2004-2005 Annual Progress Report
Winter Wheat Breeding and Genetics Program
Soil and Crop Sciences Department
Colorado State University

Introduction

Wheat breeding research at Colorado State University (CSU) is a cooperative effort involving multiple partners, including breeding program personnel, research and extension specialists at CSU and elsewhere, and farmer-cooperators who donate their time and land to assist with field testing activities. A critical component of this effort is the partnership that exists between the CSU Agricultural Experiment Station (CSUAES) and seed industry and wheat commodity groups in Colorado, including the Colorado Seed Growers Association (CSGA), the Colorado Wheat Administrative Committee (CWAC), the Colorado Association of Wheat Growers (CAWG), and the Colorado Wheat Research Foundation (CWRF). Without the excellent support from each of these groups, wheat breeding research at CSU would not be possible or, at the very least, would be severely curtailed.

The primary goals of the CSU Wheat Breeding and Genetics Program are to: a) **develop improved wheat cultivars and germplasm** adapted for the diverse production conditions in Colorado and the west central Great Plains and b) **conduct applied-basic research** to improve understanding of genetic and environmental factors that affect wheat yield and end-use quality. This report summarizes the activities of the breeding program and main areas of progress during the 2004-2005 season.

2004-2005 Site Conditions

In 2004-2005, the breeding program conducted field trials at six main locations in eastern Colorado (Akron, Burlington, Dailey, Julesburg, Sheridan Lake, and Walsh) in addition to the main location at the ARDEC research facility near Fort Collins. As discussed in last year's report, the Dailey and Sheridan Lake locations were added as new locations in fall 2004 in an effort to enhance our testing capability. Overall, environmental conditions experienced at these locations can be described as follows:

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

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

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

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

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

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

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

Under the direction of CSU Extension Agronomist Dr. Jerry Johnson, the CSU Variety Testing Program evaluated check varieties and experimental lines at seven other dryland trial locations (UVPT – Bennett, Cheyenne Wells, Genoa, Lamar, Orchard, Sheridan Lake, and Yuma) and two other irrigated trial locations (IVPT – Stratton and Rocky Ford). In addition to these dryland locations, experimental lines and a reduced set of check entries were also tested at two dryland locations (Hudson, Granada) that were added in fall 2004 in response to the continued loss of so many variety trial sites. Overall, the various UVPT trial locations experienced a variety of stresses, with spring drought stress, high temperatures at heading and during grain filling, and stripe rust being the most damaging. In spite of all of the problems, 10 out of 11 UVPT locations were successfully harvested with only Orchard being abandoned due to severe effects of the spring drought. In addition to the Fort Collins IVPT, both Stratton and Rocky Ford were both successfully harvested though yields were reduced in some of these trials due to stripe rust and high temperatures.

The most significant disease or insect problem in the trials in 2005 was the severe stripe rust infection that was present at many of the locations. This infection was typically heavy at some of the irrigated locations (Fort Collins, Stratton, Rocky Ford) and higher yielding dryland locations (such as Genoa) but was uncharacteristically heavy in southeast Colorado (including Walsh, Lamar, and Sheridan Lake) where stripe rust has been a much lesser concern the last few years. In spite of the severity of the infection observed, and the high degree of apparent susceptibility of some entries, differences were noted among test entries in the capacity to fill the grain from stem reserves after stripe rust killed the leaves. While not a problem in most trials, except for perhaps the UVPT at Julesburg, wheat streak mosaic virus (WSMV) was a significant problem in some areas of the state due to the mild conditions experienced in late summer and fall 2004 that provided ideal conditions for the wheat curl mite that transmits WSMV. Aside from RWA which were observed at several locations, no other significant insect (bird cherry-oat aphid, greenbug) problems were notes.

<u>Cultivar and Germplasm Development</u>

Several field, laboratory, and greenhouse-based activities contribute to the overall breeding effort. The core of this effort can be likened to a "pipeline" with materials entering the pipeline at the beginning (e.g., new crosses), materials occasionally leaving the pipeline at the end (e.g., new cultivar or germplasm releases), and materials at all possible stages in between subject to various testing, screening, and selection activities. In addition to this central pipeline, we are currently involved in several supplementary activities or areas of emphasis that will also be described.

State Variety Trials

In 2004-2005, advanced experimental lines were tested in the dryland UVPT along with released cultivars and experimental lines from various public or private breeding programs (52 total entries). A total of 19 experimental lines from our breeding program were tested in the 2005 UVPT. Of these experimental lines, 2 were *Clearfield** wheat lines (reselections from lines already discarded), 7 were hard white wheat (HWW) lines, and 10 were hard red wheat (HRW) lines in their first, second, or third year of statewide testing in the UVPT (**Table 1**).

As mentioned previously, the trials in 2005 were a definite improvement over previous years when we had lost over half of our testing locations and had little data upon which to base our selections. Data from 10 locations in 2005 were generally sound and, together with data from regional trials and breeding trials at other locations, selections were made for advancement of six lines for further testing in the 2006 UVPT:

Entry	Pedigree	Type/Description
CO00016 @	CO940606/TAM107R-2	hard red, early maturity, high yield, good quality
CO01212 §	Glenson/Akron//Yumar	hard red, excellent baking quality, KB resistant (?)
CO01385-A1 §	Yumar/Arlin	hard red, high yield, high test weight
CO01473 §	NE93552/TX93V5922//NE94479	hard red, tall wheat
CO01W171 §	96HW100-5/96HW114	hard white, excellent baking quality
CO01W172 §	96HW100-5/96HW114	hard white, excellent baking quality

@ Line submitted for evaluation in the 2005-2006 Wheat Quality Council (WQC) testing program.

§ Line submitted for evaluation in the 2005-2006 Regional Performance Testing Program (Southern Regional Performance Nursery).

Selection pressure was relaxed somewhat due to the adverse conditions experienced at several of the trial locations. Specifically, three lines (CO01212, CO01W171, CO01W172) that had relatively lower yields were advanced for further testing because they showed good yield in 2004 but are later maturing and suffered from the high temperatures at heading at some of our locations in 2005. Of the other lines, CO01385-A1 is a reselection from a CO01385 which was also tested in the UVPT for the first year. CO01385-A1 showed very high yield, very high test weight, and good stripe rust resistance and was in the top group at each of the trial locations, showing a high degree of stability across environments. The chief concern with CO01385-A1 is its low protein content, similar to both Hatcher and Bond CL, and its marginal dough mixing properties. We made 15 line reselections from CO01385 in 2005, some of which showed higher protein content than CO01385-A1, and have sent seed of these lines to Yuma AZ to enable advancement of one or more of these for testing in the UVPT in 2007. We are hopeful that we'll be able to identify a reselection from CO01385 that preserves its high yield and test weight while showing higher grain protein content.

