

# Cornell Small Grains Breeding & Genetics Project

## Value-Added Grains for Local and Regional Food Systems

Mark E. Sorrells



Cornell University

Department of Plant Breeding & Genetics

*Excellence in Plant Breeding Since 1907*





# Presentation Overview

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- Brief overview of the Cornell Small Grains Breeding & Genetics Project
- Value added grains project
- What are ancient grains?
- Why should we be interested in ancient grains?





# Cornell Small Grains Project

## Support Personnel:

David Benscher

James Tanaka

Josh Knecht

## Post Docs & Res. Assoc:

Haixiao Hu

Shantel Martinez

## Grad Students:

Shitaye Homma

Karl Kunze

Travis Rooney

Daniel Sweeney

Ellie Taagen



Malting Barley



Spelt



Emmer



Durum



Spring Oat



Hybrid Rye



# Cornell Small Grains Project

## Winter Wheat

Geneva  
Purcell  
Susquehanna  
Cayuga  
NYBatavia  
Caledonia  
Richland  
Saranac  
Hopkins  
Bridgeport  
Medina  
Otsego  
Erie  
NY99056-161

## Breeding Strategies

- Genomic Selection
- Association Analyses
- Recurrent selection

## Variety testing and development

- Soft Winter Wheat
- Spring Oats
- Spring Barley
- Winter Barley
- Winter Rye
- Specialty grains: Spelt, Emmer, Einkorn

## Traits

- Grain Yield
- Fusarium Head Blight
- Preharvest Sprouting
- Nutritional quality
- Sensory evaluation
- Seed Size & Shape
- Stem Rust

## Spring Malting Barley

Excelsior Gold

## Spring Oats

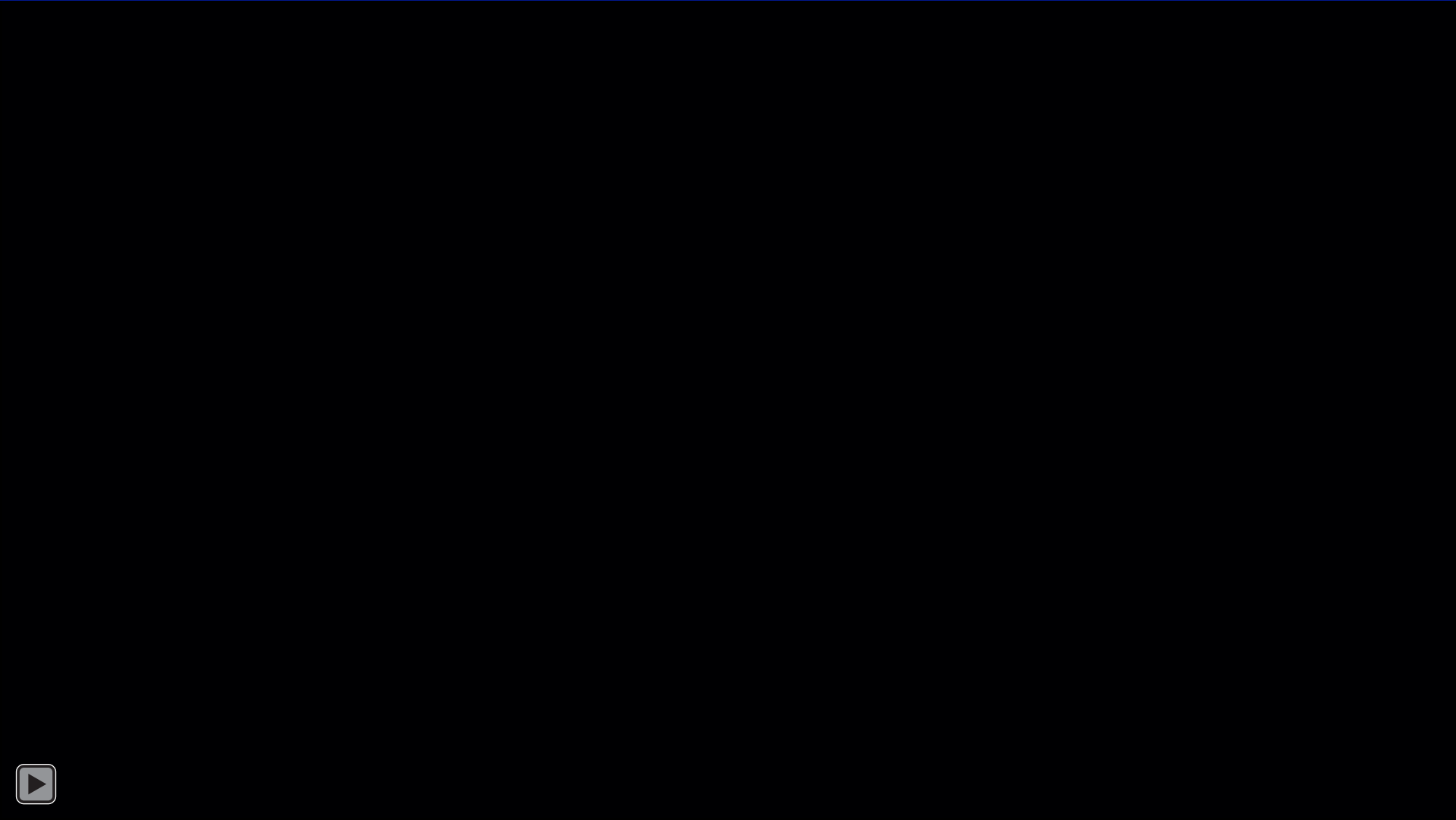
Newdak  
Rodeo  
Blaze  
Corral

## Winter Barley

Willis









# About the Project

- Breeding
  - Variety Trials at participating research institutions
  - Measure agronomic and nutritional quality traits
- Organic Management
  - What are the best practices for different types of grains
- Market Assessment
  - What type of grains are of interest to consumers
  - How do we develop the value chain
- Outreach
  - Educate stakeholders including farmers, extension personnel, consumers, chefs, etc. about the benefits of grains



# Variety Trial Testing and Breeding

- Collaboration with the following Universities:
  - Madison-Wisconsin- Lucia Gutierrez and Juile Dawson
  - Oregon State- Lane Selman
  - Illinois- Jessica Rutkoski
  - Maine- Ellen Mallory
  - Vermont- Heather Darby
- Evaluating both winter and spring grains of the following
  - Wheat, Emmer, Spelt, Covered Barley, Naked Barley, Rye, Einkorn
- Goal: Measure Agronomic and Nutritional Traits of variety trials in organic research trials





# Organic Management

- All trials will be grown under organic mgmt
- Assess priority traits value added grains in organic environments
- Develop best management practices for the NE and Mid-West environments
- Focus on post-harvest management for seed storage and threshability



# Organic Naked Barley in New York

- Through the OREI Naked Barley Project, we have been growing Organic Naked Barley in NY for three years for both winter and spring
- Big takeaways so far:
  - Organic winter barley is competitive with conventional winter barley based on agronomics
  - Organic spring barleys have been a significant challenge overall
  - Grain diseases are the largest roadblock to organic barley, particularly Fusarium head blight and smut





# Winter Naked Barley

- Agronomic

- Yield, test weight, heading date, height, lodging, winter survival, pre-harvest sprouting, threshability

- Disease

- Scald, Leaf Rust, Spot Blotch, Fusarium head blight and DON
- Smut

- Barley Competitiveness

- Stand Count
- Early Height
- Vigor

- Malting Quality

- Beta-glucan, Alpha amylase



# What are Ancient Grains?

- Traditionally, ancient grains refer to Einkorn, Emmer and Spelt.
- They are all covered grains related to wheat but do not thresh free like wheat.
- The hulls remain attached to the kernel and have to be removed before the grain can be used for food products.
- Some marketers include Quinoa, Buckwheat, Amaranth, Tef, Millet and Sorghum but technically they are not related to wheat.



