2006-07 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 2006-07 season.

Site Conditions

In 2006-07, 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. Overall, environmental conditions experienced at these locations were much more favorable for high yields than what was experienced in 2005 and 2006:

Akron – good fall emergence and growth, adequate (and non-uniform) fall subsoil moisture, excellent winter precipitation from late December snowfall, decent early spring precipitation, mild spring temperatures, drought stress symptoms appeared by early May, moderate rainfall in late May and mid-June relieved stress. No significant disease or insect problems noted.

Burlington – excellent fall emergence and growth, minimal winter precipitation from late December snowfall, moderate spring precipitation but significant drought stress symptoms evident by early May, late May and June rains moderated severity of drought stress. No significant disease or insect problems noted.

Dailey – good fall emergence in heavy residue, good fall subsoil moisture, excellent winter moisture from heavy snowfall, excellent spring precipitation in April, minor hail damage in early May, dry soil conditions by early June caused premature senescence, traces of leaf and stripe rust found but much below economic injury levels.

Julesburg – good fall emergence and growth, adequate (and non-uniform) fall subsoil moisture, excellent winter precipitation from late December snowfall, moderate early spring precipitation and temperature, drought stress developed by mid-May due to lush growth and inadequate moisture availability, moderated by rainfall in late May and June (over 9" in mid-June). Stripe rust and leaf rust both present at significant levels by mid-June. Rains at maturity delayed harvest and lowered test weights. Preliminary yield nurseries abandoned due to prolonged rains.

Sheridan Lake – excellent fall emergence and growth, good fall precipitation and subsoil moisture, excellent winter precipitation from late December snowfall, good spring precipitation and moderate spring temperature. Moderate drought stress symptoms apparent on some entries by mid-May, extending toward early June with premature senescence of leaves of some entries. Stripe rust quite evident by mid-May, caused damage on susceptible entries. Leaf rust found but at very low levels.

Walsh – uneven fall emergence, good fall subsoil moisture, excellent winter precipitation from late December snowfall, good spring precipitation and moderate spring temperature. Evidence of minor snow mold infection after melting of the snow. Moderate drought stress symptoms apparent on some entries by mid-May. Stripe rust quite evident by mid-May, but remained at low levels throughout the season. Leaf rust found at very low levels.

Fort Collins (irrigated) – good fall stands and growth, excellent winter precipitation from late December snowfall, moderate early spring precipitation and temperature, first irrigation in early May relieved minor moisture stress that had developed. Leaf and stripe rust both present at very low levels.

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 – Dailey and Rocky Ford). Overall, above-average yields were achieved at most of the UVPT trial locations as a result of good fall stand establishment, heavy winter snowfall, and adequate spring rains. Some drought stress was observed at most locations, however, due to excessive fall and spring growth and inadequate spring precipitation to sustain growth. The UVPT at Burlington was on the end of this spectrum, with drought stress limiting yields significantly in many entries (trial range 15-45 bu/acre). In general, relatively mild temperatures were observed throughout the growing season through to the end of grain filling. Most trial locations avoided significant disease or insect infestations, with the exception of stripe rust at the Lamar (most severe), Sheridan Lake, and Arapahoe locations. Leaf rust was observed at low levels at a few locations but did not cause any appreciable damage, despite severe localized infections and damage in nearby fields in southeast Colorado. All 11 UVPT locations were successfully harvested and incorporated into the statewide summary.

The IVPT was successfully harvested at each of the three trial locations (Fort Collins, Dailey, and Rocky Ford). A severe infection of wheat streak mosaic virus (WSMV) was observed at the Dailey IVPT location and yields of susceptible entries were reduced significantly. Leaf rust also caused some damage to the IVPT at Rocky Ford.

Cultivar and Germplasm Development

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.

New Cultivar Releases

One new winter wheat cultivar was released in fall 2007. The new cultivar, named **'Bill Brown'**, is a hard red winter wheat with very high dryland and irrigated yields, excellent drought stress tolerance, high test weight, resistance to both leaf and stripe rust, and excellent milling and baking quality characteristics. The name 'Bill Brown' was chosen in honor of the memory of the former CSU Extension Plant Pathologist who devoted his career to the improvement and

management of diseases of wheat and other grain crops. In three years of statewide testing in the dryland Colorado Uniform Variety Performance Trial (UVPT; 32 locations), 'Bill Brown' had grain yields equivalent to the high yielding wheat variety 'Hatcher', higher than all other entries in the trials, and 0.7 bu/acre (1.7%) higher than 'Bond CL', 0.9 bu/acre (2.2%) higher than 'Ripper', and 4.0 bu/acre (10.7%) higher than 'Jagalene'. In three years of statewide testing in the Colorado Irrigated Variety Performance Trial (IVPT; 9 locations), 'Bill Brown' was the highest yielding entry in the trials, approximately 3.4 bu/acre (3.9%) higher than 'Bond CL' and 5.2 bu/acre (6.0%) higher than 'TAM 111', the next highest yielding entries in trials. 'Bill Brown' will be an excellent replacement for wheat cultivars targeted specifically for high yield, irrigated production conditions and an excellent complement to both 'Hatcher' and 'Ripper' for dryland production conditions.

Detailed data on Bill Brown and other recently released varieties may be found at the home page of the CSU Wheat Breeding and Genetics Program (http://wheat.colostate.edu).

New Foundation Seed Increases

One new experimental line, designated as CO03W239, was advanced for Foundation Seed increase in fall 2007. Pending further yield and quality evaluations in 2007-08, CO03W239 is targeted for release as a new cultivar in fall 2008. CO03W239 is a hard white (HWW) *Clearfield** line best adapted for dryland production conditions. In two years of testing in the UVPT (22 locations), CO03W239 has been slightly lower yielding than Hatcher and higher yielding than all other HWW varieties except 'NuDakota'. Relative to available *Clearfield** wheats, CO03W239 has shown equivalent yield to 'Infinity CL' from Nebraska and higher yield than both 'Bond CL' and 'Above'. CO03W239 has moderate resistance to stripe rust, moderate susceptibility to pre-harvest sprouting (similar to 'NuHills' and 'NuDakota'), and excellent milling and bread baking quality characteristics. If released, CO03W239 would be the only dryland-adapted HWW *Clearfield** wheat available for production in the High Plains region.

