CSU Wheat Breeding Program Update

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Outline

- Fall 2017 Cultivar Releases
  - Breck HWW – Ardent Ultragrain Premium Program
  - Incline AX – CoAXium Wheat Production System (http://coaxiumwps.com)
- 2018 Foundation Seed Increases
  - Hard red winter wheats
  - Hard white winter wheats
  - Herbicide tolerant wheats (*CoAXium*, *Clearfield*)
- Grain protein issues

Breck Hard White Winter Wheat
(Tested as CO12D2011)

- Parentage – Denali/HV9W07-482W//Antero
  - HV9W07-482W: Westbred experimental (KS01HW163-4/KS01HW168-4)
  - Denali, Antero: CSU releases 2011, 2012
- Selection and testing history
  - Cross made in 2011, doubled haploid made 2012 (HPI-Manhattan KS)
  - Yuma AZ seed increase and line selection 2013
  - Advanced Yield Nursery 2014
  - CSU Elite Trial 2015-2017
  - UVPT, IVPT 2016-2017
  - Regional cooperative breeder trial (SRPN) 2017
- Seed increase, purification, release
  - Breeder seed purification (Yuma AZ 2016)
  - Foundation seed increase (Fort Collins 2017)
  - Release approved July 2017

Table 2. Grain yield (bu/acre) and test weight (lb/bushel) of CO12D2011 and other entries in the CSU Elite Trial from 2015-2017. Values are multiple-location averages of best linear unbiased predictors (BLUPs) from spatial analyses of individual-location trial data. Data are ranked by the three-year average grain yield over 28 dryland locations in Colorado. The average, maximum, and minimum values are from the entire set of entries tested.

Entry	2015 Yield	2016 Yield	2017 Yield	3 Year Avg Yield	3 Year Avg TestWt	3 Year Yield Northeast	3 Year Yield Southeast	3 Year Yield Irrigated
Langin	67.7	82.3	70.2	73.8	57.4	75.0	70.4	87.3
Byrd	65.7	79.8	69.8	72.2	58.0	73.1	69.4	85.1
Antero	68.7	80.6	65.2	71.7	58.0	72.7	68.8	90.1
CO12D2011	66.0	79.3	67.4	71.2	59.6	72.1	68.8	90.2
Avery	64.6	78.1	68.3	70.7	57.4	71.6	68.2	86.3
WB-Grainfield	62.5	81.7	63.8	69.8	57.9	70.6	67.5	91.6
Denali	66.6	78.5	60.5	68.7	57.4	69.9	65.0	88.4
Snowmass	63.8	76.1	64.8	68.5	57.3	68.9	67.3	85.2
Sunshine	61.2	78.2	63.2	68.0	57.5	69.5	63.3	83.4
Brawl CL Plus	56.9	76.0	58.3	64.2	57.6	64.4	63.8	83.0
Average	63.0	78.1	64.9	70.3	57.7	71.2	67.6	87.2
Max	75.3	82.4	74.4	75.4	59.6	76.6	71.7	91.6
Min	51.4	73.5	48.7	64.2	56.8	64.4	63.3	83.0
Locations	8	10	10	28	28	21	7	6

Table 5. Grain yield (bu/acre) and test weight (lb/bu) summary of CO12D2011 and other entries in the dryland Uniform Variety Performance Trial (UVPT) from 2016 to 2017. Data are ranked by the two-year yield average across 16 trial locations.

Entry	2016 Yield	2016 TestWt	2017 Yield	2017 TestWt	Two-Year Yield	Two-Year TestWt	Two-Year Yield Northeast	Two-Year Yield Southeast
Langin	85.4	59.0	78.3	60.4	81.8	59.7	80.8	83.5
Antero	86.2	57.2	74.1	59.9	80.2	58.6	78.5	82.9
Avery	82.4	58.6	74.5	60.3	78.4	59.4	77.1	80.6
CO12D2011	83.2	60.1	73.1	61.5	78.1	60.8	77.8	78.6
Joe	81.7	58.7	74.2	60.0	78.0	59.3	78.9	76.5
Byrd	80.0	59.3	75.9	60.2	77.9	59.7	76.8	79.8
Sunshine	81.6	56.4	69.3	59.3	75.4	57.9	77.8	71.6
WB-Grainfield	81.5	59.4	69.4	60.7	75.4	60.0	75.4	75.5
LCS Mint	80.5	59.4	69.3	60.5	74.9	60.0	74.2	76.2
Oakley CL	78.8	58.4	70.2	59.9	74.5	59.1	74.9	73.8
Snowmass	75.4	58.8	71.7	60.0	73.5	59.4	73.0	74.4
Denali	79.3	59.5	67.3	59.4	73.3	59.5	73.2	73.5
Hatcher	82.6	57.7	63.4	59.2	73.0	58.5	71.8	74.9
Cowboy	79.8	56.8	63.6	57.7	71.7	57.2	69.3	75.7
SY Monument	78.1	58.2	65.2	58.6	71.6	58.4	70.8	73.0
TAM 114	80.7	60.6	61.8	60.2	71.2	60.4	71.7	70.5
Winterhawk	78.4	59.6	63.7	59.5	71.1	59.5	71.8	69.8
SY Wolf	74.9	56.1	66.4	59.6	70.6	57.9	71.9	68.4
Ruth	76.8	60.3	63.6	60.3	70.2	60.3	71.7	67.8
Brawl CL Plus	76.5	58.0	63.9	60.2	70.2	59.1	70.1	70.3
WB4721	78.2	60.4	60.7	60.6	69.4	60.5	68.8	70.6
LCS Chrome	75.6	59.1	61.6	59.4	68.6	59.3	67.9	69.7
Settler CL	76.8	57.7	60.2	58.6	68.5	58.2	67.6	70.1
Average	79.7	58.7	67.9	59.8	73.8	59.2	73.6	74.2
Locations	8	8	8	8	16	16	10	6

