Technical Report Wheat Field Days Edition- 2014

Agricultural Experiment Station

Colorado State University

College of Agricultural Sciences | Department of Soil & Crop Sciences | Extension

Crops Testing

Making Better Decisions

2013 Colorado Winter Wheat Variety Performance Trials

Table of Contents

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2013 Eastern Colorado Winter Wheat Variety Performance Trials

Jerry Johnson and Scott Haley

The Colorado State University Crops Testing and Wheat Breeding and Genetics programs provide current, reliable, and unbiased wheat variety information as quickly as possible to Colorado producers for making better variety decisions. CSU has an excellent research faculty and staff, a focused breeding program, graduate and undergraduate students, and dedicated agricultural extension specialists. Wheat improvement in Colorado would not be possible without the support and cooperation of the entire Colorado wheat industry. On-going and strong producer support for our programs is critical for sustained public variety development and testing.

Our wheat variety performance trials and Collaborative On-Farm Test (COFT) represent the final stages of a wheat breeding program where promising and newly released experimental lines are tested under an increasingly broad range of environmental conditions. As a consequence of large environmental variation in our region, Colorado State University annually conducts a large number of performance trials and on-farm tests. These trials serve to guide producer variety decisions and to assist our breeding program to more reliably select and advance the most promising lines toward release as new varieties.

There were 40 entries in the dryland performance trials (UVPT) and 28 entries in the irrigated performance trials (IVPT). All trials included a combination of public and private varieties and experimental lines from Colorado, Texas, Kansas, Oklahoma, Nebraska, and Montana. All dryland and irrigated trials were planted in a randomized complete block design with three replicates. Plot sizes were approximately 175 ft^2 (except the Fort Collins IVPT, which was 60 ft^2) and all varieties were planted at 700,000 viable seeds per acre for dryland trials and 1.2 million viable seeds per acre for irrigated trials. Yields were corrected to 12% moisture. Test weight information was obtained from an air blower-cleaned sample of the first replication or from a combine equipped with a Harvest Master measuring system.

2013 Dryland Variety Performance Trials

Without a doubt, 2013 will go down in the books as one of the toughest years in history for winter wheat in eastern Colorado. As a result of an extremely dry spring and summer 2012, very dry planting conditions were experienced at most trial locations at planting time in fall 2012. In spite of extremely dry conditions, decent plant stands were achieved at several sites, in some cases due to timely rains that came after the trials had been “dusted in”. One trial location, Roggen, crusted in the fall due to rain after being “dusted in” and a new field location was replanted in early October. Unfortunately, incomplete or extremely variable plant stands at the Lamar, Arapahoe, and Genoa dryland trial locations led to abandonment of these trials.

Drought conditions persisted throughout the winter, most critically in southeast Colorado. In many areas of southeast Colorado, lack of precipitation coupled with very short subsoil moisture, led to complete stand loss as the crop came out of the winter. The dryland trial location at Sheridan Lake (Brandon) had decent stands in the fall (after being “dusted in”) but was abandoned in early spring due to complete death of the plants from extreme drought.

By early spring, dryland trials and the crop in many areas of northeast Colorado looked extremely good with high yield potentials. Subsoil moisture was not plentiful, yet expectations for above-average wheat yields were high. Unfortunately, the crop in many areas, including the trials at five of the seven remaining dryland locations in northeast Colorado (Akron, Julesburg, Orchard, Roggen, and Yuma), received inadequate precipitation to meet these expectations. While these five trial locations were successfully harvested, average trial yields were at least 50% less than visual estimates made during site visits in late April and early May. The remaining two dryland trials, Walsh and Burlington, also suffered from continued drought throughout the spring and although they were successfully harvested, the trial yields were extremely low. Very little or no hail affected the trials, with the exception of a light hail at Akron (estimated 10% damage) a week prior to harvest.

While 2012 and 2013 will both be remembered as “drought years”, the patterns of the stresses and the temperature regimes experienced were markedly different. First, the 2012 crop emerged extremely well with good fall moisture conditions whereas the 2013 crop had a tough time moisture-wise from the start, hindering good fall root development. Second, warm temperatures in spring 2012 resulted in accelerated plant development and a crop that was 2-3 weeks early whereas in 2013 cool temperatures in early spring resulted in much delayed plant development and jointing that was roughly 2-3 weeks later than “average” (and thus three to four weeks later than in 2012). Interestingly, the wheat showed a remarkable ability to “catch up” (responding to the high temperatures in mid- and late-May), as heading dates recorded at the Fort Collins and Akron trial locations were right on the long-term average for these locations. Finally, several severe spring freezes occurred from March through May that damaged the 2013 crop. Although plant development was behind normal, it was far enough along in southeast Colorado to result in severe damage to the growing points of the plants, especially for wheat under irrigation. From east-central to northeast Colorado, due to delayed plant development, the growing point was still at or below ground when the freezes occurred and thus damage was restricted to burning off of the above-ground foliage, which undoubtedly reduced yields.

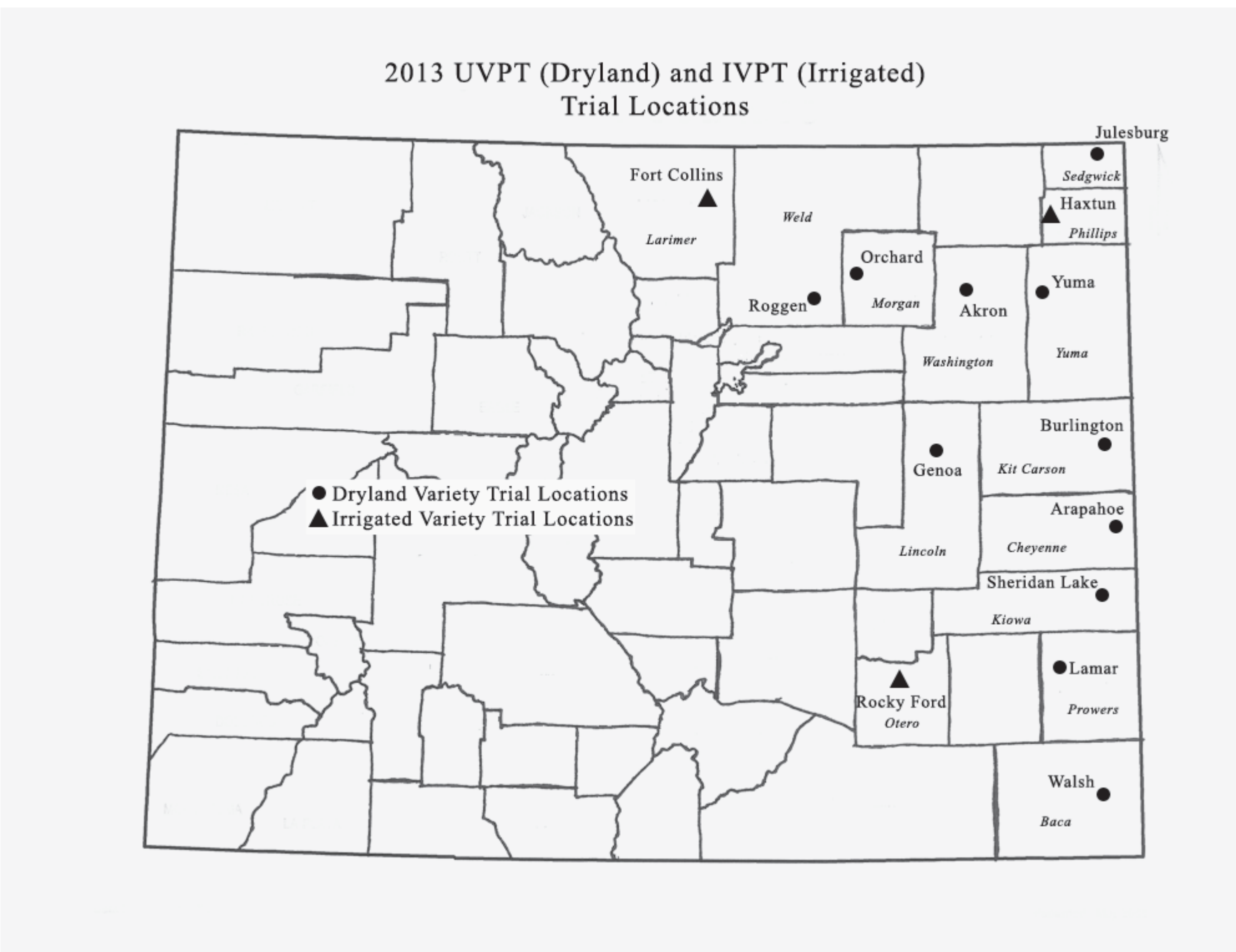
In 2013, there was a general lack of foliar disease pressure due to the drought conditions. Isolated leaf and stripe rust was observed only at the irrigated trial location at Fort Collins. With the prolonged drought, root rot symptoms were observed at several trial locations, though perhaps not as severe as in 2012. As has become common in eastern Colorado, dry conditions in early spring favored severe brown wheat mite infestations as the wheat came out of the winter. Russian wheat aphid and bird cherry-oat aphids were observed at several locations and isolated wheat streak mosaic virus and barley yellow dwarf observations were recorded.

<u>2013 Irrigated Variety Performance Trials</u>

The Irrigated Variety Performance Trials (IVPT) also experienced a mixed bag of conditions. The worst of these occurred at Rocky Ford where severe brown wheat mite infestation, prior crop herbicide damage, and perennial weed infestation led to abandonment of the trial.

At Fort Collins, good stand emergence was achieved but a very dry fall and winter led to significant drought stress by late winter. While nearly four feet of snow came in late March to early April to save the trial, inadequate irrigation and very warm temperatures throughout June limited yields (trial average 73 bu/ac). No disease pressure was observed at Fort Collins, but light Russian wheat aphid pressure was observed. The freeze events, particularly the one in early April, damaged the above-ground foliage, although the growing points were not damaged.

Due to excellent management, very high yields (trial average 118 bu/ac) were again achieved at the location near Haxtun, as has become common for this location. Significant lodging was observed in some entries in the first replication of the trial, but foliar diseases were completely lacking, due to lack of inoculum and timely fungicide application.



Summary of 2013 Dryland Variety Performance Results

Brand/Source	Variety[a]	Market Class[b]	Yield[c]	Yield	Test Weight[c]	Plant Height[c]
			bu/ac	% trial average	lb/bu	in
PlainsGold	Antero	**HWW**	27.5	114%	56.3	22
PlainsGold	Byrd	HRW	27.1	113%	55.3	23
Limagrain	LCS Mint	HRW	26.7	111%	57.9	24
PlainsGold	Brawl CL Plus	HRW	26.0	108%	56.2	23
Husker Genetics	Settler CL	HRW	26.0	108%	54.6	21
KS Wheat Alliance	Oakley CL	HRW	25.8	107%	56.6	22
CO State Univ. exp.	CO07W722-F5	**HWW**	25.7	107%	54.7	20
Oklahoma Genetics	Iba	HRW	25.4	105%	56.6	21
Watley Seed	TAM 112	HRW	25.3	105%	55.8	22
WestBred Monsanto	Winterhawk	HRW	25.3	105%	57.3	23
WestBred Monsanto	WB-Grainfield	HRW	25.1	104%	54.7	23
PlainsGold	Denali	HRW	25.0	104%	56.9	23
Limagrain	T154	HRW	25.0	104%	55.6	20
PlainsGold	Ripper	HRW	25.0	104%	54.4	22
Limagrain	T158	HRW	24.9	103%	55.0	21
CO State Univ. exp.	CO08W218	**HWW**	24.8	103%	56.7	22
KS Wheat Alliance	Clara CL	**HWW**	24.7	103%	56.9	23
PlainsGold	Above	HRW	24.7	103%	54.5	21
CO State Univ. exp.	CO05W111	**HWW**	24.5	102%	56.8	22
CO State Univ. exp.	CO08346	HRW	24.4	101%	57.3	21
Limagrain	T153	HRW	24.2	100%	54.8	20
PlainsGold	Bill Brown	HRW	24.1	100%	54.8	22
AgriPro Syngenta	TAM 111	HRW	24.1	100%	55.7	22
Husker Genetics	Robidoux	HRW	24.0	100%	55.3	22
Limagrain	T163	HRW	24.0	100%	56.1	22
AgriPro Syngenta	SY Wolf	HRW	23.8	99%	57.0	22
Oklahoma Genetics	Gallagher	HRW	23.7	98%	55.7	22
AGSECO	TAM 113	HRW	23.3	97%	55.7	21
Limagrain	LCS Wizard	HRW	23.3	97%	55.0	20
Nebraska exp.	NI08708	HRW	23.0	95%	55.8	22
KS Wheat Alliance	1863	HRW	22.7	94%	56.4	21
PlainsGold	Hatcher	HRW	22.5	94%	56.0	21
PlainsGold	Bond CL	HRW	22.3	93%	53.2	22
Husker Genetics	Freeman	HRW	22.1	92%	54.3	22
Nebraska exp.	NE05496	HRW	22.1	92%	56.0	21
Husker Genetics	McGill	HRW	22.1	92%	54.6	23
AGSECO	Protection	HRW	21.8	91%	53.4	24
CO State Univ. exp.	CO08263	HRW	21.2	88%	54.6	19
PlainsGold	Snowmass	**HWW**	20.5	85%	53.9	23
Montana State Univ.	Bearpaw	HRW	19.4	81%	56.2	19
		Average	**24.1**		**55.6**	**22**

[a]Varieties ranked according to average yield in 2013.

[b]Market class: HRW=hard red winter wheat; **HWW**=hard white winter wheat.

[c]The 2013 average yield, test weight, and plant heights are based on seven 2013 trials.

Summary of 2-Year (2012-2013) Dryland Variety Performance Results

			2-Year Average[c]			
Brand/Source	Variety[a]	Market Class[b]	Yield	Yield	Test Weight	Plant Height
			bu/ac	% trial average	lb/bu	in
PlainsGold	Byrd	HRW	42.8	112%	58.9	26
PlainsGold	Antero	**HWW**	42.7	112%	59.6	26
CO State Univ. exp.	CO07W722-F5	**HWW**	40.8	107%	58.4	23
Watley Seed	TAM 112	HRW	40.1	105%	59.5	25
PlainsGold	Brawl CL Plus	HRW	40.0	105%	59.8	26
PlainsGold	Ripper	HRW	39.6	104%	57.9	25
CO State Univ. exp.	CO08W218	**HWW**	39.5	104%	60.1	25
Limagrain	T158	HRW	38.9	102%	59.0	25
AGSECO	TAM 113	HRW	38.8	102%	59.4	25
Husker Genetics	Settler CL	HRW	38.6	101%	58.6	24
PlainsGold	Denali	HRW	38.4	101%	60.0	26
WestBred Monsanto	Winterhawk	HRW	38.4	101%	60.1	26
PlainsGold	Above	HRW	38.4	100%	58.2	24
CO State Univ. exp.	CO08263	HRW	38.3	100%	58.4	23
AgriPro Syngenta	TAM 111	HRW	38.2	100%	59.1	26
AgriPro Syngenta	SY Wolf	HRW	38.1	100%	59.8	26
CO State Univ. exp.	CO05W111	**HWW**	38.0	100%	59.5	26
Limagrain	T163	HRW	37.8	99%	59.6	26
PlainsGold	Bill Brown	HRW	37.6	98%	59.2	24
Husker Genetics	Robidoux	HRW	37.5	98%	58.9	25
CO State Univ. exp.	CO08346	HRW	37.5	98%	60.5	24
PlainsGold	Hatcher	HRW	37.0	97%	59.1	24
AGSECO	Protection	HRW	36.9	97%	57.0	27
KS Wheat Alliance	Clara CL	**HWW**	36.7	96%	60.4	25
KS Wheat Alliance	1863	HRW	35.9	94%	58.9	24
PlainsGold	Bond CL	HRW	35.8	94%	56.4	26
Husker Genetics	McGill	HRW	35.4	93%	58.2	27
Nebraska exp.	NE05496	HRW	35.3	92%	58.9	24
PlainsGold	Snowmass	**HWW**	34.7	91%	58.2	26
		Average	**38.2**		**59.0**	**25**

[a]Varieties ranked according to average 2-year yield.

[b]Market class: HRW=hard red winter wheat; **HWW**=hard white winter wheat.

[c]The 2-year average yield, test weight, and plant height are based on nine 2012 trials and seven 2013 trials.

Summary of 3-Year (2011-2013) Dryland Variety Performance Results

Brand/Source	Variety[a]	Market Class[b]	3-Year Average[c] Yield	Yield	Test Weight	Plant Height
			bu/ac	% trial average	lb/bu	in
PlainsGold	Byrd	HRW	46.4	112%	59.0	27
PlainsGold	Antero	**HWW**	46.0	111%	59.6	26
Watley Seed	TAM 112	HRW	42.9	103%	59.7	26
PlainsGold	Ripper	HRW	42.6	103%	58.0	25
PlainsGold	Denali	HRW	42.2	102%	59.8	27
Husker Genetics	Settler CL	HRW	41.8	101%	58.6	25
PlainsGold	Brawl CL Plus	HRW	41.6	100%	59.6	27
PlainsGold	Above	HRW	41.5	100%	58.2	25
PlainsGold	Hatcher	HRW	41.3	99%	59.1	25
PlainsGold	Bill Brown	HRW	41.2	99%	59.3	25
WestBred Monsanto	Winterhawk	HRW	41.1	99%	59.9	27
AgriPro Syngenta	SY Wolf	HRW	41.1	99%	59.4	26
CO State Univ. exp.	CO05W111	**HWW**	41.0	99%	59.2	27
Limagrain	T163	HRW	40.7	98%	59.2	26
Husker Genetics	Robidoux	HRW	39.9	96%	58.9	26
PlainsGold	Snowmass	**HWW**	39.0	94%	58.3	27
PlainsGold	Bond CL	HRW	38.7	93%	56.7	27
Husker Genetics	McGill	HRW	38.2	92%	58.2	27
		Average	**41.5**		**58.9**	**26**

[a]Varieties ranked according to average 3-year yield.

[b]Market class: HRW=hard red winter wheat; **HWW**=hard white winter wheat.

[c]The 3-year average yield, test weight, and plant height are based on six 2011 trials, nine 2012 trials, and seven 2013 trials.

Summary of 2013 Northeast Colorado Dryland Variety Performance Results

Brand/Source	Variety[a]	Market Class[b]	Yield[c]	Yield	Test Weight[c]	Plant Height[c]
			bu/ac	% trial average	lb/bu	in
PlainsGold	Antero	**HWW**	28.9	114%	56.3	22
PlainsGold	Byrd	HRW	28.4	112%	55.3	23
PlainsGold	Brawl CL Plus	HRW	27.5	108%	56.2	23
Limagrain	LCS Mint	HRW	27.3	107%	57.9	24
CO State Univ. exp.	CO07W722-F5	**HWW**	27.1	107%	54.7	20
Husker Genetics	Settler CL	HRW	26.9	106%	54.6	21
KS Wheat Alliance	Oakley CL	HRW	26.8	105%	56.6	22
WestBred Monsanto	Winterhawk	HRW	26.8	105%	57.3	23
PlainsGold	Denali	HRW	26.8	105%	56.9	23
Watley Seed	TAM 112	HRW	26.7	105%	55.8	22
Oklahoma Genetics	Iba	HRW	26.7	105%	56.6	21
Limagrain	T154	HRW	26.5	104%	55.6	20
Limagrain	T158	HRW	26.5	104%	55.0	21
PlainsGold	Ripper	HRW	26.5	104%	54.4	22
WestBred Monsanto	WB-Grainfield	HRW	26.2	103%	54.7	23
Limagrain	T153	HRW	26.0	102%	54.8	20
PlainsGold	Above	HRW	26.0	102%	54.5	21
Limagrain	T163	HRW	25.9	102%	56.1	22
AgriPro Syngenta	TAM 111	HRW	25.8	102%	55.7	22
CO State Univ. exp.	CO08346	HRW	25.8	101%	57.3	21
CO State Univ. exp.	CO05W111	**HWW**	25.7	101%	56.8	22
CO State Univ. exp.	CO08W218	**HWW**	25.6	100%	56.7	22
KS Wheat Alliance	Clara CL	**HWW**	25.5	100%	56.9	23
PlainsGold	Bill Brown	HRW	25.4	100%	54.8	22
Oklahoma Genetics	Gallagher	HRW	25.1	99%	55.7	22
Husker Genetics	Robidoux	HRW	25.1	99%	55.3	22
AgriPro Syngenta	SY Wolf	HRW	25.1	99%	57.0	22
AGSECO	Protection	HRW	24.7	97%	53.4	24
AGSECO	TAM 113	HRW	24.6	97%	55.7	21
Limagrain	LCS Wizard	HRW	24.5	96%	55.0	20
PlainsGold	Hatcher	HRW	24.4	96%	56.0	21
Nebraska exp.	NI08708	HRW	24.3	95%	55.8	22
PlainsGold	Bond CL	HRW	24.1	94%	53.2	22
KS Wheat Alliance	1863	HRW	23.9	94%	56.4	21
Husker Genetics	McGill	HRW	23.4	92%	54.6	23
Husker Genetics	Freeman	HRW	23.3	92%	54.3	22
Nebraska exp.	NE05496	HRW	23.2	91%	56.0	21
CO State Univ. exp.	CO08263	HRW	22.3	88%	54.6	19
PlainsGold	Snowmass	**HWW**	22.2	87%	53.9	23
Montana State Univ.	Bearpaw	HRW	20.6	81%	56.2	19
		Average	**25.5**		**55.6**	**22**

[a]Varieties ranked according to average yield in 2013.

[b]Market class: HRW=hard red winter wheat; **HWW**=hard white winter wheat.

[c]The average yield, test weight, and plant heights are based on six trials in 2013 in northeast Colorado (north of I-70).

