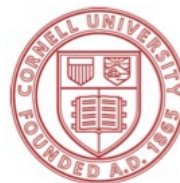


# Born, Bred, and Brewed in New York

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# Why Malting Barley in New York?

- Farm brewery bill Passed in 2012
  - “New York State labeled beer”, permit not required to serve by glass, branch offices, tax incentive
  - Until end of 2018, at least 20% of ingredients have to be grown in NY, increasing to 60% in 2019
  - Jumps to 90% minimum by end of 2024
- How much barley is NY producing now?
  - ~1600 acres in 2015, ~2000 in 2016
- What has the Cornell Small Grains program done so far?
- Why are we implementing a NY malting barley breeding program?



Malthouses, breweries, and distilleries in New York

# Spring Two Row Malting Barley Breeding for the Northeastern U.S.

- Spring 2-row: avoid winterkill risk, short generation time, preferred by brewers & maltsters
- Dependent on excellent collaboration in the barley community – Oregon State Univ, Univ of Minnesota, Canadian and European programs et al.
- Opportunity to test approaches to rapidly and efficiently start a small breeding program from scratch
  - Integration of high-throughput phenotyping methods and genomic selection to speed up development of a spring two row malting variety adapted to New York
- Base population - 7 biparentals linked by common female parent

# Traits of interest

- Fusarium head blight (*Fusarium graminearum*)
- Spot blotch (*Cochliobolus sativus*)
- Pre-harvest sprouting
- Malt quality



# 2016 Spring Malting Barley Summary

Entry	Row#	Class	Grain Yield (kg/h)						Test			Preharv			FHB	FHB	FHB	Rank			
			Regional Locations						Weight		Lodg	Head	Height	Sprout	Inc	Sev	Index				
			Ith-Hel	Ith-Ket	SteCo.	GenCo.	Mean**	Rank	Kg/hl	Rank	0-9	Date	cm	0-9	Rank	(%)	(%)		(%)		
1	Conlon	2	Malt	890	1905	1474	964	1689	32	65.4	14	N	6/17	55	6.1	38	27	9	2.3	26	
2	Lacey	6	Malt	1265	2390	1813	1096	2102	7	63.7	29	O	6/19	54	4.1	21	15	8	1.2	21	
3	Quest	6	Malt	1393	2119	1774	1055	1946	14	63.1	32	N	6/19	59	4.4	24	5	9	0.5	12	
4	Cerveza	2	Malt	1023	1974	1691	452	1833	19	62.1	38	E	7/3	49	3.6	11	17	10	1.6	23	
5	Newdale	2	Malt	989	1965	1474	363	1720	26	64.0	27		7/3	48	5.8	37	12	6	0.7	15	
6	AAC Synergy	2	Malt	1171	2228	1954	765	2091	8	64.4	24		7/2	56	4.9	29	8	7	0.6	14	
7	KWS Tinka	2	Malt	1030	2445	2080	909	2262	2	63.5	30		6/24	55	3.7	13	3	4	0.1	6	
8	KWS13/3353(Beckie)	2	Malt	1259	2103	2137	668	2120	6	62.8	34		6/27	44	3.3	8	45	7	3.3	31	
9	KWS13/207 (Fantex)	2	Malt	1112	2456	1788	894	2122	5	64.3	25		6/30	50	4.0	20	43	9	3.8	34	
10	Craft	2	Malt	1252	2205	1824	911	2014	12	67.6	4		6/25	58	2.6	4	22	12	2.6	28	
11	Pinnacle	2	Malt	1126	1778	1750	493	1764	23	65.1	17		6/24	46	4.4	25	8	2	0.2	8	
12	ND Genesis	2	Malt	1082	2113	1400	1133	1757	24	64.9	18		6/26	56	4.4	26	45	13	5.7	37	
13	ND26891	6	Malt	1256	2116	1703	887	1909	17	62.1	37		6/20	53	3.7	14	12	7	0.8	17	
14	2ND28065	2	Malt	1128	1815	1537	882	1676	33	66.5	8		6/28	52	5.3	34	5	3	0.2	7	
15	Harmony	6	Feed	1461	2236	1587	746	1912	16	61.3	39		6/23	67	5.5	36	0	0	0.0	1	
16	Oceanik	6	Feed	1611	2504	1790	1117	2147	4	60.4	40		6/25	63	3.0	7	0	0	0.0	2	
17	Bastille	6	Feed	1160	1637	1207	371	1422	40	74.5	2		6/29	53	0.8	1	35	13	4.4	36	
18	HS5617-11	6	Feed	1390	2637	1667	802	2152	3	62.5	36		6/22	64	3.5	10	8	4	0.3	10	
19	AAC Azimuth	6	Food	971	2286	1096	774	1691	31	65.1	16		6/19	62	2.1	2	13	10	1.3	22	
20	AAC Starbuck	2	Food	1318	2126	1923	817	2025	11	77.2	1		6/29	64	2.2	3	3	3	0.1	4	
21	M160	6	Malt	1302	2077	2054	743	2066	9	63.2	31		6/16	61	4.1	22	22	8	1.7	25	
22	09N2-31	2	Malt	1228	2189	2338	987	2264	1	66.3	9		6/23	53	4.9	30	17	6	1.0	18	
23	09N2-96	2	Malt	1251	1891	1656	563	1774	22	63.8	28		6/29	52	6.1	39	3	3	0.1	5	
24	09N2-84	2	Malt	1156	1977	1594	868	1785	21	62.6	35		6/25	54	4.7	27	43	33	14.3	40	
25	09N2-51	2	Malt	625	1766	1444	349	1605	36	64.6	21		6/30	53	5.1	33	18	6	1.1	20	
26	09N2-58	2	Malt	1014	1957	2116	800	2037	10	63.0	33		6/25	59	5.4	35	27	9	2.3	27	
27	06N2-79	2	Malt	968	1723	1505	705	1614	35	64.6	22		6/25	58	3.7	15	10	7	0.7	16	
28	09N2-16	2	Malt	1001	1390	1808	919	1599	37	66.8	7		6/29	50	4.8	28	32	12	3.8	35	
29	09N2-68	2	Malt	651	1498	1691	756	1595	38	64.1	26		6/29	52	3.9	18	45	23	10.4	39	
30	09N2-65	2	Malt	798	1773	1638	433	1706	29	64.9	19		7/1	53	2.8	5	40	9	3.6	33	
31	2MS14_3342-018	2	Malt	1240	1812	1805	613	1809	20	66.0	10		6/29	50	3.4	9	30	11	3.2	30	
32	2MS14_3336-002	2	Malt	657	1771	1652	1054	1711	28	65.7	11		6/23	54	3.7	16	7	6	0.4	11	
33	2MS14_3305-002	2	Malt	641	2102	1757	827	1929	15	64.7	20		6/30	53	4.9	31	27	11	2.8	29	
34	2MS14_3336-018	2	Malt	1072	1555	1876	980	1716	27	66.8	6		6/24	55	2.8	6	13	4	0.6	13	
35	2MS14_3345-009	2	Malt	1175	1928	1326	740	1627	34	64.5	23		6/25	52	4.3	23	5	4	0.2	9	
36	2MS14_3317-018	2	Malt	1377	1817	2000	756	1908	18	68.1	3		6/27	55	4.9	32	0	0	0.0	3	
37	2MS14_3335-007	2	Malt	855	1405	1997	439	1701	30	65.3	15		6/28	52	3.9	19	58	15	8.6	38	
38	2MS14_3342-026	2	Malt	670	1768	1707	705	1738	25	65.6	12		6/26	51	3.8	17	25	4	1.0	19	
39	2MS14_3342-019	2	Malt	825	1816	1333	577	1575	39	65.5	13		7/1	54	3.6	12	27	6	1.7	24	
40	2MS14_3317-015	2	Malt	1011	2043	1857	693	1950	13	67.4	5		6/30	55	7.1	40	25	14	3.4	32	
<b>Mean</b>				1085	1982	1721	765	1852		65.1			6/20	55	4.1		19.9	8.1	2.3		
<b>CV</b>				27.9	13.3	11.8	31.8	** Ith-Hel & GenCo. Not included in mean yield or Test Weight													

