2002-2003 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 2002-2003 season.

2002-2003 Site Conditions

In 2002-2003, the breeding program conducted field trials at four main locations in eastern Colorado (Akron, Burlington, Julesburg, and Walsh) in addition to the main location at the ARDEC research facility near Fort Collins. Overall, environmental conditions experienced at these locations can be described as follows:

Akron – adequate yet less than optimal stands from poor planting moisture. Fairly dry winter, very wet spring and early summer. Very high level of stripe rust infection along with leaf rust in entries with good stripe rust resistance. Significant lodging. Very moderate temperatures until the last 10 days before harvest. Very high yields despite stripe rust.

Burlington – poor fall stands resulted from uneven moisture, stands filled in considerably with late fall and early spring moisture. Fairly dry winter, good early spring moisture, significant drought stress in May, good moisture in June saved the trials. Very moderate temperatures until the last week before harvest. No significant disease or insect problems.

Julesburg – excellent fall stands, dry winter, adequate spring moisture, significant dry period around heading, adequate June moisture. Low levels of stripe rust and leaf rust. Some lodging observed. Moderate temperatures until the last 10 days before harvest. Very high yields, though limited by inadequate nitrogen availability (reflected in low grain protein).

Walsh – excellent fall stands, no winter injury, fairly dry winter, adequate early spring moisture, significant dry period from jointing through heading, severe (30-70% damage) hailstorm two weeks after heading in early June, a second significant hailstorm two days before harvest. Moderate RWA observed, most likely biotype B based on susceptible reaction of RWA-resistant varieties.

Fort Collins (irrigated) – good fall stands and moisture. Excellent spring growth, good spring rains reduced need for irrigation. Low levels of stripe rust and leaf rust. Significant RWA observed, most likely Biotype-A based on reaction of resistant varieties. Significant lodging observed. Very moderate temperatures until the last two weeks before harvest.

In cooperation with the CSU Variety Testing Program, under the direction of CSU Extension Agronomist Dr. Jerry Johnson, varieties and experimental lines were tested at six other dryland trial locations (UVPT – Bennett, Cheyenne Wells, Genoa, Lamar, Orchard, and Sheridan Lake) and two other irrigated trial locations (IVPT – Ovid and Rocky Ford). Overall, both the dryland UVPT and the irrigated IVPT were a drastic improvement over 2002 as a good range of production conditions and yield levels were experienced.

Of the total of 10 UVPT locations, four locations were either not harvested or were not used for the overall variety summary due to production conditions that prevented reliable data interpretation. The Genoa location was adversely affected by a severe hailstorm near the heading growth stage. The trial at Bennett did not emerge in the fall and only partially emerged following the March 17 snowstorm and stands remained highly variable. The Lamar and Sheridan Lake UVPT locations were characterized by uneven emergence, severe spring drought, multiple damaging hailstorms, and extremely low and variable yields. Both the Rocky Ford and Ovid IVPT locations were successfully harvested, although yields at the Ovid location were severely affected by stripe rust, perhaps surpassing the level observed in 2001. Very little virus (e.g., barley yellow dwarf, wheat streak mosaic) infection was observed at any of the testing locations. Russian wheat aphid was observed at higher levels than in recent years at several trial locations. Leaf rust was observed at very low levels at some locations, although at Akron it may have affected yields in those entries that had managed to maintain their leaves in response to the severe stripe rust infection.

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.

Foundation Seed Increases

No new cultivars were released in fall 2003. In September 2003, however, three experimental lines were put on Foundation Seed increase for potential release in 2004.

The first of these lines, **CO980607** (Yuma/T-57//TAM 200/3/4*Yuma/4/KS91H184/Vista pedigree), would be positioned as a higher-yielding replacement for RWA-resistant (Biotype-A) cultivars including Stanton (from Kansas State), Prairie Red, and Yumar. CO980607 is an awned, white-chaffed, medium maturity, semidwarf hard red winter wheat. CO980607 is moderately resistant to stem rust, moderately susceptible to leaf rust, moderately resistant to stripe rust, susceptible to both wheat streak mosaic virus and barley yellow dwarf virus, and resistant to Biotype-A of RWA. CO980607 was the highest performing entry in the 2003 Colorado UVPT (Table 1) and had the second highest yield in the Southern Regional Performance Nursery (SRPN) across a six-location average of western Great Plains testing locations. Averaged across 17 trial locations of the dryland Colorado UVPT between 2001 and 2003, CO980607 (45.9 bu/a) yielded slightly less than Trego (47.2 bu/a) but greater than all other entries in the trial, including Stanton and Enhancer (45.0 bu/a), Above (44.5 bu/a), Yuma and Alliance (44.3 bu/a), Ankor and Jagger (41.5 bu/a), Akron (43.7 bu/a), Prairie Red (43.0 bu/a), Halt (42.8 bu/a), Yumar (42.4 bu/a), and Prowers 99 (41.1 bu/a). Average test weight of CO980607 in these trials (58.4 lb/bu) was lower than Prowers 99 (59.5 lb/bu) and Trego (59.8 lb/bu), similar to Yumar (58.3 lb/bu), and greater than Prairie Red (57.5 lb/bu). Milling and bread baking characteristics of CO980607 were determined from field-grown samples from the 2000, 2001, and 2002 seasons. Overall, CO980607 is characterized as having excellent milling properties and average to slightly better than average baking properties. CO980607 was

entered for a second year of testing in the 2004 Southern Regional Performance Nursery (SRPN) and for evaluation in the 2003-crop Hard Winter Wheat Quality Council (HWWQC). Approximately eight acres of CO980607 were planted in Colorado in fall 2003 for Foundation Seed production.

