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Improved Winter Barley Varieties for Montana

Spring planted barley is an important crop in Montana, utilized as malt, feed, forage and food. Winter planted barley is grown in areas with milder 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

By gaining material from other breeders and our own crosses we have initiated a barley breeding pipeline with our first crosses in 2018. In previous years, we have created the generations detailed in Table 1 that were field tested in 2020. We are in the process of making another set of crosses. Interestingly, we found old material from the MSU program 20 years ago that we are screening (PH pops) and thus far has survived very well.

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 2021

Generation	Families (lines)	Rationale all plots no till	Location 2020
F2	111 Montana crosses	73 malt/feed, 35 forage, 3 hull-less	Post farm
F2	OSU (70)	Test cold tolerance	Post farm
F3	28 (spring x winter)	4 forage, 24malt/feed	Post farm
F4 (single plants)	28(784)	2forage, 26 malt/feed	Post Farm
F4 (bulked f3)	12 (60) (9 winterxwinter; 3 spring x winter)	Feed/malt	Post Farm
F5	25 (120)	Spring X winter, 9 forage, 1 hull-less, 12 feed	Post Farm
PH pops	4 (100)	Cold tolerance	Post Farm
Elite	37	Malt or feed	Post Farm
Advanced	200	AMBA low temperature tolerance panel	Post Farm
Advanced	38	Old MSU material (cold tolerance)	Post Farm
F4 (F3 Bulks)	25 malt/feed	Cold Tolerance	CARC
F4 (F3 BULKS)	52 forage	Cold tolerance	NWARC

Below is pictured some F4 spring x winters in Bozeman MT in 2020. Each short row is a line of one of the 19 families. We observed differential survival with most of some families not surviving.

Crosses in spring of 2020

Since winter lines require vernalization, the breeding process takes longer. We planted winter material in the fall of 2019, but it was not available for crossing until spring of 2020. We were very successful making winter crosses creating a total of 171 new winter lines (see Table below). Of those, 57 were winter X winter, focusing on crosses using the Vavilov lines to make other winter lines cold tolerant and improve the performance of the Vavilov lines. The F1s from the winterxwinter crosses were inbred one generation in the greenhouse. The remaining crosses were spring x winters with 5 being hull-less, 45 forage and 77 malt. The F1s from the springXwinter crosses were grown in the field to create a large amount of F2 seed. All F2 families were planted in the field in Bozeman for selection over the 2021 growing season. We reserved some seed for cold tolerance in the greenhouse this winter. If this is successful it will narrow the number of lines requiring less testing in the field.

	Breeding Goals	2015	2016	2017	2018	2019	2020
	Forage					8	39
	Cold tolerance					21	57
	Malt					45	53
	Hull-less						3
	Low beta glucan						4
	Low GN						2
	Stay green						4
	Fast hydrating/dormant						8
	low proline						1
Winter	Total					74	171

Crosses in spring of 2021

We are in the process of making the 2021 winter crosses.

Screen available germplasm

Since our winter breeding program is new, we did not have our own advanced lines to test in 19/20. However, Pat Hays, the OSU barley breeder, has been focusing on winter barely for several years. He has shared two panels with us. In 19/20 Bozeman, we tested the Low Temperature Tolerance Panel (LTT) of 68 lines. Note in the table below a number had good winter survival and high yield.

Bozeman Low Temperature Tolerance Panel						
		Protein	*Plumps*	*Yield*	*Test Wt*	*WINTER*
Name	***Pedigree***	*%*	*%*	*bu/ac*	*lbs/bu*	SURVIVAL %
DH160968	NB10440/DH120293	12.63	94.0	**134.8**	52.1	100
DH161265	NB10440/DH120293	12.56	97.1	**133.1**	52.0	78
DH161788	Antelope/DH130004	13.04	91.6	**130.7**	54.8	100
DH162122	Antelope/DH130004	14.46	88.8	**128.7**	54.2	64
DH162138	Antelope/DH130004	14.42	96.2	**123.6**	56.1	100
DH162113	Antelope/DH130004	14.47	95.1	**122.8**	52.7	100
DH161017	MOB2301/DH10.1044	12.72	95.1	**122.4**	51.6	69
DH160990	KWS Scala/VA11B-143	13.90	95.3	**120.6**	50.9	92
DH161999	Antelope/DH130004	13.89	94.7	**120.3**	50.1	NA
DH161440	MOB2301/DH10.1044	13.49	96.8	**120.3**	53.0	100
DH160949	Antelope/DH130004	14.11	93.3	**118.6**	55.4	100
DH161365	Violetta/VA11B-141	13.12	86.2	**118.3**	53.2	96
DH161998	Antelope/DH130004	12.86	85.6	**118.2**	55.3	100
DH162169	NB10425/KWS Scala	14.67	96.8	**117.8**	48.2	100
DH120293	Parent	12.37	93.1	**117.1**	52.4	74
DH161787	Antelope/DH130004	13.72	94.3	**116.5**	52.9	88
DH162195	Violetta/VA11B-141	13.35	94.2	**115.0**	55.4	100
KWS Scala	Parent	13.31	95.5	**112.6**	52.0	87
DH161780	Antelope/DH130004	15.39	86.7	**111.1**	52.7	94
Antelope	Parent	13.79	85.8	**111.0**	54.7	92
DH162129	Antelope/DH130004	13.96	96.4	**110.2**	54.2	84
DH161022	MOB2301/DH10.1044	14.46	94.4	**109.7**	53.6	96
DH161866	Violetta/VA11B-141	15.65	94.7	**109.1**	51.7	79
DH161406	MOB2301/DH10.1044	15.19	88.4	**108.6**	52.5	100
DH162179	KWS Scala/VA11B-143	14.42	96.1	**108.1**	54.6	58
DH161997	Antelope/DH130004	14.77	96.6	**107.6**	51.0	99
DH161810	NB10440/DH120293	13.47	96.4	**107.6**	53.2	70