Summary of 2-Year (2012-2013) Northeast Colorado Dryland Variety Performance Results

			2-Year Average[c]			
Brand/Source	Variety[a]	Market Class[b]	Yield	Yield	Test Weight	Plant Height
			bu/ac	% trial average	lb/bu	in
PlainsGold	Antero	**HWW**	45.8	113%	59.0	26
PlainsGold	Byrd	HRW	44.0	109%	58.4	26
CO State Univ. exp.	CO07W722-F5	**HWW**	43.2	106%	57.8	23
PlainsGold	Brawl CL Plus	HRW	42.8	106%	59.3	26
Watley Seed	TAM 112	HRW	42.4	105%	58.9	25
CO State Univ. exp.	CO08W218	**HWW**	41.8	103%	59.7	25
Limagrain	T158	HRW	41.7	103%	58.5	24
PlainsGold	Ripper	HRW	41.5	102%	57.4	25
PlainsGold	Denali	HRW	41.4	102%	59.6	26
AGSECO	TAM 113	HRW	41.1	101%	58.8	25
Husker Genetics	Settler CL	HRW	41.0	101%	58.0	24
AgriPro Syngenta	SY Wolf	HRW	40.9	101%	59.5	25
PlainsGold	Above	HRW	40.9	101%	57.5	24
WestBred Monsanto	Winterhawk	HRW	40.9	101%	59.7	26
AgriPro Syngenta	TAM 111	HRW	40.9	101%	58.6	26
CO State Univ. exp.	CO05W111	**HWW**	40.4	100%	59.2	26
AGSECO	Protection	HRW	40.3	99%	56.6	27
Limagrain	T163	HRW	40.0	99%	59.1	25
PlainsGold	Bill Brown	HRW	39.8	98%	58.5	25
CO State Univ. exp.	CO08263	HRW	39.7	98%	57.7	23
CO State Univ. exp.	CO08346	HRW	39.5	98%	60.1	24
Husker Genetics	Robidoux	HRW	39.4	97%	58.4	25
PlainsGold	Hatcher	HRW	38.9	96%	58.7	24
KS Wheat Alliance	Clara CL	**HWW**	38.7	95%	59.8	26
KS Wheat Alliance	1863	HRW	38.5	95%	58.8	24
Husker Genetics	McGill	HRW	38.3	94%	57.7	26
PlainsGold	Bond CL	HRW	38.2	94%	55.8	26
Nebraska exp.	NE05496	HRW	37.5	92%	58.6	24
PlainsGold	Snowmass	**HWW**	36.4	90%	57.6	26
		Average	**40.5**		**58.5**	**25**

[a]Varieties ranked according to average 2-year yield.

[b]Market class: HRW=hard red winter wheat; **HWW**=hard white winter wheat.

[c]The average yield, test weight, and plant heights are based on six 2013 trials and six 2012 trials in northeast Colorado (north of I-70).

Summary of 3-Year (2011-2013) Northeast Colorado Dryland Variety Performance Results

			3-Year Average[c]			
Brand/Source	Variety[a]	Market Class[b]	Yield	Yield	Test Weight	Plant Height
			bu/ac	% trial average	lb/bu	in
PlainsGold	Antero	**HWW**	48.2	111%	59.0	27
PlainsGold	Byrd	HRW	47.7	110%	58.6	27
Watley Seed	TAM 112	HRW	44.8	103%	59.2	26
PlainsGold	Denali	HRW	44.4	102%	59.3	28
PlainsGold	Ripper	HRW	44.2	102%	57.4	25
AgriPro Syngenta	SY Wolf	HRW	44.1	102%	59.2	26
PlainsGold	Brawl CL Plus	HRW	44.1	102%	59.0	27
Husker Genetics	Settler CL	HRW	43.7	101%	58.0	25
PlainsGold	Above	HRW	43.3	100%	57.5	25
WestBred Monsanto	Winterhawk	HRW	43.3	100%	59.5	27
CO State Univ. exp.	CO05W111	**HWW**	42.8	99%	58.9	27
PlainsGold	Bill Brown	HRW	42.7	99%	58.6	25
Limagrain	T163	HRW	42.7	98%	58.6	26
PlainsGold	Hatcher	HRW	42.5	98%	58.6	25
Husker Genetics	Robidoux	HRW	41.5	96%	58.3	26
PlainsGold	Bond CL	HRW	40.5	93%	56.1	27
Husker Genetics	McGill	HRW	40.3	93%	57.8	27
PlainsGold	Snowmass	**HWW**	40.1	92%	57.7	27
		Average	**43.4**		**58.4**	**26**

[a]Varieties ranked according to average 3-year yield.

[b]Market class: HRW=hard red winter wheat; **HWW**=hard white winter wheat.

[c]The average yield, test weight, and plant heights are based on six 2013 trials, six 2012 trials, and four 2011 trials in northeast Colorado (north of I-70).

Summary of 2-Year (2012-2013) Southeast Colorado Dryland Variety Performance Results

			2-Year Average[c]			
Brand/Source	Variety[a]	Market Class[b]	Yield	Yield	Test Weight	Plant Height
			bu/ac	% trial average	lb/bu	in
PlainsGold	Byrd	HRW	39.0	125%	61.5	26
CO State Univ. exp.	CO08263	HRW	34.2	110%	62.1	23
PlainsGold	Ripper	HRW	34.1	109%	60.7	25
CO State Univ. exp.	CO07W722-F5	**HWW**	33.8	108%	61.5	22
PlainsGold	Antero	**HWW**	33.4	107%	63.0	25
Watley Seed	TAM 112	HRW	33.0	106%	62.6	25
CO State Univ. exp.	CO08W218	**HWW**	32.7	105%	62.4	22
AGSECO	TAM 113	HRW	32.0	103%	62.8	26
Husker Genetics	Robidoux	HRW	31.9	102%	61.9	26
PlainsGold	Brawl CL Plus	HRW	31.6	101%	62.8	24
CO State Univ. exp.	CO08346	HRW	31.3	100%	62.8	24
Limagrain	T163	HRW	31.3	100%	62.5	28
Husker Genetics	Settler CL	HRW	31.3	100%	62.3	24
PlainsGold	Hatcher	HRW	31.3	100%	61.7	22
PlainsGold	Bill Brown	HRW	31.0	100%	63.0	21
WestBred Monsanto	Winterhawk	HRW	31.0	100%	62.4	28
CO State Univ. exp.	CO05W111	**HWW**	30.9	99%	61.2	23
PlainsGold	Above	HRW	30.8	99%	61.8	25
KS Wheat Alliance	Clara CL	**HWW**	30.7	99%	63.2	24
Limagrain	T158	HRW	30.4	98%	61.8	30
AgriPro Syngenta	TAM 111	HRW	30.1	97%	62.1	29
PlainsGold	Snowmass	**HWW**	29.7	95%	61.5	27
PlainsGold	Denali	HRW	29.7	95%	62.4	24
AgriPro Syngenta	SY Wolf	HRW	29.4	94%	61.3	27
Nebraska exp.	NE05496	HRW	28.8	92%	60.9	21
PlainsGold	Bond CL	HRW	28.7	92%	59.5	24
KS Wheat Alliance	1863	HRW	28.2	90%	59.3	29
Husker Genetics	McGill	HRW	27.0	87%	60.8	29
AGSECO	Protection	HRW	26.7	86%	59.5	26
		Average	**31.2**		**61.8**	**25**

[a]Varieties ranked according to average 2-year yield.

[b]Market class: HRW=hard red winter wheat; **HWW**=hard white winter wheat.

[c]The 2-year average yield, test weight, and plant height are based on three 2012 trials and one 2013 trial in southeast Colorado (south of I-70).

Summary of 3-Year (2011-2013) Southeast Colorado Dryland Variety Performance Results

Brand/Source	Variety[a]	Market Class[b]	3-Year Average[c] Yield	Yield	Test Weight	Plant Height
			bu/ac	% trial average	lb/bu	in
PlainsGold	Byrd	HRW	42.9	117%	60.8	26
PlainsGold	Antero	**HWW**	40.2	110%	61.8	25
PlainsGold	Ripper	HRW	38.6	106%	60.0	24
PlainsGold	Hatcher	HRW	37.9	104%	61.0	22
Watley Seed	TAM 112	HRW	37.8	104%	61.4	25
PlainsGold	Bill Brown	HRW	37.2	102%	61.6	21
Husker Genetics	Settler CL	HRW	36.8	101%	60.8	23
PlainsGold	Above	HRW	36.4	100%	60.6	24
PlainsGold	Denali	HRW	36.3	100%	61.6	24
CO State Univ. exp.	CO05W111	**HWW**	36.2	99%	60.6	23
PlainsGold	Snowmass	**HWW**	35.9	98%	60.5	26
Husker Genetics	Robidoux	HRW	35.6	97%	61.0	25
WestBred Monsanto	Winterhawk	HRW	35.3	97%	61.4	27
Limagrain	T163	HRW	35.3	97%	61.2	26
PlainsGold	Brawl CL Plus	HRW	35.0	96%	61.8	24
PlainsGold	Bond CL	HRW	33.8	93%	59.0	24
AgriPro Syngenta	SY Wolf	HRW	33.2	91%	60.2	25
Husker Genetics	McGill	HRW	32.5	89%	59.6	28
		Average	**36.5**		**60.8**	**24**

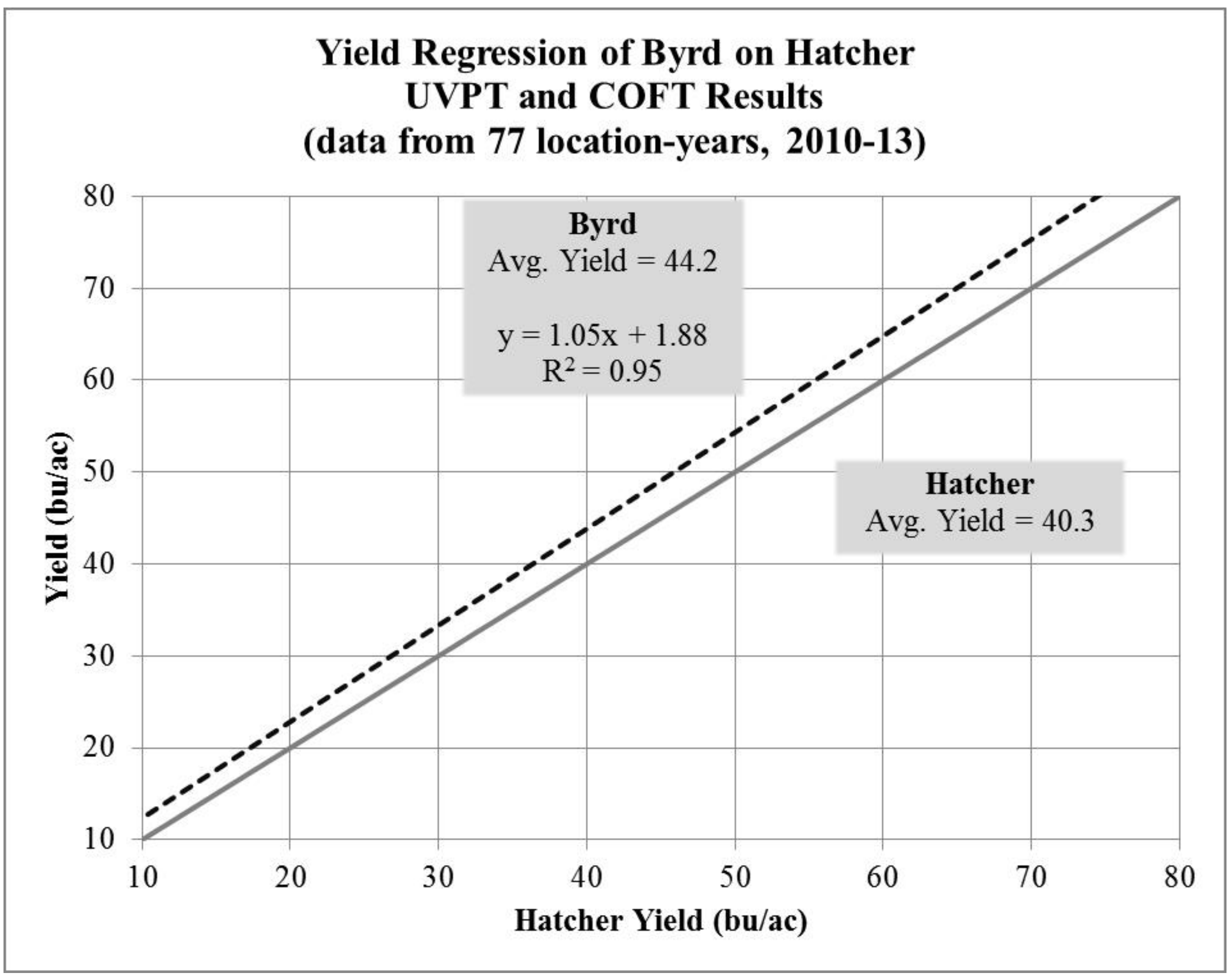
[a]Varieties ranked according to average 3-year yield.

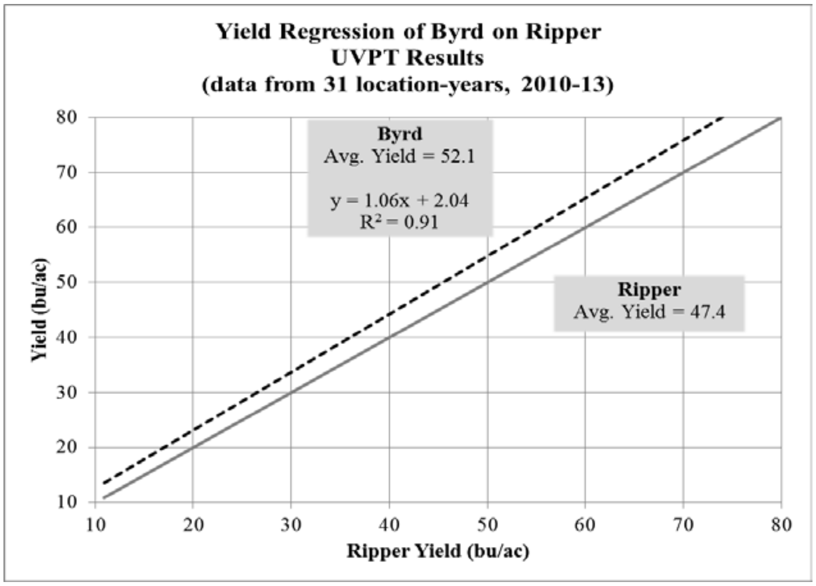
[b]Market class: HRW=hard red winter wheat; **HWW**=hard white winter wheat.

[c]The 3-year average yield, test weight, and plant height are based on two 2011 trials, three 2012 trials, and one 2013 trial in southeast Colorado (south of I-70).

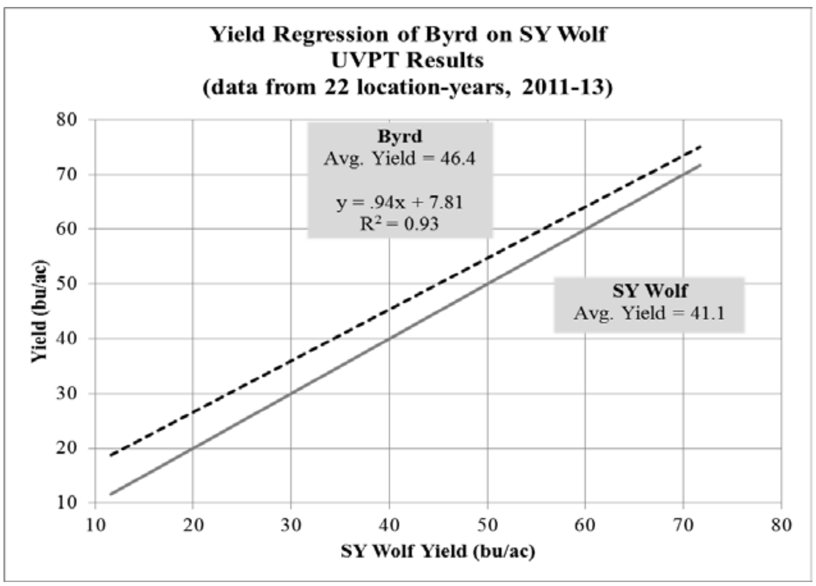
Yield Regressions to Compare Expected Performance of Varieties

The following linear regressions are based on multiple Dryland Variety Performance Trials and Collaborative On-Farm Test results from 2008 through 2013. They can be used as a tool to help growers visualize the expected performance of each variety in low-to-high yielding environments. If the lines do not cross over one another, this means the yield of one variety would be expected to be consistently higher or lower than the yield of the other variety over all yield environments. Farmers can predict the yield of Byrd given the yield of Hatcher, which is shown on the first regression. The second regression can be used to predict the yield of Byrd given the yield of Ripper. The equation shown in each graph can be used to predict the expected yield of a variety, given a yield of the variety listed on the bottom (x-axis) of the graph. For example, in the first regression, the expected yield of Byrd = 1.05 *(yield of Hatcher) + 1.88 bu/ac. If the yield of Hatcher is 50 bu/ac then you would expect the yield of Byrd to be 54.4 bu/ac. The R-squared value of the regression is a statistical measure that represents how well a regression line fits the actual data points. R-squared values equal to 1.0 means the regression line fits the data perfectly. It is important to point out that the comparisons are expected to be more reliable when they include more results over multiple locations from different years. Additional testing of varieties might change the relationships portrayed in the following graphs.

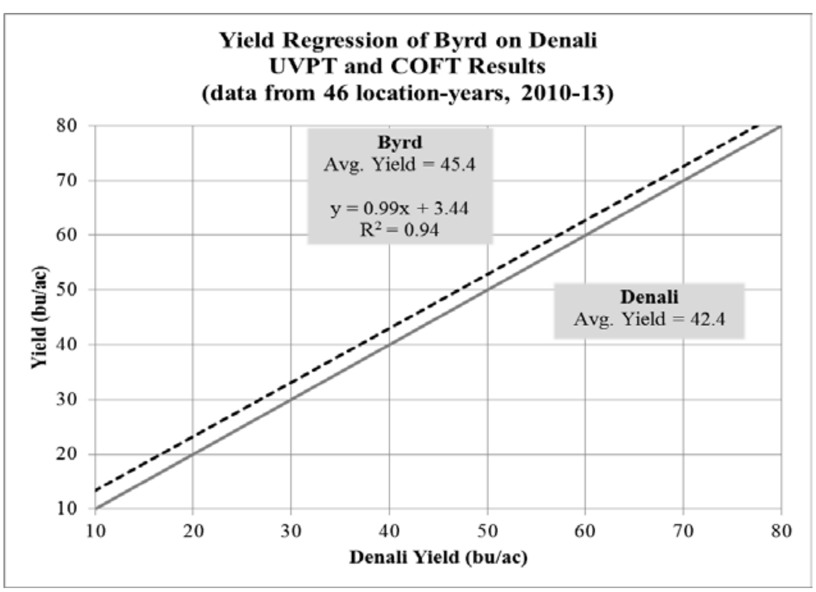




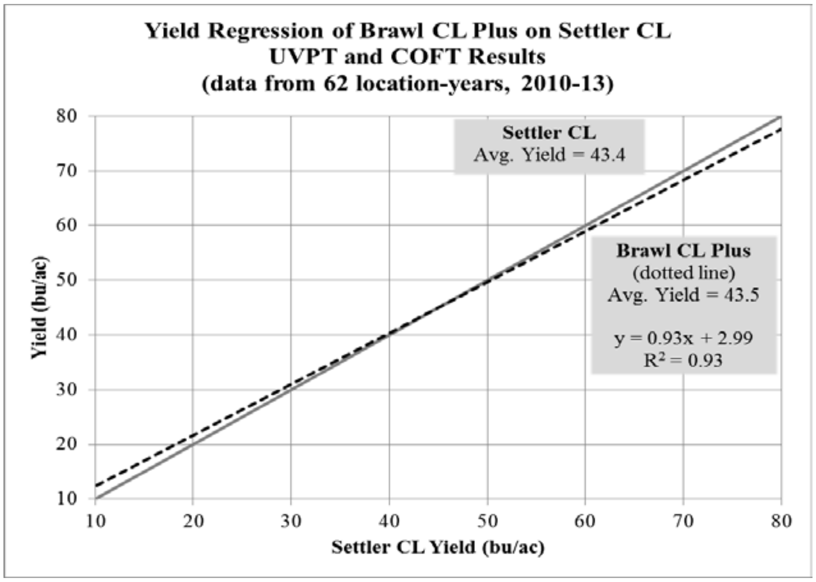
Yield Regression of Byrd on Ripper
UVPT Results
(data from 31 location-years, 2010-13)
Byrd
Avg. Yield = 52.1
y = 1.06x + 2.04
R² = 0.91
Ripper
Avg. Yield = 47.4
Yield (bu/ac)
Ripper Yield (bu/ac)
10
20
30
40
50
60
70
80

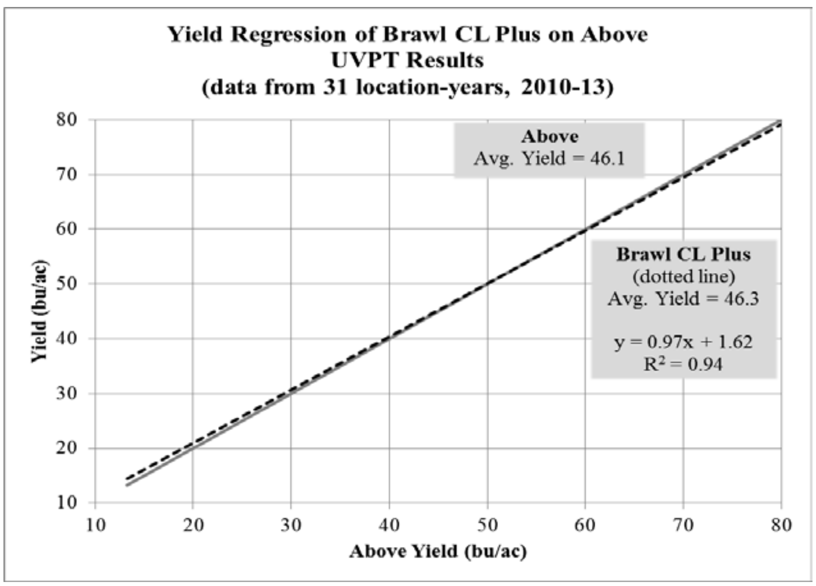


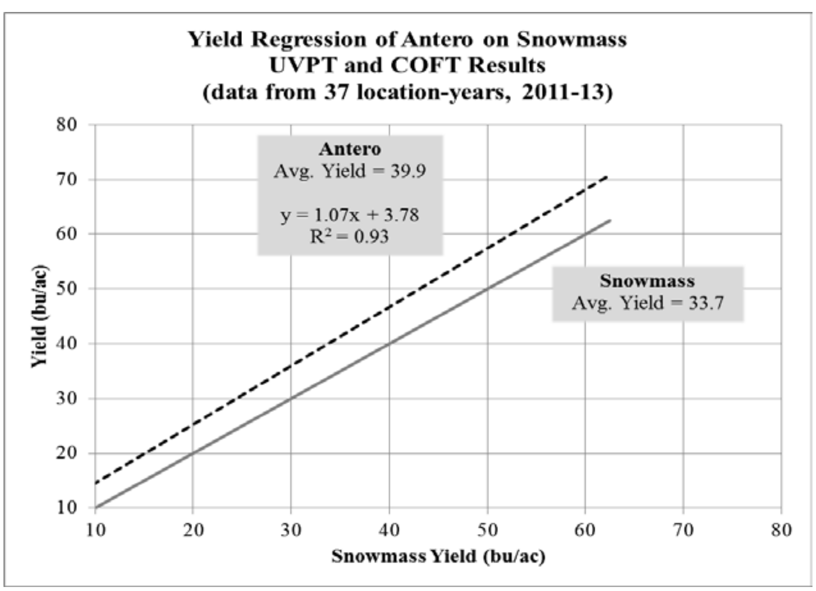
Yield Regression of Byrd on SY Wolf
UVPT Results
(data from 22 location-years, 2011-13)
Byrd
Avg. Yield = 46.4
y = .94x + 7.81
R² = 0.93
SY Wolf
Avg. Yield = 41.1
Yield (bu/ac)
SY Wolf Yield (bu/ac)
10
20
30
40
50
60
70
80