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

Table 1. Data summary from the 2005 Dryland Variety Performance Trial (UVPT). Entries are ranked in descending order by grain yield. †

Entry	Akron	Arapahoe	Bennett	Burlington	Genoa	Julesburg	Lamar	Sh Lake	Walsh	Yuma	Yield Avg	Test Wt Avg	HT	HD
CO01385-A1*	29.1	27.6	44.0	25.7	71.1	36.9	49.8	26.4	69.8	32.1	41.2	58.5	23.8	142.7
Bond CL	33.6	30.5	41.2	33.1	66.2	28.4	37.5	27.1	60.3	30.8	38.9	56.4	22.1	141.3
CO00016*	31.3	34.6	37.3	33.5	53.1	31.9	44.9	38.4	57.4	25.1	38.8	56.9	23.2	140.7
CO01385	32.0	23.7	42.7	20.7	63.3	38.1	43.2	28.8	68.0	25.0	38.6	58.9	23.7	142.3
Hatcher	26.5	24.3	35.2	14.3	66.2	33.4	43.5	30.4	65.0	18.1	35.7	57.6	20.4	142.7
Enhancer	28.6	25.7	37.4	25.8	59.4	26.0	44.0	24.9	57.4	24.5	35.4	55.3	24.6	142.0
CO991057-A4	24.8	23.3	38.6	22.4	53.7	41.1	41.3	24.2	50.4	26.5	34.6	58.3	22.8	142.3
WB Keota	26.6	20.9	36.9	16.9	72.5	28.1	37.4	20.3	51.7	25.1	33.7	56.2	24.0	142.3
CO01434	19.9	22.3	33.2	22.5	58.9	21.9	54.5	21.6	53.2	24.9	33.3	58.2	22.6	142.0
AP502 CL	25.5	23.3	36.4	28.4	54.5	29.8	33.6	30.9	44.2	24.3	33.1	57.5	22.7	140.3
Above	27.0	30.6	33.7	23.5	60.0	27.9	34.7	28.2	45.4	19.5	33.0	58.2	21.3	140.7
Prairie Red	26.6	25.0	40.6	24.4	57.8	32.3	35.1	25.1	46.0	17.5	33.0	57.6	20.5	140.3
Jagalene	22.3	18.8	31.3	18.8	63.5	35.0	40.3	24.0	50.5	25.2	33.0	57.2	23.0	143.0
Avalanche	26.4	19.1	36.2	18.0	57.8	33.9	40.6	28.2	43.4	25.2	32.9	58.5	23.0	143.3
Jagger	31.4	25.8	26.6	18.9	66.8	28.9	32.8	16.8	53.5	25.1	32.7	56.4	22.8	140.7
CO00739	22.6	19.4	28.4	14.4	59.1	26.8	48.0	26.3	61.8	19.2	32.6	57.8	23.3	142.3
AP530W	28.7	15.3	35.3	21.2	63.8	31.9	38.3	21.6	45.9	21.7	32.4	58.2	23.5	143.3
NuHills	25.2	24.8	38.1	14.8	59.4	21.7	35.2	29.2	47.0	26.3	32.2	54.9	22.8	141.3
Alliance	25.1	21.1	33.7	20.1	55.2	27.4	41.2	26.6	50.4	20.7	32.1	57.7	21.6	141.0
NuFrontier	23.5	20.3	38.0	17.6	61.5	26.9	31.1	22.2	55.6	22.1	31.9	57.4	24.1	142.3
CO00554	23.5	19.1	36.4	13.9	54.5	29.6	44.6	23.6	56.9	16.7	31.9	58.1	22.4	140.7
Overley	17.0	25.9	34.0	24.6	53.7	29.9	35.6	15.7	48.6	32.8	31.8	56.2	23.8	141.0
CO00796	23.9	23.5	35.2	19.3	53.6	25.5	40.1	21.3	49.5	22.1	31.4	57.8	24.3	143.0
Harry	30.1	20.1	28.4	14.8	51.8	25.7	43.7	25.3	53.5	20.1	31.3	54.4	22.5	143.3
Prowers 99	24.1	15.9	39.0	18.1	54.4	32.8	36.0	21.0	50.4	20.6	31.2	57.7	23.7	144.3
Infinity CL	26.4	23.2	31.9	17.1	57.1	27.4	37.3	26.8	45.8	17.8	31.1	56.6	22.3	142.0
CO991407-A3	22.8	26.1	29.7	24.9	49.9	27.3	31.2	18.5	58.4	20.6	30.9	58.5	22.1	141.0
Danby	20.3	18.6	38.8	11.5	66.4	22.8	33.5	25.5	52.8	17.9	30.8	57.8	22.9	142.7
CO01W172*	21.6	23.0	26.2	20.1	54.4	23.6	44.6	23.9	47.3	23.2	30.8	58.4	22.3	143.0
Yuma	18.9	19.6	35.2	18.5	56.0	28.8	28.8	23.2	54.1	24.2	30.7	56.5	20.4	143.3
CO01212*	22.6	22.3	34.2	13.0	50.9	31.8	35.4	23.7	52.7	20.4	30.7	57.8	24.4	143.7
Yumar	25.7	20.5	33.3	16.1	50.8	29.0	32.2	22.3	53.2	23.7	30.7	56.5	22.3	142.7
Endurance	16.9	22.9	29.3	22.1	61.4	25.4	30.4	28.6	48.2	20.5	30.6	58.0	23.9	142.7
CO01W191	15.8	22.6	37.1	12.5	56.6	18.1	42.6	23.9	56.4	18.9	30.5	58.0	22.6	141.7
CO01473*	24.7	18.4	31.8	14.4	55.2	34.6	33.9	24.2	48.4	18.2	30.4	58.1	24.3	143.0
CO01W173	25.4	19.6	31.1	17.8	50.4	22.5	42.7	25.4	45.7	22.7	30.3	58.7	21.0	141.7
Goodstreak	18.9	22.2	33.7	18.0	55.7	26.4	41.2	22.2	45.6	16.1	30.0	58.2	24.3	144.0
Ankor	21.8	21.1	38.3	9.3	55.8	27.3	33.3	24.5	51.1	14.4	29.7	57.1	21.4	143.0
TAM 111	22.8	17.0	28.2	6.8	62.4	27.4	32.4	23.4	56.7	16.7	29.4	57.5	24.7	142.0
CO01W189	17.4	20.7	33.9	12.9	57.3	19.6	42.2	25.6	43.9	18.7	29.2	58.2	21.2	142.3
Millennium	23.0	16.8	31.5	20.3	43.3	31.0	32.0	22.7	44.2	22.6	28.7	55.4	24.5	142.3
CO01W189-A1	21.1	25.4	28.0	18.5	47.1	18.5	38.1	26.9	45.2	17.6	28.6	58.4	22.6	141.3
CO01434-A1	17.5	22.2	18.6	17.9	56.9	19.5	43.7	23.7	47.4	17.4	28.5	58.0	22.6	142.0
CO01W173-A3	24.7	19.4	29.0	17.9	50.8	19.1	32.3	23.3	45.8	21.9	28.4	58.4	20.1	141.7
Thunderbolt	19.3	13.2	27.4	21.6	47.7	34.9	30.6	22.7	41.1	25.4	28.4	56.7	22.1	142.3
CO01W171*	18.1	19.9	33.2	13.9	53.1	15.5	38.8	25.8	42.0	20.9	28.1	57.9	21.8	142.7
Akron	20.7	22.1	28.6	8.5	50.4	24.4	34.8	22.4	43.9	15.5	27.1	57.3	21.3	142.3
Wahoo	17.0	12.7	30.2	5.8	60.0	20.8	36.4	26.4	49.0	12.0	27.0	56.4	23.4	142.0
Stanton	22.3	22.5	23.7	10.0	53.8	23.0	25.9	22.2	41.9	18.6	26.4	58.2	21.9	142.0
Trego	20.0	17.3	31.7	7.5	50.2	20.4	31.7	30.1	39.3	13.1	26.1	58.2	21.9	143.3
NuHorizon	21.0	16.0	24.9	10.2	47.9	12.4	39.6	20.8	51.1	16.6	26.0	58.8	20.7	142.0
Lakin	12.3	22.3	16.5	3.6	44.1	20.3	37.5	19.2	41.7	9.7	22.7	58.1	22.3	141.7
Average	23.3	21.7	33.0	17.6	56.5	27.0	37.9	24.5	50.6	21.1	31.3	57.5	22.6	142.2
CV%	13.4	15.2	14.1	12.7	12.0	17.2	16.4	14.8	7.5	14.7				
LSD(0.05)	5.1	5.3	6.3	3.6	11.0	7.5	10.1	5.9	6.2	5.0				