# Einkorn, Emmer and Spelt

- Are NOT gluten free.
- Emmer and einkorn tend to have lower gluten than wheat.
- Some people with gluten sensitivity are able to eat these grains without digestive difficulties but consult with your doctor.
- They have high protein content and other nutritional benefits.
- They are versatile as whole grains, and as flour.
- They have great flavor!



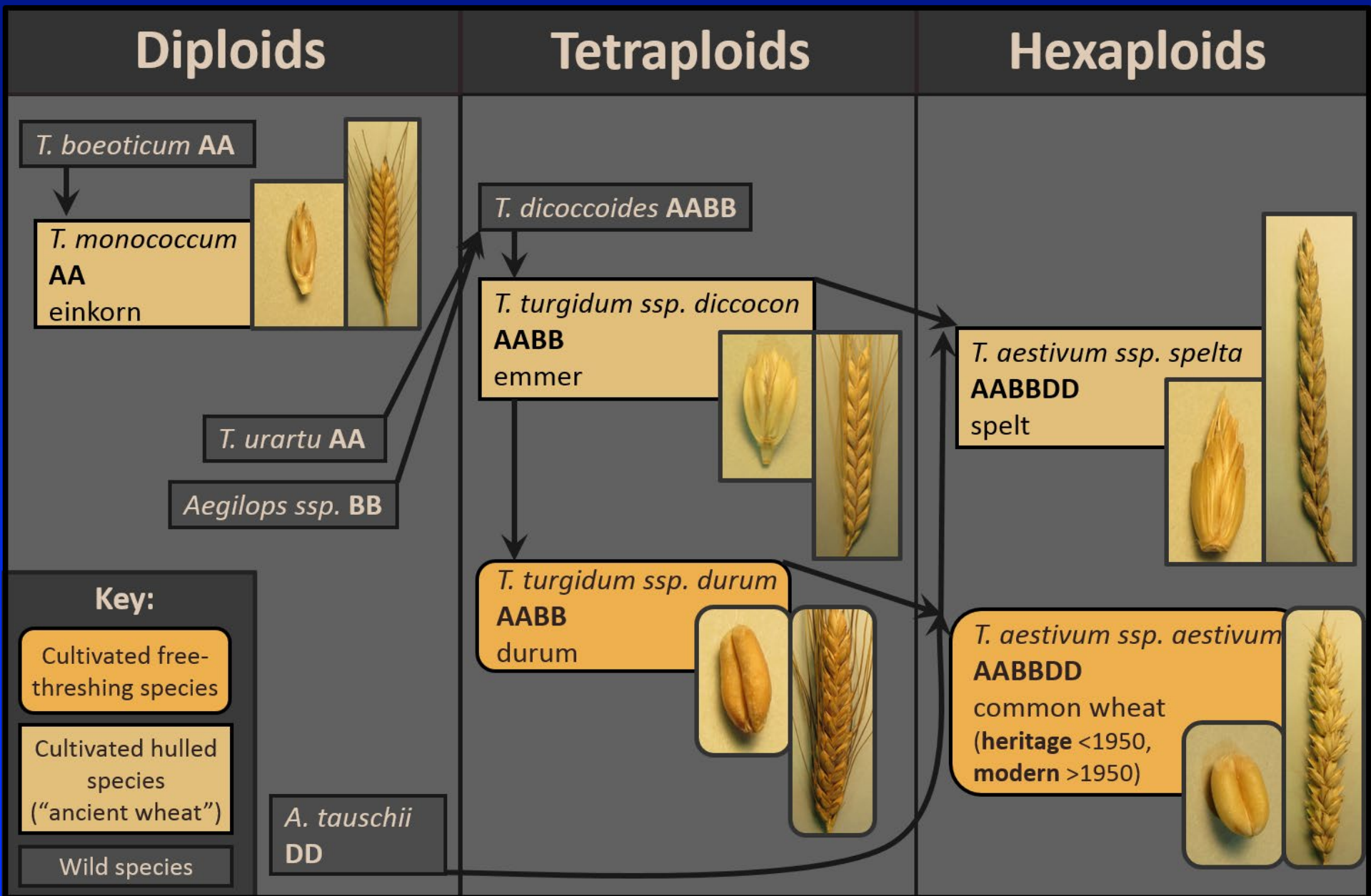


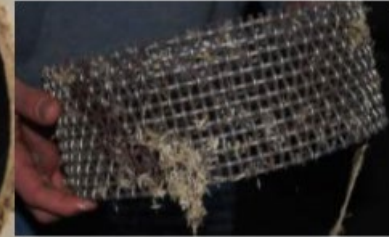
Figure from Kissing Kucek et al. 2015, adapted from Dawson and



# 7D Forsberg impact dehuller



## Horn Dehuller







Spelt from the dehuller  
(dehulled + unde-hulled  
kernels)



Large, whole kernel spelt



# Einkorn, Emmer and Spelt

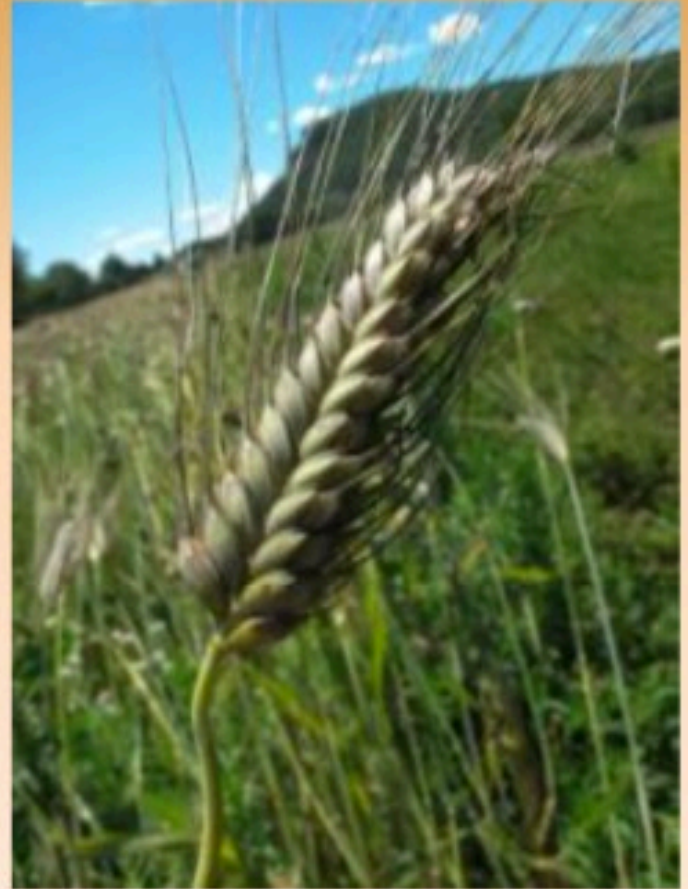
- Einkorn, emmer and spelt have a relatively low profile in the US, with spelt being the best known.
- These grains are more well known and utilized in Europe.
- Regions in Switzerland, France, Italy and the UK are growing emmer and einkorn.
- Spelt has been grown in Eastern Europe & the Mediterranean continuously, for millennia.



Einkorn bread, Zurich, Switzerland

# Einkorn

- Einkorn is diploid wheat
- There is a lot of interest in einkorn, as many people with celiac disease or who have sensitivity to gluten are finding that they are able to digest einkorn—
- It has excellent flavor!





# Emmer Wheat

- Emmer is tetraploid and related to durum wheat
- Emmer is great as a whole grain and when ground into flour, can be made into pasta and bread.
- Emmer and farro are the same thing so any recipe calling for farro should use emmer
- Emmer is a well known and popular grain in Italian cuisine.





