

Barley Breeding for Malting and Brewing

Kevin Smith – University of Minnesota
Malt U –BSG & Rahr Malting

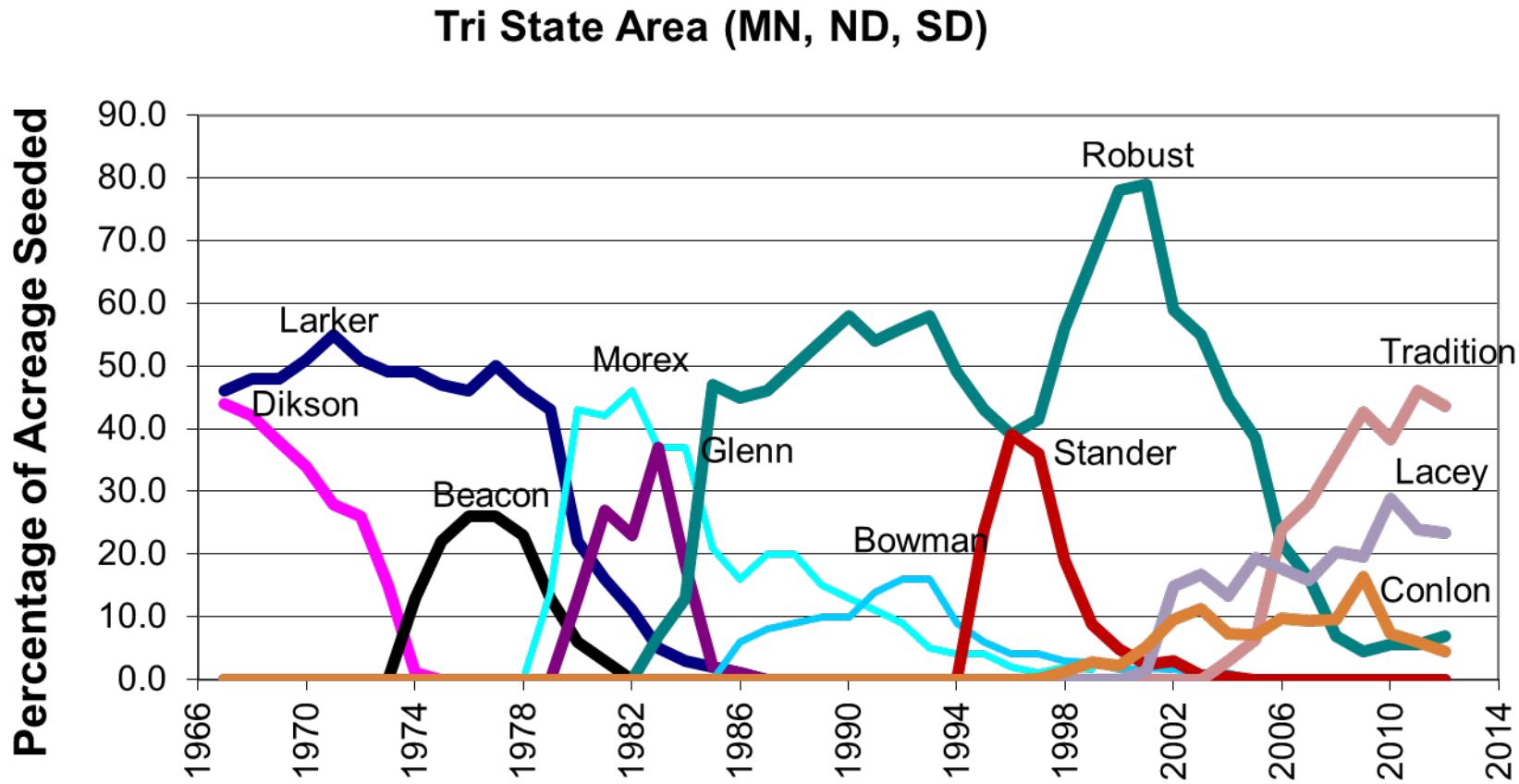
Breeding Better Barley for Brewing Better Beer

- Barley Market Classes:
2-row, 6-row, spring, winter
- Production Traits
- Quality Traits
- Breeding Pipeline



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Barley Varieties Planted in Midwest



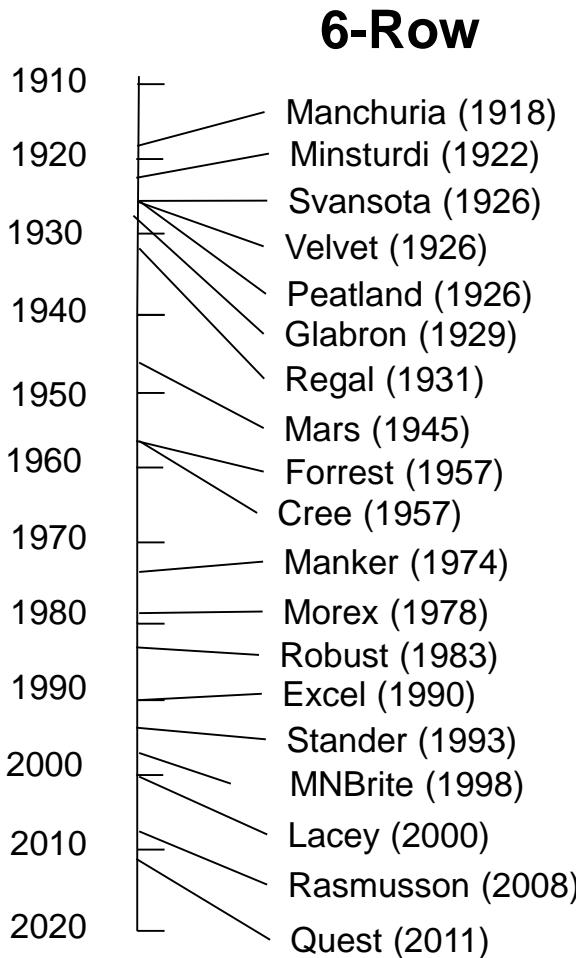
Barley varieties persist for many years



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University of Minnesota Barley Breeding

