			6							6	12
ND	Field	2	1												100		
ND	Nursery	23	61	69		3	10		2	2		3	2	7	3		
NE	Nursery	2	6	67				17			17						
SD	Nursery	3	9	67			33										
TX	Nursery	3	8				25	38	38								
WA	Nursery	1	3						100								
WI	Nursery	1	3	100													
U.S.	Field	2	1												100		
	Nursery	40	110	62	3	5	10	4	5	1	1	2	1	4	2	1	2
	Total	42	111	61	3	5	10	4	5	1	1	2	1	4	3	1	2

In the second week in March, light amounts of leaf rust were in fields in central Oklahoma. In late March, only traces of leaf rust were found in fields throughout Oklahoma. In early May, leaf rust was light in fields and severe on susceptible cultivars in plots from north central Oklahoma to central Alabama (Fig. 1). In mid-May, leaf rust was severe in plots and fields in central Oklahoma, but the crop was near maturity, which reduced losses.

Central Plains. In mid-May, leaf rust in Kansas was common on the flag leaves of susceptible cultivars in the south central area and light in the northern part of the state.

In the last week in May, leaf rust was severe in plots and fields of susceptible cultivars from central Kansas to westcentral Missouri. In fields of Jagger wheat, at the late berry stage in south central Kansas, there were 60 % severities, whereas Jagger in northeast Kansas had 5 % severities. In central Kansas plots, rust severities ranged from trace to 60 %. In late May, plots at Lincoln, Nebraska, had light leaf rust infections.

In late May, leaf rust severities were 40 % on *Ae. cylindrica* (goatgrass) growing in the roadsides in north central Oklahoma and southcentral Kansas. In 2001 in the same areas, high levels of stripe rust were found on goatgrass.
Leaf rust was severe in the southern part of Kansas in late May. In the second week of June in southeastern Nebraska fields, leaf rust incidence ranged from 30 to 100 %. Drought-like conditions in much of Nebraska slowed leaf rust development for the remainder of the season.

Northern Plains. In mid-June, light infections of leaf rust were on flag leaves of HRWW in eastcentral South Dakota.

In the third week in June, 10 % leaf rust severities were on susceptible winter wheats at anthesis in eastcentral Minnesota plots. Traces of leaf rust were found in two fields in northwestern Minnesota in the third week of June. Weather conditions were ideal for rust infection throughout Minnesota in June.

In the last week in June, rust severities were 60 % on susceptible winter wheat cultivars in east central and southcentral Minnesota plots. During the last week in June, leaf rust on winter wheat was light in central and eastern areas of South Dakota. On a few susceptible cultivars like Jagger and Alliance, leaf rust severities reached 30 %.

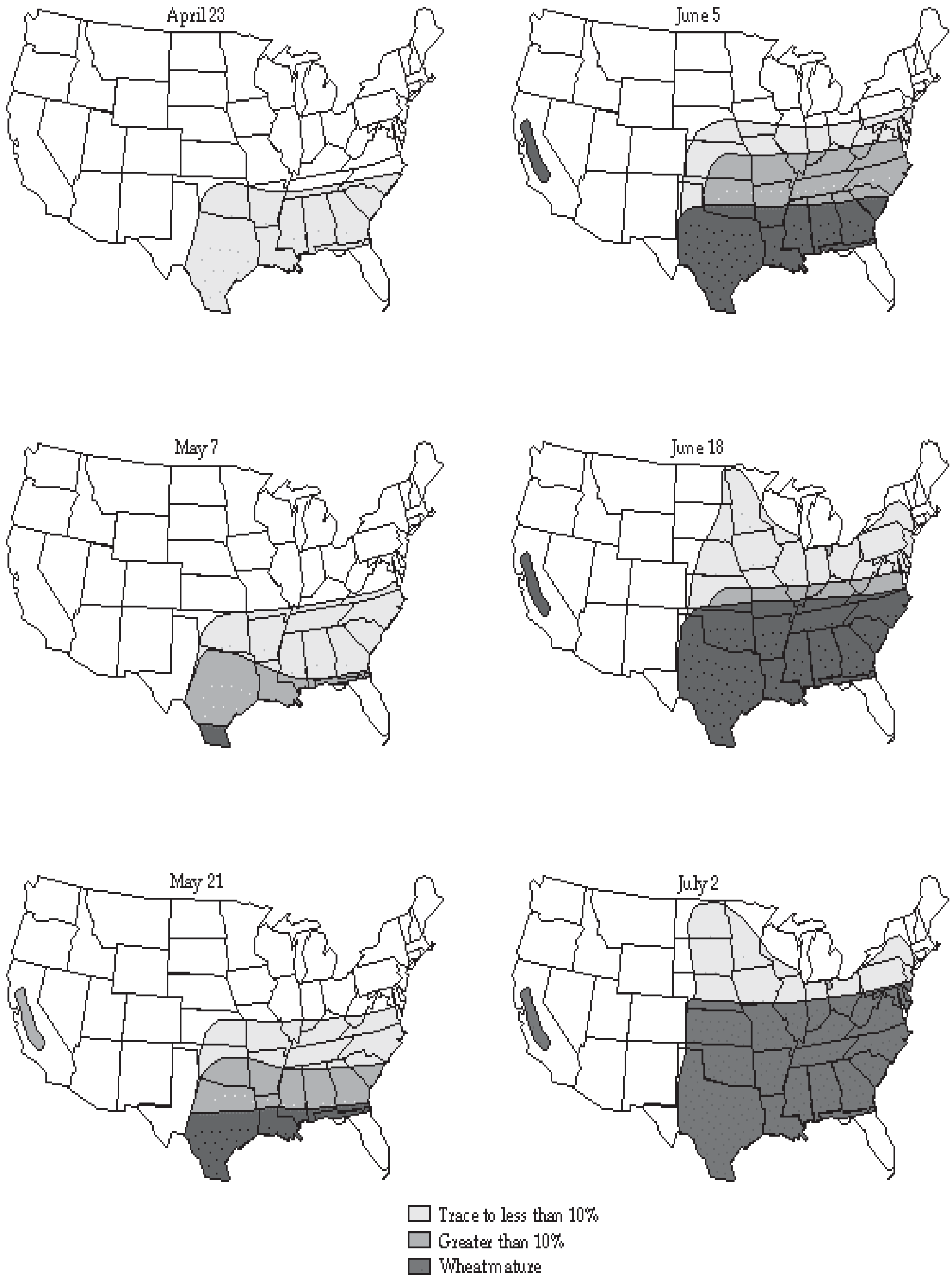

Fig. 1. Leaf rust severities in wheat fields in 2002.

Table 2. Virulence code and corresponding virulence formula for the most commonly identified wheat leaf rust races in 2002.

Race code [1]	Virulence formula [2]	Race code [1]	Virulence formula [2]
MBDS	1, 3, 10, 14a, 17, B	TBRJ	1, 2a, 2c, 3, 3ka, 9, 10, 11, 14a, 30
MBRJ	1, 3, 3ka, 10, 11, 14a, 30	TCTD	1, 2a, 2c, 3, 3ka, 11, 14a, 17, 26, 30
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	TLGJ	1, 2a, 2c, 3, 9, 10, 11, 14a
MCRK	1, 3, 3ka, 10, 11, 14a, 18, 26, 30	TLGS	1, 2a, 2c, 3, 9, 10, 11, 14a, B
MCRT	1, 3, 3ka, 10, 11, 14a, 18, 26, 30, B	TNRJ	1, 2a, 2c, 3, 3ka, 9, 10, 11, 14a, 24, 30
TBBJ	1, 2a, 2c, 3, 10, 14a		

[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.*

The majority of cultivars had only trace levels of infections on the flag leaves. In early June, leaf rust was more severe in Minnesota than in South Dakota since moisture conditions were more favorable for rust in Minnesota. In the last week of June, lower leaves (flag-2) of susceptible spring wheat cultivars had severities of 40 % in southern Minnesota plots. In most of the spring wheat cultivars only traces of rust were observed at this time.

During the fourth week of June, winter wheat plots in eastcentral North Dakota had trace to 20 % rust severities. In the same area, traces of leaf rust were common in fields of spring wheats. In the Fargo, North Dakota nursery, the susceptible cultivar Thatcher had 30 % rust severity. In mid-July, durum lines at the Carrington research center in central North Dakota had 30 % leaf rust severities.

In the third week in July, spring wheat fields had trace–40 % leaf severities in plots in southeastern North Dakota and westcentral and southern Minnesota. In early August, leaf rust was present at high severity in the Red River Valley of Minnesota and North Dakota. In many wheat fields the leaves dried prematurely due to the heavy leaf rust infections combined with high temperatures. Many wheat fields were sprayed with fungicide to reduce leaf rust severities. In the Red River Valley the commonly grown wheat cultivars had 40 % severity levels of leaf rust. High levels of leaf rust were in fields in central and southeastern North Dakota. In the northern tier of counties of North Dakota leaf rust was at reduced levels due to very dry conditions. The wheat in this area was in poor condition due to drought stress.

Most of the spring wheat cultivars currently grown are moderately susceptible to leaf rust. Significant economic losses due to leaf rust occurred in northwestern Minnesota and eastern North Dakota (Table 5).

Southeast. In mid-December 2001, light infections of leaf rust development were uniform on lower leaves in a northeastern Arkansas wheat field. In mid-January, light leaf rust infections were observed on entries in a nursery in southwestern Arkansas. In mid-February, light infections of leaf rust were found throughout Arkansas in plots and fields. In the third week in February, infections that overwintered were observed in northwestern Arkansas and in plots of wheat in southwestern Arkansas. Because of the cold weather in mid-March, there were no signs of leaf rust in northwestern Arkansas wheat plots. In the last week in April, northeastern Arkansas wheat plots had 10 % leaf rust severities and fields had trace levels of infection. In late January, leaf rust was reported in northeastern Louisiana plots. In mid-February, susceptible cultivars in southern Louisiana had 20 % leaf rust severities.

During the second week in February, light amounts of leaf rust were found on the cultivar Coker 9835 in a southcentral Georgia nursery. In late February, rust levels were severe in the vicinity of the initial focus indicating this was a likely overwintering site.

In mid-April, from northeastern Louisiana through Alabama and Georgia to North Carolina, trace to light amounts of leaf rust were observed in wheat plots. Leaf rust was widely present in at least trace amounts throughout the winter wheat area of the southern plains and the southeastern states.

Table 3. Races of *Puccinia triticina* identified from wheat collections in 2002. States grouped according to agroecological area (1–8), see Plant Dis 86:15-19. Numbers in last two rows indicate total number of isolates and total number of races identified.

Percent of isolates per state

	1							2				3							4			5	6				7	8	
Code	AL	AR	FL	GA	LA	MS	Total	MD	NY	VA	Total	IL	IN	KY	MO	OH	WI	Total	OK	TX	Total	KS	MN	ND	SD	Total	CA	WA	USA
MBDS	0	8	0	4	6	0	3	0	0	0	0	0	13	0	0	0	0	4	45	30	32	61	47	17	26	31	18	0	24.6
MBRJ	11	0	0	13	0	0	7	0	0	0	0	43	25	0	0	0	0	15	0	1	1	0	0	2	0	1	2	0	3.1
MBRK	4	0	0	0	9	0	4	0	0	18	14	0	0	0	0	29	33	9	0	0	0	0	2	0	0	1	0	0	1.9
MCDS	0	25	0	6	0	0	3	0	0	0	0	14	0	0	33	0	0	7	0	10	9	10	3	9	16	7	30	0	7.9
MCRK	19	0	0	4	2	0	7	100	0	18	29	0	0	50	0	0	0	4	0	0	0	0	0	0	0	0	0	0	2.3
MCRT	0	0	0	0	0	0	0	0	0	18	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3
TBBJ	4	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	4	13	10	10	0	0	3.4
TBRJ	0	0	0	0	0	0	0	0	0	0	0	0	6	50	0	0	0	7	0	0	0	0	1	0	0	0	0	0	0.5
TCTD	0	0	0	0	0	0	0	0	0	36	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5
THBJ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	8	0	14	17	23	16	0	0	6.8
TLGJ	9	8	0	33	30	0	22	0	0	9	7	14	25	0	33	0	0	15	0	4	3	0	2	0	0	1	0	0	7.0
TLGS	9	17	0	0	15	0	8	0	0	0	0	14	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	1.9
TNRJ	0	17	40	0	2	0	3	0	0	0	0	0	6	0	0	0	0	2	30	20	21	3	3	0	0	1	0	0	6.1
No. isol	47	12	5	54	54	9	181	2	1	11	14	7	16	4	6	7	6	46	20	153	173	72	110	109	31	250	44	5	785
Races	15	8	4	15	16	5	63	2	2	6	10	6	9	3	4	5	4	31	7	24	31	12	20	19	9	48	7	3	67

In early May, from central Louisiana to central Alabama, susceptible cultivars had 60 % leaf rust severities and resistant cultivars had trace levels of infection in nursery plots. In some locations, like eastcentral Alabama, where conditions were drier, susceptible cultivars had leaf rust severities of 10–20 %. In 2002, leaf rust was scattered and more severe than 2001 throughout the southeastern winter wheat area of the U.S.

East. In mid-December, leaf rust was easily found on the cultivar Saluda at Kinston, North Carolina. In mid-May, moderately severe leaf rust was reported in eastern Virginia plots. In late May, light leaf rust was reported in Blacksburg (western Virginia) plots. In early June, susceptible cultivars in a nursery in western Virginia and east central Maryland had 50–75 % leaf rust severities. Traces of leaf rust were found in central New York fields in mid-June. In mid-June, light leaf rust was observed in southwestern Ontario. In 2002, leaf rust was observed throughout the eastern SRWW area.

Ohio Valley. In the second week in June, plots of SRWW had trace–40 % leaf rust severities and traces in fields from north-eastern Missouri to northwestern Ohio (Fig. 1) at the early to late berry maturity stage. One field of susceptible wheat in northwestern Ohio had 60 % severities.

California. In early May, wheat fields in the Sacramento Valley of California had 75 % leaf rust severities. Rust development was reduced in California this year because of the dry conditions in March and April.

In mid-May, leaf rust of wheat had spread throughout the Central Valley of California. In the southern San Joaquin Valley, lines and cultivars in nurseries had 40 % severities. Leaf rust was also found on a few durum wheat cultivars and lines and moderate severity was reported on one triticale cultivar. During the third week in May, leaf rust was severe on flag leaves in most commercial wheat fields throughout the Sacramento Valley, obscuring the stripe rust that occurred earlier in the season on some of the same cultivars in the region.