# Spelt

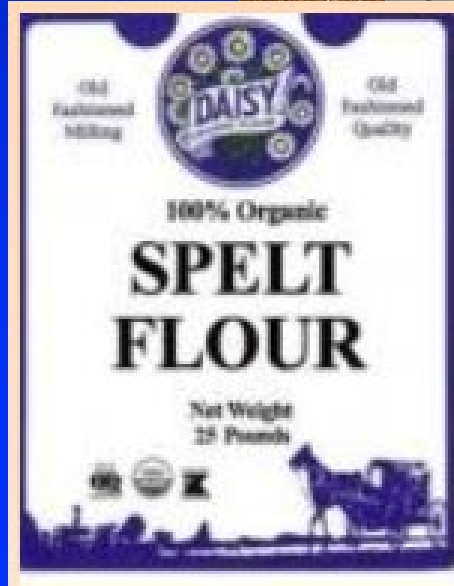
- Spelt has been grown for many years in New York and Pennsylvania.
- Available in health food stores & coops.
- Spelt bread is sometimes preferred as an alternative to white bread.
- Spelt crackers and snacks are available.
- Some Artisan bakers are working with spelt.



Spelt

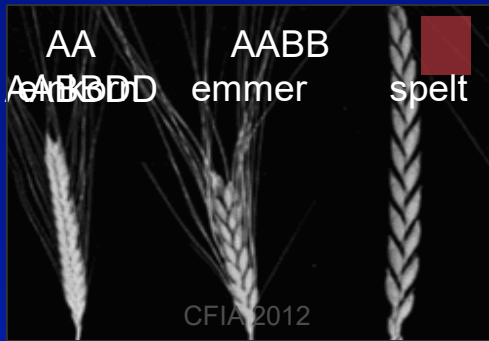


Wide Awake Bakery, Trumansburg NY



Bread Alone Bakery, Boiceville, NY





# Celiac Immunoreactivity

## Among Wheat Species and Genotypes

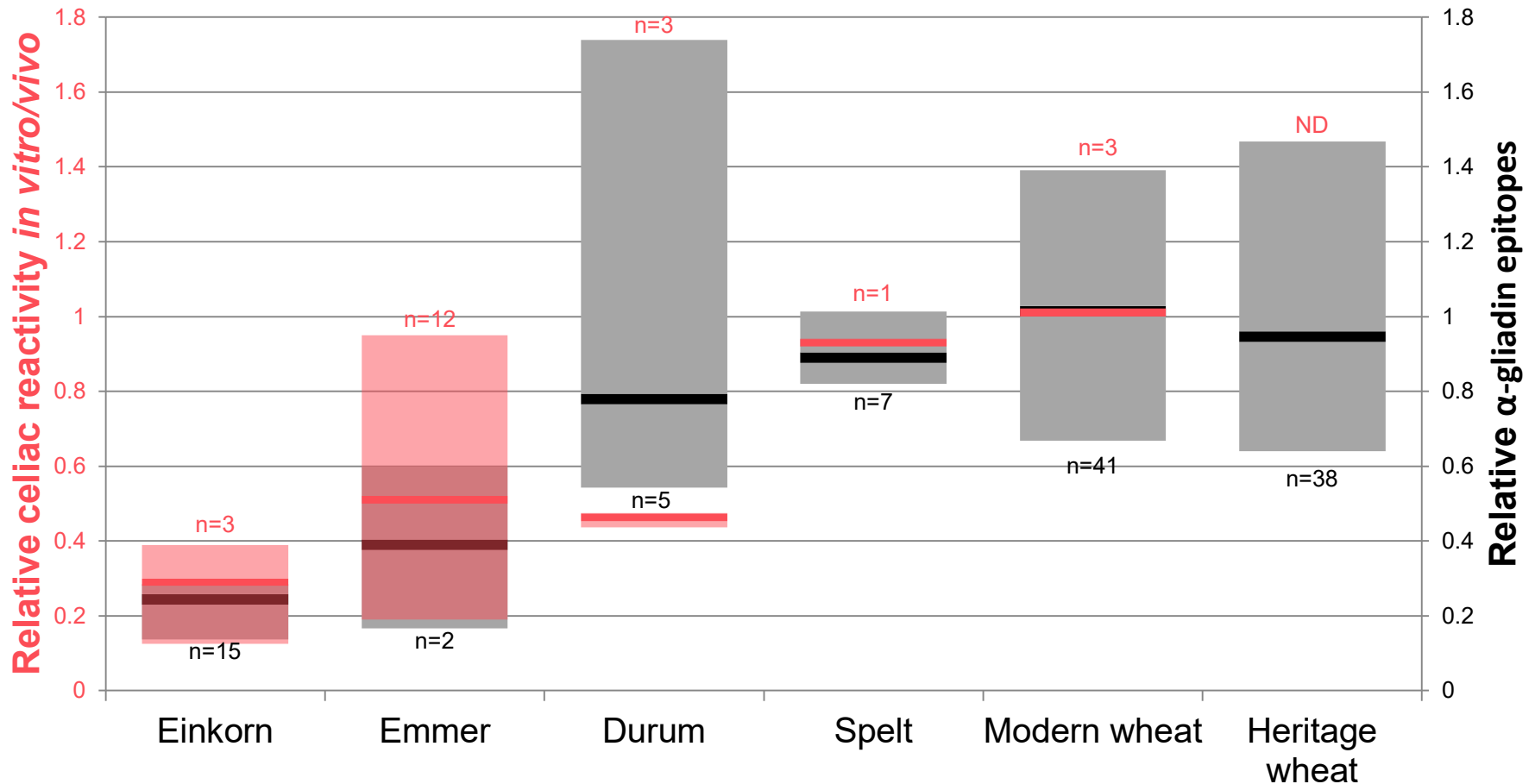


Figure from Kissing Kucek et al., 2015

# Participatory Breeding of Organic Wheat for Local Markets of the Northeast United States



Photo from June Russell

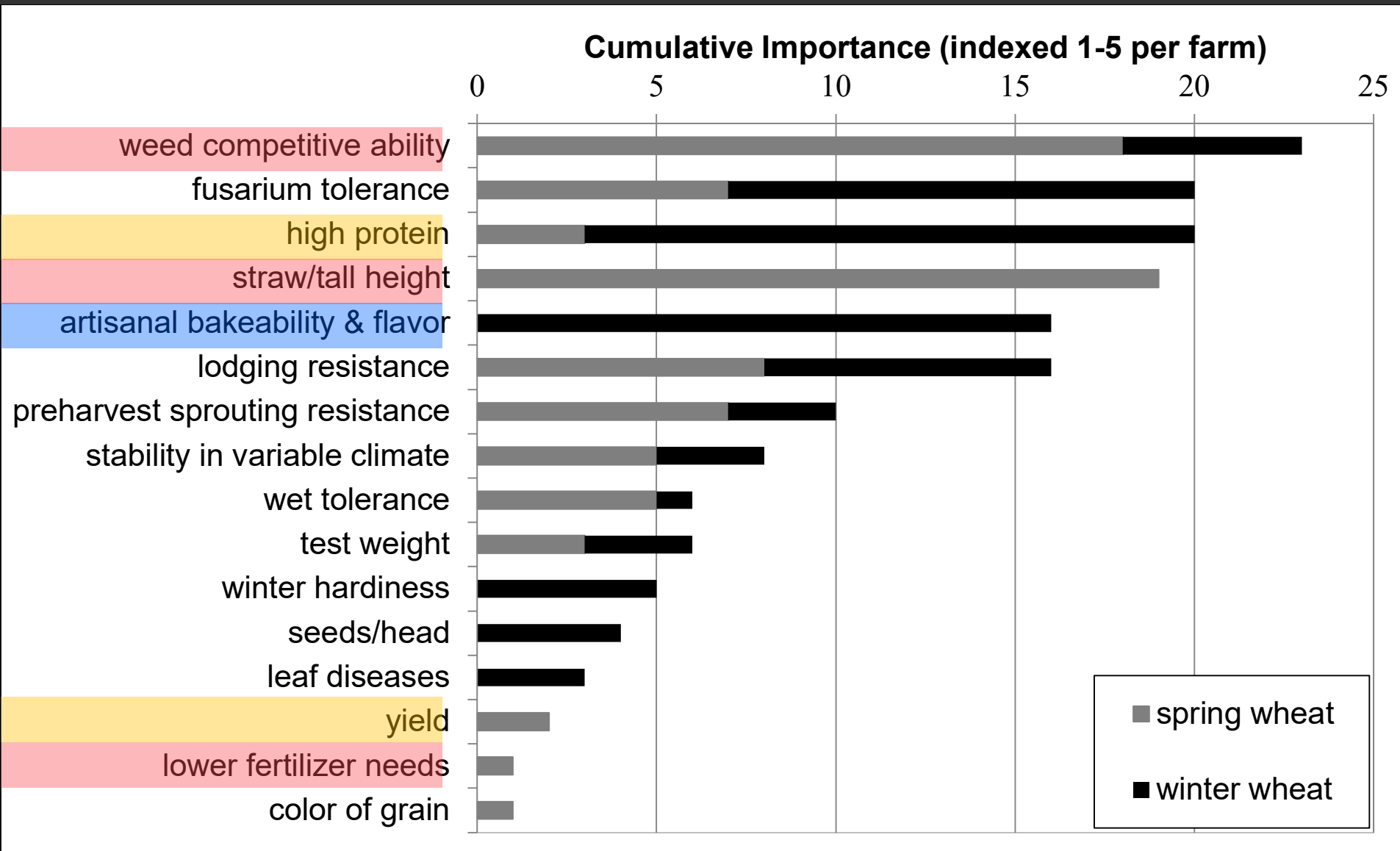
Lisa Kissing Kucek<sup>1</sup>, David Benscher<sup>1</sup>, Heather Darby<sup>3</sup>, Mike Davis<sup>1</sup>, Julie Dawson<sup>2</sup>, Elizabeth Dyck<sup>5</sup>, June Russell<sup>6</sup>, Ellen Mallory<sup>4</sup>, Jack Lazor<sup>8</sup>, Liz Clark<sup>7</sup>, Tom Molloy<sup>4</sup>, Sean O'donnell<sup>8</sup>, Sam Mudge<sup>8</sup>, Mark Kimball<sup>8</sup>, Tom Molloy<sup>4</sup>, Erica Cummings<sup>3</sup>, James Tanaka<sup>1</sup>, Thor Oechsner<sup>8</sup>, Klaas Martens<sup>8</sup>, Hugh Williams<sup>8</sup>, Kit Kelley<sup>8</sup>, Ben Gleason<sup>8</sup>, Mark Sorrells<sup>1</sup>