SPRING BARLEY



2-Row

WINTER BARLEY

6-Row

2-Row

Started 2009

Started 2012

Started 2013



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2-ROW

Plump
Higher Extract
Lower DON
Lower Protein



6-ROW

Higher Amylase
Higher yield in Midwest
Better leaf disease resistance

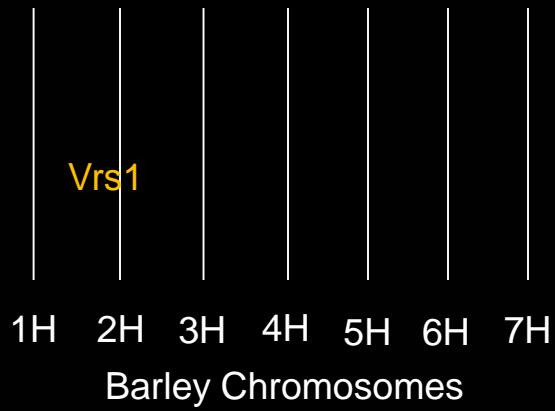


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2-ROW

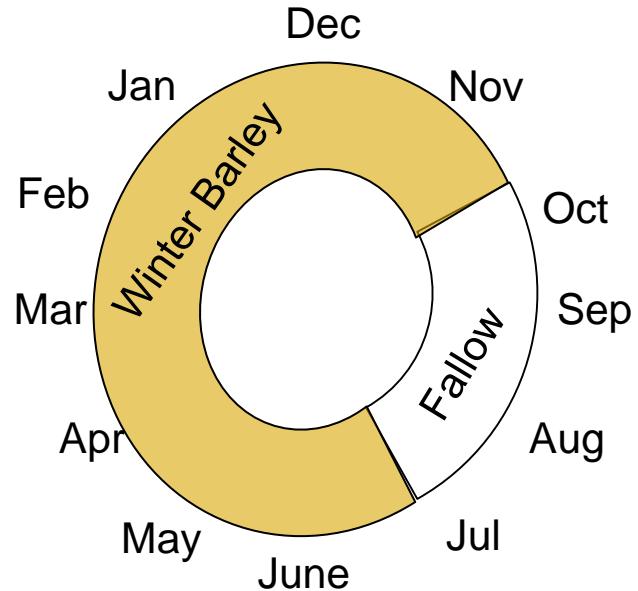
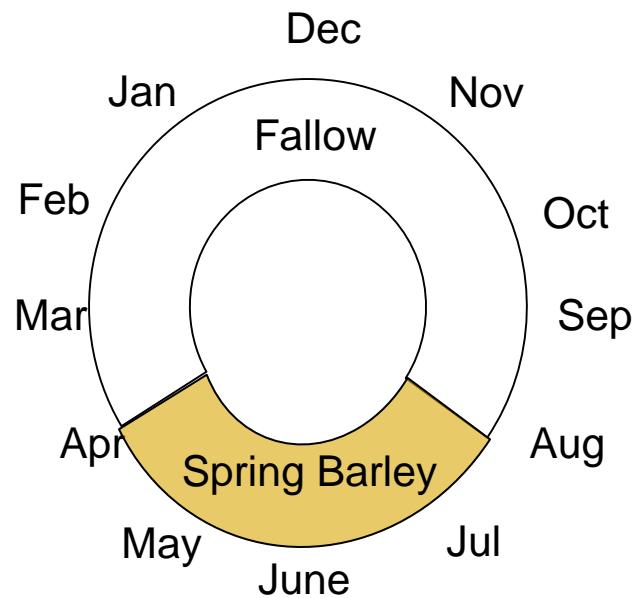


6-ROW



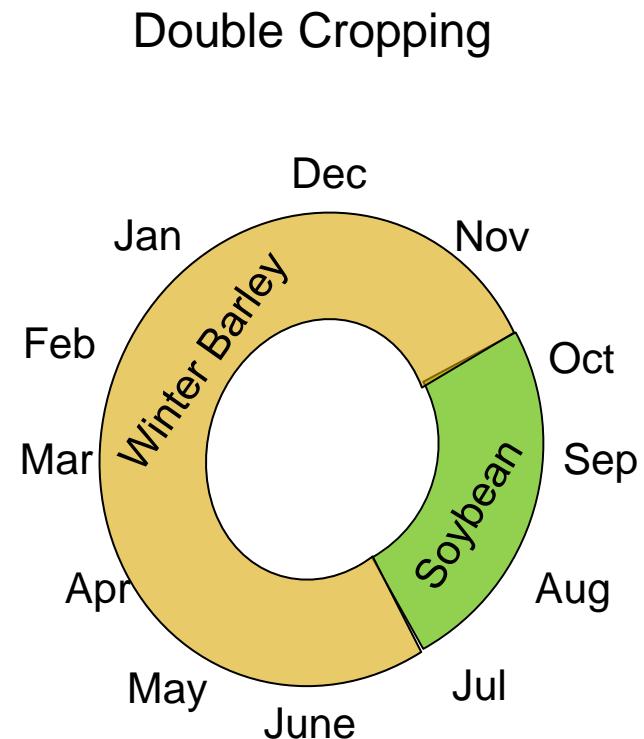
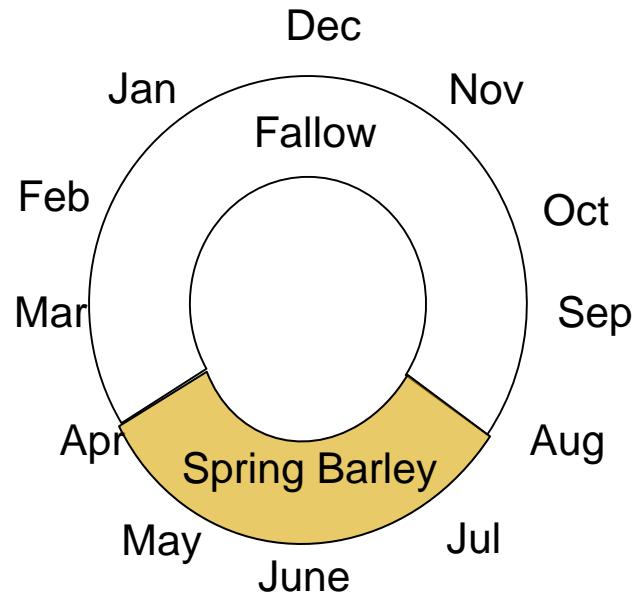
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Spring Barley and Winter Barley



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Spring Barley and Winter Barley



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Agronomic Benefits: increased yield, disease avoidance, weed suppression, water use efficiency, nitrogen use efficiency