Table 4. Estimated losses in winter wheat due to rust in 2002 (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
AL	60	40.0	2,400	0.0	0.0	2.0	49.0	T	T
AR	840	46.0	38,640	0.0	0.0	T	T	5.0	2,033.7
CA	300	75.0	22,500	0.0	0.0	3.0	741.8	6.0	1,483.5
CO	1,650	22.0	36,300	0.0	0.0	0.0	0.0	0.0	0.0
DE	58	70.0	4,060	0.0	0.0	0.0	0.0	0.0	0.0
FL	7	43.0	301	0.0	0.0	T	T	0.0	0.0
GA	200	41.0	8,200	0.0	0.0	1.0	82.8	T	T
ID	690	79.0	54,510	0.1	54.9	0.2	109.9	0.5	274.7
IL	650	49.0	31,850	0.0	0.0	T	T	0.0	0.0
IN	330	53.0	17,490	0.0	0.0	T	T	T	T
IA	16	50.0	800	0.0	0.0	0.0	0.0	0.0	0.0
KS	8,100	33.0	276,300	T	T	1.0	2,700.0	T	T
KY	340	53.0	18,020	0.0	0.0	T	T	0.0	0.0
LA	220	40.0	8,800	0.0	0.0	3.5	299.5	3.0	273.6
MD	180	66.0	11,880	0.0	0.0	T	T	0.0	0.0
MI	490	67.0	32,830	0.0	0.0	T	T	0.0	0.0
MN	30	30.0	900	T	T	T	T	0.0	0.0
MS	205	44.0	9,020	0.0	0.0	2.0	184.1	0.0	0.0
MO	760	45.0	34,200	T	T	1.0	347.2	0.5	173.6
MT	750	28.0	21,000	0.0	0.0	T	T	0.0	0.0
NE	1,520	32.0	48,640	0.0	0.0	T	T	0.0	0.0
NJ	32	58.0	1,856	0.0	0.0	0.0	0.0	0.0	0.0
NM	170	22.0	3,740	0.0	0.0	0.0	0.0	0.0	0.0
NY	128	58.0	7,424	0.0	0.0	T	T	0.0	0.0
NC	480	42.0	20,160	0.0	0.0	T	T	0.0	0.0
ND	70	38.0	2,660	0.0	0.0	T	T	0.0	0.0
OH	810	62.0	50,220	0.0	0.0	T	T	T	T
OK	3,500	28.0	98,000	0.0	0.0	2.0	2,000.0	T	T
OR	710	41.0	29,110	0.1	29.3	0.2	58.7	0.5	146.7
PA	185	54.0	9,900	0.0	0.0	T	T	0.0	0.0
SC	190	37.0	7,030	0.0	0.0	T	T	0.0	0.0
SD	625	29.0	18,125	T	T	1.0	183.1	0.0	0.0
TN	300	46.0	13,800	0.0	0.0	T	T	0.0	0.0
TX	2,700	29.0	78,300	0.0	0.0	2.0	1,614.4	1.0	807.2
UT	125	35.0	4,375	0.0	0.0	0.0	0.0	0.0	0.0
VA	170	63.0	10,710	0.0	0.0	T	T	T	T
WA	1,750	59.0	103,250	0.2	210.0	0.5	523.0	1.0	1,050.4
WV	7	48.0	336	0.0	0.0	0.0	0.0	0.0	0.0
WI	170	62.0	10,540	T	T	T	T	T	T
WY	120	19.0	2,280	0.0	0.0	0.0	0.0	0.0	0.0
Total	29,638	38.5	1,141,547		294.2		8,844.5		6,078.6
U.S. % loss				0.03		0.76		0.53	
U.S. Total	29,651	38.5	1,142,802						

Table 5. Estimated losses in spring wheat due to rust in 2002 (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	24	100.0	2,400	0.0	0.0	0.0	0.0	0.0	0.0
ID	510	65.0	33,150	0.0	0.0	0.2	6.8	0.5	166.9
MN	1,800	34.0	61,200	0.0	0.0	2.0	1,249.0	0.0	0.0
MT	3,500	23.0	80,500	0.0	0.0	T	T	T	T
NV	2	75.0	150	0.0	0.0	0.0	0.0	0.0	0.0
ND	6,000	28.0	168,000	T	T	3.0	5,195.9	0.0	0.0
OR	140	35.0	4,900	0.0	0.0	0.1	4.9	1.0	49.5
SD	1,000	24.0	24,000	0.0	0.0	2.0	489.0	0.0	0.0
UT	11	47.0	517	0.0	0.0	0.0	0.0	0.0	0.0
WA	615	43.0	26,445	0.2	56.7	0.5	141.7	6.0	1,700.6
WI	7	33.0	231	T	T	T	T	0.0	0.0
WY	4	24.0	96	0.0	0.0	0.0	0.0	0.0	0.0
Total	13,613	29.5	401,589		56.7		7,088.1		1,917.0
U.S. % loss				0.01		1.73		0.47	
U.S. Total	14,569	35.2	512,608						

Table 6. Estimated losses in durum wheat due to rust in 2002 (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	89	95.0	8,455	0.0	0.0	0.0	0.0	0.0	0.0
CA	90	100.0	9,000	0.0	0.0	0.0	0.0	0.0	0.0
MN	4	35.0	140	0.0	0.0	0.0	0.0	0.0	0.0
MT	570	22.0	12,540	0.0	0.0	0.0	0.0	0.0	0.0
ND	2,000	25.0	50,000	0.0	0.0	0.0	0.0	0.0	0.0
SD	5	22.0	110	0.0	0.0	0.0	0.0	0.0	0.0
Total	2,758	29.1	80,245		0.0		0.0		0.0
U.S. % loss				0.00		0.00		0.00	
U.S. Total	2,758	29.1	80,245						

Washington. In mid-July, wheat leaf rust was increasing on spring wheats in eastern Washington fields and susceptible wheats in nurseries had 10–20 % severities. In late July, traces of leaf rust were found in commercial fields. Yield losses due to leaf rust were minimal in the PNW this year.

Wheat leaf rust virulence. The 2002 leaf rust race identifications from the most common races identified are presented in Tables 2 and 3. A total of 52 races were found in the U.S. in 2002. From the central and southern Plains the most common races were M-B- (virulent to *Lr1*, *Lr3*, *Lr10*, *Lr17*, +) (Table 3). Many of the MBDS and MCDS races were identified from collections made from Jagger, which is widely grown in the southern and central Plains states. There has been an increase in T— races with virulence to *Lr9* and *Lr10* in the southern SRWW area. There also has been an increase in the number of T— races (TNRS, TNRJ, TNGS and TNGJ) with virulence to *Lr9*, *Lr10*, and *Lr24* in Texas. Many of the T—races with virulence to *Lr9* and *Lr24* were identified from collections made from the cultivars Lockett (*Lr9* resistance) and Thunderbolt (*Lr41* resistance). Race MBBJ was the predominant race found in California as it has been for the past 10 years.

Yield loss estimates due to leaf rust are in Table 4 (winter wheats) and Table 5 (spring and durum wheats).

Wheat stripe rust. Great Plains. In mid-January 2002, hot spots (70–80 % severities) of stripe rust infection were found in central Texas wheat plots. This indicated that stripe rust may have overwintered in this region. In early February, stripe rust was light in plots in southern Texas. In early March, stripe rust was slowed by cold temperatures in southern Texas plots, but was at 50–70 % severity on lower leaves. The cold temperatures in early March damaged leaves and destroyed much of the rust infected leaf tissue. In the third week in March, rain improved conditions for rust development in much of central and southern Texas. Stripe rust requires cool temperatures (generally less than 70°F) and moist conditions for infection and development. In 2002, stripe rust was widespread and survived the cold temperatures in early March in greater amounts than leaf rust.

In early April, light stripe rust was found in wheat fields in southern and central Texas and from trace amounts to approximately 40 % severity in southern Texas nurseries. Stripe rust severities on SRWW cultivars generally were higher than those on the HRWW cultivars in the southern and central Texas nurseries. Jagger and Cutter were two cultivars that had the best stripe rust resistance in the Uvalde nursery in southern Texas.

By mid-April**,** wheat stripe rust development in central Texas had slowed in some areas, but was still active despite the warm weather in southcentral Texas. From initial collections made in central Texas race PST-79 was identified. This race was very prevalent in Texas and Great Plains in 2001. By late April, the warmer temperatures slowed stripe rust development in central Texas and eastern Oklahoma.

In the first week in May**,** wheat stripe rust was still active on some cultivars in northern Texas plots. In early May, severe wheat stripe rust was reported in north central Oklahoma plots; in fields in the same area rust was light or not found. In early May, stripe rust was observed in southcentral Kansas. In mid-May, a 2-meter foci of stripe rust was found in a plot of the highly susceptible cultivar Lakin in northeastern Kansas. In late May, traces of stripe rust were found in central and southern Kansas plots and fields (Fig. 2). In late May, traces of stripe rust were found in wheat plots in eastcentral Nebraska.

Much less stripe rust was found in Oklahoma and Kansas in 2002 than in 2001. In both years, cool spring and night temperatures in the 40s and 50s, plus humid weather were conducive for stripe rust development throughout the Great Plains.

Louisiana, Arkansas and Missouri. In mid-March, stripe rust was severe in plots in a southern Louisiana. In mid-April, northeastern Louisiana fields had stripe rust infections of 40 % severity. Across all of Louisiana, stripe rust was at moderate levels, and a number of fields were sprayed with fungicides to reduce yield losses. Significant amounts of stripe rust have occurred in three of the last 5 years in Louisiana. Wheat lines Coker 9663 and AGS 2000 were resistant to stripe rust in Louisiana.

By the third week in February, foci of rust infection were in northwestern Arkansas fields and in plots in southwestern Arkansas. In late March, stripe rust was found in fields and cultivar demonstration plots in eastcentral Arkansas. In mid-April, warm weather slowed the development of stripe rust in Arkansas. In the first week in May, stripe rust development had slowed in southern Arkansas but in the northern part of the state, rust infections were still viable.

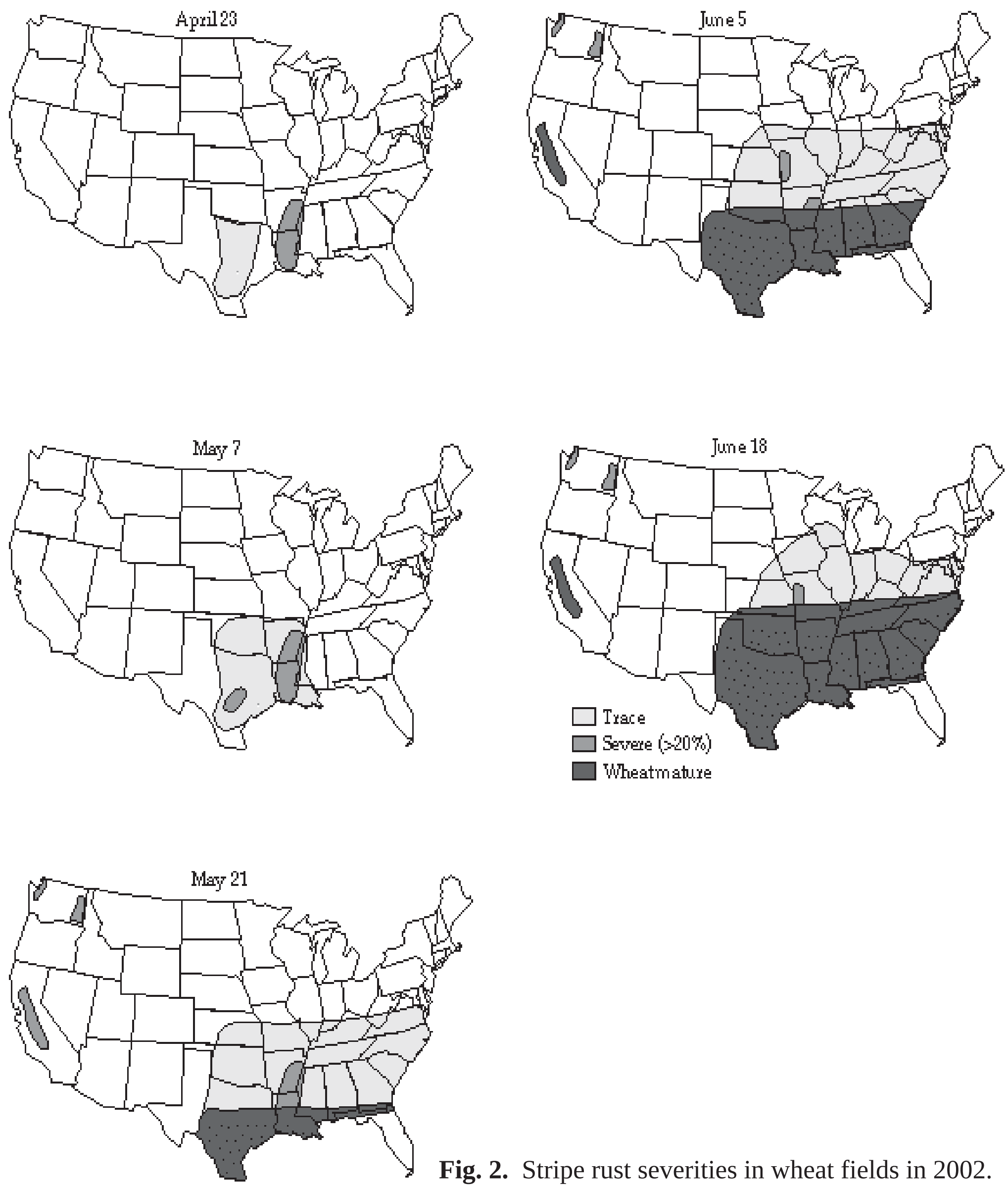

Fig. 2. Stripe rust severities in wheat fields in 2002.

In 2002, stripe rust developed in the lower Mississippi Valley area. Stripe rust caused significant yield losses in Arkansas in 2002 (Table 4). Infection levels of up to 95 % severity at flowering stage were seen in fields and research plots. The fungicide Tilt was widely used to reduce stripe rust infections and yield losses. Stripe rust was not as severe in Arkansas as in 2000, because the cultivar CK 9663 (which comprises half of the acreage) was more resistant in 2002.

In the third week in May, soft red cultivars at the late-berry stage in westcentral Missouri had 40 % stripe rust severities. Weather conditions were conducive for the stripe rust inoculum coming from infection sites in Louisiana leading to increased stripe rust in Arkansas and Missouri. In 2002 more stripe rust overwintering sites occurred further east in the U.S. These focal points of stripe rust originated from infections that were established in the autumn of 2001. A general relationship exists between rust severity and the amount of rust that has overwintered.

Southeast. In mid-April, light amounts of stripe rust were found in southern Alabama wheat plots. In early May, stripe rust was found in plots in northcentral Alabama. Severities ranged from traces to 40 %.

Virginia and Maryland. In mid-May, traces of stripe rust were found scattered throughout the state of Virginia. In late May, wheat stripe rust was higher than normal in the plots at the Blacksburg, Virginia. In mid-June, stripe rust was found in eastcentral Maryland plots.

Ohio Valley. During the third week in May, stripe rust foci were found in plots in southwest Indiana. The wheat was in the early milk stage. In mid-June, fields of SRWW cultivars in northeastern Missouri to northwestern Ohio had trace to 10 % stripe rust severities (Fig. 2). In mid-June, traces of stripe rust were found in winter wheat plots in southcentral Wisconsin.

California. By late April, moderate to severe wheat stripe rust was reported on susceptible cultivars in the Sacramento/San Joaquin Valley Delta and the Sacramento Valley. In mid-May, stripe rust of wheat had spread throughout the Central Valley of California. In the San Joaquin Valley, some durum wheat cultivars also had stripe rust infections, but at lower levels than hard red wheat. In 2002, stripe rust development in California was less than normal because of the drought-like conditions in late winter.

Pacific Northwest. The 2002 wheat stripe rust epidemic was the most severe in the last 5 years in the PNW. Stripe rust severity of 100 % occurred on susceptible entries in wheat nurseries in western Oregon, western Washington, eastern Washington, and northern Idaho. Although some susceptible winter wheat cultivars had severe rust, the stripe rust epidemic mainly affected spring wheat crops in eastern Washington and northern Idaho. The recently released cultivar Zak, which was grown on over 93,000 acres in Washington and ranked the No. 2 spring wheat cultivar in 2002, was susceptible. Most of the susceptible spring wheat fields were sprayed with fungicides. Stripe rust caused multimillion-dollar losses including fungicide cost and application (Table 5).

Race PST-78 (virulent on Lemhi, Heines VII, Lee, Fielder, Express, *Yr8*, *Yr9*, Clement, and Compair) and similar races, which were predominant in California, southcentral states, and the Great Plains in 2000, 2001, and/or 2002, became prevalent in the PNW in 2002. The relatively warm winter and cool weather in spring and summer were favorable to survival and development of the rust. The relatively large acreage of susceptible cultivars like Zak made the severe and large-scale epidemics possible. Fortunately, the No. 1 spring wheat cultivar Alpowa (about 280,000 acres in Washington) and most of winter wheat cultivars (over 70 % of total wheat acreage in Washington) still showed good high-temperature, adult-plant resistance.

MISSOURI

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2002 Missouri winter wheat crop.

Crop statistics. Missouri's wheat crop was harvested from 760,000 acres, equal to the 2001 acreage and down from 1,000,000 acres harvested in 2000. Statewide, yields averaged 44 bushels, down 10 bu/acre from that reported in 2001. Total Missouri production was 33.4 x 10^6 bu with the highest regional production being in the southeast (11.1 x 10^6 bu).

Winter Wheat Performance Tests. The statewide yield of SRWW cultivars tested in 2002 was 55.7 bu/acre, down 7.3 bu/acre from the 2001 test average of 63.0 bu/acre. Statewide yields were down 15.3 bu/acre from the record high yield (71.0 bu/acre) recorded in 1997. Average yields across the six test locations ranged from 39.3 bu/acre at Lamar to 75.0 bu/acre at Trenton. Average regional yields ranged from 41.7 bu/acre in the southwestern region to 58.5 bu/acre in the southeastern region to a high of and 63.2 bu/acre in the northern region of the state.