<sup>1</sup>Cornell University, <sup>2</sup>University of Wisconsin, <sup>3</sup>University of Vermont, <sup>4</sup>University of Maine, <sup>5</sup>Organic Growers Research and Information Sharing Network, <sup>6</sup>Greenmarket- Grow NYC, <sup>7</sup>Gimme! Coffee, <sup>8</sup>Regional Farmers (members of Adirondack Organic Grains also participated)

7 October 2015



# Farmer Priority Traits (n=11)



Needs

Parental Evaluation

Genetic Improvement

Adoption



# Value-added Grains for Organic Production

Lisa Kissing Kucek<sup>1</sup>, Julie Dawson<sup>2</sup>, David Benscher<sup>1</sup>, Liz Clark<sup>3</sup>, Mike Davis<sup>1</sup>, Elizabeth Dyck<sup>7</sup>, Greg Roth<sup>4</sup>, June Russell<sup>5</sup>, Steve Zwinger<sup>6</sup>, and Mark E. Sorrells<sup>1</sup>

USDA NIFA OREI Grant #2011-51300-30697

<sup>1</sup>Cornell University; <sup>2</sup>University of Wisconsin-Madison; <sup>3</sup>Gimme! Coffee; <sup>4</sup>Pennsylvania State University; <sup>5</sup>Greenmarket, Grow NYC; <sup>6</sup>North Dakota State University; <sup>7</sup> Organic Growers Research and Information Network



# Organic Ancient Grains Field Day





**Overall goal: To add value to wheat and specialty grain crops so as to increase their production and enhance the diversity and sustainability of organic farms.**



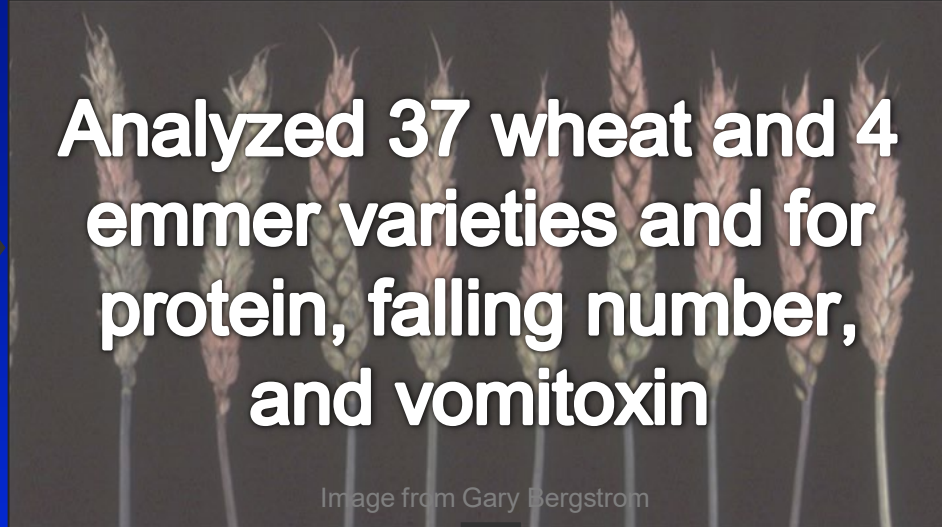


# Parental Evaluation



Compared performance of 146 winter wheat, 34 spelt, 66 emmer, and 31 einkorn varieties

Image from June Russell



Analyzed 37 wheat and 4 emmer varieties and for protein, falling number, and vomitoxin

Image from Gary Bergstrom



Evaluated sensory profiles of 7 bread wheat, 3 emmer, and 4 soft wheat varieties

Image © Allison Usavage



Assessed 7 bread wheat varieties for sourdough, 4 emmers for pasta; and 4 soft wheats for matzah

Image © Allison Usavage

# Bread wheat quality for sourdough and cooked grain



Photo © Allison Usavage  
2014

Needs

Parental  
evaluation

Selection

Adoption



# Sourdough Baking Evaluation

8 bakers evaluated 7 varieties in replicate



**Type III ANOVA with Satterwaite approximation**

$H_0: \mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu_5 = \mu_6 = \mu_7$ ;  $\alpha \leq 0.05$