Ecosystem Services: carbon sequestration, nutrient cycling, reduced erosion, wildlife habitat

Producer/Industry Benefits: crop diversity, spread out field activities, double cropping, earlier harvest



Fall Planted



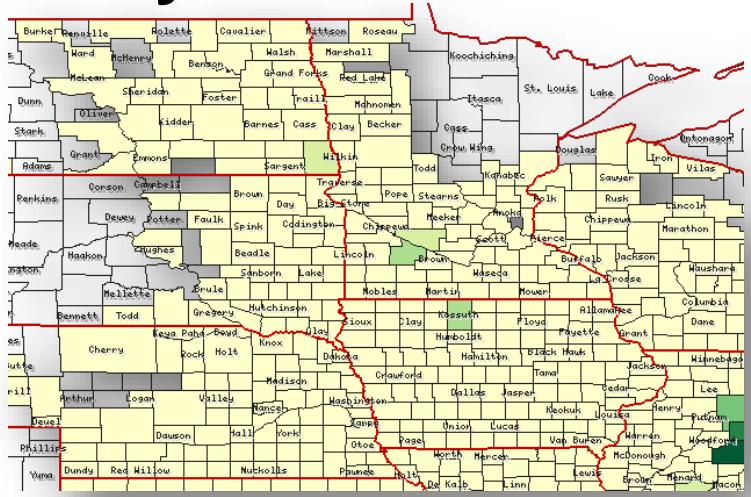
Spring Planted

Photos taken in late April

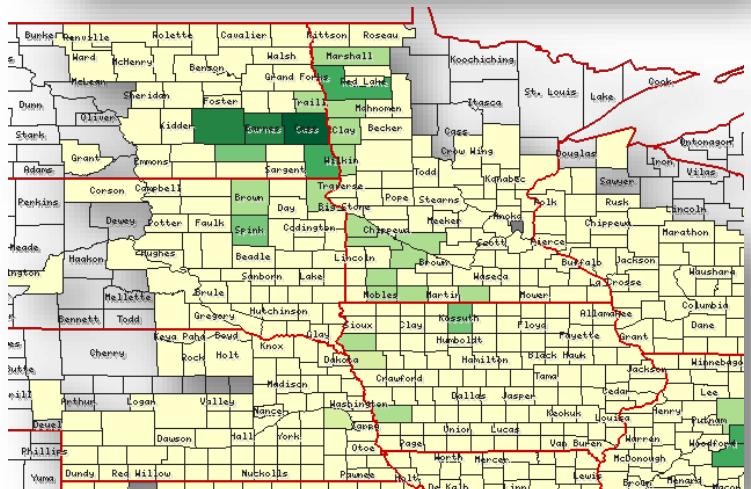


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Soybean

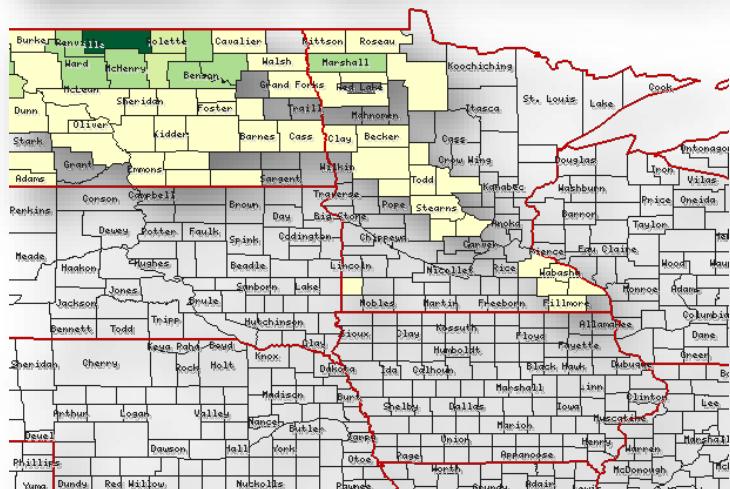
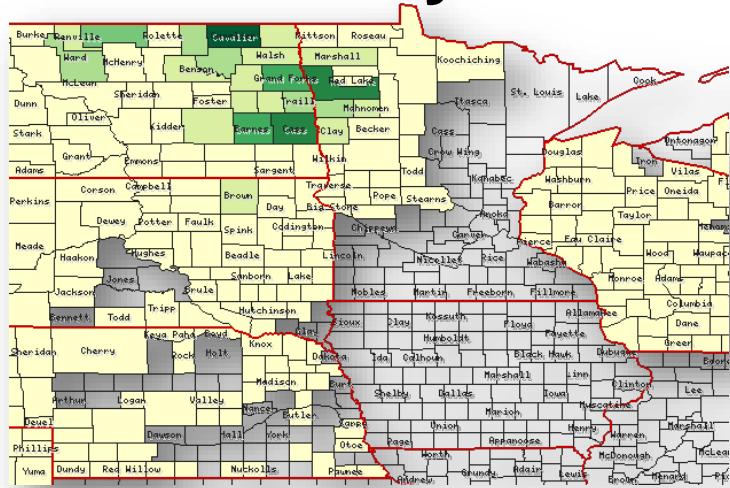