State Variety Trials

In 2006-07, experimental lines were tested in the dryland UVPT along with released cultivars and experimental lines from various public or private breeding programs (40 total entries). Beginning with the 2007 UVPT, we decided with the CSU Crops Testing Program (under the leadership of Dr. Jerry Johnson) to reduce the number of CSU experimental lines in the trial in order to improve the value of the UVPT in making dryland variety recommendations for wheat producers in Colorado. Under this system, only lines targeted toward either Breeder or Foundation seed increase will be tested in the UVPT, and thus only two years of variety trial data will be available for a line prior to release. To ensure that adequate yield data are available on experimental lines before release, testing of the CSU Elite Nursery in Colorado has been increased (see page 5 in this report). We are confident that this change in our testing scheme will result in improved ability to make reliable variety recommendations to farmers as well as provide reliable data on experimental line performance to justify selection and release decisions.

Excluding Bill Brown and CO03W239, five other experimental lines were tested in the 2007 UVPT. Together with these data (**Table 1**), and regional trials and breeding trials at other locations in Colorado and adjacent states, only one line was advanced for further testing in the 2008 UVPT (CO02W237, KS98HW519/KS96HW94). This line has also been placed on preliminary Breeder seed increase to enable Foundation seed increase in 2008-2009, pending evaluation in 2007-08.

As mentioned previously, yields at most of our trial locations in 2007 were much higher than what was experienced in the drought years of 2005 and 2006, largely due to increased moisture in 2007. With this moisture, trials at some locations were affected by either leaf rust or stripe rust (or both) and thus many entries that typically perform better in dry years with little leaf disease pressure were lower in the rankings in 2007.

Table 1. Grain yield (GY) and test weight (TW) summary from the 2007 Dryland Uniform Variety Performance Trial (UVPT). Entries are ranked in descending order by average grain yield across locations.

ID	Akron	Arapahoe	Bennett	Burlington	Genoa	Julesburg	Lamar	Orchard	Sh Lake	Walsh	Yuma	Avg GY	Avg TW
NuDakota	56.3	49.5	57.1	39.6	29.9	103.1	80.0	62.2	67.7	58.7	74.0	61.6	57.5
Hatcher	52.4	60.7	60.2	40.9	51.1	79.9	76.7	56.0	74.7	61.5	53.2	60.6	59.2
Hawken	61.8	46.9	47.3	39.4	42.4	69.8	86.9	50.9	69.0	64.2	55.4	57.6	58.6
TAM 111	62.0	55.0	58.3	21.1	42.6	81.7	77.4	46.6	64.2	59.4	62.4	57.3	59.1
Fuller	60.5	49.4	61.3	32.9	37.0	75.1	81.0	52.9	68.4	53.3	58.3	57.3	58.6
Smoky Hill	54.6	48.8	57.3	33.9	38.2	78.2	76.1	53.3	74.4	55.6	50.7	56.5	58.9
Infinity CL	56.2	47.4	52.8	33.7	41.7	91.6	67.4	48.2	64.4	54.2	61.5	56.3	58.7
Keota	58.6	42.6	56.9	38.1	26.7	74.4	74.3	56.6	64.3	58.4	65.4	56.0	59.6
CO03W239	56.8	50.8	50.9	36.0	43.9	68.9	70.3	50.0	64.1	61.7	61.8	55.9	58.3
Bond CL	62.8	45.6	49.9	44.7	39.7	77.2	65.8	50.7	68.1	54.2	52.5	55.5	57.9
Overland	48.0	49.5	58.9	43.1	40.0	67.8	67.0	47.5	66.4	56.7	63.7	55.3	58.6
Alice	54.1	42.2	55.4	35.9	32.8	85.2	72.7	41.7	56.1	63.0	65.4	55.0	59.6
TAM 112	58.9	52.6	57.0	42.2	33.3	69.9	48.3	58.0	67.1	59.1	56.1	54.8	58.4
Duster	57.5	48.1	45.8	41.3	42.8	76.9	72.1	47.7	64.5	54.4	50.3	54.7	59.3
Above	55.5	44.1	62.2	31.0	32.6	86.5	58.5	53.9	62.8	58.1	54.5	54.5	57.8
Bill Brown	54.8	51.3	48.8	42.7	38.5	60.1	65.5	56.0	70.5	60.6	49.4	54.4	59.0
Endurance	60.6	46.0	55.9	40.9	33.0	64.0	62.3	49.6	66.4	59.8	59.0	54.3	58.8
Danby	62.4	46.0	53.3	29.9	34.6	72.0	68.3	54.5	65.2	55.5	54.0	54.2	60.7
Jagger	50.4	43.5	55.4	38.6	27.1	71.7	68.8	50.8	60.5	62.6	65.7	54.1	58.6
Yuma	53.2	46.8	59.3	37.9	36.8	69.2	71.3	51.8	61.6	58.7	45.5	53.8	58.4
Postrock	43.4	44.7	56.5	35.3	23.8	86.5	76.7	43.7	56.3	63.9	59.6	53.7	59.6
Jagalene	45.6	39.4	53.2	35.6	30.0	82.6	74.7	49.7	61.1	53.5	63.7	53.5	59.8
Ripper	43.5	46.4	57.3	43.1	36.2	72.0	48.2	56.8	75.6	55.2	50.8	53.2	57.2
CO03W238	49.7	45.6	59.1	34.2	35.7	70.5	71.6	47.4	56.8	56.3	57.4	53.1	57.3
OK Bullet	56.5	44.4	55.9	34.0	23.0	81.7	73.5	44.5	61.5	54.2	53.3	53.0	59.8
CO02W214	49.5	41.7	50.3	38.5	34.1	70.2	66.1	52.8	59.9	59.8	58.3	52.8	59.0
NuGrain	54.3	44.5	48.1	38.0	40.8	59.9	64.9	50.8	57.6	58.4	63.9	52.8	60.5
CO02W237	60.5	49.2	52.5	41.2	29.8	57.1	70.3	50.0	64.9	54.8	49.0	52.7	59.0
Alliance	55.5	43.6	53.5	36.1	37.8	77.5	57.2	47.1	66.5	51.4	51.8	52.6	57.8
CO02W280	60.9	43.4	52.3	30.9	31.8	70.7	72.4	52.1	62.1	52.3	49.2	52.6	58.9
Ankor	51.4	46.8	53.8	29.8	32.5	72.2	48.5	52.0	67.8	57.4	62.1	52.2	57.8
Prairie Red	52.4	43.5	54.7	39.6	29.5	79.8	49.9	50.1	59.5	55.2	54.1	51.7	57.6
Akron	55.2	44.2	51.5	34.5	35.9	64.5	53.6	41.9	70.5	54.8	58.8	51.4	58.1
Avalanche	50.7	44.7	55.4	34.6	32.0	69.6	57.4	49.7	66.3	53.2	49.7	51.2	59.7
NuFrontier	53.8	40.5	44.5	37.0	32.3	79.8	60.2	56.9	58.8	50.0	48.5	51.1	59.6
Trego	40.8	48.2	48.0	27.5	38.7	68.9	56.1	48.1	60.4	55.9	55.2	49.8	59.6
CO03W269	56.1	42.3	47.8	28.3	37.8	55.3	65.2	45.2	62.2	56.7	50.8	49.8	58.1
Goodstreak	46.1	44.2	54.0	28.9	29.2	45.3	63.5	48.3	58.3	47.5	49.5	46.8	59.5
RonL	35.7	49.7	57.5	14.6	38.8	57.6	63.4	34.5	58.4	56.5	46.4	46.6	59.0
Prowers 99	41.8	43.5	47.5	32.0	31.5	68.1	58.1	43.4	51.6	47.0	45.1	46.3	59.7
Average	53.5	46.4	53.9	35.4	35.1	72.8	66.6	50.1	63.9	56.6	55.9	53.7	58.8
LSD (0.30)	7.3	3.5	4.5	2.3	4.6	12.4	3.3	3.9	4.3	3.1	7.2		

