Organic Wheat Breeding for the Northeast

Photo from June Russell

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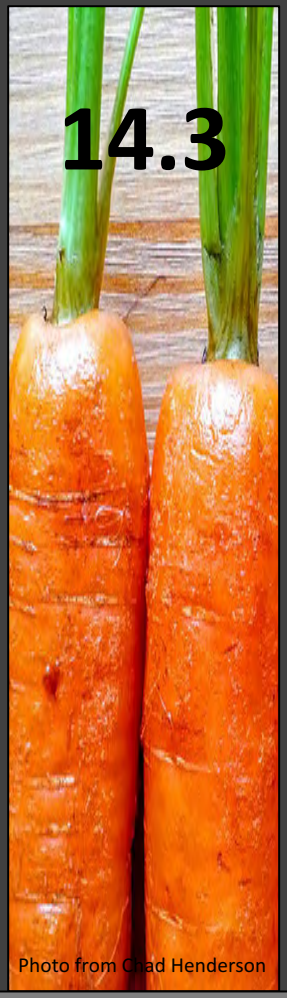
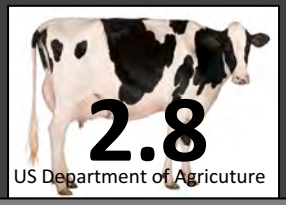
6 February 2016

Underrepresentation

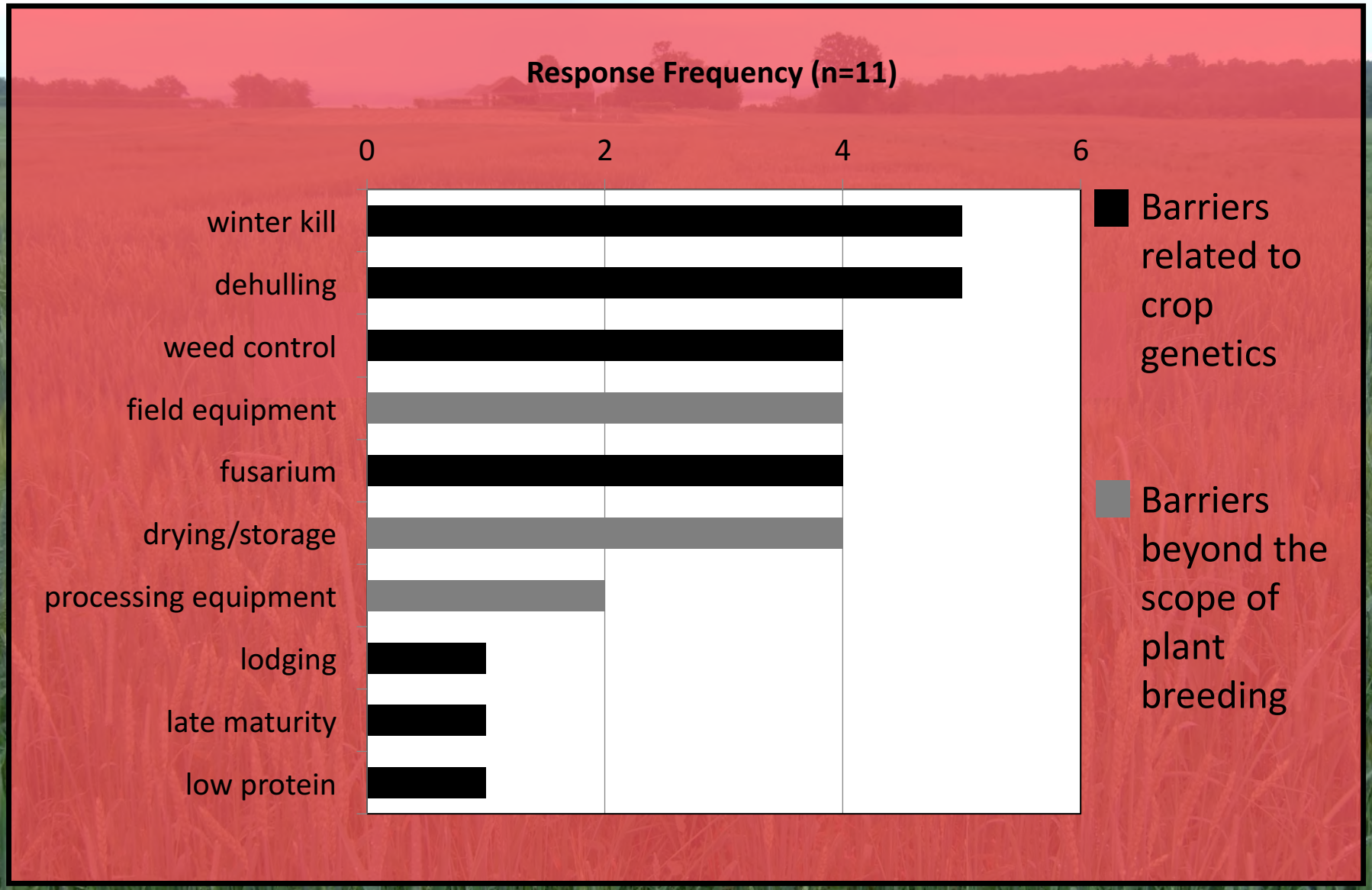




% of U.S acres or animals that are certified organic by commodity

Why Wheat?

Barriers to growing organic wheat



A rich toolbox

T. boeoticum **AA**

T. monococcum
AA
einkorn

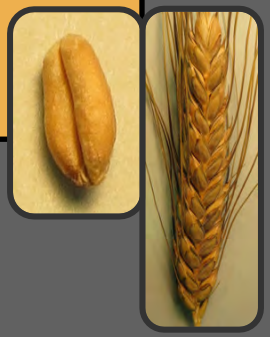
T. urartu **AA**

Aegilops ssp. **BB**

T. dicoccoides **AABB**

T. turgidum ssp. diccocon
AABB
emmer

T. turgidum ssp. durum
AABB
durum



A. tauschii
DD

T. aestivum ssp. spelta
AABBDD
spelt

T. aestivum ssp. aestivum
AABBDD
common wheat
(**heritage** <1950,
modern >1950)

Key:

Wild species

Cultivated hulled species ("ancient wheat")

Cultivated free-threshing species

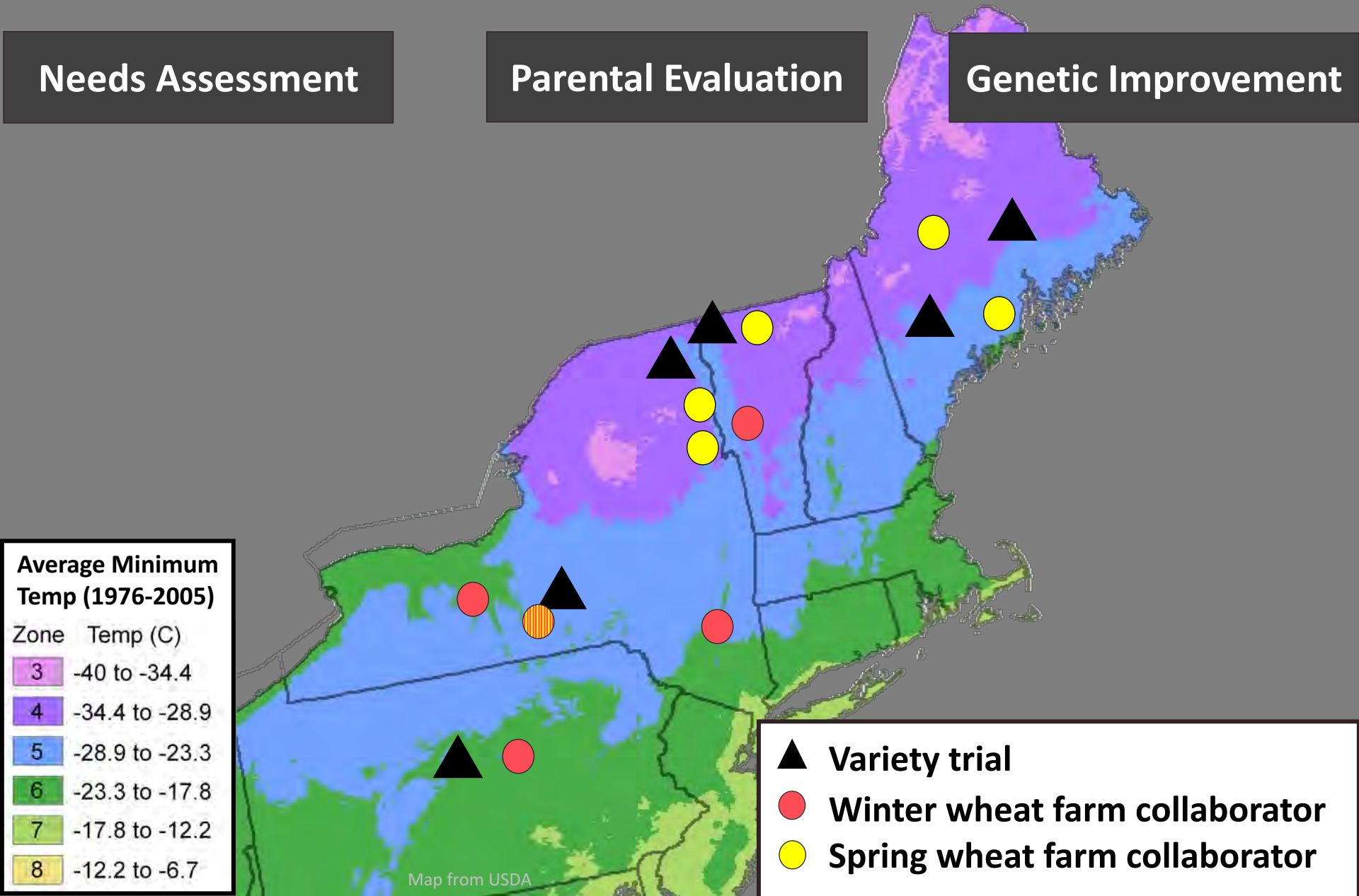
(Figure from Kissing Kucek et al. 2015, adapted from Dawson and others 2013).