MO 980725, an experimental line from the university of Missouri's wheat-breeding program, was the highest yielding SRWW tested, averaging 64.3 bu/acre statewide. Five proprietary cultivars, including Excel 400-1 (63.7 bu/acre), MFA Brand 2020 (63.0 bu/acre), Lewis 864 (62.2 bu/acre), MFA Brand 1828 (62.1 bu/acre), and MFA brand 766 (61.5 bu/acre), did not differ significantly in yield from MO 980725. Two other University of Missouri experimental lines, MO 980525 (63.3 bu/acre) and MO 960903 (61.0 bu/acre), rounded out the top yield group. Release of both MO 980725 and MO 980525 is anticipated. Both of these lines have exceptionally high levels of scab resistance

Regional test weights varied significantly due to differential environmental conditions and disease pressures during the 2002 crop season. Statewide, the average test weight was 56.7 lb/bu, down 1.3 lb/bu from the statewide average of 58.0 lb/bu recorded in 2001. Location averages ranged from a low of 54.0 lb/bu at Novelty where disease pressure from FHB was significant, to a high of 58.6 lb/bu at Columbia. Statewide, VA 98W-593 had the heaviest test weight (59.5 lb/bu). Roane (59.3 lb/bu) and Lewis 864 (58.9 lb/bu) did not differ significantly from VA 98W-593.

Complete results of the 2002 Missouri Winter Wheat Performance Tests are available on the WWW under Crop Performance Testing at: http://www.agebb.missouri.edu.

Wheat genetics research.

J.P. Gustafson, K. Ross, T. Chikmawati, J. Layton, X. Ma, A. Mahmoud, Miftahuddin, and M. Rodriguez.

The genes governing Al tolerance on the 4DL and 4RL arms of wheat and rye, respectively, have been bracketed by AFLP and SSR markers using a BAC clone from rice and EST clones from wheat. Our results indicate that a single Al-tolerance (*Alt3*) gene controls Al tolerance in our rye RIL population derived from a cross between Al-tolerant and AL-sensitive parents. An attempt to construct a high-resolution map of the gene region was initiated by developing codominant PCR markers flanking the gene. One simple codominant PCR marker, SUT1, was developed using primers derived from a rice BAC end. In addition, an EST approach was used to analyze changes in gene expression in roots of rye when grown under Al stress. Two cDNA libraries were constructed (Al ssed and unstressed), and a total of 1,194 and 774 ESTs were generated, respectively. In order to understand the mechanisms responsible for Al toxicity and tolerance in plants, we utilized an EST approach to analyze changes in gene expression in roots of rye when placed under Al stress. In this manner, we were able to study the response of rye roots when placed in Al. Out of all the genes analyzed, we were able to locate 13 that showed significant levels of increased expression when grown in toxic levels of Al.

Fusarium head blight research.

A.L. McKendry, D.N. Tague, J.A. Tremain, R.L. Wright, S. Liu, and Z. Abate.

Germ plasm evaluation. We have hypothesized that germ plasm from different geographical regions may possess genes for scab resistance that differ from those currently in use and that these potentially new sources of resistance may complement those already in use to improve either effectiveness or the stability of the scab resistance in breeding programs. Winter wheat germ plasm research over the past 4 years has resulted in evaluation of scab resistance (types I and II and kernel quality) for 4,262 winter wheat accessions. Among these accessions, approximately 180 have shown intermediate to good levels of resistance in replicated testing, however, no accessions with immunity have been observed. Lines possessing resistance on initial screening followed by two subsequent generations of verification have been made available upon request to breeders for incorporation in to breeding programs nationally.

In addition to accessions currently housed in the National Small Grains Collection at Aberdeen, Idaho, researchers worldwide are actively searching for and combining genes for resistance into their own breeding materials. Through a collaborative research agreement with CIMMYT, we are attempting to identify and acquire sources of resistance in improved genetic backgrounds from scab researchers globally. Approximately 320 lines have been introduced into the U.S. through this collaborative effort. Because the putative scab-resistance genes in many of these lines, are in improved genetic backgrounds, this germ plasm also may contain resistance to other important U.S. pathogens (e.g., *Septoria* spp., leaf rust, and BYDV).

Genetics of resistance to Fusarium head blight. Studies investigating the inheritance of scab resistance in Ernie are ongoing. A set of populations (F1, reciprocal F_1, F_2, BC_1, and BC_2) from the cross 'Ernie/MO 94-317' (a high-yielding, scab-susceptible parent) were developed and a replicated six-generation means analysis experiment currently is being completed. Data will be published in the autumn of 2003. A QTL associated with scab resistance in Ernie measured as either disease spread or as the FHB index, are being identified using AFLP and SSR markers in a set of 300 recombinant inbred lines developed from the above cross. To date, QTL on 3B (different region from Sumai 3), 4B, and 5A have been found that are associated with both FHB index and spread, whereas separate QTL on 2B and 2D have been linked to FHB index and spread, respectively. Work continues to construct a fine map of these chromosome regions. QTL for days-to-flower and for spike length also are being mapped and interactions among these QTL will be investigated.

Personnel.

Kara Bestgen, who has been with the scab germ plasm program for the past 4 years, has returned to school. Jessica Tremain, M.S. University of Missouri, has replaced her in this position. Gordana Surlan Momorovic is a visiting scientist.

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NEBRASKA

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Wheat production in Nebraska in 2001 to 2002.

The 2002 Nebraska Wheat Crop was estimated at 48,600,000 bu, which represented a 32 bu/acre state average yield on 1,520,000 harvested acres. Winter wheat was planted on 1,650,000 acres. The 2002 crop was the smallest crop since 1944 and had the lowest yield since 1991. Despite continued genetic improvement, the main determinant in wheat production seems to be acres harvested, government programs, and weather (which also affects disease pressure). Drought was the main cause for these low yields. Alliance (16.6 % of the state) continued to be the most popular cultivar in Nebraska, followed by Arapahoe. Pronghorn is the third most widely grown cultivar followed by 2137 and Niobrara. Cultivars developed by the coöperative of USDA–University of Nebraska wheat improvement program occupied 75 % of the state acreage, other public cultivars occupied 17 %, and private cultivars occupied 8 % of the state acreage.

New red wheat cultivars.

In 2002, **Harry** and **Goodstreak** were recommended for release with foundation seed distributed in 2002. In addition, NE97638 (a sister line to Harry) and NE97426 (an awnless line) were recommended for licensing with seed available in 2002. All of the lines will be sold with a research and development fee assessed at $0.01/pound of seed sold. In the case of Harry and Goodstreak, the research and development fee will be assessed on certified seed sold. For licensed lines, certified and quality assured seed may be sold, hence the assessment may be slightly different.

Goodstreak (PI 632434) is a HRWW cultivar developed coöperatively by the Nebraska Agricultural Experiment Station and the USDA–ARS and released in 2002 by the developing institutions and the Wyoming Agricultural Experiment Station. Goodstreak was released primarily for its superior adaptation to rainfed wheat-production systems in western Nebraska where conventional height wheat cultivars with long coleoptiles are needed for good emergence and harvest in low-moisture conditions. The name was chosen for the area in which it will most likely be grown, known as Goodstreak, because the grasslands were better than the surrounding areas. In this area, drought is common and Goodstreak is an indication that water use efficient annual crops, such as wheat can be grown. The release notice can be accessed at http://agronomy.unl.edu/grain/goodstreakrelwy.PDF.

In positioning Goodstreak, based on performance data to date, it is best adapted to low-rainfed wheat-production systems where conventional height wheat cultivars are grown. Where it is adapted, Goodstreak should be a good replacement for Buckskin, because it has higher yield potential, similar straw strength, and superior disease and insect resistances. Goodstreak is genetically complementary to 2137, Alliance, Buckskin, Culver, Jagger, Millennium, Niobrara, Pronghorn, Vista, and Windstar. Goodstreak was developed with partial financial support from the Nebraska Wheat Development, Utilization, and Marketing Board.

Harry (PI 6322435) is a HRWW cultivar developed coöperatively by the Nebraska Agricultural Experiment Station and the USDA–ARS and released in 2002 by the developing institutions. Harry was released primarily for its superior adaptation to rainfed wheat-production systems in western Nebraska. The name Harry was chosen to honor Mr. Harry Cullan, deceased, who was a proponent of well-adapted cultivars and certified-seed production in western Nebraska. The release notice for Harry can be accessed at http://agronomy.unl.edu/grain/harryrel.PDF.

In positioning Harry, based on performance data to date, it should be well adapted to most rainfed wheat-production systems in western Nebraska and in adjacent states with similar growing seasons where its later maturity and full-season, grain-filling capabilities are favored except in times of drought. Being a later maturity wheat may explain its exceptional performance in the Northern Regional Performance Nursery, where later wheat genotypes (by Nebraska standards) are preferred. Where adapted, Harry should be a good replacement for Arapahoe, Windstar, and 2137, because it has a higher yield potential and similar or superior disease and insect resistances. Harry is genetically complementary to 2137, Alliance, Buckskin, Jagger, Pronghorn, and Windstar, but is noncomplementary to Arapahoe, Culver, Millennium, Niobrara, and Vista. Harry was developed with partial financial support from the Nebraska Wheat Development, Utilization, and Marketing Board.

Increase of new, experimental wheat lines.

Based on last year's results and our recent releases, we have decided to slow down the release process by 1 year. The feeling was that our seed producers were having trouble knowing which lines to produce and in what quantity. An additional year of testing should greatly help them identify the best lines for production, while minimizing their risk. The new plan will be for us to test lines in the state variety trial for 2 years and then make the release decision (as was done before), but that the seed increase will not be made until after the line is released. Hence, 1 year before foundation seed is available, the seed producers will know which lines are tracking for release and can adjust their seed inventories accordingly.

Five lines were advanced for intermediate-scale increase (goal is to have 1,000 kg of breeder seed) at the Nebraska Foundation Seed Division for possible release in 2004. Five lines were advanced to small-scale increases at the Nebraska Foundation Seed Division. They are

NE97V121	(Pedigree: N87V106/OK88767),
NE98471	(Pedigree: NE90461/NIOBRARA),
NE98632	(Pedigree: NIOBRARA/NE91525),
NI98439	(Pedigree: NE90476/(10Ax88-1643)X10927 592-1-5), and
NE98466	(Pedigree: KS89H50-4/NE90518).

Winter triticale cultivar development.

S. Baenziger, K. Vogel, C. Thompson, and J. Jannink.

Our efforts in forage triticale continue. Our recent releases, NE422T and GroGreen Plus are being well accepted by producers and the market continues to grow, perhaps due to the persistent drought in the Great Plains. One new line, **NE95T426**, which has exceptional grain yield and good autumn forage characteristics (determined by Dr. Carlyle Thompson of Kansas State University, Hays, KS whose help and interest in fostering triticale production is invaluable) is under increase. Our goal will be to develop triticale blends involving NE95T426 with our forage triticales (which are haying or spring-forage types), so that the blend will have good autumn and spring forage potential and will have less costly to produce. Excellent collaborations were established with a team of triticale researchers at Iowa State University (the breeder is Dr. Jean Luc Jannick) who are interested in grain triticale to diversify their cropping systems.

Wheat transformation and tissue-culture studies.

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

Wheat transformation continues to be a key strategic effort in the wheat improvement overall effort. In our current research, we are emphasizing the development of wheat lines with improved FHB resistance as part of the U.S. Wheat and Barely Scab Initiative. To date, we have concentrated on putting in wheat the following genes: a) inhibitors of apoptosis (programmed cell death): *ced9*, *IAP*, and *BCL* X(L), b) lactoferrin and a related derived protein, lactoferricin, and c) related antifungal proteins that have been derived based on similar protein structures. Based on our screening data, it appears that inhibitors of apoptosis, and lactoferrin and lactoferricin inhibit FHB. The level of inhibition in our transgenic lines is less than that of Alsen (an elite FHB-tolerant spring wheat with resistance derived from Sumai 3). However, the tolerance indicates our concept is good.

Chromosome substitution lines.

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

In this research we expect to learn more about the wheat genome so that better breeding strategies can be developed. The work will be in collaboration with Drs. Kent Eskridge, Kulvinder Gill (now the Vogel Chair at Washington State University), and Ismail Dweikat. Dr. Mustafa Erayman, a former graduate student, has continued as a postdoctoral research associate. Mustafa is putting into bins the known probes for chromosome 3A (including the recently developed ESTs) using 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, completed his Ph.D. and evaluated 95 recombinant inbred chromosome lines (RICLs) for Cheyenne (CNN)-Wichita (WI) chromosome 3A lines [e.g. CNN(RICLs3A)] in the field. Because Todd had more replications in each testing location than we have had in the past, he was able to more tightly link markers to traits of interest and to thoroughly study ‘genotype x environment’ interactions. Thanks to excellent collaborations with Dr. Mujeeb-Kazi of CIMMYT, we have created a larger population of CNN(RICLs3A), which will greatly assist our fine mapping of traits on chromosome 3A and in the future chromosome 6A.

Hikmet Budak studied a series of D-chromosome substitution lines in Presto triticale. The goal of this research was to determine if the genomic constitution of hexaploid triticale could be improved by replacing some of the chromosomes from the D genome of common wheat. As expected, groups 1 and 6 D chromosomes greatly improved end-use quality (these chromosomes contain major glutenin and gliadin genes). No D-genome chromosome substitution improved agronomic performance. At least with the limited substitutions that were tested, the D-genome chromosomes do not have promise for agronomically improving triticale. Perhaps translocations involving D-genome chromosome segments would be more successful.

In a very sad note, Mr. Yehia Mater died in a car accident. He, in collaboration with Drs. Ismail Dweikat and Bob Graybosch was developing a new T1A·1R chromosome in which he hoped to combine the best attributes of T1A·1R from Amigo with T1B·1R from Kavkaz. This research is possible because of the elegant cytogenetic manipulations of Dr. Adam Lukaszewski (University of California–Riverside) who created T1A·1R lines where 1R was previously on 1B in Kavkaz. We are continuing to evaluate his lines.

Hard white wheat development.

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

Two HWWW lines, **NW97S278** and **NW97S182**, were approved for release by the varietal release committee and moved to Foundation Seed Increase. Seed will be available for distribution to certified-seed growers in the autumn of 2003. NW97S278 (Pronghorn/Arlin) is a strong-gluten HWWW with excellent yield potential under irrigation and in other high yielding environments. The line has excellent resistance to lodging and genes for resistance to strip rust. NW98S182 (KS87809-10/Arapahoe) is a tall HWWW more suited for dry-land production and similar in adaptation and quality to Arapahoe. The cultivar generally produces above-average grain and flour-protein contents. Tentative cultivar names for these two lines are Antelope (NW97S278) and Arrowsmith (NW97S182).

Three new white wheat experimental lines were advanced from regional trials to the Nebraska Statewide Small Grains Variety trial for 2003. These lines are NW99L7068 and NW99L7083, sister lines from the cross ‘KS84HW1968*RioBlanco/HBY762A//Halt’, and NW99L7171 (VH09553-753/N91L019//AP-WI89-163). NW99L7068 and NW99L7083 are both high-yield potential, medium (Nuplains height) wheats with some tolerance to prehavest sprouting, and medium-strength glutens that will make them suitable for both bread and noodles. NW99L7171 has excellent bread-making quality, is tolerant to preharvest sprouting, and is a tall (Scout height), long-coleoptile wheat that might be well suited for western Nebraska. These lines also were reëntered in the 2003 USDA–ARS Northern Regional Performance Nursery (NRPN).

Wheat germ plasm releases.

R.A. Graybosch, P.S. Baenziger, and C.J. Peterson.

The following wheat germ plasm lines were jointly released by USDA–ARS and the University of Nebraska. Nineteen spring, amylose-free (waxy) wheats were developed. Waxy wheats have starch composed only of amylopectin and promise to find application in a number of food products. Also approved for release was N96L9970, a HRWW with resistance to multiple biotypes of greenbug. N96L9970 (PI 619231, GRS1201/TAM202) has resistance to greenbug biotypes B, C, E, G, and I. Finally, N95L11881 (PI 617064) and 97L9521 (PI 617066) HRWWs were released. These lines have the T1BL·1RS wheat–rye chromosomal translocation originally derived from Siouxland HRWW, but they possess improved gluten strength relative to this parent.

Wheat-quality research.

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

The relative effects of environment, genotype, and their interactions on the modification of Asian noodle-quality attributes were assessed using 38 winter wheat cultivars and breeding lines grown in replicated trials at three Nebraska locations in harvest year 2000. Noodle color was determined in both white-salted and yellow-alkaline procedures, and noodle textural features were investigated by producing white-salted noodles. Significant environmental, genotypic, and 'genotype x environment' variation was observed for nearly all initial and 24-hour, noodle-color traits in both types of noodles. Significant genotypic effects were observed for several textural traits, whereas significant environmental effects were observed only for noodle hardness and water uptake. Among the noodle textural traits, the 'genotype x environment' interaction, however, was significant only for noodle firmness. Noodle stickiness and springiness were not influenced by the main effects or their interactions. Noodle-color traits in the two noodle systems were highly correlated, suggesting that breeding wheat cultivars for use in a variety of noodle applications with diverse final product color requirements will be difficult. Textural traits largely were independent of noodle-color traits.

Personnel.