$$Y_{ijk} = \mu + \alpha_i + \beta_j + \epsilon_{ij}$$

$y_{ij}$ : response for variety  $i$  and baker  $j$

$\mu$ : overall mean response

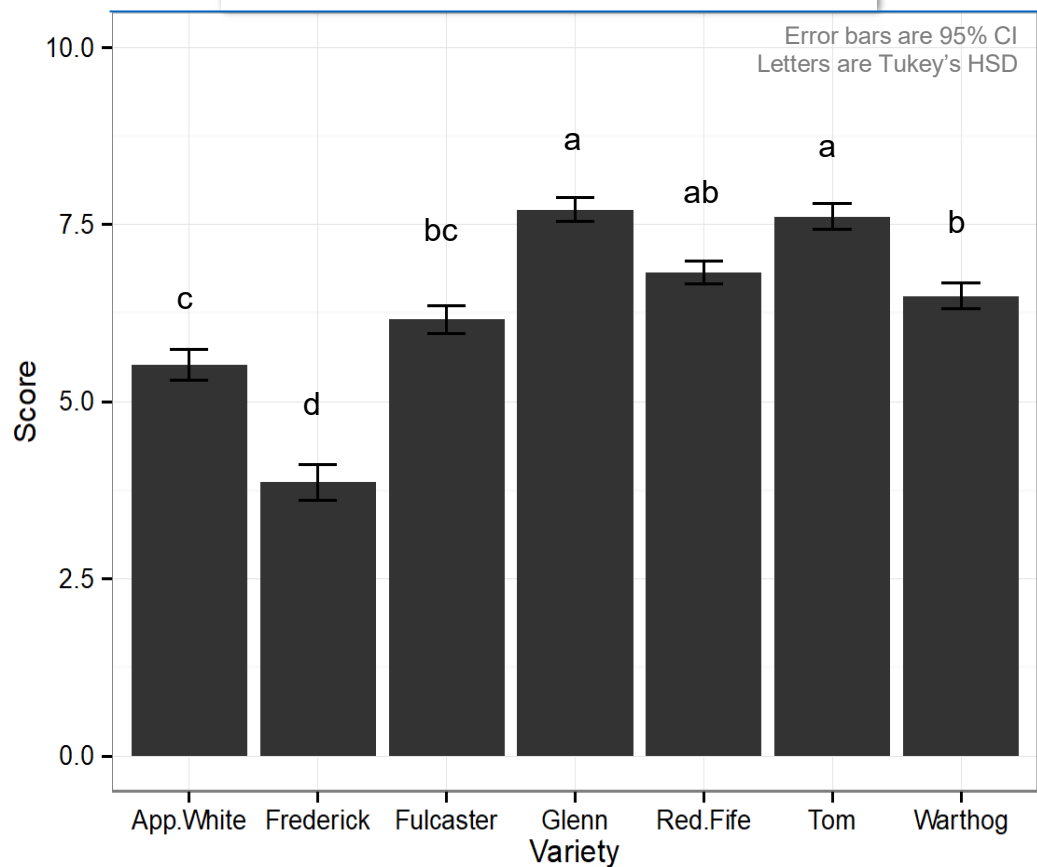
$\alpha_i$ : fixed effect of variety  $i$

$\beta_j$ : random effect of baker  $j$

$\epsilon_{ijkl}$ : experimental error associated with response  $l, j$

To validate model assumptions, errors and random effects were checked for normal distribution, homogeneous variance, and independence.

## Overall Baking Score



Significant differences among varieties at  $p < 0.0001$ .  $n = 1567$

Needs

Parental Evaluation

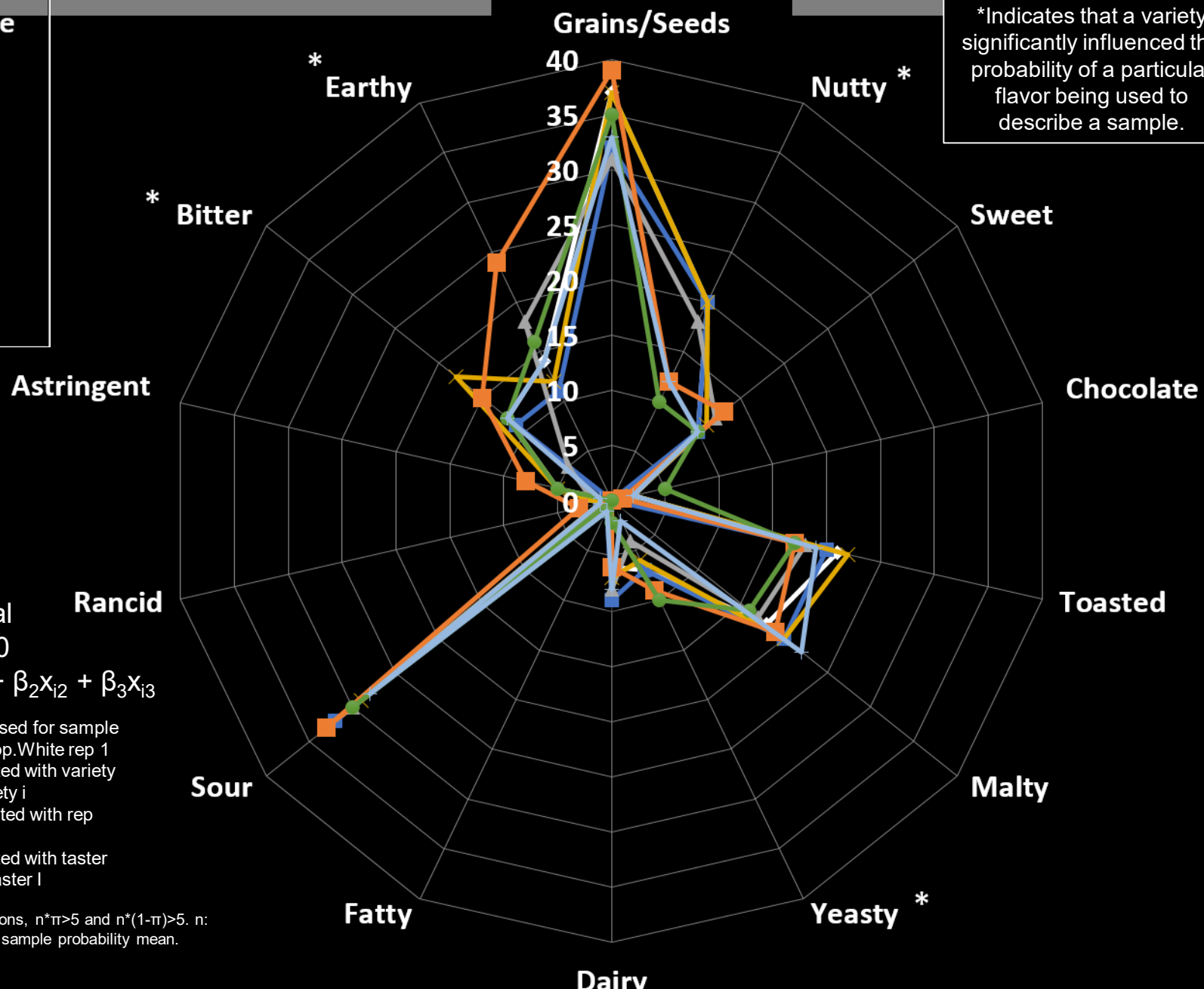
Genetic Improvement

Adoption

# Flavors Identified in Sourdough Bread

- ◊ App.White
- Frederick
- ▲ Fulcaster
- ✕ Glenn
- Red.Fife
- Tom
- ◆ Warthog

\*Indicates that a variety significantly influenced the probability of a particular flavor being used to describe a sample.



Wald  $\chi^2$  binomial  
 $H_0: \beta_1=0; \alpha \leq 0.10$   
 $Y_{ijk} = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \beta_3 x_{i3}$   
 $Y_{ij}$ : log odds of a flavor used for sample  
 $B_0$ : intercept log odds App.White rep 1  
 $\beta_1$ : partial slope associated with variety  
 $x_{i1}$ : fixed variable of variety i  
 $B_2$ : partial slope associated with rep  
 $x_{i2}$ : fixed variable of rep i  
 $\beta_3$ : partial slope associated with taster  
 $x_{i3}$ : random variable of taster l

To validate model assumptions,  $n \cdot \pi > 5$  and  $n \cdot (1-\pi) > 5$ . n: number of observations;  $\pi$ : sample probability mean.



