

# Grain Protein Deviation & Wheat Stem Sawfly



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[wheat.colostate.edu](http://wheat.colostate.edu)

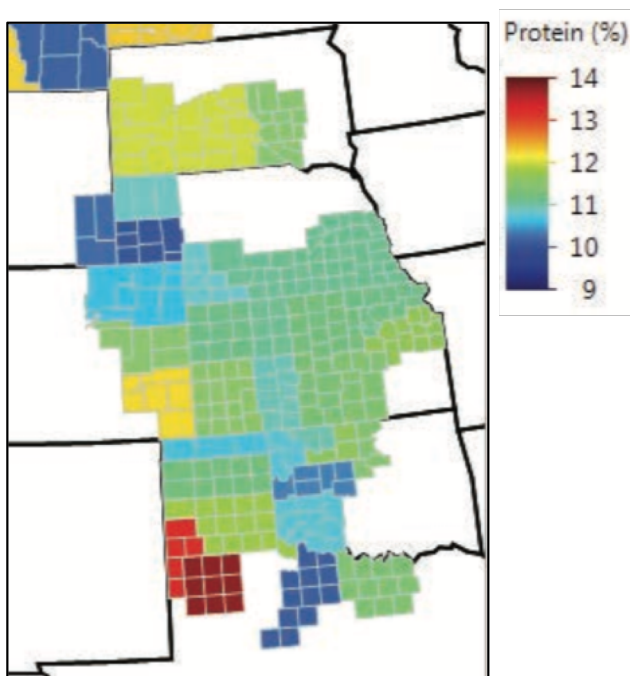
# Outline

- Grain protein deviation
  - Recent issues with low grain protein
  - Influence on bread baking quality
  - Grain protein deviation – rationale, approach
  - Variety ratings for grain protein deviation
- Wheat stem sawfly
  - History and nature of the problem
  - Breeding approaches and progress
    - Montana solid stem variety evaluation
    - Implementation of doubled haploid breeding
    - Selected-bulk population breeding
    - Non solid-stem based resistance
  - Looking towards the future

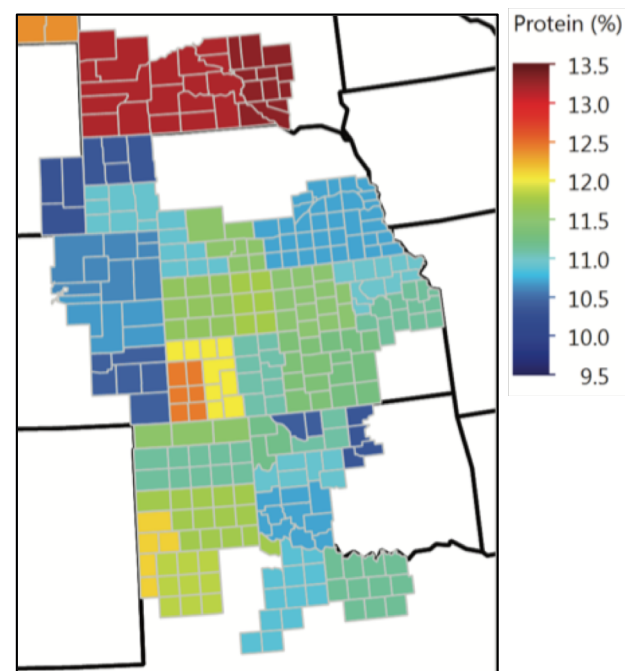
# Grain Protein Issues

- 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.

2016



2017



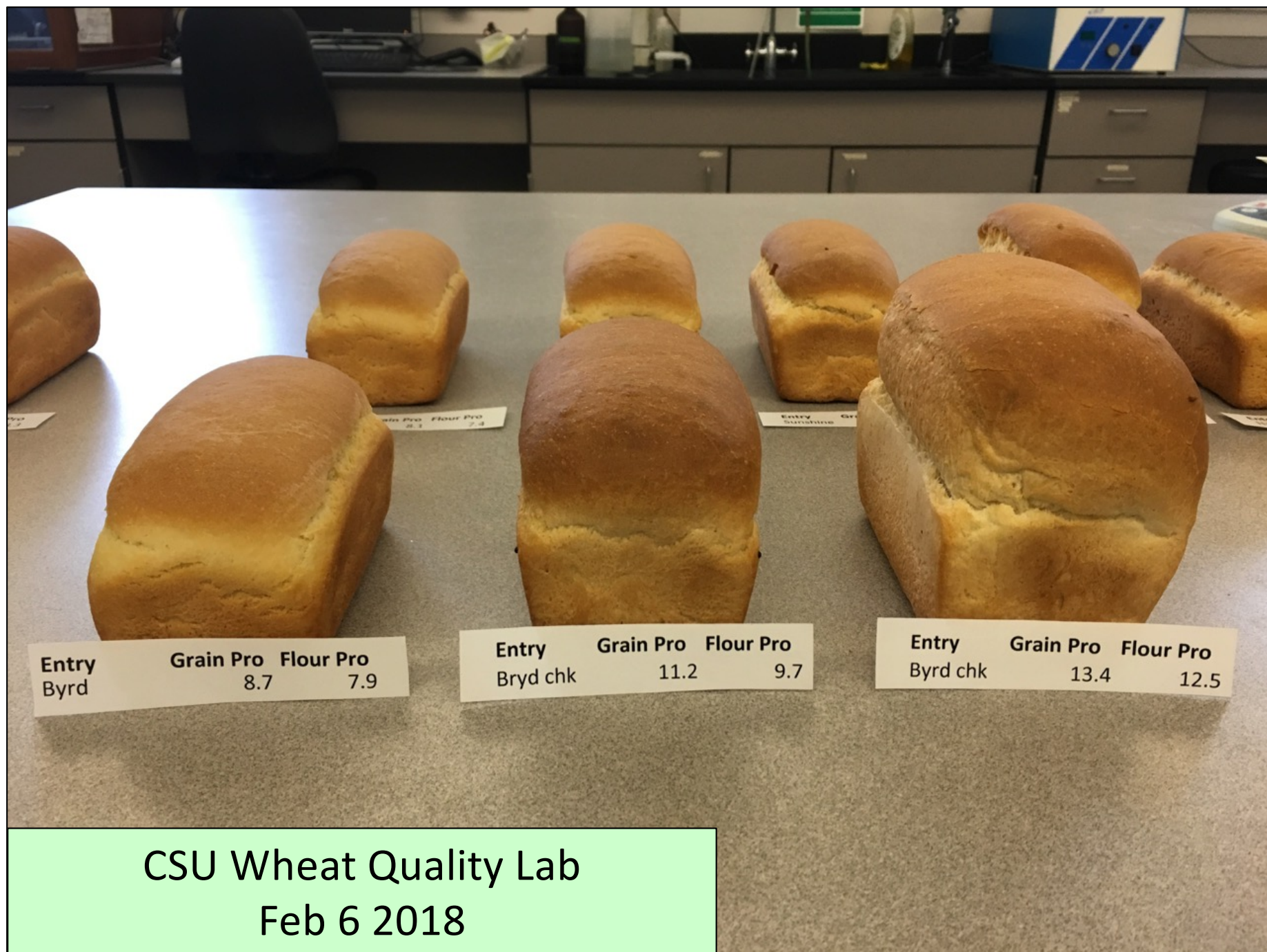
<https://www.plainsgrains.org>



# Grain Protein Issues – Factors Involved

- Precipitation – 2014-2017 dryland variety trial avg yield = 66.9 bu/a  
2010-2013 dryland variety trial avg yield = 47.0 bu/a
- Higher grain yield potential of newer varieties – [ramwheatdb.com](http://ramwheatdb.com)
  - Prairie Red vs Hatcher = 4.6 bu/a (9.9%)
  - Hatcher vs Byrd = 4.6 bu/a (7.5%)
  - Prairie Red vs Byrd = 9.8 bu/a (15.3%)
- Later season precipitation, after the time when many wheat producers have completed top-dressing with nitrogen fertilizers, resulting in nitrogen deficiency during the grain filling period.
- A lack of historical price premiums for higher grain protein, and current low market prices and economic returns for wheat production, causing a reduction of inputs including nitrogen fertilizer.
- Larger acreages managed by individual operations, resulting in fewer fields and fewer acres being soil tested to enable optimum fertility management.