As mentioned previously, the Irrigated Variety Performance Trial (IVPT) was successfully grown at three locations in Colorado (**Table 2**). Leaf rust and lodging were observed at Rocky Ford and a severe infection of wheat streak mosaic virus (WSMV) was observed at Dailey. The predominant factor limiting yields at Fort Collins was the lateness of the initial irrigation.

CSU Elite Nursery

In 2006-07, the CSU Elite Nursery was grown at each of our seven main breeding locations (Akron, Burlington, Dailey, Julesburg, Sheridan Lake, Walsh, and Fort Collins) as well as several locations where only the UVPT has traditionally been planted (Arapahoe, Bennett, Genoa, Lamar, Orchard, and Yuma). These latter locations were planted and harvested by the CSU Crops Testing Program under the direction of Dr. Jerry Johnson. In addition to locations in Colorado, the CSU Elite was planted at several other locations in adjacent states (Amarillo TX, Goodwell OK, Colby KS, Healy KS, Ulysses KS, Sidney NE, and Pierre SD). Between our locations in Colorado and locations in other states, the CSU Elite was planted at 19 different testing environments, 17 of which were dryland and 2 were irrigated. With the exception of Pierre SD, each of the locations was successfully harvested.

The CSU Elite in 2006-07 had 75 total entries, including 10 check varieties and 65 experimental lines, planted in a two-rep Latinized row-column design. The experimental lines included lines tested in the CSU Elite in previous years (and already advanced for testing in the UVPT) and new lines advanced from the Advanced Yield Nursery (AYN) in 2005-06. Grain yield data (**Table 3**) and relative variety rankings from the CSU Elite Nursery were generally in close agreement with data from the UVPT. Based on data and observations from locations across Colorado, as well as yield and other observations from the other locations, five experimental lines (in addition to CO03W239 and CO02W237) were advanced for further testing in the UVPT/IVPT and Breeder seed increase. These lines included three hard white lines (CO03W043, CO03W054, and CO03W139) and one hard red line (CO03064). While the average grain yield CO03W054 was somewhat lower in the Colorado locations than it was in 2005-06 CSU Elite, it was advanced for further testing largely because it performed very well at several locations in adjacent states, it carries near-immunity to wheat streak mosaic virus (WSMV), and it has very strong dough mixing properties.

In addition to these lines, 11 other lines were retained for a second year of testing in the CSU Elite Nursery. Of these 11 lines, seven are single-gene *Clearfield*® wheats (four red and three white), seven are conventional hard red wheats, and four are conventional hard white wheats. Small scale increases of each of these lines will be done in 2007-08 to enable planting a Breeder seed increase of one or more of these lines in 2008-09. From the group of lines advanced from the 2007 CSU Elite, extensive milling and baking quality evaluations will be done during winter 2007-08 in the CSU Wheat Quality Lab.

Advanced Yield Nursery (AYN)

In 2006-07, the AYN was grown in two replications at all seven of our main breeding locations. The AYN was sub-divided into hard red (HRW) and hard white (HWW) groups to manage experimental error and minimize seed mixing during harvest. Both of these trials included 75 total entries, with 5 checks and 70 experimental lines planted in a two-rep Latinized row-column design.