The second line on increase, **CO00D007** (Yumar//TXGH12588-120*4/FS2 pedigree), is an awned, white-chaffed, medium-early maturity, tall semidwarf hard red winter wheat. CO00D007 is a *Clearfield** wheat that has shown dryland yields comparable to Above, improved baking quality characteristics, and resistance to Biotype-A of Russian wheat aphid. CO00D007 is about one day later at heading and two inches taller compared to Above. The straw strength of CO00D007 is slightly less than Above, similar to Akron. CO00D007 was the second highest performing entry in the 2003 Colorado UVPT (Table 1) across a six-location average. Across nine trial locations of the dryland Colorado UVPT during 2002 and 2003, CO00D007 (47.2 bu/a) yielded less than CO980607 (48.0 bu/a) but greater than all other entries in the trial, including TAM 111 (46.8 bu/a), Above and Trego (46.7 bu/a), Ankor (45.8 bu/a), Yuma (45.3 bu/a), Prairie Red (45.0 bu/a), Yumar (43.8 bu/a), and AP502 CL (43.5 bu/a). Average test weight of CO00D007 from these trials (58.4 lb/bu) was about 1 lb/bu lower than the trial average, lower than Above (59.0 lb/bu) and Yumar (59.3 lb/bu), and similar to AP502 CL (58.6 lb/bu). Milling and bread baking characteristics of CO00D007 were determined from a composite of field grown samples from both the 2001 and 2002 field seasons. Overall, CO00D007 is characterized as having slightly below average milling properties and better than average baking properties (especially when compared to Above), in spite of its lower protein and bake water absorption. In fall 2003, a large Foundation Seed increase (20 acres) of CO00D007 was planted in Colorado. As a backup, a smaller increase (five acres) of CO00D007 was planted in Yuma, Arizona. CO00D007 was also entered for regional testing in the 2004 Southern Regional Performance Nursery (SRPN) and for evaluation in the 2003-crop Hard Winter Wheat Quality Council (HWWQC).

The third line on Foundation Seed increase, **CO991132** (Jagger//TXGH12588-120*4/FS2 pedigree), is a *Clearfield** wheat that shows distinct visual similarity to Jagger. CO991132 did not perform as well as *Above* or CO00D007 in Colorado but appeared to show promise in other areas of the Great Plains, particularly in Kansas where it outperformed Jagger by 5 bu/a and the new Kansas State release Overley by 2 bu/a on a four location average. CO991132 has shown better baking quality scores than Above, but not quite as good as the Jagger parent. In fall 2003, a 10-acre Foundation seed increase of CO991132 was planted in Colorado to allow release of this line in fall 2004, pending 2004 performance evaluations. As a backup, a smaller increase (five acres) of CO991132 was also planted in Yuma, Arizona. In addition to tests in Colorado, CO991132 was entered for regional testing in the 2004 Southern Regional Performance Nursery (SRPN) and is again being grown along with CO00D007 in Westbred and AGSECO trials in Kansas and Montana.

Samples of all lines on Foundation Seed increase are being tested for milling and baking quality in our own quality laboratory, the USDA Hard Winter Wheat Quality Laboratory (Manhattan, KS), and various private industry collaborators. The *Clearfield** lines were also planted in replicated *Clearfield* Qualification Trials in fall 2003, with five locations in Colorado and two locations in both Oklahoma and Nebraska with our counterparts in those states. As we did not conduct the *Clearfield** qualification trials in 2003, we are hopeful that we will obtain the required data to support cultivar release in 2004.

State Variety Trials

In 2002-2003, 39 advanced experimental lines were tested in the dryland UVPT. Of these lines, six were *Clearfield** wheat lines, six were hard white wheat (HWW) lines with Biotype-A RWA resistance, and 27 were hard red wheat (HRW) lines in their first, second, or third year of statewide testing in the UVPT (Table 1).

Table 1. Data summary from 2003 Dryland Variety Performance Trials (UVPT). Entries (with checks in **bold**) are ranked in descending order by grain yield. †