Put the tools to work for our region

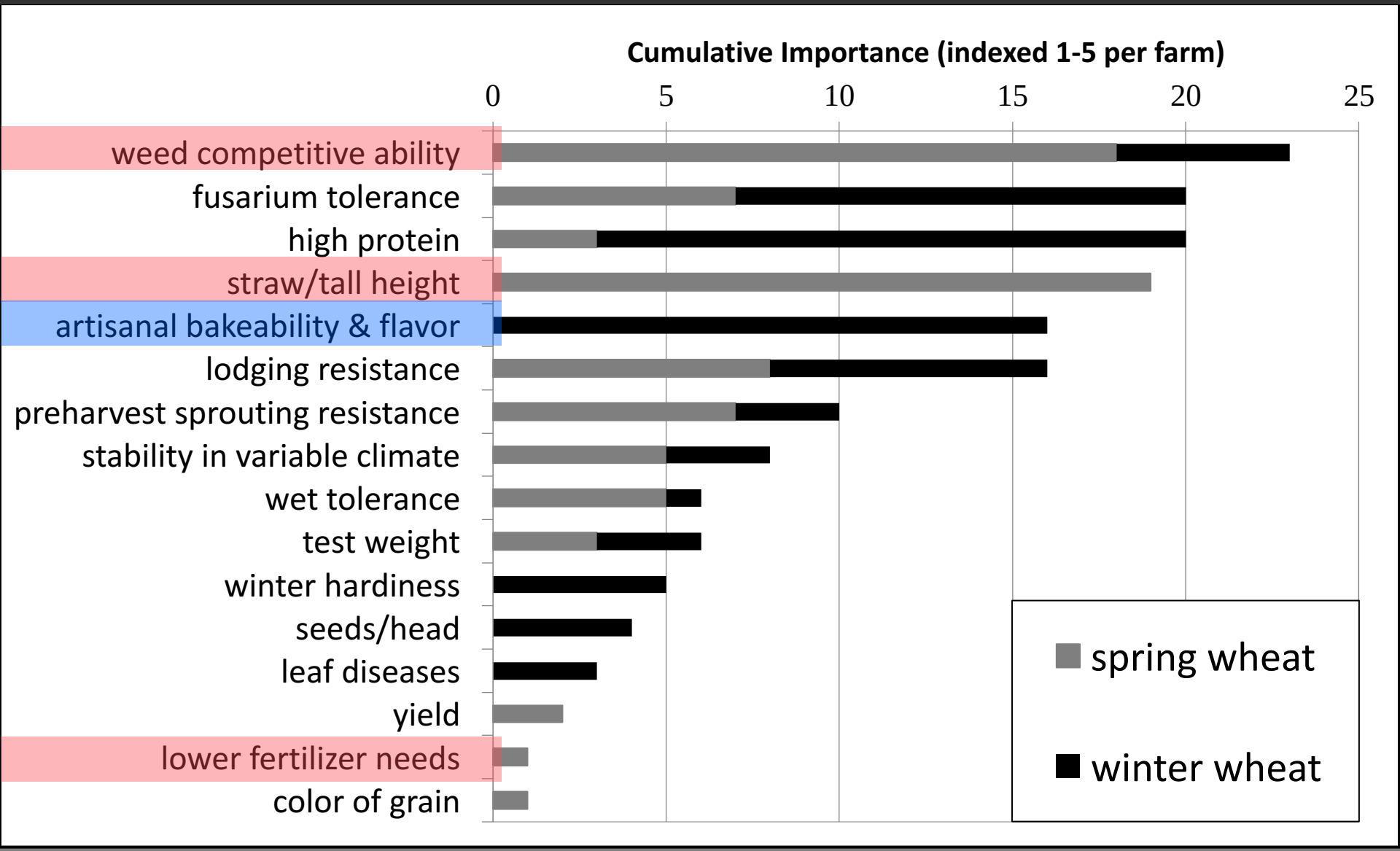
Needs Assessment

Parental Evaluation

Genetic Improvement



Farmer priority traits (n=11)