As with the CSU Elite, all seven locations in Colorado were successfully harvested (**Tables 4 & 5**). The row-column designs used for these trials were highly efficient, as evidenced by the relatively high R^2 values from the analyses, with the exception of the trials at Sheridan Lake and Walsh.

Table 2. Grain yield (GY), test weight (TW), and agronomic data summary from the 2007 Irrigated Variety Performance Trial (IVPT). Entries are ranked in descending order by average grain yield across locations.

ID	Dailey GY	Dailey TW	Fort Collins GY	Fort Collins TW	Rocky Ford GY	Rocky Ford TW	Avg GY	Avg TW	HT†	HD†	WSMV†	LD†
TAM 112	105.1	60.3	88.2	60.6	104.8	63.0	99.4	61.3	33	141	3	5
Bill Brown	83.6	57.0	102.2	62.3	101.1	60.8	95.6	60.0	33	142	6	3
Bond CL	89.1	58.2	100.5	61.0	96.6	60.7	95.4	60.0	36	142	4	3
CO03W054	93.7	59.0	95.9	60.9	96.3	59.3	95.3	59.7	36	143	3	3
NuDakota	85.6	54.7	97.3	59.0	101.3	62.2	94.8	58.6	31	143	7	5
Yuma	91.7	57.6	92.3	60.4	98.2	60.4	94.1	59.5	34	143	3	4
CO03W239	79.1	57.4	97.1	60.5	98.2	62.4	91.5	60.1	33	142	4	3
Hatcher	83.9	58.2	86.8	61.2	97.6	60.9	89.4	60.1	34	143	6	6
CO03064	76.8	55.9	99.4	60.7	88.9	60.8	88.4	59.1	36	144	7	6
CO03W108	81.3	56.1	91.2	60.8	91.5	61.1	88.0	59.3	36	147	7	4
CO03W043	78.0	56.7	96.8	60.8	88.1	60.3	87.6	59.2	33	144	8	7
TAM 111	88.5	56.4	75.7	61.0	97.1	60.0	87.1	59.1	34	143	7	3
CO03W238	82.8	55.6	83.7	60.2	94.5	61.9	87.0	59.2	32	140	6	5
CO03W139	69.9	56.7	96.3	60.8	93.5	61.1	86.6	59.5	32	142	6	4
CO02W214	88.2	58.4	86.8	59.8	84.2	59.9	86.4	59.4	34	143	4	4
NuGrain	85.1	59.0	85.6	62.3	87.8	60.3	86.2	60.5	31	144	5	2
Hawken	73.5	57.3	92.5	60.7	91.8	60.9	85.9	59.6	32	142	7	3
Jagalene	78.9	57.3	76.8	61.6	101.2	61.2	85.7	60.1	33	144	7	4
CO02W237	76.6	56.8	91.6	60.1	88.5	59.9	85.5	58.9	33	142	7	6
Keota	82.3	57.9	87.0	61.5	87.2	60.2	85.5	59.9	36	144	8	5
CO03W269	74.5	57.2	93.5	60.5	87.5	61.5	85.2	59.7	34	144	7	4
CO03W127	91.1	57.1	78.1	60.6	85.4	59.8	84.9	59.1	33	140	6	5
CO03W146	95.8	59.2	71.4	60.6	86.7	61.8	84.6	60.5	35	145	3	7
Postrock	76.1	56.8	83.6	60.9	90.8	61.3	83.5	59.7	33	142	4	2
CO02W280	78.2	57.4	78.3	61.2	89.9	58.9	82.1	59.2	36	142	5	5
Aspen	85.1	56.3	57.9	59.8	100.2	59.3	81.1	58.5	31	142	5	1
Platte	82.1	58.6	75.9	62.1	84.2	60.8	80.7	60.5	31	145	7	1
CO03W033	75.4	57.9	77.1	61.4	89.3	59.8	80.6	59.7	34	140	6	4
Ankor	76.4	55.8	70.2	60.4	94.3	61.6	80.3	59.3	34	144	6	4
Danby	83.7	59.4	66.0	62.7	85.6	62.4	78.5	61.5	34	144	4	3
Prairie Red	79.7	57.0	62.6	59.5	88.5	62.0	77.0	59.5	31	140	3	2
CO03443	68.9	56.3	65.0	60.2	89.5	61.7	74.5	59.4	37	144	8	4
Average	82.5	57.4	84.5	60.8	92.5	60.9	86.5	59.7	33	143	6	4
LSD (0.30)	4.8	0.7	7.1	0.3	7.6	1.0						

† HT=average plant height across locations; HD=average heading date at Fort Collins (days from Jan. 1); WSMV=wheat streak mosaic virus tolerance score at Dailey (1=very tolerant, 9=very susceptible); LD=average lodging score at Rocky Ford (1=no lodging, 9=complete lodging).

Table 3. Grain yield and test weight summary for check entries and experimental lines advanced from the 2007 CSU Elite Nursery. Entries are ranked in descending order by average grain yield across 11 Colorado dryland locations (DRY Avg). Lines highlighted in BOLD are under Breeder seed increase in 2007-08.