# Sourdough Sensory Evaluation

30 tasters evaluated 7 varieties over 2 replicates

Type	Variety	Market	Variety	Taste Intensity	Crumb Texture	Surface Texture	Ability to Dissolve	Graininess	Dryness
	Name	Class	Age	10=highest	10=hearty	10=rough	seconds	10=grainy	10=moist
Winter Wheat	Appalachian White	Hard White	Modern	5.2	6.7	5.6	20.3	5.1	4.5
	Frederick	Soft White	Modern	5.5	7.9*	6.7*	20.7	5.6*	3.8*
	Fulcaster	Soft Red	Heritage	5.1	6.9	5.0	19.5	5.3	4.0
	Warthog	Hard Red	Modern	4.8*	6.6	5.6	20.3	5.4	4.0
Spring Wheat	Red Fife	Hard Red	Heritage	5.7*	6.9	4.8	21.9	4.7	4.8
	Tom	Hard Red	Modern	5.4	6.5	3.9*	23.5	4.7	4.6
	Glenn	Hard Red	Modern	5.3	5.4*	3.7*	27.8*	3.9*	5.6*

higher scoring,
  lower scoring,
 \*significantly lower or higher than other varieties at p<0.05

Needs

Parental Evaluation

Selection

Adoption

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



Photo © Allison Usavage  
2014

Needs

Parental  
evaluation

Selection

Adoption



# Emmer variety quality for pasta and cooked grain



GTS                      FYQ                      KTE

Whole Grain Evaluation											
<p><b>Flavor intensity</b> 1: No taste present 5: Mild taste 10: Intense taste, very noticeable</p> <p><b>Most prominent</b> Select which flavor is most prominent.</p>	<table border="1"> <tr> <td>Wheat Bran Nutty Bitter Fresh</td> <td>Woody Grassy Earthy Herbal Warming Sweet</td> <td>Wheat Bran Nutty Bitter Fresh</td> <td>Woody Grassy Earthy Herbal Warming Sweet</td> <td>Wheat Bran Nutty Bitter Fresh</td> <td>Woody Grassy Earthy Herbal Warming Sweet</td> </tr> </table>	Wheat Bran Nutty Bitter Fresh	Woody Grassy Earthy Herbal Warming Sweet	Wheat Bran Nutty Bitter Fresh	Woody Grassy Earthy Herbal Warming Sweet	Wheat Bran Nutty Bitter Fresh	Woody Grassy Earthy Herbal Warming Sweet				
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<p><b>Least prominent</b> Select which flavor is least prominent.</p>	<table border="1"> <tr> <td>Wheat Bran Jutty Bitter Fresh</td> <td>Woody Grassy Earthy Herbal Warming Sweet</td> <td>Wheat Bran Nutty Bitter Fresh</td> <td>Woody Grassy Earthy Herbal Warming Sweet</td> <td>Wheat Bran Nutty Bitter Fresh</td> <td>Woody Grassy Earthy Herbal Warming Sweet</td> </tr> </table>	Wheat Bran Jutty Bitter Fresh	Woody Grassy Earthy Herbal Warming Sweet	Wheat Bran Nutty Bitter Fresh	Woody Grassy Earthy Herbal Warming Sweet	Wheat Bran Nutty Bitter Fresh	Woody Grassy Earthy Herbal Warming Sweet				
Wheat Bran Jutty Bitter Fresh	Woody Grassy Earthy Herbal Warming Sweet	Wheat Bran Nutty Bitter Fresh	Woody Grassy Earthy Herbal Warming Sweet	Wheat Bran Nutty Bitter Fresh	Woody Grassy Earthy Herbal Warming Sweet						
<p><b>Texture</b> Take a bite of the whole grains, describe the texture in terms of chewiness. Delicate, easy to chew Medium firmness Very chewy, difficult to chew</p>											
<p><b>DSS</b> Rate the dryness of the sample. Rate the total dryness from 1 (dry; takes moisture from tongue) to 10 (moist; exudes moisture)</p>											

Photos by June Russell

# 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.



# Questions?

- Both projects are part of research grants awarded from the USDA OREI
- Conventional winter malting barley work is funded by New York State Agriculture and Markets







# Untitled at the Whitney Food Event

Organized by Cornell Communications



Mark Sorrells

Suzanne Cupps

June Russell

## Untitled

### First Course

#### Heirloom Tomato

*Cracked spelt tabbouleh, yogurt, sumac*

#### Chicory Salad

*Frederick wheat berries, corn, sour cherries*

#### She Wolf Bread

*Vermont butter*

### Second Course

#### Grilled Shrimp

*Farmer Ground polenta, sofrito*

#### Charred Pole Beans

*Sweet and spicy peppers, She Wolf breadcrumbs*

### Third Course

#### Black Emmer Risotto

*Roasted chicken, english peas, artichokes*

#### Japanese Eggplant

*Cashew butter, puffed spelt*

### Dessert

#### Buckwheat Crêpes

*Lemon curd, summer berries*



NY City Journalists enjoying ancient grains











# Newsletter

## August 2018



The Greenmarket Regional Grains Project is a program of GrowNYC

*"It all starts with the choice of grain,  
which is first a question of place and time."  
— Karen Hess, A Century of Change in the American Loaf*

The Greenmarket Regional Grains Project is pioneering the new frontier in local food: grains. With our partners, we're building the marketplace for grains grown and milled in the Northeast. We are educating and connecting growers, processors, bakers and chefs -- sparking a rise in demand for local grains while helping ensure the crop supply and processing infrastructure are there to meet that demand. The evidence is clear: Regional grains have arrived.

The Greenmarket Regional Grains Project and the [Grainstand](#) are programs of GrowNYC, the sustainability resource for New Yorkers: providing free tools and services anyone can use in order to improve our City and environment. More gardens, Greenmarkets, more recycling, and education for all. Learn more at [www.grownyc.org](http://www.grownyc.org).

## Upcoming Market Dates

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**The Grainstand** continues its weekly presence at **GrowNYC's Union Square Greenmarket every Wednesday and Saturday.** Our rotating **Grainstand is BACK in September, and it's BETTER THAN EVER with new pop-ups at Dag Hammarskold Plaza, Cortelyou, and Bay Ridge!**

**#drinklocal** : **Beer & Spirits of New York** pop-ups continue at all of our **Grainstand** locations. Stay current with pop-up news at [gownyc.org/drinklocal](http://gownyc.org/drinklocal) and explore what New York State craft beverage producers have to offer at the following locations:

### **Grainstand and Beer & Spirits Pop-up Locations:**

**Saturday, August 25th** Union Square Breuckelen Distilling  
**Wednesday, August 29th** Union Square Springbrook Hollow  
**Saturday, September 1st** Union Square Black Dirt Distilling  
**Wednesday, September 5th** Union Square Hillrock Farm Distillery  
**Saturday, September 8th** Union Square Hillrock Farm Distillery  
**Saturday, September 8th** Grand Army Plaza Black Dirt Distilling  
**Wednesday, September 12th** Union Square Moto Spirits  
**Saturday, September 15th** Union Square Springbrook Hollow  
**Sunday, September 16th** Jackson Heights Springbrook Hollow  
**Wednesday, September 19th** Union Square Hillrock Farm Distillery  
**Saturday, September 22nd** Union Square Finger Lakes Distilling  
**Saturday, September 22nd** Fort Greene Moto Spirits

Pre-ordered bulk bags are available at the Union Square Greenmarket every Wednesday and Saturday. [Check availability and pricing here.](#)

Wholesale orders of \$250 or more can be delivered through Greenmarket Co., GrowNYC's wholesale distribution program.

For more information or to place an order, email us at

[grains@gownyc.org](mailto:grains@gownyc.org)



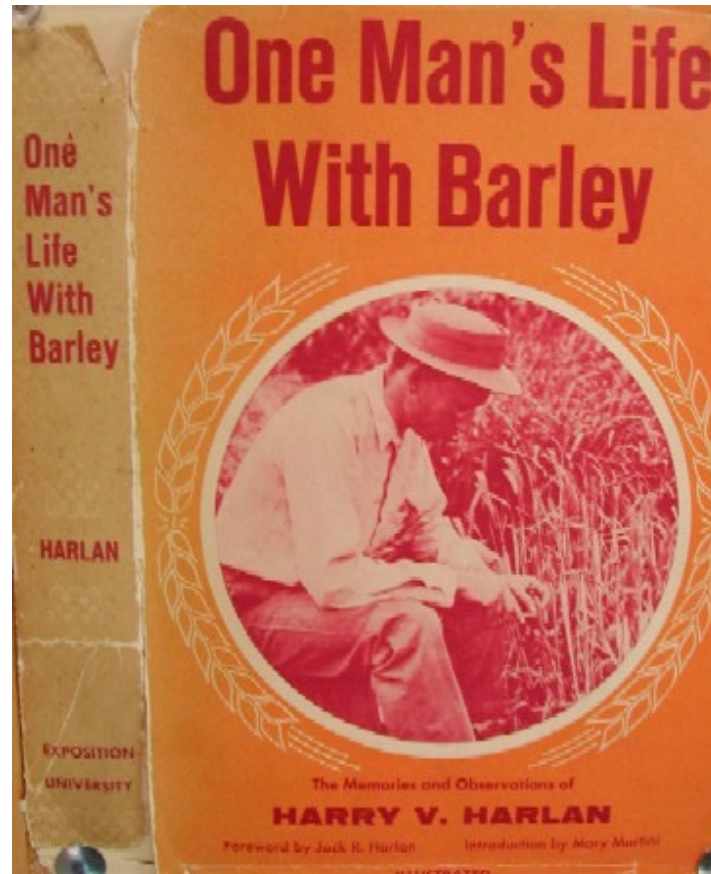
# Is it time for barley to go naked after 10,000 years?