1990



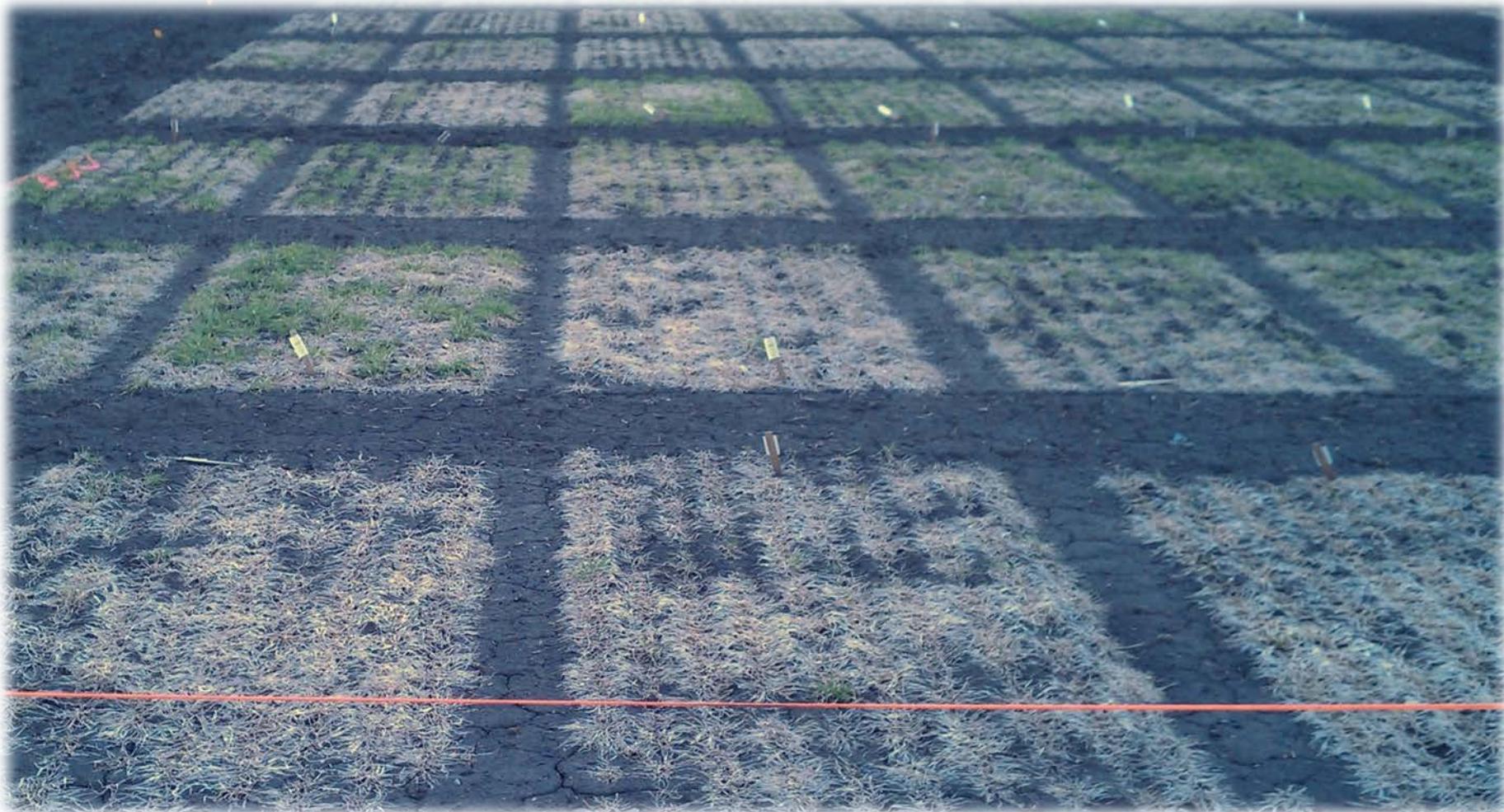
2010

Barley



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Challenge: winter hardiness



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Production Traits

Heading Date
Days to Maturity
Lodging
Disease Resistance
Yield
Grain Pumpness
Grain Protein

Heading

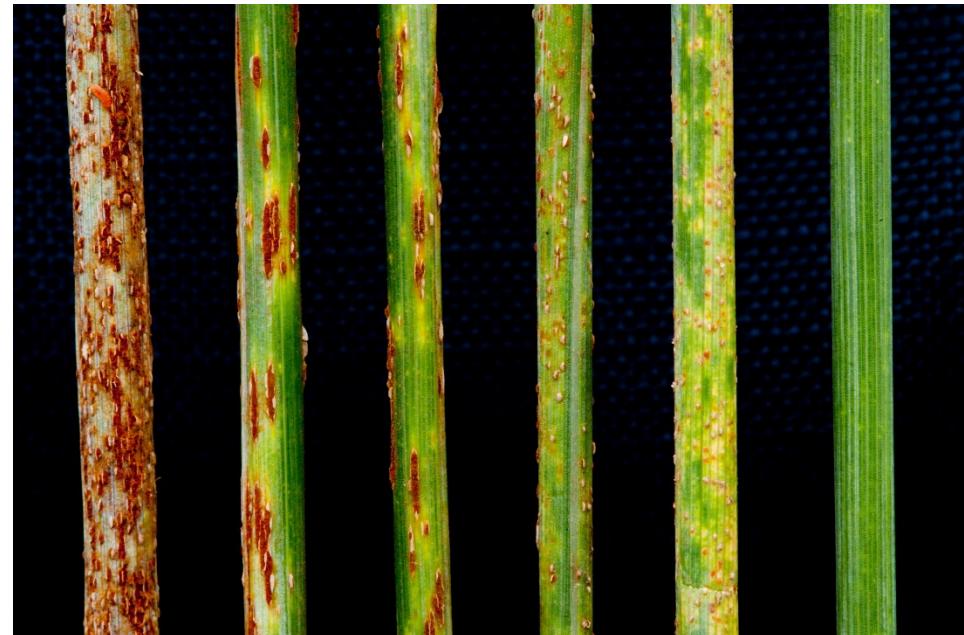


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Production Traits

Heading Date
Days to Maturity
Lodging
Disease Resistance
Yield
Grain Plumpness
Grain Protein

Stem Rust



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Production Traits

Heading Date
Days to Maturity
Lodging
Disease Resistance
Yield
Grain Plumpness
Grain Protein