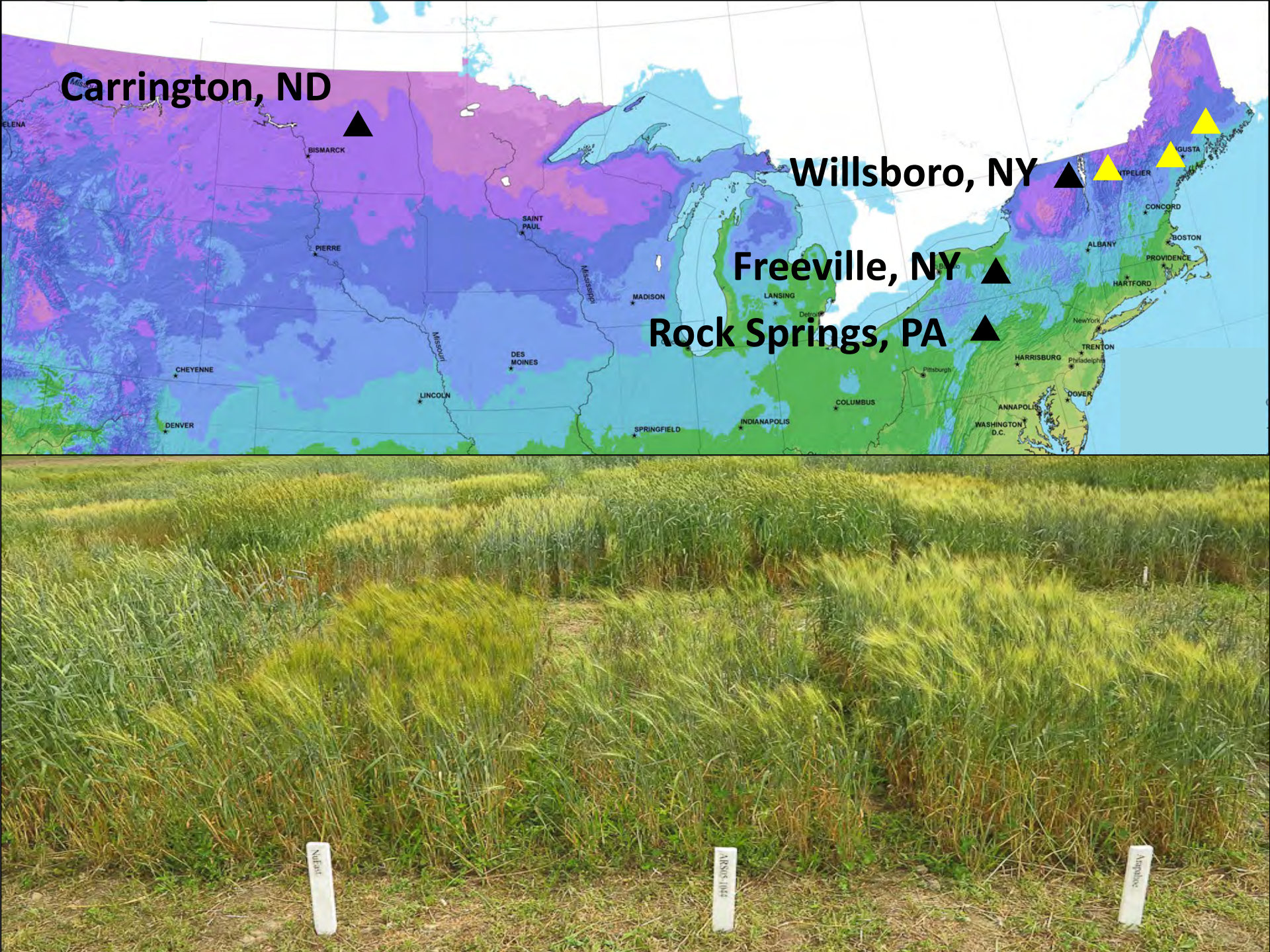
Needs

Parental Evaluation

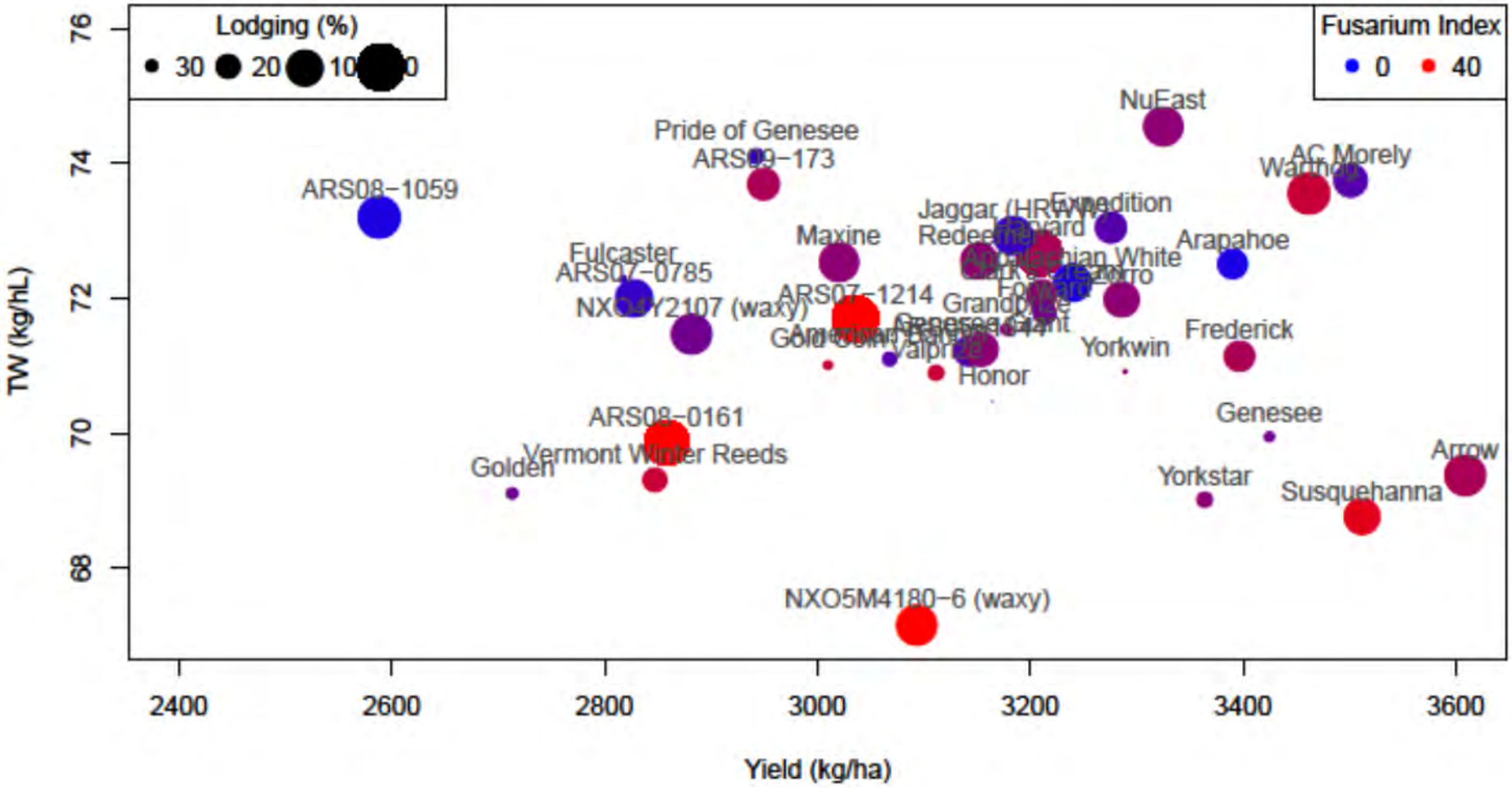
Genetic Improvement

Current Varieties = Potential Parents

Needs | Parental Evaluation | Genetic Improvement

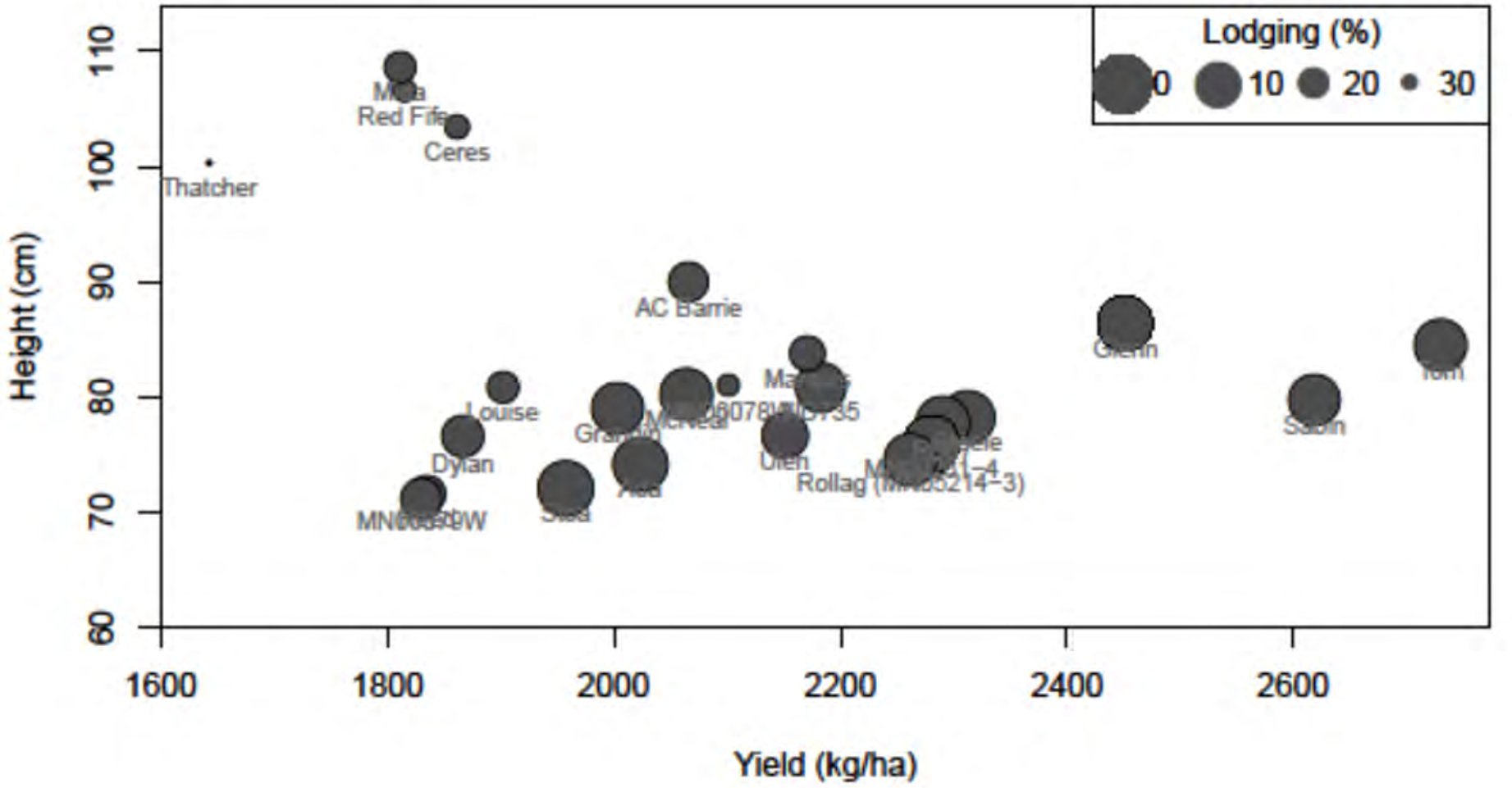

Carrington, ND
Willsboro, NY
Freeville, NY
Rock Springs, PA
BISMARCK
PIERRE
SAINT PAUL
MADISON
LANSING
DES MOINES
CHEYENNE
LINCOLN
DENVER
SPRINGFIELD
INDIANAPOLIS
COLUMBUS
HARRISBURG
TRENTON
ANNAPOLIS
DOVER
WASHINGTON D.C.
ALBANY
CONCORD
BOSTON
PROVIDENCE
HARTFORD

Winter wheat varietal field performance



Needs | Parental Evaluation | Genetic Improvement

Spring wheat varietal field performance



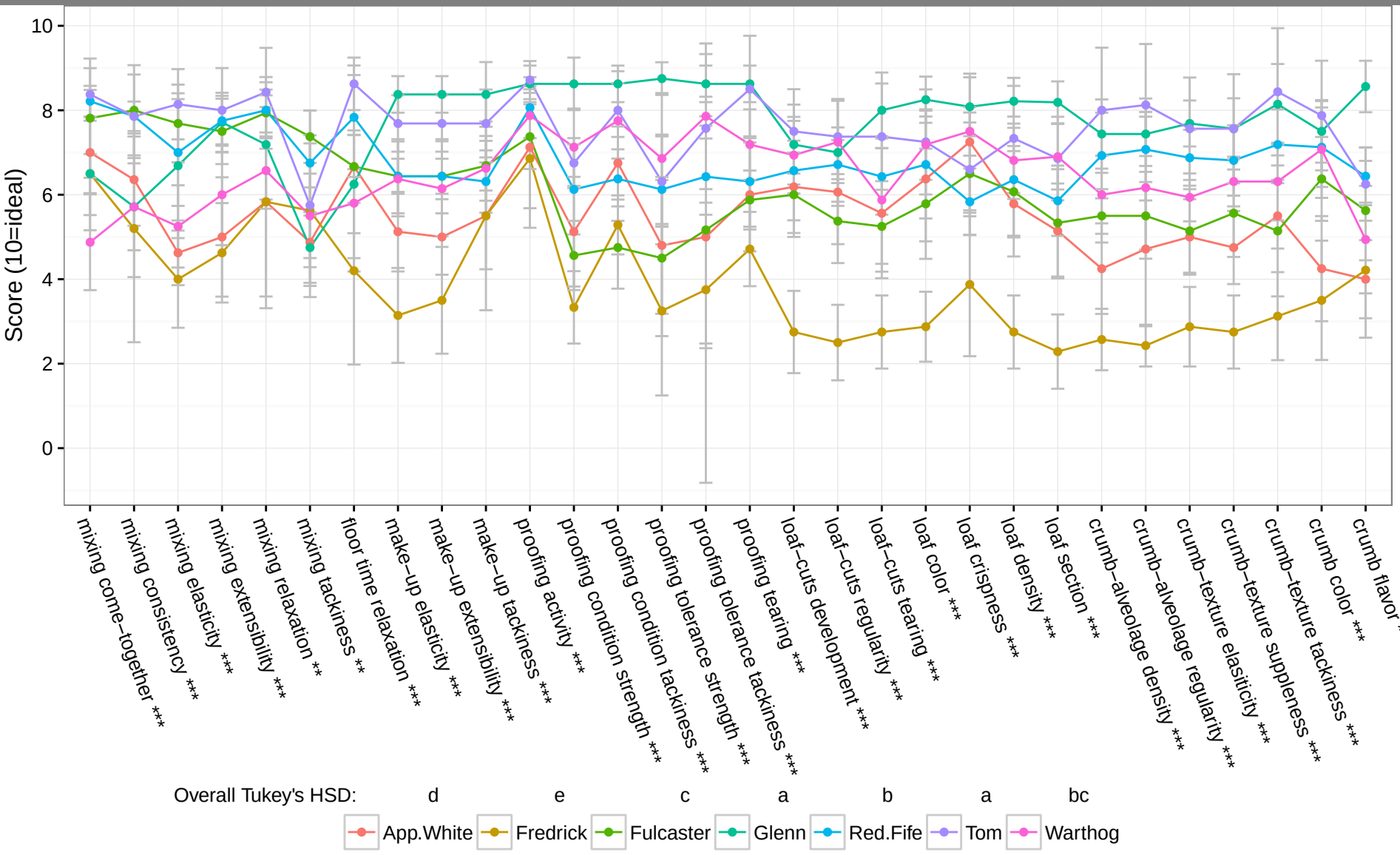
Bread wheat variety quality evaluation for sourdough