† Key to trait values: yield – bushels/acre; test weight – pounds/bushel; heading – days from Jan. 1; height – inches.

* Line retained for further testing.

Small-scale seed increases of the other lines retained for further testing were planted in fall 2005. In addition to continued yield testing, extensive milling and baking quality evaluations will be done on each of these lines during winter 2005-2006 by Bruce Clifford in the CSU Wheat Quality Lab, the USDA-ARS Hard Winter Wheat Quality Lab (Manhattan KS), and by various private-industry collaborators.

As mentioned previously, the Irrigated Variety Trial (IVPT) was planted at three locations in Colorado and yield data were obtained from each of these locations (**Table 2**). Severe stripe rust infection and high temperatures affected yields at all locations, even though a fungicide was applied to the plots at Stratton (though it was applied too late). Of the experimental lines tested, the most encouraging entry was CO01385-A1 and it's "mother line" CO01385. Both of these lines also performed well in the dryland UVPT. As the CO01385-A1 reselection performed better than CO01385, it was advanced for further testing in the 2006 UVPT and IVPT.

<u>CSU Elite Nursery</u>

As mentioned previously, in fall 2004 we added two locations (Dailey and Sheridan Lake) for testing of the CSU Elite and the Advanced Yield Nursery (AYN). The rationale for adding these locations was that we had lost many dryland trial locations the last few years and we felt that we have had inadequate data to make sound decisions on line selection and discard. In 2005, the CSU Elite was planted at each of our breeding locations in Colorado (Akron, Burlington, Dailey, Julesburg, Sheridan Lake, Walsh, and Fort Collins) as well as at several other locations in adjacent states (Amarillo TX, Goodwell OK, Colby KS, Healy KS, Ulysses KS, and Pierre SD). Between our locations in Colorado and locations in other states, the CSU Elite is planted at 13 total locations, although trials at some locations either were not harvested (Amarillo-hail) or data from those trials was too variable to allow reliable variety comparisons (Dailey, Burlington).

Based on data from all available locations (**Table 3**), considering irrigated trial data (Fort Collins, Goodwell OK), dryland trial data at Colorado locations only, and dryland trial data at all available locations, 7 new experimental lines were advanced to the 2006 UVPT.

Of these lines, 3 were HRW lines and 4 were HWW lines. In general, these lines overall have better stripe rust resistance than some of the more susceptible materials in our program. From the group of lines advanced to the 2005 UVPT, we will conduct extensive milling and baking quality evaluations during winter 2005-2006 in the CSU Wheat Quality Lab and the USDA-ARS Hard Winter Wheat Quality Lab (Manhattan KS). For each of these lines advanced to the UVPT, a headrow increase will be done in at Fort Collins in 2005-2006 for line purification and reselection (where variability within the line persists).

<u>Advanced Yield Nursery (AYN)</u>

In 2004-2005, the AYN was grown in three replications at all seven main breeding locations. The AYN was sub-divided into hard red, hard white, and *Clearfield** (both red and white types) groups to manage experimental error. For each subset, check entries were included for comparison. As with the CSU Elite, data from trials at Dailey and Burlington were too variable to allow reliable entry comparisons. From the AYN, 32 total experimental lines were advanced for further testing (**Table 4**); 12 of these lines were hard red wheats and 20 were hard white wheats, which is a greater percentage of hard whites than we've advanced in recent years. Within each of these groups, emphasis was placed on yield, test weight, stripe rust resistance, and end-use quality evaluations done during the winter 2004-2005 in the CSU Wheat Quality Lab.