Yield Regression of Byrd on Denali
UVPT and COFT Results
(data from 46 location-years, 2010-13)
Byrd
Avg. Yield = 45.4
y = 0.99x + 3.44
R² = 0.94
Denali
Avg. Yield = 42.4
Yield (bu/ac)
Denali Yield (bu/ac)
10
20
30
40
50
60
70
80


Yield Regression of Brawl CL Plus on Settler CL
UVPT and COFT Results
(data from 62 location-years, 2010-13)
Settler CL
Avg. Yield = 43.4
Brawl CL Plus
(dotted line)
Avg. Yield = 43.5
y = 0.93x + 2.99
R² = 0.93
Yield (bu/ac)
Settler CL Yield (bu/ac)


Yield Regression of Brawl CL Plus on Above
UVPT Results
(data from 31 location-years, 2010-13)
Above
Avg. Yield = 46.1
Brawl CL Plus
(dotted line)
Avg. Yield = 46.3
y = 0.97x + 1.62
R² = 0.94
Yield (bu/ac)
Above Yield (bu/ac)


Yield Regression of Antero on Snowmass
UVPT and COFT Results
(data from 37 location-years, 2011-13)
Antero
Avg. Yield = 39.9
y = 1.07x + 3.78
R² = 0.93
Snowmass
Avg. Yield = 33.7
Yield (bu/ac)
Snowmass Yield (bu/ac)

2013 Collaborative On-Farm Test (COFT) Variety Performance Results

The objective of the 2013 COFT was to compare performance and adaptability of popular and newly released CSU varieties (Byrd, Brawl CL Plus, Denali, and Antero) with a proven high-yielding variety (Hatcher), and with a variety with a grower price-premium (Snowmass) under unbiased, field-scale testing conditions. The COFT program is in its 15th year and the majority of Colorado's 2013 wheat acreage was planted to winter wheat varieties that have been tested in the COFT program.

In the fall of 2012, thirty-three eastern Colorado wheat producers planted on-farm tests in Baca, Bent, Prowers, Kiowa, Cheyenne, Kit Carson, Washington, Yuma, Phillips, Sedgwick, Lincoln, Logan, Adams, and Weld counties. Each collaborator planted the six varieties in side-by-side strips (approximately one acre per variety) at the same seeding rate as they seeded their own wheat. Fifteen viable harvest results were obtained from the thirty-three tests due to the extremely dry conditions farmers experienced during the growing season. The COFT results need to be interpreted based on all tests within a year and not on the basis of a single variety comparison on a single farm in one year.

Colorado extension wheat educators who conducted the COFT program in 2013:

Jerry Johnson – Extension Specialist-Crop Production, Fort Collins
Bruce Bosley – Extension Agronomist, Logan County
Wilma Trujillo – Extension Agronomist, Prowers County
John Deering – Extension Specialist-Ag. Business Management, Washington County
Ron Meyer – Extension Agronomist, Golden Plains Area

2013 Collaborative On-Farm Test (COFT) Variety Performance Results

2013 Varieties[a]

	Byrd				Antero				Brawl CL Plus				Denali				Hatcher				Snowmass				COFT Average			
County/Nearest Town	Yield[b]	Test Weight	Protein	Protein Yield[c]	Yield[b]	Test Weight	Protein	Protein Yield[c]	Yield[b]	Test Weight	Protein	Protein Yield[c]	Yield[b]	Test Weight	Protein	Protein Yield[c]	Yield[b]	Test Weight	Protein	Protein Yield[c]	Yield[b]	Test Weight	Protein	Protein Yield[c]	Yield[b]	Test Weight	Protein	Protein Yield[c]
	bu/ac	lb/bu	percent	lb/ac	bu/ac	lb/bu	percent	lb/ac	bu/ac	lb/bu	percent	lb/ac	bu/ac	lb/bu	percent	lb/ac	bu/ac	lb/bu	percent	lb/ac	bu/ac	lb/bu	percent	lb/ac	bu/ac	lb/bu	percent	lb/ac
Baca/Vilas	8.2	56.1	-	-	10.0	55.2	-	-	6.5	57.9	-	-	5.2	57.1	-	-	5.7	56.0	-	-	6.3	54.6	-	-	*7.0*	*56.2*	-	-
Kit Carson/Burlington	15.0	57.9	16.4	147	12.5	59.0	16.5	124	16.5	58.6	16.6	164	14.2	59.1	16.0	137	11.5	59.1	16.1	111	11.4	58.2	15.2	104	*13.5*	*58.7*	*15.2*	*104*
Lincoln/Arriba	32.8	57.5	15.0	295	36.3	56.6	14.6	319	34.8	56.6	14.9	312	37.0	55.6	14.3	317	31.6	55.8	14.1	267	28.4	55.4	15.0	256	*33.5*	*56.3*	*15.0*	*256*
Logan/Leroy	25.6	59.0	11.7	180	24.2	59.5	11.6	168	24.2	62.0	12.9	187	26.9	59.0	11.5	186	23.4	59.5	11.4	160	21.1	58.0	11.7	148	*24.2*	*59.5*	*11.7*	*148*
Logan/Peetz	30.1	59.0	-	-	30.8	59.0	-	-	19.6	59.0	-	-	37.8	58.0	-	-	36.3	57.2	-	-	29.6	58.0	-	-	*30.7*	*58.4*	-	-
Logan/Sterling W	34.8	55.0	14.1	295	32.0	56.0	13.5	260	35.3	55.5	14.3	304	31.5	56.0	14.0	265	33.8	56.5	13.7	277	27.2	53.5	13.0	212	*32.4*	*55.4*	*13.0*	*212*
Phillips/Haxtun	48.0	53.8	14.0	403	43.3	54.1	14.5	378	46.7	55.4	14.9	417	44.5	55.8	14.2	378	43.5	52.8	13.9	363	36.3	52.4	14.1	306	*43.7*	*54.1*	*14.1*	*306*
Washington/Akron S	39.0	60.0	13.7	320	36.3	60.0	14.0	305	40.5	61.5	15.0	364	34.8	62.0	14.0	292	30.5	60.0	14.4	264	37.8	60.0	12.6	285	*36.5*	*60.6*	*12.6*	*285*
Washington/Akron W	16.7	55.0	13.7	137	19.8	55.0	14.5	172	18.1	56.0	14.9	162	17.0	56.0	15.5	157	15.6	55.0	14.1	132	15.5	55.0	14.5	135	*17.1*	*55.3*	*14.5*	*135*
Washington/Central	21.3	55.5	12.4	159	22.6	58.5	12.6	171	22.0	56.9	13.1	173	21.7	58.2	13.9	182	20.4	57.5	12.6	154	19.8	55.3	11.5	137	*21.3*	*57.0*	*11.5*	*137*
Washington/Otis	48.8	58.5	14.1	414	39.9	58.5	14.5	346	42.5	60.5	15.0	382	41.7	61.0	14.4	362	40.2	59.0	14.1	340	34.8	59.0	13.4	281	*41.3*	*59.4*	*13.4*	*281*
Weld/Keenesburg	37.7	56.0	15.1	343	33.1	57.0	14.4	287	35.3	56.5	15.1	320	27.9	58.0	14.9	250	34.7	59.0	13.4	279	25.2	57.0	13.3	201	*32.3*	*57.3*	*13.3*	*201*
Weld/New Raymer	26.8	56.5	14.0	225	33.0	57.0	13.0	258	24.9	58.0	13.8	206	25.3	57.0	14.5	220	26.2	56.0	13.9	218	26.7	56.0	13.1	210	*27.1*	*56.8*	*13.1*	*210*
Weld/Roggen	49.8	59.0	-	-	56.6	60.0	-	-	48.4	60.0	-	-	52.2	60.0	-	-	49.4	61.0	-	-	41.0	60.0	-	-	*49.6*	*60.0*	-	-
Yuma/Yuma	37.8	59.6	9.3	210	34.1	60.3	9.2	188	37.0	61.5	9.8	218	33.7	61.2	9.7	197	32.8	59.4	9.4	185	27.8	59.1	9.0	150	*33.9*	*60.2*	*9.0*	*150*
Average	**31.5**	**57.2**	**13.6**	**261**	**31.0**	**57.7**	**13.6**	**248**	**30.1**	**58.4**	**14.2**	**267**	**30.1**	**58.3**	**13.9**	**245**	**29.0**	**57.6**	**13.4**	**229**	**25.9**	**56.8**	**13.0**	**202**	***29.6***	***57.7***	***13.0***	***202***
Significance[d]	A				A,B				B,C				B,C				C				D							

LSD $_{(P<0.30)}$ for yield = 1.2 bu/ac

LSD $_{(P<0.30)}$ for test weight = 0.3 lb/bu

LSD $_{(P<0.30)}$ for protein = 0.3 percent

LSD $_{(P<0.30)}$ for protein yield = 12 lb/ac

[a]Varieties are ranked left to right by highest average yield.

[b]The protein yield is calculated by multiplying the grain yield by the percent grain protein.

[c]All yields are corrected to 12% moisture.

[d]Significance: Varieties with different letters have yields that are significantly different from one another.

Summary of 3-Year (2011-2013) Limited Irrigation Variety Performance Results at Fort Collins

Brand/Source	Variety[a]	Market Class[b]	3-Year Average Yield	Yield	Test Weight	Plant Height	Heading	Lodging[c]
			bu/ac	% trial average	lb/bu	in	days from trial average	scale (1-9)[d]
PlainsGold	Byrd	HRW	87.0	114%	60.1	33	-1	3
Husker Genetics	Robidoux	HRW	83.8	110%	59.9	32	1	3
Husker Genetics	Settler CL	HRW	79.6	104%	59.4	32	1	2
PlainsGold	Hatcher	HRW	78.8	103%	59.1	30	1	2
AgriPro Syngenta	SY Gold	HRW	78.6	103%	59.1	31	-1	1
AgriPro Syngenta	SY Wolf	HRW	78.4	103%	59.3	32	3	2
CO State Univ. exp.	CO05W111	**HWW**	76.2	100%	60.9	35	3	1
WestBred Monsanto	Armour	HRW	75.9	100%	58.9	29	-3	2
PlainsGold	Bond CL	HRW	75.8	99%	57.8	32	-2	2
PlainsGold	Denali	HRW	75.3	99%	60.4	33	3	2
PlainsGold	Brawl CL Plus	HRW	73.5	96%	59.9	34	-2	1
CO State Univ.	Yuma	HRW	73.0	96%	58.6	31	0	2
PlainsGold	Thunder CL	**HWW**	72.3	95%	59.6	31	0	1
Husker Genetics	McGill	HRW	71.4	94%	58.0	35	1	1
WestBred Monsanto	WB-Cedar	HRW	64.4	84%	57.9	30	-4	1
		Average	**76.3**		**59.3**	**32**		**2**

[a]Varieties ranked according to average 3-year yield at Fort Collins.

[b]Market class: HRW=hard red winter wheat; **HWW**=hard white winter wheat.

[c]Lodging scores based on 2011 trial data.

[d]Lodging scale: 1=no lodging, 9=severe lodging.

Summary of 3-Year (2011-2013) Irrigated Variety Performance Results at Haxtun

			3-Year Average				
Brand/Source	Variety[a]	Market Class[b]	Yield	Yield	Test Weight	Plant Height	Lodging
			bu/ac	% trial average	lb/bu	in	scale (1-9)[c]
AgriPro Syngenta	SY Wolf	HRW	125.2	104%	60.7	36	3
PlainsGold	Denali	HRW	124.8	103%	61.1	39	4
PlainsGold	Brawl CL Plus	HRW	124.8	103%	62.3	38	2
WestBred Monsanto	WB-Cedar	HRW	124.7	103%	60.9	34	2
WestBred Monsanto	Armour	HRW	124.4	103%	61.2	34	2
PlainsGold	Byrd	HRW	122.8	102%	61.6	39	4
Husker Genetics	Settler CL	HRW	122.2	101%	60.8	38	3
PlainsGold	Bond CL	HRW	120.9	100%	59.6	39	3
CO State Univ.	Yuma	HRW	120.8	100%	61.4	39	3
AgriPro Syngenta	SY Gold	HRW	120.2	100%	61.1	37	2
Husker Genetics	McGill	HRW	117.7	97%	59.9	41	4
PlainsGold	Thunder CL	**HWW**	117.4	97%	61.6	36	3
CO State Univ. exp.	CO05W111	**HWW**	117.1	97%	60.3	40	3
PlainsGold	Hatcher	HRW	114.4	95%	61.1	38	5
Husker Genetics	Robidoux	HRW	113.9	94%	61.1	39	4
		Average	**120.7**		**61.0**	**38**	**3**

[a]Varieties ranked according to average 3-year yield at Haxtun.

[b]Market class: HRW=hard red winter wheat; **HWW**=hard white winter wheat.

[c]Lodging scale: 1=no lodging, 9=severe lodging. Scores are based on 2011-2013 data.

Summary of 2-Year (2011-2012) Irrigated Variety Performance Results at Rocky Ford

Brand/Source	Variety[a]	Market Class[b]	2-Year Average Yield	Yield	Test Weight	Plant Height	Lodging[c]
			bu/ac	% trial average	lb/bu	in	scale (1-9)[d]
PlainsGold	Byrd	HRW	117.2	112%	60.7	37	4
Husker Genetics	Robidoux	HRW	113.4	109%	61.7	38	3
Husker Genetics	Settler CL	HRW	113.0	108%	59.4	37	3
PlainsGold	Ripper	HRW	112.3	108%	59.1	35	2
PlainsGold	Bond CL	HRW	110.6	106%	58.5	38	2
PlainsGold	Denali	HRW	110.1	106%	59.8	38	3
WestBred Monsanto	Armour	HRW	105.4	101%	61.3	32	1
Oklahoma Genetics	Billings	HRW	104.9	101%	60.5	35	1
WestBred Monsanto	WB-Cedar	HRW	102.3	98%	61.0	30	1
Husker Genetics	McGill	HRW	102.2	98%	60.4	42	4
PlainsGold	Thunder CL	**HWW**	101.2	97%	61.3	36	2
PlainsGold	Hatcher	HRW	99.9	96%	60.1	37	4
PlainsGold	Brawl CL Plus	HRW	98.9	95%	60.1	35	1
AgriPro Syngenta	SY Wolf	HRW	94.9	91%	58.7	36	3
CO State Univ.	Yuma	HRW	92.7	89%	58.2	36	2
AgriPro Syngenta	SY Gold	HRW	88.6	85%	59.5	37	2
		Average	**104.2**		**60.0**	**36**	**2**

[a]Varieties ranked according to average 2-year yield at Rocky Ford.

[b]Market class: HRW=hard red winter wheat; **HWW**=hard white winter wheat.

[c]Lodging scores based on 2011 trial data.

[d]Lodging scale: 1=no lodging, 9=severe lodging.

Winter Wheat Variety Selection in Colorado for Fall 2013 Planting

Our variety performance summary tables are intended to provide useful information to farmers, seed producers, and wheat industry representatives in Colorado and surrounding states. Variety selection and planting should be based on some general guidelines.

- Producers should focus on multi-year and multi-location yield summary results when selecting a new variety. Over time, the best buffer against making poor variety decisions has been to select varieties based on three-year average performance and not on performance in a single year – and especially not on performance at a single location in a single year.

- Producers should strongly consider planting more than one variety in order to minimize production risks from variable weather conditions and unexpected pest outbreaks. Recent surveys have indicated that many wheat producers in eastern Colorado do typically plant more than one variety.

- Producers should pay attention to other "non-yield" characteristics in making their variety selection decisions, including ratings for maturity, plant height, coleoptile length, disease and insect resistance, and end-use quality characteristics. These "non-yield" traits are useful to spread production risks due to the unpredictability of weather conditions and pest problems. Refer to the *Description of Winter Wheat Varieties in Eastern Colorado Trials* for variety-specific information for these and other traits (pages 29-33).

- Producers should control volunteer wheat and weeds to avoid the negative effects of a green bridge that could lead to serious virus disease infections vectored by the wheat curl mite (wheat streak mosaic virus, High Plains virus, Triticum mosaic virus) or aphids (barley yellow dwarf virus).

- Producers should soil sample to determine optimum fertilizer application rates. Sampling should be done prior to planting so nitrogen and phosphorus fertilizer requirements can be met. The CSU Extension factsheet entitled *Fertilizing Winter Wheat* is available online at http://tinyurl.com/c88u3x2 for assistance with wheat fertilization.

- Producers should consider monitoring seed size in order to adjust planting rates for abnormally large or small seed size. Varieties and different seed-lots can vary widely and planting small-seeded or large-seeded varieties can result in plant populations much different than desired. Refer to the *How to Calibrate Your Drill* guide for information on the importance of seed size and tips on how planter adjustments can be easily made. (Available at: http://tiny.cc/6p7kgx)

- Producers should be aware that new races of stripe rust emerged in 2010 and again in 2012 and many varieties that were resistant before are now susceptible. Farmers should refer to the *Description of Winter Wheat Varieties in Eastern Colorado Trials* (pages 29-33) for updated information on variety susceptibility. If variety resistance/susceptibility, market prices, expected yield levels, and fungicide and application costs warrant an application, farmers should consult the *North Central Regional Committee on Management of Small Grain Diseases* (NCERA-184) fungicide efficacy chart. Regular updates to this chart can be found on the CSU Wheat Breeding Program "Wheat Links" page (http://wheat.colostate.edu/links.html).

Variety Selection For Dryland Production Conditions

Many new varieties possessing multiple valuable traits and high dryland or irrigated yields are currently available. The first six varieties are described in greater detail below, ranked based on their three-year average yield performance. Snowmass and Brawl CL Plus are also highlighted because of specific traits they possess.

Byrd – A medium-maturing, medium-height hard red winter (HRW) wheat, marketed by PlainsGold. Byrd was the top-yielding variety across locations in the UVPT in 2010, 2011, and 2012 and second to Antero in 2013. In addition to being the top-yielding variety in the 2012 and 2013 three-year averages and the top yielder in the 2012 and 2013 COFT, Byrd has excellent drought stress tolerance and excellent milling and baking qualities. It has average test weight and an intermediate reaction to stripe rust. Byrd has relatively small kernels, similar to Bill Brown, so seed size should be monitored so that planting rates can be adjusted to avoid excessive plant populations.

Antero – A new hard white wheat (HWW), released in 2012, marketed by PlainsGold. Has shown three-year average dryland yield in the UVPT essentially equivalent to Byrd. It has good drought stress tolerance, good test weight, good stripe rust resistance, and moderate sprouting tolerance (similar to Hatcher). For the 2014 crop, a grower premium will not be offered by ConAgra Mills for Antero grown in Colorado.

TAM 112 – An early-maturing HRW with good dryland adaptation, marketed by Watley Seed. TAM 112 has excellent wheat streak mosaic virus tolerance, high test weight and good baking quality. It is very susceptible to stripe rust. It has done very well in recent years whenever drought stress has been an important factor in trial results, as in 2012 and 2013.

Ripper – An early-maturing HRW variety, marketed by PlainsGold. Ripper is high yielding, very drought stress tolerant, and has good baking quality. It has relatively lower test weight, and is very susceptible to stripe rust. Ripper has shown extremely stable yields, being in the top four of the three-year dryland yield averages every year from 2005 to 2013.

Denali – A medium-late maturing HRW variety, marketed by PlainsGold for production in Colorado and in Kansas through the Kansas Wheat Alliance. It has “photoperiod sensitivity” which caused excessive late heading in 2012. It is medium-tall, has excellent test weight and average milling and baking quality, and is moderately susceptible to the new races of stripe rust.

Settler CL – A later maturing HRW single-gene Clearfield® winter wheat, marketed by Husker Genetics. It has medium height, good test weight, good milling and baking quality, and is moderately susceptible to the new races of stripe rust. Very strong combined dryland and irrigated performance in CSU variety trials.

Brawl CL Plus – A two-gene HRW Clearfield® variety, marketed by PlainsGold. In combination with methylated seed oil (MSO), control of feral rye with Beyond herbicide is much improved relative to control achieved with single-gene Clearfield wheat varieties. Brawl CL Plus has early maturity, medium height, excellent test weight, an intermediate reaction to stripe rust, and excellent milling and baking quality. Brawl CL Plus has shown excellent yield in 2012 and 2013 in dryland variety trials and the COFT, though its long term average is equivalent to Hatcher.

Snowmass – A hard white wheat (HWW) variety, marketed by PlainsGold through the CWRF ConAgra Mills Ultragrain Premium Program. Snowmass has a very strong and unique quality profile, making it extremely valuable in whole-grain flour applications. It is medium maturing, has good test weight, and is a taller semi-dwarf which provides additional crop residue. It has excellent resistance to wheat streak mosaic virus, moderate sprouting tolerance (similar to Hatcher), and moderate susceptibility to the new races of stripe rust. It has shown lower yields in 2012 and 2013 dryland variety trials and the COFT, though its long term average is equivalent to Hatcher.