	Akron	Burlington		Dailey	Orchard		Sh Lake			Walsh	Dry Avg		YR†	HD†		
ID		Bennett	Genoa		Julesburg		Arapahoe		Lamar		Ft Collins	TW Avg		LR†		HT†
Bill Brown	55.5	40.3	41.8	59.3	51.3	42.1	59.4	58.0	73.7	65.2	49.0	97.6	54.2	60.3	4	1	139	27
CO04025	50.1	62.4	35.4	41.1	41.4	62.2	59.2	46.2	71.5	73.2	41.6	87.4	53.1	60.7	4	4	139	27
Hatcher	43.1	58.7	33.3	57.4	56.0	40.8	52.6	56.4	64.9	64.1	52.7	85.2	52.7	59.9	2	2	140	26
Bond CL	44.3	56.3	34.1	36.5	45.4	56.2	54.0	48.2	71.6	83.5	47.0	102.4	52.5	59.2	6	6	138	31
CO03W239	64.4	48.3	33.1	44.7	45.4	46.2	62.1	44.7	62.5	73.3	47.5	84.2	52.0	60.3	3	5	139	28
CO03W043	**47.7**	**61.1**	**31.1**	**38.5**	**42.6**	**46.3**	**65.3**	**57.5**	**64.3**	**67.6**	**47.9**	**99.9**	**51.8**	**59.1**	**4**	**1**	**140**	**28**
CO04549	61.2	65.8	35.9	37.2	43.3	49.9	45.4	54.4	74.3	56.3	43.6	73.0	51.6	59.5	2	6	137	32
TAM 111	59.8	65.1	14.0	45.8	42.6	46.5	45.8	53.7	64.2	73.4	50.9	78.1	51.1	60.6	1	6	139	29
CO04499	48.1	56.9	27.4	56.9	47.7	49.8	53.2	46.8	66.0	61.5	44.1	68.2	50.8	59.9	4	7	138	30
CO03064	**29.8**	**46.4**	**42.4**	**43.3**	**42.9**	**46.6**	**60.0**	**55.2**	**67.5**	**82.5**	**39.3**	**88.5**	**50.5**	**59.8**	**2**	**6**	**140**	**30**
CO04448	46.8	56.1	18.2	42.8	40.3	48.9	60.2	60.9	68.5	64.1	44.2	83.7	50.1	60.2	1	3	141	30
CO03W139	**59.3**	**55.9**	**37.7**	**41.0**	**42.9**	**48.2**	**51.8**	**49.1**	**63.3**	**54.3**	**47.2**	**74.2**	**50.1**	**59.8**	**6**	**5**	**139**	**26**
CO04551	55.6	63.3	31.3	27.8	43.7	48.6	58.1	47.4	67.4	53.4	50.5	84.1	49.7	59.6	4	7	140	30
CO04W369	41.1	62.4	25.2	33.9	41.8	51.7	56.9	38.8	74.2	72.9	46.8	88.0	49.6	59.9	1	4	141	28
Jagalene	41.7	59.1	32.8	31.4	41.6	48.4	53.2	45.2	66.2	77.8	46.7	74.8	49.5	61.0	1	7	140	28
CO04W320	49.6	61.1	37.4	27.2	41.0	50.8	58.9	45.7	70.1	46.4	52.4	83.8	49.2	59.5	2	1	141	30
Above	39.6	63.2	28.7	39.8	42.6	53.6	50.9	53.7	62.4	57.2	48.6	67.6	49.1	59.2	7	8	137	28
CO04W323	48.5	63.4	31.4	21.0	41.4	47.6	59.3	43.5	69.9	60.9	50.7	76.0	48.9	60.0	1	1	140	30
CO02W237	**52.7**	**55.2**	**29.8**	**37.3**	**41.5**	**40.3**	**49.9**	**50.7**	**62.4**	**67.9**	**47.8**	**78.8**	**48.7**	**60.8**	**6**	**4**	**139**	**29**
CO04575	63.4	47.4	27.6	30.4	39.4	46.1	53.5	49.1	71.8	61.6	42.7	92.2	48.4	59.9	2	7	139	28
CO04W210	39.9	42.5	39.3	46.9	44.0	37.6	55.3	51.4	64.9	63.4	42.2	86.1	48.0	59.4	3	3	141	29
CO04393	28.1	50.4	12.5	42.2	43.4	44.4	54.7	55.7	65.7	78.9	50.3	89.1	47.8	59.9	2	3	140	28
Danby	39.6	58.5	17.4	33.1	41.7	46.4	44.5	47.1	69.2	82.4	44.7	65.3	47.7	61.3	1	7	140	27
CO03W054	**36.0**	**50.1**	**27.3**	**36.7**	**43.3**	**44.3**	**60.6**	**45.9**	**65.7**	**66.6**	**43.6**	**89.5**	**47.3**	**59.8**	**3**	**1**	**140**	**29**
Ripper	22.3	46.8	38.1	43.4	40.9	53.1	67.3	46.9	72.5	38.4	43.8	78.2	46.7	58.7	8	6	139	27
Ankor	40.5	54.6	24.9	37.7	41.8	43.9	50.0	51.6	58.3	56.0	53.9	72.3	46.7	59.5	7	5	141	27
Avalanche	39.8	55.6	31.1	35.2	38.1	48.2	47.6	41.3	65.1	62.5	42.2	83.9	46.1	60.7	7	7	140	29
NuFrontier	43.3	53.3	33.5	29.3	40.2	34.7	66.8	41.4	67.8	53.1	41.2	83.2	45.9	60.4	2	2	141	30
Mean	45.1	55.1	28.3	38.2	41.7	45.7	54.8	49.0	66.8	61.9	45.9	80.6	48.4	59.8	4	4	140	29
LSD (0.05)	13.1	13.8	7.2	10.2	6.4	13.8	9.6	9.8	9.3	9.8	5.2	12.0						
CV (%)	14.4	12.2	12.5	12.9	7.5	14.9	8.5	9.6	6.8	7.4	5.6	7.4						

† HT=average plant height across locations; HD=average heading date at Fort Collins and Akron (days from Jan. 1); YR=average stripe rust resistance score at Lamar (1=resistant, 9=susceptible); LR=average leaf rust resistance score at Colby KS (1=resistant, 9=susceptible).

Table 4. Grain yield, test weight, and agronomic summary of hard red (HRW) check entries and experimental lines advanced from the 2007 Advanced Yield Nursery. Entries are ranked in descending order by average grain yield across 6 Colorado dryland locations (AVG Dry). Check entries are in **BOLD**.