CSU Wheat Quality Lab  
Feb 6 2018

# Grain Protein and Quality

Entry	Grain Protein (%)				Water Absorption (%)				Loaf Volume (cc)			
	Burl	Akr	Orch	Jules	Burl	Akr	Orch	Jules	Burl	Akr	Orch	Jules
Antero (W)	12.5	11.2	9.7	8.8	62.2	59.2	58.2	56.2	815	715	655	605
Denali	12.5	10.9	10.3	9.6	62.3	58.2	59.1	56.9	705	710	705	625
Avery	12.6	9.8	9.7	8.5	63.1	58.2	57.1	56.0	850	810	725	675
Byrd	12.6	10.2	9.4	8.7	65.0	58.3	57.1	55.1	870	805	740	615
Hatcher	12.8	10.5	10.2	9.3	62.9	59.3	58.2	57.2	985	720	695	625
Langin	12.9	10.6	9.0	8.1	63.0	59.3	54.1	53.9	945	845	690	610
Breck (W)	13.2	12.6	9.7	9.2	65.1	62.2	59.2	57.1	900	850	805	650
Snowmass (W)	13.1	11.2	9.9	8.6	65.0	62.3	60.0	56.0	1020	915	865	720
Sunshine (W)	13.0	12.2	10.1	8.8	65.9	63.4	59.2	57.2	945	865	765	665
Average	12.8	11.0	9.8	8.8	63.8	60.0	58.0	56.2	893	804	738	643

**Hard Winter Wheat Quality Targets**  
(see <http://bit.ly/2E2ZHjP>)

Value Meets Target

Protein – 12.0% +

Water absorption – 62.0% +

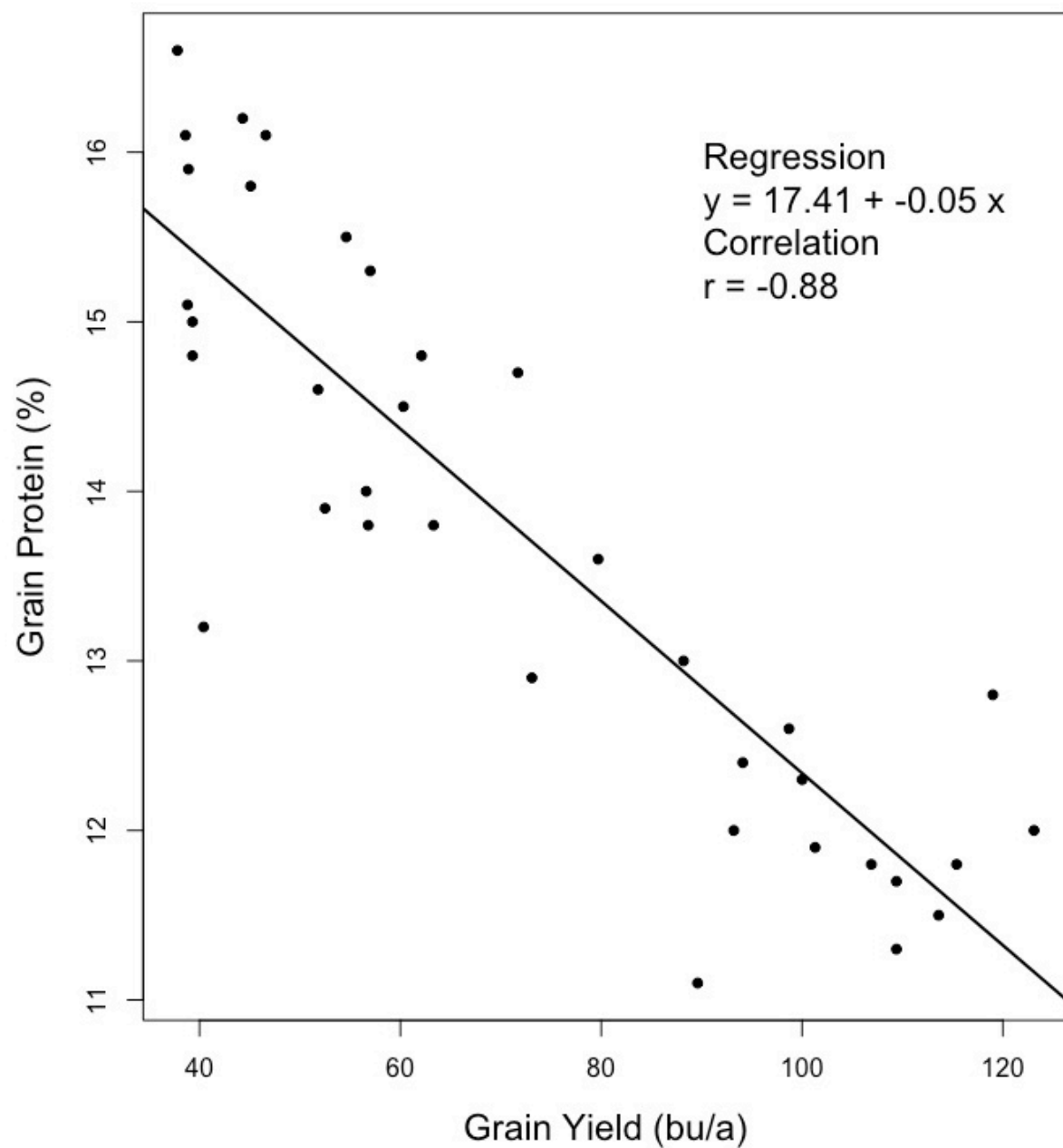
Loaf volume – 850 cc +

# Breeding for Grain Protein?

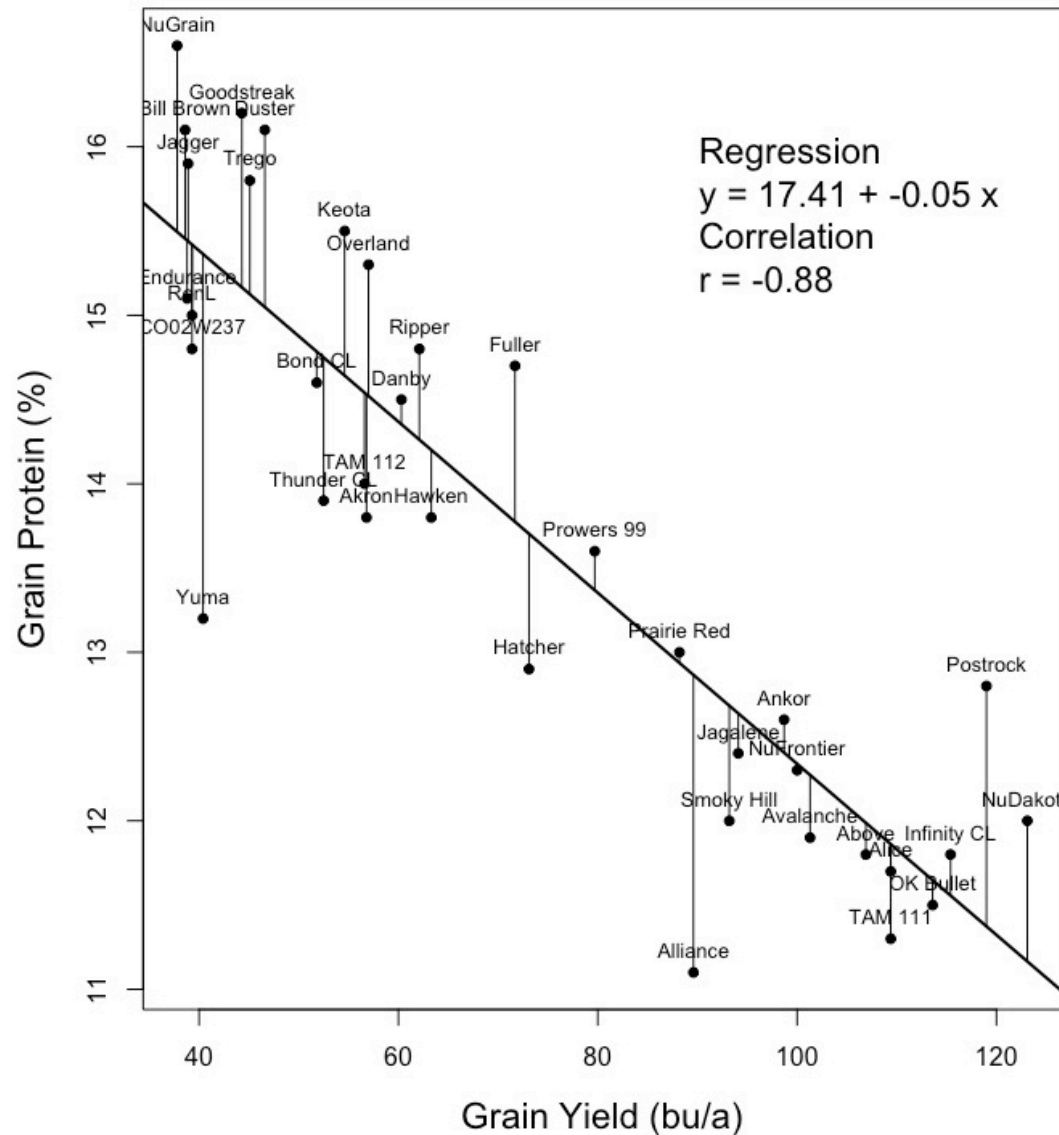
- Due to what has been called the “dilution effect”, grain protein content and grain yield are usually inversely related.
  - Same management in the field, with some spatial variation (soil texture, application variation, organic matter, etc)
  - High yielding plots/varieties -> lower protein
  - Lower 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.
- What does this relationship look like?