## 2016 Spring Malting Barley Summary

Cumulative Summary			Grain Yield		Test Weight		Head	Lodg.	Ht.	PreHarv	FHB	FHB	FHB			
Entry	Row#	Class	3 Years		2 Years		2 Years		Date	0-9	cm	0-9	Inc	Sev	Indx	
			kg/h	b/a	kg/h	b/a	kg/hl	lbs/b	2 Yr	2 Yr	2 Yr	2 Yr	2 Yr	2 Yr	2 Yr	
1	Conlon	2	Malt	2470	46	2417	45	64.0	50.0	6/19	2.0	62	4.1	40	11	5
2	Lacey	6	Malt	3055	57	3072	57	62.8	49.1	6/21	0.8	64	2.6	21	8	2
3	Quest	6	Malt	3083	57	2960	55	61.9	48.4	6/21	1.7	71	2.6	20	9	2
4	KWS Tinka	2	Malt	3390	63	3383	63	61.4	48.0	6/25	0.8	61	3.2	18	8	2
5	KWS13/3353(Beckie)	2	Malt			2970	55	58.1	45.4	6/27	0.8	49	2.7	42	9	4
6	KWS13/207 (Fantex)	2	Malt			3099	58	61.0	47.6	6/30	0.4	55	2.3	51	10	5
7	Craft	2	Malt			3246	60	66.1	51.6	6/24	1.2	67	1.5	33	11	4
8	Pinnacle	2	Malt			2842	53	62.8	49.0	6/25	0.5	59	2.2	20	6	2
9	ND Genesis	2	Malt			2996	56	62.9	49.2	6/24	1.1	66	3.6	52	13	7
10	ND26891	6	Malt			3103	58	61.5	48.1	6/21	1.0	64	2.2	25	10	3
11	2ND28065	2	Malt			3067	57	65.2	51.0	6/25	1.0	59	2.9	22	7	2
12	Harmony	6	Feed			3225	60	60.2	47.0	6/25	0.8	81	3.7	18	5	2
13	Oceanik	6	Feed			3454	64	60.1	47.0	6/25	0.9	73	1.8	18	4	1
14	Bastille	6	Feed			2468	46	70.8	55.3	6/30	0.7	65	0.7	46	14	6