Variety Selection For Irrigated Production Conditions at Haxtun, Rocky Ford, and Fort Collins

The most important variety selection criteria for irrigated varieties are yield, straw strength, and stripe rust resistance. Under limited-irrigation conditions, drought stress tolerance can also be important. The top five yielding varieties at each trial location based on a three-year average are emphasized below.

Haxtun

SY Wolf – A medium-maturing HRW, marketed by AgriPro Syngenta. It has a very broad disease resistance package, with good protection for leaf spotting diseases (tan spot and septoria), leaf rust, and stripe rust. Good straw strength and milling and baking quality.

Brawl CL Plus – See dryland description above. It has above average straw strength and an intermediate reaction to stripe rust.

Denali – See dryland description above. It has average straw strength and an intermediate reaction to stripe rust.

WB-Cedar – An early-maturing HRW, marked by WestBred Monsanto. It has good leaf and stripe rust resistance and excellent straw strength for high-input irrigated conditions. Does not perform well under limited-irrigation situations.

Armour – An early-maturing HRW, marked by WestBred Monsanto. It has good straw strength, good leaf rust resistance, and an intermediate reaction to stripe rust. Has shown lower test weight in dryland trials, but this is not an issue under irrigation.

Rocky Ford
(based on 2010, 2011, 2012 Three-Year Average)

Byrd – See dryland description above. Straw strength is only average for high-input irrigated conditions, though it has performed extremely well under limited-irrigation due to its drought stress tolerance. Intermediate reaction to stripe rust. Byrd is also susceptible to many North

American races of stem rust, which would be more of a risk with later-maturing irrigated wheat.

Settler CL – See dryland description above. It has good straw strength and is moderately susceptible to new races of stripe rust.

Ripper – See dryland description above. It has good straw strength and is very susceptible to stripe rust. Has shown lower test weight in dryland trials, but this is not an issue under irrigation.

Bond CL – A medium maturing HRW single-gene Clearfield® variety, marketed by PlainsGold. Is medium-tall with average straw strength. Very susceptible to stripe rust. Has shown lower test weight in dryland trials, but this is not an issue under irrigation.

Denali – See dryland description above. It is medium-tall, has average straw strength, and is moderately susceptible to stripe rust.

Fort Collins

Byrd – See descriptions above.

Robidoux – A medium-height, medium-maturing HRW variety, marketed by Husker Genetics. It has excellent test weight, average straw strength, and moderate resistance to stripe rust.

Settler CL – See descriptions above.

Hatcher – A medium-height, medium-maturing HRW variety, marketed by PlainsGold. Historical yield record under irrigation has shown that its lower straw strength is a risk for high-input irrigated conditions but its drought stress tolerance favors its performance under limited-irrigation. Moderate resistance to stripe rust.

SY Gold – A medium-maturing HRW, marketed by AgriPro Syngenta. Good test weight, average straw strength, and is susceptible to new races of stripe rust (similar resistance as Jagger and Jagalene).

Description of Winter Wheat Varieties in Eastern Colorado Trials (2013 and 2014)

Name, Class, and Pedigree	Origin	RWA*	HD	HT	SS	COL**	YR	LR	WSMV	TW	MILL	BAKE	Comments
1863 Hard red winter KS940786-6-4/Karl92//Cutter	KSU 2012	S	5	4	--	4	3	7	--	3	3	3	KSU-Manhattan release (2012). First entered into CSU Variety Trials in 2012. Medium height and medium maturing, good test weight, intermediate reaction to stripe rust, moderately susceptible to leaf rust. Good quality characteristics.
Above Hard red winter TAM 110*4/FS2	CSU-TX 2001	S	3	5	3	8	8	9	5	7	4	7	CSU/Texas A&M release (2001), marketed by PlainsGold. Single-gene Clearfield© wheat. Early maturing semidwarf. Leaf and stripe rust susceptible. Marginal baking quality.
Akron Hard red winter TAM 107/Hail	CSU 1994	S	5	6	5	4	8	9	9	5	5	6	CSU release (1994). Vigorous growth pattern, closes canopy early in spring and competes well with weeds. Best adapted under higher production dryland conditions. Leaf and stripe rust susceptible.
Antero Hard white winter KS01HW152-1/TAM 111	CSU 2012	S	4	6	4	6	2	8	4	3	3	5	CSU release (2012), marketed by PlainsGold. High dryland and irrigated yield, medium height and maturity, good test weight, good straw strength, good resistance to stripe rust. Moderate sprouting tolerance.
Armour Hard red winter B1551-WH/KS94U326	Westbred 2008	S	1	1	3	8	7	5	7	8	4	5	Westbred release (2008). Early maturing short semidwarf, heavy tillering, good leaf rust resistance, moderate susceptibility to new races of stripe rust. Lower test weight.
Bearpaw Hard red winter DMS/Rampart//Pronghorn/3/2*Rampart	MT 2011	S	9	1	--	2	--	--	--	4	6	1	Montana State University release (2011). First entered in CSU Variety Trials in 2013. Carries solid stem trait conferring some protection against wheat stem sawfly damage. Short plant stature, late maturing.
Bill Brown Hard red winter Yumar/Arlin	CSU 2007	R*	4	4	4	2	6	2	7	4	6	4	CSU release (2007), marketed by PlainsGold. High test weight, good leaf rust resistance, moderate susceptibility to new races of stripe rust. Very susceptible to stem rust. Good baking quality, short coleoptile.
Bond CL Hard red winter Yumar//TXGH12588-120*4/FS2	CSU 2004	R*	5	6	5	5	8	6	8	8	6	3	CSU release (2004), marketed by PlainsGold. Single-gene Clearfield© wheat. Slightly later, slightly taller than Above. High irrigated yields, good baking quality. Low test weight, leaf and stripe rust susceptible.
Brawl CL Plus Hard red winter Teal 11A/Above//CO99314	CSU 2011	S	2	6	2	8	5	5	--	2	3	2	CSU release (2011), marketed by PlainsGold. Two-gene Clearfield© wheat. Excellent test weight, straw strength, milling and baking quality. Early maturity, medium height, long coleoptile. Intermediate reaction to stripe rust.
Byrd Hard red winter TAM 112/CO970547-7	CSU 2011	S	4	5	4	7	5	6	--	5	3	3	CSU release (2011), marketed by PlainsGold. High dryland and irrigated yield, excellent drought tolerance and quality. Medium height, maturity, coleoptile length. Average test weight and straw strength. Intermediate reaction to stripe rust.

Russian wheat aphid resistance (RWA), heading date (HD), plant height (HT), straw strength (SS), coleoptile length (COL), stripe rust resistance (YR), leaf rust resistance (LR), wheat streak mosaic virus tolerance (WSMV), test weight (TW), milling quality (MILL), and baking quality (BAKE). Rating scale: 1 - very good, very resistant, very early, or very short to 9 - very poor, very susceptible, very late, or very tall.

* RWA rating denotes resistance to the original biotype (biotype 1) of RWA. All available cultivars are susceptible to the new biotypes of RWA.

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Description of Winter Wheat Varieties in Eastern Colorado Trials (2013 and 2014)

Name, Class, and Pedigree	Origin	RWA*	HD	HT	SS	COL**	YR	LR	WSMV	TW	MILL	BAKE	Comments
Clara CL Hard white winter KS03HW154/KS03HW1	KSU 2011	S	7	6	6	4	5	2	2	2	1	3	KSU-Hays release (2011). First entered in CSU Variety Trials in 2012. Single-gene hard white Clearfield© wheat. Carries same WSMV resistance as RonL and Snowmass. Moderate resistance to stripe rust, excellent test weight.
CO09W293 Hard white winter KS01HW152-6/HV9W02-267W	CSU EXP	S	5	5	5	8	7	8	--	5	6	2	CSU experimental, targeted for fall 2014 release. Hard white, carries quality profile similar to Snowmass. Similar yield as Antero in two years of testing in CSU Elite Trial. Pre-harvest sprouting tolerance similar to Hatcher, Snowmass, Antero.
Cowboy Hard red winter CO980829/TAM 111	WY-CSU 2011	R*	8	6	6	3	6	7	7	4	4	5	CSU release (2011), marketed by Crop Research Foundation of Wyoming. Sister selection to Denali, but slightly shorter, lower straw strength, and 1 lb/bu lower test weight. Similar disease reaction and quality (except RWA biotype 1 resistant).
CSU Blend13 Hard red winter Hatcher/Bearpaw Blend	CSU-MT 2004/2011	--	--	--	--	--	--	--	--	--	--	--	50:50 blend of Hatcher (hollow stem wheat) and Bearpaw (solid stem wheat) for evaluation as a tool for wheat stem sawfly management. First entered into CSU Dryland Variety Trial (UVPT) in 2014.
Denali Hard red winter CO980829/TAM 111	CSU 2011	S	8	7	5	7	6	7	7	2	4	5	CSU release (2011), marketed by PlainsGold and KWA in Kansas. High yields, excellent test weight. Medium tall, medium-late, medium-long coleoptile. Average straw strength and quality. Moderate susceptibility to stripe rust.
Freeman Hard red winter KS92-946-B-15-1=(ABI86*3414/JAG//K92)/ALLIANCE	NE 2012	S	4	6	6	4	5	5	--	9	8	4	Nebraska release (2012), first entered in CSU Variety Trials in 2013. Low test weight and low yield in CSU and Nebraska dryland trials in 2013.
Gallagher Hard red winter OK93P656-(RMH 3299)/OK99711	OK 2012	S	7	5	6	4	2	3	--	5	7	5	Oklahoma State release (2012), first entered in CSU Variety Trials in 2013. Good leaf disease resistance (leaf and stripe rust resistance).
Hatcher Hard red winter Yuma/PI 372129//TAM-200/3/4*Yuma/4/KS91H184/Vista	CSU 2004	R*	6	2	7	4	3	7	8	4	4	3	CSU release (2004), marketed by Plainsgold. Medium maturing semidwarf. Good test weight, moderate resistance to stripe rust. Excellent High Plains yield record, good milling and baking quality. Develops “leaf speckling” condition.
Iba Hard red winter OK93P656-(RMH 3299)/OK99621	OK 2012	S	6	3	5	6	5	3	--	2	3	4	Oklahoma State release (2012), first entered in CSU Variety Trials in 2013. Good stripe rust resistance, good test weight, good quality. Good performance in CSU dryland trials in 2013.
LCS Mint Hard red winter Overley/CO980829	Limagrain 2011	S	4	8	4	4	3	8	--	2	2	2	Limagrain release (2011). First entered in CSU Variety Trials in 2013, previously tested in 2010 under experimental designation CO050175-1. Moderately resistant to stripe rust, good test weight, good milling and baking quality.

Russian wheat aphid resistance (RWA), heading date (HD), plant height (HT), straw strength (SS), coleoptile length (COL), stripe rust resistance (YR), leaf rust resistance (LR), wheat streak mosaic virus tolerance (WSMV), test weight (TW), milling quality (MILL), and baking quality (BAKE). Rating scale: 1 - very good, very resistant, very early, or very short to 9 - very poor, very susceptible, very late, or very tall.

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Description of Winter Wheat Varieties in Eastern Colorado Trials (2013 and 2014)

Name, Class, and Pedigree	Origin	RWA*	HD	HT	SS	COL**	YR	LR	WSMV	TW	MILL	BAKE	Comments
LCS Wizard Hard red winter S6742/92PAN1#33//92PIN#107	Limagrain 2013	S	7	1	2	5	6	7	--	6	4	8	Limagrain release (2013), previously tested as LCH08-80. First entered in CSU Variety Trials in 2013. Very good straw strength for irrigation. Poor baking quality. Tolerant to barley yellow dwarf virus, resistant to Hessian fly.
McGill Hard red winter NE92458/Ike	NE 2010	S	5	8	8	3	6	4	--	7	5	5	Nebraska release (2010). First entered in CSU Variety Trials in 2011. Medium maturity, medium height. Lower test weight, poor straw strength. Intermediate reaction to new races of stripe rust.
Oakley CL Hard red winter Above/Danby//KS03HW10	KSU 2013	S	6	5	--	6	2	7	2	3	3	2	KSU-Hays release (2013). First entered in CSU Variety Trials in 2013. Single-gene hard red Clearfield© wheat. Good test weight, good stripe rust resistance, carries same WSMV resistance as Clara CL and Snowmass.
Prairie Red Hard red winter CO850034/PI372129//5*TAM 107	CSU 1998	R*	4	3	3	8	8	9	5	7	5	7	CSU release (1998). Backcross derivative of TAM 107, resistant to RWA biotype 1. Good stress tolerance, poor end-use quality reputation, lower yields relative to more recent wheat releases. Leaf and stripe rust susceptible.
Protection Hard red winter Jagger//TXGH12588-120*4/FS2	AGSECO/CSU 2004	S	2	8	3	4	7	9	5	8	4	6	CSU release (2004), marketed by AGSECO. Single-gene Clearfield© wheat. Lower yield relative to Bond CL in CSU Variety Trials. Taller plant stature, susceptible to stripe rust. Low test weight.
Ripper Hard red winter CO940606/TAM107R-2	CSU 2006	R*	2	5	4	8	9	9	7	8	4	4	CSU release (2006), marketed by PlainsGold. Excellent stress tolerance, high dryland yields in Colorado, good baking quality. Very good recovery from stand reduction. Leaf and stripe rust susceptible, lower test weight.
Robidoux Hard red winter NE96644/Wahoo (sib)	NE 2010	S	5	5	6	7	4	6	8	5	3	3	Nebraska release (2010). First entered in CSU Variety Trials in 2011. Medium maturity, medium short. Moderate resistance to stripe rust. Better performance in CSU Irrigated Variety trials.
Settler CL Hard red winter N95L164/3/MILLENNIUM SIB//TXGH125888-120*4/FS2	NE 2008	S	7	4	2	6	6	8	7	6	3	4	Nebraska release (2008). Single-gene Clearfield© wheat. Good dryland and irrigated yield in CSU Variety Trials. Later maturing, medium height. Moderately susceptible to new races of stripe rust.
Snowmass Hard white winter KS96HW94//Trego/CO960293	CSU 2009	S	6	8	8	4	5	6	2	7	6	2	CSU release (2009), marketed by PlainsGold. Hard white winter wheat (HWW). Medium-maturing, medium-tall. Good WSMV resistance, moderately susceptible to stripe rust, moderate sprouting tolerance. Grown under contract with ConAgra.
SY Gold Hard red winter W95-301/W98-151	Agripro 2010	S	4	5	5	2	8	2	6	3	5	5	Agripro release (2010). First entered in CSU Variety Trials in 2009. Good leaf rust resistance, susceptible to stripe rust.

Russian wheat aphid resistance (RWA), heading date (HD), plant height (HT), straw strength (SS), coleoptile length (COL), stripe rust resistance (YR), leaf rust resistance (LR), wheat streak mosaic virus tolerance (WSMV), test weight (TW), milling quality (MILL), and baking quality (BAKE). Rating scale: 1 - very good, very resistant, very early, or very short to 9 - very poor, very susceptible, very late, or very tall.

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Description of Winter Wheat Varieties in Eastern Colorado Trials (2013 and 2014)

Name, Class, and Pedigree	Origin	RWA*	HD	HT	SS	COL**	YR	LR	WSMV	TW	MILL	BAKE	Comments
SY Monument Hard red winter BC991149-11/00x0090-4	Agripro 2014	S	7	6	4	6	2	2	--	3	2	2	Agripro release (2014). First entered in CSU Variety Trials in 2014. Good drought tolerance and very good irrigated yields. Resistant to leaf and stripe rust, good test weight. Certified Seed available in 2015.
SY Southwind Hard red winter W99-188$-1/BC950814-1-1	Agripro 2012	S	3	3	2	4	2	2	--	3	2	2	Agripro release (2012). First entered in CSU Irrigated Variety Trials in 2014. Positioned as high yielding irrigated wheat with very good straw strength. Resistant to stripe, leaf, and stem rust.
SY Wolf Hard red winter W99-331/97x0906-8	Agripro 2010	S	7	5	3	4	5	1	--	3	4	4	Agripro release (2011). First entered in CSU Variety Trials in 2011. Good resistance to tan spot, septoria, and leaf rust. Moderate resistance to stripe rust.
T153 Hard red winter T136//T81/KS93U206	Limagrain 2008	S	1	2	2	7	2	6	--	6	5	6	Limagrain release (2008), first entered in CSU Variety Trials in 2013. Very early maturity. Broad disease package including good stripe rust resistance and fusarium head blight resistance. Medium long coleoptile.
T154 Hard red winter T88/2180//T811	Limagrain 2008	S	2	2	5	5	3	6	--	3	4	5	Limagrain release (2008). First entered in CSU Variety Trials in 2013. Good resistance to stripe rust and leaf rust. Early maturity. Tolerant to acid soils.
T158 Hard red winter KS93U206/2*T81	Limagrain 2009	S	2	5	5	3	2	6	--	4	3	5	Trio (Limagrain) release (2009). First entered in CSU Variety Trials in 2012. Good stripe rust and leaf rust resistance. Medium early maturity, excellent tolerance to drought, covers ground quickly in fall.
T163 Hard red winter 93WGRC27/T811	Limagrain 2010	S	2	6	8	4	5	6	4	5	3	3	Trio (Limagrain) release (2010). First entered in CSU Variety Trials in 2011. Some plants carry resistance to wheat streak mosaic virus. Moderate resistance to stripe rust. Poor straw strength, good quality.
TAM 111 Hard red winter TAM-107//TX78V3630/CTK78/3/TX87V1233	TX 2002	S	6	6	3	8	8	8	7	3	4	5	Texas A&M release (2002), marketed by Agripro. Medium maturing, taller wheat. Good test weight, good straw strength, good irrigated yield. Leaf rust susceptible, intermediate reaction to stripe rust.
TAM 112 Hard red winter U1254-7-9-2-1/TXGH10440	TX 2005	S	2	4	7	5	8	7	3	3	4	2	Texas A&M release (2005), marketed by Watley Seed. Early maturing semi-dwarf. Good test weight, good quality, excellent wheat streak mosaic virus tolerance. Susceptible to leaf and stripe rust, inadequate straw strength for high yield irrigated conditions.
TAM 113 Hard red winter TX90V6313/TX94V3724	TX 2010	S	7	3	8	3	4	4	5	4	4	4	Texas A&M release (2010), marketed by AGSECO. First entered in CSU Variety Trials in 2012. Good leaf and stripe rust resistance, good test weight. Poor straw strength.

Russian wheat aphid resistance (RWA), heading date (HD), plant height (HT), straw strength (SS), coleoptile length (COL), stripe rust resistance (YR), leaf rust resistance (LR), wheat streak mosaic virus tolerance (WSMV), test weight (TW), milling quality (MILL), and baking quality (BAKE). Rating scale: 1 - very good, very resistant, very early, or very short to 9 - very poor, very susceptible, very late, or very tall.

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Description of Winter Wheat Varieties in Eastern Colorado Trials (2013 and 2014)

Name, Class, and Pedigree	Origin	RWA*	HD	HT	SS	COL**	YR	LR	WSMV	TW	MILL	BAKE	Comments
TAM 304 Hard red winter TX92U3060/TX91D6564	TX 2006	S	4	2	2	7	8	2	--	7	6	4	Texas A&M release (2006), marketed by Scott Seed Co. First entered in CSU Variety Trials in 2012. Good straw strength, susceptible to stripe rust, lower test weight.
Thunder CL Hard white winter KS01-5539/CO99W165	CSU 2008	R*	4	4	3	7	3	5	4	6	5	2	CSU release (2008), marketed by PlainsGold. Single-gene HWW Clearfield© wheat. Good straw strength for irrigation. Excellent quality, moderate stripe rust resistance, moderate sprouting susceptibility. Grown under contract with ConAgra.
Warhorse Hard red winter MT9908//Nuplains/MTS9862	MT 2013	S	--	--	--	5	--	--	--	--	--	--	Montana State University release (2013). First entered in CSU Variety Trials in 2014. Carries solid stem trait conferring some protection against wheat stem sawfly damage.
WB-Cedar Hard red winter TAM 302/B1551W	Westbred 2010	S	2	2	1	5	3	5	7	7	3	5	Westbred release (2010). First entered in CSU Variety Trials in 2011. Hard red selection from Aspen HWW. Good stripe rust resistance, excellent straw strength for high-input irrigation. Very drought susceptible, lower test weight.
WB-Grainfield Hard red winter G982231/G982159//KS920709W	Westbred 2012	S	2	7	4	2	3	2	--	7	5	6	Westbred release (2012). First entered into CSU Trials in 2013. Early maturing tall semi-dwarf. Good leaf and stripe rust resistance, lower test weight, shorter coleoptile.
Winterhawk Hard red winter 474S10-1/X87807//HBK736-3	Westbred 2007	S	4	7	5	8	5	7	7	2	2	4	Westbred release (2007). Medium maturing, medium tall, long coleoptile. Intermediate reaction to new races of stripe rust, susceptible to leaf rust, very susceptible to stem rust. Good test weight, good quality.
Yuma Hard red winter NS14/NS25//2*Vona	CSU 1991	S	6	3	3	1	5	5	6	6	5	3	CSU release (1991). Medium maturity, semidwarf, short coleoptile, good baking quality characteristics. Moderate resistance to stripe rust. Higher yield under irrigation.
Yumar Hard red winter Yuma/PI 372129,F1//CO850034/3/4*Yuma	CSU 1997	R*	5	5	4	2	5	4	6	4	5	3	CSU release (1997), marketed by PlainsGold. Russian wheat aphid resistant version of Yuma. Medium-maturing semidwarf. Good straw strength, good baking quality characteristics.

Russian wheat aphid resistance (RWA), heading date (HD), plant height (HT), straw strength (SS), coleoptile length (COL), stripe rust resistance (YR), leaf rust resistance (LR), wheat streak mosaic virus tolerance (WSMV), test weight (TW), milling quality (MILL), and baking quality (BAKE). Rating scale: 1 - very good, very resistant, very early, or very short to 9 - very poor, very susceptible, very late, or very tall.