Table 6. Grain yield (bu/acre), test weight (lb/bushel), and lodging score (1=erect to 9=flat) summary of CO12D2011 and other entries in the CSU Irrigated Variety Performance Trial (IVPT) in 2016 and 2017. Data are ranked by the average yield across all six trial locations.

	2016			2017			Avg	Avg	Avg
Entry	Fort Collins	Haxtun	Rocky Ford	Fort Collins	Haxtun	Burlington	Yield	TestWt	Lodging
Denali	86.0	61.6	58.1	105.0	74.6	106.8	95.3	58.4	3.7
SY Sunrise	91.1	61.3	59.9	94.3	73.1	110.9	94.8	59.3	1.6
CO12D2011	83.5	61.2	61.8	94.9	78.0	118.9	93.9	59.0	3.8
WB4303	90.0	56.3	53.7	108.2	72.0	108.0	93.6	54.7	1.2
KanMark	83.8	57.9	58.5	103.0	68.5	111.6	93.0	57.1	1.7
SY Wolf	80.6	57.8	55.8	102.3	74.1	115.9	92.9	56.5	2.2
Langin	75.0	60.6	58.2	87.8	82.4	114.4	92.6	57.6	5.7
Brawl CL Plus	88.3	60.2	59.6	83.5	75.4	113.3	92.5	58.1	2.1
Byrd	74.8	60.2	59.9	96.2	78.8	110.1	91.2	57.8	5.3
Sunshine	63.4	54.4	55.5	74.4	74.1	116.1	90.2	54.7	4.3
Thunder CL	100.2	57.9	58.0	85.8	57.9	109.5	89.1	57.6	1.5
Avery	64.1	61.0	59.1	91.4	79.9	98.0	87.0	57.1	6.9
Cowboy	61.9	59.8	55.0	103.7	67.8	109.4	86.3	55.5	6.8
Antero	62.7	58.7	56.9	77.8	79.8	92.7	82.8	56.3	6.2
Average	79.0	59.2	57.9	93.5	74.0	109.7	91.1	57.1	3.8
LSD (0.30)	6.3	5.9	7.4	5.1	4.2	8.0			

Breck Hard White Winter Wheat

- Primary strengths
  - Higher dryland grain yield relative to both Snowmass and Sunshine and similar grain yield compared to Antero.
  - Higher irrigated grain yield relative to Sunshine and Thunder CL.
  - Milling and baking quality characteristics similar to Sunshine, with significantly lower polyphenol oxidase (PPO) concentration.
  - Very high test weight, excellent pre-harvest sprouting tolerance, and good straw strength.
  - Good stripe rust resistance (likely carries same two genes as Antero), and significantly better than Snowmass and Sunshine.
- Primary weaknesses
  - End-use quality, specifically water absorption and dough strength, is only to the level of Sunshine, but not Snowmass.

Incline AX Hard Red Winter Wheat (*CoAXium*)
(Tested as CO14A065)

- Parentage – (AF28/Byrd)/(AF10/2*Byrd) – about 66% Byrd
  - AF28: Hatcher derived line (A-genome *Axigen* trait)
  - AF10: Hatcher derived line (D-genome *Axigen* trait)
  - Byrd: CSU release 2011
- Selection and testing history
  - First crosses made fall 2010, last cross made spring 2012
  - Greenhouse increase fall 2012, greenhouse selection spring 2013
  - Yuma AZ seed increase and line selection 2014
  - Fort Collins herbicide tolerance trial 2015
  - CSU Elite Trial 2016-2017
  - UVPT 2016-2017
- Seed increase and purification
  - Breeder seed purification (Yuma AZ 2016)
  - Foundation seed increase (Fort Collins, Yuma AZ 2017)
  - Release approved July 2017

Table 4. Grain yield (bu/acre) and test weight (lb/bushel) of CO14A065 and other entries in the CSU Elite Trial from 2016-2017. Values are multiple-location averages of best linear unbiased predictors (BLUPs) from spatial analyses of individual-location trial data. Data are ranked by the two-year average grain yield over 20 dryland locations in Colorado. The average, maximum, and minimum values are from the entire set of entries tested.