Dr. B. Todd Campbell completed his Ph.D. degree and took a position at the California Rice Research Foundation. Dr. Hikmet Budak completed his Ph.D. degree and is a postdoctoral scientist/turfgrass breeder at the University of Nebraska. Dr. Soleman Al-Otayk completed his Ph.D. degree and returned to Saudi Arabia to rejoin the faculty of his university. Sadly, Mr. Yehia Mater, a Ph.D. student, died in a car accident. He is greatly missed. Dr. Abid Mahmood joined our program for 1 year as a visiting scientist. Mr. Beau Bearnes joined our project as an M.S. student.

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NORTH DAKOTA

USDA–ARS CEREAL CROPS RESEARCH UNIT
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Justin Faris, Timothy Friesen, Steven Xu, James Miller, Daryl Klindworth, Leonard Joppa, Karri Haen, Erik Doehler, and Huangjun Lu.

Genomic targeting and high-resolution mapping of the Tsn1 locus in wheat.

Karri M. Haen and Justin D. Faris.

Tan spot, caused by the fungal pathogen *P. tritici-repentis* (PTR) causes severe yield losses in wheat and durum. The *Tsn1* gene acts dominantly to confer sensitivity to a host-selective proteinacious toxin (Ptr ToxA) produced by the fungus. Our objectives were to 1) target markers to the *Tsn1* genomic region and 2) develop a high-resolution map of the *Tsn1* locus. The techniques of methyl sensitive and traditional AFLP and cDNA-AFLP were combined with BSA using RSLs and chromosome-deletion lines to target markers to the *Tsn1* genomic region. Over 500 primer combinations were screened resulting in the identification of 47 positive fragments that were converted to RFLP markers and mapped in segregating populations. High-resolution mapping was performed by analyzing 1,266 gametes derived from a cross between the cultivar Kulm and the synthetic hexaploid W-7976. Nineteen low-copy markers closely linked to *Tsn1* have been identified, and two markers flank the *Tsn1* locus at 0.2 and 0.4 cM. *Tsn1* is located within a gene-rich recombination hot spot region. Based on estimated physical to genetic distance ratios within the region, the predicted physical distance separating the flanking markers may be less than 200 kb. Therefore, these markers will serve as a basis for the map-based cloning of *Tsn1*. The isolation of *Tsn1* will further our knowledge of wheat–tan spot interactions and host-pathogen interactions in general.

A BAC contig spanning the major domestication locus Q in wheat and identification of a candidate gene.

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

The *Q* locus played a major role in the domestication of wheat because it confers the free-threshing character and influences many other agronomically important traits. We constructed a physical contig spanning the *Q* locus using a *T. monococcum* BAC library. Three chromosome walking steps were performed by complete sequencing of BACs and identification of low-copy markers through similarity searches of database sequences. The BAC contig spans a physical distance of about 300 kb corresponding to a genetic distance of 0.9 cM. The physical map of *T. monococcum* had perfect colinearity with the genetic map of wheat chromosome arm 5AL. Recombination data in conjunction with analysis of fast-neutron deletions confirmed that the contig spanned the *Q* locus. The *Q* gene was narrowed to a 100-kb segment that contains an *APETALA2* (*AP2*)-like gene that cosegregates with *Q*. *AP2* is known to play a major role in controlling floral homeotic gene expression and thus, is an excellent candidate for *Q*.

Genomic analysis of segregation distortion and recombination in durum wheat.

Justin D. Faris and Huangjun Lu.

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*. We are now in the process of assessing chromosome 5A in for segregation distortion in crosses derived from 'LDN/LDN–DIC 5A'. 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 it suggests that this phenomenon may lead to reduced recombination frequencies.

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

Erik Doehler, Justin Faris, Steven Xu, 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 short arm and most of the long 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 also were derived from *Ae. speltoides* by translocations to hexaploid wheat chromosome 2B.

Disease evaluation of 40 synthetic hexaploid wheat lines for their seedling reaction to tan spot and Stagonospora leaf blotch.

Timothy L. Friesen, Steven S. Xu, and Justin D. Faris,

Forty SH wheats (2n = 6X = 42, AABBDD) developed by L.R. Joppa were produced by crossing the durum wheat Langdon with 40 *Ae. tauschii* accessions. These SH lines were evaluated for seedling resistance to *St. nodorum* and *P. tritici-repentis*. Evaluations were also done for sensitivity to the host selective toxin, Ptr ToxA, a major necrosis inducing toxin of *P. tritici-repentis*. Evaluations of resistance were done 7 days postinoculation for tan spot and 10 days postinoculation for Stagonospora leaf blotch with a 24-h wet period following inoculation. North Dakota field isolates of *St. nodorum* and *P. tritici-repentis* (race 1) were used in the evaluation. Both diseases were evaluated on a one to five reaction scale with 1 being resistant, 2 moderately resistant, 3 moderately resistant/moderately susceptible, 4 susceptible, and 5 highly susceptible. Langdon, the durum parent in each SHW line, was moderately susceptible to tan spot and highly susceptible to Stagonospora leaf blotch. The SHs showed average tan spot disease reactions ranging from 1.33 to 4.17 with Langdon averaging 3.33. Average disease reactions for Stagonospora leaf blotch ranged from 1.67 to 4.67 with Langdon averaging 4.83. These results indicate that some *Ae. tauschii* accessions are contributing resistance to *St. nodorum* and *P. tritici-repentis*. These SHW lines should prove useful for incorporation into breeding programs for crop improvement.

Resistance to tan spot in CIMMYT elite synthetic hexaploid wheats and their durum parental lines.

Steven S. Xu and Timothy L. Friesen.

CIMMYT developed and characterized two sets of elite SH wheats (ELITE 95 and ELITE 2) and evaluated resistance of the lines to stripe rust, leaf rust, Fusarium head blight, Karnal bunt, Septoria tritici blotch, and spot blotch (Mujeeb-Kazi and Delgado 2001; Kujeeb-Kazi et al. 2000). In this study, 120 SHW lines from the ELITE 95 and ELITE 2, along with their durum wheat parents, were evaluated for seedling resistance to tan spot of wheat and sensitivity to the host selective toxin, Ptr ToxA. The original seed for the evaluation was obtained from Wheat Genetics Resource Center, Kansas State University, Manhattan, KS. Plant leaves were infiltrated with Ptr ToxA at the 2-leaf stage, and evaluation of sensitivity was conducted 3-4 days post infiltration. After evaluation of sensitivity, all the plants were inoculated with *P. tritici-repentis* (race 1) and evaluation was done 7 days post inoculation. The disease was scored on a one to five scale with 1 being resistant, 2 moderately resistant, 3 moderately resistant/moderately susceptible, 4 susceptible, and 5 highly susceptible. Evaluation results indicated that most SHW lines are the same as their parental durum lines in the sensitivity to ToxA because the sensitivity locus is located on chromosome 5B and sensitivity is dominant. However, some SH lines differed from their durum parents in reaction to Ptr ToxA. Differences could be due to the heterozygosity of the sensitivity locus, heterogeneity of the durum parents, or outcrossing of the SH lines. The original pedigree of the CIMMYT synthetics showed that the durum parents of a number of SH lines are the F_1 hybrids of two durum cultivars. The SH lines have average disease reactions from 1.00 to 3.5, compared with durum parent lines of 2.67 to 5.0. Fifteen of 120 SH lines were highly resistant and may be good sources for improving tan spot resistance in wheat.

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Reciprocal transfer of chlorina genes derived from hexaploid and tetraploid chlorina mutants.

Daryl L. Klindworth.

Chlorina alleles *cn-A1d* and *cn-B1a* derived from the tetraploid mutants CDd6 and CDd1, respectively, were backcrossed to a Chinese Spring euploid and Chinese Spring ditelosomic background. Six stocks were produced. Chlorina alleles *cn-D1a* and *cn-A1a*, derived from hexaploid mutants CD3 and Chlorina-1, respectively, were backcrossed into four Langdon stocks, one being euploid and three others being disomic substitutions. All of the tetraploid stocks produced needed to be maintained as heterozygotes because homozygous plants were lethal. For the hexaploid stocks carrying genes from tetraploid mutants, we found that the *cn-A1d* allele could be maintained in a 2:2 dosage (homozygous) in the CS ditelosomic background. However, we found that a 2:2 dosage of the *cn-B1a* allele in a CS7AS and CS7DS background was lethal in the greenhouse. Although the donor of *cn-B1a* (CDd1) is lethal in the field at Fargo, it is viable in a 2:2 dosage in the greenhouse, suggesting the possible presence of modifying genes that differ in Langdon versus Chinese Spring. These stocks should be useful for studies of dosage effects, the influence of each genome on chlorina gene expression, and other photosynthetic studies. This study was initiated under the direction of the late Norman Williams.

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OKLAHOMA

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B.F. Carver, E.G. Krenzer, A.K. Klatt, and A.C. Guenzi.

Wheat production.

E.G. Krenzer.

In 2002, 98 x 10^6 bushels of hard winter wheat were harvested from 3.5 x 10^6 acres for an average yield of 28 bu/acre. Both acres harvested and average yield decreased from last year's numbers of 4.2 x 10^6 acres harvested and 34 bu/acre.

The 2001–02 wheat crop started slowly for the second consecutive year. Soils remained exceedingly dry through early September, when the first significant rainfall occurred around 10 September 2001. September temperatures were not exceptionally high, so early-planted wheat resulted in very good stands. By 1 October 2001, 60 % of the wheat acreage had been planted compared to a 5-year average of 31 %. Little rainfall occurred from October 2001 through January 2002, with the National Weather Service reporting between 25 and 50 % of the normal precipitation for Oklahoma during that period. Wheat in most areas continued to suffer drought stress, limiting forage production. Spring rains were barely adequate in many areas and were too little, too late, or nonexistent in the panhandle where the dryland wheat was almost 100 % abandoned. Grain-filling conditions were quite good except where limited moisture hastened maturity and reduced test weight.

The leading cultivars planted in Oklahoma for the 2002 crop were Jagger, 2174, 2137, 2180, and Custer at 45,13, 5, 4, and 4 % of the acres, respectively.

Cultivar development and breeding research.

B.F. Carver.

Seven HRWW breeding lines were placed under final breeder seed increase in 2002–03.

OK94P549-21	HBY756A/Siouxland//2180
OK94P549-11	HBY756A/Siouxland//2180
OK95616-56	TXGH13622/2180
OK96705-38	2180//OK88803/Abilene
OK95548-54	OK86216/Cimarron sib//2180
OK98699	TAM 200/HBB313E//2158 seln
OK98690	OK91724(=Chisholm*2/Yantar)/Karl

OK98690 and OK98699 have above-average milling and baking quality, whereas OK96705-38 and OK95548-54 (the latter has the T1BL·1RS wheat–rye translocation from Aurora) possess below-average quality and will likely not be released for that reason. All seven show a high level of resistance to WSBMV and, with the exception of OK96705-38 and OK98699, a moderately high level of APR to leaf rust. Extremely high priority has been given to improving resistance to these diseases in the cultivar-development program in the past 5 years. Other agronomic priorities have included improving field tolerance to acidic soils and adaptation to a dual-purpose management system. A key component to the latter objective is the combination of early heading date with a nonprecocious dormancy release in the late winter, which is quantified by date of first hollow-stem stage. Though changes are not yet confirmed, this type of selection pressure could elicit upward shifts in vernalization requirement and photoperiod sensitivity or a downward shift in heat sensitivity. All lines listed above show timely dormancy release patterns except OK95616-56, which is similar to Jagger.

The Wheat Improvement Team at OSU is also attempting to incorporate the awnletted character into a grain-type cultivar to allow producers in the southern Great Plains the added flexibility to defer their decision to use a standing crop either for grain production or for hay or late-season grazing. Though the vast majority of HRWW cultivars are awned, we tested the hypothesis that an awnletted type would produce equivalent grain yield and quality if flag leaf senescence was delayed by protection against leaf rust. NILs were developed by Dr. Stan Cox (formerly with USDA–ARS, Manhattan, KS) in a Century background featuring all combinations of leaf rust resistance (from either *Lr41* or *Lr42*) and awn type. For most attributes, genes controlling awns and rust resistance acted additively but with unequal effects. The average effect of leaf rust resistance genes was more than twofold greater than the average effect of awns for grain yield, test weight, and kernel weight. Awnletted genotypes with leaf rust resistance were equivalent in yield and quality to the conventional awned types. We are aggressively pursuing the development of leaf rust-resistant, awnletted cultivars with moderate-to-high forage production and desirable external and internal quality characteristics. OK98690 fits that description.

Wheat germ plasm enhancement.

A.K. Klatt.

The variability enhancement/germ plasm development program at OSU has two primary objectives: 1) incorporate new genetic diversity into the winter wheat improvement program that will serve as the basis for future increases in productivity and 2) transfer improved resistance to leaf rust into adapted winter wheat materials for Oklahoma. Spring and winter wheat materials from CIMMYT serve as the primary sources of genetic diversity. More than 3,000 lines from CIMMYT and numerous materials from other sources have been introduced in the past 4 years. All introductions are screened for multiple disease resistance and agronomic type, and the best materials were incorporated into the crossing program.

Long-term, stable leaf rust resistance has not been achieved in the southern and central Great Plains. A new cultivar typically maintains leaf rust resistance for a short period of time (2–4 years). As a result, breeders in the region must devote extensive resources to breeding for leaf rust resistance. Efforts are underway to transfer durable leaf rust resistance from CIMMYT spring wheat germ plasm into adapted winter wheats. This resistance is characterized by low levels of infection and generally is based on one or more major genes plus several minor genes. Additionally, an extensive crossing program to synthetic wheats and synthetic derivatives developed by CIMMYT is underway and this effort has multiple objectives, including new sources of leaf rust resistance, improved kernel size, enhanced stay green characteristics, and improved biomass and yield potential. For information regarding this program, contact Dr. Art Klatt, Department of Plant and Soil Sciences, 274 Ag Hall, Stillwater, OK 74078 or via E-mail at aklatt@okstate.edu.

Wheat transformation and gene discovery.

A.C. Guenzi.

We continue to evaluate the use of osmoprotectants to improve drought tolerance and the quality of refrigerated and frozen-dough products. Osmoprotectants are small molecules (e.g., glycine betaine, proline, trehalose, and mannitol) that raise the osmotic potential of the cell's cytoplasm to drive water uptake or that act as osmolytes to counteract imbalances caused by dehydration. Alternatively, these substances have a protective role during dehydration by stabilizing macromolecules and scavenging free radical oxygen species. During the past year, hybrids containing a transgene for mannitol biosynthesis were backcrossed to elite lines in the wheat breeding program. Physiological characterization of one transformation event is in press (Abebe et al. 2003; Plant Physiol **131**:1-8).

Now that transformation has become a tool for the genetic manipulation of wheat, it is becoming apparent that the bottleneck for directing the use of this technology is having genes to transform and understanding the biology of traits we wish to manipulate. With this in mind, we have initiated a functional genomics project to understand the responses of wheat roots to soilborne fungal pathogens. A systematic characterization is being initiated to define transcription profiles between the interactions of wheat roots and 1) *Gaeumanomyces graminis* var. *tritici* 2) *Rhizoctonia solani*, and 3) *Pythium arrhenomanes*. Light and confocal microscopy was utilized to identify key stages of infection (root surface colonization, epidermis penetration, and cortex colonization) and DNA libraries for each stage were established. To date, approximately 7,000 clones have been recovered for DNA sequencing and expression analysis.

SOUTH DAKOTA

SOUTH DAKOTA STATE UNIVERSITY AND THE USDA–ARS NORTHERN GRAIN INSECT RESEARCH LABORATORY (NGIRL).
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Personnel changes.

Dr. Karl Glover joined the Faculty of Plant Science Department as the spring wheat breeder and assistant professor of plant science in June 2002. Glover received his B.S. and M.S. degrees in agronomy from South Dakota State University (SDSU) in 1994 and 1996, respectively. In 2000, Glover earned his Ph.D. in plant breeding at Kansas State University. Immediately prior to beginning his duties at SDSU, Glover was a post-doctoral research fellow with the University of Illinois at Urbana–Champaign. His research efforts at SDSU focus towards the development of improved cultivars adapted for production in South Dakota and the northern Plains along with other aspects of spring wheat breeding and genetics research.

Winter wheat breeding and genetics.

A.M.H. Ibrahim, S.A. Kalsbeck, R.S. Little, and D. Gustafson.

Crop report and testing sites. Winter wheat production in 2002 was estimated at 18.1 x 10^6 bushels from 0.63 x 10^6 harvested acres (1.15 x 10^6 planted acres), for a state average of 29 bu/acre (3 bushels less than 2001). The total production for 2002 was up 53 % from 2001. Overall, the excellent winter survival rate due to a mild winter came under extreme drought conditions during heading and grain-filling stages which lead to significant yield loss.