	Grain Yield							Avg					
Entry	Walsh	Orchard	Ch Wells	Burlington	Julesburg	Akron	Average	Test Wt	Heading	Height	Lodging	Shatter	Stripe Rust
CO980607 *	24.0	36.4	47.1	57.9	73.0	97.6	56.0	59.9	145	27	2.0	3.0	5
CO00D007 *	25.6	34.2	48.0	53.4	72.9	97.3	55.2	58.4	143	30	4.3	2.5	7
CO980630	24.4	37.0	44.0	54.9	73.0	96.9	55.0	59.8	145	28	2.7	3.8	4
CO991350	24.5	34.3	50.1	57.3	73.9	88.3	54.7	58.4	145	29	2.0	2.8	9
CO980376	20.4	38.4	48.0	51.0	72.6	96.6	54.5	59.8	143	30	2.3	4.5	7
CO00016 *	25.1	37.7	43.9	55.2	72.1	87.7	53.6	58.8	144	28	2.7	2.8	9
CO970547-7 *	15.6	34.1	40.2	52.0	77.5	100.5	53.3	59.8	146	29	5.3	4.8	6
CO00698 *	20.8	31.7	52.1	53.4	73.2	87.0	53.0	58.1	145	29	2.7	2.8	9
CO980684-1	17.3	32.6	43.2	54.7	75.7	94.6	53.0	58.9	144	29	4.7	6.7	9
Yuma	17.2	33.0	42.5	56.0	75.9	93.4	53.0	59.3	146	28	2.0	4.5	7
Trego	24.9	35.3	41.9	48.3	74.0	92.8	52.9	60.9	148	27	2.0	2.8	5
Above	25.0	39.2	41.0	46.0	72.4	93.1	52.8	58.9	142	28	2.3	3.5	9
CO991407	21.6	32.6	45.5	51.7	72.9	92.3	52.8	59.4	143	29	3.7	4.0	9
CO00501	22.4	36.3	40.9	49.9	73.5	93.1	52.7	59.1	142	30	6.0	2.5	7
TAM 111	18.7	35.4	41.4	46.5	72.6	101.3	52.6	60.3	145	28	2.0	4.0	2
CO99W192 *	28.7	28.7	46.0	44.2	67.4	99.2	52.4	58.7	147	28	2.3	3.0	4
Ankor	22.8	37.3	41.8	45.2	73.5	90.4	51.8	59.0	146	30	2.7	2.8	8
Enhancer	14.0	32.4	42.8	48.0	76.8	94.9	51.5	59.2	144	31	6.7	3.8	3
CO00347 *	16.2	32.6	38.7	47.3	78.1	95.9	51.5	59.2	143	29	2.0	4.0	9
CO991057 *	18.6	34.1	47.1	52.2	68.8	85.6	51.1	59.5	146	29	2.0	3.0	8
CO00345 *	20.3	32.3	39.8	45.2	74.0	94.4	51.0	59.6	142	28	2.0	4.3	8
CO991132 *	19.1	32.2	39.5	49.7	68.0	97.3	51.0	58.7	144	31	2.3	4.7	2
CO00554 *	17.5	32.1	39.4	47.0	75.9	93.9	50.9	59.2	146	28	3.7	3.5	6
CO00739 *	16.3	32.7	39.8	47.7	73.7	94.2	50.7	59.0	146	29	2.3	4.3	6
Alliance	20.4	34.4	39.3	42.7	74.2	92.2	50.5	59.4	145	28	2.0	4.3	5
Avalanche	22.9	34.4	42.3	47.7	65.4	89.9	50.4	60.6	146	29	2.0	3.5	8
CO00D011	20.3	34.0	42.7	46.4	68.3	90.2	50.3	59.9	148	26	2.0	4.0	5
Yumar	16.0	29.1	38.4	50.2	77.0	91.0	50.3	59.6	144	28	2.0	4.8	6
CO99W183 *	22.3	33.1	44.8	42.9	66.4	91.9	50.2	57.8	144	29	2.3	3.0	6
Prairie Red	22.6	32.3	40.7	48.8	68.2	88.5	50.2	58.8	141	28	2.0	2.3	9
TAM 110	21.6	33.8	41.0	44.3	71.9	87.7	50.0	58.8	141	27	3.0	2.5	8
CO00484	22.6	31.9	44.7	51.6	65.4	83.9	50.0	58.1	145	29	6.3	2.5	7
CO99W254 *	19.0	33.5	41.6	44.6	65.7	95.7	50.0	59.9	144	27	2.0	4.5	4
CO00480	18.1	33.6	41.4	50.0	74.3	82.3	49.9	57.9	146	30	5.0	3.0	8
Akron	19.5	33.4	42.6	46.3	67.5	88.4	49.6	59.0	146	29	3.7	3.0	8
CO99314	13.9	35.9	33.9	46.8	72.8	94.4	49.6	59.7	144	28	3.7	4.3	6

Table 1. (continued)