Entry	2016 Yield	2017 Yield	2 Year Avg Yield	2 Year Avg TestWt	2 Year Yield Northeast	2 Year Yield Southeast	2 Year Yield Irrigated
Langin	82.3	70.2	76.2	57.5	77.5	73.2	88.9
Byrd	79.8	69.8	74.8	58.0	75.9	72.3	86.9
Avery	78.1	68.3	73.2	57.5	74.1	71.1	88.9
Joe	79.3	67.0	73.1	57.6	75.2	68.4	89.1
Antero	80.6	65.2	72.9	58.1	73.2	72.2	85.2
WB-Grainfield	81.7	63.8	72.7	57.9	73.6	70.6	90.6
Sunshine	78.2	63.2	70.7	57.7	72.5	66.5	86.2
Snowmass	76.1	64.8	70.4	57.4	70.9	69.3	85.1
Denali	78.5	60.5	69.5	57.6	70.2	67.9	90.6
TAM 114	77.7	58.5	68.1	58.0	68.9	66.3	87.2
Brawl CL Plus	76.0	58.3	67.2	58.0	67.5	66.5	86.9
CO14A065	73.7	59.1	66.4	55.2	66.7	65.8	88.2
Average	78.1	64.9	72.5	57.7	73.4	70.3	90.4
Max	82.4	74.4	78.4	59.9	78.8	78.5	97.4
Min	73.5	48.7	66.4	55.1	66.7	65.3	85.1
Locations	10	10	20	20	14	6	4

Table 7. Grain yield (bu/acre) and test weight (lb/bu) summary of CO14A065 and other entries in the dryland Uniform Variety Performance Trial (UVPT) from 2016 to 2017. Data are ranked by the two-year yield average across 16 trial locations.

Entry	2016 Yield	2016 TestWt	2017 Yield	2017 TestWt	Two-Year Yield	Two-Year TestWt	Two-Year Yield Northeast	Two-Year Yield Southeast
Langin	85.4	59.0	77.5	60.0	81.5	59.5	80.8	82.5
Antero	86.2	57.2	72.9	59.6	79.5	58.4	78.5	81.3
Avery	82.4	58.6	73.6	60.1	78.0	59.3	77.1	79.5
Byrd	80.0	59.3	75.8	60.1	77.9	59.7	76.8	79.7
Joe	81.7	58.7	72.3	59.8	77.0	59.2	78.9	74.0
Sunshine	81.6	56.4	68.4	58.9	75.0	57.7	77.8	70.3
WB-Grainfield	81.5	59.4	67.9	60.4	74.7	59.9	75.4	73.5
LCS Mint	80.5	59.4	67.3	60.3	73.9	59.9	74.2	73.6
Oakley CL	78.8	58.4	68.0	59.7	73.4	59.0	74.9	70.9
Hatcher	82.6	57.7	63.4	59.0	73.0	58.3	71.8	74.9
Snowmass	75.4	58.8	70.5	59.7	73.0	59.3	73.0	72.8
Denali	79.3	59.5	65.1	59.1	72.2	59.3	73.2	70.6
TAM 114	80.7	60.6	61.2	59.9	70.9	60.2	71.7	69.7
Cowboy	79.8	56.8	61.6	57.3	70.7	57.1	69.3	73.1
SY Monument	78.1	58.2	63.0	58.4	70.5	58.3	70.8	70.1
Winterhawk	78.4	59.6	61.9	59.3	70.2	59.4	71.8	67.4
Ruth	76.8	60.3	63.1	60.2	70.0	60.3	71.7	67.1
SY Wolf	74.9	56.1	64.9	59.3	69.9	57.7	71.9	66.4
Brawl CL Plus	76.5	58.0	63.1	59.9	69.8	58.9	70.1	69.4
WB4721	78.2	60.4	58.7	60.4	68.4	60.4	68.8	67.9
Settler CL	76.8	57.7	59.3	58.3	68.0	58.0	67.6	68.8
LCS Chrome	75.6	59.1	60.0	59.2	67.8	59.2	67.9	67.5
CO14A065	73.1	55.4	59.3	56.0	66.2	55.7	65.1	67.9
Average	78.9	58.3	65.8	59.2	72.3	58.8	72.6	71.9
Locations	8	8	8	8	16	16	10	6

Incline AX Hard Red Winter Wheat (CoAXium)

- Primary strengths
  - A novel, non-GMO herbicide tolerance trait to provide more economic and effective control of both cheatgrass and feral rye in winter wheat:

    Axigen herbicide tolerance trait (CSU-developed)
    Aggressor herbicides (Albaugh LLC)
    CoAXium Wheat Production System (http://coaxiumwps.com)

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    Axigen herbicide tolerance trait (CSU-developed)
    Aggressor herbicides (Albaugh LLC)
    CoAXium Wheat Production System (http://coaxiumwps.com)
  - Statistically similar grain yield as the widely grown two-gene *Clearfield* wheat variety *Brawl CL Plus*.
  - Good quality characteristics, good straw strength.
- Primary weaknesses
  - Lower yield and test weight compared to most available hard red and hard white winter wheat varieties.
  - Lateness to heading, approximately 4 days later than Denali.