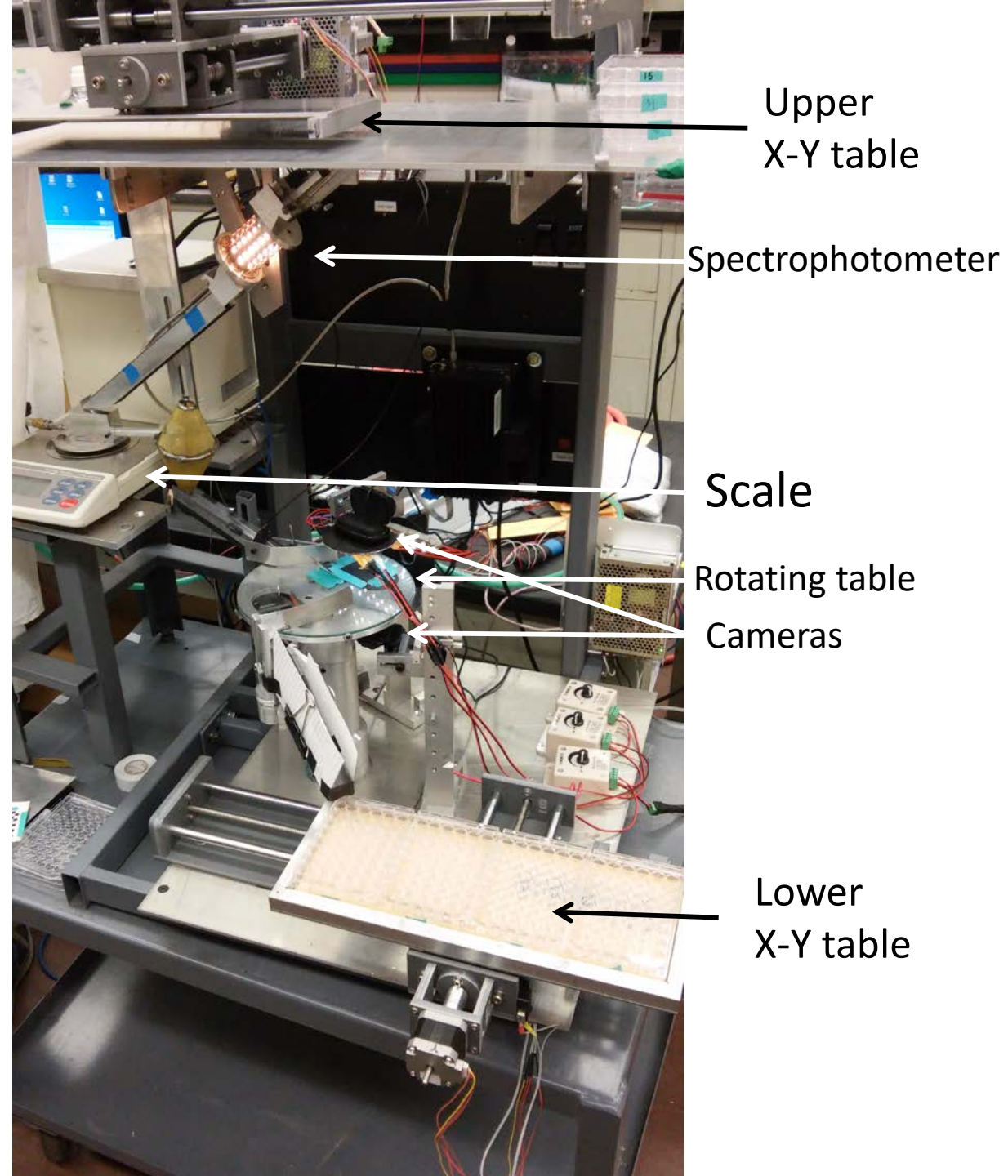
The primary reason for implementing a spring 2-row malting barley program for the Northeast is because the environments in the northeast pose constraints that are unique to this region – FHB, foliar pathogens, preharvest sprouting.

# Near Infrared Spectroscopy: Plant Breeding Applications

- NIR spectroscopy for non-destructive measurement of chemical composition of grain
- Non-destructive prediction of grain chemistry traits - moisture, oil, protein, mycotoxins
- Can we build single kernel calibration models for barley grain protein and  $\beta$ -glucan for selection of single kernels in  $F_2$  generation?
- How does early selection for quality traits in  $F_2$  and  $F_3$  seeds affect training population performance and selection for disease resistance?