# 2007 Julesburg UVPT Grain Yield vs Grain Protein

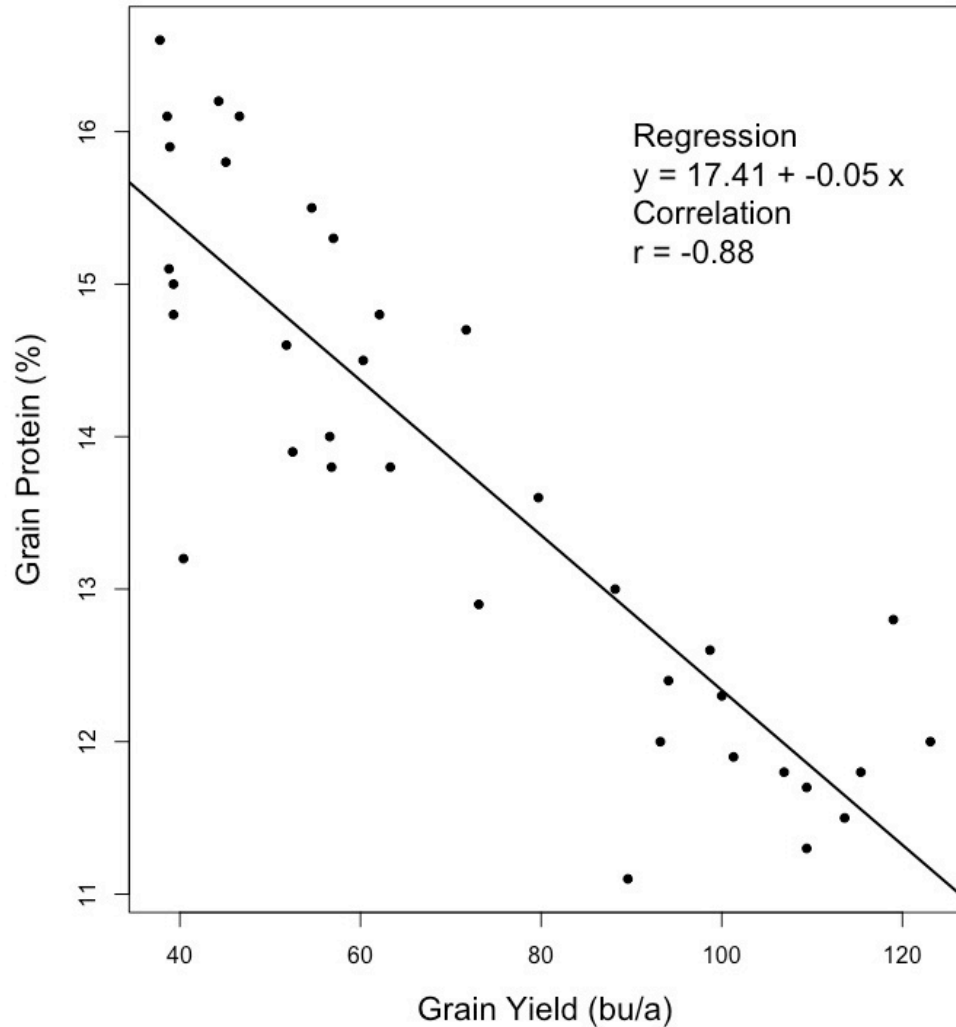


## 2007 Julesburg UVPT Grain Yield vs Grain Protein



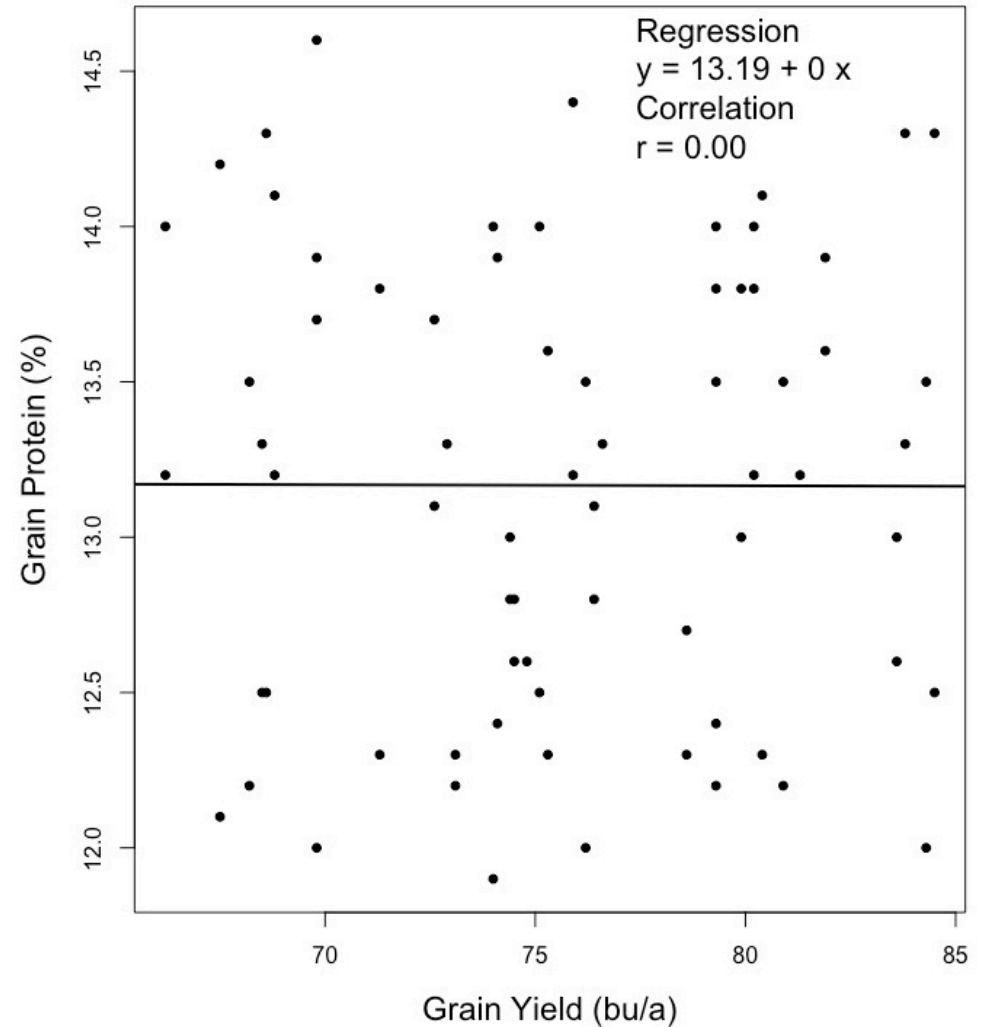
- **Grain Protein Deviation (GPD)**  
the distance above and below the best-fit line between the data.
- GPD allows direct comparison of protein content between varieties without confounding influence of yield differences between those varieties.
- Dataset – 7,093 data-points
  - Trial years – 2003 to 2018
  - Both CSU Variety Trials and CSU Elite Trials included
  - 149 total year-location-trial combinations
  - 431 different varieties and experimental lines

**2007 Julesburg UVPT  
Grain Yield vs Grain Protein**



86/149 trials with negative slope  
(117/149 trials with prob = 0.30)  
average correlation = -0.51

**2008 Julesburg UVPT  
Grain Yield vs Grain Protein**



63/149 trials without negative slope  
(32/149 trials with prob = 0.30)