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CSU Wheat Breeding and Genetics Program Update
Scott Haley, CSU Wheat Breeder
June 2014

Introduction

The primary goal of the CSU Wheat Breeding and Genetics Program is to develop and release improved wheat cultivars and germplasm adapted for the diverse production conditions in Colorado and the High Plains region. Over 50 years of continuous activity at CSU we have developed a germplasm base uniquely adapted for the High Plains region and have released many new cultivars to address production and marketing constraints facing Colorado's wheat producers. We are fortunate to receive generous funding support from CSU (Colorado Ag Experiment Station) and from the Colorado wheat industry through the Colorado Wheat Administrative Committee (CWAC) and the Colorado Wheat Research Foundation (CWRF). The following descriptions of our program's activities summarize some of our main areas of focus over the last year.

Breeding Program Core

The primary goals of the CSU Wheat Breeding and Genetics Program are to: a) develop improved hard red (HRW) and hard white (HWW) winter wheat cultivars and germplasm adapted for the diverse production conditions in Colorado and the west-central Great Plains, and b) conduct research to improve understanding of genetic and environmental factors that affect wheat yield and end-use quality. Our program is staffed by extremely dedicated and experienced researchers and overall we have the necessary funding, facilities, and equipment to ensure success.

- In summer 2013, we harvested breeding trials at eight locations in eastern Colorado (Akron, Burlington, Dailey, Fort Collins, Julesburg, Lamar, Orchard, Yuma). While yields were generally very low, adequate data were available to inform selection decisions in the breeding program. Due to emergence problems from the drought, severe drought after emergence, or spring freeze injury, we abandoned breeding trials at Arapahoe, Genoa, Roggen, Sheridan Lake, and Walsh.
- No lines were on Foundation Seed increase in 2013 and no new cultivars were released in fall 2013. Three HRW and two HWW lines were on Breeder Seed increase in 2013, yet all but one of these was discarded from further consideration. The one line retained, a HWW designated as CO09W293, carries the glutenin trait that is present in Snowmass. Foundation Seed is currently being produced in Yuma AZ to enable release of CO09W293 in fall 2014. In two years of testing in the CSU Elite Trial (18 locations), dryland grain yield of CO09W293 was 102% of trial average, compared to 109% for Byrd, 103% for Brawl CL Plus, 101% for Antero, 97% for Hatcher, 92% for Thunder CL, and 88% for Snowmass. CO09W293 has average test weight and straw strength, and is moderately susceptible to stripe rust and susceptible to leaf rust.
- CWRF royalty funds and our partnership with ConAgra Mills are providing for a significant expansion of experimental HRW and HWW line development through the use of doubled haploid (DH) breeding technology. Since 2010, we have utilized the DH capacity at Heartland Plant Innovations (HPI) and Washington State University (WSU). In 2012, we began to develop our own DH laboratory capacity at CSU and funding secured from CWAC and various internal CSU sources was recently used to renovate a lab in the CSU greenhouse for DH production.
- We continue to utilize a wide variety of diverse germplasm sources in our crossing program, including elite materials from other regional programs, new sources of leaf and stripe rust resistance, solid-stem varieties from Montana State for wheat stem sawfly resistance, winter wheat lines introduced from Turkey and other areas of eastern Europe, and germplasm carrying various novel traits from our program and other programs.

Genomic Selection

The objective of this program is to implement "genomic selection" (GS) in the CSU Wheat Breeding Program. Genomic selection takes advantage of next-generation DNA sequencing technologies and statistical models to predict the trait potential of breeding lines prior to, or as a complement to, evaluation in the field or quality lab. If successful, the value of GS will be realized through shortening of the breeding cycle time, in conjunction with doubled haploid (DH) technology, and increased rates of genetic improvement over time for yield, quality, and other traits.

- In 2012-13, we were successful in adopting techniques for dense, genome-wide marker analysis using "genotyping by sequencing" (GBS). Our use of GBS involves DNA sample preparation at CSU (using protocols from the Jesse Poland Lab, USDA-ARS), outsourcing of the DNA sequencing to the University of Missouri core facility, and processing/marker data extraction of the raw sequencing data by Jesse Poland or at CSU by Harish Manmathan.
- In 2012-13, we carried out GBS on the set of 1,900 new lines mentioned above. In 2013-14, we are planning to conduct GBS on an additional set of 2,806 lines. Due to the increasing numbers of individuals we have genotyped, the number of marker datapoints per individual obtained via GBS has increased from 22,000 with our first run to over 45,000 with our last run. Thus, since we implemented GBS we have obtained a total of around 233 million marker datapoints.
- Using 2006-2012 data on our GS training panel (n=2,368), and the GBS markers obtained on the panel, we have developed GS models for grain yield and test weight. Predictions obtained were used in selection of crossing parents for crossing in spring 2014. Cross-validation accuracies (correlation between observed and predicted trait values) are above r=0.60 for both traits.
- We currently have three PhD graduate students focusing on different aspects of GS model development and implementation in the breeding program. Sue Latshaw is focusing on nitrogen use efficiency (through GS modeling of "grain protein deviation"), Jessica Cooper is focusing on GS modeling of end-use quality traits (including pre-harvest sprouting tolerance), and Craig Beil is focusing on GS- and GBS-facilitated exploitation of eastern European winter wheat germplasm for diversity enhancement and yield improvement.

DNA Marker-Assisted Selection

The objectives of this program are to apply DNA molecular marker-assisted selection (MAS) as a tool in selection for traits of interest in the breeding program. On a limited basis, we would hope to be able to identify and validate our own markers for new traits and also optimize marker-trait associations identified by other programs.

- Beginning in 2012, we increased the number of preliminary lines that we develop and test in our program (1,013 in 2011, 1,815 in 2012, 1,903 in 2013). In 2013, we significantly expanded routine marker testing of these lines. Of the group of 1,903 preliminary lines tested in 2013, 1,710 had one or more marker assays done for key markers associated with various traits.
- In 2013, we conducted marker analysis on a group of 1,780 DH lines that were under increase in Yuma AZ in 2013. Most of the DH lines in Yuma AZ were hard whites (HWW) developed through our partnership with ConAgra Mills. From this group, we tested 1,390 lines for one or more DNA markers. The marker data were also used to target certain lines for crossing purposes for further DH production.
- We continued to utilize DNA markers for backcrossing various traits from different germplasm sources. Our efforts over the last year have focused on introgression of the following traits into various backgrounds: herbicide resistance, drought stress tolerance (TILLING mutants), high amylose (TILLING mutants), polyphenol oxidase, stem solidness (wheat stem sawfly), UG-99 stem rust resistance, and leaf and stripe rust resistance.

- We have succeeded in implementing a new rapid and inexpensive marker analysis platform known as KASP for screening for several target traits. We have implemented KASP assays for several traits of interest: herbicide resistance, high amylose, high grain protein content (*GPC-B1*), rye translocations, several disease resistance traits, and several quality-related traits.

TILLING for Novel Trait Development

Our objective is to develop and validate novel traits in wheat using advanced, functional genomics-based techniques, such as TILLING or other technologies. TILLING (Targeted Induced Local Lesions In Genomes) has shown promise in wheat for novel trait development using mutation induction rather than transgenics (GM). Therefore, TILLING-derived traits are non-GM and may provide new and beneficial technologies for wheat. Our current trait emphases include drought stress tolerance, insect resistance, and human health related traits.

- In 2013, we successfully integrated next-generation DNA sequencing with TILLING in a novel technique called "TILLING-by-Sequencing" (TBS). Mutations in all three genomes of nine different genes were identified using TBS. A total of 34 different plants carrying mutations were identified and nine of the most promising plants have been confirmed.
- In 2012, we identified mutants on all three genomes for a gene related to Celiac disease in humans and a gene related to production of a chemical in the wheat plant that attracts the wheat stem sawfly. For both traits, materials are currently being developed to validate the function of the mutations to determine if they produce the desired traits.
- Mutations identified in genes for high amylose (developed by UC-Davis) and drought stress tolerance (developed at CSU) continue to be transferred to elite wheat germplasm for trait validation. The high amylose traits were backcrossed to Snowmass and materials are currently in the field for validation. The drought tolerance traits were also backcrossed to Snowmass and doubled haploids are currently being generated for trait validation.

Russian Wheat Aphid Resistance

The objectives of this program are to incorporate Russian Wheat Aphid (RWA) resistance into our germplasm and ultimately develop improved varieties carrying RWA resistance. Due to much lower RWA incidence in recent years and inexpensive chemical control options, RWA resistance now occupies a somewhat lesser position among our program's breeding objectives. We will continue to address RWA resistance, however, as uncertainties exist with regard to the future importance of RWA in Colorado and the economics and availability of chemical control options. All of our RWA resistance effort is done in close collaboration with Frank Peairs and his team (BSPM Department).

Selected activities, highlights, and accomplishments of our program are as follows:

- Over the last few years we have developed and tested many experimental lines carrying RWA Biotype 2 resistance. None of the lines have been yield-competitive with our best varieties (Byrd HRW or Antero HWW) and thus none have been advanced toward larger scale seed increase. In order to move the "RWA yield curve" forward a bit more rapidly, we are generating a limited of number of doubled haploid (DH) lines from crosses with different sources of the *Dn7* resistance gene. The first of these is a group of DHs that are planted in multi-locational trials in 2014.
- In 2013, we conducted field trials of a group of near-isogenic lines derived from backcrossing a modified version of *Dn7* into Bill Brown. This source of resistance has now been transferred to Byrd and Antero and resistant selections were planted in the field in fall 2013.
- In addition to RWA, we are also pursuing wheat stem sawfly (WSS) resistance as a formal breeding objective. Terri Randolph from Frank Peairs' team helped to coordinate solid stem evaluations of materials growing at Fort Collins. Using conventional and DH methods, we hope to rapidly develop

semi-solid or solid-stemmed varieties that provide some protection against WSS and show better performance in Colorado than the Montana varieties.

End-Use Quality Improvement

The objectives of this program are to conduct end-use quality evaluations on experimental lines in our breeding program and those collected from the state dryland (UVPT) and irrigated (IVPT) variety trials. We are also engaged in several other research areas that are not focused directly on line selection but are complementary to the quality improvement efforts in the breeding program.

Selected activities, highlights, and accomplishments of our program are as follows:

- End-use quality evaluations are done annually on samples from a variety of different field trials and research studies. In 2012, 6,950 total samples went through our lab for one or more different tests. Our quality testing capacity is second to none in the Great Plains region, including the full spectrum of quality tests such as: NIR, single kernel characterization system (SKCS), Mixographs, polyphenol oxidase (PPO), and Quadrumat Senior milling and pup-loaf baking tests. Our overall strategy in breeding line evaluation is to properly characterize experimental lines in order to inform the line selection and seed increase decision-making processes.
- Comprehensive milling and baking quality evaluations (as described above) are done annually on selected locations of the state dryland (UVPT) and irrigated (IVPT) variety trial program. Data from these evaluations are reported in the *Making Better Decisions* booklet and are also used to develop and update the milling and baking quality scores that are reported in the "Variety Characteristics Table" in the *Making Better Decisions* booklet.
- From trials in 2012, we obtined NIR protein content from every plot of five locations of the CSU Elite Trial (750 total samples) and from every plot of our genomic selection training panel grown at Akron and Fort Collins (3,500 total samples). From trials in 2013, we are doing NIR protein on over 1,800 samples from six locations of an advanced doubled haploid trial. Our objective is to begin to use "grain protein deviation" (protein content adjusted for grain yield) as a measure of nitrogen use efficiency (NUE) and eventually develop genomic selection (GS) prediction models for NUE selection in the breeding program.

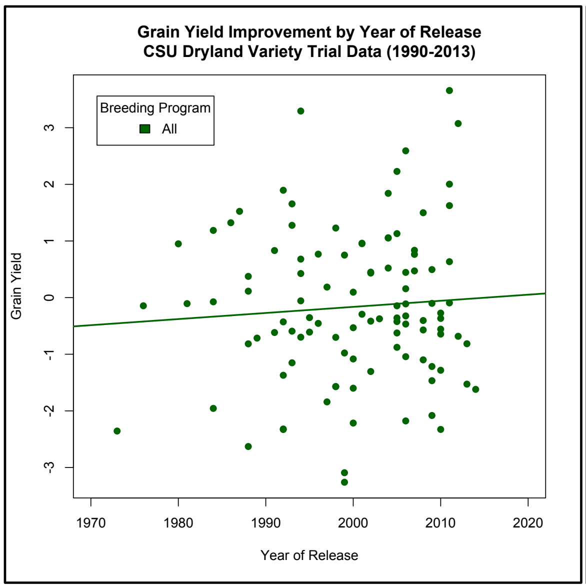
Scott Haley's Sabbatical Leave

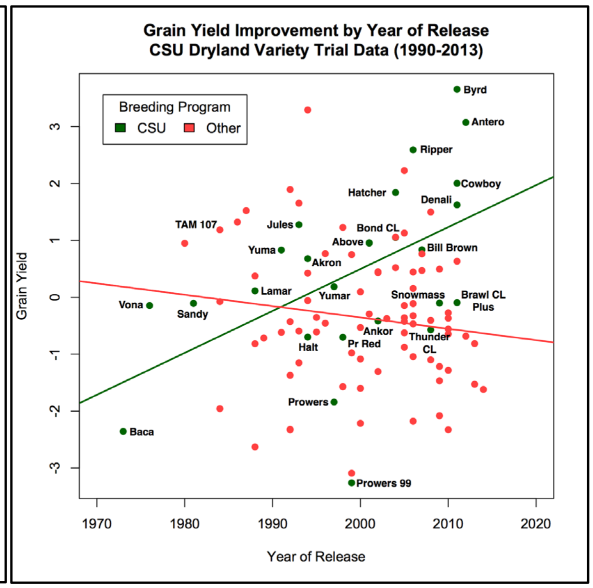
I recently returned from a six-month sabbatical leave in Europe. I spent the first three months (December 2013 – February 2014) in Bologna Italy at the University of Bologna and the second three months (March 2014 – May 2014) in Norwich England at the John Innes Centre. Sabbatical leave is a privilege extended to tenured faculty members at universities like CSU. This is the second sabbatical leave that I have taken in my 21 years as a wheat breeder, the first being to Australia eight years ago. With both of my sabbatical leave opportunities, I have tried to learn new things that I can bring back to CSU to help make our breeding program better. Sabbatical leave is also a time to "get away and refresh", meet new people, and see new things. While on sabbatical I had the opportunity to visit wheat breeding programs both in Italy and the UK (which have all been privatized) and give many presentations about our wheat breeding program at various scientific meetings and other settings.

One of the main things I focused on during sabbatical is coming up to speed with new software for analysis of genomic and plant breeding data. The software is called "R" and it is a too-long story to describe all the amazing things that it can do. One of the different types of analyses I have been working on with R is trying to determine if we are making any progress in grain yield improvement in wheat breeding at CSU. There are several ways of doing this, and the approach that I used is one that I learned about in Australia several years ago and was exposed to again during my sabbatical.

Essentially, the method allows one to combine an historical dataset over years and locations into one analysis. A perfect dataset for this is the variety trial data from the CSU Crops Testing Program (coordinated by Dr. Jerry Johnson) which for many years has served the Colorado wheat industry by providing an unbiased source of information on variety performance in Colorado. Curiously, this type of analysis enables direct comparison of varieties that have never been in the same trial together. While such comparisons are possible, I personally don't believe they are that useful or informative. The main objective of this type of analysis is to explore the pattern of yield improvement over time.

The varieties plotted in the graphs below include 104 wheat varieties released between 1973 and 2014. All varieties were tested in the CSU Dryland Variety Trials (HMVT, LMVT, UVPT) for at least three years. Varieties were developed by the CSU Wheat Breeding Program, other public programs in the region (TX, OK, KS, NE), and private breeding companies marketing varieties in the region. The data represented on the vertical (Y) axis are "yield values" which are really in units of "bushels/acre", although the statistical methods "shrink" these values toward the mean (which is represented by the zero point on the vertical axis). For example, the 6 bushels/acre difference between Byrd (2011) and Baca (1973) shown in this graph is likely less than what we would observe under typical conditions.





The graph on the left above shows all 104 varieties with the best trend-line ("regression") plotted between the data points. This slope of this graph is essentially zero, suggesting that virtually no genetic progress for grain yield has been made in wheat breeding for Colorado over the 40-year period from 1973 to 2013. The graph on the right above shows the trend-lines separated for the varieties from CSU and "Other" programs. While the slope of the trend-line for the "Other" programs appears to be negative, statistical analysis confirms that it is essentially zero, suggesting that virtually no genetic gain for grain yield in Colorado has been made by breeding programs based outside of Colorado. The slope of the trend-line for the CSU varieties, however, is positive and both significantly greater than zero and significantly greater than the slope of the "Other" breeding program line.

The conclusion to be drawn from these analyses is obvious. The CSU Wheat Breeding Program, with a program based on an extensive field trial system within Colorado, has been the best-positioned program to develop varieties adapted for the difficult climatic conditions facing wheat producers in Colorado. The support of Colorado wheat producers over the past 50 years that we have been breeding wheat in Colorado has been key to this success.

Wheat Quality Evaluations from the 2013 CSU Dryland and Irrigated Variety Trials

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Jerry Johnson, CSU Extension Agronomist

Introduction

End-use quality maintenance and improvement is an important objective of virtually all wheat breeding programs. Grain buying and end-use industries have become increasingly sophisticated in both domestic and export markets and, while wheat producers are seldom rewarded for improved functional quality, technological advancements promise to increase the ability of the trade to identify and source good quality and discount poor quality.

Breeding for wheat end-use quality is relatively complex in comparison to many common breeding objectives. Quality is a function of variety interacting with climate and agronomic practices and Colorado's harsh and variable climatic conditions often negatively impact quality. Quality assessment is commonly done through evaluation of multiple traits with many underlying genetic factor involved in expression of each. Most experimental quality tests only approximate average quality needs of product manufacturers and don't exactly match specific requirements of different wheat product types and processes. For hard winter wheat, high grain protein content is an important criterion for improved quality but is often associated with lower yields (and vice versa). Finally, wheat quality testing must accommodate the reality of large sample numbers and small sample sizes that are typical of all wheat breeding programs. Despite these challenges, standard testing methodologies have been developed that are consistent, repeatable, and can be done on large numbers of relatively small samples. These analyses provide reliable assessments of functional quality characteristics for a broad array of potential product types and processes.

Our objective with providing quality data and summaries for entries in the Colorado variety trials is to fully characterize the quality of public and private trial entries that are currently or have the potential to be marketed in Colorado. We hope that these data and ratings will be included among the criteria by which wheat producers make their variety selection decisions. At the very least, we encourage producers to carefully consider avoiding varieties that have lower wheat quality when other agronomically acceptable varieties with better quality are available.

Testing Methodology

In 2013, grain samples were collected from five dryland (UVPT) variety trial locations (Akron, Julesburg, Orchard, Roggen, Yuma) and two irrigated (IVPT) variety trial locations (Fort Collins, Haxtun). Preliminary small-scale quality analyses were carried out to determine sample suitability for full-scale analyses, with criteria including grain protein not too far below or above 12% grain protein content, sound grain free of visual defects, and good discrimination among samples at a given location for experimental dough mixing properties. In this process of sample selection, four of the dryland locations (Akron, Julesburg, Roggen, Yuma) were excluded from analyses beyond protein content with the primary problem being elevated protein values far above the level conductive for meaningful dough mixing and baking quality evaluations.

Using standard protocols, analyses were done in the CSU Wheat Quality Laboratory on samples from the remaining locations. These tests, reported in the attached tables, include the following:

<u>Milling-Related Traits</u>

- Test weight: obtained by standard methodology on a cleaned sample of the harvested grain.
- Grain protein and ash content: obtained by prediction using whole-grain near-infrared reflectance spectroscopy (NIRs) with a Foss NIRSystems 6500. Both grain protein and ash are reported on a standard 12% moisture basis. High grain protein content is associated with

higher water absorption of flours and higher loaf volumes in the bakery. Grain ash represents the remaining weight of a grain sample following incineration in a high-temperature oven. Millers prefer low wheat ash (values < 1.6%), as this tends to result in low-ash flour following milling and products with improved color properties.

- Single kernel characterization system (SKCS): the Perten SKCS 4100 provides data on kernel weight and hardness of a grain sample. From 100-300 kernels are analyzed to provide an average and a measure of variability (standard deviation, STD) for each trait. Millers prefer a uniform sample with heavier (>30 grams/1000 kernels) kernels for improved milling performance. Hardness should be representative of the hard winter wheat class (60-80 hardness units).
- Flour yield: obtained using a modified Brabender Quadrumat Milling System. Flour yield represents the percentage of straight grade flour obtained from milling a grain sample (approximately one pound). In general, millers prefer high flour extraction percentage with low flour ash values. Due to variation among different milling systems, valid comparison of values from different mills and establishment of a single target value is not possible.

Baking-Related Traits

- Mixograph mixing time and tolerance: obtained using a National Manufacturing Computerized Mixograph. The Mixograph measures the resistance of dough during the mixing process. Bakers generally prefer flours with moderate mixing time requirements (between 3 and 6 minutes) and good tolerance to breakdown of the dough with overmixing (subjective score >3). Some varieties with exceptionally long mixing times (i.e., Snowmass, Thunder CL) may not compare favorably with other varieties in conventional evaluations but have unique characteristics that merit handling in an identity-preserved program such as with the CWRF ConAgra Mills Ultragrain® Premium Program.
- Pup loaf bake test: using a 100-gram straight-dough test, data on bake water absorption, mixing time, loaf volume, and crumb characteristics are obtained. In general, bakers prefer higher water absorption (> 62%), high loaf volume (> 850 cubic centimeters), and a higher crumb grain score and crumb grain color (score > 3). The crumb grain and color scores are subjective assessments of the color and size, shape, and structure of the small holes in a slice of bread.

Composite Scores

Because none of the traits measured can be used alone to represent overall milling or baking quality, development of a composite score may be used as a means to differentiate and characterize quality of different samples. The development of a composite score also has the advantage of "smoothing" out differences in environmental conditions from year to year and utilizing all of the data generated on the samples from year to year.