2018 Foundation Seed Increases

- Hard red
  - **CO12D1770** - Denali/Antero//Byrd
  - CO13D1783 - CO08W218/Snowmass//Byrd
- Hard white
  - **CO13D1299** - CO07W722-F5/Snowmass//Brawl CL Plus
  - CO13D1479 - CO07W722-F5/Antero//Snowmass
  - CO13D1383 - CO07W722-F5/Snowmass//CO07W722-F5
- Hard red *Clearfield*
  - **CO13003C** - CO06072/4*Byrd (two-gene *Byrd*)
- Hard red *CoAXium*
  - **CO14A050** - AF28/Byrd//AF10/2*Byrd
  - CO14A136 - AF10/2*Byrd//AF26/Byrd
  - CO15A018 - AF28/Byrd//AF26/Byrd/AF28/Byrd//AF10 M3/2*Byrd
  - CO14A070 - AF28/Byrd//AF10/2*Byrd

Grain Protein Issues

- Since 2014, winter wheat in eastern Colorado has generally received above average precipitation, resulting in higher than average grain yields.
- Unfortunately, in many areas producers have experienced low grain protein in their crop, resulting in price discounts not just here in Colorado but throughout the region.
- There are many factors involved -
  - Higher than average grain yields – CSU dryland variety trial average from 2010-13 was 47 bu/a, and from 2014-17 was 66 bu/a (http://ramwheatdb.com).
  - Higher grain yield of newer varieties, and in particular, higher yield potential of newer varieties compared to older varieties.

Colorado Wheat Variety Database

Database Main Page | Wheat Variety Information | Single Location Trial Data | Multiple Location Trial Data | Head-to-Head Comparisons

Head-to-Head Summary

Byrd vs **Prairie Red**
CO -- Northeast
CO -- Southeast

Dataset: 41 replicated trials
Yield: Byrd is superior 39 times (95%)
Test Weight: Byrd is superior 33 times (89%)

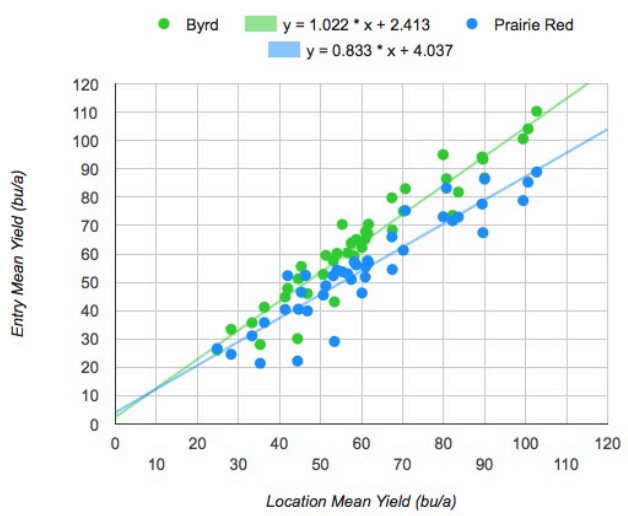
				Grain Yield		Test Weight	
State	Region	Location	Year	Byrd	Prairie Red	Byrd	Prairie Red
CO	Northeast	Akron	2010	**63.8**	51.0	57.6	**58.4**
CO	Northeast	Akron	2011	**51.2**	40.5	**60.4**	58.3
CO	Northeast	Akron	2014	**70.5**	56.8	**59.5**	57.8
CO	Northeast	Akron	2015	**30.1**	22.2	**54.6**	53.5
CO	Northeast	Burlington	2010	**95.0**	73.1	60.5	**60.6**
CO	Southeast	Sheridan Lake	2015	**62.3**	46.2		
CO	Southeast	Sheridan Lake	2016	**110.3**	88.9	**60.7**	58.7
CO	Southeast	Walsh	2010	**57.6**	52.3	**58.4**	56.4
CO	Southeast	Walsh	2011	**41.2**	35.8	**58.5**	57.7
CO	Southeast	Walsh	2014	**35.7**	31.1	**59.6**	58.9
CO	Southeast	Walsh	2016	**60.4**	53.0	**57.1**	56.1
Averages				**64.6**	54.8	**59.8**	58.0
Percentage of Trial Wins*				**58.5%**	4.9%		
Statistically Different?**				**YES**		**YES**	

click here → View Grain Yield Regression Plot | View Test Weight Regression Plot

ramwheatdb.com

Grain Yield Response Comparison

CO -- Northeast, CO -- Southeast



Grain Protein – Factors Involved

- Higher moisture years, higher grain yields.
- Higher yielding varieties.
- Some other ideas -
  - Later season precipitation, after winter/early spring fertilizer top-dressing.
  - Low market prices, lack of protein premiums, resulting in some wheat producers reducing inputs.
  - Larger farm acreages, resulting in fewer acres getting a soil test.
  - A lack of understanding of the relationship between soil N availability, grain yield, and grain protein of winter wheat (CSU Wheat Production Manual, http://bit.ly/2AjV3Km)
  - "I always got good protein with Scout, why don't I get good protein with these new varieties?"

Grain Protein and Wheat Quality

Grain proteins from several variety trial locations reported along with milling and baking quality data annually since 2007.

Overall milling and baking quality ratings derived from the data are updated in Variety Characteristics Table.