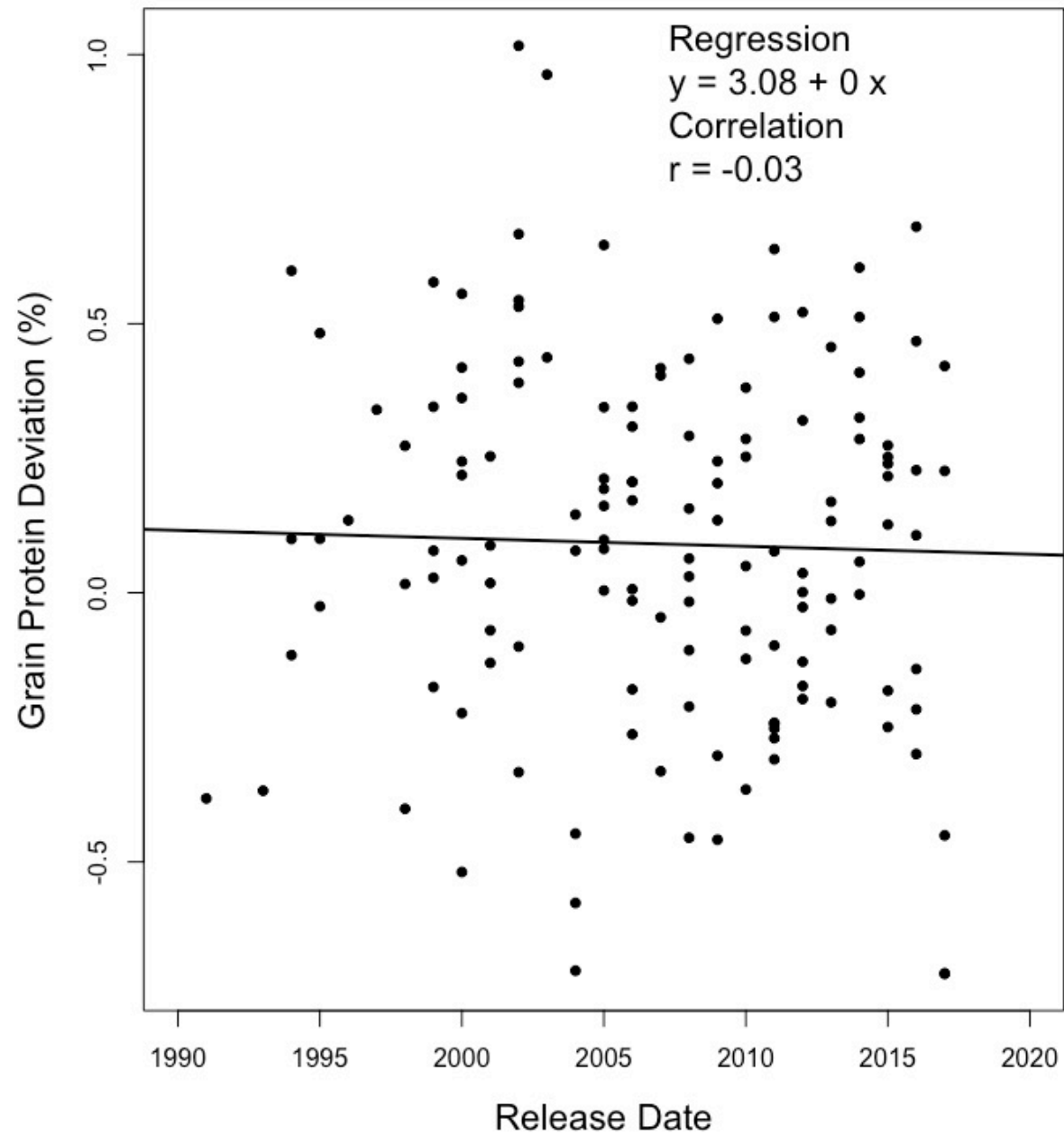
# Grain Protein Deviation Scores

## 2018 Update

Higher Positive GPD	Medium GPD	Medium GPD	Higher Negative GPD
Brawl CL Plus (1)	Ruth (4)	Larry (5)	Avery (7)
Breck (1)	Settler CL (4)	LCS Mint (5)	Byrd CL Plus (7)
Loma (1)	Snowmass 2.0 (4)	Winterhawk (5)	Cowboy (7)
WB4721 (1)	SY Legend CL2 (4)	Antero (6)	Crescent AX (7)
LCS Chrome (2)	SY Monument (4)	Byrd (6)	Incline AX (7)
Oakley CL (2)	SY Sunrise (4)	Denali (6)	Monarch (7)
SY Wolf (2)	Underwood (4)	Joe (6)	Snowmass (7)
WB4458 (2)	WB4303 (4)	Langin (6)	Tatanka (7)
Sunshine (3)	WB4418 (4)	Long Branch (6)	Thunder CL (7)
SY Rugged (3)	AM Eastwood (5)	Spur (6)	Hatcher (8)
TAM 114 (3)	Canvas (5)	WB-Grainfield (6)	LCS Fusion AX (9)
WB4462 (3)	KanMark (5)	Whistler (6)	

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

## Grain Protein Deviation By Year of Release



# Wheat Stem Sawfly



Photo - R.K.D. Peterson, MT State

*Cephus cinctus*

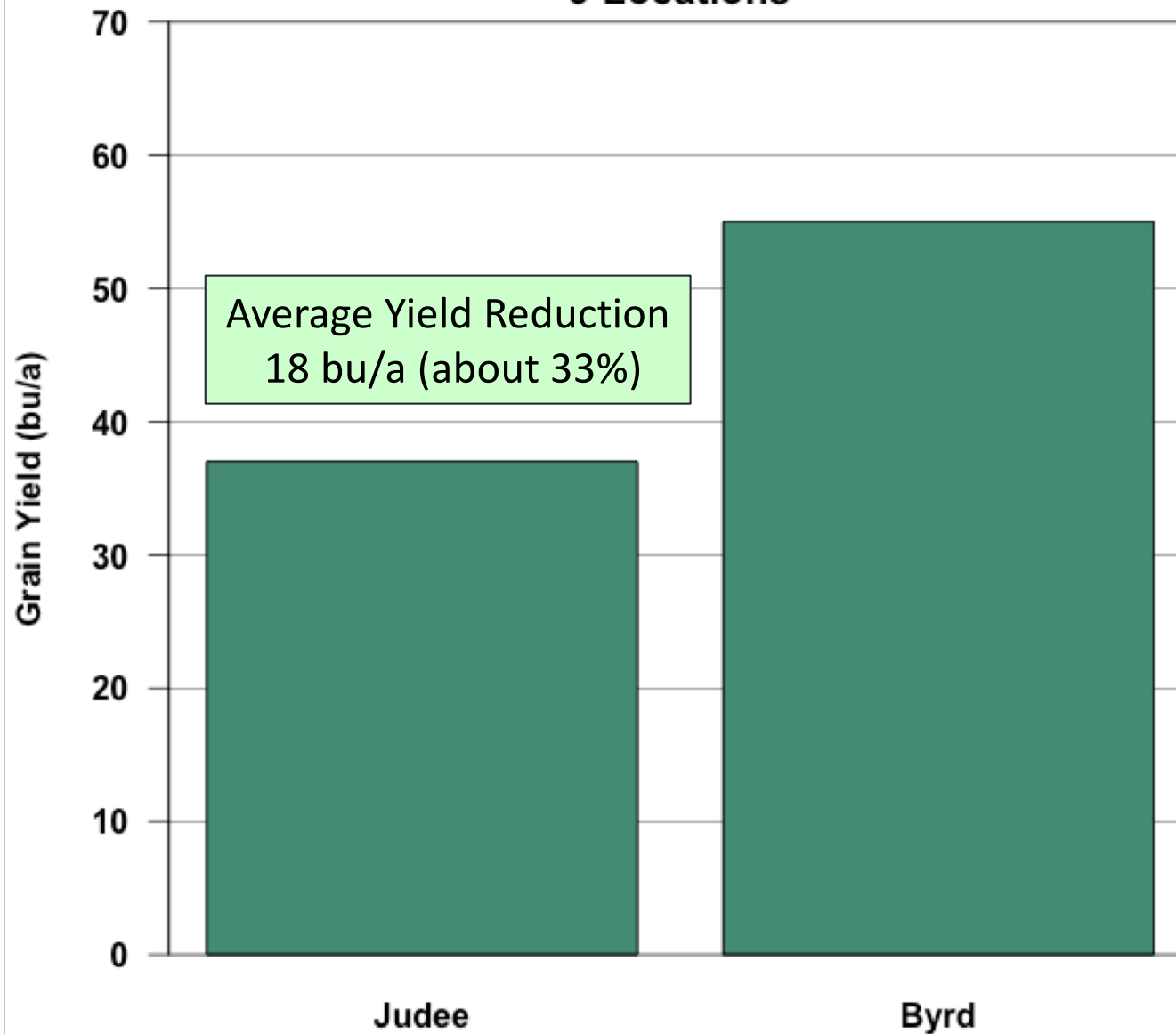
- Serious and expanding US wheat production problem
  - Early 1900s – spring wheat region
  - 1980s – Montana winter wheat
  - 2000s – Wyoming winter wheat
  - 2011 – Colorado winter wheat
- Nature of the damage
  - Inhibits translocation to grain, reduces yield and test weight
  - Cuts stem, reduces harvest efficiency
  - Affects wheat residue persistence
- Management
  - Insecticides – not effective
  - Parasitoids – not effective yet
  - Cropping – partially effective
  - Variety resistance – partially effective