From the non-*Clearfield** hard red group (10 lines advanced), three lines (CO03758, CO03761, CO03765) are Lamar-backcross derivatives that carry RWA biotype 2 resistance from Triticale. While these lines did not perform at the top of the group, they did show decent test weight and their yield was at least close to Ankor and Stanton, and thus likely similar to what Lamar or Prowers 99 might have been had they been in the test. These three lines were

Table 2. Data summary from the 2005 Irrigated Variety Performance Trial (IVPT). Entries are ranked in descending order by grain yield. †

	Fort Collins		Rocky Ford		Stratton			
Entry	Yield	Test Weight	Yield	Test Weight	Yield	Test Weight	Avg Yield	Avg Test Wt
CO01385-A1*	114.3	61.2	94.3	59.6	87.9	62.1	98.8	61.0
CO01385	90.8	60.1	92.5	56.6	92.2	62.5	91.8	59.7
CO01W191	76.5	58.9	91.3	59.9	104.3	63.4	90.7	60.8
Bond CL	94.8	59.4	92.0	58.6	82.7	60.9	89.8	59.6
Hatcher	80.3	58.2	97.2	61.6	91.6	62.2	89.7	60.7
AP530W	93.7	59.6	88.9	61.8	81.3	62.6	88.0	61.3
CO991057-A4	86.4	59.9	92.4	59.4	83.0	61.9	87.3	60.4
TAM 111	68.8	56.8	97.5	61.8	95.4	63.5	87.2	60.7
Jagalene	75.4	60.1	92.5	61.7	86.8	62.9	84.9	61.6
CO01212*	88.3	60.8	91.1	61.7	73.9	62.6	84.4	61.7
NuHills	66.8	56.4	99.1	62.7	87.1	63.0	84.3	60.7
CO991407-A3	74.3	59.0	92.0	61.5	80.5	62.5	82.3	61.0
CO01W173	86.0	61.1	82.2	59.0	77.7	62.5	82.0	60.9
Ankor	77.3	56.9	81.6	58.3	86.6	61.3	81.8	58.8
CO01W189-A1	62.1	58.0	91.8	58.9	88.6	62.1	80.8	59.7
CO01473*	90.4	57.8	88.9	61.5	62.5	63.7	80.6	61.0
CO01434	68.9	57.4	84.1	59.9	86.8	61.4	80.0	59.6
NuFrontier	75.9	58.5	99.1	58.9	62.0	64.3	79.0	60.6
Yuma	74.3	56.8	82.1	60.8	79.2	61.2	78.5	59.6
Antelope	70.2	55.8	83.9	60.2	81.4	63.0	78.5	59.7
CO01434-A1	55.1	53.5	88.1	60.1	88.5	62.1	77.2	58.6
CO01W189	65.1	57.3	84.2	58.0	81.4	61.8	76.9	59.0
Overley	62.2	57.4	80.2	61.6	87.9	62.9	76.8	60.6
Ok102	74.1	58.4	78.4	60.3	75.8	62.0	76.1	60.2
CO00016*	83.6	58.2	86.4	57.6	58.0	59.9	76.0	58.6
CO01W171*	63.4	56.3	84.3	58.3	80.1	63.4	75.9	59.3
CO01W173-A3	74.3	59.7	83.4	59.6	65.3	62.6	74.3	60.6
Dumas	62.2	57.8	87.3	58.7	70.5	62.4	73.4	59.6
Wesley	44.2	53.0	88.7	59.4	82.9	60.1	71.9	57.5
NuHorizon	54.0	57.4	84.6	61.8	76.2	62.4	71.6	60.5
CO01W172*	66.7	54.9	87.5	61.1	60.5	62.4	71.6	59.5
Platte	65.5	58.9	77.7	60.3	62.8	62.3	68.7	60.5
W04-417	32.3	51.2	80.0	60.5	84.9	62.4	65.7	58.0
Prairie Red	46.9	53.0	81.0	59.0	65.3	60.0	64.4	57.3
Average	72.5	57.6	87.8	60.0	79.8	62.2	80.0	60.0
LSD (0.30)	10.0		3.9		9.0			

† Key to trait values: yield: bushels/acre; test weight: pounds/bushel.

* Line retained for further testing.

Table 3. Data summary from the 2005 CSU Elite Nursery. Entries are ranked in descending order by average dryland grain yield. †