Composite scores are generated through a two-step process. First, each trait is ranked from high to low (or "good" to "bad") at individual locations and a score from 1=good to 9=bad is assigned to each variety for each trait. Second, these individual-trait scores are used to generate a composite score that weights the trait scores by the relative importance of that trait to overall milling or baking quality. The weights that we have used are similar to those developed by the USDA-ARS Hard Winter Wheat Quality Laboratory for the Wheat Quality Council evaluations. These weights are as follows:

Milling – test weight 30%, grain protein content 10%, kernel weight 20%, grain hardness 10%, flour yield 20%, grain ash content 10% (100% total)

Baking – bake absorption 20%, Mixograph mixing time 20%, Mixograph tolerance 20%, loaf volume 20%, crumb color 10%, crumb grain 10% (100% total)

Wheat Milling and Baking Quality Data - 2013 Orchard

* Value in **bold** indicates superior value, value in *italics* indicates inferior value.

Entry	Test Weight	Grain Protein	SKCS Weight	SKCS Hardness	Flour Yield	Grain Ash	Bake Absorption	Mixograph Mix Time	Mixograph Tolerance	Loaf Volume	Crumb Color	Crumb Grain	**Milling Score**	**Baking Score**
1863	57.1	**13.9**	20.3	64.3	**69.6**	**1.32**	63.6	3.30	3	810	4	3	**3**	**3**
Above	*54.8*	**14.9**	19.9	73.4	*66.3*	1.58	**65.6**	*2.21*	3	*695*	*2*	*2*	6	6
Antero	57.5	12.7	22.5	67.7	**70.6**	**1.47**	*60.7*	**4.40**	4	*720*	*2*	*2*	**2**	5
Bearpaw	*55.1*	**13.9**	*18.4*	*84.3*	**69.8**	1.63	63.7	**4.22**	*2*	**950**	**5**	4	6	**1**
Bill Brown	57.3	*12.1*	*19.2*	*81.4*	*67.1*	*1.66*	62.6	**3.67**	**5**	750	3	3	*7*	**3**
Bond CL	*53.2*	**14.4**	20.5	64.5	*63.8*	1.63	**66.5**	**4.28**	4	845	3	3	*9*	**1**
Brawl CL Plus	**58.4**	13.7	**23.6**	71.3	**70.6**	*1.65*	**64.7**	**4.04**	4	**945**	**5**	4	**1**	**1**
Byrd	56.2	*12.2*	20.2	69.5	**70.7**	1.58	*61.7*	5.61	**5**	**975**	**5**	4	**3**	**2**
Clara CL	**59.4**	12.8	22.8	74.1	**69.5**	1.59	62.9	**4.69**	4	870	4	3	**1**	**3**
Denali	**57.9**	13.4	22.0	71.6	68.0	1.63	63.7	3.29	3	*730*	*2*	*2*	**2**	5
Freeman	*53.9*	13.1	20.8	*57.3*	68.2	1.52	**64.6**	*6.21*	**5**	795	3	3	*8*	4
Gallagher	56.8	*11.8*	21.4	76.7	*66.7*	*1.71*	*60.4*	**4.58**	4	*725*	4	3	*7*	5
Hatcher	56.4	13.0	21.9	67.8	68.6	1.53	*61.7*	**3.82**	4	760	4	3	4	4
Iba	**58.3**	*12.4*	20.1	75.1	69.5	1.59	62.8	**3.98**	4	825	4	3	**3**	**3**
LCS Mint	**59.4**	12.6	**24.1**	70.5	**69.9**	**1.48**	62.7	5.21	4	**915**	**5**	4	**1**	**3**
LCS Wizard	*54.5*	**14.9**	*18.0*	70.1	**69.6**	1.57	**64.7**	*1.90*	*1*	*705*	*1*	*1*	5	*8*
McGill	55.2	12.8	20.0	68.0	**69.8**	**1.49**	63.7	**3.86**	3	805	3	*2*	4	**3**
Oakley CL	**57.9**	13.3	22.4	79.9	69.3	1.57	**64.6**	**4.17**	4	875	**5**	4	**3**	**1**
Protection	*54.7*	13.6	21.6	69.1	69.4	1.52	**66.0**	2.50	3	*675*	*2*	*2*	4	5
Ripper	*54.6*	*11.8*	**24.1**	65.1	68.9	1.50	62.5	**3.64**	4	750	4	3	5	4
Robidoux	57.3	*12.2*	22.7	72.6	**69.7**	1.54	*60.8*	4.96	4	**910**	**5**	4	**2**	**3**
Settler CL	*55.1*	**15.0**	22.3	66.4	68.9	*1.66*	**66.7**	5.52	**5**	**910**	4	3	4	**1**
Snowmass	*53.7*	13.3	*19.3*	73.7	*65.2*	1.61	**65.2**	*11.62*	**6**	**990**	**5**	**5**	*9*	**1**
SY Wolf	**59.2**	*12.2*	**23.6**	77.3	**70.2**	1.59	*59.7*	**4.62**	*2*	790	3	3	**1**	6
T153	*55.1*	**13.9**	21.2	70.7	*64.2*	1.59	63.7	2.83	3	*725*	*2*	*2*	6	5
T154	56.8	13.6	21.4	67.8	67.5	1.52	62.7	2.98	*2*	*730*	3	3	4	6
T158	56.7	*12.0*	22.3	68.3	68.2	1.54	*60.8*	3.37	3	750	*2*	*2*	4	6
T163	56.5	*11.7*	21.5	63.6	69.0	**1.44**	*59.8*	5.15	4	845	**5**	4	4	4
TAM 111	57.2	**14.6**	21.9	67.3	68.8	*1.69*	**64.7**	2.88	3	770	3	*1*	**3**	5
TAM 112	55.4	13.4	*19.5*	77.8	*62.7*	*1.73*	**65.4**	**3.86**	4	825	4	3	*8*	**1**
TAM 113	57.1	12.7	21.6	71.4	68.3	1.50	63.7	3.34	3	880	**5**	3	4	**3**
WB-Grainfield	*55.1*	*12.2*	20.3	71.4	68.3	**1.47**	*60.6*	2.50	*2*	750	*2*	*2*	5	*8*
Winterhawk	57.7	12.5	**23.9**	73.5	**70.6**	1.55	62.8	3.36	3	835	4	3	**2**	4
Average	56.4	13.1	21.4	71.0	68.4	1.57	63.2	4.14	3.5	813	3.5	2.9		
Minimum	53.2	11.7	18.0	57.3	62.7	1.32	59.7	1.90	1	675	1	1		
Maximum	59.4	15.0	24.1	84.3	70.7	1.73	66.7	11.62	6	990	5	5		

Wheat Milling and Baking Quality Data - 2013 Fort Collins

* Value in **bold** indicates superior value, value in *italics* indicates inferior value.

Entry	Test Weight	Grain Protein	SKCS Weight	SKCS Hardness	Flour Yield	Grain Ash	Bake Absorption	Mixograph Mix Time	Mixograph Tolerance	Loaf Volume	Crumb Color	Crumb Grain	**Milling Score**	**Baking Score**
Antero	60.1	14.7	32.3	64.1	**73.6**	1.54	62.9	**2.35**	*0*	965	**5**	3	**3**	5
Armour	59.4	15.7	29.7	74.5	72.9	**1.43**	63.1	**2.35**	*0*	**1105**	**5**	3	4	4
Bond CL	60.5	*13.9*	31.5	67.7	*70.1*	1.56	*62.0*	**2.21**	*1*	1025	**5**	4	4	4
Brawl CL Plus	60.5	15.2	31.6	68.6	72.6	1.52	64.1	**2.31**	*0*	**1160**	**5**	3	**2**	**2**
Byrd	60.5	*13.9*	30.1	65.1	**75.8**	**1.39**	62.9	3.18	3	1025	**5**	3	**2**	4
Denali	**61.2**	**15.7**	29.9	67.6	*70.2*	*1.67*	64.4	**2.13**	*0*	*870*	4	3	4	5
Freeman	*57.0*	15.5	*28.0*	62.8	72.0	1.54	**65.9**	3.19	*2*	975	4	3	*8*	**3**
Hatcher	60.4	*14.2*	31.2	65.3	72.3	1.47	64.0	**3.02**	3	1005	**5**	3	**3**	**3**
Iba	**61.9**	14.6	**32.7**	67.1	**73.6**	1.59	62.9	**2.32**	*0*	1070	**5**	3	**1**	4
LCS Wizard	59.3	14.7	*27.7*	75.1	73.0	1.46	64.1	**1.70**	*0*	*760*	4	3	5	*7*
McGill	*58.2*	14.8	29.4	68.2	72.0	**1.44**	63.2	**1.82**	*0*	950	**5**	**5**	5	5
Robidoux	59.1	15.0	29.5	64.3	**73.8**	**1.39**	**65.1**	**2.96**	*2*	**1170**	**5**	4	**3**	**1**
Settler CL	59.9	*14.2*	**32.5**	67.2	72.9	1.56	*61.8*	**2.77**	*1*	1050	**5**	3	**3**	5
SY Gold	59.0	**16.3**	*27.3*	*83.8*	*70.8*	*1.63*	**67.0**	**2.85**	*2*	*860*	4	3	*7*	4
SY Wolf	59.2	**16.8**	29.1	70.5	*68.9*	*1.76*	64.8	**2.23**	*0*	*920*	4	*2*	6	5
T153	58.6	*14.2*	**32.8**	68.9	*69.2*	1.50	*59.7*	**1.81**	*0*	*805*	**5**	3	6	*8*
T158	59.9	15.5	30.3	70.9	73.0	1.55	64.4	**1.76**	*0*	950	**5**	3	**3**	5
TAM 112	**61.1**	14.9	**34.3**	75.7	71.4	1.51	63.9	**2.71**	*2*	1000	**5**	3	**2**	**3**
TAM 113	60.5	**16.1**	30.6	71.9	71.9	1.51	**65.8**	**1.98**	*0*	**1115**	**6**	3	**3**	**2**
TAM 304	58.6	15.1	*27.3*	*81.8*	72.1	1.56	63.9	**2.37**	*0*	**1100**	**5**	4	*7*	**3**
Thunder CL	59.9	*14.0*	**33.0**	65.8	72.3	**1.44**	*62.5*	**2.80**	*1*	**1150**	**6**	3	**3**	**3**
WB-Cedar	*58.3*	14.4	**32.9**	69.0	72.0	1.59	*62.0*	**1.84**	*0*	940	4	4	4	6
Yuma	58.9	15.1	*28.4*	66.8	*70.5*	1.55	**66.1**	**2.20**	*2*	**1115**	**6**	**5**	6	**1**
Average	59.6	15.0	30.5	69.7	72.0	1.53	63.8	2.39	0.8	1004	4.9	3.3		
Minimum	57.0	13.9	27.3	62.8	68.9	1.39	59.7	1.70	0	760	4	2		
Maximum	61.9	16.8	34.3	83.8	75.8	1.76	67.0	3.19	3	1170	6	5		

Wheat Milling and Baking Quality Data - 2013 Haxtun

* Value in **bold** indicates superior value, value in *italics* indicates inferior value.

Entry	Test Weight	Grain Protein	SKCS Weight	SKCS Hardness	Flour Yield	Grain Ash	Bake Absorption	Mixograph Mix Time	Mixograph Tolerance	Loaf Volume	Crumb Color	Crumb Grain	**Milling Score**	**Baking Score**
Antero	59.1	*11.5*	31.0	*54.7*	**75.2**	1.57	*57.8*	**3.63**	*2*	765	3	*2*	5	5
Armour	58.0	11.9	31.3	63.6	75.1	1.56	*57.0*	**3.69**	*2*	765	3	4	4	5
Bond CL	58.6	12.1	31.1	64.6	*72.7*	1.56	**61.1**	**3.00**	3	860	4	3	5	**2**
Brawl CL Plus	**60.2**	**13.6**	**35.0**	65.3	74.4	1.58	60.2	2.72	*1*	**880**	4	4	**1**	4
Byrd	57.5	12.5	*29.6*	60.0	**75.8**	1.56	60.3	4.41	4	**945**	4	4	5	**1**
Denali	*57.1*	**14.3**	*29.5*	66.0	*72.0*	*1.79*	**63.2**	**3.45**	3	*720*	3	*2*	*7*	**2**
Freeman	*53.2*	**14.0**	*27.8*	64.3	*71.5*	1.59	**64.9**	4.35	4	**875**	*2*	*1*	*8*	**2**
Hatcher	*54.8*	**13.2**	*26.9*	64.2	*71.9*	**1.47**	**61.8**	**3.95**	4	**875**	3	*2*	*8*	**2**
Iba	58.5	**13.1**	*30.2*	61.7	**75.6**	1.62	60.1	**3.25**	*2*	790	3	*2*	4	4
LCS Wizard	**60.7**	11.7	32.4	70.7	74.4	1.64	*57.3*	2.21	*1*	*675*	3	*1*	**3**	*9*
McGill	58.9	*11.0*	31.3	64.8	73.7	1.52	*58.0*	**3.45**	*2*	*720*	3	*1*	4	6
Robidoux	58.7	*11.3*	31.6	*59.0*	74.7	1.55	59.1	**3.65**	4	835	**5**	4	4	**2**
Settler CL	59.0	12.9	33.0	68.3	74.8	*1.73*	**62.1**	4.34	3	**895**	4	3	4	**2**
SY Gold	**60.3**	11.8	**34.5**	68.8	74.2	*1.72*	*58.0*	**3.66**	3	*685*	4	3	**2**	5
SY Wolf	**60.3**	11.9	33.3	73.0	74.4	1.65	*58.2*	**3.75**	*2*	760	4	3	**3**	5
T153	59.1	12.3	**34.6**	64.0	*72.7*	1.53	59.9	**3.26**	3	765	**5**	3	**3**	**3**
T158	**60.4**	11.7	**37.7**	*56.9*	**75.7**	1.55	*57.1*	**3.15**	*2*	765	4	3	**1**	5
TAM 304	*56.9*	12.2	30.9	68.5	73.6	**1.47**	59.0	**3.38**	*1*	825	4	3	5	4
Thunder CL	57.7	12.6	*29.9*	70.6	74.0	**1.51**	**62.2**	**3.99**	4	815	4	3	5	**2**
WB-Cedar	59.2	*11.4*	**39.1**	*57.2*	74.1	1.62	*57.1*	**3.38**	*2*	*675*	3	*2*	**3**	6
Yuma	59.0	12.7	**34.0**	66.8	72.9	1.54	**61.2**	**2.75**	3	835	**5**	*2*	**3**	**2**
Average	58.4	12.4	32.1	64.4	74.0	1.59	59.8	3.50	2.6	796	3.7	2.6		
Minimum	53.2	11.0	26.9	54.7	71.5	1.47	57.0	2.21	1	675	2	1		
Maximum	60.7	14.3	39.1	73.0	75.8	1.79	64.9	4.41	4	945	5	4		

2013 Dryland and Irrigated Trial Protein Yield Results

The table below and the tables on the following page are included to present the grain protein results in a way that combines both the grain yield and the protein content percentage into a single measurement (protein yield in lb/ac). A high protein yield value can be due to either a high grain yield or a high percentage of protein in the grain. The Haxtun irrigated site had the highest protein yield (lb/ac), but the lowest protein content among the four locations. It may have had a lower protein content partially becuase of inadequate fertilizer for the high yield level that was achieved at the site. At Fort Collins, the high protien content shows that it had adequate fertilizer for the yield level acheived. The high yields at Haxtun and Fort Collins account for the higher protein yield, but we are mainly interested in protein yield for the varieties within each location or within a set of locations as presented on the next page.

Summary of 2013 Protein Yield Results Across Four Locations

Location	Yield[a]	Protein	Protein Yield[b]
	bu/ac	percent	lb/ac
Haxtun Irrigated	120.1	12.5	896
Fort Collins Irrigated	71.8	15.0	642
Julesburg Dryland	36.5	14.2	310
Orchard Dryland	32.4	13.1	252
Average	65.2	13.7	525

[a]Yields are averaged across all varieties in each of the four locations.

[b]Protein yield is calculated by multiplying the grain yield by the percent protein.

Summary of 2013 Dryland
Variety Protein Yield Results at Two Locations
(Julesburg & Orchard)

Variety[a]	Yield[b]	Protein	Protein Yield[c]
	bu/ac	percent	lb/ac
SY Wolf	**42.1**	13.3	**338**
Antero	**41.2**	13.4	**334**
Oakley CL	38.7	14.0	**325**
Clara CL	**39.4**	13.6	**319**
CO07W722-F5	38.0	13.8	**316**
Ripper	**39.8**	13.0	**314**
Bill Brown	**39.1**	13.0	**308**
Winterhawk	37.4	13.5	304
Robidoux	38.5	13.1	302
Byrd	38.9	*12.9*	301
Denali	36.8	13.5	298
Brawl CL Plus	34.2	**14.3**	293
WB-Grainfield	36.4	13.3	293
McGill	36.1	13.4	292
TAM 111	33.1	**14.5**	287
Settler CL	33.6	14.2	284
LCS Mint	34.6	13.5	282
Bond CL	32.7	14.2	278
Hatcher	34.0	13.5	274
LCS Wizard	31.5	**14.5**	273
T163	34.9	*13.0*	273
NE05496	34.8	*13.0*	272
Above	31.7	**14.3**	270
T153	31.5	14.2	270
NI08708	33.2	13.4	270
T154	31.9	14.0	270
Bearpaw	30.8	**14.3**	265
TAM 112	31.5	13.9	264
1863	31.3	14.0	263
T158	32.7	13.2	258
Freeman	30.8	13.5	*250*
Protection	*29.8*	13.9	*249*
Snowmass	*29.3*	13.6	*239*
Gallagher	*30.7*	*13.0*	*238*
Iba	*30.6*	*12.9*	*237*
TAM 113	*27.5*	13.5	*222*
Average	34.4	13.6	281
LSD (P<0.30)[d]			32

[a]Varieties ranked in descending order based on protein yield.

[b]Yields are from a single plot in each of the two locations.

[c]Protein yield is calculated by multiplying the grain yield by the percent protein to get pounds of protein per acre.

The top five values (except protein yield where values are

Summary of 2013 Irrigated
Variety Protein Yield Results at Two Locations
(Fort Collins & Haxtun)

Variety[a]	Yield[b]	Protein	Protein Yield[c]
	bu/ac	percent	lb/ac
Brawl CL Plus	**104.3**	**14.4**	**895**
Byrd	**108.9**	13.2	**857**
Settler CL	103.3	13.5	**833**
TAM 304	**103.4**	13.6	**826**
Bond CL	**104.7**	*13.0*	805
Antero	**106.1**	*13.1*	804
Iba	96.8	13.8	794
Denali	*88.6*	**15.0**	785
WB-Cedar	103.0	*12.9*	773
T158	99.4	13.6	773
Freeman	*87.8*	**14.7**	763
Hatcher	93.4	13.7	762
CO07W722-F5	96.7	13.7	755
Armour	95.1	13.8	751
NI08708	*86.0*	**14.8**	751
LCS Wizard	97.0	13.2	750
Thunder CL	94.7	13.3	748
Yuma	91.6	13.9	744
T153	95.8	13.2	743
NE05496	*86.1*	**14.4**	*740*
Robidoux	95.8	*13.1*	*738*
SY Gold	89.3	14.0	*716*
McGill	92.0	*12.9*	*690*
SY Wolf	*83.3*	14.4	*660*
Average	96.0	13.7	769
LSD (P<0.30)[d]			81

[a]Varieties ranked in descending order based on protein yield.

[b]Yields are from a single plot in each of the two locations.

[c]Protein yield is calculated by multiplying the grain yield by the percent protein to get pounds of protein per acre.

The top five values (except protein yield where values are separated by an LSD) for each variable are in bold, the bottom five are in italics.

[d]If the difference between two variety protein yields equals or exceed the LSD value, there is a 70% chance the difference is statistically significant.

Drought Stress Adaptation in Winter Wheat through Soil Microbial Interactions and Root Architecture

Patrick Byrne, Mary Stromberger, and Tiffany Weir

Plants cope with drought and other abiotic stresses by a variety of mechanisms that occur above and below ground. Below the soil surface, root length, density, and architecture may contribute to differences in drought tolerance. Recent studies have also revealed complex interactions with root-associated microbial communities that are correlated with tolerance to moisture stress. An important group of soil bacteria involved in plant abiotic stress tolerance is the ACC deaminase positive (ACC+) bacteria. These bacteria break down the precursor of ethylene (a stress hormone) through the action of their ACC deaminase enzyme. Studies in some plant species have shown that this results in greater root elongation and tolerance to water stress. We have initiated an interdisciplinary collaboration to investigate whether Great Plains winter wheat cultivars differ in their root characteristics and their ability to recruit bacteria that improve their drought tolerance.

Our preliminary data demonstrate that winter wheat cultivars differ in root length, biomass, and distribution, when grown in 1 m by 10 cm plastic tubes in a greenhouse. Cultivars classified as drought tolerant had greater lengths of small-diameter roots (which are more effective at water absorption) throughout the soil profile compared to the drought sensitive group. Some cultivars also showed evidence of greater proportions of their root systems allocated to deeper sections of the profile.

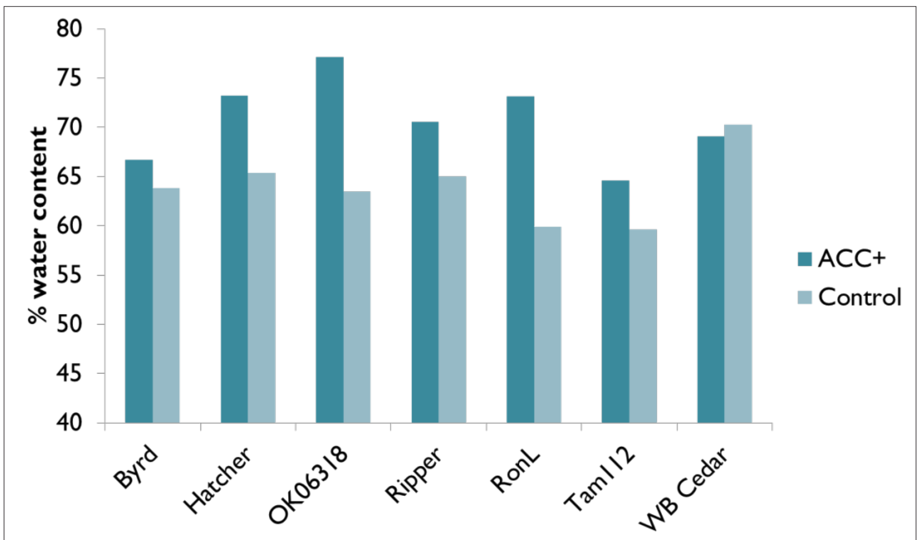

Figure 1. Leaf relative water content in water-stressed wheat cultivars inoculated with sterile water or with ACC+ bacteria (n=4). The main effect of inoculation was significant (*P*=0.03).