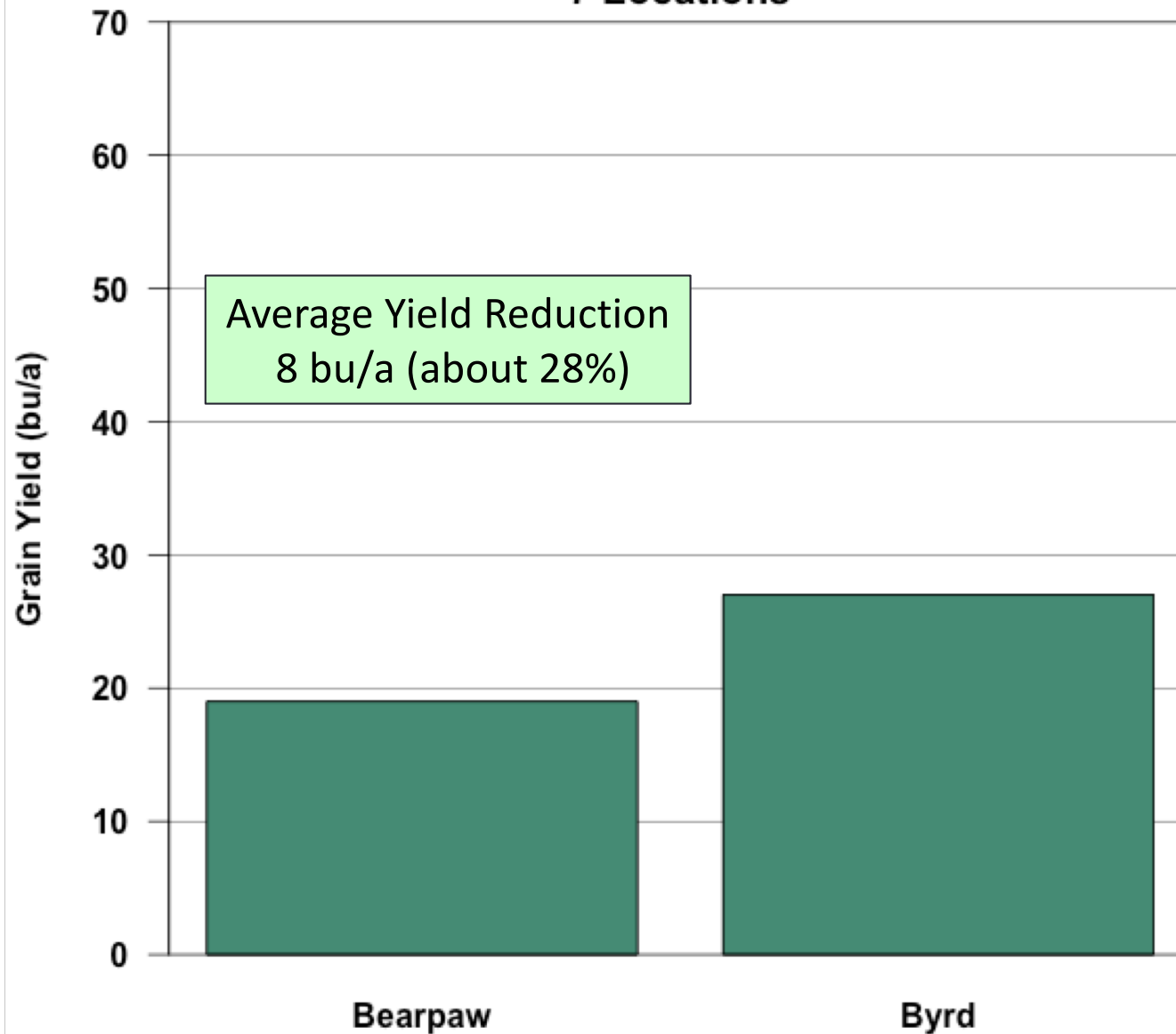
# Variety Development for Colorado

- 1 Evaluation of available solid-stem varieties from Montana State
- 2 Doubled haploid (DH) breeding and DNA marker-assisted incorporation of solid-stem trait
- 3 Selected-bulk breeding approach for incorporation of solid-stem trait
- 4 Non solid-stem based resistance

