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Improved **Winter** Barley Varieties for Montana

Opportunity Overview (Characters limited to 2000)*

Spring planted barley is an important crop in Montana, utilized as malt, feed, forage and food. Winter planted barley is grown in areas with more mild winters than we usually experience in Montana. Winter barley, planted in the fall, has some advantages over spring barley. Winter barley can yield 25% higher than spring barley. Winter malt barley could have lower protein ensuring better malt quality. Winter barley, usually harvested a couple of weeks earlier than winter wheat, can help spread harvest for growers. Since winter barley finishes about one month earlier than spring barley, quality can be more stable because high temperatures are avoided during grain-fill. Winter barley can use less water than spring barley because it takes advantage of early spring rains and when irrigation is used can require less. Winter barley can help manage pests especially out competing many weeds. Winter barley provides ground cover over the winter reducing erosion and nitrate runoff protecting watersheds.

Although winter barley historically has not been cold tolerant enough to survive most winters in Montana, we believe the advantages of winter barley necessitate its development for Montana. We believe winter barley might now be possible in Montana for several reasons: 1) Warmer winters are allowing some winter barley to be grown in the state. Interestingly, a Limagrain winter barley, called Saturn, has recently been grown successfully in Montana as a feed. 2) Germplasm that is cold tolerant is now available to us. In 2016 and 2017, we screened a set of cold tolerant winter barley lines from the Vavilov collection with some survival. 3) Planting winter barley into no-till might ensure winter barley survival. 4) Rotating with pulse crops could make winter barley even more sustainable. With the support of MWBC we have initiated a winter barley breeding program at MSU.

Build the winter barley breeding pipeline

We initiated crosses in 2018. By gaining material from other breeders and our own crosses we have initiated a barley breeding pipeline. In previous years, we have created the generations detailed in Table 1 that are being field tested in 2020. We are in the process of making another set of crosses. Interestingly, we found old material from the MSU program that we are now screening. It survived very well in 2019. Another positive for 2020, we achieved the earliest planting date and have fall emergence data, which will result in better survival data.

We have several breeding targets for winter barley improvement. The first goal will be a cold tolerant winter barley for feed. We have also made crosses to create a winter barley for forage. A much longer-term goal will be a winter malt barley for Montana. We have made crosses between cold-tolerant lines and Charles, a cold-sensitive winter 2 row barley with AMBA approval for malt. We have also made crosses between our best spring lines and cold tolerant winter lines.

We have a strategy to overcome the extended amount of time required to develop a winter line. True winter lines have genes that require 6 weeks of cold treatment to induce flowering (vernalization), which increases the length of each generation and slows the breeding process. Investigators in other states have reported that the genes requiring vernalization do not provide cold tolerance. Therefore, we can cross winter and spring lines and select for lines that do not require vernalization but are cold tolerant, allowing for the creation of cold tolerant lines with the same speed as spring barley. Lines resulting from spring by winter crosses will be available for initial yield trials winter of 2020, a full two years before the true winters will be ready. To confirm that vernalization is not required for cold tolerance in Montana, we are deriving and will test both types of lines.

Table 1: Winter germplasm in the ground for 2020 season

Generation	Number of Families	Rationale	Location 2020
F2	29 Montana crosses	25 malt, 4 forage	Post farm
F3	60 (19 spring x winter and 47 winter x winter)	2 forage, 17 malt 47 cold tolerance	Post farm
F4	19 (all spring x winter)	1 hull-less, 3 forage, 15 malt	Post Farm
Elite	37	Malt or feed	Post Farm
Advanced	100	AMBA low temperature tolerance panel	Post Farm
Advanced	38	Old MSU material (cold tolerance)	Post Farm
Till/No Till	15 lines from elite malt	Test impact of till/ no till	CARC

Screen available germplasm

In 2017 and 2018, we began screening germplasm for cold tolerance with the Vavilov collection. We will continue that screening in 2019 on even more germplasm contributed by various collaborators. The goal of this screening is to identify good parents for Montana cold tolerant barley. Pat Hays, the OSU barley breeder, has been focusing on winter barely for several years. He shared material from his program with us in 2019. In the first set of material, a cold tolerant line, Wintmalt, was crossed with Maris Otter, a high quality winter malt line and doubled haploids were developed. Several of these lines