Needs

Parental Evaluation

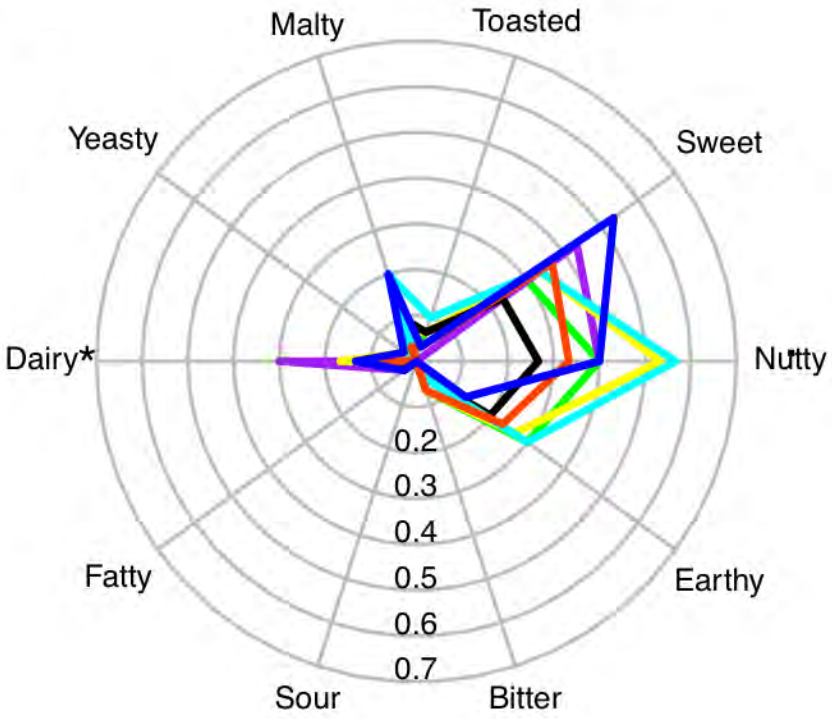
Genetic Improvement

Sourdough baking trial results

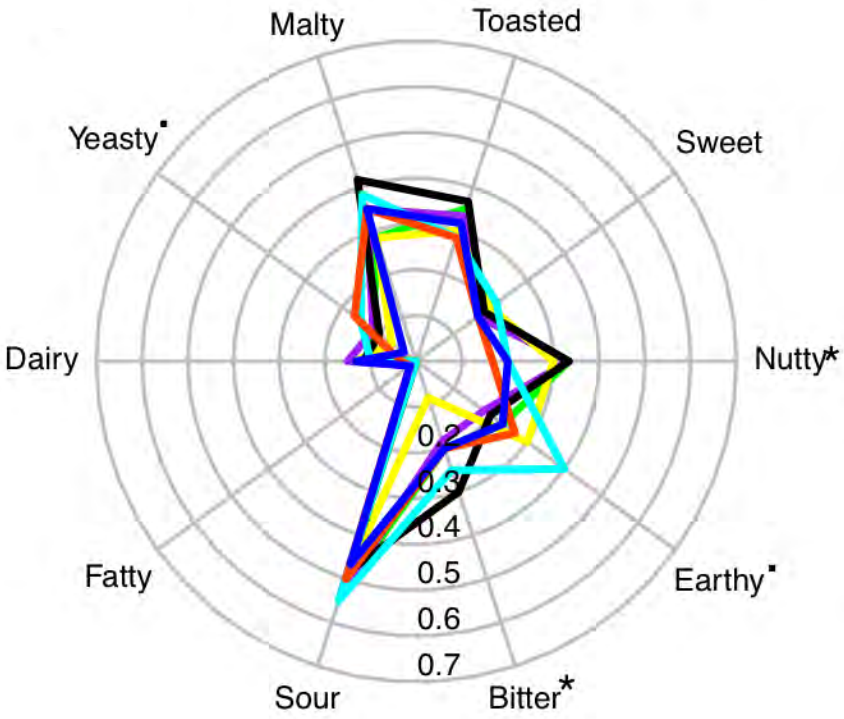


Flavor odds in:

Cooked Whole Grain



Sourdough



Appalachian White
Fredrick
Fulcaster
Glenn
Red Fife
Tom
Warthog

*indicates significant difference among varieties at $p<0.05$

Type	Variety Name	Class	Variety Age	Yield Rank	Test Wght Rank	Protein %	Baking 10= ideal	Bread Height cm	Bread Taste 10= intense	Crumb Texture 10= hearty	Surface Texture 10= rough	Bread Cohes-ion seconds	Bread Grain-iness 10= grainy	Bread Dryness 10= moist	Cooked Grain Taste 10= intense
Winter Wheat	Appalach-ian White	Hard White	Modern	13 of 35	15 of 35	9.8	5.5*	6.5	5.2	6.7	5.6	20.3	5.1	4.5	3.3*
	Fredrick	Soft White	Modern	6 of 35	23 of 35	9.5	3.9*	5.1*	5.5	7.9*	6.7*	20.7	5.6*	3.8*	4.7
	Fulcaster	Soft Red	Herit-age	31 of 35	13 of 35	10.5	6.2	5.9	5.1	6.9	5.0	19.5	5.3	4.0	4.1
	Warthog	Hard Red	Modern	2 of 35	4 of 35	9.9	6.5	7.5*	4.8	6.6	5.6	20.3	5.4	4.0	5.4*
Spring Wheat	Red Fife	Hard Red	Herit-age	19 of 22	16 of 22	14.8	6.8	6.3	5.7	6.9	4.8	21.9	4.7	4.8	4.0
	Tom	Hard Red	Modern	1 of 22	2 of 22	14.7	7.6*	7.4*	5.4	6.5	3.9*	23.5	4.7	4.6	4.2
	Glenn	Hard Red	Modern	4 of 22	1 of 22	15.0	7.7*	8.0*	5.3	5.4*	3.7*	27.8*	3.9*	5.6*	3.7

generally preferred values generally unpreferred values

*indicates significant difference among varieties at $p<0.05$

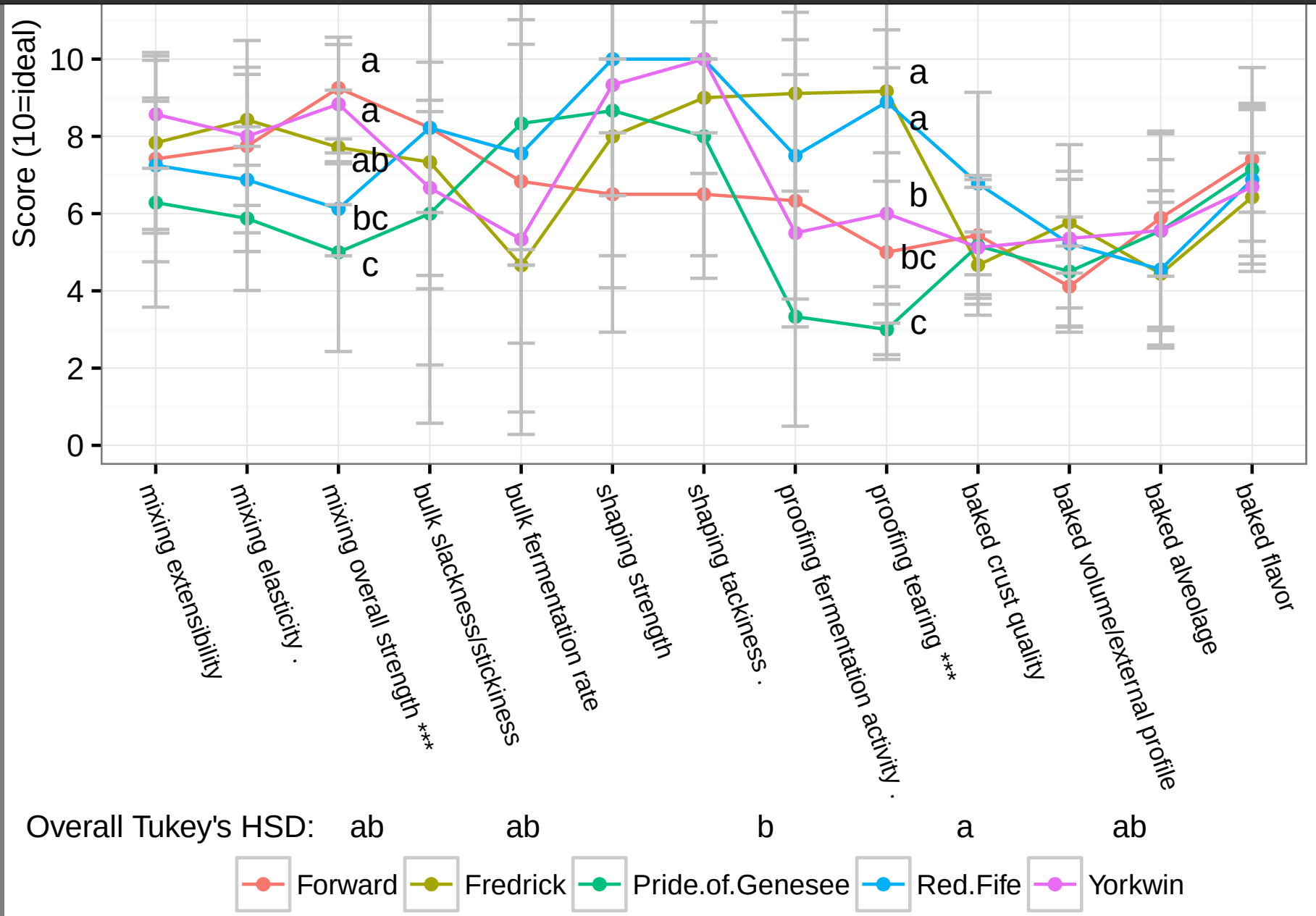
Grain for evaluations was blended 21% from 2012 and 79% from 2013 Freeville, NY harvests.