	Grain Yield							Avg					
Entry	Walsh	Orchard	Ch Wells	Burlington	Julesburg	Akron	Average	TestWt	Heading	Height	Lodging	Shatter	Stripe Rust
CO00580	18.4	29.4	43.9	40.6	70.8	94.4	49.6	58.2	146	27	2.0	4.0	4
CO00582	18.1	32.5	32.5	47.8	68.4	97.6	49.5	59.9	143	29	2.0	3.8	6
Stanton	21.0	31.7	39.7	41.7	69.9	92.2	49.4	59.9	145	30	2.0	3.5	5
AP502 CL	20.6	31.1	39.2	43.5	71.4	87.6	48.9	58.9	143	29	2.3	2.5	9
CO00796 *	16.6	31.2	42.5	39.7	73.5	89.5	48.8	59.6	146	31	2.0	3.8	8
Ok101	17.1	33.1	37.8	46.6	69.5	88.4	48.8	59.4	143	29	2.0	4.8	8
CO99W277	22.4	34.2	44.2	44.1	63.4	83.1	48.6	60.0	146	30	5.3	2.5	6
CO99W329 *	20.5	32.5	34.3	41.0	67.7	93.5	48.3	59.3	141	28	3.7	3.3	6
CO00579	18.1	30.2	36.0	44.7	69.4	88.7	47.9	58.0	146	27	2.3	3.0	5
CO99W188	24.2	30.9	39.2	36.9	66.8	88.9	47.8	59.0	146	28	5.7	2.5	5
Cisco	22.4	32.5	37.5	48.3	57.2	88.9	47.8	59.2	143	28	3.3	3.5	8
Lakin	13.2	34.1	38.8	48.2	71.0	81.5	47.8	59.2	146	29	2.3	4.0	9
CO00523	16.6	33.6	35.6	46.3	69.8	84.2	47.7	58.1	146	28	2.0	3.8	8
CO00W015	19.0	31.2	39.0	48.3	59.1	89.0	47.6	60.1	144	32	4.7	4.0	9
2137	13.1	30.2	38.0	45.8	71.5	85.7	47.4	59.4	147	28	2.0	4.5	9
CO99141	23.3	30.2	38.2	37.9	59.9	94.3	47.3	60.0	142	27	3.7	3.0	6
Ok102	19.2	30.7	39.8	44.8	64.1	84.7	47.2	59.7	144	27	2.0	3.5	7
CO970547	14.9	32.2	32.4	43.1	71.2	87.2	46.8	59.6	145	29	5.3	4.8	6
Halt	17.8	30.5	33.1	41.7	71.5	85.4	46.7	58.7	144	27	2.0	4.8	8
CO99177	17.2	34.1	30.7	41.4	70.0	86.4	46.6	58.7	144	28	5.0	4.5	5
Jagalene	15.4	26.7	37.9	41.7	67.3	90.6	46.6	60.1	146	28	2.0	6.3	2
Jagger	12.4	30.8	33.4	44.2	62.2	93.2	46.0	59.2	142	29	2.7	5.3	2
CO970547-2	11.5	32.5	29.8	45.9	69.7	86.5	46.0	58.8	146	30	5.0	7.0	7
Kalvesta	14.1	31.4	35.2	40.8	66.0	87.8	45.9	59.2	144	27	2.0	4.8	9
CO00583	13.8	30.8	31.7	41.9	65.2	91.8	45.8	59.4	145	27	2.3	5.3	8
Prowers 99	15.2	31.4	40.2	40.0	62.2	83.3	45.4	60.7	148	33	5.3	4.0	7
G980091-1	10.8	33.0	28.7	39.7	66.5	85.1	44.0	58.9	143	26	2.0	5.8	6
CO00335	9.7	28.3	27.2	36.9	66.2	81.0	41.6	59.8	148	31	4.3	6.8	9
Venango	6.0	29.3	27.9	33.4	68.6	81.2	41.1	58.8	147	28	2.0	7.5	9
Thunderbolt	8.8	28.1	26.5	35.3	61.0	78.0	39.6	60.4	148	28	2.0	6.8	8
Mean	18.7	32.7	39.5	46.2	69.8	90.4	49.6	59.1					
LSD (0.05)	4.7	5.3	3.9	5.2	5.8	8.7							
CV (%)	15.6	9.9	11.3	7.0	5.2	5.9							

† **Key to trait values**: yield – bushels/acre; test weight – pounds/bushel; heading – days from Jan. 1; height – inches; lodging – 1=none to 9=complete; shatter – 1=minimal to 9=severe; stripe rust – 1=resistant to 9=susceptible.

* Line retained for further testing.

As mentioned previously, the trials in 2003 were a drastic improvement over those in 2002. Yield averages ranged from 18.7 bu/a at Walsh to 90.4 bu/a at Akron, with a range of different yield levels in between. While random, non-genetic variability at four locations (Lamar, Sheridan Lake, Genoa, Bennett) prevented reliable data interpretation from those locations, data from the other six locations were sound and of great value for variety selection and recommendation. Based on agronomic, performance, pest resistance, and end-use quality evaluations, the following experimental lines were retained and advanced for further testing:

Entry	Pedigree	Type
CO980607 @§	Yuma/T-57//TAM 200/3/4*Yuma/4/KS91H184/Vista	Hard red wheat
CO00D007 @§	Yumar//TXGH12588-120*4/FS2	*Clearfield*® wheat
CO00016 §	CO940606/TAM107R-2	Hard red wheat
CO00345	T812/Yumar	Hard red wheat
CO00347	T812/Yumar	Hard red wheat
CO00554	TAM 302/Akron//Halt	Hard red wheat
CO00698 §	CO931083/Oro Blanco//Halt	Hard red wheat
CO00739	CO931111/CO910239//Halt	Hard red wheat
CO00796	Transvaal/Arlin/2/CO910424/Halt	Hard red wheat
CO970547-7 §	Ike/Halt	Hard red wheat
CO991057	Akron//TXGH12588-26*4/FS2	*Clearfield*® wheat
CO991132 §	Jagger//TXGH12588-120*4/FS2	*Clearfield*® wheat
CO99W183	KS92WGRC25/Halt	Hard white wheat
CO99W192	KS92WGRC25/Halt	Hard white wheat
CO99W254	CO931029/Halt	Hard white wheat
CO99W329	CO931091/Halt	Hard white wheat

@ Line submitted for evaluation in the 2003-crop Wheat Quality Council (WQC) testing program.

§ Line submitted for evaluation in the 2003-2004 Regional Performance Testing Program (Southern Regional Performance Nursery).

Small-scale seed increases of each of the lines retained for further testing were planted in fall 2003. Seed supply from any of these lines that perform well in 2004 should be adequate to enable Breeder Seed increase in 2004-2005 (for earliest possible release fall 2006). In addition to continued yield testing, extensive milling and baking quality evaluations will be done on these materials during winter 2003-2004 in the CSU Wheat Quality Lab, the USDA-ARS Hard Winter Wheat Quality Lab (Manhattan, KS), and by various private-industry collaborators.