Entry	Goodwell	Colby	Healy	Ulysses	Pierre	Walsh	Sh Lake	Julesburg	Akron	Ft Collins	Dryland Avg GY	Avg GY	Avg TW	YR
CO01385	53.8	76.2	50.3	85.3	64.7	68.9	34.9	29.2	37.9	96.4	52.6	56.6	60.2	6.0
CO01385-A1*	45.8	74.0	51.4	89.3	59.7	75.7	30.0	31.8	39.5	100.8	52.4	56.8	60.0	5.5
TAM 111	75.3	68.6	52.9	80.3	73.2	63.5	29.8	23.2	36.0	84.6	51.9	54.9	59.4	1.5
Hatcher	52.7	66.0	48.1	84.1	67.5	59.9	31.8	30.5	34.7	84.7	50.0	53.2	59.0	4.5
CO02320**	54.2	60.6	47.2	75.0	73.3	51.4	40.0	28.9	43.0	84.3	49.8	52.9	58.8	7.0
Bond CL	56.9	66.5	37.0	78.0	66.2	56.5	32.0	27.2	47.4	101.1	49.7	54.4	58.3	8.5
Jagalene	66.8	60.2	45.2	72.2	69.7	59.4	30.1	40.1	39.6	84.8	49.6	52.8	59.3	3.5
CO991057-A4	51.8	56.0	46.6	72.6	70.2	55.1	37.0	32.9	37.5	78.7	48.1	50.9	58.4	6.0
CO00554	53.0	64.6	42.6	78.3	58.5	53.9	30.7	28.6	36.7	89.8	46.8	50.7	59.3	6.5
CO02W214*	57.6	58.2	52.0	66.5	62.6	57.3	25.7	28.9	34.0	79.4	46.3	49.3	58.4	2.0
CO02W237*	59.4	55.4	49.3	68.6	58.1	50.7	30.1	26.5	37.1	75.9	45.4	48.1	58.8	4.5
CO02322**	64.1	54.1	48.7	69.2	56.5	61.2	30.0	17.4	37.0	75.1	45.0	47.7	59.2	4.0
CO02W280*	65.3	60.3	46.9	67.4	68.7	57.4	21.6	14.7	27.2	66.1	44.6	46.6	59.5	3.0
CO00739	46.2	60.7	39.7	76.7	53.6	54.6	26.3	25.5	34.6	98.3	43.5	48.5	57.9	6.5
CO01W191	44.5	56.2	47.5	69.8	69.8	58.8	28.9	13.9	29.7	76.4	43.5	46.4	59.0	6.5
CO01212*	40.1	61.8	46.3	64.4	60.7	53.3	28.3	25.0	35.2	89.0	43.4	47.6	60.0	6.0
CO01473*	42.2	62.5	31.9	67.2	57.9	49.7	30.0	29.3	37.4	84.7	43.4	47.2	59.2	5.0
CO02W040*	56.8	55.3	40.8	71.2	61.9	57.2	22.4	20.1	33.6	75.3	43.4	46.3	58.6	7.0
Above	49.6	50.4	36.5	70.3	63.1	34.8	32.0	25.8	43.8	54.2	42.8	43.9	59.0	9.0
Stanton	40.9	58.0	39.5	61.8	69.3	46.0	33.0	21.8	38.1	61.8	42.6	44.4	58.9	7.0
CO02265*	40.4	55.9	49.0	72.9	66.6	59.9	22.0	19.5	24.3	55.2	42.6	43.8	58.6	2.5
Avalanche	47.8	58.6	31.1	63.1	55.2	41.2	43.1	28.6	34.0	80.5	42.3	45.8	60.0	7.5
CO02W274R	45.7	56.0	37.5	64.4	68.1	48.3	30.0	20.8	36.7	68.4	41.9	44.3	57.7	8.0
CO00016*	33.3	55.0	32.2	66.9	57.9	49.0	36.8	27.0	37.4	85.9	41.9	45.9	57.2	9.0
CO991407-A3	45.3	50.9	39.4	75.2	62.6	55.1	22.7	27.4	26.3	74.3	41.8	44.7	59.2	9.0
CO01434	35.7	56.3	41.2	66.6	68.9	49.7	27.0	13.9	32.5	80.4	41.1	44.6	59.0	9.0
CO02467	29.5	54.5	41.6	69.2	58.4	51.1	33.0	25.0	31.8	78.0	40.6	44.0	58.7	7.0
Ankor	34.8	57.0	35.3	67.2	56.0	46.7	24.6	22.9	41.0	81.8	40.6	44.3	57.3	9.0
CO01W189-A1	35.0	53.2	39.6	63.8	69.5	47.5	36.5	7.4	29.4	71.5	39.9	42.8	59.0	9.0
CO02440	38.8	55.5	30.6	59.8	56.9	53.5	24.0	30.9	32.0	82.6	39.5	43.5	59.3	6.5
CO02W021	52.7	58.5	35.4	71.0	66.7	51.3	26.8	10.5	13.2	49.5	39.5	40.4	59.1	7.0
CO01W172*	43.4	51.3	37.9	64.1	58.4	52.9	25.8	11.3	29.0	70.8	39.5	42.3	59.0	8.5
CO00796	43.3	49.2	38.2	68.8	52.8	40.2	24.0	26.8	31.6	79.8	39.5	43.1	57.5	7.0
CO01434-A1	36.3	54.0	38.3	69.6	62.9	45.7	24.4	8.1	27.5	48.3	38.6	39.4	59.2	8.5
CO02W023	50.9	55.2	37.1	72.5	61.7	47.8	24.7	8.6	11.5	50.2	37.9	39.0	58.6	6.5
CO01W173	39.2	50.4	31.0	61.5	63.2	43.6	30.5	10.3	28.2	70.6	37.8	40.8	59.0	9.0
CO01W173-A3	38.7	52.2	32.0	64.4	57.5	45.7	29.0	10.8	24.0	69.0	37.7	40.5	59.1	9.0
Platte	49.6	57.2	30.1	59.8	60.5	39.7	22.1	17.2	28.9	61.8	37.7	39.8	59.8	9.0
CO02W183	32.5	54.5	38.2	61.7	47.5	45.6	29.1	10.4	41.9	71.7	37.5	40.6	60.3	8.0
Trego	31.4	58.1	36.5	50.5	56.4	44.6	34.3	19.5	28.1	77.3	37.5	41.1	60.1	8.5
CO02W283	25.3	46.5	32.6	60.7	62.5	34.3	29.2	28.0	29.6	70.6	37.3	40.3	58.0	8.5
CO02W192	25.4	50.4	36.2	58.0	60.9	40.4	31.4	15.1	32.5	68.6	37.1	40.0	59.3	6.5
CO01W189	37.7	54.1	34.8	61.9	68.5	38.6	28.0	8.0	18.6	64.6	37.0	39.5	58.7	8.5
CO02W010	27.2	58.4	31.3	67.5	67.8	42.3	21.7	13.9	21.7	61.0	36.3	38.6	57.8	8.5
CO02213	35.0	49.6	35.3	47.2	62.2	36.8	23.9	20.4	37.4	66.0	35.9	38.6	59.7	7.0
CO02487	35.2	54.6	33.0	60.7	54.5	43.1	23.6	18.5	21.8	61.9	35.4	37.8	58.4	9.0
CO02W185	31.0	48.3	31.0	52.4	55.4	35.5	27.5	20.1	31.1	68.6	35.1	38.1	59.0	8.5
CO02W180	31.9	43.7	31.4	56.9	63.1	30.5	29.1	13.7	32.8	64.7	34.9	37.6	58.4	6.5
CO01W171*	31.7	49.7	34.1	58.5	61.9	44.4	22.5	7.3	21.0	65.6	34.8	37.6	58.0	9.0
CO02316	19.4	52.7	25.7	60.9	50.7	34.6	29.5	21.2	33.5	80.6	34.6	38.8	57.3	9.0
Average	43.6	56.5	39.2	67.3	62.0	49.3	28.8	20.9	32.2	74.4	41.8	44.7	58.9	7.0
LSD (0.05)	10.4	7.6	2.8	3.5	8.7	11.1	7.9	5.4	9.0	13.6				
CV%	14.7	8.3	5.3	3.8	8.7	11.9	13.4	16.0	17.3	11.3				

† Key to trait values: yield: bushels/acre; test weight (TW): pounds/bushel; YR: stripe rust (1=resistant to 9=susceptible scale).

* Line retained for further testing.

** Line reselection advanced for further testing.

Table 4. Data summary for hard red, hard white, and *Clearfield** wheat experimental lines in the 2005 Advanced Yield nursery. Entries are ranked by average grain yield within grouping. †