The conclusion of Harry Harlan after a life with barley

## Developing Multi-use Naked Barley for Organic Farming Systems

USDA-NIFA-OREI Grant Coordinated by Pat Hayes at Oregon State Univ.

Web: [eorganic.info/barley](http://eorganic.info/barley) and [barleyworld.org/orei-project](http://barleyworld.org/orei-project)





# Is it time for barley to go naked after 10,000 years?



- **NAKED BARLEY:** Our goal is to make it an economically rewarding and sustainable alternative organic crop.
- **WE NEED NAKED BARLEY** varieties that serve multiple functions: brewing, feed, and nutritious, tasty, fiber-rich food.
- **NAKED BARLEYS** transcend the limitations of covered barleys and don't hide their true colors.



## **Deliverables:**

- Testing the multi-use hypothesis
- Germplasm and varieties
- Genotype x environment data for agronomics, end use quality, consumer preference
- Platform for genetic analysis of flavor and nutrition



# Past and Present Small Grains People



Lisa Kissing Kucek







# Questions?



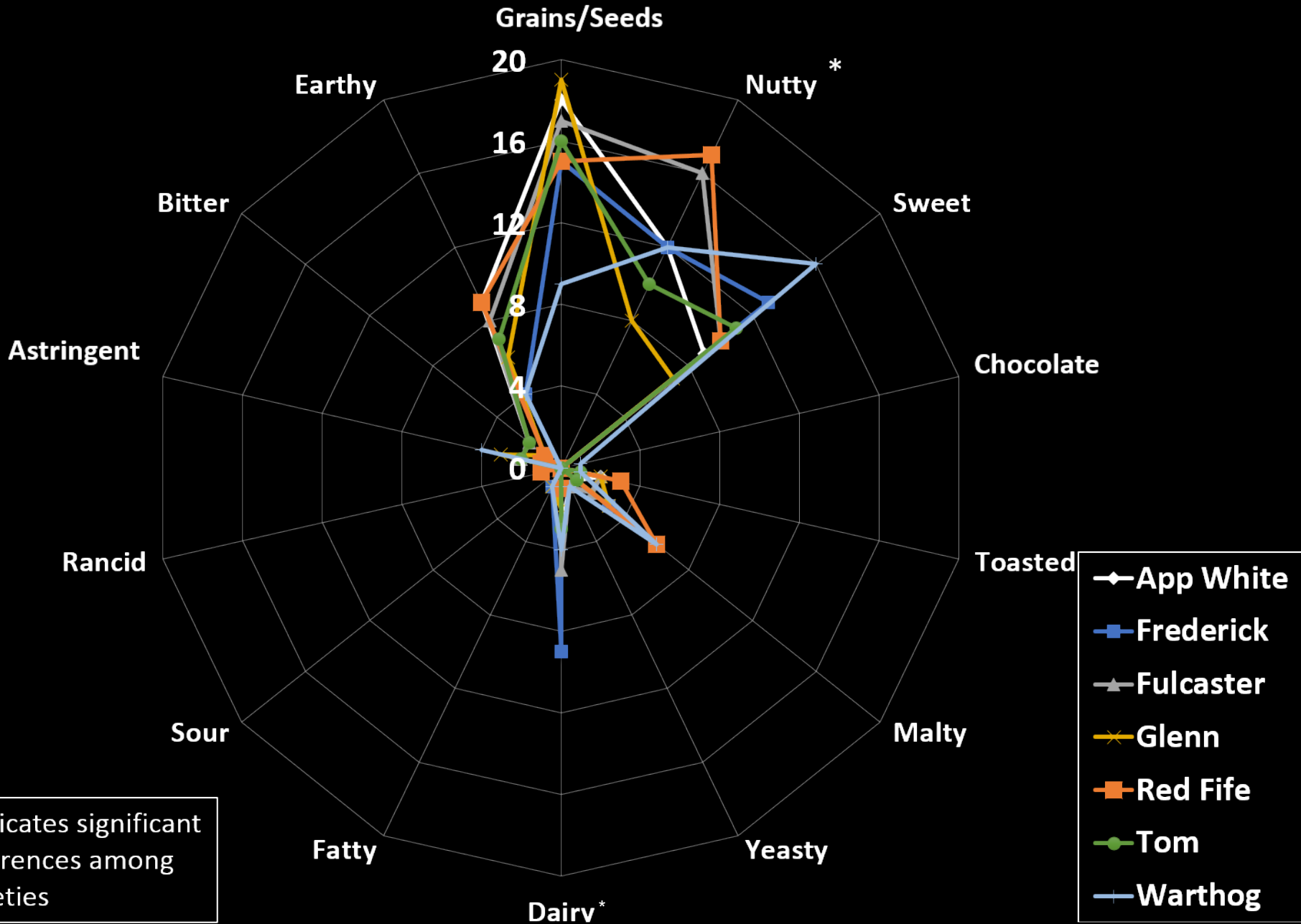
Funded by OREI



Cornell Small Grains Breeding Project Team: David Benscher, James Tanaka, Amy Fox  
Cornell Cooperative Extension Team: Gary Bergstrom, Mike Stanyard, Kevin Ganoe