ID	Akron	Burlington	Dailey	Julesburg	Sh Lake	Walsh	Ft Collins	AVG Dry	Avg TW	Heading	Height
CO05079	48.4	34.7	46.5	48.4	69.8	51.3	88.8	49.9	57.9	140	31
CO050303	53.2	32.7	45.7	41.4	71.9	52.0	81.4	49.5	58.4	141	32
CO05060	52.8	33.7	43.6	38.9	75.8	50.2	74.2	49.2	58.5	141	29
CO050337	48.9	29.0	45.8	40.8	76.1	51.0	88.0	48.6	58.2	144	32
CO050270	42.7	35.4	47.1	41.6	71.2	53.1	64.4	48.5	58.2	140	33
CO050262	44.4	32.3	46.1	39.4	73.8	53.0	71.0	48.2	59.2	141	29
Ripper	**39.9**	**34.6**	**44.1**	**43.2**	**74.4**	**50.9**	**79.5**	**47.8**	**57.3**	**142**	**28**
CO050322	48.0	26.4	44.5	40.8	76.4	49.1	91.7	47.5	58.4	145	33
CO050175	41.3	27.9	47.0	42.0	72.6	52.9	82.9	47.3	59.0	141	30
CO050233	44.5	28.8	45.8	40.7	74.6	48.5	77.7	47.1	58.0	142	30
CO050541	43.4	29.5	43.3	46.9	70.5	49.0	81.7	47.1	58.1	145	28
CO050165	45.3	29.8	46.4	42.8	68.2	49.8	74.6	47.1	58.7	141	29
CO05090	47.4	33.2	45.3	35.7	71.8	48.5	77.2	47.0	58.4	140	32
CO050173	46.3	31.2	45.7	35.8	70.1	52.7	79.7	47.0	58.9	141	30
CO050476	45.0	28.7	42.9	43.6	70.3	50.6	86.2	46.8	58.8	142	31
CO050203	47.6	30.8	43.9	41.0	67.5	50.1	87.0	46.8	58.2	142	34
CO050217	44.0	33.5	43.5	37.8	70.6	51.5	86.5	46.8	58.2	141	33
CO05068	46.8	26.2	47.6	37.2	71.6	50.2	83.5	46.6	58.0	145	33
CO050141	45.0	32.5	43.0	36.5	70.5	51.2	81.0	46.5	58.7	142	33
Hatcher	**41.2**	**29.1**	**46.9**	**38.6**	**72.7**	**49.9**	**81.5**	**46.4**	**58.3**	**142**	**33**
TAM 111	**47.3**	**17.5**	**45.0**	**44.8**	**71.9**	**51.1**	**82.4**	**46.3**	**58.2**	**143**	**34**
CO05066	46.1	29.2	45.3	31.6	74.1	51.2	84.8	46.3	58.4	143	28
CO05088	41.2	33.7	44.6	37.1	69.8	50.4	85.5	46.1	58.0	145	35
CO050133	42.1	32.3	44.6	35.7	72.5	48.4	79.8	45.9	59.0	143	33
CO050343	42.3	25.1	43.4	41.4	71.1	52.1	87.2	45.9	58.8	142	32
Jagalene	**48.8**	**31.1**	**42.4**	**30.7**	**69.9**	**48.5**	**74.2**	**45.2**	**58.8**	**142**	**29**
Ankor	**47.9**	**25.9**	**44.1**	**34.9**	**68.9**	**49.2**	**77.2**	**45.1**	**58.1**	**142**	**29**
Mean	45.2	29.1	44.7	39.0	71.4	50.5	80.4	46.6	58.4	142	31
RSquare	0.94	0.89	0.93	0.93	0.66	0.66	0.93				

Table 5. Grain yield, test weight, and agronomic summary of hard white (HWW) check entries and experimental lines advanced from the 2007 Advanced Yield Nursery. Entries are ranked in descending order by average grain yield across 6 Colorado dryland locations (AVG Dry). Check entries are in **BOLD**.

ID	Akron	Burlington	Dailey	Julesburg	Sh Lake	Walsh	Ft Collins	AVG Dry	Avg TW	Heading	Height
CO05W024	48.9	35.8	48.9	51.8	76.4	48.5	92.4	51.7	59.1	141	33
CO05W006	51.8	31.5	50.7	47.3	76.1	49.8	84.7	51.2	58.0	140	34
CO05W150	50.6	31.7	49.4	48.7	76.2	49.9	86.0	51.1	58.6	141	30
CO05W062	52.1	34.8	48.3	42.6	76.0	51.5	93.3	50.9	58.2	142	30
CO05W130	48.7	27.9	52.5	47.6	76.9	51.0	81.8	50.8	58.4	141	32
CO05W104	42.9	35.9	49.0	49.7	76.8	49.9	90.3	50.7	59.7	142	30
CO05W115	51.3	29.1	49.3	48.9	75.7	49.8	82.1	50.7	58.8	142	32
CO05W064	53.7	28.4	49.2	44.2	77.2	51.5	83.3	50.7	58.6	143	31
CO05W180	48.9	32.8	47.8	48.5	75.8	49.9	75.5	50.6	59.3	140	30
CO05W059	47.7	27.2	49.8	50.8	75.0	50.5	83.4	50.2	58.8	142	33
CO05W250	50.5	37.1	48.1	43.9	74.0	47.3	94.2	50.2	58.7	140	33
CO05W176	46.5	34.8	48.9	45.1	76.8	48.8	78.8	50.1	59.1	140	33
CO05W171	49.6	30.0	50.5	47.8	75.1	47.8	87.3	50.1	58.3	142	33
CO05W194	44.3	33.5	48.2	48.1	75.6	51.0	87.0	50.1	58.9	142	26
CO05W045	39.9	35.3	50.5	45.1	77.3	51.6	85.1	49.9	59.2	145	33
CO05W001	48.6	33.0	46.3	47.0	74.6	49.6	67.8	49.9	58.5	141	33
CO05W067	49.9	27.2	53.8	40.1	76.3	51.1	68.3	49.7	58.9	141	30
CO05W111	44.5	32.2	51.1	43.9	77.1	49.5	92.7	49.7	59.3	145	38
CO05W056	48.6	28.2	49.4	44.8	74.5	50.3	87.8	49.3	58.5	140	32
CO05W022	44.3	25.9	49.2	47.0	76.2	50.9	68.6	48.9	59.1	140	32
CO05W156	43.0	33.1	48.7	44.8	75.3	48.2	92.4	48.8	60.1	141	33
CO05W153	50.7	28.8	48.9	33.6	76.8	52.0	83.2	48.5	59.3	141	33
CO05W165	48.7	26.1	46.9	44.5	74.9	49.6	85.9	48.5	59.5	141	32
Danby	**49.6**	**20.6**	**49.0**	**43.4**	**76.3**	**51.1**	**59.3**	**48.3**	**60.0**	**143**	**31**
CO05W020	47.7	24.4	50.0	39.5	77.0	51.4	88.9	48.3	59.1	142	31
CO05W112	47.7	25.8	50.5	38.9	76.5	50.1	92.2	48.3	58.3	142	31
NuFrontier	**42.7**	**33.8**	**47.0**	**43.6**	**74.9**	**46.8**	**84.5**	**48.1**	**59.2**	**143**	**33**
CO05W101	45.5	33.7	49.9	37.2	73.6	46.7	89.5	47.8	58.5	140	30
Avalanche	**41.7**	**29.2**	**47.2**	**46.7**	**74.3**	**47.0**	**80.0**	**47.7**	**59.2**	**142**	**30**
NuDakota	**43.1**	**27.8**	**47.0**	**44.5**	**75.0**	**46.3**	**77.0**	**47.3**	**60.0**	**143**	**27**
RonL	**30.7**	**9.7**	**51.3**	**31.6**	**74.6**	**48.1**	**75.7**	**41.0**	**60.7**	**143**	**24**
Mean	46.4	28.3	49.3	43.9	75.7	49.5	81.7	48.8	59.0	142	31
RSquare	0.92	0.91	0.94	0.91	0.57	0.73	0.97				