Entry	Dailey	Burlington	Walsh	Sh Lake	Akron	Julesburg	Ft Collins	Dryland Avg	Yield Avg	TW Avg	Stripe Rust Score
Hard Red Winter Wheats (HRW)											
Hatcher	20.9	13.1	72.9	36.5	48.7	33.8	101.1	48.0	58.6	58.4	4.5
CO03063	14.8	20.5	60.0	31.5	61.4	36.9	85.8	47.4	55.1	59.1	7.5
CO03064	20.0	20.4	64.3	29.8	53.7	29.7	95.1	44.4	54.5	58.4	6.0
CO03373	17.4	34.5	62.0	34.7	45.9	42.1	87.4	46.2	54.4	58.6	6.5
CO03451	17.2	25.0	71.5	27.7	49.6	23.8	96.8	43.2	53.9	58.0	5.0
Jagalene	9.4	28.5	56.7	31.2	61.8	31.0	77.7	45.2	51.7	59.4	4.5
CO03343	10.0	24.7	60.8	35.0	39.8	37.5	84.9	43.3	51.6	59.0	6.5
TAM 111	12.1	13.8	66.4	31.3	43.6	21.4	90.8	40.7	50.7	59.0	1.5
CO03443	6.6	21.7	68.5	28.4	38.4	23.2	90.1	39.6	49.7	59.3	5.0
CO03011	11.5	18.8	65.0	25.4	43.0	31.8	82.3	41.3	49.5	59.3	5.0
CO03758	17.8	15.9	49.9	23.3	44.3	30.5	78.8	37.0	45.4	58.7	5.5
Ankor	12.2	5.6	44.4	33.9	44.8	25.0	73.1	37.0	44.3	56.8	9.0
CO03761	13.2	9.4	52.0	18.3	41.6	29.1	67.8	35.2	41.7	58.7	5.0
CO03765	14.6	10.4	49.0	23.2	38.4	29.4	65.4	35.0	41.1	57.6	5.5
Stanton	16.7	6.1	43.4	35.5	43.1	21.9	58.2	36.0	40.4	58.4	9.0
Average	14.3	17.9	59.1	29.7	46.5	29.8	82.4	41.3	49.5	58.6	5.7
LSD (0.05)	4.6	8.7	9.1	7.3	6.3	6.6	13.6				
CV%	22.5	35.9	10.1	15.8	9.4	15.4	10.8				
Hard White Winter Wheats (HWW)											
CO03W054	17.7	26.9	61.6	53.4	58.0	39.7	90.9	53.1	60.7	58.7	7.0
Danby	8.6	5.7	63.2	45.0	62.7	23.4	92.6	48.6	57.4	61.4	5.5
CO03W108	12.5	16.5	63.2	42.5	57.2	37.3	85.9	50.0	57.2	59.4	5.5
CO03W033	22.2	34.0	54.3	56.3	56.5	32.3	83.3	49.8	56.5	59.4	8.0
CO03W043	21.9	32.3	54.6	39.9	55.3	34.7	96.8	46.1	56.2	58.5	5.0
CO03W139	11.1	24.6	58.0	45.8	46.6	33.5	85.6	46.0	53.9	58.1	8.0
CO03W035	16.1	14.5	56.9	43.6	47.5	26.9	89.1	43.7	52.8	59.0	5.5
NuFrontier	12.0	14.4	61.5	31.9	47.8	28.1	87.7	42.3	51.4	59.2	4.0
CO03W032	9.3	17.2	57.2	43.2	44.1	25.8	83.1	42.6	50.7	58.4	2.0
Avalanche	21.4	15.5	42.1	43.6	42.7	35.0	82.3	40.8	49.1	59.6	9.0
CO03W144	10.7	13.1	52.7	38.5	53.1	24.0	77.2	42.1	49.1	58.8	7.5
CO03W127	7.6	16.5	56.1	38.5	47.0	25.7	74.0	41.8	48.3	58.6	8.5
CO03W146	10.1	11.9	52.9	41.8	54.0	14.6	71.3	40.8	46.9	58.6	8.0
CO03W031	16.2	11.1	51.7	27.2	49.9	28.9	72.4	39.4	46.0	58.2	6.0
Trego	8.4	8.7	38.3	41.8	45.3	19.4	81.5	36.2	45.2	59.9	9.0
Platte	8.9	6.4	35.6	30.9	38.5	23.6	62.9	32.1	38.3	59.5	9.0
Average	11.0	16.4	51.2	38.8	44.2	24.9	73.0	39.8	46.4	58.7	7.0
LSD (0.05)	4.7	11.4	7.7	6.7	8.2	7.5	9.2				
CV%	30.2	49.5	10.7	12.4	13.2	21.4	9.0				
Clearfield* Wheats (CO03W denotes HWW)											
CO03W239	9.9	31.3	61.5	53.3	60.5	43.7	85.0	54.7	60.8	58.1	6.0
CO03637	24.2	39.3	51.0	54.9	58.9	39.8	90.6	51.2	59.1	57.3	6.5
CO03W238	19.7	23.9	50.8	48.1	56.8	44.8	87.5	50.1	57.6	57.7	6.0
CO03621	15.0	37.3	51.6	54.8	52.6	35.4	85.6	48.6	56.0	57.3	6.0
CO03W259	18.6	27.9	49.0	52.0	62.1	41.7	75.0	51.2	56.0	57.7	7.5
CO03W269	21.2	34.0	50.9	46.9	58.0	40.7	79.9	49.1	55.3	57.9	7.0
CO03W253	22.3	33.3	45.6	54.5	56.4	38.4	81.4	48.7	55.2	58.7	6.5
CO03W263	16.6	39.3	48.3	52.5	56.2	36.3	82.0	48.3	55.0	57.3	7.0
Bond CL	26.1	31.3	53.0	54.8	54.8	39.5	68.1	50.5	54.0	57.4	8.5
CO03W261	18.3	32.6	44.3	51.1	56.8	41.2	72.6	48.3	53.2	57.5	7.0
CO03W262	12.0	28.2	53.2	49.5	54.4	34.4	72.5	47.8	52.8	57.7	6.0
CO03W267	16.2	20.2	39.9	53.2	57.1	25.7	73.8	44.0	49.9	58.9	6.0
Above	21.5	17.8	42.8	46.4	53.2	33.9	73.1	44.0	49.9	58.2	8.5
Infinity CL	13.3	26.6	45.3	48.5	53.5	30.9	71.0	44.5	49.8	57.6	4.5
AP502 CL	19.3	26.9	47.6	47.3	48.0	37.7	67.3	45.1	49.6	56.9	8.0
AP401 CL	8.6	5.1	32.3	32.5	39.6	15.2	43.2	29.9	32.6	59.1	9.0
Average	15.8	26.5	45.8	48.1	50.5	34.6	68.7	44.7	49.5	57.3	7.4
LSD (0.05)	6.3	17.8	8.9	6.7	6.7	9.0	10.1				
CV%	28.5	47.8	13.8	9.9	9.4	18.7	10.5				

advanced directly to the 2006 UVPT and will not be tested in the 2006 CSU Elite due to seed supply limitations. We are not yet certain if the resistance in these lines is stable and will be expressed at a high level over multiple generations of seed increase. We have been working with Dr. Kabwe Nkongolo in Canada, who was at CSU in the late 1980s and actually began the work in transferring the resistance gene from Triticale. He has examined the chromosomes of these three lines and his preliminary results suggest that they appear to be normal, though he has yet to finalize his evaluations. We are hopeful that one or more of these lines will be acceptable agronomically, and have a good level of resistance to RWA biotype 2, and we will be able to move toward variety release following the 2007 or 2008 season.

With regard to the hard white and *Clearfield** groups, several very promising lines were identified in 2005. The most promising among these are the hard white *Clearfield** types, several of which showing higher yield than Bond CL which had an outstanding year. Because we had adequate seed supply, we advanced all of these *Clearfield** lines directly to the 2006 UVPT, though all but one will also be tested in the 2006 CSU Elite. As a group the *Clearfield** lines have overall better stripe rust resistance than Above or Bond CL, yet much improvement remains to be made to incorporate better resistance.