# Single Seed Analyzer

- Designed and built by Paul Armstrong, USDA Kansas State University
- Load seed into 48 well microtiter plate
- Single seed NIR spectroscopy
- Seed weight
- 3-D photography
- Returns seed to same well in microtiter plate
- Runs 4-48-well plates in 1 to 1.5 hrs





# Calibration Samples

- Single kernels are small samples so separate calibrations for protein &  $\beta$ -glucan
- Each seed was run through SSA twice and absorbance values averaged
- Seed weight recorded for all samples
- Spectrophotometer wavelengths 957-1635nm used for model calibration
- Partial least squares regression models fit with ParLes chemometrics software
- Seed from replicated regional yield trials in 2014 and 2015



# Calibration sets

- **Protein:** 132 seeds (12 varieties, 11 seeds each variety)
- Destructively phenotyped on a LECO TrueMac N combustion analyzer
- Single kernel protein values ranged from 2.9 – 19.6%
- **$\beta$ -glucan:** 192 seeds (8 varieties, 12 seeds each variety)
- Destructively phenotyped with modified Megazyme mixed linkage  $\beta$ -glucan enzymatic assay kit, scaled to 1/10 for microtiter plate
- $\beta$ -glucan values ranged from 0.7 - 6.3 % w/w

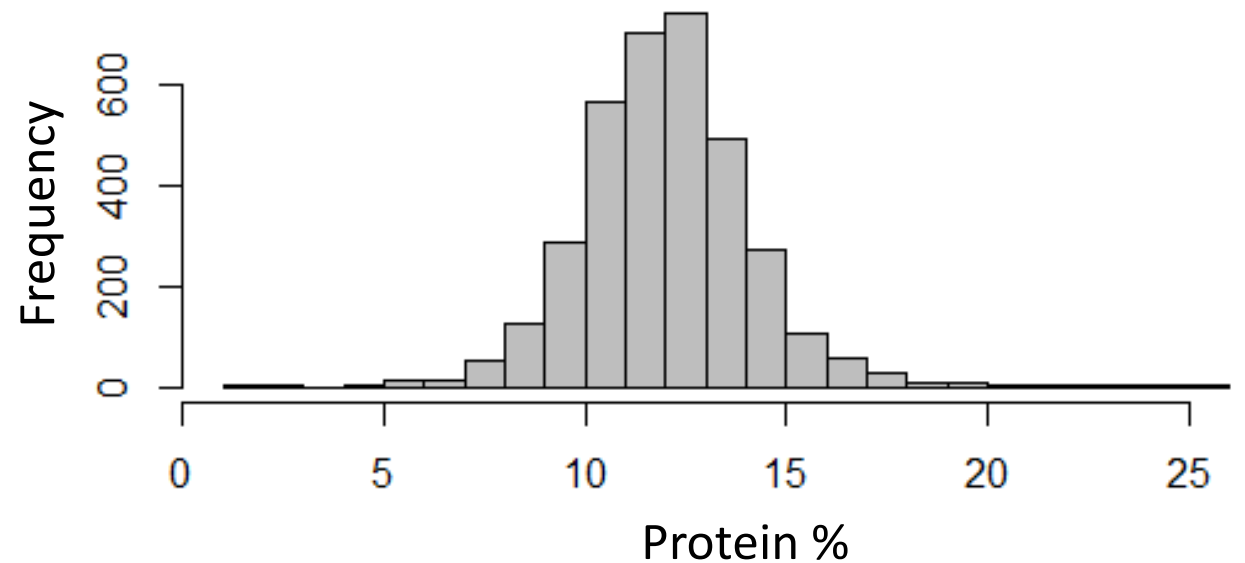
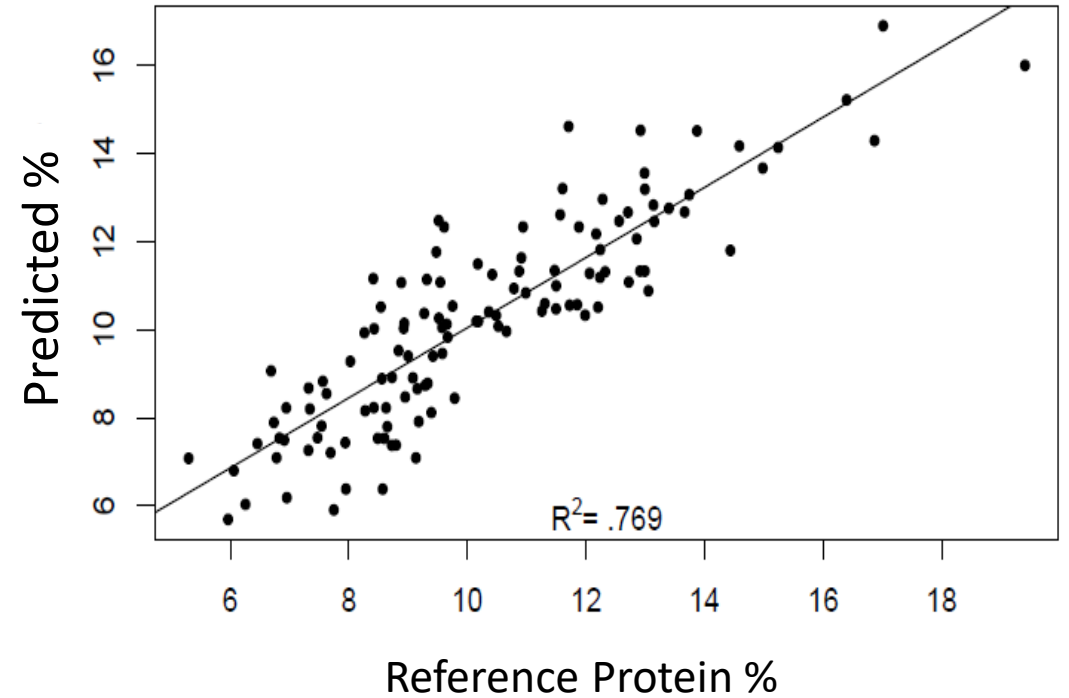