Table 2: Agronomic Data 2019

	Oregon Double Haploid Progeny of Maris Otter							
	Heading	Maturity	Height	Yield	Test Weight	Plump	Protein	Winter Survival Score
	Julian	Julian	cm	bu/ac	lb/bu	%	%	poor 1-5 Good
Maris Otter	193	233	85	96.25581345	51.4	91.63561077	13.71	4
Wintmalt	188	235	64	112.7226409	49.2	98.14990512	13.11	3.5
DH141515	179	229	63	84.20338182	50.1	91.65946413	14.35	3.5
DH141969	180	234	67	79.14153204	49	91.97215777	15.67	2
DH142000	176	227	72	94.87377285	49.3	93.85225583	15.29	3.5
DH141982	176	229	63	104.0780327	48.6	94.72960587	14.52	3
DH150115	190	234	85	97.50503264	50.5	92.14380826	15.4	3
DH142013	185	235	63	61.1858776	48.2	95.56701031	16.61	3
DH142010	182	229	61	74.86600758	48.4	94.85148515	15.59	3.5

survived the winter in Bozeman. Agronomic data for Maris Otter x Wintmalt is in Table 2. We plan to malt this material, select the best malt lines and cross with more cold tolerant lines. Hays also shared another doubled haploid population, called Oregon Elite Malt that consists of several crosses. Agronomic data for Elite Malt is reported in Table 3. We will also malt this population and use as parents for future crosses. While plumps and yields for both populations look good, winter survival needs improvement and proteins are too high.

Table 3: Agronomic Data 2019

Oregon Elite Malt								
	Heading	Maturity	Height	Yield	Test Weight	Plump	Protein	Winter Survival Score
Name	Julian	Julian	cm	bu/ac	lb/bu	%	%	poor 1-5 good
Endeavor	188	236	74	105.40	49.30	91.85	16.38	1.00
Wintmalt	189	234	71	125.27	49.40	97.46	12.87	3.33
Thunder	186	236	66	95.79	48.00	96.81	15.28	2.00
DH130939	177	221	62	77.00	48.40	94.65	17.92	3.33
DH130910	171	227	58	93.99	48.70	93.46	15.41	3.67
DH140088	182	234	71	115.57	48.70	97.65	16.39	3.33
DH120304	174	235	59.5	72.99	48.60	92.44	16.39	2.33
DH141000	176	235	70	111.69	48.50	94.95	14.62	3.00
DH141222	175	225	69	108.28	50.30	95.17	15.15	3.00
DH141364	177	237	60	88.44	48.90	97.26	15.6	3.00
DH140963	182	233	67	108.94	47.70	97.27	13.64	3.67
DH141077	179	231	70	99.56	50.10	95.16	14.75	3.00
DH141132	179	229	65	111.28	49.00	95.26	14.3	3.67
DH141221	169	221	53	58.27	48.60	95.72	17.85	3.00
DH141001	176	235	70	123.95	49.80	96.32	15.2	3.00
DH141217	168	222	57	106.41	50.50	96.62	16.44	3.33
DH141225	170	226	66	73.98	50.10	95.84	16.84	4.00
DH141932	177	232	61	128.73	49.50	97.20	14.62	3.33
DH141947	185	232	68	138.42	48.20	97.65	14.52	3.67
DH141917	182	231	61	112.33	48.30	97.63	16.9	2.67
DH141940	185	237	67	140.14	49.20	98.17	14.25	3.67
DH141944	189	235	69	119.06	47.70	96.25	14.83	3.33
DH150120	175	228	70	109.74	48.70	96.67	15.89	3.00
DH150682	178	230	73	96.29	48.70	98.22	16.14	3.00
DH150683	177	227	68	93.09	48.70	95.26	15.75	2.67
DH150686	180	231	68	106.60	48.70	97.85	16.5	2.67
DH150720	178	227	67.5	98.95	49.10	96.38	15.19	2.67
DH150157	186	234	74	136.26	47.10	96.08	14.53	3.33
DH150991	168	224	55	77.31	47.30	92.94	17.23	2.33
DH151006	170	231	62	63.15	46.40	93.08	15.95	1.67

In 2019, we also screened 450 lines in short rows from the AMBA low temperature tolerance program. We obtained good winter survival data and are incorporating this material into the crossing block.