A significant change was made in 2003 to the flow of germplasm through our breeding program. This change involved the establishment of a nursery (called the ***CSU Elite Nursery***) that is intermediate to the Advanced Yield Nursery (AYN) and the first year of line entry into the UVPT. There are several important reasons for this change. First, it had become increasingly difficult to control the size of the UVPT with private entries, experimental lines from our program, and check cultivars all vying for a limited number of spots in the trial. Because of this, we were forced to make very difficult decisions between inclusion of experimental lines from our program and recent cultivar releases from other states. The size of the trial had also led to difficulties in timely planting and harvesting and increased field variability that led to reduced ability to accurately test differences among entries. Second, it had become apparent that the CSU Foundation Seed program was not able to handle risk of non-release of an experimental line that was on Foundation Seed increase. The additional year of yield, quality, and agronomic testing will allow us to have more data to ensure that Foundation Seed increase decisions are

based on sound data. To compensate for the reduced sampling of field environments, we will continue reciprocal evaluation of entries in the CSU Elite Nursery with public counterparts in other states.

As mentioned previously, the Irrigated Variety Trial (IVPT) was planted at three locations in Colorado (Table 2). Excellent separation among entries was observed at all locations, although marginal stands (due to late planting) and stripe rust adversely affected the Ovid trial location. A few hard white (HWW) experimental lines performed quite well in the trials, especially CO99W254 which was at or near the top of the trial at all three locations. While the baking quality of CO99W254 is in question, it is encouraging that we are beginning to identify experimental lines with very high yield potential for irrigated production conditions. Under these conditions, stripe rust may continue to be a concern and so we have begun to focus a bit more on stripe resistance in the crossing program. Good sources of resistance are available in Great Plains germplasm and these sources should prove useful in the absence of a race change that makes them ineffective.

Table 2. Data summary from 2003 Irrigated Variety Performance Trials (IVPT). Entries (with checks in **bold**) are ranked in descending order by average grain yield. †

	Grain Yield				Avg.			
Entry	Fort Collins	Rocky Ford	Ovid	Yield Average	Test Weight	Height	Lodging	Stripe Rust
CO99W254 *	129.4	116.3	102.7	116.2	59.8	35	1.2	2
Jagalene	128.0	116.8	100.6	115.1	57.4	35	1.7	2
CO99141	109.9	108.9	108.3	109.0	57.5	36	4.7	3
Prairie Red	124.7	119.1	81.7	108.5	55.9	36	1.8	8
CO99W183 *	112.0	116.6	96.5	108.4	54.7	36	3.5	5
CO99W329 *	118.3	111.8	94.2	108.1	57.8	37	4.7	4
Wesley	113.1	116.6	91.7	107.1	57.8	34	1.0	2
Yuma	120.2	103.5	97.5	107.1	56.4	41	2.2	4
G980091-1	116.8	106.7	92.4	105.3	58.0	35	3.5	5
Cisco	119.9	101.0	88.3	103.1	57.0	38	3.3	5
CO970547-7 *	105.0	108.9	93.4	102.5	56.6	39	6.0	5
Antelope	107.1	106.5	90.8	101.5	58.3	39	2.2	2
CO980607 *	107.3	108.5	88.3	101.4	57.8	39	4.5	3
Ok101	115.2	107.7	79.8	100.9	56.7	41	2.5	8
CO980630	111.8	109.3	80.9	100.7	56.0	39	3.7	4
G980122	117.4	105.6	78.3	100.4	57.9	37	1.2	6
Dumas	126.4	96.1	78.5	100.3	59.7	36	1.0	6
Platte	121.5	121.8	53.2	98.8	59.3	35	1.0	9
CO99314	116.7	110.2	69.7	98.8	58.4	38	3.5	4
Kalvesta	116.8	101.3	74.7	97.6	58.3	36	2.7	6
2137	121.4	94.9	76.0	97.4	57.5	40	1.2	8
CO99W192 *	101.5	108.4	80.5	96.8	55.0	38	5.2	5
Ok102	113.8	101.0	73.9	96.2	57.8	39	1.0	8
Ankor	109.0	108.5	65.5	94.3	57.7	41	3.2	6
CO970547-2	109.2	97.1	72.9	93.1	57.3	39	5.0	3
CO99W188	99.6	86.0	87.8	91.1	56.9	38	7.2	6
CO99W277	89.8	103.1	79.6	90.8	58.6	37	7.5	5
Venango	116.1	69.9	82.1	89.4	59.8	37	1.3	7
Arrowsmith	86.4	98.6	81.9	89.0	56.2	41	3.7	2
Nuplains	92.7	98.6	51.6	81.0	58.7	36	2.0	8
Mean	112.6	105.3	83.1	100.3	57.6			
LSD (.05)	14.5	13.0	9.4					
CV (%)	7.9	7.6	13.3					

† Key to trait values: yield: bushels/acre; test weight: pounds/bushel; height: inches; lodging: 1=none to 9=complete; stripe rust (Ovid location): 1=resistant to 9=susceptible. * Line retained for further testing.