In a separate root tube study, seven wheat cultivars were grown with and without inoculation with ACC+ bacteria, under well-watered and drought stressed conditions. In the drought stressed treatment, the relative water content of leaves from the inoculated tubes was greater than in leaves from the non-inoculated tubes (Fig. 1), indicating that inoculated plants were better able to acquire or conserve water.

To determine whether wheat cultivars differ in the chemicals secreted by their roots, root exudates of cultivars RonL and Ripper were collected under limited hydroponic growth conditions and fractionated with polar, non-polar, and aqueous solvents. We discovered that the polar (ethyl acetate) fraction of RonL had a different chemical profile than that of Ripper (Fig. 2). When added to plant-free soil, this exudate fraction of RonL but not Ripper significantly increased the relative abundance of ACC+ bacteria (Fig. 3). These results support our hypothesis that root exudation in different winter wheat cultivars may influence the population of ACC+ bacteria in the rhizosphere, potentially improving plant fitness and productivity under conditions of drought stress.

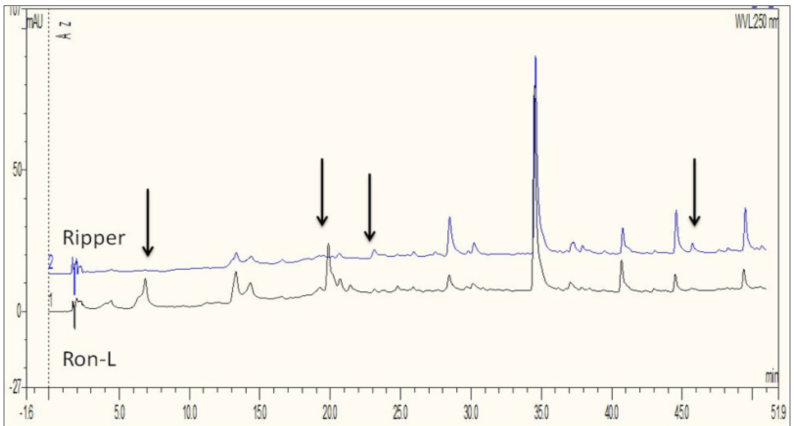

Figure 2. High Performance Liquid Chromatography data of root exudates of cultivars Ripper and RonL, showing quantitative and qualitative differences in their chemical profiles (indicated by black arrows) in 3-week old plants. The chromatogram is from the ethyl acetate extraction of pooled crude exudates from approximately 10 plants of each cultivar.

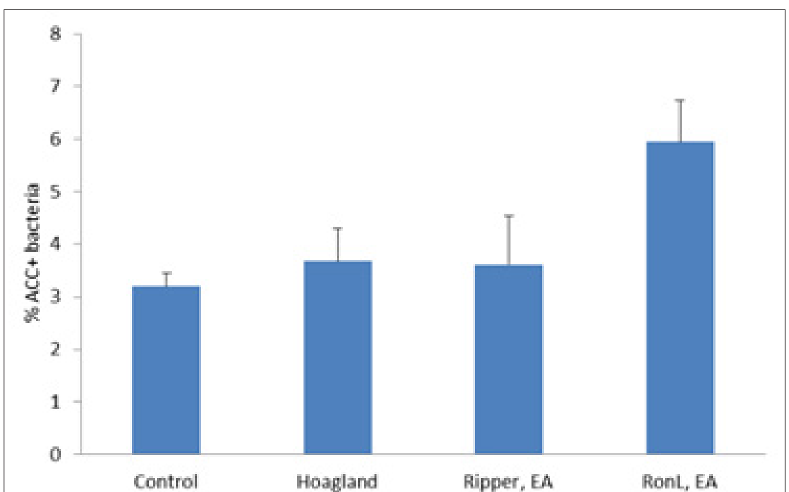

Figure 3. The percentage of ACC+ bacteria (relative to total culturable bacteria) in a Colorado soil following amendment with sterile water (control), sterile Hoagland solution (water + nutrients), ethyl acetate fraction of Ripper root exudates (Ripper, EA), and ethyl acetate fraction of RonL root exudates (RonL, EA).

Future studies will investigate the rhizosphere bacterial composition of 20 wheat cultivars in relation to yield performance and root traits under a range of moisture conditions in field trials. We will also examine in more detail the specific chemical differences in root exudates of different cultivars. If successful, these results may lead to breeding strategies that select plants for the most effective root exudate patterns.

Research reported here was partially funded by the CSU Water Center (http://watercenter.colostate.edu/) and by a grant from USDA-NIFA-AFRI.

Colorado State University
Extension

Wheat Stem Sawfly: A New Pest of Colorado Wheat

Fact Sheet No. **5.612** Insect Series | **Crops**

B. Irell and F. Peairs*

Introduction

The wheat stem sawfly is a native grass-feeding insect that has long been a threat to spring wheat production in the northern plains. In the early 1980s, however, it emerged as a significant pest of winter wheat as well. Since then, sawfly infestations in winter wheat have spread from North Dakota and Montana into southeastern Wyoming, the Nebraska Panhandle, and, most recently, northeastern Colorado. Damage to winter wheat was first reported in Colorado in 2010, from areas along Colorado Highway 14 in Weld County.

Identification/Life Cycle

The wheat stem sawfly produces one generation per year. Adults emerge in late May or early June and are generally active when winds are calm and field temperatures are above 50° F. The adult wheat stem sawfly (Figure 1) is about ¾ of an inch long with smoky-brown wings. It is wasplike in appearance, with a shiny black body with three yellow bands around the abdomen. When not in flight they often are found on wheat stems, positioned with the head pointed downward.

Figure 1: Adult wheat stem sawfly.

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Figure 2: Sawfly larva in stub.

Females lay eggs immediately upon emergence and typically live about one week. The adult emergence and flight period continues for 3-6 weeks. They are not strong fliers and usually only fly until they find the nearest wheat field or other suitable host grasses. In wheat, this often results in more serious problems occurring at the field margins closest to the adult emergence site, which is the previous year's wheat field. They preferentially select the largest wheat stems available and insert eggs into the first available internode or when a stem is fully developed, below the uppermost node. If sawflies are abundant, eggs may be laid in smaller stems, and multiple eggs may be laid in a single stem. However, only one larva will survive in each stem due to cannibalism. Females lay an average of 30-50 eggs, depending on the size of available host stems. Eggs are difficult to detect because they occur inside the stem.

Sawfly larvae are always found within the stem and will assume an S-shaped position when taken out of the stem. They move slowly down the stem as they feed, for approximately 30 days. Sawfly larvae (Figure 2) are cream colored, have a broad head, and are ½ to ¾ of an inch in length when fully grown. When they are mature they move down towards soil level and cut a V-shaped

Quick Facts

- The wheat stem sawfly is a native grass-feeding insect that emerged as a significant pest of winter wheat in Colorado in 2010.
- Adults emerge in late May or early June and are generally active when winds are calm and field temperatures are above 50° F.
- Several parasitic wasps attack wheat stem sawfly but the presence and effectiveness of natural enemies in Colorado has not been determined.

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notch around the interior of the stem. They then seal the interior of the stem just below the notch with frass and move down near the crown. The upper stem often breaks at this weakened notch just prior to harvest, and the remaining stem containing the overwintering chamber is referred to as the 'stub' (Figure 3). The larvae overwinter in the stubs, slightly below soil level, before pupating in early spring. They produce a clear protective covering that protects them from excess moisture and moisture loss.

Figure 3: Stubs in which wheat stem sawfly larvae overwinter.

Host Plants and Damage

The wheat stem sawfly has traditionally infested spring wheat, but over the last few decades the damage is becoming increasingly common in winter wheat. It also feeds in several hollow-stemmed non-cultivated grasses, including quackgrass, smooth brome and various wheatgrasses. It does not attack corn or broad leaf crops. Although the sawfly may lay eggs in other cereals, including barley, oat, and rye, larvae rarely mature in barley and rye and do not survive in oat.

Darkened areas on the stem, just beneath the node, indicate larval infestation. To verify the presence of the sawfly in a suspected plant, split the stem from top to bottom. A stem filled with a sawdust-like substance indicates feeding activity. The larva will most likely be located in a chamber within the stem, just above the crown.

The most visible wheat stem sawfly damage is stem breakage or lodging just prior to harvest (Figure 4). The stem is greatly weakened by the groove the larva cuts around the base of the plant. Lodging becomes more obvious as harvest approaches and results in yield loss of five to ten percent due to unrecoverable wheat heads because the combine cannot pick up the lodged stems. In addition, physiological damage caused by feeding activity results in yield losses of ten to twenty percent in infested heads that are harvested.

Management

Cultural Controls:

Tillage reduces wheat stem sawfly survival, however, its impact on overall sawfly abundance and on damage to the next wheat crop is variable. Shallow tillage after harvest lifts the crowns and loosens the soil around them. This maximizes the larvae's exposure to the late summer dryness and winter cold, increasing mortality. Intense tillage that buries stubble also reduces sawfly survival, but to a lesser degree. Intense tillage may interfere with important biological control agents and will increase the risk of soil erosion. No-till has been linked to many of the recent wheat stem sawfly problems in the region. However, the advantages of controlling the sawfly with tillage must be weighed against the considerable benefits of no-till.

Planting attractive varieties of trap crops such as barley, oat or rye along the edge of wheat fields may be effective in decreasing damage and reducing the number of sawflies the following year. The sawflies will oviposit in the trap crop, but the larvae will be unable to complete development. This method is especially effective when sawfly abundance is low to moderate and significant infestations are limited to the field margins. However, when sawflies are abundant, females may move past the trap crop and into the wheat to oviposit, resulting in significant damage.

Figure 4: Lodging caused by wheat stem sawfly.

Planting wheat in larger blocks as opposed to narrow strips is another cultural practice that may reduce sawfly damage potential. This minimizes the amount of field border adjacent to stubble where sawfly adults will be emerging, and thus, the part of the field most vulnerable to infestation. Sawflies are not strong fliers and tend to fly only until they reach a stem that is suitable for egg-laying, which is the basis for this practice. Though the soil erosion benefits of planting in narrow strips may be reduced, larger fields are still a viable option if erosion is addressed by no-till practices.

Resistant Wheat Varieties:

Solid stem varieties of wheat have been shown to be effective in reducing damage caused by the wheat stem sawfly. The availability of several adapted solid-stemmed wheat cultivars provides a viable management option for parts of the northern High Plains. In areas where the sawfly is a recent arrival, wheat breeding programs are beginning to focus on incorporation of the solid stem characteristic into adapted varieties, using both conventional selection and linked DNA markers. The program at Colorado State University also is initiating long term research into novel methods for making the wheat plant less attractive to the sawfly.

Biological Control:

Several parasitic wasps attack wheat stem sawfly on the northern plains, and these are thought to be important mortality factors. The presence and effectiveness of natural enemies in Colorado has not been determined.

Chemical Control:

Currently available insecticides are ineffective and cost-prohibitive. The most promising strategy seems to be control of adults to prevent egg-laying. However, the prolonged flight period likely would require repeated treatments and there is no evidence for the effectiveness of this approach. Using solid-stemmed cultivars and cultural controls are currently the most effective alternatives.

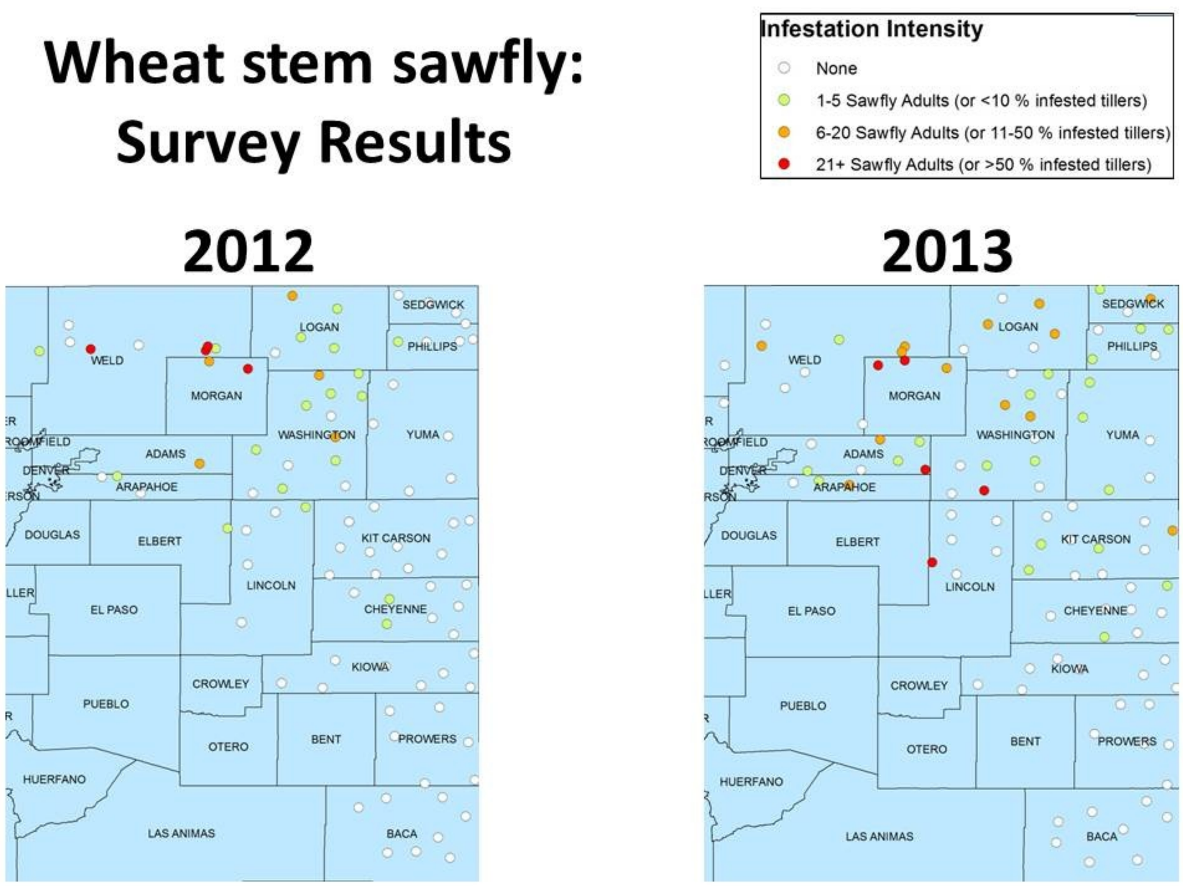
Wheat Stem Survey Addendum for 2013

Frank Peairs, Terri Randolph, and Ben Irell

Important questions with the emerging wheat stem sawfly problem are how far it will expand into Colorado and how long does it take from initial detection to economic infestations. We are trying to answer these questions with an annual survey. We survey about 100 fields in the main wheat producing counties for both adults and larvae. The two-year results are shown in the figure below.

Wheat stem sawfly infestations increased both in incidence and intensity over the two years. The most important observation is that the number of fields positive for larvae went from 14% to 36% from 2012 to 2013. Larval infestations are clear evidence that the detected sawflies have made the switch to winter wheat from grasses. Adults detected in wheat may have come from noncrop grasses and may or may not lay eggs in wheat plants. The lack of positive samples from the southeast may be related to poor growing conditions.

We plan to conduct this survey for at least two more years. However, it does seem clear that the wheat stem sawfly is making the switch to winter wheat in Colorado, and there is no indication that the expansion will not continue.



The Wheat Stem Sawfly
A New Pest of Colorado Wheat from an Old Colorado Insect

Courtney Jahn

Wheat stem sawfly (WSS) is one of the most important economic insect pests of wheat in the northern Great Plains. For decades, economic damage by WSS was restricted to spring wheat in the Prairie Provinces of Canada as well as in Montana and North Dakota in the U.S. More recently, damage in winter wheat in these areas has been observed. However, in 2011 major damage was first reported in winter wheat in Colorado, and subsequent field surveys found widespread WSS infestation and damage in eastern areas of the state. This represents a significant expansion southward for this insect and advances it toward the major winter wheat production area of the central and southern Great Plains.

The WSS life-cycle is complex and this has hindered control. The insect is a native to North America and was first described over 130 years ago after being collected from grass in Colorado. Extensive damage and economic losses in wheat were not reported until 1922, which was the first indication that the insect had jumped hosts and now preferred wheat over native grass species. The WSS life-cycle in wheat begins as adults emerge after overwintering as larvae in previous-year wheat stubble. Emergence in Colorado can happen as early as late April while in Manitoba, Canada, it may not occur until June or July. Mating takes place immediately after emergence and each female is capable of laying 50 eggs directly inside of wheat stems. New larvae begin feeding on stems directly after hatching and although multiple eggs often occur in the same stem, larvae will destroy other eggs until usually only one larva remains. Larvae feed within the stems until the wheat is nearly mature and towards the end of the season environmental cues trigger the larvae to move to soil level and cut a V-shaped notch around the interior of the stem. This girdled section is then filled with frass (polite term for insect excrement), which creates a protective solid plug in the wheat plant. The larvae overwinter in this wheat stub, pupate in the early spring, and new adults chew through either the frass plug or the side of the wheat stub to start the cycle again.

Losses from the WSS can be two-fold, first from stem feeding followed by cutting at the end of the season. The season-long stem feeding causes internal damage to the wheat plant and leads to significant reductions in the plant's ability to produce energy through photosynthesis. In addition, grain filling reductions due to feeding are typically 10 – 17%, but further reductions in yield can result from the combination of stem damage with drought stress. The late season stem-cutting (when the larvae girdle the plant in preparation for overwintering) results in additional yield losses and causes plants to lodge, especially under windy conditions. Stem-cutting can reduce yields up to 25-30%, mostly because it is difficult to harvest fallen stems efficiently. In cases where severe stem-cutting has occurred, in order to reduce losses at harvest, the field must first be processed with a swather equipped with a pickup reel and crop lifters. The extra labor required to harvest the fallen wheat crop adds additional fuel cost to the grower's budget and may also require the purchase and installation of equipment the grower does not already own.

Multiple cultural control strategies have been employed to try and reduce losses from WSS, but none have been able to provide complete control. Several cultural methods have attempted to reduce larvae numbers through removal of wheat stubs by burning or tillage. However, burning has had little to no effect on the pests in wheat stubble, and both burning and tillage methods have induced severe negative effects such as serious soil erosion. Another strategy altered field configurations to replace large monoculture areas with small strips of crop and fallow land, but these narrow strips were easily crossed by WSS and also impeded efficient wheat harvest. Additional cultural control methods include using trap crops, rotating out of wheat production for at least two years, increasing row spacing, and fine tuning crop nutrient management. These have met with varying success but none have been the silver bullet that effectively mitigates losses from WSS.

The use of insecticides to control WSS has also been investigated with varying results. Several studies in the U.S and in Canada have investigated the use of a systemic insecticide (Heptachlor), and showed considerable larval death. However, heptachlor was banned in the U.S. in 1988 because it was found to persist in the soil for decades. Additionally, as the sawfly completes 97% of its lifecycle protected inside of the wheat plant, it is doubtful that a pesticide can be developed that will not compromise grain safety. Further, these insecticides negatively impact other insects that are parasites of WSS larvae (called parasitoids). Spraying insecticides during adult WSS emergence might be effective, but would require excessive monitoring and precise timing, which may be difficult as the WSS and their parasitoids can emerge over a several-week period.

To date, the best control of the WSS is through plant resistance via the “solid-stem” trait. The wheat line S-615, released in 1949, contains a solid-stem trait that exhibits significantly reduced stem-cutting by WSS. Prior to 2010, all solid-stemmed varieties were derived from S-615, and this solid-stem trait is still used in modern spring and winter wheat varieties. However, WSS outbreaks persist due to incomplete resistance and low levels of adoption of solid-stem varieties by wheat growers. Additionally, it is believed that there is a fitness penalty to the solid-stem trait, as solid-stemmed varieties generally produce lower grain yields then their hollow-stemmed counterparts, although it is yet unclear why this is the case. Additional genes have been investigated, including those related to wheat volatiles (chemicals given off by wheat which make certain varieties more attractive to the WSS), but significant breeding in this area has not taken place.

In conclusion, despite a century-long effort to control WSS proliferation and countless efforts towards development of cultural, chemical, and biological controls, only host-plant resistance has proven to be both reliable and effective. The rich history of work in this area makes clear that there is a need to identify new plant-based control methods for the WSS. The combined efforts of several groups at CSU aim to tackle this problem through multiple strategies—including the identification of novel traits for plant resistance, understanding the insect’s life-cycle and southern expansion, as well as breeding efforts from existing traits and materials.

Improving Management of Herbicide Resistant Weeds in Colorado

Todd Gaines

As herbicides continue to be an essential tool for weed control, ongoing herbicide sustainability is essential in Colorado cropping systems. Research projects pertaining to the evolution and management of resistance in important species including kochia, Palmer amaranth, and barnyardgrass are ongoing in the CSU weed science program. Several Colorado kochia samples collected in 2011 showed glyphosate resistance when tested in glyphosate dose response studies in the CSU weed science greenhouse. Some individual plants survived up to 1.25 gallons of glyphosate, although the general level of increased resistance appears to be in the 3-6 fold range. The CSU weed science program is conducting surveys to understand the distribution of glyphosate-resistant kochia in Colorado and numerous studies to look for other herbicides that can be used to control this resistant kochia. We are also heavily involved in projects with the CSU Wheat Breeding program including spraying field plots of Clearfield breeding lines and developing novel herbicide resistance traits in wheat.