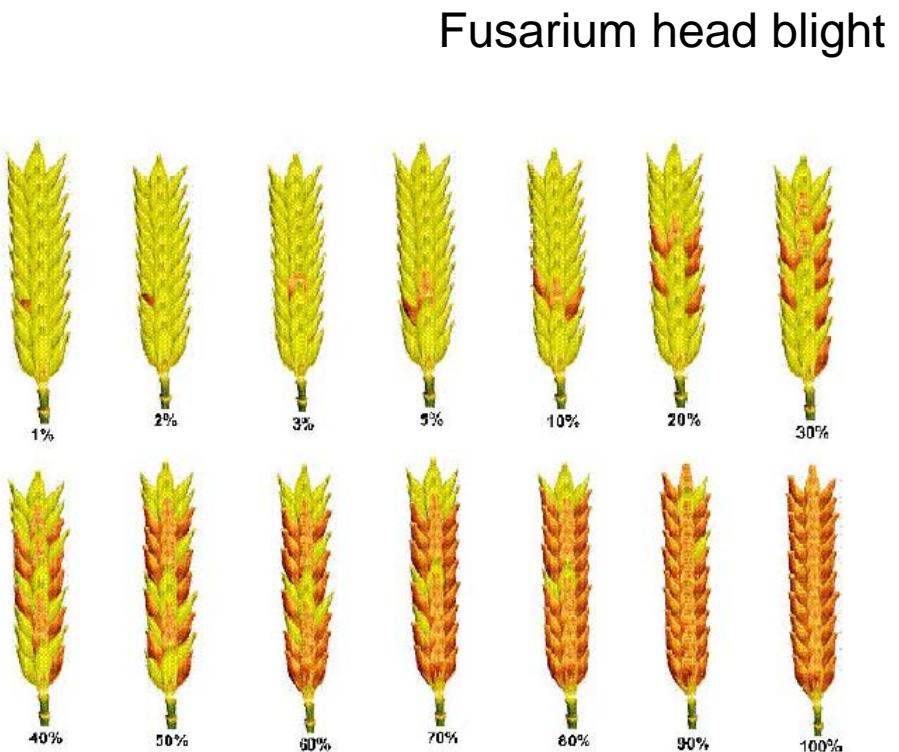
Powdery Mildew



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Production Traits

Heading Date
Days to Maturity
Lodging
Disease Resistance
Yield
Grain Plumpness
Grain Protein



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Quality Traits

Malt extract
 Wort protein
 S/T protein
 Diastatic power
 Alpha amylase
 FAN
 Beta-glucan
 Viscosity

MALTING BARLEY BREEDING GUIDELINES IDEAL COMMERCIAL MALT CRITERIA

	Six-Row	Adjunct Two-Row	All Malt Two-Row	Distillers'
AMBA Member Interest*	10%	61%	25%	4%
Barley Factors				
Plump Kernels (on 6/64)	> 80%	> 90%	> 90%	> 70%
Thin Kernels (thru 5/64)	< 3%	< 3%	< 3%	< 5%
Germination (4ml 72 hr. GE)	> 98%	> 98%	> 98%	> 98%
Protein	≤ 13.0%	≤ 13.0%	≤ 12.0%	11.5 -14.0%
Skinned & Broken Kernels	< 5%	< 5%	< 5%	< 5%
Malt Factors				
Total Protein on 7/64 screen	≤ 12.8% > 60%	≤ 12.8% > 70%	≤ 11.8% > 75%	11.0 - 13.5% >50%
Glycosidic Nitrile (gm/MT)				< 1.5
Measures of Malt Modification				
Beta-Glucan (ppm)	< 120	< 100	< 100	
F/C Difference	< 1.2	< 1.2	< 1.2	
Soluble/Total Protein	42-47%	40-47%	38-45%	>48%
Turbidity (NTU)	< 10	< 10	< 10	
Viscosity (absolute cp)	< 1.50	< 1.50	< 1.50	
Congress Wort				
Soluble Protein	5.2-5.7%	4.8-5.6%	< 5.3%	>6.0%
Extract (FG db)	> 79.0%	> 81.0%	> 81.0%	> 79.0%
Color (°ASBC)	1.8-2.5	1.6-2.5	1.6-2.8	<4.0
FAN	> 210	> 210	140-190	>250
Malt Enzymes				
Diastatic Power (°ASBC)	> 150	> 120	110-150	>200
Alpha Amylase (DU)	> 50	> 50	40-70	>75

Quality Traits

Malt extract
 Wort protein
 S/T protein
 Diastatic power
 Alpha amylase
 FAN
 Beta-glucan
 Viscosity

B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Variety or Selection	Rowed	Kernel Weight (mg)	on 6/64"	Barley Color (Agrtron)	Malt Extract (%)	Wort Color	Wort Clarity	Barley Protein (%)	Wort Protein (%)	S/T (%)	DP (°ASBC)	Alpha-amylase (20°DU)	Beta-glucan (ppm)	FAN (ppm)
ND_Genesis	2	42.4	98.1	37.5	82.0	3.2	1	12.1	5.1	43.8	119.5	78.9	259.4	199.3
ND_Genesis	2	41.9	97.4	34.5	82.4	2.9	1	12.4	5.2	44.9	113.2	79.9	279.1	217.8
ND_Genesis	2	42.7	97.7	30.5	82.4	2.7	1	12.0	5.1	45.4	111.3	81.1	241.8	195.0
Pinnacle	2	41.7	95.8	29.5	82.1	3.4	1	12.0	5.2	45.3	98.1	65.4	293.6	192.4
Pinnacle	2	43.4	97.8	22	82.2	2.7	1	11.8	5.0	43.8	104.3	61.5	296.4	177.7
Pinnacle	2	43.1	98.0	23	81.9	2.8	1	12.5	5.2	43.2	94.8	85.9	343.2	189.6
2MS14_3323-012	2	41.1	94.8	29.5	79.7	2.9	1	13.3	5.1	39.0	131.7	57.6	391.0	194.6
2MS14_4005-006	2	40.5	93.3	37.5	80.6	4.5	1	14.7	6.1	44.0	111.1	69.2	192.1	238.9
2MS14_4005-007	2	42.6	97.1	43.5	80.4	4.1	1	14.7	6.3	44.8	118.4	68.8	174.8	294.4
2MS14_4005-010	2	41.2	95.2	26	80.7	4.1	1	13.9	6.1	44.4	153.1	78.3	209.5	249.3
2MS14_4009-007	2	45.4	95.8	30	80.4	2.5	1	14.2	5.4	40.1	145.6	74.5	343.1	207.3
2MS14_4012-009	2	42.4	97.8	34.5	79.6	1.6	1	13.8	4.6	34.3	144.5	59.7	373.4	158.1
2MS14_4012-011	2	42.0	97.1	32.5	81.2	3.5	1.5	13.0	5.8	47.0	107.7	80.5	309.8	259.2
TM14.004-16	2	39.4	97.1	41	81.9	3.7	1	13.4	5.3	40.8	115.7	66.1	435.9	195.3
TM14.004-25	2	44.4	98.6	28	80.2	2.4	2	12.8	4.6	38.2	101.3	62.9	305.9	170.0
TM14.006-01	2	43.3	97.9	28	81.2	2.2	1.5	12.9	5.2	42.5	125.8	82.7	248.8	187.6
TM14.013-07	2	47.1	98.7	37.5	81.5	3.8	2	12.7	5.3	44.0	68.0	60.6	392.6	209.0
TM14.013-10	2	41.7	96.5	29	82.4	3.6	1	12.0	5.3	47.2	100.3	83.1	163.1	228.0
TM14.013-17	2	42.9	97.5	33.5	82.9	3.1	1	12.1	5.6	49.2	102.5	76.6	225.4	231.4
TM14.013-23	2	44.5	97.9	33.5	81.6	3.1	1.5	13.1	5.4	43.3	88.5	68.6	371.9	215.8
TM14.013-27	2	44.1	98.8	34.5	82.5	3.2	1	12.3	5.5	46.5	86.3	73.1	139.4	233.2
TM14.013-41	2	47.2	98.6	34.5	82.3	4.6	1	12.6	5.5	45.8	96.5	62.3	399.2	199.8
TM14.013-42	2	46.5	98.4	29	82.6	3.5	1	11.9	5.4	48.1	110.6	89.1	229.7	233.8
TM14.013-52	2	43.7	97.7	28.5	81.5	3.6	1	12.9	5.5	44.0	78.8	67.4	251.4	220.7
TM14.013-61	2	44.6	96.6	32.5	83.1	3.2	1.5	12.2	5.6	47.5	82.5	78.8	303.9	245.6
TM14.013-62	2	44.5	98.9	29	83.2	3.4	1	12.1	5.4	46.3	106.1	88.7	194.8	222.8
TM14.026-18	2	47.6	98.6	43	82.1	1.9	1	14.5	5.6	41.4	155.6	68.2	438.3	249.9
TM14.030-07	2	45.3	99.2	35	83.3	2.2	1.5	11.9	5.1	44.5	99.2	79.0	177.6	188.2