Advanced Yield Nursery (AYN)

In 2002-2003, the Advanced Yield Nursery was grown in three replications at all five main breeding locations. The AYN was sub-divided into of hard red, hard white, and *Clearfield** wheat groups to manage experimental error. For each subset, check entries were included for comparison. From the AYN, 34 experimental lines were advanced to the 2004 CSU Elite Nursery. Many of these lines were reselections from their respective parent lines made in Yuma, Arizona, the previous year. In addition to continued yield testing, extensive milling and baking quality evaluations will be done on all of these materials during winter 2003-2004 in the CSU Wheat Quality Lab and the USDA-ARS Quality Lab (Manhattan KS). For each of these lines advanced to the CSU Elite Nursery, a headrow increase will be done in Yuma AZ in 2003-2004 for line purification and reselection (where variability within the line persists).

Early-Generation Germplasm Development

In 2002-2003, 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 new experimental lines were planted in seven groups of replication trials at all five main breeding locations. Approximately 63% of these were HRW types while the remainder (37% of the total) were HWW types. Based on grain yield, test weight, agronomic data, RWA Biotype-A resistance, small-scale quality data (on remnant bulk samples and samples tested following harvest in August 2003), 90 of these lines were selected and planted in the 2002-2003 AYN. To facilitate earlier line reselection, a small group of headrow selections made from 80 of these lines will be grown in Yuma AZ in 2003-2004. To complement this group of PYN selections, a group of 64 line reselections (including HRW, HWW, and *Clearfield*™ lines) made in Yuma AZ from advanced lines were included among the lines advanced to the AYN.

2) **F4 Headrows**: Approximately 27,000 headrows were grown at Fort Collins in 2002-2003. From visual observations and pedigree information, and quality information from the remnant bulk in 2002, approximately 1600 of these were harvested in July 2003. Following small-scale quality screening in August (NIR protein, NIR hardness, SDS sedimentation), about 900 lines were selected and advanced to the single replication PYN in fall 2003. Among this group of 900 lines, approximately 75%% are HRW lines and 25% are HWW lines. Many of the HWW lines showed low polyphenol oxidase (PPO) content in the grain (associated with darkening of Asian noodle products) during quality screening in August.

3) **F3 Bulks**: Approximately 315 F3 bulk populations were grown in 2002-2003. The F3 bulk populations were grown under both irrigation at Fort Collins and under dryland conditions at Akron. Based on yield, test weight, and visual observations at both locations, about 40,000 heads were selected from 150 populations for advancement to the F4 headrow nursery in fall 2003. From this group of 40,000, about 30% are HWW types and about 28% are *Clearfield*™ types (both HRW CL and HWW CL). Stringent selection among bulks, both in the conventional and *Clearfield*™ groups, was practiced for agronomic type and test weight prior to advancement.

4) **F2 Bulks**: Approximately 900 F2 bulk populations were grown at Fort Collins in 2002-2003. Of this total, about 130 were populations with *Clearfield*™ wheat parents in the pedigree; these were sprayed with *Beyond*™ herbicide in spring 2003 to selectively eliminate plants lacking the herbicide tolerance trait. About 100 of these F2 populations were obtained from the University of Nebraska Wheat Breeding program, with selection based on pedigree and visual observations of agronomic type in Yuma Arizona in May

Table 3. Grain yield and test weight summary for hard red, hard white, and Clearfield* wheat experimental lines in the 2003 Advanced Yield nursery. Entries are ranked by yield within grouping.