In 2002, the winter wheat-breeding program conducted testing at eight sites throughout South Dakota. These environments included 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 dry land 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 cooperation with Clair Stymiest and John Rickertson (SDSU West River Agricultural Research and Extension Center, Rapid City).

Autumn stand establishment at all testing locations was very good. Excellent statewide top-soil moisture in September followed by temperatures ranging from 7–11°F above normal for October and November lead to early plant development. May temperatures were 4–10°F below normal, whereas June temperatures were 5–10°F above normal.

Limited subsoil moisture and drought conditions in the spring lead to abandonment of 46 % of winter wheat acreage statewide. The canola and spring wheat stubble nurseries at Dakota Lakes Research Farm near Pierre were abandoned as a result. Plants produced very few tillers at the Central Crops and Soils Research Station in Highmore but compensated by good grain filling aided by a mid June rainfall. Conversely, plants in the nurseries at Wall had excellent plant tillering but poor yield due to poor grain filling as a result of limited post-anthesis moisture. At Platte, Brookings, Watertown, and Britton yield and test weights were comparable to the 3-year averages due to timely rains during plant development. Seed was planted into spring wheat stubble at Selby with excellent moisture, but colder than normal May temperatures combined with herbicide damage (1.5 pt/acre bronate) in drought conditions resulted in low yields.

New cultivar. Expedition HRWW, developed by the South Dakota Agricultural Experiment Station, was released in August 2002 because of its excellent winter survival and high yield potential in South Dakota and the northern Great Plains.

Expedition was selected as an $F_{3:4}$ line from the cross 'Tomahawk/Bennett' made during 1993. The cultivar is early maturing (147 d to heading from 1 January), similar to Jagger and similar in plant height to that of Alliance. The winter survival of Expedition is good to excellent, similar to Harding. Expedition has a medium-length coleoptile similar to that of Wesley and fair straw strength similar to that of Arapahoe. Expedition has exhibited moderate adult plant and seedling resistance to prevalent races of stem rust and has been postulated to carry *Sr6* and other unidentified genes based on tests conducted by the USDA Cereal Disease Laboratory, St. Paul, MN. Moderately susceptible to leaf rust, field disease ratings of reaction to FHB between 2000 and 2002 suggested some degree of tolerance. Expedition is susceptible to tan spot, WSMV, and the Great Plains biotype of Hessian fly. Expedition has exhibited intermediate reaction to WSBMV.

Composite milling and bread baking properties of Expedition were determined by the USDA-ARS Hard Winter Wheat Quality Laboratory at Manhattan, KS, during 2000 and 2001. Relative to the check cultivars Alliance and Nekota, Expedition had larger kernels that contributed to higher flour extraction and lower flour ash than both checks. Flour protein of Expedition was similar to that of Nekota and better than that of Alliance. In bread-baking tests, bake absorption of Expedition was similar to that of Alliance and better than that of Nekota, whereas its loaf volume was comparable to those of both checks. Expedition had better mixograph tolerance than those of both checks but had stronger mixing characteristics.

Fusarium head blight.

A.M.H. Ibrahim and D. Gustafson.

We have established a proactive effort to develop FHB-resistant hard winter wheat varieties and germ plasm. A mist-irrigated scab evaluation nursery was used to evaluate elite breeding lines, regional nurseries, commercial cultivars, and segregating populations. In 2002, we continued investigating planting schemes to determine if direct seeded row materials are affected differently than transplanted hill plots when they are inoculated with FHB. Preliminary results indicated significant correlations between the two methods ($r = 0.60$; $P < 0.05$). However, there was a smaller experimental error (CV = 14.7 %) associated with direct-seeded rows testing compared to transplanted hills (CV = 22.9 %). These results indicate that delayed direct seeding could replace transplanting for screening for FHB tolerance. However, transplanted hills should be used if improper weather conditions prevent successful direct seeded nursery. We started screening lines for type-II resistance using point inoculation in the greenhouse. We started forming a complex scab population for breeding purposes and for distributing bulked seed to interested breeding programs in the region. Parents have been selected based on resistance to FHB and other diseases prevalent in the region, high yield potential, superior quality, winter survival ability, and other agronomic traits.

White wheat.

A.M.H. Ibrahim, R. Little, and S.A. Kalsbeck.

In previous years, our breeding efforts for HWWW have centered on making crosses between adapted red lines and unadapted white germ plasm. We incorporated resistance to prevalent races of stem rust and increased the winter survival ability of the hybrid material. We are currently working on increasing the coleoptile length, decreasing preharvest sprouting susceptibility, and decreasing PPO activity (a predictive measure of noodle-making quality) without sacrificing bread-making qualities.

Intensive screening for coleoptile length and PPO enzyme activity over the past two years has been very successful. For both red and white germ plasm in advanced nurseries, the coleoptile length increased by an average of 1 cm. The percentage of white lines (40 %) with coleoptiles longer than that of Harding was twice that of red lines (20 %) in 2003 advanced nurseries. (The coleoptile length of Harding is considered to be a standard for acceptable emergence following deep planting).

We have developed a screening regime for PPO activity that includes testing early generation materials between harvest and planting. In order to complete the tests quickly and to simultaneously screen for bread-making quality, we developed a protocol that combines a meal PPO test with a meal sedimentation test (a predictive measure of bread-baking quality). The protocol is currently being tested for repeatability before implementation in the autumn of 2003.

Preharvest-sprouting resistance is one of our biggest challenges and commands an intense effort for both screening and germ plasm development. We collect heads for screening for sprouting resistance at physiological maturity (20 % moisture) when the peduncle looses all green color or at the Zadock's 87 stage (hard dough). In our tests, the hard dough stage provided the most consistent and reliable results. A scoring formula was developed that combines the percent of germinated seeds on the third, fourth and seventh day after imbibing. The formula gave greatest weight to the number of seeds germinated on the third day. The germination percent was normalized to a scale of 1–9, where 1 = excellent resistance and 9 = very poor resistance to sprouting.

Nuplains and Trego, two elite HWWW varieties, were identified as good (score of 3) and fair to good (score of 4) lines for sprouting resistance, respectively. Of the tested experimental lines entered into 2003 advanced nurseries, 96L9643-3 scored 2 (very good); SD97W671-1, SD99W022, and SD00W005 scored 3; and SD 97W604 and SD00W087 scored 4. Three advanced HWWW lines from Kansas with superior sprouting resistance were included in crossing block to improve preharvest-sprouting susceptibility.

Cereal aphids and other arthropods.

L. Hesler, W. Riedell, and S. Osborne (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 are also evaluating how agronomic practices affect infestations of cereal aphids and other insects. For instance, with Dr. Robert Berg, SDSU Southeast Research Farm, we are evaluating how tillage influences cereal-aphid infestation. With Dr. Marie Langham (SDSU, plant virologist), we are determining how planting date of wheat affects insect infestations, incidence of viral diseases, and plant growth and yield. We also are collaborating with Dr. Dean Kindler (USDA–ARS-PSWCRL, Stillwater, Oklahoma) 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 BYDV.

Wheat chloride nutrition affects on disease: rusts.

W. Riedell, S. Osborne, L. Osborne, and R. Gelderman (USDA–ARS–NGIRL).

Greenhouse and growth chambers are planned to investigate the interaction of chloride nutrition with wheat diseases. Chloride is an essential plant nutrient that is mobile in the soil profile. Soils in the U.S. northcentral region are often low in this essential nutrient. Application of Cl fertilizers to low-testing soil (based upon soil test) will result in a yield increase about 80 % of the time. Anecdotal evidence suggests that wheat diseases are suppressed with Cl fertility under field conditions. These experiments are planned to augment this data. Experimental results gained from controlled experiments will be put into practice on field-scale research plots at the Eastern South Dakota Soil and Water Research Farm near Brookings, SD. Intensive wheat management practices (higher plant populations, starter fertilizer, cover crops, and time application of nitrogen fertilizer) currently are being deployed on these plots. Chloride levels and chloride fertilizer may also be used on these plots depending on the outcome of the controlled experiments. Annual updates and other information on these experiments will be presented at annual field days, annual research reports, and technical publications.

W. Riedell is a Plant Physiologist, S. Osborne is an Agronomist, L. Osborne is a Plant Pathologist at SDSU, and R. Gelderman is Professor and manager of the SDSU soil-testing laboratory.

VIRGINIA

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W.L. Rohrer, J.A. Wilson, C.A. Griffey, D. Nabati, J. Chen, T.H. Pridgen, E.G. Rucker, and D.E. Brann.

2002 Wheat Production in the Commonwealth of Virginia.

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

Growing conditions. The 2001–02 growing season was extremely dry with temperatures fluctuating but generally mild. Very little precipitation fell during the winter months. The dry and mild conditions were briefly interrupted by flash flooding in some areas (particularly southwest Virginia) and a spring freeze, both occurring in March. A later spring freeze occurred in May causing additional damage to wheat that was in the heading to post anthesis stages. As in recent years, both the Blacksburg and Warsaw areas remained extremely dry throughout most of the spring and summer. Because of the dry conditions, disease prevalence and severity was low in most areas. Crop lodging also was generally low because of lack of heavy precipitation late in the growing season. Rains during the harvest season delayed combining and resulted in reduced test weights in a portion of the crop.

Disease incidence and severity. Leaf rust, powdery mildew, and BYDV were the most prevalent diseases of wheat in Virginia in 2002. 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, although isolated foci were observed. Stripe rust was prevalent in Virginia Tech yield nurseries near Blacksburg in the western part of the Commonwealth.

Production. According to Virginia Agricultural Statistics Service, Virginia producers harvested 185,000 acres (74,925 ha) of winter wheat for grain in 2002, which was up from the 170,000 (68,850 ha) acres harvested in 2001. Grain yields across the state averaged 63 bu/acre (4,233 kg/ha), which was 4 bu/acre (269 kg/ha) lower than the state yield-record set in 1997 and 6 bu/acre (403 kg/ha) higher than in 2001. Total grain production for the Commonwealth in 2002 was 11.7 million bushels (318,367 metric tons).

Virginia wheat yield contests. Participation in the conventional-till and no-till wheat yield contests was up in 2002. In the 2002 Virginia Conventional-Till Wheat Yield Contest, Robbie Newcomb of Hanover County took first place with a grain yield of 112 bu/acre (7,525 kg/ha) over a minimum area of 3 acres (1.2 ha). Battle Park Farm, located in Culpeper County, came in second with a yield of 111 bu/acre (7447 kg/ha) followed closely by Richard Sanford of Westmorland County with 110 bu/acre (7,394 kg/ha). Clay Newcomb of Hanover County led a group of four participants in the Conventional-Till Rookie Class with a yield of 106 bu/acre (7,090 kg/ha). Jimmy Newcomb of Hanover County, F.F. Chandler, Jr. of Westmoreland County, and Sam B. Drewery, Jr. of Southampton County captured 2nd, 3rd, and 4th places, respectively. In the 2002 Virginia No-Till Wheat Yield Contest, Todd Price of Prince George County took first place with a grain yield of 99 bu/acre (6,629 kg/ha). Finishing in 2nd and 3rd places were Alvis Farms of Goochland County (97 bu/acre (6,541 kg/ha)) and William Bendle, Jr. of Henrico County (96 bu/ac (6,439 kg/ha)), respectively. In the No-Till Rookie Class, Tony Knasnicka of Prince George county captured first place with a grain yield of 93 bu/acre (6,242 kg/ha) and was followed by Joseph Reamy of Richmond County (2nd place) and Craig Brann of Northumberland County (3rd place). Congratulations go out to all of the participants in this year's yield contests.

State cultivar tests. A total of 65 entries were evaluated at 6 locations across Virginia in 2002. Included in the tests were 37 experimental lines (including one white-seeded line) and 28 released cultivars. Average grain yields ranged from 59 to 90 bu/acre (3,964–6,047 kg/ha) with an overall test average of 76 bu/acre (5,106 kg/ha). Wheat genotypes with yields significantly above the test average included Tribute, McCormick, Sisson, SS 550, SS520, SS 560, USG 3209, USG 3650, Pioneer 2580, and 17 experimental lines (16 from the Virginia Tech program, including one white-seeded entry). Yields among genotypes in this group ranged from 80 to 90 bu/acre (5,375–6,047 kg/ha). Tests conducted in the Coastal Plain Region had a yield average of 83 bu/acre (5,577 kg/ha), whereas tests conducted in the Piedmont and Blue Ridge Region had a yield average of 71 bu/acre (4,770 kg/ha). Test weights of wheat lines (based on five locations across the state) ranged from 56.8 lb/bu (731 kg/m^3) to 60.7 lb/bu (781 kg/m^3) with a test average of 58.6 lb/bu (754 kg/m^3). Of the 19 entries with test weights significantly higher than the test average, nine were experimental lines (six from Virginia) and 10 were released cultivars. Six entries (four Virginia experimental lines and two released cultivars) had both grain yields and test weights that were significantly higher than the test average.

Release of McCormick. Formerly designated VA98W-591, **McCormick** was released by the Virginia Agricultural Experiment Station in May 2002. The name McCormick was selected in tribute to Robert Hall McCormick of Walnut Grove in Rockbridge County, Virginia, and his sons Cyrus Hall McCormick and Leander James McCormick. Their invention and perfection of the mechanical reaper initiated the era of modern agriculture and wrought one of the greatest advancements in agricultural history, thus enabling the world's production of food to keep pace with the vast increase of population.

McCormick is a broadly adapted, mid-season, high-yielding, short-stature, awnleted, SRWW with good straw strength. McCormick was derived from the cross 'VA92-51-39/AL870365'. The cross was made in spring 1992, and the F_1 generation was grown in the field as a single 4-ft headrow in 1993 to produce F_2 seed. The population was advanced from the F_2 to F_4 generation using a modified bulk-breeding method. McCormick was selected as an F_5 headrow in 1997.

Head emergence of McCormick is 2 days later than AGS 2000 and 1 to 2 days earlier than Roane. Average plant height of McCormick (31 inches, 79 cm) is similar to that of Coker 9835 and 2 to 3 inches (5 to 8 cm) shorter than AGS 2000. Straw strength of McCormick is good and is better than that of Coker 9663. Based on data from six test sites in the 2001 Uniform Eastern SRWW Nurseries, winter survival of McCormick is good and similar to that of Caldwell. Milling and baking quality of McCormick is good and superior to that of Roane.

Reaction of McCormick to disease and insect pests has been evaluated over a broad area. McCormick is resistant to powdery mildew. In seedling tests of entries in the 2001 Uniform Eastern and Southern SRWW Nurseries conducted by USDA–ARS Plant Science Research Unit in Raleigh, NC, McCormick expressed resistance to 24 of 30 isolates. McCormick possesses the *Pm17* gene from Amigo in addition to other unidentified genes. Similar data from the Cereal Disease Laboratory in St. Paul, MN, indicates that McCormick possess gene *Lr24* conferring resistance to leaf rust and genes *Sr6*, *Sr17*, and *Sr24* conferring resistance to stem rust. McCormick is resistant to stripe rust and WSBMV. McCormic is moderately resistant to leaf blotch, glume blotch, FHB, BYDV, and WSSMV.

In Virginia, grain yields of McCormick have been similar to or exceeded those of the best check cultivars and over the past 2 years (2000–01) have averaged 83 bu/acre (5,577 kg/ha) versus a mean yield over all genotypes of 76 bu/acre (5,106 kg/ha). Grain of McCormick is high in test weight (mean of 60.5 lb/bu; 779 kg/cm^3), which is similar to that of Roane (60.2 lb/bu) and 3 lb/bu higher than that of Coker 9835. McCormick was evaluated for 2 years in the USDA–ARS Uniform Southern SRWW Nursery and ranked first among 43 entries for grain yield (77 bu/acre; 5,174 kg/ha) and sixth in test weight (59.1 lb/bu; 761 kg/cm^3) in 2001. In 2002, it ranked third among 40 entries for grain yield (63 bu/ac; 4233 kg/ha) and fifth in test weight (58.3 lb/bu; 750 kg/cm^3). McCormick also was evaluated for two years in the Uniform Eastern SRWW Nursery, and ranked first among 44 entries for grain yield (79 bu/acre; 5,308 kg/ha) and ranked fifth in test weight (60.1 lb/bu; 773 kg/cm^3) in 2001. In 2002, it ranked eighth among 44 entries for grain yield (71 bu/acre; 4,770 kg/ha) and third in test weight (59.4 bu/acre; 764 kg/cm^3).