# Calibration results: Percent Protein

$R^2 = 0.77$  ( $r = 0.88$ )

Root Mean Sq. Error = 1.24

Mean = 10.3% protein

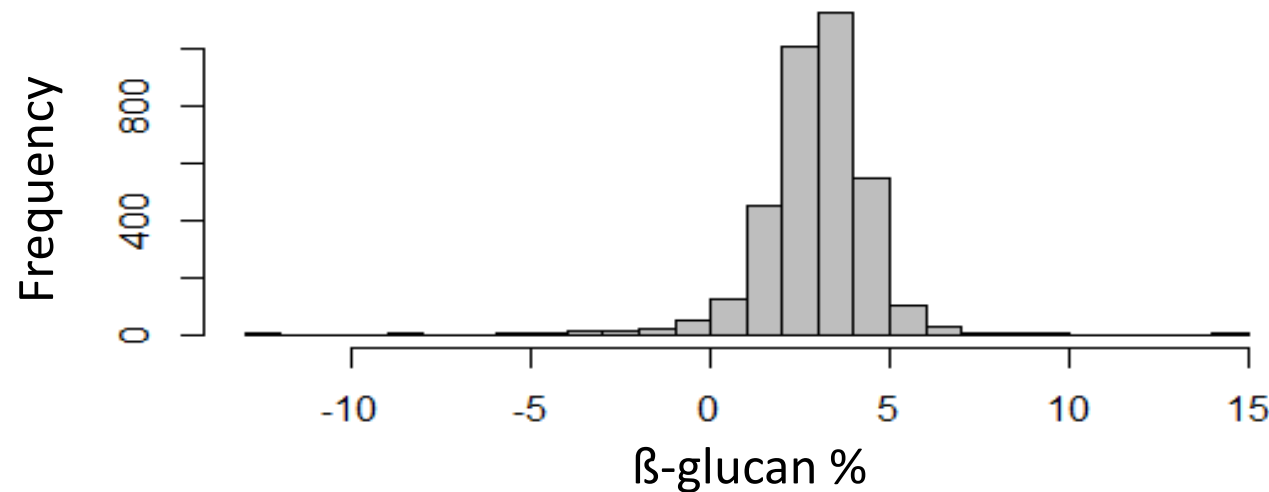
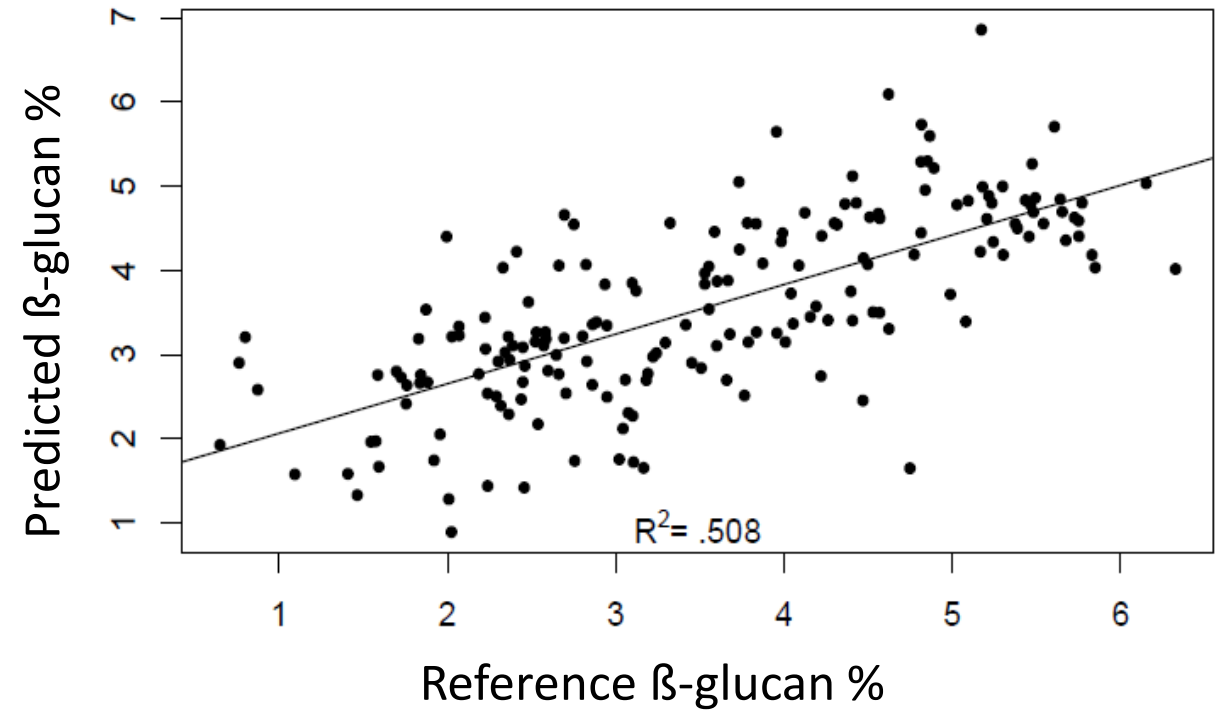