Entry	Walsh	Burlington	Julesburg	Akron	Fort Collins	Dryland Average	Average Test Wt
Hard Red Winter Wheats (HRW)							
CO980607-A1	10.7	46.2	69.5	116.8	101.9	60.8	58.4
CO01385	15.3	48.1	66.7	106.1	93.2	59.0	58.9
CO980630-A1	12.9	54.6	71.0	97.7	93.3	59.0	57.8
Prairie Red	11.6	40.4	65.8	111.1	104.0	57.2	58.4
CO01212	9.5	47.1	70.9	98.5	100.9	56.5	59.9
CO01287	13.9	42.6	68.1	98.9	85.8	55.8	58.9
CO01434	10.8	40.6	68.1	103.9	88.1	55.8	58.6
CO980607-A3	12.6	50.3	64.3	92.5	100.8	54.9	59.1
Ankor	13.9	39.7	65.2	100.9	95.2	54.9	58.2
CO01473	10.9	41.5	60.1	104.2	88.2	54.2	59.1
CO01252	9.7	43.7	70.3	92.8	100.5	54.1	59.4
CO99314-A1	8.0	40.9	68.8	97.1	105.5	53.7	58.1
CO01242	10.0	43.8	70.3	89.9	97.2	53.5	58.2
Jagalene	4.5	38.2	71.1	98.9	104.4	53.2	59.2
CO01245	7.1	33.1	65.6	106.3	104.8	53.0	58.8
CO01433	11.0	41.8	62.4	92.3	74.2	51.9	58.5
TAM 111	11.3	38.8	72.5	78.3	104.3	50.2	59.1
Stanton	11.6	35.2	68.8	83.3	108.6	49.7	59.6
Mean	9.7	39.1	63.1	92.3	95.2	51.0	58.8
CV (%)	26.1	9.2	7.5	12.2	6.8		
Hard White Winter Wheats (HWW)							
CO01W165	18.1	50.6	62.5	98.7	94.3	57.5	58.6
NuFrontier	14.7	53.8	60.8	98.9	79.0	57.0	59.9
Trego	17.5	44.6	64.6	101.2	97.5	56.9	60.6
CO01W014	14.2	46.4	64.7	96.0	98.4	55.3	60.3
CO01W191	12.6	45.6	67.2	94.8	93.2	55.1	58.2
CO01W189	19.0	42.5	68.0	89.0	93.2	54.6	57.5
CO01W173	20.3	44.7	57.2	95.5	83.9	54.4	57.7
CO01W171	20.2	37.4	65.1	95.0	84.6	54.4	58.4
CO01W073	13.5	46.9	61.8	95.3	106.8	54.4	58.4
Avalanche	13.9	43.8	61.6	96.8	91.1	54.0	59.7
Lakin	7.9	47.9	64.5	94.1	101.3	53.6	58.9
CO01W172	16.9	43.5	62.1	90.9	87.8	53.3	59.3
CO01W190	15.3	44.2	60.4	92.0	91.5	53.0	58.8
CO01W097	6.7	36.8	70.6	97.0	101.5	52.8	58.4
Platte	15.1	44.1	63.4	83.0	106.0	51.4	60.3
Mean	13.4	40.0	63.5	91.9	95.6	52.2	58.4
CV (%)	23.1	9.9	6.1	6.1	7.3		
Clearfield* Wheats							
CO991407-A13	13.7	49.2	76.2	89.6	114.1	57.2	59.9
CO991407-A10	13.7	52.6	72.0	82.9	108.9	55.3	60.0
CO991407-A5	14.5	49.7	73.6	81.8	110.2	54.9	60.2
CO991350-A5	15.9	52.9	68.8	81.1	111.1	54.7	59.3
CO991407-A2	14.2	46.1	74.3	84.0	106.8	54.7	60.1
CO991325-8	14.2	49.1	77.0	76.2	111.1	54.1	58.6
CO991132	11.1	47.9	65.7	89.7	117.6	53.6	58.9
CO991407-A3	12.8	45.5	72.5	83.2	106.2	53.5	60.3
CO991057-A4	14.9	48.3	65.7	84.9	105.0	53.5	60.1
CO991407-A9	15.9	50.0	69.1	78.5	107.9	53.4	59.9
CO991057-A1	14.0	46.7	68.0	84.0	98.3	53.2	60.2
CO00D007	19.4	51.1	66.6	74.4	110.3	52.9	59.0
AP502 CL	17.2	41.1	64.5	86.2	118.3	52.3	59.9
Above	16.0	40.3	70.1	76.4	111.8	50.7	59.5
AP401 CL	15.4	34.0	55.8	79.1	90.7	46.1	61.1
Mean	14.2	45.8	68.8	78.9	109.1	51.9	59.5
CV (%)	14.8	8.5	4.5	13.8	4.6		

2003. About 315 populations (including about 59 *Clearfield*™ populations) were advanced to F3 bulk plots in fall 2003. Stringent selection among bulks, both in the conventional and *Clearfield*™ groups, was practiced for agronomic type and test weight prior to advancement.

5) **F1 Increase**: Nearly 700 new crosses were increased in the field in 2003. Two environments were used for F1 seed increase: fall planting at Fort Collins (285 crosses) and spring planting at Fort Collins (408 crosses). Of this group, very few populations developed from crosses with *Clearfield*™ wheats, due to incorporation of the second Clearfield gene into our breeding program.

6) **Crossing**: Over 1600 crosses were made in 2002-2003, split between crossing blocks in fall 2002 and spring 2003. Included among these crosses were three main types of materials: a) crosses targeted toward direct increase, bulk evaluation, and line development (1016 crosses), b) crosses targeted only for backcrossing (183 crosses) or three-way crossing (139 crosses), and c) crosses targeted for marker-assisted backcrossing as part of the USDA-IFAFS grant funded program (304 crosses). Of the group targeted toward direct increase, approximately 85% were single or three-way crosses between elite parents and 15% were three-way and backcrosses developed to broaden genetic diversity and introgress unique germplasm. With regard to HWW vs. HRW emphasis, approximately 35% of all single crosses were made between two HWW parents (will produce only HWW types) while 40% of all single crosses were made between one HRW parent and one HWW parent (will produce mostly HRW types). We will continue to focus on HWW cross development through both single and three-way crossing strategies. Among the total group of crosses, nearly 100 crosses and backcrosses were made with the new source of tolerance to Beyond herbicide.

Research Support Projects and Other Activities

New Russian Wheat Aphid Biotype

In late March through May, 2003, reports were received of severe RWA infestations and plant damage in fields of 'Prairie Red' winter wheat in southeastern Colorado. Infested plants in these fields displayed characteristic susceptible symptoms, raising concern that a new RWA biotype was present. Greenhouse seedling screening experiments with a colony reared from this isolate (provisionally denoted as "Biotype-B") confirmed that it is virulent to all resistant wheat cultivars available in the U.S. hard winter wheat region. These include the *Dn4*-based resistance deployed in several cultivars by CSU and the resistance from PI 220350 deployed by Kansas State University in the cultivar 'Stanton'.

Upon confirmation of the presence of the new biotype, we evaluated a broad collection of resistance sources used in our breeding program. These sources included all previously numbered genes (*Dn1* through *Dn9*) in addition to eight other sources that have not received numbers but had shown promise in evaluations at CSU and elsewhere. With one exception, each of these sources proved to be as susceptible to the new biotype as the *Dn4* sources and Stanton. The lone exception, accession '94M370' from South Africa, showed a very high level of resistance to the new biotype. Unfortunately, the resistance in 94M370 is conferred by the *Dn7* gene that resides on a 1BL.1RS wheat-rye translocation has been associated with serious adverse effects on bread baking quality. We obtained a group of five lines from the USDA-ARS in Stillwater that carry this resistance and we are currently evaluating these in the field for their release potential.