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Quality Traits

Malt extract

Soluble (wort) protein

S/T protein

Diastatic power

Alpha amylase

FAN

Beta-glucan

Viscosity

Flavor?



ASBC Hot Steep Malt Sensory Method

Hot Steep

Application of method: sensory evaluation of extractable malt flavors and aromas

Target audience: sensory panels, brewers

Reagents

- (a) Whole kernel malt
- (b) Deionized water

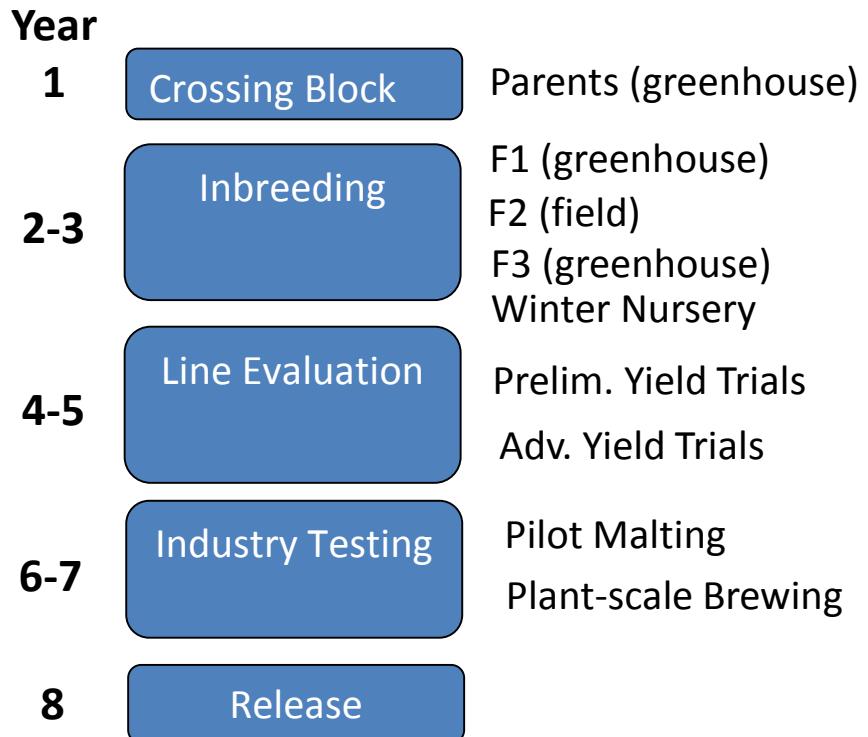
Apparatus

- (a) Thermos®, insulated, stainless steel, 24 ounce volume
- (b) Thermometer, standard, 0-200°C
- (c) Heating apparatus, capable of heating water to 65°C
- (d) Funnel, plastic, short stem, 16 cm in diameter or similar
- (e) Filter paper, fluted, 32 cm in diameter (Ahlstrom No. 515 or similar)
- (f) Electric Grinder, 3 ounce volume, 200-watt (KRUPS F203 or similar)
- (g) Glass Beaker, tall, 600 mL volume
- (h) Graduated cylinder, 500 mL volume
- (i) Analytical balance, capable of weighing 50.0 g (\pm 0.1 g)



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Breeding Pipeline



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Breeding Pipeline

Year

1 Crossing Block

2-3 Inbreeding

4-5 Line Evaluation

6-7 Industry Testing

8 Release

Parents (greenhouse)