Soft wheat quality for yeast bread, shortbread, & matzah

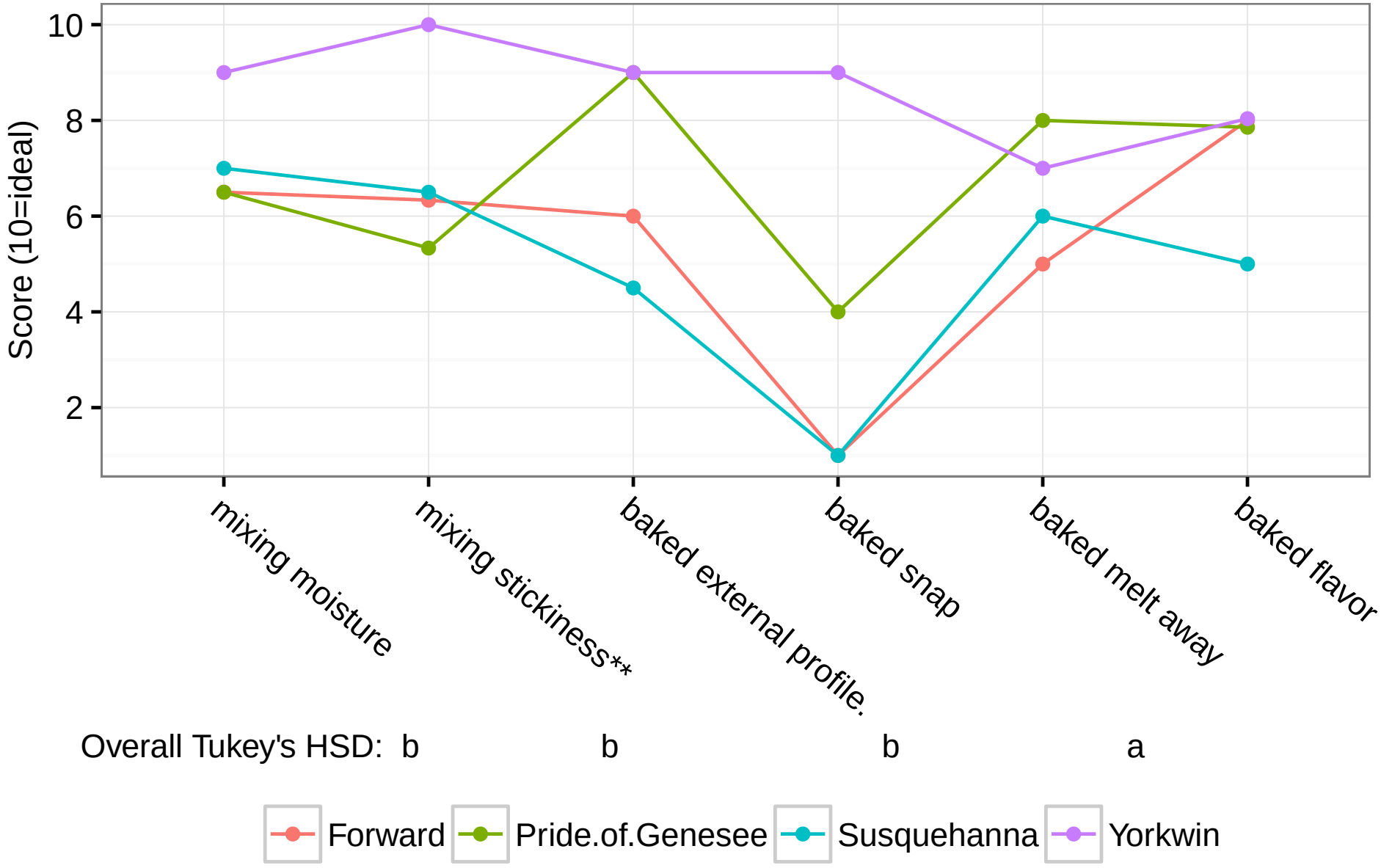
Photo from Matzah Cliff 2010. Blogged at apinnick.wordpress.com/2010/04/04/matzah-trek/. Appeared in Appeared in "http://www.amny.com/eat-and-drink/jewish-delis-nyc-deli-man-taught-us-valuable-lessons-1.10026087"

Needs | Parental Evaluation | Genetic Improvement

Soft wheat varieties for quick-rise yeast breads

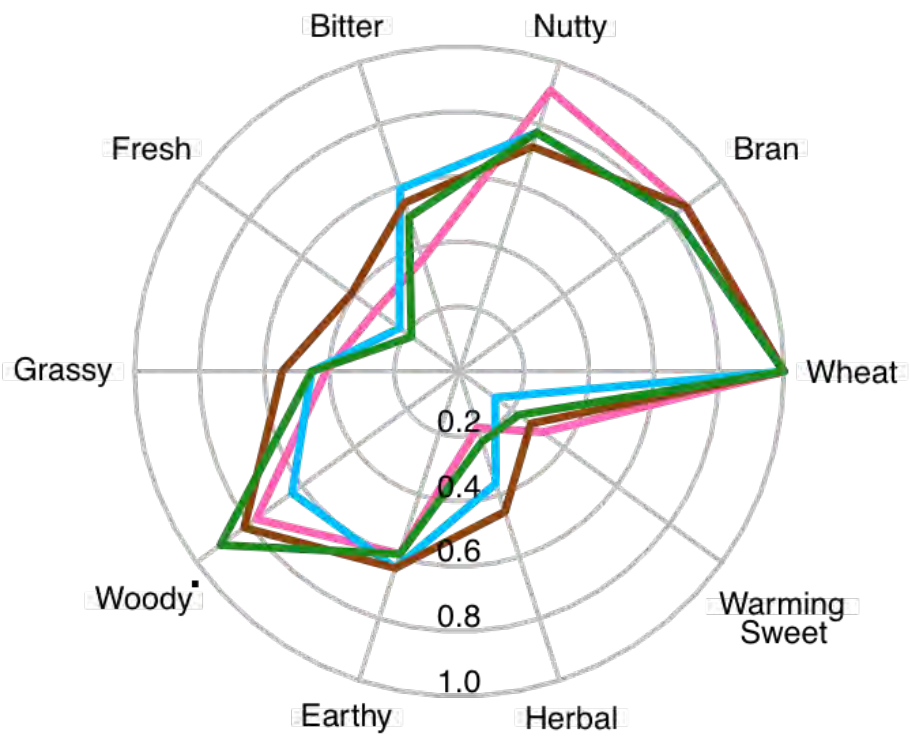


Soft wheat varieties for shortbread

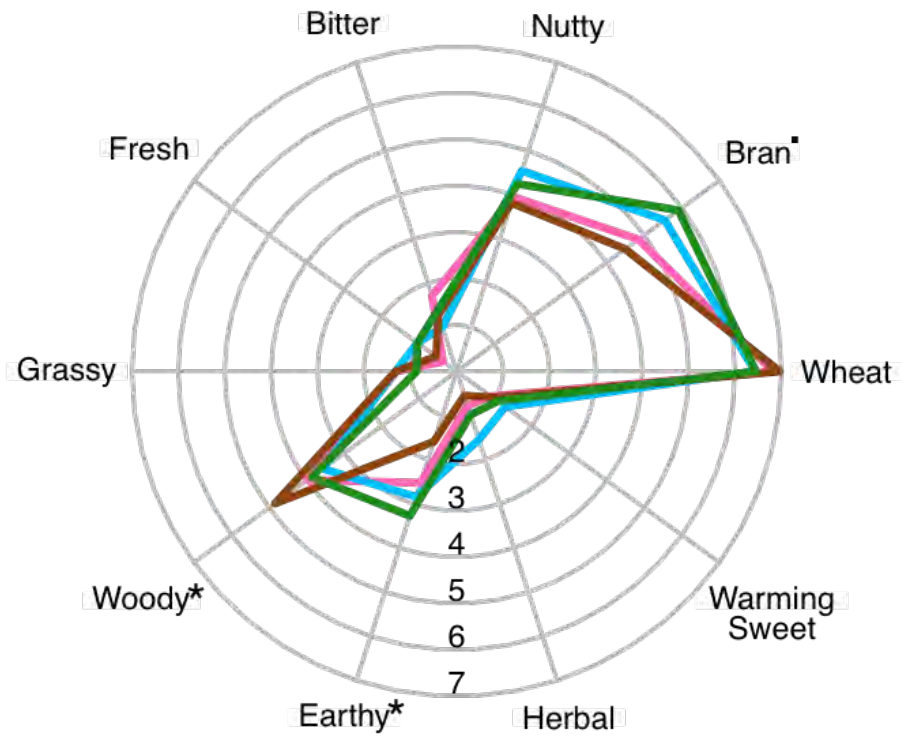


Flavor odds and intensity in:

Cooked Whole Grain



Matzah Crackers



Forward
Pride of Genesee
Susquehanna
Yorkwin

*indicates significant difference among varieties at p<0.05

Soft wheat variety quality for matzah crackers, yeast bread, shortbread cookies, and cooked grain

Type	Variety	Class	Variety	Yield	Test Wght	Pro-tein	Falling #	Short-bread	Bread Baking	Matzah Visual Texture	Matzah Rough-ness	Matzah Grain-iness	Cooked Grain Pref	Cooked Grain Texture	Cooked Grain Dryness
	Name	Class	Age	Rank	Rank	%	second	10= ideal	10= ideal	1= smooth	10= rough	10= grainy	1= best	10= chewy	10= moist
Winter Wheat	Forward	Soft Red	Herit-age	16 of 35	17 of 35	13	403	6.4	7.2	5.6*	5.0	5.6	2.4	5.0	4.2
	Fredrick	Soft White	Modern	6 of 35	23 of 35	11.5	233		7.7						
	Pride of Genesee	Soft White	Herit-age	30 of 35	2 of 33	13.3	311	6.9	6.0*	4.6*	4.7	5.9*	2.0*	6.5*	3.9
	Susqueh-anna	Soft Red	Modern	5 of 35	35 of 35	11.1	301	5.6	NE	4.7	4.7	5.1*	2.4*	4.8	5.2*
	Yorkwin	Soft White	Herit-age	12 of 35	25 of 35	12.8	308	8.9*	7.2	5.2	4.2	5.6	3.0*	6.5*	3.6
Spring	Red Fife	Hard Red	Herit-age	19 of 22	16 of 22				7.9*						

generally preferred values generally unpreferred values

*indicates significant difference among varieties at $p<0.05$

Grain for quality evaluations was from one harvest at Freeville , NY in 2014.

Emmer variety quality for pasta and cooked grain

Needs

Parental Evaluation

Genetic Improvement

Emmer varieties for pasta making

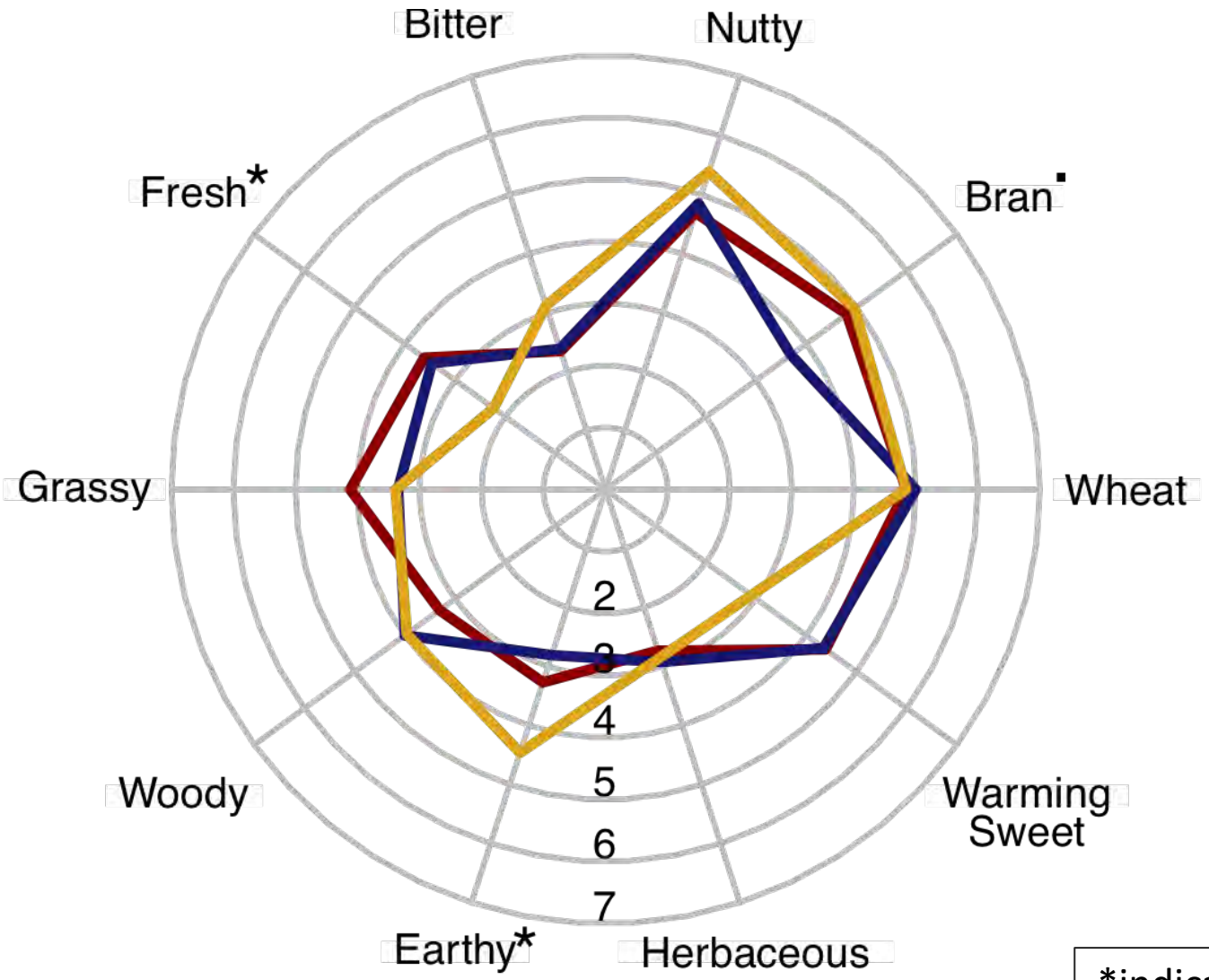
Lucille (score 7) – best technical performance, strong, easy to roll out and cut with the machine.

Red Vernal (score 7) – less hydration, best texture, the pasta chef liked the flavor

North Dakota Common (score 5) – very tacky dough, needed a lot of flour to roll out and took longer to get the right texture.

Black-glumed Emmer (score 3) – tore very easily, tacky, hard to work with, stuck to the machine and took a long time to roll out.

Flavor intensity in pasta



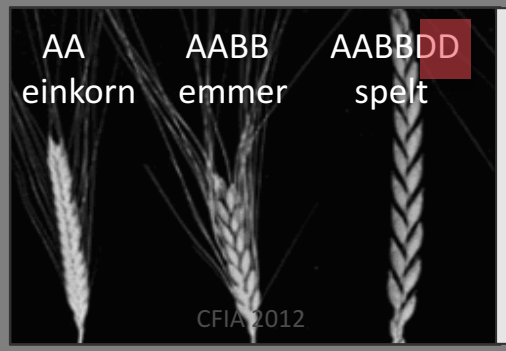
*indicates significant difference among varieties at p<0.05

Variety	Yield	Test Weight	Protein	Pasta making	Pasta Pref-erence	Pasta Shin-iness	Pasta Rough-ness	Pasta Grain-iness	Pasta Firmnes s	Cohes-ion
Name	Rank	Rank	%	10= ideal	prob-ability	10= shiny	10= rough	10= grainy	10= chewy	seconds
Lucille	2 of 12	5 of 12	14.1	7	0.42*	5.24	4.58	3.88	4.46*	11.12
ND Common	1 of 12	2 of 12	13.5	5	0.19*	5.88*	3.46*	3.61	3.63*	10.12
Red Vernal	3 of 12	4 of 12	15.0	7	0.27	4.84*	5.04	5.65*	6.21*	13.50*
Black-Glumed Emmer				3						

generally preferred values generally unpreferred values

*indicates significant difference among varieties at $p<0.05$

Grain for evaluations was blended 45% from 2012 and 55% from 2014 Freeville, NY harvests.