In separate screening experiments, we have also identified effective resistance from two other sources. The first of these is an experimental line from the USDA-ARS in from Stillwater, OK, designated as '2414-11' (derived from PI 366515). The resistance in this source is currently being backcrossed into several elite backgrounds. The second resistance source is a group of

lines from our own program that carry resistance from Triticale accession PI 386148. The resistance in these Triticale-based lines had previously been transferred to a 'Lamar' background, yet we are presently uncertain about the stability of this resistance.

In an attempt to identify additional resistance sources, we recently completed the first evaluation of a collection of 761 wheat accessions from the National Plant Germplasm System (NPGS). The accessions that we chose to evaluate showed a similar level of resistance to the original RWA biotype as the resistant cultivar 'Halt' in systematic germplasm evaluations conducted by the USDA-ARS in Stillwater, OK, in the 1990s. From the group of 761 accessions we have identified a group of 68 accessions that show promise for a replicated follow-up evaluation planned for spring 2004. Only eight of these accessions, however, showed a level of resistance similar to the resistant check 94M370. Four of these are from Afghanistan (PI 135064, PI 366566, PI 366572, PI 366589), two are from Iran (PI 140204, PI 429398), is from Kazakhstan (PI 572652), and one is from Tajikistan (CI 2401). Initial crosses have now been made with each of these resistance sources.

With very few resistance sources currently available, additional germplasm screening is needed. We recently began the evaluation of a group of 7,000 Iranian landrace selections that are relatively new additions to the National Plant Germplasm System (NPGS). These accessions have been evaluated by other researchers (e.g., CIMMYT, Univ. California-Davis) for RWA and other agronomic characteristics but have not been evaluated for resistance to the new RWA biotype present in Colorado. As many of the resistant accessions from the original screenings by the USDA-ARS originated from Iran we expect that this collection will contain at least some resistant accessions.

Our resistance breeding strategy will emphasize the most rapid deployment of resistance possible in a new cultivar. An overriding objective of this effort will be the maintenance of a broad diversity of resistance sources to hopefully be better prepared in the event that additional biotypes are identified.

Graduate Student Research

Several graduate student research projects are currently underway or were completed in 2002-2003. While we expect that these research projects will contribute vital information to direct breeding efforts, both the breeding project and the students benefit in many other ways though student involvement in the overall breeding program. Briefly, these include the following important areas of research:

- evaluation of environment and genotype x environment interaction effects on Asian noodle quality characteristics (Aaron Brown)
- assessment of the breeding potential of gibberellic acid sensitive semidwarfing genes that do not reduce coleoptile length (Sally Clayshulte)
- development of geographic information systems (GIS) technology to improve variety recommendations and identify variety-specific production and quality zones (Federico Pardina-Malbrán)
- identification of RWA Biotype-B resistance sources and characterization of field protection provided by the *Dn7* RWA resistance gene (Meghan Collins)
- characterization (inheritance, allelism, marker-tagging) of Biotype-B RWA resistance sources (Joshua Butler)

USDA-IFAFS Project

We continue to work on backcrossing novel genes into our germplasm base through the multi-institutional grant effort funded by the USDA-IFAFS grant funding agency. The focus of this grant, entitled “Bringing Genomics to the Wheat Fields”, is to utilize DNA marker technology

as a means to transfer desirable quality and pest resistance traits into released varieties and elite experimental lines. Our program at CSU is one of 12 public plant breeding programs involved in this effort, with Dr. Nora Lapitan serving as co-investigator in our effort at CSU. When the program began two years ago, we chose recently released varieties or advanced experimental lines (e.g., Avalanche, Above, Ankor, CO970547, Stanton, and Lakin) as target parents to transfer or combine genes for wheat streak mosaic virus and barley yellow dwarf virus tolerance (from wheatgrass), high grain protein content (from wild durum wheats), and RWA resistance. We have complete three cycles of marker assisted selection and are nearing the stage when improved populations will be grown in the field. Due to the identification of the new RWA biotype, we abandoned our efforts on transfer of the Dn2 and Dn4 resistance genes to different backgrounds. As a replacement for this project, we have begun the marker-based transfer of the Yr5 and Yr15 stripe rust resistance genes into multiple backgrounds. Continued funding for this project past 2005 will depend on the success of a grant initiative to develop a national effort in marker assisted selection in wheat. Coordination of this effort is again through the University of California-Davis.

Germplasm Introduction

In 2002-2003, we continued our long-term effort to systematically explore wheat germplasm from CIMMYT (in Mexico) and eastern European countries. The objective of this effort is to broaden the genetic diversity in our program in order to insure long-term genetic improvement primarily for yield under irrigated conditions and for stress tolerance under dryland conditions. Our strategy for using these sources is to evaluate them under field conditions in Colorado and then select among the larger group for the most promising sources for introgression. The crossing strategy that we are currently using is what we would call a "focused backcrossing" approach where two or three backcrosses are made with one or two of our elite backgrounds and segregating progenies are identified in field nurseries. We are hopeful that we will identify recombinants that maintain the desirable characteristics of our recurrent parents while transferring in desirable genes from the wheat germplasm sources.

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