Authorized seed classes of McCormick are Breeder, Foundation, and Certified. McCormick is protected under the amended U.S. Plant Variety Protection Act of 1994 (Application pending). The Department of Crop and Soil

Environmental Sciences and the Virginia Agricultural Experiment Station, Blacksburg, Virginia, will maintain Breeder seed. Requests for participation in production of McCormick and availability of Foundation seed should be directed to Bruce Beahm (804-472-3500), Manager, Foundation Seed Farm, Mt. Holly, VA.

Release of Tribute. Formerly designated VA98W-593, **Tribute** was released on an exclusive basis by the Virginia Agricultural Experiment Station in May 2002. Tribute is a broadly adapted, mid-season, high-yielding, short-stature, awnleted, SRWW with good straw strength. Tribute was derived from the cross 'VA92-51-39/AL870365'. The cross was made in spring1992, and the F_1 generation was grown in the field as a single 4-ft headrow in 1993 to produce F_2 seed. The population was advanced from the F_2 to F_4 generation using a modified bulk-breeding method. Tribute was selected as an F_5 headrow in 1997.

Head emergence is 2 to 3 days later than AGS 2000 and 2 days earlier than Roane. The average plant height of Tribute (32 inches, 81 cm) is 1 to 2 inches (3 to 5 cm) taller than Coker 9835 and 2 inches (5 cm) shorter than AGS 2000. Straw strength of Tribute is good and better than that of Coker 9663. Based on data from seven test sites in the 2000 and 2001 Uniform Eastern SRWW Nurseries, winter-survival of Tribute is good and similar to that of Caldwell. Milling and baking quality of Tribute is slightly better than that of Roane. Tribute has the 5+10 glutenin-protein subunit and strong gluten strength, thus making it potentially suitable for cracker production.

Reaction of Tribute to disease and insect pests has been evaluated over a broad area. Tribute is resistant to powdery mildew. Based on seedling tests of entries in the 2000 Uniform Eastern and Southern SRWW Nurseries conducted by USDA–ARS Plant Science Research Unit in Raleigh, NC, Tribute possesses the *Pm17* gene from Amigo in addition to other unidentified genes. Similar data from the Cereal Disease Laboratory in St. Paul, MN, indicates that Tribute possesses genes *Lr9* and *Lr24* conferring resistance to leaf rust and gene *Sr24* conferring resistance to stem rust. Tribute is moderately resistant to stripe rust, leaf blotch, glume blotch, FHB, BYDV, and WSSMV; it is susceptible to WSBMV.

In Virginia, grain yields of Tribute have been similar or exceeded those of the best check cultivars and have averaged 83 bu/acre (5,577 kg/ha) versus a mean yield over all genotypes of 76 bu/acre (5,106 kg/ha). Grain of Tribute has a very high test weight (mean of 60.8 lb/bu; 782 kg/m^3), which is similar to that of Roane (60.2 lb/bu; 775 kg/m^3) and 4 lb/bu (51 kg/m^3) higher than that of Coker 9835. Tribute was evaluated for 3 years in the USDA–ARS Uniform Southern SRWW Nursery and ranked third in grain yield among 33 entries in 2000 (79 bu/acre; 5,308 kg/ha), fifth among 43 entries in 2001 (74 bu/acre; 4,962 kg/ha), and first among 40 entries in 2002 (64 bu/acre; 4,300 kg/ha). During the same period, Tribute also was evaluated in the Uniform Eastern SRWW Nursery and ranked third in grain yield among 40 entries in 2000 (81 bu/acre; 5,442 kg/ha), eleventh among 44 entries in 2001 (79 bu/acre; 5,308 kg/ha), and fourth among 44 entries in 2002 (73 bu/acre; 4,905 kg/ha). In all six nurseries, Tribute ranked first in test weight, with overall means ranging from 59.2 to 61.1 lb/bu (762 to 786 kg/cm^3). Tribute also performed well in tests conducted under 12 environments in Ontario, Canada.

Authorized seed classes of Tribute are Breeder, Foundation, and Certified. Tribute is protected under the amended U.S. Plant Variety Protection Act of 1994 (Application pending). The Department of Crop and Soil Environmental Sciences and the Virginia Agricultural Experiment Station, Blacksburg, Virginia, will maintain Breeder seed. Certified seed of Tribute will be available to producers beginning in autumn 2003.

Progress in breeding Fusarium head blight resistance in soft red winter wheat.

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A primary goal of our breeding program is to accelerate the development of adapted and commercially viable, FHB-resistant SRWW cultivars by identifying and incorporating diverse types of resistance into elite genotypes. Breeding methods being used to accomplish this goal include topcrossing, backcrossing, DH techniques, and molecular marker genotyping. In 2002, 229 segregating populations were evaluated in a mist-irrigated FHB nursery, inoculated using colonized maize seed, at Mt. Holly, VA. Seventy-seven of these populations (34 %) were advanced on the basis of FHB incidence and severity, agronomic traits, and resistance to other prevalent diseases such as powdery mildew, leaf rust, and glume blotch.

In other field tests, approximately 4,500 headrows (F_3-F_8 and various backcross generations) were evaluated for agronomic traits and resistance to diseases other than FHB at Warsaw, VA. In addition, approximately 2,800 F_5–F_7 headrows were evaluated for FHB resistance and agronomic traits in an inoculated, mist-irrigated nursery at Blacksburg, VA. From these headrows, 32 backcross-derived lines and 26 top cross-derived lines were selected for further testing in our scab nursery at Blacksburg and in Observation yield tests at two locations in 2003. Twelve lines from the 2001–02 Observation yield test were selected for further testing in Preliminary wheat trials. Four elite lines were selected for testing in our advance yield trial, and two elite lines will be tested in Virginia's official variety trial. Twelve lines will be tested in the 2002–03 Uniform Winter Wheat FHB Nurseries. Two newly released varieties from the Virginia Tech Small Grains Program, McCormick and Tribute, possess a significant level of scab resistance (Tables 1 and 2).

Table 1. Entry means for 2001 Northern Uniform Winter Wheat Scab Nursery. Each entry was compared to the lowest (L) and highest (H) means in each column using $LSD_{(0.05)}$. # low scores is the number of disease traits for which an entry received a low score, # high scores is the times it received a high score. Numbers below column headings indicate the number of tests (locations) upon which data are based.

Line/ cultivar	FHB severity (%)	FHB incidence (%)	FHB index (%)	Kernel rating (0–100)	Scabby seed (%)	Vomitoxin DON (ppm)	FHB severity in GH tests (%)	# low scores	# high scores
No. of tests	9	8	8	4	3	3	5		
Patterson	38.4 H	61.6 H	34.1 H	31.0 L	14.7 L	6.9 L	52.4	3	3
Freedom	21.4	62.8 H	21.8	50.1	17.5 L	12.6 L	30.5	2	1
P2545	39.8 H	71.4 H	40.7 H	66.5 H	26.8 H	16.2 L	55.8	1	5
Ernie	20.1 L	51.4	19.4	29.9 L	16.9 L	7.9 L	28.7	4	0
Roane	20.0 L	60.3 H	19.9	32.0 L	16.3 L	5.4 L	27.3	4	1
McCormick	20.4 L	56.4	16.6 L	34.5 L	9.7 L	7.4 L	47.1	5	0
Tribute	27.4	59.8 H	21.6	36.3 L	7.2 L	5.3 L	58.8	3	1
Mean (n = 49)	24.6	57.5	22.6	42.0	18.4	11.9	46.3		
LSD (0.05)	9.3	15.0	10.5	17.1	15.0	14.2	18.9		

Table 2. Entry means for 2001 Uniform Southern Fusarium Head Blight Nursery. The number below each column heading indicates the number of tests (locations) upon which data are based. Seed quality on a scale of 0 = poor, 1 = fair, and 2 = good. Check cultivars are McCormic and Tribute.

Line/ Cultivar	FHB incidence	FHB severity	FHB index	Scabby seed	Kernel quality	Seed quality	Vomitoxin DON	Greenhouse type-2 resistance
No. of tests	6	7	5	5	1	1	4	4
Ernie	32	13	7	18	1.3	1.3	6.6	25.7
Coker 9835	74	47	43	53	7.0	0.7	11.6	71.2
Coker 9474	40	19	10	16	1.3	1.7	3.3	31.4
McCormick	48	19	12	23	4.3	1.0	6.0	38.8
Tribute	45	26	15	21	3.7	1.3	4.3	48.7
Mean (n=29)	53	27	20	31	4.1	1.0	11.0	52.2
LSD (0.05)	13.0	10.0	12.0	14.0	1.4	0.5	8.7	21.2
C.V. (%)	23.9	27.3	51.5	34.1	20.7	27.3	62.4	28.8

Progress in transferring type-II resistance into SRWW genotypes has been accelerated via use of the wheat by maize DH system. One DH line, VA01W-476, developed from the cross 'Roane/W14', was found to have good scab resistance in greenhouse and field tests and also has major genes for scab resistance as determined by DNA analysis. A total of 135 DH lines derived from nineteen three-way crosses consisting of diverse scab-resistant parents were selected on the basis of field and greenhouse tests this year and will be evaluated for scab resistance in our inoculated, mist-irrigated nursery at Blacksburg and for agronomic traits at Warsaw.

Type-II resistance from five different sources (Futai8944, Futai8945, Shaan85, VR95B717, and W14) has been backcrossed into seven adapted SRWW backgrounds, and two of the recurrent parents (Roane and Ernie) possess FHB resistance other than type II. A total of 180 BC_4F_2 and BC_5F_2 individuals were selected on the basis of scab severity in greenhouse tests and will be evaluated for scab resistance in our inoculated, mist-irrigated nursery at Blacksburg and for agronomic traits and similarity to the recurrent parent at Warsaw. Near-isogenic SRWS lines with type-II resistance are being developed and will facilitate pyramiding of different types of FHB resistance.

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Epidemiology and Control of Wheat Rusts in the Western United States, 2002.

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Rust monitoring, loss assessment, and race identification. Wheat stripe rust, leaf rust, and stem rust were monitored throughout the PNW using trap plots and field surveys in 2002. Stripe rust was predicted accurately for the PNW using monitoring data and predictive models based on susceptibility of wheat cultivars and environmental factors such as temperature and precipitation. Through collaborators in other states, wheat stripe rust was monitored throughout the United States. Wheat stripe rust occurred from California and the PNW to Georgia and Virginia and from Louisiana and Texas to Wisconsin and Ohio. Severe yield losses caused by stripe rust occurred in Arkansas, California, and the PNW. In 2002, stripe rust epidemics caused wheat yield losses about 8 x 10^6 bushels plus multi-million dollars on fungicide application in the United States.

In the PNW, 2002 was the most severe year of wheat stripe rust probably for the last 10 years. The stripe rust epidemics were more severe in the higher rainfall regions in eastern Washington and northern Idaho, mainly on spring wheat. Severe stripe rust occurred in nurseries of common and durum wheat in Oregon. In Washington state, the 2002 stripe rust epidemic affected about 440,000 acres (70 %) of spring wheat and 45,000 acres (2.5 %) of winter wheat. Acreage affected by stripe rust was about 20 % of the total wheat acreage. Over 170, 000 acres of spring wheat were sprayed with fungicides at a cost of over $2.5 x 10^6 USD. Without the fungicide control, stripe rust could have caused 20–25 % (about 5.7–7.1 x 10^6 bushels) yield losses. The fungicide applications saved $17 to 30 x 10^6 USD for Washington wheat growers. The severe stripe rust epidemics on spring wheat were due to the favorable weather conditions, new races of the pathogen, and widely grown susceptible cultivars. The 2001–02 winter temperatures were higher and the 2002 spring temperatures were lower than normal, favoring stripe rust development. Precipitation was frequent in May and June and provided adequate moisture for stripe rust infection over a long period. A group of new races and races that were detected in 2000–01 in California and east of the Rocky Mountains attacked Zak and some other spring wheat cultivars that were grown over 150,000 acres in eastern Washington and northern Idaho. The durable, high-temperature, adult-plant resistance that is in most winter wheat cultivars and some spring wheat cultivars grown prevented wheat crops from epidemics that could have caused much worse damages. The multiline cultivar Rely, with various seedling-resistance genes, has been grown for more than 10 years and was the number one club wheat cultivar from 1994–2000 and the second most-grown club wheat cultivar in 2002, still showed excellent resistance to stripe rust.

Through collaborators, a total of 314 samples of wheat stripe rust were obtained from 16 states (AL, AR, CA, CO, GA, ID, IN, KS, LA, MO, OH, OR, TX, VA, WA, and WI) in 2002. More than 20 races of *P. striiformis* f. sp. *tritici* were detected. Races PST-78 (virulent on Lemhi, Heines VII, Lee, Fielder, Express, *Yr8*, *Yr9*, Clement, and Compair), PST-80 (the same virulences of PST-78 plus virulence on Produra), and two new races (the same virulences of PST-78 or PST-80 plus virulence on Stephens) were predominant throughout the United States except northwestern Washington. This group of races caused the epidemics in Arkansas, California, and Washington.

In 2002, wheat leaf rust was light in the PNW, probably because of the wide application of fungicides to control stripe rust that also controls leaf rust and stem rust. Only trace stem rust was found in commercial fields. Yield losses due to leaf rust and stem rust were minimal. Leaf rust and stem rust samples were sent to the USDA–ARS Cereal Disease Laboratory, University of Minnesota, for race identification . Two races, MBGJ (virulent on *Lr1*, *Lr3a*, *Lr10*, *Lr11*, and *Lr14a*) and MBBS (virulent on *Lr1*, *Lr3a*, *LrB*, *Lr10*, and *Lr14a*), of *P. triticina* were detected in Washington state. These races were different from MDBJ (virulence on *Lr1*, *Lr3a*, *Lr10*, *Lr14a*, and *Lr24*), the only race detected in 2001. Virulences of the 2002 Washington races were similar to those of the most predominant race MBDS (virulent on *Lr1*, *Lr3a*, *Lr10*, *Lr14a*, *Lr17*, and *LrB*).

Evaluation of wheat germ plasm and breeding lines for resistance to stripe rust. In 2002, more than 8,000 entries of wheat germ plasm and breeding lines from the NSGC and wheat breeders were evaluated for stripe rust resistance in fields under natural infections and in the greenhouse with selected races to cover all possible virulences. The evaluation data were provided to the NSGC for the germ plasm database and to breeders for developing and releasing resistant cultivars. Resistant germ plasm was selected for characterizing resistance, determining genetics of resistance, and mapping genes conferring resistance.

Determining the genetics of stripe rust resistance and developing wheat germ plasm with superior resistance to stripe rust. To determine genetics of stripe rust resistance in wheat cultivars Alpowa, Express, ID377s. and Zak, crosses and backcrosses of these cultivars with susceptible cultivars Avocet Susceptible (AVS) were made in the field and greenhouse. Seed of F_1, F_2, and BC_1 were obtained for developing RILs for genetic studies and molecular-marker development. Advanced backcrosses will be made for developing NILs for determining the virulences of the pathogen, study host-pathogen interactions, and to improve genetic resistance. To fix the problem of susceptibility in Zak to stripe rust and improve the level of resistance in Alpowa, both Zak and Alpowa were crossed with the *Yr5*, *Yr15*, and *Yr18* NILs that were developed in the Plant Breeding Institute, University of Sydney, Australia. F_1 seed were obtained for all these crosses and also obtained from four-way crosses (Zak/*Yr5*//Zak/*Yr15* and Alopwa/*Yr5*//Alpowa/*Yr15*). Molecular markers we developed for *Yr5* and *Yr15* will be used to screen backcross progeny and to accelerate the introgression of the effective resistance genes into the Zak and Alpowa backgrounds. We also made crosses between the *Yr18* NIL with AVS for developing molecular markers for the durable APR gene and use the markers to incorporate *Yr18* into Zak and Alpowa, which would bring durable resistance into Zak and improve the level of durable resistance in Alpowa.

To determine wheat resistance to the barley stripe rust pathogen, crosses were made between Lemhi and PI 478214. Lemhi is susceptible to all races except PST-21 of *P. striifromis* f. sp. *tritici* but resistant to all races of *P. striifromis* f. sp. *hordei*. PI 478214, an Ethiopian spring wheat genotype, is susceptible to both *P. striiformis* f. sp. *tritici* and f. sp. *hordei*. Preliminary results indicate that Lemhi has a single dominant gene for resistance to the barley stripe rust pathogen. Similarly, the barley cultivar Steptoe, which is susceptible to all races of *P. striifromis* f. sp. *hordei*, has a single dominant gene conferring resistance to *P. striiformis* f. sp. *tritici*. Currently, F_2, F_3, and BC_1 progeny are being tested with appropriate and inappropriate races to determine the relationship between the Lemhi gene for resistance to *P. striiformis* f. sp. *hordei* and its *Yr21* for resistance to PST-21 of *P. striiformis* f. sp. *tritici*. Molecular markers are being developed to map these genes.