From the AYN, 48 total experimental lines were advanced for further testing in the 2008 CSU Elite; of this total, 22 were HRW lines (**Table 4**) and 26 were HWW lines (**Table 5**). Overall, strict selection was practiced for test weight in an overall effort to move test weight in our program in a more positive direction. Yield and visual observations under drought stress at Burlington, shattering observations at Julesburg, and quality data from evaluation done during winter 2006-07 also influenced selection and discard decisions. In addition to continued yield testing, extensive milling and baking quality evaluations will be done on all of these materials during winter 2007-08 in the CSU Wheat Quality Lab. For each of these lines advanced to the CSU Elite Nursery, a headrow increase was planted at Fort Collins in fall 2007 for line purification and reselection in 2008 (where variability within the line exists).

Early-Generation Germplasm Development

In 2006-07, 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 900 experimental lines were planted in seven groups of single-replication trials at four of our main breeding locations (Fort Collins, Burlington, Akron, Julesburg). Approximately 65% of these lines were hard red lines and 35% were either hard white lines or mixed for grain color lines. About 130 of these lines (~14%) were double-gene *Clearfield** wheats. Based on grain yield, test weight, agronomic observations, and small-scale quality data, 185 of these lines were advanced to the 2007-08 Advanced Yield Nursery (AYN) which was divided among hard red, hard white, and double-gene *Clearfield** nurseries. To facilitate line reselection, we also planted a group of head selections from each of these lines in Yuma AZ for reselection in 2007-08. Most of the HWW lines were subject to reselection by sampling heads at physiological maturity and running these through our intact head sprout testing procedure.

2) **F4 Headrows**: Over 30,000 headrows were grown at Fort Collins in 2006-07. From visual observations and pedigree information, over 1800 headrows were hand harvested in July 2007. Grain from these headrow selections was visually inspected for kernel characteristics (color, shriveling, etc) and then subjected to a modified small-scale test weight test and whole-grain NIR. Based on visual observation, test weight, and whole-grain NIR estimates for grain protein content, wheat ash, and grain hardness, about 1040 lines were selected and advanced to the single replication 2007-08 PYN. Among this group, approximately 30% were hard red lines and 70% were either hard white lines or were mixed for kernel color. Double-gene *Clearfield** lines represented approximately 12.5% of the total.

3) **F3 and F4 Bulks**: Approximately 260 conventional non-*Clearfield** F3 or F4 bulk populations were grown under irrigation at Fort Collins and under dryland conditions at Akron in 2006-07. Of this set, 152 populations were advanced to the 2007-08 headrow nursery by head selection and 113 of these populations (~75%) had only hard white segregants because of the parents used in the crosses or because of mechanical purification for hard white types using the high-speed sorter at the USDA-ARS-Engineering Research Unit in Manhattan KS. Among the group of about 116 *Clearfield** bulk populations, about 88 populations were advanced as head selections to the 2007-08 headrow nursery. While hard white populations were represented among this group, the vast majority of these were hard red types.

4) **F2 Bulks**: Approximately 577 non-*Clearfield** F2 bulk populations were grown at Fort Collins in 2006-07. A total of 260 populations were advanced as a bulk to the F3 and F4

bulk trial in fall 2007; approximately 66% of these populations contain only hard white types, either based on the parents of the cross or as a result of sorting with an experimental kernel sorter provided by the USDA-ARS Engineering Research Unit in Manhattan KS. Stringent selection among bulks was practiced for agronomic type and test weight prior to advancement. We also continue to sieve our F2 bulk samples to increase the frequency of larger-kernelled types in the bulk population.

5) **F1 Increase**: Approximately 1496 F1 populations were grown in the field at Fort Collins in 2006-07. Based on visual observations and pedigree, we advanced about 522 of these to the F2 bulk nursery in 2007-08. Among this group, the vast majority were three way crosses that included both red and white parents and will thus be segregating for both red and white types.