In addition to continued yield testing, extensive milling and baking quality evaluations will be done on all of these materials during winter 2005-2006 in the CSU Wheat Quality Lab and the USDA-ARS Hard Winter Wheat Quality Lab (Manhattan KS). For each of these lines advanced to the CSU Elite Nursery, a headrow increase will be done in at Fort Collins in 2004-2005 for line purification and reselection (where variability within the line persists).

<u>Early-Generation Germplasm Development</u>

In 2004-2005, we continued to aggressively emphasize early generation germplasm development efforts, from new line derivation down through the pipeline to the crossing program. Early-generation germplasm efforts at each phase in the pipeline are summarized as follows:

1) **F5 Preliminary Yield Nursery (PYN)**: Over 1040 new experimental lines were planted in eight groups of single-replication trials at four of our main breeding locations. As described in last year's report, we discontinued evaluation of the PYN at Walsh in 2005 in "compensation" for increased breeding trial plots at Dailey and Sheridan Lake. Eliminating one location also leaves us with more remnant seed for each line that we can use for predictive quality tests during the winter. Approximately 56% of 1040 lines were hard red lines, 44% were hard white lines, and 25% were *Clearfield** lines (both red or white). Based on grain yield, test weight, agronomic observations, stripe rust resistance at Fort Collins, small-scale quality data (on remnant bulk samples during winter 2004-2005 and samples tested following harvest in August 2005), 135 of these lines were advanced to the 2005-2006 Advanced Yield Nursery (AYN), which again were planted in separate hard red, hard white, and *Clearfield** groups. To facilitate line reselection, we also planted a group of head selections from each of these lines at Fort Collins for reselection in 2006.

2) **F4 Headrows**: Over 34,000 headrows were grown at Fort Collins in 2004-2005. Of this group, approximately 79% were HRW lines while 21% were HWW lines. From visual observations (including stripe rust resistance), pedigree information, and quality information from the remnant bulk grown in 2004, over 1850 headrows were hand harvested in July 2005. Seed supply from over 1320 of these was sufficient for whole-grain NIR analysis in our quality lab. We also obtained estimates for kernel weight and kernel diameter, based on calibrations developed from samples collected in 2004 and 2005, and these were used together with visual examination of the grain to select among lines for advancement. Based on these evaluations, and whole-grain NIR estimates for grain protein content, wheat ash, milling extraction, and grain hardness, about 918 lines

were selected and advanced to the single replication PYN in fall 2005. In addition to these lines, we also advanced a set of 42 lines that had been reselected from entries in the AYN and CSU Elite, reselections made largely based on stripe rust resistance. Among the total group of 960 lines advanced from headrows, approximately 67% were HRW lines, 33% were HWW lines, and 7% were single-gene *Clearfield** lines, whether HRW or HWW. These *Clearfield** lines represent the last of our single-gene *Clearfield** types that will be advanced forward in the program.

3) **F3 and F4 Bulks**: Approximately 378 F3 or F4 bulk populations were grown in 2004-2005. As described in last year's report, we have started advancing F4 bulk populations from superior F3 populations that have also been advanced through head selection the previous year. Of this set of 378 bulk populations, about 118 were F1-derived F3 bulk populations segregating for both the B-genome and D-genome *Clearfield** genes; these were grown only at Fort Collins and sprayed with 18 oz/a *Beyond*™ herbicide in fall 2004 to purify the populations for plants that carry both *Clearfield** genes. The conventional F3/F4 bulk populations were grown under both irrigation at Fort Collins and under dryland conditions at Akron. Based on yield, test weight, and visual observations of the bulk populations (including stripe rust observations at Fort Collins), about 31,000 total head selections were made for advancement to the F4 headrow nursery in fall 2005. Of this total group, about 81% (from 106 populations) were from conventional crosses and 19% (from 49 populations) were from two-gene *Clearfield** crosses. The overall breakdown of hard red vs. hard white head selections was approximately 70% hard red and 30% hard white. To increase the frequency of hard whites in our bulk populations, we took 2-3 lb samples of 71 populations that were segregating for hard red and hard white types to the USDA-ARS in Manhattan KS and ran them over a high speed color sorter. These HWW-sorted populations were planted along with the rest of the F3 and F4 bulks in fall 2005 at Fort Collins. To further strengthen our hard white program, we also obtained about 130 bulk populations from the KSU wheat breeding program at Hays. These populations were all sorted on the kernel color sorter at Manhattan for hard white purification.

4) **F2 Bulks**: Approximately 690 F2 bulk populations were grown at Fort Collins in 2004-2005. Of this group, 278 were from F1 crosses increased in Yuma AZ in 2003-2004, 85 were from F1 crosses obtained from the University of Nebraska, and 196 were from three-way cross F1 populations selected in 2004. A total of 215 populations were advanced to the F3 and F4 bulk trial in fall 2005. Stringent selection among bulks was practiced for stripe rust resistance, agronomic type, and test weight prior to advancement.

5) **F1 Increase**: About 340 new single-cross F1 populations were increased at Fort Collins in 2005. In addition to these single-cross F1s, a group of approximately 724 three-way cross and backcross populations were planted in spring 2005 at Fort Collins. Among these spring planted populations were: 314 three-way crosses made in fall 04, 110 F1-derived F2 cross populations segregating for RWA biotype 2 resistance, 74 F1-derived F2 cross populations segregating for both *Clearfield** herbicide tolerance genes, and 114 backcross populations for the IFAFS molecular marker project. About 349 single-cross or topcross F1 populations were advanced to the F2 Bulk trials in fall 2005. In addition to those advanced as bulks, we also made 27 line selections among visually-uniform backcross lines carrying both *Clearfield** genes and 27 line selections among visually-uniform backcross lines carrying RWA biotype 2 resistance. Many populations were also advanced by head selection for evaluation in the headrow nursery in 2006.