Wheat Milling and Baking Quality Data - 2016 Arapahoe

* **Bold** indicates superior value; underlined indicates inferior value.

Entry	Test Weight	Grain Protein	SKCS Weight	SKCS Hardness	Flour Yield	Protein Recovery	Bake Absorption	Mixograph Mix Time	Mixograph Tolerance	Loaf Volume	Crumb Color	Crumb Grain	**Milling Score**	**Baking Score**
Akron	54.1	11.9	28.5	46.9	65.7	-0.9	61.1	3.91	4	**1000**	5	5	4	2
Antero	55.4	10.0	**31.9**	45.3	68.4	-0.9	57.0	5.11	3	775	3	3	4	2
Arapaho	55.3	11.1	27.6	45.1	67.1	-0.6	61.2	3.31	3	770	3	3	6	5
Brawl CL Plus	55.8	11.8	29.2	46.8	**68.7**	-0.9	60.7	5.08	4	**955**	5	4	3	2
Byrd	53.6	11.5	25.6	38.8	**69.2**	**-0.5**	61.2	5.35	5	**965**	5	5	4	1
CO11D1539	52.7	10.6	**31.1**	35.9	67.1	-1.4	58.2	4.39	4	775	4	3	6	5
CO12D2011	**57.5**	11.5	28.6	46.6	**69.1**	-1.0	62.2	4.53	4	885	5	4	1	3
CO14A958	55.1	11.3	25.3	51.2	64.8	-1.1	60.2	3.36	3	670	4	5	6	5
CO14A963	55.3	11.2	25.9	51.7	65.5	**-0.8**	60.0	3.36	3	870	4	5	5	5
Cowboy	52.7	**13.7**	25.7	51.2	65.3	-0.8	**65.0**	3.49	3	835	2	2	5	4
Denali	55.2	11.4	29.2	38.1	65.7	**-0.4**	61.2	3.33	3	795	3	5	5	5
Doublestop CL	**57.8**	12.2	**32.7**	55.1	67.1	-0.6	**63.1**	3.50	3	920	5	4	1	3
Hatcher	52.1	11.5	27.6	41.7	64.8	-1.2	60.2	4.36	4	825	4	3	2	4
Joe	52.6	11.9	25.3	42.3	67.3	**-0.5**	61.3	3.67	2	765	3	2	5	6
Kanemark	54.8	11.1	26.9	42.5	67.5	-1.0	61.3	5.97	5	865	5	5	4	1
Langin	52.8	11.1	26.1	32.8	68.0	-1.2	59.1	**6.15**	5	920	4	4	6	2
LCH13-032	**56.5**	11.9	**33.0**	47.3	67.2	-1.1	61.2	3.31	3	770	3	3	2	5
LCH13MDDH-14	55.7	11.6	**32.5**	39.4	68.5	-1.2	59.0	3.55	2	735	4	3	3	6
LCS Chrome	53.0	12.2	24.0	50.0	67.6	**-0.4**	62.3	3.97	3	840	4	4	3	4
LCS Mint	53.8	11.6	27.5	51.8	67.7	-0.8	62.3	4.49	4	865	4	3	3	4
MT6102A	53.8	11.6	27.9	44.2	68.3	-0.8	**64.1**	4.49	4	905	2	2	3	3
Oakley CL	54.5	**13.0**	27.7	57.1	66.3	-1.3	**63.0**	4.13	4	825	3	3	6	3
Prairie Red	55.3	12.1	30.4	52.7	63.3	**-0.5**	60.2	2.26	2	860	4	4	5	3
Ripper	52.1	**13.5**	28.9	43.7	**69.3**	-1.3	60.2	3.87	2	785	2	2	4	6
Ruth	55.1	11.7	26.0	50.1	67.9	-0.7	60.0	2.86	2	775	2	1	4	2
Settler CL	54.8	9.8	29.7	30.4	**69.1**	-0.9	57.3	**6.20**	5	775	4	4	4	2
Sharpe CL	54.5	11.8	29.3	46.9	67.1	-0.9	61.2	3.67	3	825	4	4	4	4
Sunshine	55.4	10.3	**33.7**	32.2	67.1	-0.8	61.1	5.09	5	860	5	4	3	2
SY Monument	52.8	12.5	26.3	54.1	67.1	-1.0	**64.1**	**5.86**	5	**985**	5	5	6	1
SY Sunrise	54.7	**12.7**	29.5	43.9	66.2	-0.8	**63.1**	2.79	3	770	3	3	5	5
SY Wolf	54.5	11.9	26.4	50.4	66.9	-1.1	59.4	3.85	2	795	4	4	5	5
TAM 105	**55.8**	12.0	27.7	46.9	68.3	**-0.5**	62.1	5.64	4	**1005**	5	5	2	1
TAM 204	54.3	12.3	29.9	45.2	69.5	-0.9	62.2	3.80	2	795	2	2	3	6
WB-Grainfield	54.7	10.4	28.5	46.8	66.5	-0.9	57.2	4.97	4	880	4	5	6	3
WBK721	**56.6**	12.1	29.2	50.0	68.6	-0.7	61.2	3.02	2	835	4	4	2	5
Winterhawk	55.3	12.1	28.2	47.3	**68.8**	-1.3	62.4	4.48	3	825	2	3	3	4
Average	54.4	11.7	28.1	46.5	67.1	-0.9	60.9	4.40	3.5	848	3.7	3.4		
Minimum	50.3	9.8	21.5	29.3	63.5	-1.4	57.0	2.63	1	690	2	1		
Maximum	57.8	13.7	33.7	57.1	69.3	-0.4	65.0	8.63	5	1020	5	5		