# Flavors Identified in Cooked Whole Grains

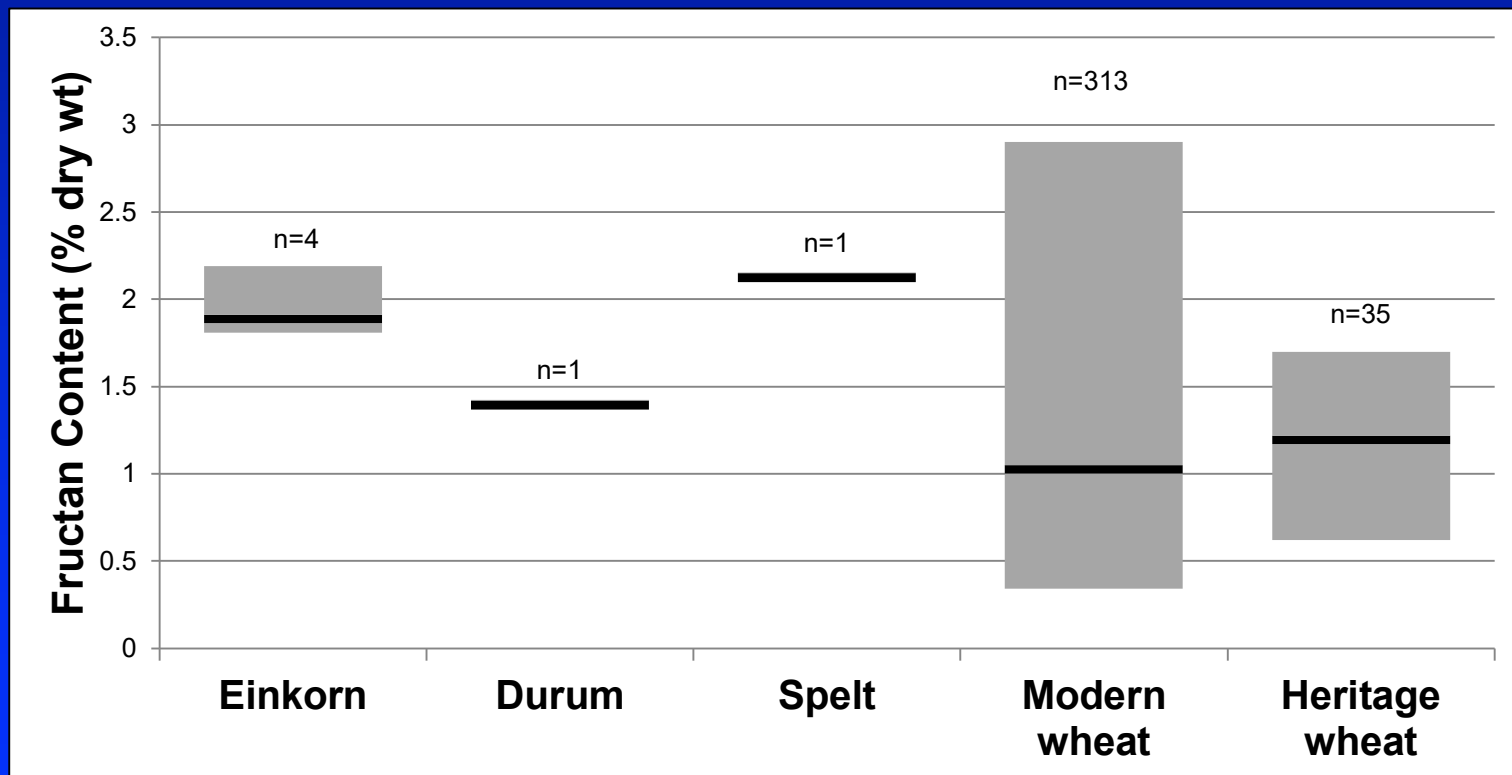


# Fructans

Among Species and Genotypes of Wheat  
(Fructose Malabsorption, IBS, and NCWS)



Lynn  
Veenstra



Meta-analysis of five studies. Max, min, and mean (black lines) values presented. Labels “n=” refer to the number of unique varieties evaluated.



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

Habit	Variety	Class	Variety	Yield	Test Wt	Protein	Matzah making	Shortbread	Bread Baking	Matzah Visual Texture	Matzah Roughness	Matzah Graininess	Cooked Grain Pref	Cooked Grain Texture	Cooked Grain Dryness
	Name	Class	Age	Rank	Rank	%	Score	10= ideal	10= ideal	1= smooth	10= rough	10= grainy	1= best	10= chewy	10= moist
Winter Wheat	Forward	Soft Red	Heritage	16 of 35	17 of 35	13	7.1*	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			7.7						
	Pride of Genesee	Soft White	Heritage	30 of 35	2 of 33	13.3	5.2*	6.9	6.0*	4.6*	4.7	5.9*	2.0*	6.5*	3.9
	Susquehanna	Soft Red	Modern	5 of 35	35 of 35	11.1	6.4	5.6	NE	4.7	4.7	5.1*	2.4*	4.8	5.2*
	Yorkwin	Soft White	Heritage	12 of 35	25 of 35	12.8	6.4	8.9*	7.2	5.2	4.2	5.6	3.0*	6.5*	3.6

 generally preferred values

 generally unpreferred values

\*indicates significant difference among varieties at p<0.05

# Overview of Emmer Results

Variety	Yield	Test Weight	Protein	Pasta Preference	Pasta Shininess	Pasta Roughness	Pasta Graininess	Pasta Firmness	Ability to Dissolve	Grain Preference	Grain Texture
Name	Rank	Rank	%	Probability	10=shiny	10=rough	10=grainy	10=chewy	seconds	Probability	10=chewy
Lucille	1	6	14.1	0.42*	5.24	4.58	3.88	4.46*	11.12	0.19	5.42*
ND Common	2	2	13.5	0.19*	5.88*	3.46*	3.61	3.63*	10.12	0.42*	6.27*
Red Vernal	4	4	15.0	0.27	4.84*	5.04	5.65*	6.21*	13.50*	0.15	6.19

  higher scoring, 
   lower scoring, 
 \*significantly lower or higher than other varieties at  $p < 0.05$



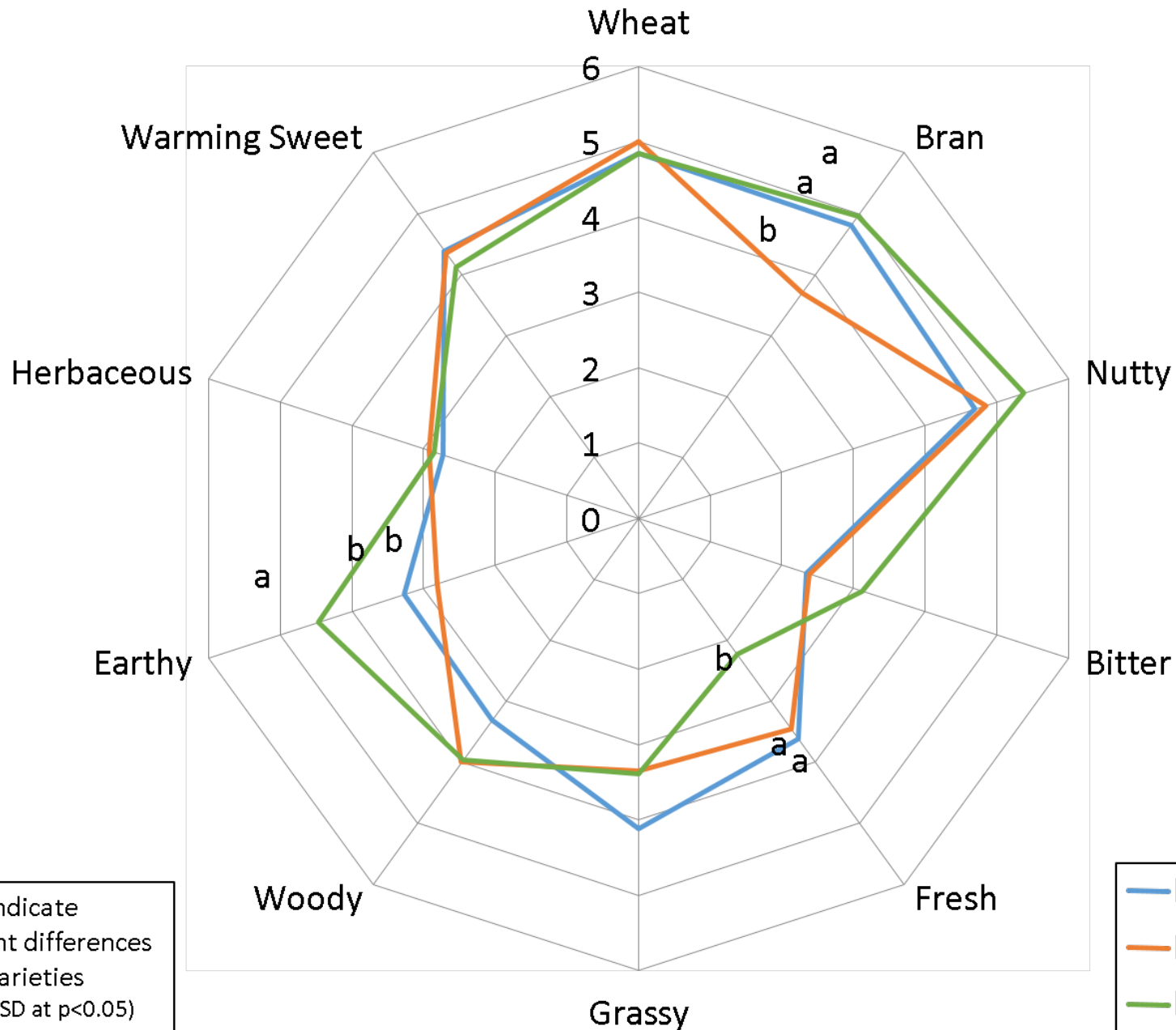
Image from June Russell



Image from June Russell



# Intensity of Flavors in Pasta



# Cooked Whole Grain Most Prominent Flavor