6) **Crossing**: Over 1506 new crosses were made in 2004-2005, split between crossing blocks in fall 2004 (650 crosses) and spring 2005 (856 crosses). Included among these crosses were three main types of materials: a) crosses targeted toward direct increase, bulk evaluation, and line development (633 crosses), b) crosses targeted only for backcrossing (341 crosses) or three-way crossing (393 crosses), and c) crosses targeted

for marker-assisted backcrossing as part of the USDA-IFAFS grant funded program (139 crosses). As the IFAFS program has terminated, we are continuing backcrossing the Yr5 and Yr15 stripe rust resistance genes to some of our elite backgrounds with funding from a CWRF grant. Of the group targeted toward direct increase, approximately 44% were three-way crosses (including a few backcrosses for *Clearfield** and RWA projects) and 56% were single crosses between elite parents. Special emphasis was made during both crossing cycles to utilize synthetic-derived germplasm sources from CIMMYT, continue the transfer of the *Lr19* gene from 'Agatha' into several elite backgrounds using marker-assisted selection, and introgress through crossing and backcrossing both the two-gene *Clearfield** trait and several different sources of RWA biotype 2 resistance into our germplasm base. With regard to HWW vs. HRW emphasis, we have completely discontinued making either HRW/HRW or HRW/HWW crosses, both of which yield very few if any HWW segregates in subsequent generations. Our strategy for utilizing desirable HRW types from our program and other programs is to use these as one of the first parents in a three-way cross with two other HWW parents.

Research Support Projects and Other Activities

New Russian Wheat Aphid Biotype Research

With the identification of a new, virulent biotype of RWA in Colorado in 2003, and additional virulent biotypes in 2004, we have been actively involved in several different research areas to address this problem. These activities have focused on continued germplasm screening, molecular marker identification for key resistance genes, and breeding line and population development. The following are the highlights of these activities:

- We completed the screening of 7,300 Iranian landrace selections from the NPGS for resistance to RWA biotype 2. Approximately 330 biotype 2 resistant accessions were then screened in spring 2005 for resistance to biotype 1 RWA. Approximately 155 accessions carry resistance to both biotypes; mapping populations are under development with at least 5 of these accessions. We are coordinating with the USDA-ARS Stillwater OK group to evaluate these lines with additional biotypes.
- A set of 5 lines carrying biotype 2 resistance from Triticale were evaluated in replicated trials at 7 breeding locations. Two of these lines were very low yielding and were also shown to have problems with chromosomal stability (by Dr. Kabwe Nkongolo in Canada). Three lines showing reasonable performance and agronomics, as well as showing no chromosomal abnormalities, were advanced for testing to the 2006 UVPT.
- A set of 27 line selections were made from backcross populations derived from crosses with 2414-11 and 2002 Altus-034 (a winter wheat line from Stillwater carrying the Dn7 resistance gene). These selections were planted in a single-replication observation nursery at Fort Collins in fall 2005.
- Many new crosses and backcross populations have been developed using resistance sources identified.

Wheat Antioxidant Research

Previous research, at CSU and elsewhere, has shown that antioxidants are present in wheat bran and that varieties differ for the amount of antioxidants in the bran. Several other studies, in wheat and other plant materials, have suggested that these antioxidants contribute to reduced risk from different types of cancers. In past research, our breeding program collaborated with a scientist (who has since left CSU) on these evaluations. Unfortunately, these tests were extremely costly and laborious, thus reducing our ability to evaluate large numbers of samples for genetic experiments or selection purposes. In collaboration with Dr. Cecil Stushnoff (Horticulture and Landscape Architecture Department, CSU), one of our research associates

(John Stromberger) has developed modified standard laboratory protocols for measuring antioxidant properties to allow us to conduct more high-throughput analysis. Procedures for rapid measurement of two different antioxidant properties were developed: total phenolic content and ABTS-free radical scavenging capacity. Using these assays, John evaluated a group of common varieties from several locations in eastern Colorado in 2004 to determine the extent of genetic and environmental influence on the expression of the antioxidant tests. In addition to this work, John also worked with one of our other research associates (Joshua Butler) to develop whole-grain near-infrared reflectance (NIR) calibrations that would be particularly useful for mass sample screening. We hope to complete these studies using samples collected from several locations in 2005 and will then work to validate and hopefully implement the calibrations in subsequent years.

Pre-Harvest Sprouting Tolerance Evaluation

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

Graduate Student Research

Several graduate student research projects are currently underway or were completed in 2004-2005. While we expect that these research projects will contribute vital information to help direct and focus breeding efforts, both the breeding project and the students benefit in many other ways though direct student involvement in the overall breeding program. Briefly, these include the following areas of research:

- Assessment of the agronomic potential of the gibberellic acid sensitive semidwarfing gene *Rht8* (Sally Clayshulte). Sally's research demonstrated that the molecular marker that is supposedly linked to *Rht8* (based largely on linkage analysis with European wheats) may not be linked with *Rht8* in Great Plains germplasm. The second year of her field evaluation of a group of recombinant inbred lines from two populations was also completed. These studies showed that an allele at the *Rht8* marker locus, the WMS 261-210 allele, conferred taller plant height than the allele in most of our germplasm (WMS261-165). Sally recently successfully defended her dissertation and has just accepted a position as a cotton breeder with Monsanto in Arizona. We thank Sally for all of her hard work and dedication over the years; she will definitely be missed.

- Development and validation of near infrared reflectance (NIR) spectroscopy calibrations for whole-grain prediction of end-use quality characteristics (Joshua Butler). Josh began his Ph.D. dissertation studies (and his appointment as a research associate) in fall 2004 and immediately focused on developing calibrations for test weight, kernel weight, and kernel diameter. These calibrations are extremely promising and we are nearing the point where we will use these calibrations for screening of headrow and other samples. Josh will continue to work in the coming year to refine these calibrations and also begin to develop calibrations for various measures of dough mixing strength and starch viscosity.
- Validation of the BYDV resistance and high grain protein content traits introgressed to several elite background as part of the IFAFS molecular marker grant (Jennifer Roth, new student July 2005). Backcross populations segregating for either the BYDV resistance segment from *Agropyron intermedium* or the high grain protein content segment from *Triticum dicoccoides* were planted in the spring at Fort Collins. Tissue samples were collected from over 2000 plants and screened with molecular markers by the USDA-ARS Genotyping Center in Manhattan KS. Based on these assays, a subset of these lines will be increased in the greenhouse and Yuma AZ in winter 2005-2006. Jennifer hopes to identify a subset of near-isogenic lines, homozygous for the presence or absence of the introgressed segment, that will be planted at several locations in fall 2006 to test for the direct and indirect effects of the introgressed segments.
- RWA biotype 2 resistance gene mapping and gene transfer from *Triticum dicoccoides* (Ben Beyer, new student July 2005). Ben is currently developing several mapping populations developed using crosses with several RWA biotype 2 resistant Iranian landrace selections, in addition to some other sources. One of these populations will be used to identify a molecular marker linked with the resistance, which will then enable marker-assisted pyramiding of multiple RWA biotype 2 resistance genes into the same wheat variety. Ben will also be working to try to transfer RWA biotype 2 RWA resistance from a tetraploid wheat (*Triticum dicoccoides*) to common wheat.

IFAFS and CAPS Grants

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

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

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