Description of Winter Wheat Varieties in Eastern Colorado Dryland and Irrigated Trials (2016, 2017)

Name, Class, and Pedigree	Origin	MWMT	MD	HT	SS	CSS[a]	YR	LR	VIGOR[b]	TW	WBG	BAKE	Comments
Prairie Red Hard red winter CO00D2E8/PI557126/3/T1Ner 107	CSU 1998	R*	2	3	2	7	9	9	5	7	5	4	CSU release (1998), marketed by PlainGold. Bronze / BWA resistant version of Ner 107. Good stress tolerance, poor end-use quality, leaf and stripe rust susceptible. Lower yields relative to more recent wheat releases, entered as historical check.
Ripper Hard red winter CO05N06/TAM107B-2	CSU 2006	R*	3	4	4	6	3	3	7	7	5	4	CSU release (2006), marketed by PlainGold. Early maturing, long coleoptile, Excellent drought stress tolerance, good baking quality. Very good recovery from stand reduction. Leaf and stripe rust susceptible, lower test weight.
Ruth Hard red winter CM98D07/Jagalene/Camelot	NE 2016	5	5	6	4	8	3	6	7	2	3	6	Nebraska release (2016), marketed by Husker Genetics. First entered in CSU Variety Trials in 2015. Medium height, medium maturity, medium length coleoptile. Good stripe rust resistance and good test weight.
Settler CL Hard red winter NX11A13/PI613994/KUM 3B1/TX01H12688-12/T*6/5/2	NE 2008	5	5	4	2	7	7	8	7	6	3	4	Nebraska release (2008), marketed by Husker Genetics. Single-gene Clearfield wheat. Later maturing, medium height. Moderately susceptible to stripe rust.
Sharpe CL Hard red winter KS06H096/Thegal/CO06D293	CSU 2009	5	5	7	8	6	6	6	2	4	6	2	CSU release (2009), marketed by PlainGold in CWRP-Arident Mills Ultragrain Premium Program. Hard white wheat. Medium maturing, medium-tall. Good WSMV resistance, moderately susceptible to stripe rust, moderate sprouting tolerance.
Spur Hard red winter NT02127*4/NT02058	MT 2016	5	3	5	2	7	4	–	–	3	8	2	MT State release (2016), marketed by Crop Research Foundation of Wyoming. First entered into CSU trials in 2015. Late maturity, good stripe rust resistance. Carries wild stem rust conferring seedling protection against wheat stem sawfly damage.
Sunshine Hard white winter X02W4152-6/9YRW02-267W	CSU 2014	5	3	4	5	6	5	8	–	7	3	2	CSU release (2014), marketed by PlainGold in CWRP-Arident Mills Ultragrain Premium Program. Hard white wheat. Excellent quality, good sprouting, tolerance and straw strength, intermediate reaction to stripe rust.
SY Monument Hard red winter WCR11W-11/DOK359-4	Syngenta 2014	5	8	6	5	5	2	1	7	5	4	1	Syngenta release (2014). First entered in CSU Variety Trials in 2014. Good drought tolerance, winterhardiness, quality, and resistance to both leaf and stripe rust.
SY Wolf Hard red winter WCR07-10-16/CDC Falcon/TB2034S8	Syngenta 2016	5	3	3	6	5	2	6	7	3	3	4	Syngenta release (2016), first entered in CSU Variety Trials in 2017. Dryland adapted, good stripe rust resistance, good milling and baking quality.
SY Sunrise Hard red winter WCR0007-10-16/CDC Falcon/TB2034S8	Syngenta 2015	5	6	2	2	3	2	3	7	2	3	7	Syngenta release (2015), first entered in CSU irrigated Trials in 2015. Short semidwarf with good straw strength, winterhardiness, drought tolerance, stripe rust resistance, test weight. Stewardship Agreement requires no saved seed. Certified seed only.

Column Key. Russian wheat aphid resistance (RWA), heading date (HD), plant height (HT), straw strength (SS), coleoptile length (CSS), stripe rust resistance (YR), leaf rust resistance (LR), wheat streak mosaic virus tolerance (WSMV), test weight (TW), milling quality (MQ), 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.
[a] Coleoptile length is measured in the greenhouse. Values of 1 to 3 are considered short, 4 to 6 are considered intermediate and 7 to 9 are considered tall for relative variety comparisons only.
[b] WSMV ratings for Byrd, Avery, and Langin are based on mechanical WSMV inoculation and do not take into account their resistance to the wheat curl mite vector of WSMV.