Developing molecular markers for stripe rust-resistance genes and constructing BAC libraries for cloning resistance genes. To incorporate *Yr5* and *Yr15* resistance against all races of *P. striiformis* f. sp. *tritici* identified in the U.S. into wheat cultivars, the resistance-gene analog polymorphism (RGAP) technique was used to identify markers for the genes. The *Yr5* and *Yr15* NILs were backcrossed to AVS to develop mapping populations. We constructed a high-density map for *Yr5* with 16 RGAP markers using 202 BC_7:F_3 lines. Six of the markers were completely associated with the *Yr5* locus. Sequence analyses revealed that two codominant and *Yr5*-cosegregating markers, *Xwgp-17* and *Xwgp-18*, had 98% homology with each other and had significant homology with many plant resistance genes, resistance gene analogs, and expressed sequence tags. We developed STS markers with primers based on the sequences of *Xwgp-17* and *Xwgp-18*. The STS markers worked well in some, but not all, F_1 progeny of crosses and cultivars. Through collaborating with Jorge Dubcovsky at U.C. Davis, we further developed CAPS markers for *Yr5* by digesting the STS fragments with the *Dpn*II enzyme. The CAPS markers worked well with F_1 progeny of all tested crosses and cultivars. For *Yr15*, we constructed a high-density map with 11 RGAP markers using 196 BC_7:F_4 lines, one marker completely co-segregated with and the others were linked to *Yr15*. We used five of the markers to determine presence or absence of *Yr15* in breeding lines. Both marker and disease tests clearly indicated *Yr15* in one of 13 lines tested. The markers are used to combine *Yr5* and *Yr15* into elite-breeding lines.

Toward cloning *Yr5* and other wheat genes for resistance to stripe rust, we have been constructing a BAC library using the genomic DNA from the *Yr5* NIL digested with *Hind*III. The library now contains 200,000 clones with an average size between 120 and 130 kb, equivalent of 2X hexaploid wheat genome. The *Yr5*-cosegregating RGAP markers will be used to screen the library to identify clones containing the *Yr5* gene.

Evaluating fungicides for integrated control of stripe rust. Foliar fungicides were evaluated for controlling stripe rust in spring wheat plots near Pullman, WA. Susceptible Fielder and moderately susceptible Vanna spring wheat cultivars were planted on 30 April, 2002. Seven fungicide treatments were conducted on 25 June at early boot stage. Plots that were not sprayed were used as untreated check. A randomized-block design was used with four replications for each treatment. Data on stripe rust severity (percent foliage with stripe rust) were recorded on 19 July at milk stage and on 26 July at soft-dough stage. Yields were determined from plots harvested in September. All the fungicide treatments effectively reduced stripe rust severity. Folicur, Quadris, and A 13705 SC 200 applied at 2.6 and 1.96 fl oz significantly increased grain yield compared to the untreated checks on Fielder. Only A13705 SC 200 applied at 1.96 fl oz significantly increased grain yield in Vanna.

To determine the yield gain in cultivars with various levels of resistance/susceptibility from fungicide application to control stripe rust, 24 cultivars were used in the winter wheat experiment and 16 cultivars were used in the spring wheat experiment using a randomized split-plot design with four replications. The fungicide Quadris was sprayed at the rate of 6.2 oz/acre when the winter crops were in late heading stage and the spring crops were in late boot to early heading stage and highly susceptible cultivars had 10 % stripe rust. Stripe rust occurred naturally in the nonfungicide-treated plots. Rust severities were recorded 33 and 25 days after the fungicide spray in the winter wheat and spring fields, respectively. Stripe rust severities developed in the winter wheat field to 80–85 %, 50–60 %, 10–30 %, and 0–9 % on the susceptible, moderately susceptible, moderately resistant, and resistant cultivars, respectively; and in the spring wheat field to 85–95 %, 70–80 %, 38–45 %, and 0–5 % on the susceptible, moderately susceptible, moderately resistant, and resistant cultivars, respectively. The fungicide application increased yield by over 45 %, 20–40 %, 10–18 %, and 0–9% for the susceptible, moderately susceptible, moderately resistant, and resistant winter wheat cultivars, respectively; and by 40–83 %, 25–39 %, 10–20 %, and 4–8 % for the susceptible, moderately susceptible, moderately resistant, and resistant spring wheat cultivars, respectively. These data can be used to make appropriate recommendations for fungicide application according to cultivars.

Near-isogenic lines differing for morphological and physiological traits.

R.E. Allan.

Several sets of NILs have been developed, described and deposited into the USDA–ARS National Plant Germplasm System. Genetic traits for which they differ and their PI numbers are provided. To date these sets have not been registered with Crop Science Society of America.

NILs differing for heading date. Paha is a soft white winter club wheat cultivar having a midseason heading date and excellent club wheat quality. Paha was grown in the U.S. PNW in the 1970s.

- Suweon 185/7*Paha.
- PI631404, PI631405, PI631406. These NILs head 6–7 days earlier than Paha deriving earliness from Suweon 185.
- PI631403, PI631407, and PI631408. These NILs are similar to Paha for heading date.
- Early Blackhull/7*Paha.
- PI631409, PI631410, and PI631411. These NILs head 7 days earlier than Paha deriving earliness from Early Blackhull.
- PI1631412, PI631413, and PI631414. These NILs are similar to Paha for heading date.

Nord Desprez NILs differing for reduced height. Nord Desprez is an old soft red French winter wheat cultivar that has been used as a parent in several U.S. PNW breeding programs. 'Norin 10/Brevor 14' contributed *RhtB1b* and *RhtD1b* genes.

- 'Norin 10/Brevor 14' and 'CI13253//7*Nord Desprez'
- PI608358, PI608359, PI608360, and PI608361. These NILs have *RhtBlb RhtDlb* and are 47–51 % shorter than Nord Desprez.
- PI608363, PI608366, PI608368, and PI608369. These NILs have *RhtB1b RhtD1a* and are 9–13 % shorter than Nord Desprez.
- PI608362, PI608364, PI608365, and PI608367. These NILs have *RhtBla RhtDlb* and are 18–20 % shorter than Nord Desprez.
- PI603870, PI608371, PI608372, and PI608373. These NILs have *RhtB1a RhtD1a* and are similar to Nord Desprez (98 cm) for plant height.

Soft white winter NILs differing for reduced height and awn expression. 'Norin 10/Brevor 14' and 'CI13253/7*Brevor'. CI13253 has genes *RhtB1b RhtD1b* for reduced height and a gene for awnedness. Brevor has *RhtB1a BhtD1a* for normal plant height (103 cm) and a gene for awnlessness. Brevor was an important SWWW grown in the U.S. PNW during 1952–64.

- Awnless *RhtB1b RhtD1b* NILs: PI631090, PI631091, and PI631092.
- Awned *RhtB1b RhtD1b* NILs: PI631093, PI631094, and PI631095.
- Awless *RhtB1b RhtD1a* NILs: PI631108, PI631112, and PI631113.
- Awned *RhtB1b RhtD1a* NILs: PI631109, PI631110, and PI631111.
- Awnless *RhtB1a RhtD1b* NILs: PI631105, PI631106, and PI631107.
- Awned *RhtB1a RhtD1b* NILs: PI631102, PI631103, and PI631104.
- Awnless *RhtB1a RhtD1a* NILs: PI631096, PI631097, and PI631098.
- Awned *RhtB1a RhtD1a* NILs: PI631099, PI631100, and PI631101.

Tom Thumb reduced-height NILs. Growth habit, market class, plant height, and plant height genes of the recurrent parents of these NILs are Brevor (SWWW, 106 cm, *RhtB1a RhtD1a*), Moro (soft white winter club, 110 cm, *RhtB1a RhtD1a*), Olympia (SWWW, 140 cm, *RhtB1a RhtD1a*), Stephens (SWWW, 82 cm, *RhtB1b RhtD1a*), Daws (SWWW, 87 cm, *RhtB1a RhtD1b*), and Tres (soft white winter club, 92 cm, *RhtB1a RhtD1b*). 'Tom Thumb/7*Burt' contributed the *RhtB1c* gene.

Brevor*4///Tom Thumb/7*Burt//3*Brevor.

- PI615589, PI615590, PI615591, PI615592, and PI615593. These NILs have *RhtB1c RhtD1a* and are 65–68 % shorter than Brevor.
- PI615594, PI615595, PI615596, PI615597, and PI615598. These NILs have *RhtB1a RhtD1a* and are similar to Brevor in plant height.

Moro*5///Tom Thumb/7*Burt//2*Moro.

- PI615599, PI615600, PI615601, PI615602, and PI615603. These NILs have *RhtB1c RhtD1a* and are 49–53 % shorter than Moro.
- PI615604, PI615605, PI615606, PI615607, and PI615608. These NILs have *RhtB1a RhtD1a* and are similar to Moro in plant height.

Olympia*5///Tom Thumb/7*Burt//2*Olympia.

- PI615629, PI615630, PI615631, PI615632, and PI615633. These NILs have *RhtB1c RhtD1a* and are 51–55 % shorter than Olympia.
- PI615634, PI615635, PI615636, PI615637, and PI615638. These NILs have *RhtB1a RhtD1a* and are similar to Olympia in plant height.

Stephens*5///Tom Thumb/7*Burt//2*Stephens.

- PI615634, PI615635, PI615636, PI615637, and PI615638. These NILs have *RhtB1c RhtD1a* and are 46–50 % shorter than Stephens.
- PI615644, PI615645, PI615646, PI615647, and PI615648. These NILs have *RhtB1b RhtD1a* and are similar to Stephens for plant height.

Daws*5///Tom Thumb/7*Burt//2*Daws.

- PI615609, PI615610, PI615611, PI615612, and PI615613. These NILs have *RhtB1c RhtD1b* and are 64–67 % shorter than Daws.
- PI615614, PI615615, PI615696, PI615617, and PI615618. These NILs have *RhtB1a RhtD1b* and are similar to Daws for plant height.
- PI615619, PI615620, PI615621, PI615622, and PI615623. These NILs have *RhtB1c RhtD1a* and are 39–43 % shorter than Daws.
- PI615624, PI615625, PI615626, PI615627, and PI615628. These NILs have *RhtB1a RhtD1a* and are 39–49 % taller than Daws.

Tres*5///Tom Thumb/7*Burt//2*Tres

- PI615649, PI615650, PI615651, PI615662, PI615653. These NILs have RhtB1c RhtD1b and are 62% shorter than Tres.
- PI615659, PI615660, PI615661, PI615662, PI615663. These NILs have RhtB1a RhtD1b and are similar to Tres for plant height.
- PI615654, PI615655, PI615656, PI615657, PI615658. These NILs have RhtB1c RhtD1a and are 49 to 52% shorter than Tres.
- PI615664, PI615665, PI615666, PI615667. These NILs have RhtB1a RhtD1a and are 16 to 18% taller than Tres.

Spring versus winter growth habit NILs. The recurrent parent Marfed is a SWSW that was widely grown in the U.S. PNW during 1956–76. Coldhardiness of these NILs was reported by Storlie et al. Crop Sci **38**:483-488, 1998.
Suweon 185/6*Marfed.

- PI631514, PI631516, PI631519, PI1631522, and PI631524. These NILs have spring growth habit and likely the *Vrn1* allele of Marfed.
- PI631515, PI631517, PI631518, PI631520, PI631521, PI631523, PI631525, and PI631526. These NILs have winter growth habit and likely the *vrn1* allele of Suweon 185.

Chugoku 81/6*Marfed

- PI631527, PI631529, PI631531, PI631533, and PI631536. These NILs have spring growth habit and likely the *Vrn1* allele of Marfed.
- PI631528, PI631530, PI631532, PI631534, PI631535, and PI631537. These NILs have winter growth habit and likely the *vrn1* allele of Chugoku 81.

Evaluation of Wanser and Daws vernalization near-isogenic lines for cold hardiness.

Kimberly Garland Campbell, Robert E. Allan, Todd Linscott, Kay Walker-Simmons, and Eric Weir.

Our objective was to compare the response to artificial freezing for near-isogenic wheat genotypes differing for vernalization (*Vrn*) loci. We regularly conduct artificial freezing tests in growth chambers in the WSU Plant Growth Center that are able to cool to –25°C. The basic test is as described in Storlie (Storlie et al. 1998) and the result is an LT_{50} value (or temperature at which 50 % of the plants are survive).

R.E. Allan has developed two sets of NILs for each of four *Vrn* genes in a winter wheat background. Each set used the Triple Dirk NILs developed by Pugsley (Zeven et al. 1986) as *Vrn*-gene donors (see Table 1). Two SWWW cultivars were used as recurrent parents: Daws (Peterson et al. 1977) with good winter hardiness and Wanser with less winter hardiness. In our tests, the LT_{50} of Daws has consistently been 3°C less (colder) than that of Wanser.

Each Triple Dirk NIL initially was backcrossed twice to each recurrent parent with selection for the presence of the *Vrn* allele. Six more backcrosses were made using the recurrent parent as a male and a spring-habit progeny from the previous generation as a female (for example: Daws*2/Triple DirkD)*6//Daws). Within the progeny of each of four or five BC_7 families/cross, a winter and a spring sibling was identified. Each sibling was selfed and its growth habit was checked in both a greenhouse and field environment during 1999 and 2000. Spring-habit NILs were retained only if they were homozygous for spring habit. Thus, each NIL set is comprised of each of the four *Vrn* loci as 4–5 families possessing both a winter and spring sib for a total of 36–40 NILs/recurrent parent. Theoretically, Triple Dirk alleles make up 0.37 % of the genome of each NIL.

Table 1. LT_{50} values for near-isogenic lines of Daws differing for *Vrn* loci. Values followed by the same letter are not significantly different based on Fisher's protected LSD test.

Spring-habit NILs			Winter-habit NILs		
Vrn locus	LT_{50}	Mean w/o *Vrn* locus	*Vrn* locus	LT_{50}	Mean w/o *Vrn* locus
Vrn-A1 (Vrn1)	–8.8		*vrn-A1 (vrn1)*	–11.5	
Vrn-A1 (Vrn1)	–9.7		*vrn-A1 (vrn1)*	–17.2	
Vrn-A1 (Vrn1)	–12.2		*vrn-A1 (vrn1)*	–15.7	
Vrn-A1 (Vrn1	–12.4	–11.3 a	*vrn-A1 (vrn1)*	–15.1	–14.6 b
Vrn-B1 (Vrn2)	–15.3		*vrn-B1 (vrn2)*	–15.5	
Vrn-B1 (Vrn2)	–13.8		*vrn-B1 (vrn2)*	–15.1	
Vrn-B1 (Vrn2)	–14.5		*vrn-B1 (vrn2)*	–13.7	
Vrn-B1 (Vrn2)	–14.0	–14.4 b	*vrn-B1 (vrn2)*	–14.7	–14.8 b
Vrn-D1 (Vrn3)	–14.5		*vrn-D1 (vrn3)*	–14.3	
Vrn-D1 (Vrn3)	–14.4		*vrn-D1 (vrn3)*	–14.9	
Vrn-D1 (Vrn3)	–13.6		*vrn-D1 (vrn3)*	–14.7	
Vrn-D1 (Vrn3)	–14.6	–14.3 b	*vrn-D1 (vrn3)*	–14.6	–14.6 b
Vrn-B1 (Vrn4)	–12.8		*vrn-B1 (vrn4)*	–15.2	
Vrn-B1 (Vrn4)	–14.0		*vrn-B1 (vrn4)*	–14.8	
Vrn-B1 (Vrn4)	–14.0		*vrn-B1 (vrn4)*	–15.9	
Vrn-B1 (Vrn4)	–14.2	-13.8 b	*vrn-B1 (vrn4)*	–16.2	–15.5 b
Mean of all spring-habit NILs	–13.6 a		Mean of all winter-habit NILs		–14.9 b
Alpowa spring check	–6.7		Daws winter check	–17.2	
			Norstar winter check	–22.1	

The LT_{50} values of the Daws NILs were determined. All *Vrn* loci resulted in LT_{50} values similar to the recurrent parent except for *Vrn-A1* (Table 1) (spring habit). The presence of the *Vrn-A1* allele caused a major reduction in cold hardiness, supporting previous research that noted the major effects of chromosome 5AL on cold hardiness. Because of the effects of the *Vrn-A1* allele, the mean LT_{50} values for spring-habit NILs were higher than the mean for winter-habit NIls. There was no change in LT_{50} values associated with the *vrn-a1* allele (winter habit) in the Daws NILs. The reduction in cold hardiness associated with *Vrn-A1* is either extremely closely linked to *Vrn-A1* or an effect of *Vrn-A1* itself. There were no differences in LT_{50} values among any of the other *Vrn* alleles. This indicates that we can develop winter hardy spring habit wheat cultivars by using *Vrn-B1* or *Vrn-D1*. Those facultative-habit cultivars are useful in dry-cropping situations when planting is depending upon moisture. These results also indicate that the *Vrn* loci and loci closely linked to them are not likely to be important sources of improved winter hardiness in winter wheat.