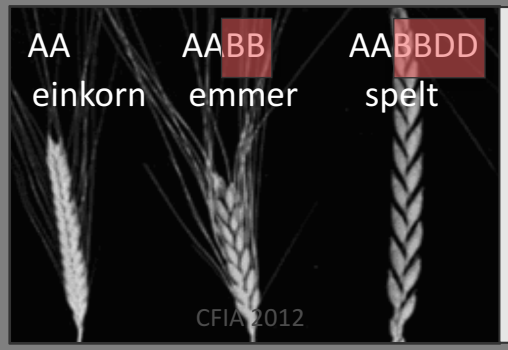


Celiac Immunoreactivity

Among Wheat Species and Genotypes

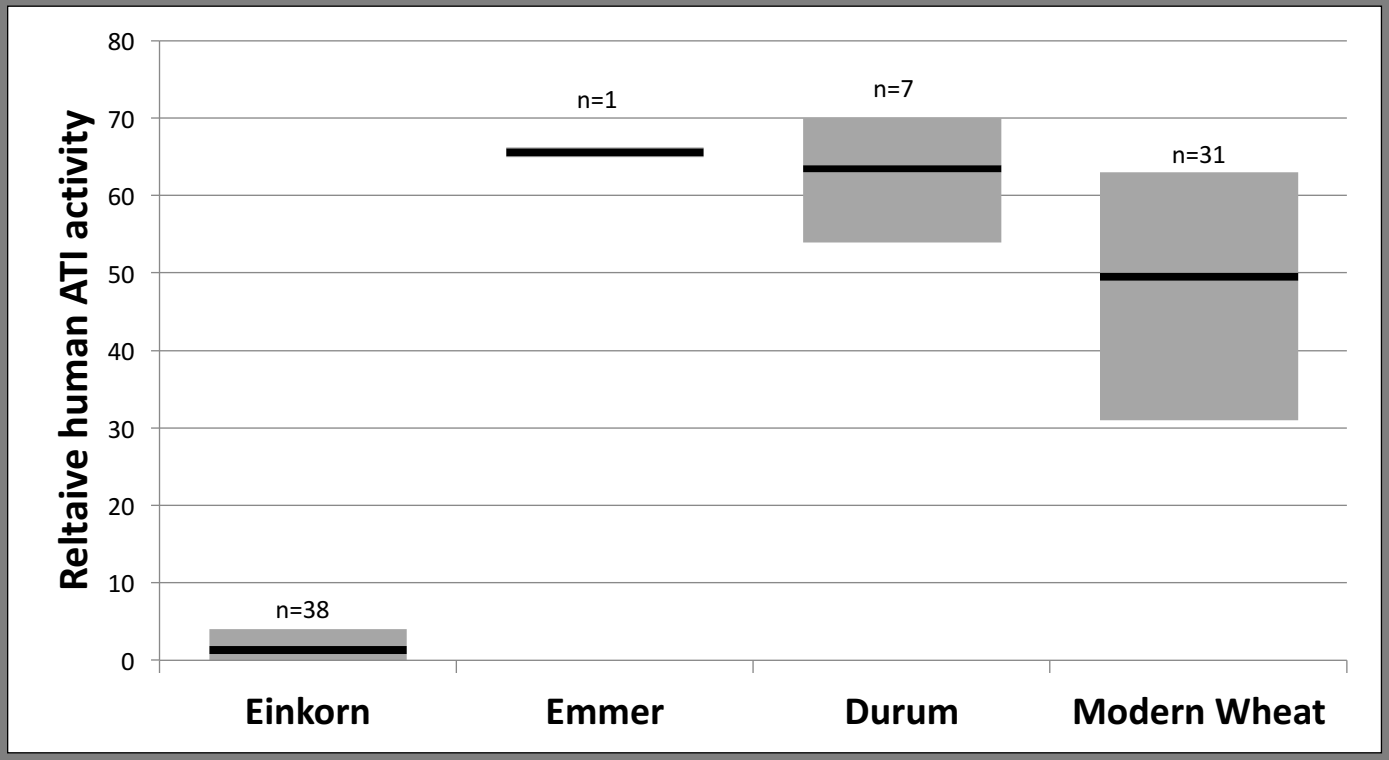
Figure from Kissing Kucek et al., 2015

Needs | Parental Evaluation | Genetic Improvement



Amylase-Trypsin Inhibitors

Among Species and Genotypes of Wheat (Celiac Disease, Wheat Allergy, and NCWS)



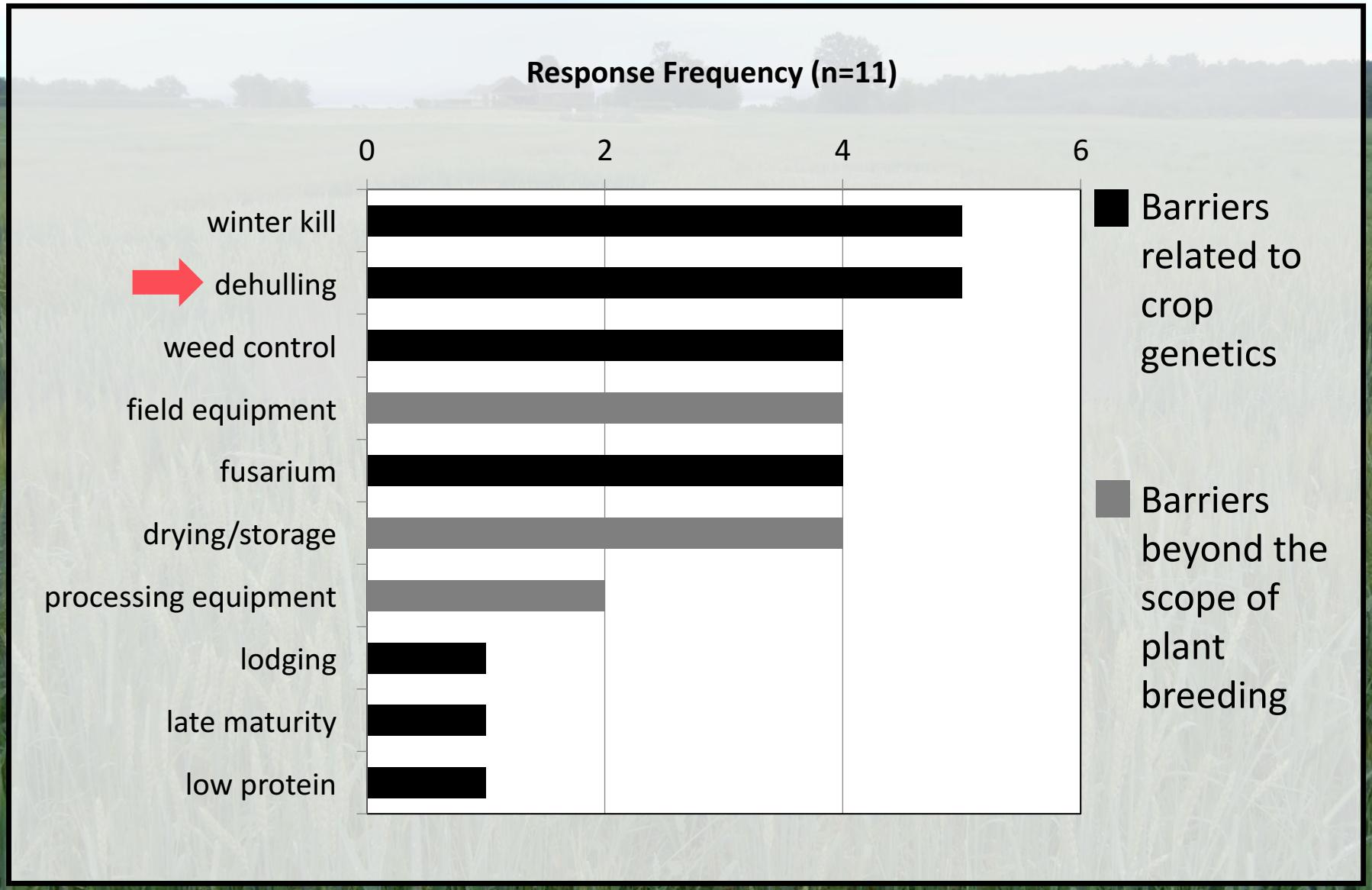
Meta-analysis of five studies (Bedetti et al. 1974; Vittozzi and Silano 1976; Sánchez-Monge et al. 1996; Wang et al. 2007; Zoccatelli et al. 2012). Max, min, and mean (black lines) values presented. Labels "n=" refer to the number of unique varieties evaluated. Values for ATIs were normalized to a relative scale by converting reported average values for modern wheat in each study to a common value.

Building better varieties

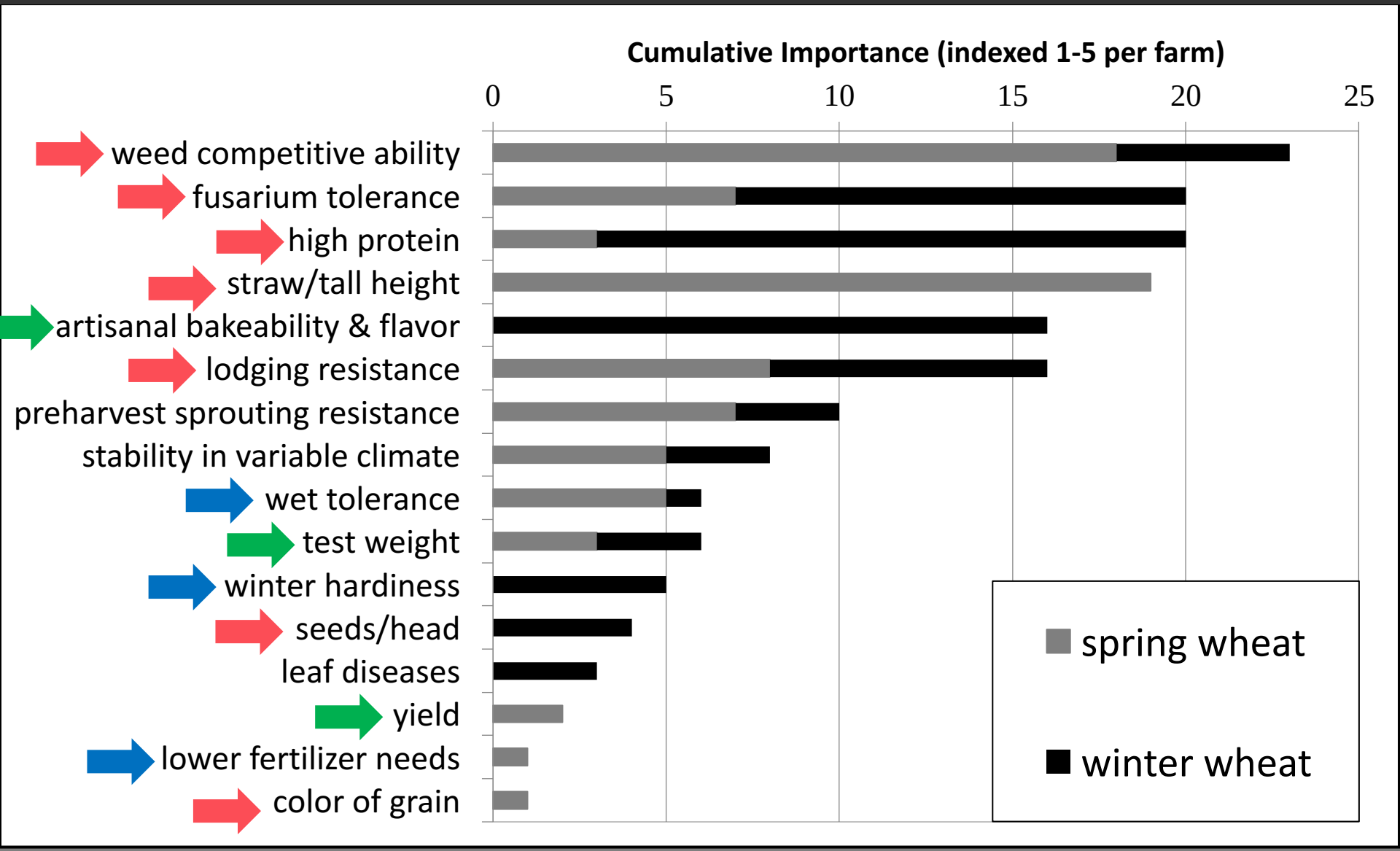
Photo from Section of Plant Breeding and Genetics, Cornell University