# Calibration result: $\beta$ -glucan

$R^2 = 0.51$  ( $r = 0.71$ )

Root Mean Sq. Error = 0.94

Mean = 3.6%  $\beta$ -Glucan



# Selection using a single kernel protein model

Protein model adequate for selection

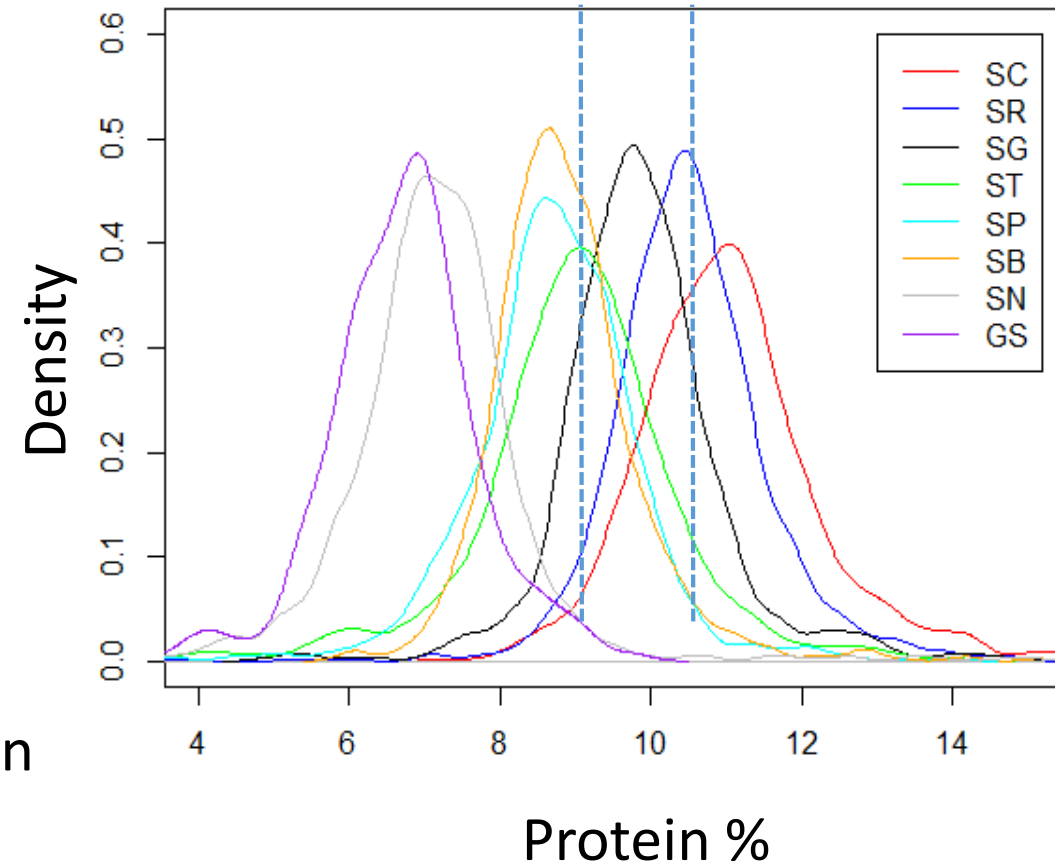
$\beta$ -glucan model may be useful for negative selection

- 1000 F<sub>2</sub> seeds from each of 7 biparental populations
- Selected seeds w/ protein values between 10 & 8.5%
- Corrected for F<sub>1</sub> plant and spike within plant
- Selection index = protein/10 + 10\*(seed weight)