**Grain Yield of MT Solid Stem Varieties  
CSU Dryland Variety Trial (UVPT) 2012  
9 Locations**

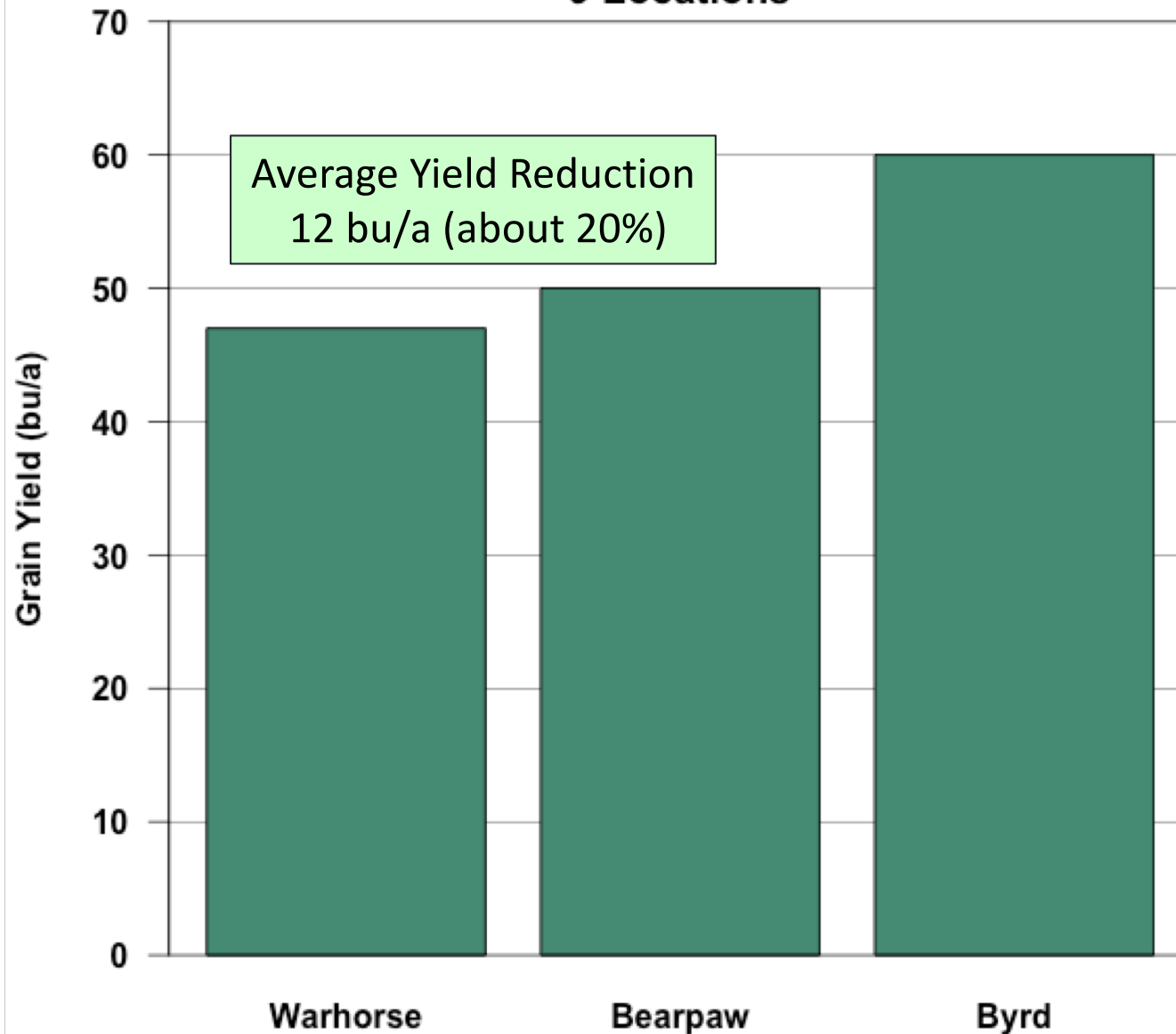


**Grain Yield of MT Solid Stem Varieties  
CSU Dryland Variety Trial (UVPT) 2013  
7 Locations**

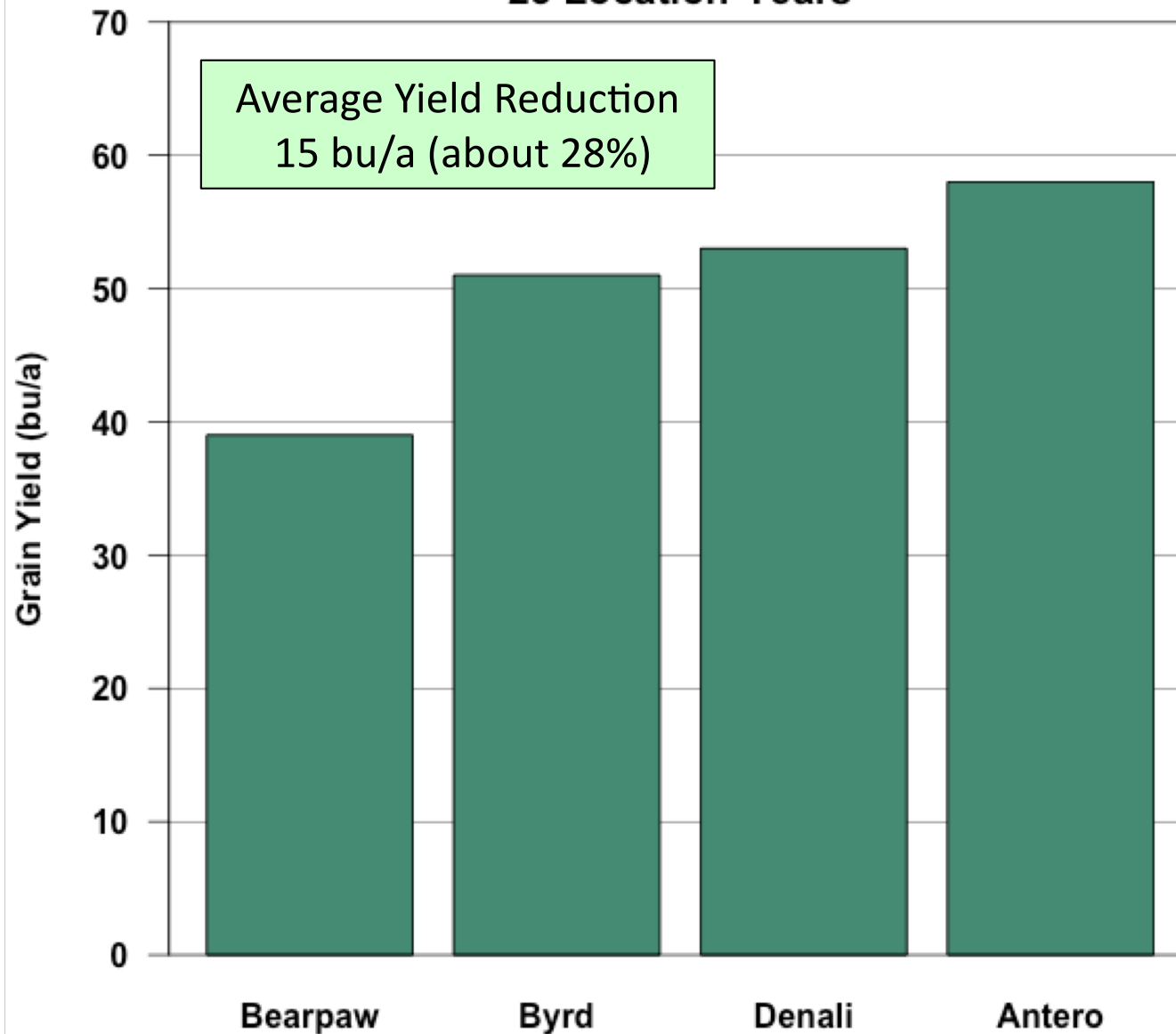




**Grain Yield of MT Solid Stem Varieties  
CSU Dryland Variety Trial (UVPT) 2014  
9 Locations**



**Grain Yield of MT Solid Stem Varieties  
CSU Dryland Variety Trial (UVPT) 2013-2015  
25 Location-Years**



2

## Doubled Haploid (DH) Breeding

Make cross, grow F1  
Pollinate with maize  
Treat with hormones



Collect immature seeds  
excise embryos  
transfer to tissue culture



Regenerate haploid  
plants in tissue culture



Vernalize, treat with  
colchicine

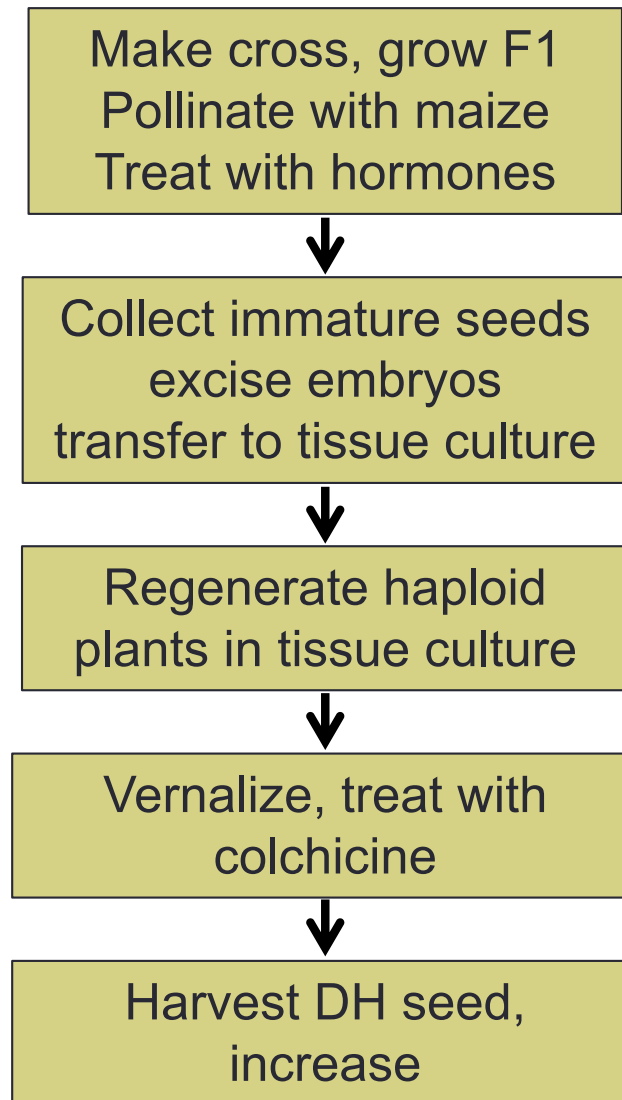


Harvest DH seed,  
increase



2

## Doubled Haploid (DH) Breeding



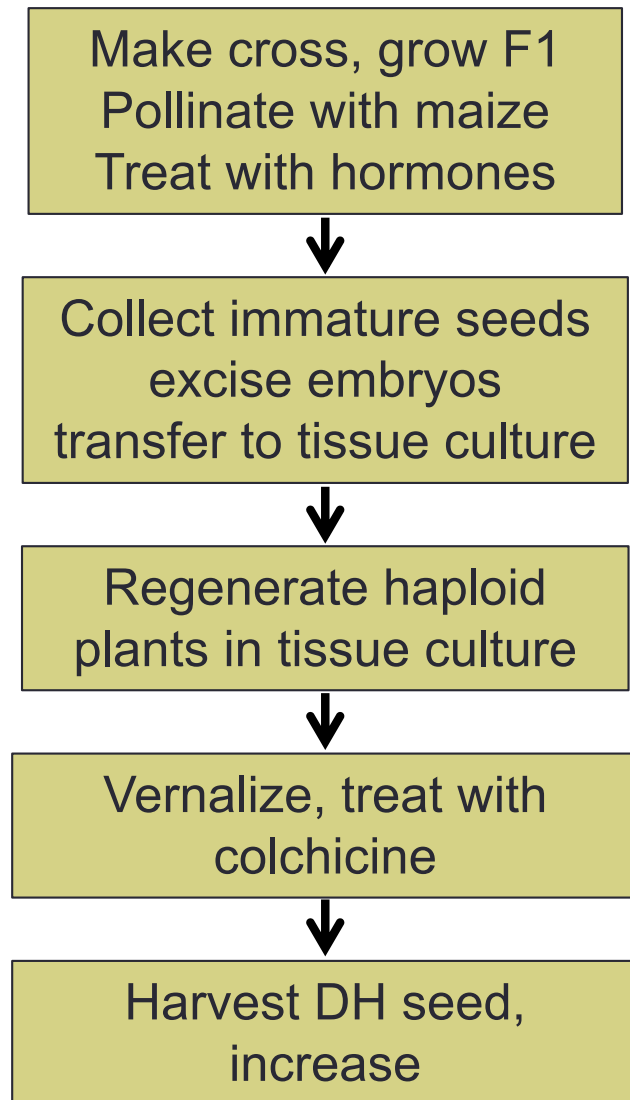
DNA marker-assisted enrichment  
for stem solidness prior to  
DH production