F1 (greenhouse)
F2 (field)
F3 (greenhouse)
Winter Nursery

Prelim. Yield Trials
Adv. Yield Trials

Pilot Malting
Plant-scale Brewing

Select parents and
Perform Cross pollinations

Parent A

yield
disease resistance
protein
malt extract
FAN

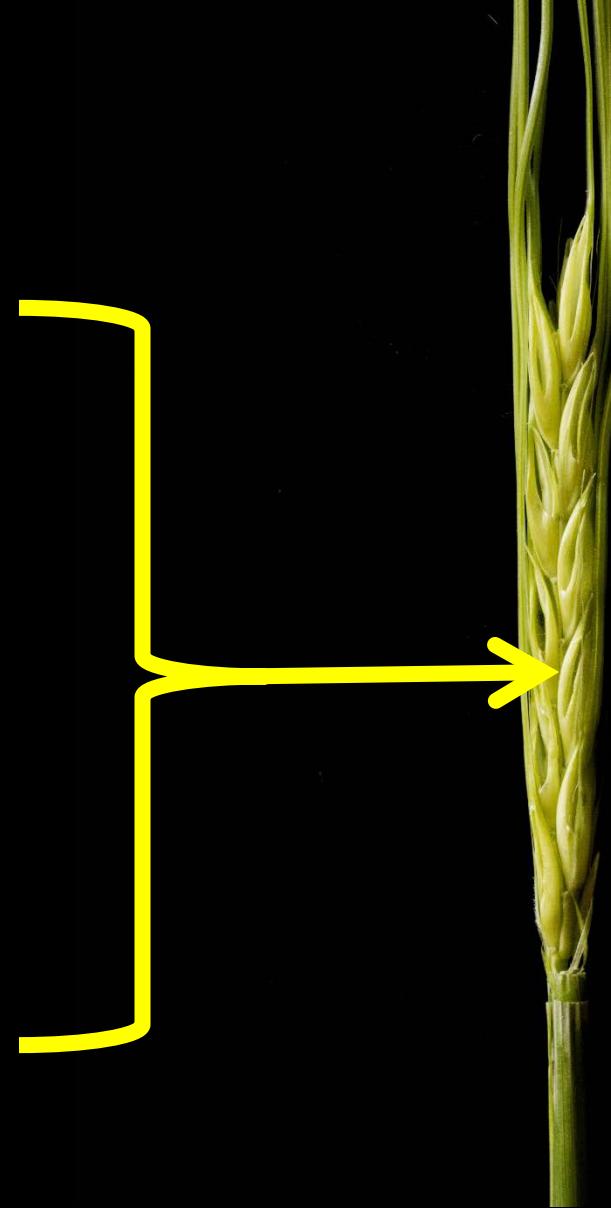
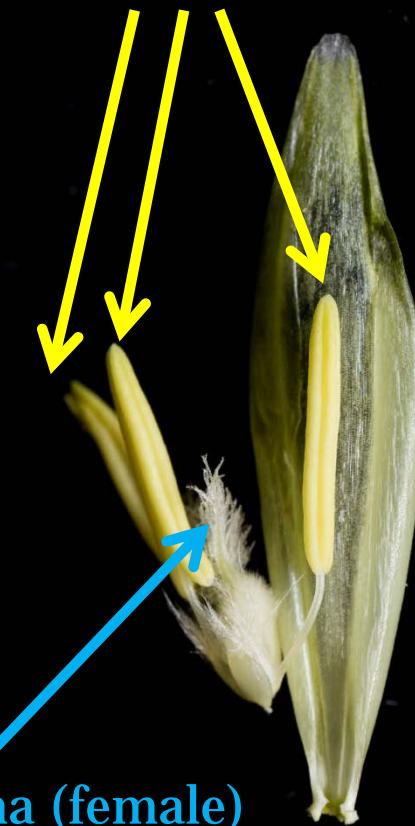
Parent B

yield
disease resistance
protein
malt extract
FAN



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3 anthers (male)



1 stigma (female)

Pollination

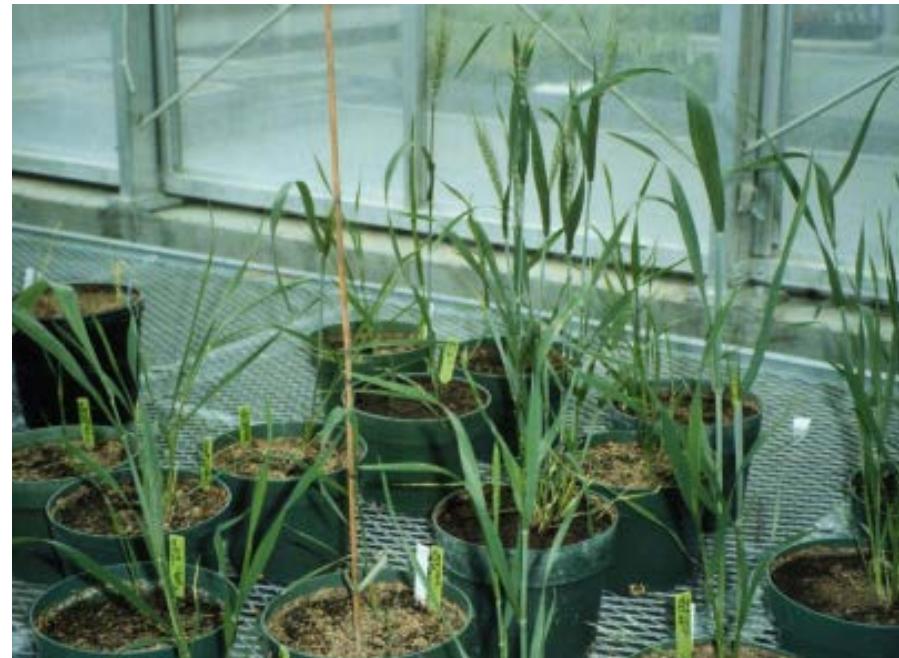


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Breeding Pipeline

Year

1	Crossing Block	Parents (greenhouse)
2-3	Inbreeding	F1 (greenhouse) F2 (field) F3 (greenhouse) Winter Nursery
4-5	Line Evaluation	Prelim. Yield Trials Adv. Yield Trials
6-7	Industry Testing	Pilot Malting Plant-scale Brewing
8	Release	



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Breeding Pipeline

Year

1	Crossing Block	Parents (greenhouse)
2-3	Inbreeding	F1 (greenhouse) F2 (field) F3 (greenhouse) Winter Nursery
4-5	Line Evaluation	Prelim. Yield Trials Adv. Yield Trials
6-7	Industry Testing	Pilot Malting Plant-scale Brewing
8	Release	

Single row plots



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Breeding Pipeline

Year

1	Crossing Block	Parents (greenhouse)
2-3	Inbreeding	F1 (greenhouse) F2 (field) F3 (greenhouse) Winter Nursery
4-5	Line Evaluation	Prelim. Yield Trials Adv. Yield Trials
6-7	Industry Testing	Pilot Malting Plant-scale Brewing
8	Release	

F3 plants



Leaf Tissue



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Breeding Pipeline

Year

1	Crossing Block	Parents (greenhouse)
2-3	Inbreeding	F1 (greenhouse) F2 (field) F3 (greenhouse) Winter Nursery
4-5	Line Evaluation	Prelim. Yield Trials Adv. Yield Trials
6-7	Industry Testing	Pilot Malting Plant-scale Brewing
8	Release	