Selected best 10% (100) per biparental & planted in GH

Included tails of each population selected for comparison

Distribution of Fitted Protein Values for each Population



# Spring Two Row Malting Barley Breeding for the Northeastern U.S.

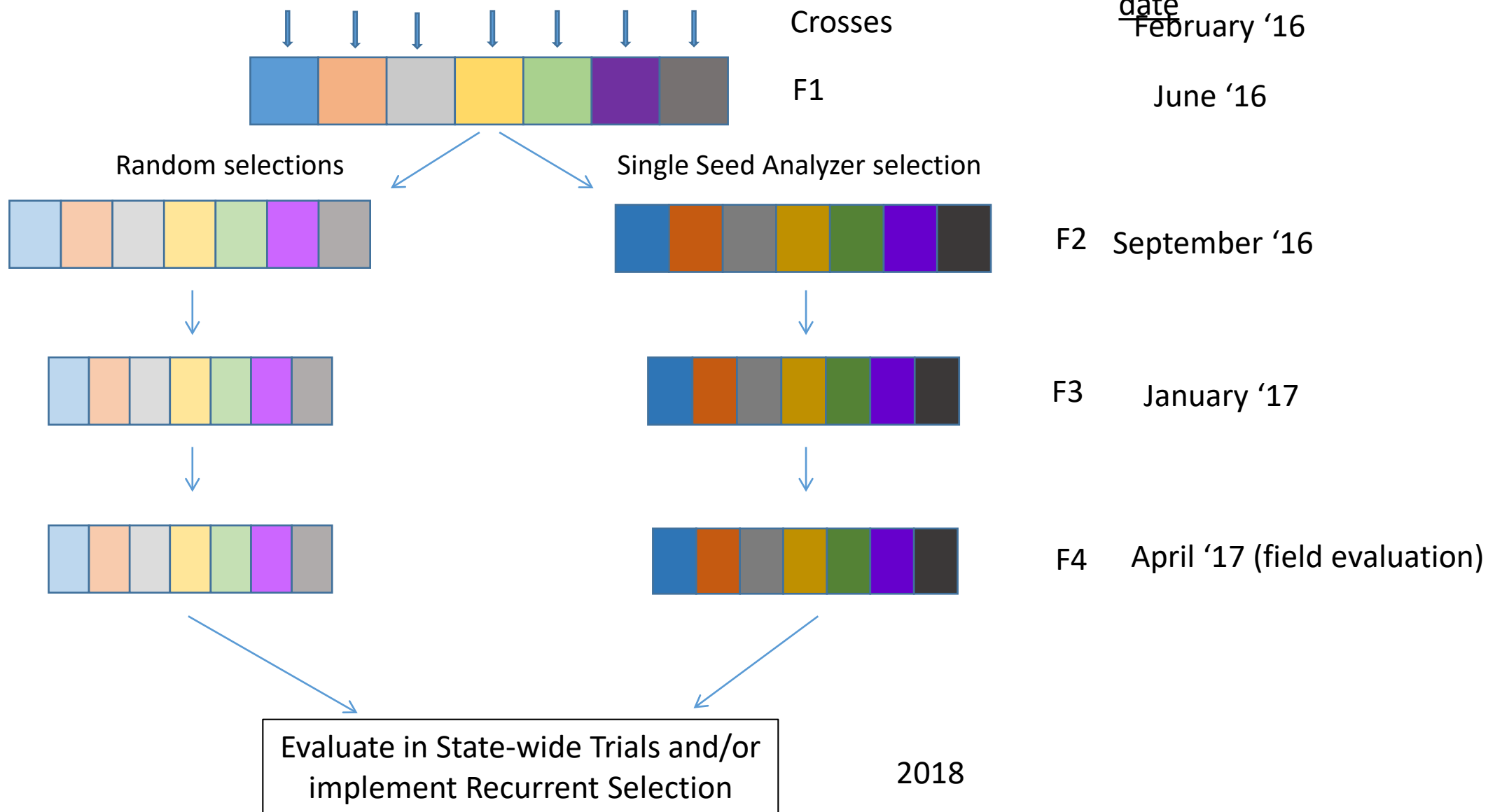
## 2016

- April: Initial crosses in
- June: 25  $F_1$  seeds from each biparental cross planted, harvested late August
- September: SSA selections made,  $F_2$  seed planted early October
- December:  $F_2$  harvest, select again in January

## 2017

- January: Plant  $F_3$
- April: Harvest and field plant  $F_4$ , phenotype and increase seed for 2018

# Experimental Plans



# Next Steps

- Phenotype  $F_{3:4}$  selections, divergent selections, and random lines at two locations in the field summer 2017
- Evaluate potential for genomic selection for traits measured in 2017
- Explore integrating environmental or genetic covariates into model
- Seed increase for state-wide evaluation in 2018



# Acknowledgements

- [USDA Wheat and Barley Scab Initiative](#), This material is based upon work supported by the U.S. Department of Agriculture, under Agreement No. FY16-BA-004 and FY16-NW-002. This is a cooperative project with the U.S. Wheat & Barley Scab Initiative
- [USDA Cooperative State Research, Education and Extension Service](#), Coordinated Agricultural Project 2005-05130-Wheat Applied Genomics
- [USDA National Institute of Food and Agriculture, NRI Triticeae](#) Coordinated Agricultural Project 2011-68002-30029 Improving Barley and Wheat Germplasm for Changing Environments
- [Bill & Melinda Gates Foundation](#) grant to Cornell University for Borlaug Global Rust Initiative Durable Rust Resistance in Wheat
- [Cornell Small Grains Breeding Project Team](#): David Benschler, Amy Fox, Jesse Chavez
- [Cornell Cooperative Extension Team](#): Gary Bergstrom, Mike Stanyard, Kevin Ganoe et al.