Image - Phil Bruckner, MT State

2

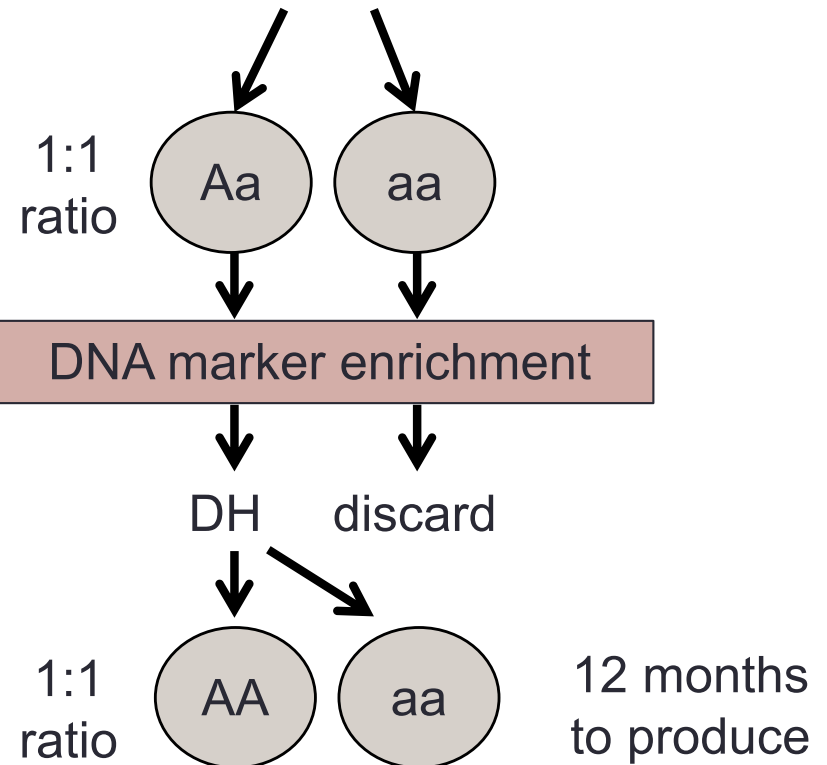
# Doubled Haploid (DH) Breeding



DNA marker-assisted enrichment  
for stem solidness prior to  
DH production

Bearpaw/Byrd//Byrd  
AA/aa//aa

Image - Phil Bruckner, MT State



# DH-Derived Semi-Solid Lines

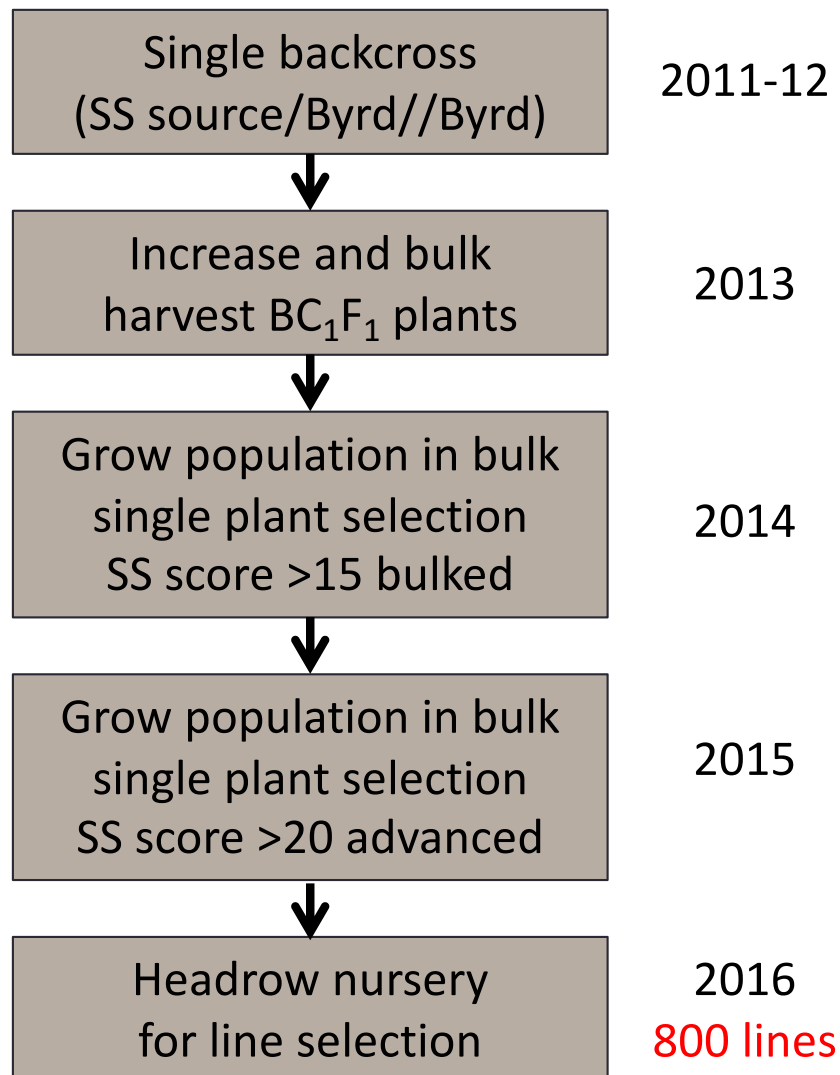
- 264 DH lines generated, grown in field in 2015
  - Visual selection – 134 lines selected
  - Visually scored for solidness in the field at harvest, assayed for DNA markers associated with major solidness gene
  - Selection history: 2016 - 102 lines, 2017 - 12 lines, 2018 - 4 lines

Entry	2016	2017		2018		Average				
	Yield WSS	Yield Non WSS	Yield WSS	Yield Non WSS	Yield WSS	Yield Non WSS	Yield WSS	Test Weight	Stem Cutting	Solidness
Byrd	57.7	71.9	56.8	53.1	69.8	60.9	61.4	57.3	5.8	6.6
Denali	60.9	62.2	54.8	54.4	65.7	59.2	60.5	57.5	5.6	6.3
CO15SFD092	59.3	64.8	56.6	54.9	68.6	59.7	61.5	57.3	2.4	13.2
CO15SFD107	60.0	64.9	53.9	54.3	67.5	59.7	60.5	58.2	2.3	12.7
Average	57.3	65.3	55.2	67.5	55.2	66.4	55.9	57.4		
Locations	2	9	2	8	2	17	6	23		



## 3

# Selected-Bulk Breeding Approach



- Widely used for breeding for durable rust resistance in wheat
- Solid stem parents
  - Judee
  - Bearpaw
  - Warhorse
  - Spur
- Adapted parents
  - Byrd
  - Antero
  - Denali
  - New elite hard red, hard white lines

# Selected Bulk-Derived Semi-Solid Lines

- About 800 line selections grown in field in 2016
  - Visual selection – 79 lines selected, scored for solidness at harvest
  - Trials at both Orchard and New Raymer in 2017
  - Selection history: 2018 - 5 lines; 2019 - 2 lines

Entry	2017	2018		Average			
	Yield WSS	Yield Non WSS	Yield WSS	Yield WSS	Test Weight	Stem Cutting	Solidness
Avery	54.2	71.8	55.7	55.0	57.3	5.5	6.2
Byrd	49.9	69.8	53.1	51.5	57.5	5.8	6.6
Denali	48.1	68.6	54.9	51.5	56.6	5.6	6.3
Snowmass	42.3	64.7	54.0	48.1	56.0	5.8	6.2
CO16SF065	50.8	68.7	55.6	53.2	57.5	2.6	15.7
CO16SF070	49.5	69.2	56.4	53.0	57.2	2.4	16.4
Average	46.8	68.6	54.5	50.7	57.0		
Locations	2	8	2	4	12		