6) **Crossing**: Over 2400 new crosses were made in 2006-07, split between crossing blocks in fall 2006 (1157 crosses) and spring 2007 (1276 crosses). Included among these crosses were three main types of materials: a) crosses targeted toward direct increase, bulk evaluation, and line development, b) crosses targeted only for backcrossing or three-way crossing, and c) crosses targeted for marker-assisted selection or germplasm introgression. Several new or unique sources of germplasm were brought into the crossing program, including new sources of adult-plant leaf and stripe rust resistance, new sources of resistance to the Ug-99 race of stem rust, a new source of wheat streak mosaic virus resistance, various sources of RWA biotype 2 resistance previously transferred to a Yuma background, a source of a novel glutenin protein subunit, a low phytic acid mutant, and blue wheat. We continued to population development with crosses that will allow us to isolate either hard red or hard white types from the same cross.

Research Support Projects and Other Activities

To complement and contribute to the overall breeding effort, we were involved with several other types of activities, often in collaboration with other researchers. These include the following:

- Russian wheat aphid resistance (Frank Peairs, Nora Lapitan collaborators)
  - Advanced of a group of 70 biotype 2-resistant lines to replicated yield trials in 2008.
  - Screening of a group of synthetic hexaploid wheats for RWA biotype 2 resistance.
  - Transfer of RWA resistance from tetraploid wheat (Ben Beyer MS thesis project).
  - Characterization of Triticale-derived RWA resistant wheat lines (collaboration with Dr. Kabwe Nkongolo, Laurentian University, Canada).
  - Development of several mapping populations with Iranian landrace selections for DNA marker identification.
  - Continued of *Dn7* from the negative quality effects of the 1BL.1RS wheat:rye translocation (collaboration with Nora Lapitan, Junhua Peng, and Guihua Bai, USDA-ARS Genotyping Lab, Manhattan KS).
  - Evaluation of elite RWA-susceptible lines for biomass loss from RWA.
  - Exchange of RWA-resistant germplasm with researchers in Australia and France for characterization of response to virulent biotypes from other areas of the world.
- *Clearfield** wheat development
  - Advanced a set of 7 single-gene Clearfield* lines for a second year of testing in the 2008 CSU Elite nursery.

  - Advanced of a group of 45 double-gene *Clearfield** lines to replicated yield trials in 2008 (Advanced Yield Nursery).
  - Implemented DNA markers for confirmation of the presence B-genome and D-genome *Clearfield** mutants in experimental wheat lines.

- End-use quality evaluation and research
  - Expansion of the CSU Wheat Quality Laboratory to isolate single kernel characterization system (SKCS) and milling equipment in a separate lab.
  - Implementation of barcode readers for SKCS and Mixograph devices.
  - Development of a relational database system for storage and retrieval of routine screening data.
  - Analyzed over 2950 grain and flour samples from the 2006 season, including 2396 whole grain NIR tests, 1737 flour NIR tests, 1996 SKCS tests, 1800 Mixographs, 540 Quad Senior mills, and 527 100 gram pup-loaf bakes.
  - Participated as a test collaborator in the Pacific Northwest Wheat Quality Council evaluation program.
  - Implementation of a higher-throughput, modified Quadromat Senior milling system (with assistance from Doug Engle, USDA-ARS-PNWWQL, Pullman WA).
  - Characterization of utility of whole-grain calibrations for SKCS kernel weight, diameter, and hardness for rapid selection (Josh Butler PhD dissertation research).
  - Characterization of agronomic management effects on wheat end-use quality (project led by Jerry Johnson).
  - Documentation of high and low molecular weight glutenin subunit composition of Great Plains winter wheat cultivars and experimental lines (project led by Pat Byrne).
  - Documentation of the influence of allelic variation *Glu-A1, Glu-B1, Glu-D1, Glu-A3, and Glu-B3* loci on Mixograph properties (project led by Pat Byrne).

- USDA-CAPS project (Pat Byrne, Nora Lapitan, Jorge Dubcovsky, Guihua Bai collaborators)
  - Completed seed increase of our mapping population (Platte/CO940610) and planted a subset of this population at Fort Collins for phenotypic evaluation in 2006-07.
  - Planted 192 individuals from the CAP population at Fort Collins in fall 2007 under a linear move for side-by-side evaluation under full- and limited-irrigation.
  - Continued marker genotyping and mapping of CAP population (led by Pat Byrne and Nora Lapitan).
  - Implemented marker assisted selection (MAS) for allele enrichment in segregating top-cross populations for various glutenin alleles, stripe rust resistance (Yr5 and Yr15), leaf and stem rust resistance (*Lr19/Sr25, Sr2, Sr24* sources), and the high grain protein content gene from tetraploid wheat.

- Pre-harvest sprouting tolerance
  - Use of the petri-dish germination test to characterize sprout tolerance of over 350 different hard red and hard white samples collected at Fort Collins and Akron.
  - Use of the intact-head sprout test for line reselection with over 1200 individual heads sampled from hard white preliminary lines at Fort Collins.
  - Assessed the utility of previously reported DNA markers to identify lines with improved sprout tolerance.

- Graduate student research: Three graduate student projects were on-going in 2006-07
  - Development and validation of near infrared reflectance (NIR) spectroscopy calibrations for whole-grain prediction of end-use quality characteristics (Joshua Butler). Josh is planning to submit and defend his PhD dissertation in spring 2008.
  - Validation of the BYDV resistance and high grain protein content traits introgressed to several elite backgrounds as part of the IFAFS molecular marker grant (Jennifer Roth). Jennifer is planning to submit and defend her MS thesis in spring 2008.
  - RWA biotype 2 resistance gene mapping and gene transfer from *Triticum dicoccoides* (Ben Beyer). Ben successfully defended his MS thesis in fall 2007.

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