New Zealand



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Breeding Pipeline

Year

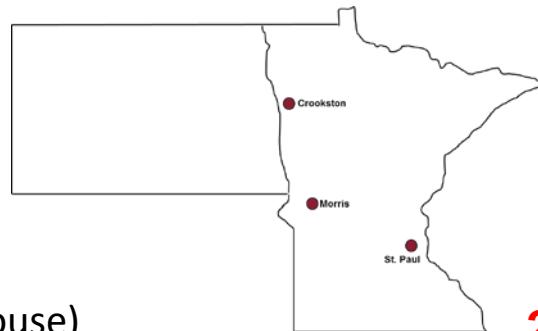
1	Crossing Block	Parents (greenhouse)
2-3	Inbreeding	F1 (greenhouse) F2 (field) F3 (greenhouse) Winter Nursery
4-5	Line Evaluation	Prelim. Yield Trials Adv. Yield Trials
6-7	Industry Testing	Pilot Malting Plant-scale Brewing
8	Release	

New Zealand



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Breeding Pipeline



Year

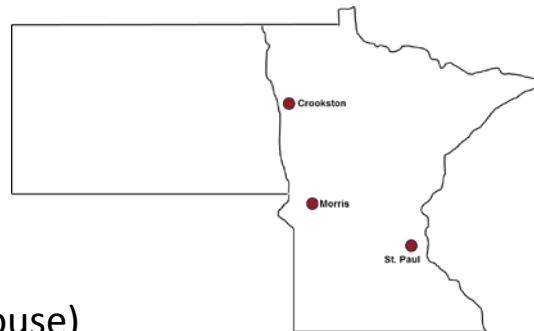
1	Crossing Block	Parents (greenhouse)
2-3	Inbreeding	F1 (greenhouse) F2 (field) F3 (greenhouse) Winter Nursery
4-5	Line Evaluation	Prelim. Yield Trials (3 locations) Adv. Yield Trials
6-7	Industry Testing	Pilot Malting Plant-scale Brewing
8	Release	

2 rows, 10' long



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Breeding Pipeline



Year

1	Crossing Block	Parents (greenhouse)
2-3	Inbreeding	F1 (greenhouse) F2 (field) F3 (greenhouse) Winter Nursery
4-5	Line Evaluation	Prelim. Yield Trials Adv. Yield Trials
6-7	Industry Testing	Pilot Malting Plant-scale Brewing
8	Release	



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Breeding Pipeline

Year

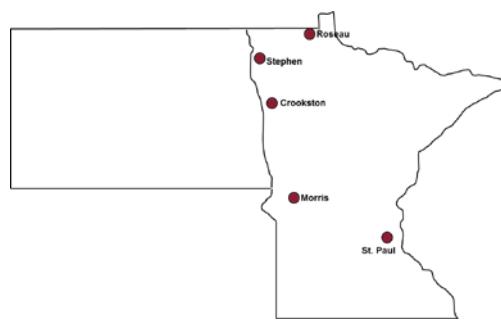
1	Crossing Block	Parents (greenhouse)
2-3	Inbreeding	F1 (greenhouse) F2 (field) F3 (greenhouse) Winter Nursery
4-5	Line Evaluation	Prelim. Yield Trials Adv. Yield Trials
6-7	Industry Testing	Pilot Malting Plant-scale Brewing
8	Release	

Fusarium Head Blight Nursery



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Breeding Pipeline



Year

1	Crossing Block	Parents (greenhouse)
2-3	Inbreeding	F1 (greenhouse) F2 (field) F3 (greenhouse) Winter Nursery
4-5	Line Evaluation	Prelim. Yield Trials Adv. Yield Trials (5 locations)
6-7	Industry Testing	Pilot Malting Plant-scale Brewing
8	Release	

5 ' x 10 ' plots



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Breeding Pipeline

Year

1	Crossing Block	Parents (greenhouse)
2-3	Inbreeding	F1 (greenhouse) F2 (field) F3 (greenhouse) Winter Nursery
4-5	Line Evaluation	Prelim. Yield Trials Adv. Yield Trials
6-7	Industry Testing	Pilot Malting Plant-scale Brewing
8	Release	

QUALITY EVALUATION SUBCOMMITTEE

2016 Crop Pilot Scale Program

Midwest Nursey Selections

M160 Unsatisfactory (*MI39/FEGI60-03*) This third year selection had slightly high barley protein and slightly low extract. It was rated unsatisfactory in 2015 testing with slightly high wort turbidity. It was satisfactory in 2014 crop testing with slightly high turbidity. *No further testing.*

S6M164 Unsatisfactory (*MS10S4021-013/MS10S4058-024*) This second year selection had slightly high barley protein and beta-glucan and slightly low extract. It was rated satisfactory in 2015 testing with slightly high beta-glucans. *No further testing.*

S6M166 Unsatisfactory (*MS10S4034-018/MS10S4029-013*) This second year selection had good extract, and slightly high S/T and beta-glucan. It was rated satisfactory in 2015 testing with good extract and slightly high beta-glucans.

S6M168 Unsatisfactory (*MS11S3058-014/MS11S3080-19*) This first year selection had high barley protein, wort viscosity and beta-glucans, and low extract and friability.

ND32889 Satisfactory (*ND28479/ND25652*) This first year selection had slightly high wort viscosity and turbidity.

ND32898 Satisfactory (*ND28479/ND25652*) This first year selection had slightly high wort viscosity and turbidity.



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Breeding Pipeline

Year

1	Crossing Block	Parents (greenhouse)
2-3	Inbreeding	F1 (greenhouse) F2 (field) F3 (greenhouse) Winter Nursery
4-5	Line Evaluation	Prelim. Yield Trials Adv. Yield Trials
6-7	Industry Testing	Pilot Malting Plant-scale Brewing
8	Release	



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Project Members / Key Collaborators

Barley Project

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Ana Poets
Celeste Falcon
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Alex Olhoff
Lu Yin
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John Price
Ian McNish
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University of Minnesota

Gary Muehlbauer
Aaron Lorenz
Ruth Dill-Macky
Brian Steffenson
Yanhong Dong
Madeline Smith



American
Malting
Barley
Association



Other Institutions

Richard Horsley, NDSU;
Shiaoman Chao, USDA Fargo;
Joshua Butler, Busch Ag.
Jean-Luc Jannink, USDA
USDA-CCRU
Mark Sorrels, Cornell
Jamie Sherman, Montana State U
Gongshe Hu, USDA Aberdeen



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Questions



Breeding Better Barley for Brewing Better Beer



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