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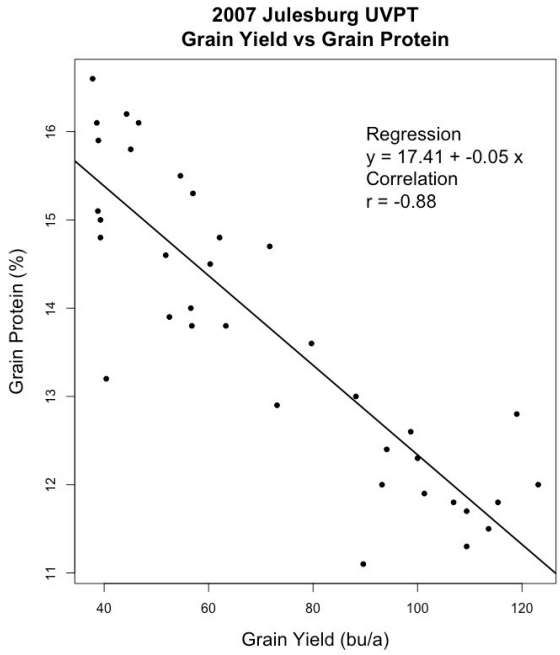
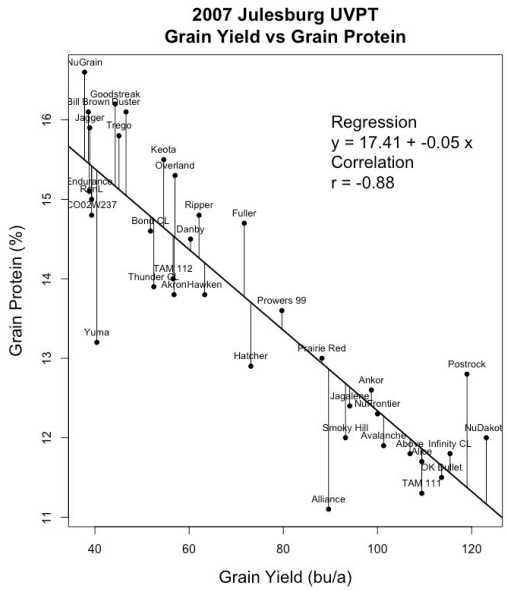
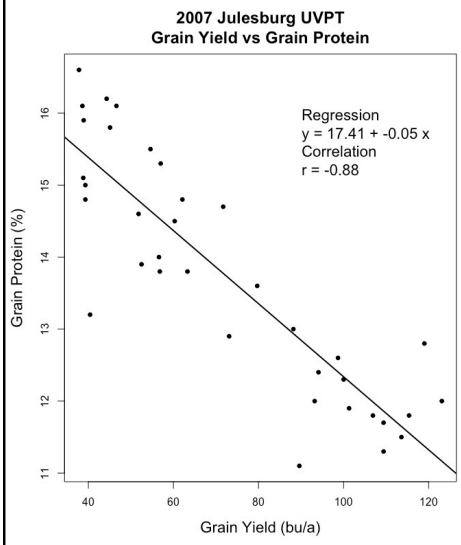
Breeding for Grain Protein?

- Due to what has been called the "dilution effect", grain protein content and grain yield are usually inversely related.
  - Same management in the field, with some spatial variation (soil texture, application variation, organic matter, etc)
  - High yielding plots/varieties -> lower protein
  - Lower yielding plots/varieties -> higher protein
- The inverse relationship between grain protein content and grain yield is a very well known phenomenon in the scientific literature.
- Because of this, few (if any) wheat breeding programs practice selection based on grain protein with the obvious concern that this would lead to lower grain yield among the selections (and not withstanding the fact that it's also not a very highly heritable trait….)
- What does this relationship look like?