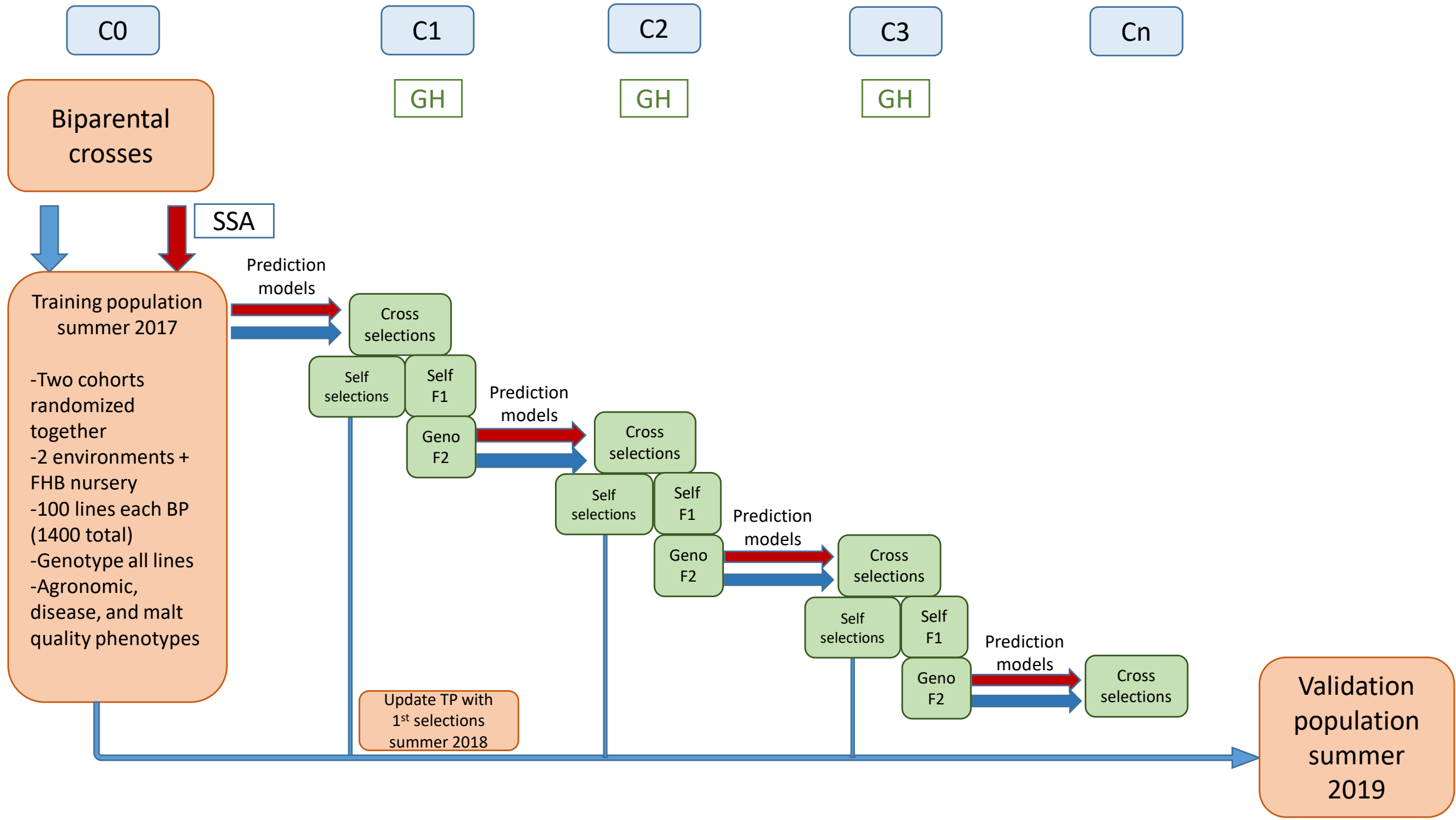
**KWS**



United States Department of Agriculture  
**National Institute of Food and Agriculture**

# Questions?





C0

C1

C2

C3

Cn

Biparental crosses

GH

GH

GH

SSA

Training population summer 2017

- Two cohorts randomized together
- 2 environments + FHB nursery
- 100 lines each BP (1400 total)
- Genotype all lines
- Agronomic, disease, and malt quality phenotypes

Prediction models

Cross selections

Self selections

Self F1

Geno F2

Prediction models

Cross selections

Self selections

Self F1

Geno F2

Prediction models

Cross selections

Self selections

Self F1

Geno F2

Prediction models

Cross selections

Update TP with 1<sup>st</sup> selections summer 2018

Validation population summer 2019

# Other projects

- Link between barley lipoxygenases (LOX) and FHB/DON susceptibility or resistance
  - LOX enzymes in malt lead to accumulation of compounds that contribute to stale “cardboard” taste in old beer
  - LOX also implicated in resistance and susceptibility to different pathogens in maize and wheat; complex relationships still being unraveled
  - Is a LOX locus co-localizing with FHB resistance QTL from mapping studies and GWAS?
  - Screen JIC panel and UMN population with KASP assay