Needs | Parental Evaluation | Genetic Improvement

Free-threshing einkorn and emmer

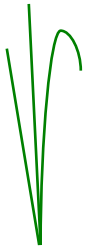
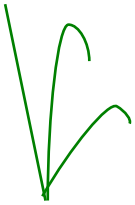
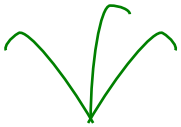
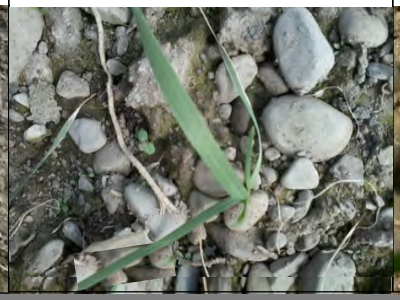


Bread wheat priority traits (n=11)



Needs | Parental Evaluation | Genetic Improvement

Selection for weed competitive ability

1	2	3	4 – flag me!	5 – flag me!
Erectophile	Erectophile	Semi-erectophile	**Planophile**	**Planophile**
				
Narrow 1st and 2nd leaves	Narrow 1st and 2nd leaves	Intermediate 1st and 2nd leaves	**Wide 1st and 2nd leaves**	**Wide 1st and 2nd leaves**
Low soil cover	Low soil cover	Intermediate cover	**Good soil cover**	**High soil cover**
				

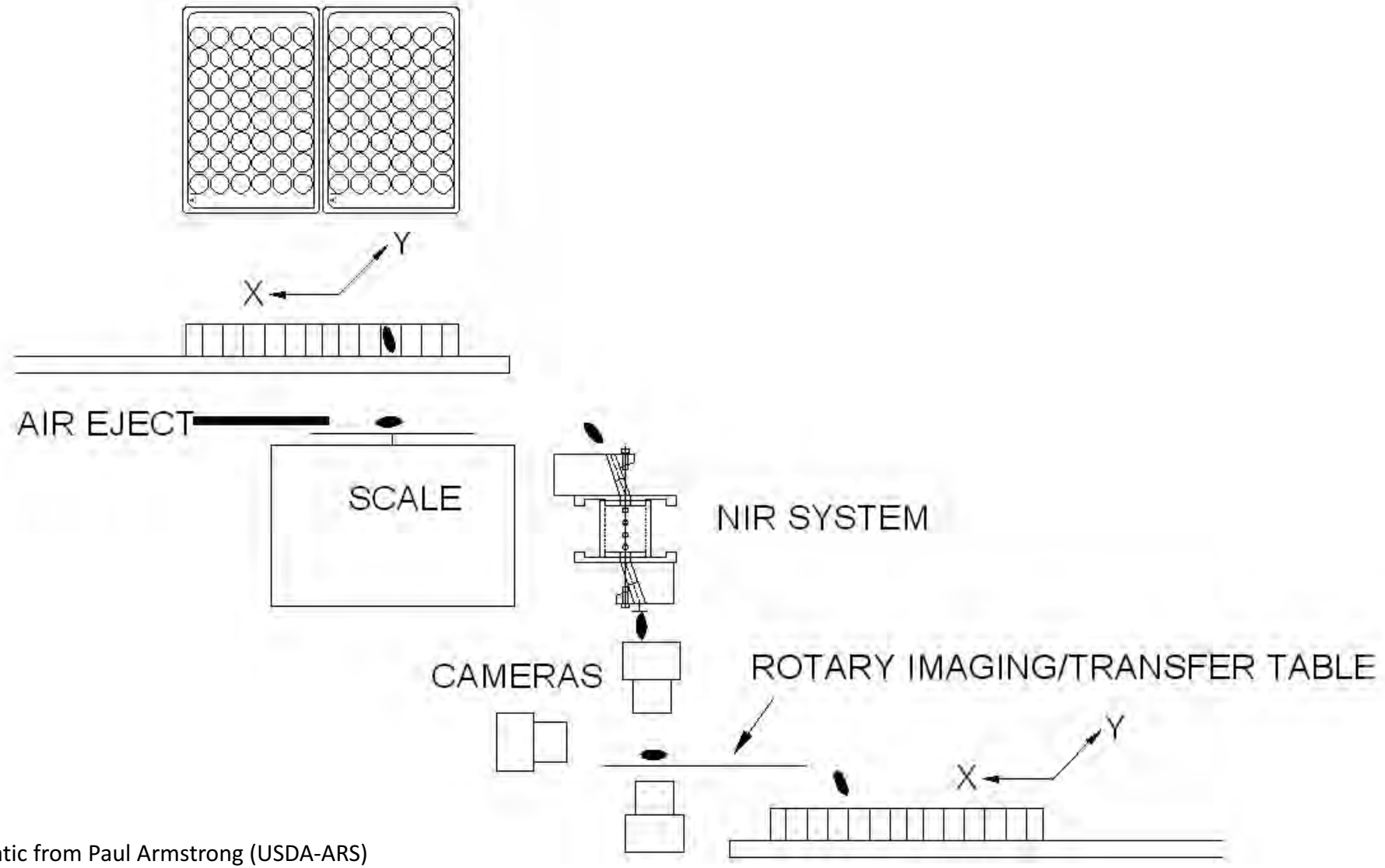
Needs | Parental Evaluation | Genetic Improvement

Selection for Fusarium tolerance

Photo from James Tanaka

Needs | Parental Evaluation | Genetic Improvement

Selection for protein

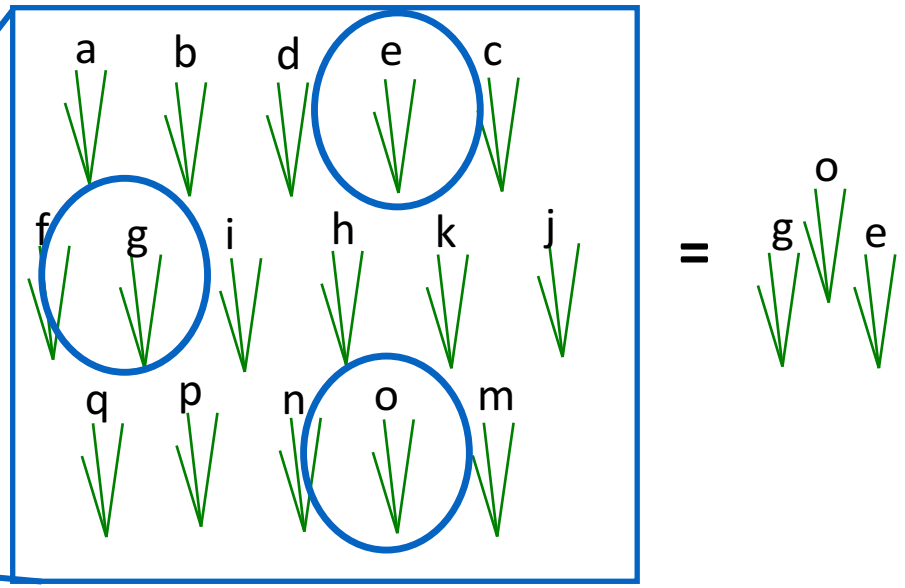


Schematic from Paul Armstrong (USDA-ARS)

On-farm selection

Red Fife x Warthog	Ladoga x Warthog
Arapahoe x Gua	Alauda x Maxine
Clark's x Arapahoe	Check
Ladoga x Warthog	Arapahoe x Gua
Alauda x Maxine	Red Fife x Warthog
Check	Clark's x Arapaoe

Example wheat selection farm plots



'Red Fife' x 'Warthog' Population

Needs | Parental Evaluation | Genetic Improvement

55 potential varieties

Red Fife x Warthog	Ladoga x Warthog
Arapahoe x Gua	Alauda x Maxine
Clark's x Arapahoe	Check
Ladoga x Warthog	Arapahoe x Gua
Alauda x Maxine	Red Fife x Warthog
Check	Clark's x Arapaoe

Example wheat selection farm plots

Farmer selection
(Photo from Threshold Farm)

Post-harvest selection for protein and seed size in lab

Needs | Parental Evaluation | Genetic Improvement

Multi-environment evaluation and release

Questions?

We thank Wide Awake bakery for hosting and Jeffrey Hamelman of King Arthur Flour for facilitating the sourdough baking trial, Gramercy Tavern for hosting the pasta making trial, The Natural Gourmet Institute for hosting the emmer sensory evaluation, Bread Alone Bakery for hosting the soft wheat baking trial, and Culinary Institute of America for hosting the soft wheat sensory evaluation. Finally, we thank the many farmers, millers, bakers, and tasters who dedicated time and effort to participate in this research.