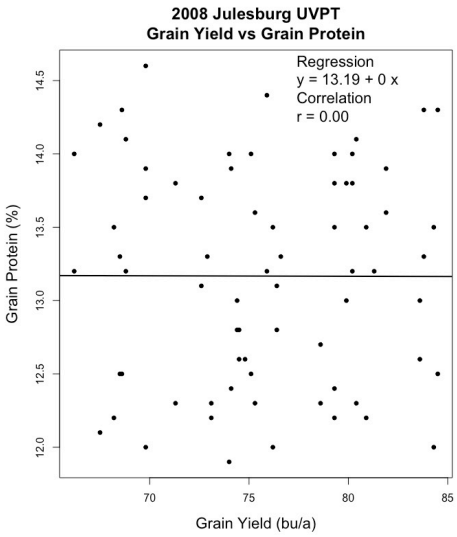




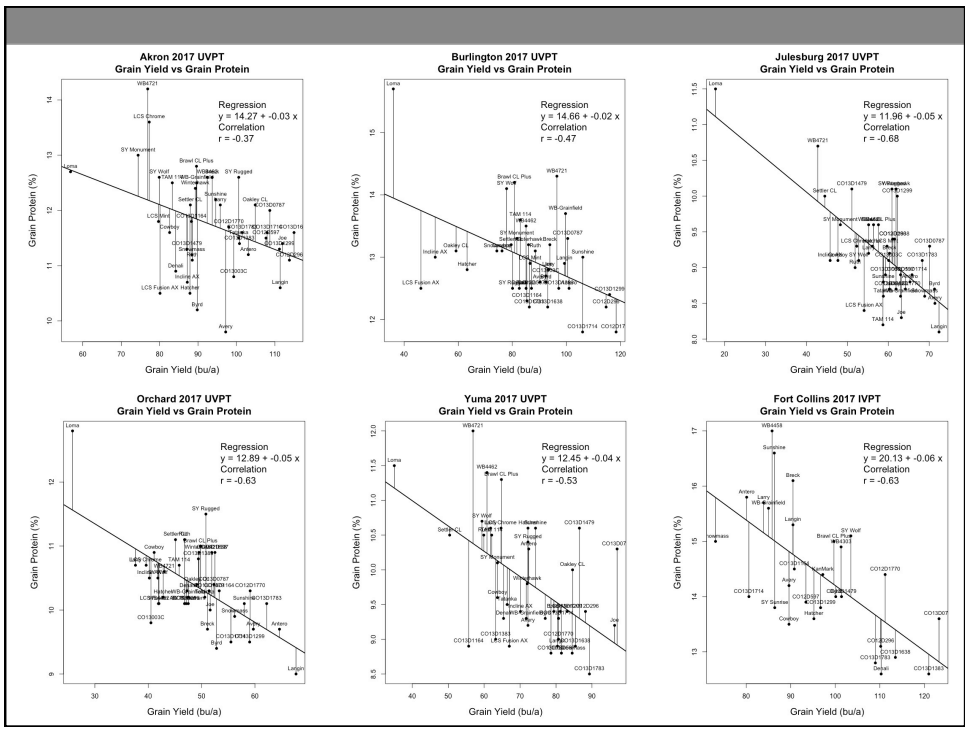
- **Grain Protein Deviation (GPD)** the distance above and below the best-fit line between the data.
- GPD allows direct comparison of protein content between varieties without confounding influence of yield differences between those varieties.
- Dataset – 3,876 datapoints
  - Trial years – 2003 to 2017
  - Both CSU Variety Trials and CSU Elite Trials included
  - 91 total year-location-trial combinations
  - 280 different varieties and experimental lines



53/91 trials with negative slope
(72/91 trials with prob = 0.30)
average correlation = -0.52



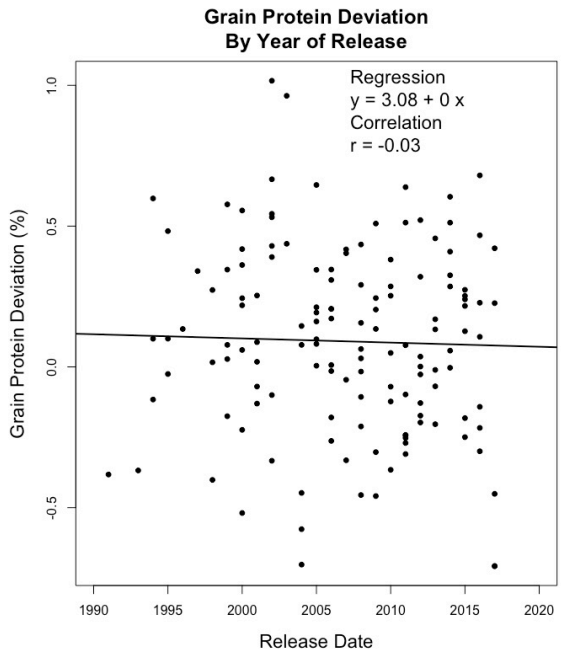
38/91 trials without negative slope
(19/91 trials with prob = 0.30)



Grain Protein Deviation Scores

Higher Positive GPD	Medium GPD	Medium GPD	Higher Negative GPD
Brawl CL Plus (1)	Breck (4)	Ripper (5)	Avery (7)
WB4721 (1)	Doublestop CL Plus (4)	Settler CL (5)	Byrd (7)
Oakley CL (2)	LCS Chrome (4)	SY Monument (5)	CO13003C (7)
TAM 204 (2)	Ruth (4)	TAM 112 (5)	Cowboy (7)
WB4458 (2)	SY Sunrise (4)	Winterhawk (5)	Denali (7)
LCS Pistol (3)	SY Wolf (4)	Above (6)	Spur (7)
Sunshine (3)	T158 (4)	Akron (6)	Tatanka (7)
SY Rugged (3)	WB4303 (4)	Antero (6)	Hatcher (8)
TAM 114 (3)	Bearpaw (5)	Gallagher (6)	Incline AX (8)
WB-Cedar (3)	CO12D1770 (5)	Joe (6)	Snowmass (8)
WB4462 (3)	CO13D1299 (5)	Langin (6)	Thunder CL (8)
	KanMark (5)	LCS Mint (6)	Yuma (8)
	Larry (5)	TAM 113 (6)	LCS Fusion AX (9)
	Prairie Red (5)	WB-Grainfield (6)	

Values will be updated each year, and posted in the Variety Characteristics Table and on the searchable database at http://ramwheatdb.com



Acknowledgements

Colorado Wheat Administrative Committee

Colorado State University

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Ardent Mills™

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Questions?