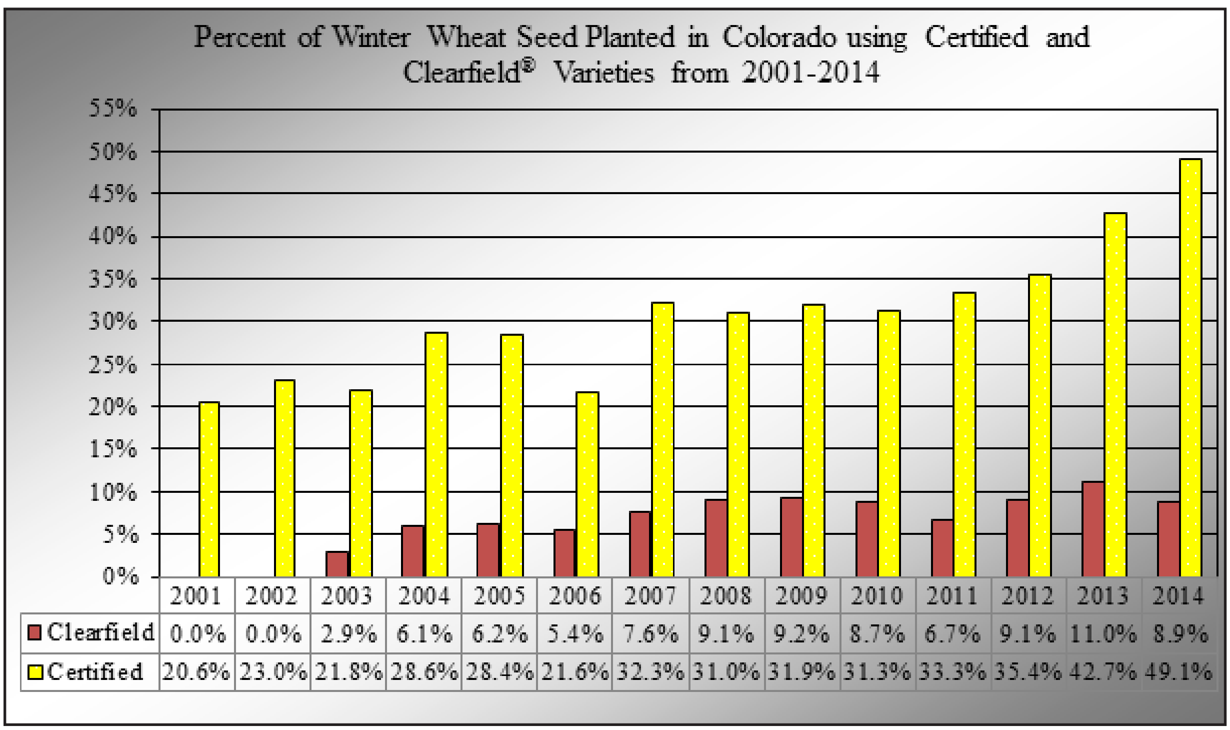
As the newest faculty member of the CSU weed science program, one of my major areas of interest is to design better weed management strategies by understanding the biochemical and the molecular basis of herbicide resistance. Some resistant weed populations rapidly break down herbicides, a process known as metabolic herbicide resistance. One category of enzyme in plants, known as P450 genes, are involved in metabolic herbicide resistance, and recently completed research has identified some of the specific genes involved in rigid ryegrass. In my research prior to joining CSU, I worked in a collaboration between the Australian Herbicide Resistance Initiative in Perth, Western Australia, and Bayer CropScience in Frankfurt, Germany, where we identified 57 different P450 enzymes in everyday ryegrass. The genes of two of these P450's were 'turned up' in resistant ryegrass. This allowed the resistant plants to produce more P450 and survive the herbicide diclofop. The susceptible ryegrass in the study also had the P450's that cause resistance, but these genes were 'turned up' only in the resistant plants. This is the first time that the genes in ryegrass likely responsible for metabolic resistance have been identified. We're planning similar research at CSU for glyphosate and dicamba resistance in kochia. The results will help improve monitoring and diagnosis of herbicide resistance.

The CSU weed science program is also initiating research into harvest weed seed control, which is an opportunity to target future weed populations. Many problematic weed species are prolific seed producers capable of establishing a large viable seed bank in just one season. However, in cases where high proportions of weed seed are retained on upright stems and tillers of weeds at crop maturity, then there is potential to target these seeds during grain harvest, restricting inputs to the weed seed bank.

Take a Few Notes!

Rick Novak

According to the USDA Agriculture Statistics Office, Colorado planted 2,850,000 acres of winter wheat in the fall of 2013. Colorado farmers increased their acres planted to winter wheat by over 600,000 acres from the previous year. As you may remember, 2013 was extremely dry in southeast Colorado with nearly 700,000 acres of wheat that were abandoned and not harvested. The continuing drought has created a shortage of farmer-saved seed. This shortage of saved seed along with new varieties that are available continue to fuel the demand for Certified Seed. Colorado wheat seed growers saw an increase of over 400,000 bushels of Certified Wheat Seed sold in 2013 when compared to the previous fall of 2012. The graph below reflects the steady increase in Certified Wheat Seed usage our Colorado seed growers have experienced over the last several years. This graph tracks the last 14 years of seed planting activity including the varieties that carry the Clearfield® trait. Colorado is currently close to achieving a level of 50% Certified Wheat Seed usage and of that total, nearly 9% were varieties tolerant to the Clearfield® chemistry. The values used in this graph were based on annual USDA fall planting acreage reports along with the Colorado Seed Growers Association annual seed distribution reports.



Farmers are innovative and will continue to look for ways to improve their agronomic practices. They will plant improved varieties that will help strengthen their financial bottom line. Every season more farmers are deciding to purchase Certified Wheat Seed because of one or several of the following reasons that they recognize as having significant value:

1. They want to plant the newer, higher yielding varieties with good disease tolerance that have been tested in our area and are known to perform well.
2. They recognize Certified Seed has been field inspected and the seed tag provides verification that it been tested for purity and germination.
3. Certified Seed is conditioned and ready to plant, making it very convenient and saving time and labor during the busy planting season. The practice saves labor costs.
4. Farmers recognize they are currently reaping the benefits of past research with the new, high-yielding varieties in the market. They realize purchasing Certified Seed supports public variety development with royalties that help fund research for the development of even better varieties in the future.

During this time of the year, many agronomic decisions such as variety selection, fertility applications, and tillage operations have already been made for the current season's crop. There are still a few weeks to go before harvest. Even though the crop is still developing, it is important to monitor and evaluate the crop while it grows. Farmers should not only be monitoring the progress, but should be evaluating performance of the individual varieties on the farm. Side-by-side comparison of varieties can be beneficial to future decision making. After all that is what variety testing is all about.

It will be useful in future decisions to collect some crop development and performance notes. Whether the issues that you deal with are fertility, insects, disease, limited irrigation, or drought there is a good probability that there will be differences in varieties within each crop that you grow. This season, adjust the work schedule to collect comparative information of the differing varieties in each crop on the farm. Factors like climate, rainfall, and soil type vary a great deal in Colorado and they can ultimately affect yield and bottom line. Farmers know that they can reduce potential risks by planting several different varieties and that variety selection should be based on sound information such as local test plot data in side-by-side trials. This summer there will be numerous Field Day plot tour opportunities for most of the crops that Colorado Farmers produce. Check with local seed suppliers or county Extension Agents for this season's field activities. It will be informative and beneficial. Mark the calendar to attend one or several local Field Day plot tours this summer.

Making Fertilizer Decisions During Drought

Jessica G. Davis

As the drought continues, many farmers are looking for ways to reduce risk and optimize yields. It may be tempting to cut back on your fertilizer program in order to reduce your costs this year. However, good nutrient management is key to optimizing water use, so be careful not to rush into any hasty decisions.

If you fertilized normally last season but experienced limited yields due to drought, there may be some nutrient storage left over from last year's applications. Soil sampling is extra important in a year like 2014 because of uncertainties about how much of last year's nutrients may still be available for this year's crops. In particular, there may be more nitrate (NO_3-N) left over than usual because of less rainfall, less crop uptake, and less leaching. So you may be able to cut back on your N fertilizer this year. But be sure to soil sample prior to making this decision!

Many studies on a variety of crops over the past 50 plus years have shown that optimal water use efficiency cannot be achieved without optimizing nutrient management. They are intimately linked. Proper fertilization removes limitations to plant growth, so plants are better able to respond to whatever rainfall or irrigation they do get. Applying fertilizer to move soil concentrations out of the deficient category and into the sufficient category will allow your crop to get the most yield out of every drop of water.

Nutrient management doesn't only supply nutrients to crops, but can also improve soil quality and alter the way that water cycles through soils. In particular, applying manure or compost has been shown to improve water infiltration into soils and reduce runoff losses from the soil surface. Reducing runoff increases potentially available water for crops. In addition, manure and compost applications also increase soil water retention, especially at field capacity, effectively increasing the amount of rainfall that is stored in the soil for crops to access.

Having a healthy root system is critical to maximizing the plants' access to stored soil water. Healthy roots need nitrogen (N) and phosphorus (P) to mine the water from the soil. A single N and P fertilizer application to the soil surface can increase wheat root growth down to a 3-foot depth! And, that increased rooting is directly related to enhanced water uptake and better yields.

Overall, be sure to avoid tunnel vision about rainfall. Of course, we need rain to get good yields, especially in our dryland crops. But rain, by itself, doesn't solve all of our problems (even though it may feel like it would!). We need to pay attention to soil fertility so the plants can perform their best with the water that they do have.

Meagan Schipanski
New Cropping Systems Faculty Member at CSU

I joined the CSU faculty in Fort Collins in January 2014. In addition to teaching courses on field crops, my research program is focused on the development of cropping systems adapted to semi-arid regions that are productive and profitable today and resilient tomorrow.

Coming to CSU feels a little like coming back home. I grew up in Manhattan, Kansas, and have three generations of family ties in Colorado. I spent the past 10 years in the humid east where I completed my Ph.D. at Cornell University and was a postdoctoral researcher at McGill University in Montreal, Canada, and Pennsylvania State University. Before starting graduate school, I spent 5 years farming that included 4 years managing field operations on a vegetable farm outside Chicago.

I have experience conducting research on farms and research stations. For my graduate research, I worked with grain farmers in New York to understand how crop rotations influence soil nitrogen and organic matter dynamics, including the use of red clover interseeded with winter wheat or spelt. The relationships I developed with these collaborating farmers were extremely rewarding and I hope to continue to do on-farm research. At Penn State, I collaborated with a diverse team to evaluate the potential of cover crops and cover crop mixtures to influence productivity, soil quality, and pest dynamics in annual dairy crop rotations.

As I shift my focus to semi-arid systems, I am particularly interested in opportunities for building and maintaining soil organic matter in dryland systems through residue management and using diverse crop rotations, including forage crops. In addition to maintaining surface residues, soil organic matter is the cornerstone of productive systems. My lab uses measurements that can serve as early indicators of changes in soil organic matter because total soil organic matter levels are slow to change.

I plan to integrate on-farm research with research at CSU research sites, including taking advantage of the long-term dryland cropping system sites initiated by Gary Peterson and Dwayne Westfall almost 30 years ago near Stratton, Sterling, and Walsh, Colorado. I also hope to collaborate with diverse teams of researchers, farmers, extension staff, and resource conservation staff, to understand how cropping systems management practices influence success from multiple angles, including economics, pest management, and soil ecology.

I look forward to working with the Colorado community of producers and I welcome your input and ideas. I can be reached at meagan.schipanski@colostate.edu.

Grain Protein Deviation: Finding High Grain Protein and High Yielding Varieties

Susan Latshaw, David Poss, Linda Hardesty, Merle Vigil, and Scott D. Haley

Introduction

Hard winter wheat produced in Colorado must have adequate protein concentration and good gluten strength to enter the commodity pipeline that ends with leavened breads and rolls. Growers are mostly interested in maximizing net returns per acre. Profitable crops have high grain yields and avoid price discounts for low protein levels. However, these traits are negatively related and it is difficult to simultaneously select traits that are genetically opposed. A solution to this selection dilemma was proposed whereby deviates from the regression of grain yield on grain protein were distinguished by high values for 'grain protein deviation (GPD)' (Monaghan et al., 2001). Grain protein deviation is assessed as standardized values of the difference of the data from the predicted relationship between grain yield (GY) and grain protein concentration (GPC). It therefore identifies genotypes that accumulate higher protein concentration than expected for a given yield level. Here we report on an assessment of GPD for 20 Great Plains adapted genotypes, grown under a range of nitrogen rates in the 2010-2011 growing season.

Methods and Statistical Analysis

Research was conducted at the USDA-ARS Central Great Plains Research Station, near Akron, CO. The experimental design was a split plot with three replications. Nitrogen fertilizer (main plot) was surface broadcast before planting at five rates: 0, 25, 50, 75, and 100 lbs N per acre as urea 46-0-0. The genotypes (sub plot) in the study were 20 hard red or white winter wheat varieties or CSU experimental lines. Best linear unbiased estimates (BLUEs) for N and genotype main effects for GY and GPC were calculated in the MIXED procedure of SAS (SAS version 9.3). Models included fixed effects for N rate, genotype, and their interaction and random effects for experimental design elements and a power anisotropic covariance adjustment for field spatial variability.

Standardized residuals for the least squares regression of GY BLUEs on GPC BLUEs were calculated with the function lm in the base R package (RCoreTeam, 2013) within each N rate and globally, across N rates, to obtain 'grain protein deviation' (GPD) values for each genotype. Following the methods of Oury and Godin (2007), the data were trimmed for three to six iterations of regression, where lines with GPDs that exceeded a threshold of 2.5% (residual>|1.96|) were removed. This procedure reduced the influence of unusual observations on the regression. Once the trimmed regression equation was determined for each data set, it was applied to all the genotypes in order to calculate the GPD from GPC BLUEs. The predicted protein concentration was subtracted from the GPC BLUE (y_i) to obtain the residual for the trimmed regression. The standardized residuals were then calculated as:

$$\text{GPD}_i = \frac{residuals_i}{standard\ deviation\ of\ residuals * \sqrt{\left(1 - \frac{predicted\ y_i}{y_i}\right)}}$$

Results and Discussion

The slope of the regression was significant for the combined data over all N rates and for the 25 and 100 lb/ac N rates. For the combined data, Brawl CL Plus and Jagger exceeded the 2.5% threshold of the Normal Standard for the standardized residuals in the positive direction (Figure 1a).

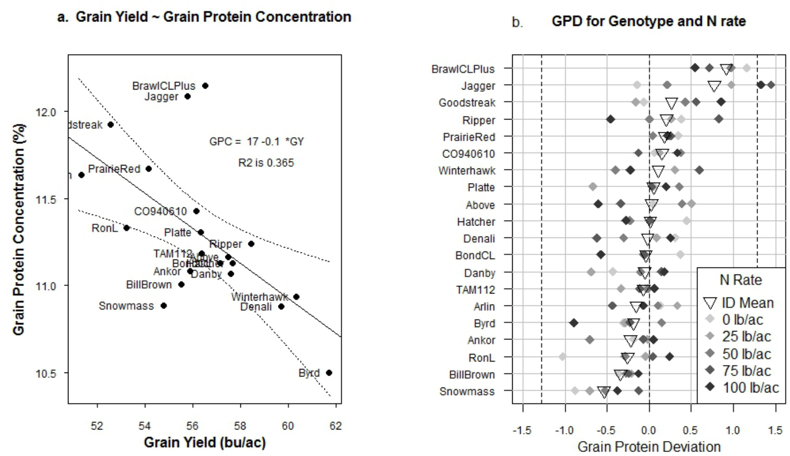


Figure 1. a. Regression of least square means for grain yield on grain protein concentration for 20 genotypes across five nitrogen rates grown at Akron, CO in the 2010-2011 growing season. The regression line is plotted, with 95% confidence intervals appearing as dotted lines. b. Standardized residuals for the trimmed regressions (GPD) for individual N rates and across all N rates (ID Mean). Genotypes are ordered by the GPD value calculated across all N rates. The 10% threshold of the Normal Standard is marked with a dashed line at 1.28.

GPDs within an N rate were most often of the same sign for the genotypes with the highest and lowest GPDs (Figure 2b). This non-random pattern is consistent with a genetic component for GPD. None of the genotypes in this study had extreme values for GPD (none exceed the 5% threshold of the Normal Standard, GPD>1.64). Earlier authors reported high GPD genotypes to be a rare occurrence (Monaghan et al., 2001; Oury and Godin, 2007). Extension of this analysis is underway for a set of 399 CSU breeding lines and released varieties to survey a larger sample of genotypes, among which may be lines with high positive values for GPD.

Given the complex of shared metabolic pathways contributing to GY and GPC and the vagaries of genotype by environment interactions, GPD provides an attractive measure for assessing those cultivars that accumulate higher protein than expected for a given yield level. GPD may be a useful index for facilitating the simultaneous selection of high grain yield and high protein concentration in the wheat breeding program.

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How Planting PlainsGold Seed Supports Public Wheat Breeding

Glenda Mostek

Hatcher. Ripper. Bill Brown. Snowmass. To winter wheat farmers in the high plains of Colorado, Kansas and Nebraska, these four varieties are legends for their reliability, yield and quality. And now new varieties Byrd, Brawl CL Plus and Denali are rapidly becoming an important part of wheat farmers' success. The wheat breeding program at Colorado State University (CSU) that developed them – and certainly the wheat farmers who supported the program individually and through the state checkoff – put a spotlight on this great public wheat-breeding program.

Actually, the CSU public wheat-breeding program has released more than 30 improved wheat varieties since 1963. The program delivered the first publicly-developed, two-gene Clearfield® wheat, which was released in 2011 under the name Brawl CL Plus. This was preceded by the launch in 2001 of the first ever Clearfield® wheat in the U.S., Above, and the first variety resistant to the Russian wheat aphid in 1995 – Halt.

Surprised? You aren't alone. And this concerned leaders at both the university and the Colorado Wheat Research Foundation (CWRF), especially as international powerhouses in corn and soybeans such as Monsanto and Syngenta began buying up regional wheat breeding companies in the past few years.

And so started the process resulting in the high plains' newest wheat brand with arguably the most proven varieties: PlainsGold.

Colorado has a very unique – and effective – collaboration between CSU and the Colorado Wheat Research Foundation (CWRF). CSU develops the varieties, and CWRF handles the public release and marketing. Royalties from seed sales are then reinvested into variety development at CSU, as well as testing and marketing.

In 2012, when PlainsGold was launched by CWRF, it caught the attention of private and public wheat breeding programs.

PlainsGold marketing included the first paid advertisement for any CSU-developed variety. This unique collaboration between CWRF and the university is now being looked at as a model by other states.

PlainsGold varieties are exclusively from the CSU wheat breeding program, and tested extensively in Colorado and surrounding states. All PlainsGold varieties have consistently performed well in the unique, and often difficult, wheat growing conditions prevalent across the high plains region. Plus many varieties offer unique options such as herbicide tolerance and premium programs that offer additional incentives for growing specific varieties.

According to information supplied by PlainsGold, "Our unique approach to wheat variety development is based on a firm foundation of field-testing. All PlainsGold varieties are tested in one of the country's strongest field-testing programs with more than 50 locations. Only the best varieties from these trials are released and all new and existing PlainsGold varieties continue participation in the testing program to provide wheat farmers across the high plains region with the yield and quality information they need to make informed decisions on their farm."

"Wheat breeders in our program have consistently made advances in wheat genetics ahead of most private research programs," said Dan Anderson, CWRF chairman. "These advances, combined with one of the largest trial programs in the country, ensure wheat farmers have high quality choices with the data they need to select a variety that aligns with their individual production goals."

Despite strong competitive pressure in Colorado and the high plains, PlainsGold varieties are on even more acres in 2014 than 2013. More than 61 percent of wheat acres in Colorado are currently planted in PlainsGold varieties. In fact, when looking at the nearly 50 percent of Colorado acres planted with certified seed, PlainsGold varieties are on 84 percent of those acres.

Now, PlainsGold is expanding into more states, including Kansas, Nebraska, Wyoming, Montana, South Dakota and Texas, as varieties prove themselves outside of Colorado. CWRF reports it added more than 20 new seed growers between Summer 2013 and Spring 2014.

PlainsGold, based in Fort Collins, Colorado, can be reached at 970-449-6994 or 1-800-WHEAT-10, or at www.plainsgold.com. The email address is info@plainsgold.com.

PlainsGold Hard Red Winter Wheat Varieties

PlainsGold's elite hard red winter wheat varieties combine impressive yields with disease resistance and outstanding quality traits.

Byrd
- High Dryland and Irrigated Yields
- Excellent Drought Tolerance
- Excellent Milling & Baking Quality

Brawl CL Plus
- Control Annual Grassy Weeds
- High Yields
- Excellent Test Weights

Denali
- High Dryland and Irrigated Yields
- Excellent Test Weights

Hatcher
- High Dryland Yields
- Good Drought Tolerance

PlainsGold Hard White Winter Wheat Varieties

Hard white winter wheat varieties remain an underserved market. PlainsGold is a leader in developing high-yielding hard white winter wheat varieties that are good for milling and baking. These hard white wheat varieties are sought after in the U.S. and abroad to make whole grain food products with a look and texture similar to refined flour. Often these varieties are in such high demand that they come with guaranteed premium pricing options. Snowmass, for example, is eligible for the CWRF/Ardent Mills Ultragrain® Premium Program.

Snowmass
- High Dryland Yields
- Premium Pricing
- Excellent Baking Quality

Thunder CL
- Premium Pricing
- Control Annual Grassy Weeds
- High Yields, Especially Irrigated

Antero
- High Dryland and Irrigated Yields
- Excellent test weight

Coming Soon!
A higher-yielding hard white wheat variety with Snowmass quality is currently being tested. Continue to look for updates, including a release date, online at www.PlainsGold.com.

Acknowledgments

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The authors are thankful for the cooperation and selfless contributions of land, labor, and equipment made by the following Colorado wheat farmers who consent to having winter wheat variety performance trials conducted on their farms: John and Jensen Stulp (Lamar, Prowers County), Burl Scherler (Brandon, Kiowa County), Dennis and Matt Campbell (Arapahoe, Cheyenne County), Randy Wilks (Burlington, Kit Carson County), Jim Carlson (Julesburg, Sedgwick County), Steve Boerner (Haxtun, Phillips County), Cooksey Farms (Roggen, Weld County), Ross Hansen (Genoa, Lincoln County), Cary and Todd Wickstrom (Orchard, Morgan County), and Bill and Steve Andrews (Yuma, Yuma County). We recognize valuable assistance provided by the CSU Extension agents who work with eastern Colorado wheat producers in all aspects of the COFT program. We are also very thankful for the efforts and sacrifices made by Colorado wheat producers who contributed time, land, and equipment to the success of the Collaborative On-Farm Test program.

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