4

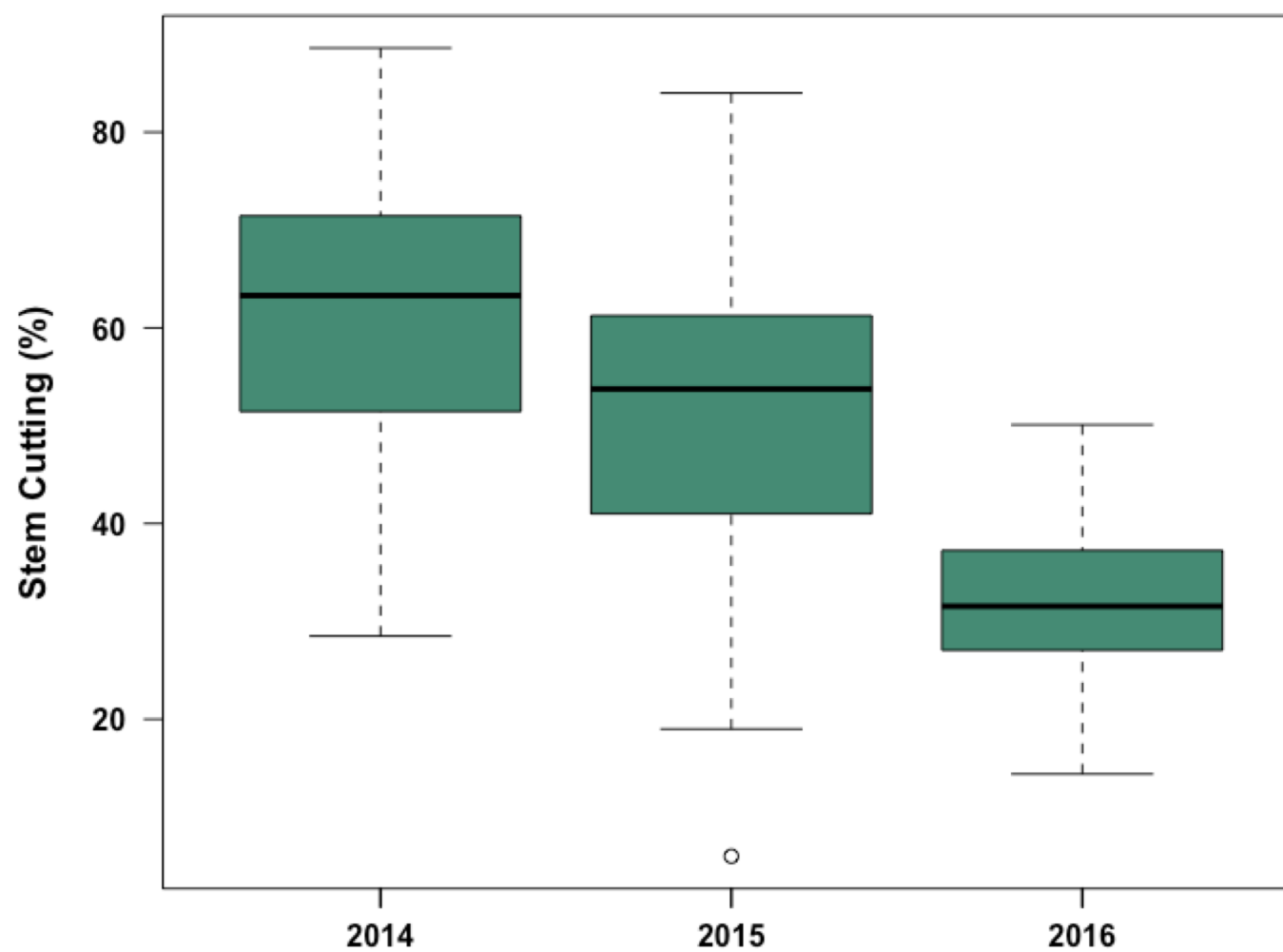
# Non Solid-Stem Based Resistance



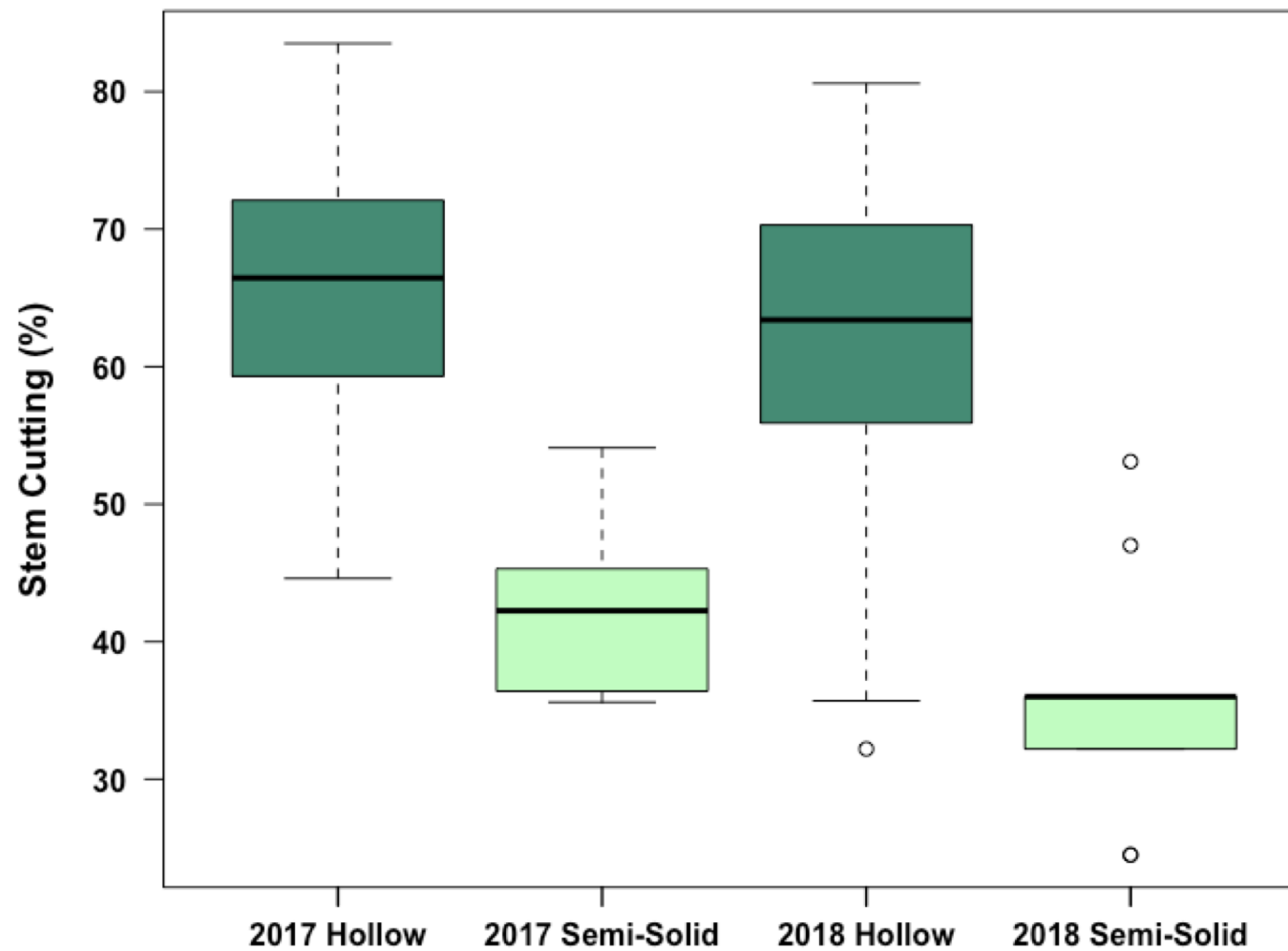
CSU Wheat Breeding Trials  
New Raymer and Orchard, Colorado (2014-2018)



## Stem Cutting Percentage - Hollow Stem Lines CSU Elite Trial (2014-2016)



## Stem Cutting Percentage - Hollow and Semi-Solid Stem Lines CSU Elite Trial (2017-2018)



# Looking Toward the Future

- We are “behind the 8-ball” in terms of providing meaningful solutions for affected growers
- Sources of resistance – too few unfortunately
  - “Common” solid stem trait (*Rescue*)
  - ‘*Conan*’ solid stem trait – different timing of pith deposition
  - ‘*Beyaz*’ (Turkish landrace) – gene on different chromosome
- Assessment of cutting and stem solidness
  - Cutting – timing of assessment is critical, yet is quite robust
  - Solidness – very labor intensive, potentially affected by environment, potentially subject to adaptation by sawflies
  - DNA markers for *Rescue* source are extremely useful
  - Genomics-enabled prediction
- Breeding priorities
  - Characterization, validation of non solid-stem based resistance
  - “Stacking” of non-preference with different solidness sources
  - Challenges: quality, stripe rust resistance, WCM/WSMV resistance, etc  
hard white wheat, *CoAXium/Clearfield*, etc, etc





Questions?