Test for malt quality

Because winter material must be planted early in fall, it is impossible to get malt data to make decisions before planting. The malt quality lab will test at least 100 lines from 2019 for malt quality once other breeding material is complete. This data will guide winter crossing decisions. However, an early goal is to release a high yielding feed or forage with good survivability, which does not require malt quality data.

Determine impact of no-till on barley survival

In collaboration with CARC, 15 winter barley lines were planted with three replications in till and no-till to determine impact of tillage on survival and agronomics. Tables 4 and 5 report the data from the till no till experiment.

Table 4: Agronomic data from Bozeman Till no Till 2019

		Bozeman Dry															
		YIELD**** BU/AC		TEST WEIGHT LBS/BU		PROTEIN %		HEADING**** JULIAN		HEIGHT CM		PLUMP %		PLANT COUNT #		MATURITY*	
	NAME	TILL	NO TILL	TILL	NO TILL	TILL	NO TILL	TILL	NO TILL	TILL	NO TILL	TILL	NO TILL	TILL	NO TILL	TILL	NO TILL
1	Charles	100.2	103.9	48.7	48.6	15	14.8	185.3	181.3	69.3	73.7	95.2	95.6	6.67	9.66	235	233
2	Dicktoo	131.7	141.1	47.7	48.3	11.9	12.5	178.7	177	59.7	57.8	90.3	92.1	14.44	16.72	224.3	224.3
3	Saturn	60.2	90.2	45.8	46.3	14.4	13.6	173.7	170.3	40.7	40.8	93.2	92.8	12.12	14.28	227	227
4	L13167	87.6	111.7	49.5	49.9	13	13	184.3	178	64	71.7	74.8	78.8	18.22	21.61	224	222
5	L13587	113.2	124.4	49.6	49.3	12.1	12.6	185.7	181.3	83.7	81.8	67.9	67.8	25.44	21.89	222.7	222.3
6	L13814	107.4	124.4	48.5	49.7	12.7	12.5	181	177.7	77.7	73.5	65	73.4	18.56	18.55	225	224.7
7	L13837	85.1	117.8	48.3	48.6	12.1	13.1	184.3	179.3	68.5	73.3	70.6	68.2	23.56	16.67	224.7	222.7
8	L13840	106.5	139.7	49.7	49.5	12.4	12	187.3	180.3	75.8	72.8	63.6	67.1	16.78	20	225.7	222
9	L13905	98.6	121.6	49.8	48.9	12.3	12	185.3	181	77.5	77.8	67	62.6	16.78	14.05	226	222.3
10	L13906	92.7	113	49.2	49.1	11.4	12.4	182.7	180.3	79	77	69	71.7	18.89	12.61	221	221.7
11	L13976	81.8	107.9	49.3	49.2	12.8	13.8	187	181	79.8	73.7	59.9	69.3	19.55	22.78	226	229.7
12	L22607	96.2	130.1	50.3	49.6	12.3	12.4	176.3	174.7	64.2	69.2	82.4	82.6	17.67	13.78	231	230
13	L23770	106.8	130.2	50	49.6	13.7	12.7	186	182	67.2	71.3	86.3	74.8	18.22	14.06	236	229.3
14	L29979	113	110.7	49.3	49.6	13.6	13.8	177.7	174.7	74.5	66.5	81.9	81	13.34	19.89	223	222.3
15	L30209	83.2	111.7	48	48.3	14.3	13.5	179	176.3	73.3	73.7	86.4	86.1	14.33	10.61	231.3	229.7
	GRAND MEAN	97.62	118.55	48.91	48.97	12.93	12.97	182.29	178.36	70.32	70.31	76.90	77.60	16.97	16.48	226.84	225.53
	CV	15.53	14.66	1.00	1.43	5.70	5.26	0.82	1.05	6.97	8.72	3.62	8.65	33.11	32.48	1.34	1.52
	LSD	30.54	35.02	0.99	1.41	1.49	1.37	3.02	3.77	9.88	12.34	5.60	13.52	11.34	10.78	6.14	6.88