Expression levels of antioxidant enzymes during cold acclimation in near-isogenic lines of winter and spring wheat.

Daniel Z. Skinner and Kwang-Hyun Baek.

The expression levels of antioxidant enzyme genes were monitored in winter and spring wheat NILs during cold acclimation. The 442 (winter wheat) and 443 (spring wheat) NILs developed by Dr. R.E. Allen differed only in the *Vrn1A-Fr1* region of chromosome 5A. Total RNA was extracted from wheat grown at a constant 20°C for 2 weeks, then at 2°C for 1, 2, or 4 weeks. Using gene-specific primers, quantitative RT-PCR was used to measure the levels of RNA transcripts from 11 genes. The antioxidant genes monitored were mitochondrial MnSOD, chloroplastic Cu, ZnSOD, Fe–SOD, CAT, ascorbate peroxidase (APX), gutathione reductase (GR), glutathione peroxidase (GP), monodehydroascorbate reductase (MDHAR), and dehydroascorbate reductase (DHAR). The expression levels of glyceraldehyde-3-phosphate dehydrogenase (GAPDH) and β-actin also were monitored during cold acclimation to evaluate these genes as possible constant-expression standards for wheat cold-acclimation studies.

The expression levels of the antioxidant enzyme genes were up-regulated (MnSOD, MDHAR, AP, DHAR, GP, and GR), down-regulated (CAT), or maintained constant expression (FeSOD and Cu, ZnSOD). The genes that were up-regulated reached their highest expression levels after 2 weeks, then declined or maintained constant expression to 4 weeks. The *Vrn1A-Fr1* region seemed to play a role in regulating the expression level of some of the antioxidant enzyme genes in low temperature. NIL 442 has significantly higher expression levels of MnSOD, CAT, and APX than NIL 443 after 4 weeks of cold exposure. GAPDH and β-actin had significantly higher expression levels during cold acclimation, therefore, those enzymes cannot be used as standards in these studies.

These results suggested that antioxidant enzyme genes may play a role in cold response of wheat plants. The response appears to manifest to its highest level within the first week of exposure to cold, and appears to be influenced by the alleles present at the *Vrn1A-Fr1* region.

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The mission of the lab is two-fold: conduct milling, baking and end-use quality evaluations on wheat breeding lines and conduct research on wheat grain quality and utilization. The lab continues to move into web-based information transfer and has added extensive enhancements to our web site, http://www.wsu.edu/~wwql/php/index.php. To provide greater access to our research, we developed a database of wheat cultivars relating kernel hardness and puroindoline allele. We are in the process of placing our research publications on our web site.

We are serving as curator of the Grain Hardness, Puroindoline and GSP-1 gene sections of the Catalogue of Gene Symbols in Wheat. Several new alleles have been documented in *Ae. tauschii* and other diploid taxa.

C.F. Morris and D.A. Engle lead the PNW Wheat Quality Council, a consortium of collaborators who evaluate the quality of new cultivars and advanced-breeding lines.

A.D. Bettge currently serves as chairman of the AACC Soft Wheat and Flour Technical Committee. New methodology for the analysis of end-use characteristics of wheat is studied by this committee for inclusion in the AACC's Approved Methods manual. Recent methods that have been studied collaboratively and approved include solvent-retention capacity, which estimates a number of end-use quality factors such as protein quality, starch damage, and pentosan content, and flour-swelling volume, which measures starch swelling and the impact of granule-bound, starch-synthase allelic state. Currently, the committee is studying an L-DOPA substrate-based method for estimation of polyphenol oxidase content of wheat, a contributor to Asian noodle discoloration.

Post-doctoral research associates include A.N. Masa, Eujayl, E.P. Fuerst, K.R. Gedye, and C.C. Burke. Y. Haruta is a visitor from a Japanese milling company.

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Spring wheat breeding and genetics.

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Overview. The overall goal of wheat breeding efforts at WSU is to enhance the economic and environmental health of wheat production in the PNW by releasing genetically superior cultivars for commercial production. Traditional breeding methods and molecular genetic technology are combined to reduce production risks associated with abiotic and biotic stresses by incorporating genetic insurance into adpated, elite varieties.

Seven hundred crosses were made in 2002, and 27,334 breeding lines were evaluated in field trials at 1 to 16 locations in Washington state. Grain samples from 522 breeding lines with superior agronomic performance were sent to the USDA–ARS Western Wheat Quality Laboratory for end-use quality assessment. Two cultivars, **Macon** (HWSW) and **Eden** (spring club) were approved for release. Macon is a Hessian fly-resistant cultivar with exceptional bread-baking and noodle-making properties. Eden has outstanding grain yield potential, traditional club quality, and excellent stripe rust resistance. Research efforts were initiated to 1) incorporate a high protein region and stripe rust resistance genes into adapted spring wheat cultivars using MAS, 2) assess broadly adapted wheat germ plasm for resistance to *Phythium*, and 3) assess soilborne disease pressure in glyphosate tolerant wheat production.

New cultivar prereleases and releases. Scarlet, a 1998 WSU release, was the primary HRWW in commercial production in Washington State in 2002. Scarlet was released for the semiarid production region as a replacement for Butte 86 and Kulm, however, the cultivar has broad adaptation and acreage has extended well beyond the targeted region into the intermediate-rainfall zone. Although Scarlet has performed well in the semiarid region of Washington state, it has relatively low test weight when stressed and is not excessively tall cultivar. Scarlet also is moderately susceptible to the race of stripe rust that prevailed in the region in 2002 and is susceptible to the Hessian fly. Originally, our goal was to develop a cultivar specifically for the semiarid region with the yield potential of Scarlet but that is taller, and has higher test weight, higher grain-protein content, and improved bread-baking quality compared to those of Scarlet. The agronomic performance and phenotypic characteristics of WA007859 align nicely with these requirements. WA007859 also is resistant to current races of stripe rust in the region, and is resistant to local Hessian fly biotypes, which improves its suitability for direct seed production in the low- and intermediate-rainfall zones. In 7 out of 8 site-years in cultivar-testing trials at Lind and Horse Heaven, WA, grain yields of Scarlet were statistically similar to those of WA007859. Based on 23 site years of data from the low-rainfall zone, WA007859 has a 0.6 lb/bu test weight advantage over Scarlet, and the grain protein content of WA007859 is 0.4 % higher than that of Scarlet. The bread-baking quality of WA007859 also is superior to that of Scarlet. WA007859, which will be named **Hollis**, was approved for cultivar release. Foundation seed of this cultivar will be produced in 2003.

Nearly 100,000 acres of the SWSW Zak were grown in Washington State in 2002, its first year in commercial production. Based on its high yield potential, superior end-use quality and Hessian fly resistance, Zak was projected to be an ideal replacement for Wawawai and Alpowa in the high-rainfall zone. In previous years, Zak demonstrated resistance to stripe rust races present in the region; however, Zak, along with many other SWSWs in commercial production, was highly susceptible to the race that prevailed in the region in 2002. Costs associated with spraying fungicide to control stripe rust reduce the profit potential of this cultivar and increase the risk of environmental contamination. The highest priority for the spring wheat-breeding program is to release a stripe rust-resistant replacement for Zak with equivalent or superior grain-yield potential and end-use quality characteristics. We also would like to replace a substantial proportion of the Alpowa acreage in the high-rainfall zone with a cultivar that has improved end-use quality, Hessian fly resistance, and better emergence under direct-seed production conditions. **WA007921** has excellent potential as the Zak and Alpowa replacement in areas receiving more that 15 inches of average annual precipitation. WA007921 was rated as having moderate resistance to stripe rust in 2002 and is partially resistant (65 %) to the Hessian fly. The grain-yield potential of WA007921 was equal to or better than those of Zak, Alpowa, and Wawawai in a majority of the dryland field trials conducted from 1999 to 2002. The end-use quality of WA007921 is equivalent or superior to that of Zak, and this cultivar is a dramatic end-use quality improvement over Alpowa. WA007921 was approved for prerelease and Breeder seed of this cultivar will be produced in 2003.

In 2002, 16,000 acres of SWSW were grown in Washington state. A majority of this acreage was sown to Idaho 377s, which was licensed by the University of Idaho to a grower coöperative. Although ADM Spokane successfully produced Idaho 377s locally on contract in 2002, many growers are interested in obtaining hard white wheat cultivars through public release channels to reduce seed costs and to create flexibility in production and marketing strategies. Although Idaho 377s has excellent yield potential and superior noodle color, it does not mill particularly well and has suboptimal bread-making quality. In 2002, we released Macon, a dual-purpose, HWSW suitable for noodle and bread making with acceptable but not exceptional agronomic performance. Macon is resistant to local biotypes of the Hessian fly; however, it is moderately susceptible to the new race of stripe rust that prevailed in the region in 2002. Our goal is to release a public cultivar to replace Idaho 377s and to identify a stripe rust resistance compliment for Macon that has superior grain-yield potential, a broad adaptation range, and dual-purpose quality. WA007931 has outstanding grain-yield potential that equals or exceeds those of Idaho 377s and Macon across production zones. WA007931 has far better bread-making quality than that of Idaho 377s, and it has excellent noodle color. However, the bread-making quality of Macon is superior to that of WA007931. WA007931 would be an outstanding compliment to Macon in that it is much taller and has higher test weight, making it more suitable for production in the semiarid and intermediate-rainfall zones. WA007931 also is moderately resistant to stripe rust and is partially resistant to the Hessian fly. WA007931 is a partial waxy type, which might make it suitable for producing different types of noodles than which Macon is suited. Releasing cultivars with complimentary quality attributes will broaden the market range for PNW hard white wheat.

Marker-assisted backcross breeding.

M. McClendon and K. Kidwell.

High protein gene introgression. Increasing grain protein content by applying high rates of N fertilizer can be effective, but it is inefficient. Instead of relying solely on fertility management to increase grain-protein content of HRS, avenues to genetically enhance this trait through traditional breeding methods are now available. A promising genetic source of high grain-protein content (HGPC) was detected in a wild relative of wheat. Researchers speculate that a grain-protein content increase of 1–2 % can be expected if the HGPC region is introgressed into a bread wheat cultivar, and this protein content increase is expected to occur without additional nitrogen fertilizer requirements. The objective of this project is to increase GPC of the hard red varieties Scarlet and Tara 2002 by introgressing the region into these lines through marker-assisted backcross breeding. BC_5F_3 and BC_6F_2 lines, containing > 99 % of the genes from the WSU lines and < 1 % of the genes from the donor parents, including the high protein segment, were developed using this strategy, and this material was evaluated in the field in 2002.

Over 100 isolines (BC_5F_3), containing 99 % of the genes from the Scarlet or Tara 2002 with 1 % of the genes from Glupro, with or without the HGPC segment, were evaluated in a nonreplicated field trial at WSU's Spillman Farm in 2002. A soft white fertility regime (2.5 lb N/expected bu) was used to maximize fertility response differences among isolines. This trial was heavily infested with stripe rust, and susceptible lines were eliminated from consideration. Even though nonreplicated data from a single site-year must be interpreted with extreme caution, several isolines appear to have excellent potential as high protein replacements for Scarlet and Tara 2002. Replicated field trials will be initiated in 2003 to assess the impact of incorporating the HGPC region into these cultivars.

Stripe rust resistance. Zak, a Hessian fly-resistant SWSW was slated to replace Wawawai, Penawawa, and perhaps some Alpowa acreage in the high-rainfall region based on its excellent yield potential and superior end-use quality. Prior to 2002, Zak had demonstrated excellent resistance to stripe rust races prevalent in the field. In commercial production in 2002, Zak showed high levels of susceptibility to stripe rust, indicating that recently developed races have circumvented the resistance in Zak. Incorporating new rust resistance genes into Zak is a high priority since this cultivar would have been the premiere SWSW in commercial production in the region if its stripe rust resistance had held. Stripe rust resistance genes *Yr5* and *Yr15* are effective against all races identified so far in the U.S., and tightly linked molecular markers for these genes have been developed. The primary goal of this project is to introgress *Yr5* and *Yr15* into Zak as quickly and efficiently as possible by utilizing the recurrent enriched backcrossing breeding scheme.

Gene discovery.

R. Higginbotham, T. Paulitz, and K. Kidwell.

Pythium root rot, a fungal pathogen of wheat, causes yield losses in virtually every field in Washington. Even though *Pythium* damage is well-documented, limited information about which isolates are most responsible for disease occurrence is available. Nineteen *Pythium* isolates were tested for pathogenicity on two spring wheat cultivars. A complete random design was used to evaluate cultivars in inoculated and non-inoculated treatments in a growth chamber maintained at 16°C with ambient humidity. Plant height, length of the first true leaf, number of seminal roots, and crown root number were recorded, and roots were digitally scanned into computer files that were analyzed using WinRhizo software. Preliminary results indicated all of the *Pythium* isolates caused a significant reduction in the number of root tips ($P < 0.0001$), root surface area ($P = 0.0001$) and root length ($P = 0.0001$), whereas average root diameter increased ($P = 0.001$) due to a reduction in the number of fine secondary roots. Virulence level varied among species, and isolates with the highest pathogenicity levels will be used to assay a broad range of germ plasm for tolerance/resistance.

Transgene assessment.

J. Baley, T. Paulitz, and K. Kidwell.

Glyphosate tolerant wheat will permit 'in crop' weed control while maintaining the intrinsic environmental and economic benefits associated with no-till crop production. However, potential yield gains may be lost because of increased activity of soilborne pathogen on dying weeds within a glyphosate tolerant wheat crop. The objective of this study is to proactively determine the risks of incorporating glyphosate tolerant wheat into no-till production systems. Bobwhite and Westbred 926 NILs with and without glyphosate tolerance were evaluated under direct-seed conditions in three agroclimatic zones in eastern Washington. A mixture of spring barley and sterilized oat seed inoculated with *Rhizcotonia solani/oryzae* or *Gaeumannomyces graminis* var. *tritici* (GGT) were direct seeded into the field plots prior to planting the NILs to simulate greenbridge volunteer. A no greenbridge control also was included. NILs from three treatments (RoundUp, Buctril/Harmony Extra, and a no-spray, hand-weeded control) were evaluated for disease severity and agronomic performance. Roots were digitally scanned and analyzed using WinRhizo software to assess morphological changes within treatments. All NILs were evaluated with the Buctril/Harmony Extra and no-spray treatments, but only the glyphosate tolerant varieties were treated with glyphosate.

Regardless of disease treatment or location, glyphosate treated Roundup Ready® (RR) spring wheat, produced significantly ($P = 0.001$) more grain than NILs treated with Buctril/Harmony Extra or the no-spray control, suggesting that greenbridge transmission of *Rhizoctonia* and GGT due to Roundup application may not occur at high enough levels to suppress yields of RR cultivars. *Rhizcotonia* and GGT naturally prevail in areas receiving low and high levels of precipitation, respectively. In trials planted in the low and high rainfall zones, grain yields of NILs treated with Buctril/Harmony Extra were significantly ($P = 0.05$) lower than NILs treated with Roundup or the no-spray control. High levels of yield depression with this treatment was unexpected since wheat producers in the PNW typically use Buctril/Harmony Extra for broadleaf weed control. However, Harmony Extra is a sulfonylurea herbicide, which is a group of herbicides that have been shown to increase the incidence of *R. solani* and GGT in wheat, which may have impacted these results.

An interesting herbicide-pathogen interaction was noted in a trial that was heavily infested with stripe rust. Bobwhite NILs that had not been treated with Roundup had a more severe incidence of stripe rust than Roundup-treated

NILs. Bobwhite NILs sprayed with Buctril/Harmony Extra or in the no spray control displayed severe stripe rust-susceptibility symptoms and matured 2–3 weeks earlier than NILs treated with Roundup. Buctril/Harmony Extra treated RR Bobwhite produced significantly (P = 0.01) less grain, than the RR Bobwhite treated with Roundup, regardless of root disease treatment. Visual differences in stripe rust severity were not apparent until 21 days after herbicide application. These results suggest that glyphosate within a RR-wheat plant may remain active for extended time periods, thereby hindering the colonization of leaf tissue by foliar pathogens. If true, residual in-plant glyphosate activity also may be responsible for increased grain yields detected for Roundup treated RR NILs across locations, regardless of disease treatment. Additional field trials, along with concurrent growth chamber analysis of root structure, defense enzymes and products, will be conducted to elucidate the effects of Roundup application on the transmission of soilborne pathogens to herbicide-resistant wheat.

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