Table 5: Agronomic data from CARC Till no Till 2019

	MOCCASIN DRY											
	YIELD*** BU/AC		TEST WEIGHT LBS/BU		PROTEIN %		HEADING DATE JULIAN		HEIGHT CM		PLANT COUNT #	
NAME	TILL	NO TILL	TILL	NO TILL	TILL	NO TILL	TILL	NO TILL	TILL	NO TILL	TILL	NO TILL
Charles	62.1	46.9	52.8	51.3	11.4	12.2	176.7	177.7	64.3	62.7	24.67	19
Dicktoo	73.1	65.1	51.8	52.8	11.2	10.9	170.3	170.3	74.5	66	26.33	25.67
Saturn	76.9	64.8	51.7	52.2	11.8	11.4	169	168.3	68.6	60.9	14.83	31.33
L13167	72.5	74.6	54.1	54	11.2	10.7	172	177	83.8	83.8	24.17	29
L13587	79.4	81.1	54.3	54.7	11.3	10.7	174.7	173.3	84.7	88.9	35	13.5
L13814	81.4	71.8	54	53.5	11.2	10.8	171	172.7	81.3	80.5	18.17	26.5
L13837	79.1	66.6	54.6	52.5	11	11.3	178	178	89.7	77	32	27.17
L13840	81	76.8	53.1	54.2	11.2	10.5	177	176.7	80.4	89.7	24.83	34.17
L13905	67.8	67.8	54.2	53.4	11.1	11	178	174.3	87.2	75.3	28.83	32
L13906	75.5	65.3	54.1	52.3	10.6	10.9	175.3	176.7	94.8	84.1	37	33.49
L13976	90.4	75.2	54.3	53.6	10.8	10.6	175	177	90.6	83.8	28.83	23.67
L22607	84.1	78.8	54.1	53.2	11.1	10.2	171.7	169.3	88.1	75.4	38.33	43.83
L23770	73.5	68.8	53.4	52.8	11	10.7	177.3	172.7	84.7	80.4	19	34.17
L29979	77.6	68.5	53.5	53.1	11	10.9	169.7	172.7	61.8	72	34.5	26.67
L30209	84.9	75.7	53.7	53.4	10.9	10.6	172.3	174.3	88.9	85.5	23.67	33
GRAND ME	77.29	69.87	53.58	53.13	11.12	10.90	173.87	174.07	81.56	77.74	27.34	28.88
CV	14.13	17.92	2.65	2.85	5.16	8.13	1.36	1.86	13.75	10.33	34.29	45.61
LSD	22.00	25.22	2.86	3.05	1.16	1.79	4.76	6.52	22.59	16.21	18.89	26.59

In Bozeman, the no till treatment had significantly higher yields and earlier heading, while the tilled treatment had higher yields at CARC. To ensure survival, we believe planting into no till is a better option. We also think, at least in Bozeman that the no till plants had access to more moisture. CARC is repeating the till no till experiment in 2020.

While the Vavilov lines have cold tolerance, they also have other traits that require improvement. Many of the lines are tall and have lodging. They also vary for heading date and we will need to determine if earlier or later heading for winter lines will be better adapted to Montana. Many of the lines are 6 row and so not preferred for malt. When we have malted the Vavilov lines many have seed dormancy and some are water sensitive. While dormancy could be a benefit to inhibit pre-harvest sprouting, water sensitivity is a problem for malt quality and needs to be improved. It is important to know the quality performance of potential parents, as that information could help speed the breeding process.