SC85942	Parent	14.06	96.3	**106.2**	53.1	80
DH161250	NB10440/DH120293	14.48	96.9	**105.6**	50.2	80
DH161015	MOB2301/DH10.1044	15.03	88.8	**104.5**	54.9	76
DH161378	MOB2301/DH10.1044	15.01	95.8	**104.5**	53.6	86
10.0777	Wintmalt/Charles	11.70	94.1	**103.6**	51.8	86
DH162077	Admire-1 (DFG)/DH130	15.64	93.3	**102.5**	52.4	82
DH161227	Antelope/DH130004	15.22	94.1	**102.2**	52.3	65
DH161209	Antelope/DH130004	15.09	93.8	**102.1**	54.5	71
DH160962	NB10440/DH120293	14.04	96.4	**101.9**	50.7	82
DH161870	Violetta/VA11B-141	15.64	91.8	**101.6**	54.6	80
DH161989	Admire-1 (DFG)/DH130	15.46	96.1	**101.2**	52.6	72
DH162018	Violetta/VA11B-141	17.34	94.4	**100.5**	53.7	68
DH161790	MOB475/DH10.1044	14.79	91.5	**100.4**	54.5	78
DH161325	NB10425/KWS Scala	14.05	97.1	**100.4**	54.4	100
DH161774	Antelope/DH130004	13.97	95.5	**99.7**	53.6	100
DH162123	Antelope/DH130004	14.38	94.1	**98.3**	54.5	88
DH160958	NB10440/DH120293	14.52	94.0	**97.4**	52.0	100
DH130910	SHORT11-7 (TC6W265)	14.68	93.9	**95.8**	54.7	100
DH161398	MOB2301/DH10.1044	15.86	93.6	**95.5**	52.3	100
DH161862	Violetta/VA11B-141	16.15	93.5	**91.7**	53.8	59
DH161390	MOB2301/DH10.1044	16.66	97.3	**90.1**	53.6	85
DH160950	Antelope/DH130004	16.06	93.2	**89.9**	55.0	94
MOB2301	Parent	16.33	94.1	**89.2**	51.7	84
DH161376	MOB2301/DH10.1044	15.61	93.3	**88.3**	50.3	71
DH161218	Antelope/DH130004	15.46	91.0	**87.2**	52.9	57
DH161375	MOB2301/DH10.1044	15.78	96.3	**85.5**	53.5	96
DH161379	MOB2301/DH10.1044	15.56	91.1	**84.2**	50.8	85
DH161753	Admire-1 (DFG)/DH130	17.55	91.5	**83.9**	54.7	84
DH161392	MOB2301/DH10.1044	15.51	94.2	**82.7**	47.4	76
DH161417	MOB2301/DH10.1044	15.44	90.3	**82.2**	51.0	NA
DH161252	NB10440/DH120293	13.95	95.9	**81.1**	49.6	34
DH161377	MOB2301/DH10.1044	16.79	86.6	**80.1**	51.1	100
DH161399	MOB2301/DH10.1044	15.62	96.2	**77.5**	53.8	46
DH161431	MOB2301/DH10.1044	16.51	98.2	**76.2**	49.7	39
DH162068	Admire-1 (DFG)/DH130	16.25	95.7	**74.6**	54.5	64
DH162010	MOB2566/SC85942	16.75	95.6	**73.5**	50.7	100
DH161309	MOB2566/SC85942	18.53	97.8	**68.7**	48.9	70
DH161845	KWS Scala/VA11B-143	17.55	84.9	**68.3**	52.9	77
DH160954	MOB475/DH10.1044	15.60	87.7	**66.7**	51.1	95
DH161314	MOB2566/SC85942	16.60	93.8	**64.7**	52.0	60
DH162012	MOB2566/SC85942	18.32	93.7	**54.7**	50.1	53

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We also screened 39 double haploid lines from OSUs elite panel at CARC and Bozeman. Note that DH141947 was the highest yielder in both environments (see below).

Bozeman Winter 2020						
	YIELD	PROTEIN	PLUMP	TEST WEIGHT	SPRING PLANT	WINTER
name	BU/AC	5	%	LBS/BU	COUNT/FT^2	SURVIVAL %
Maris Otter	71	12.8	90.1	53.9	15	110
Wintmalt	77.1	12.4	95.5	51.8	12	91
Charles	77.8	11.8	91.1	50.2	12	110
DH141364	69.2	14.3	94.6	54.8	12	98
DH141000	76.1	14.2	95.2	53.6	12	97
DH141077	92.5	13.8	94.3	55.2	13	122
DH141217	70.6	15.7	96.3	54.8	11	108
DH140088	93.1	15.8	97.7	54.9	15	99
DH130939	71.6	14.4	96.1	55.2	11	103
DH141947	101.9	13.5	95.3	52.7	13	99
DH130910	78.4	14.6	97.4	54.6	12	107
DH141221	59.4	16.4	96.3	54.9	12	99
DH141222	61.9	14.5	95.2	55	14	103
DH141944	96	13.6	91.6	52	15	94
DH141225	68.5	13.9	95.5	55.1	14	112
DH140963	84.3	13.2	96.6	53.5	13	105
DH150686	67.7	14.3	96.1	54	11	100
DH150157	100.1	13.6	95.6	52	13	100
DH141917	81.1	14	97.9	53.9	13	110
DH151006	67.7	14	95.2	54.2	13	104
DH141940	90.6	13	95.3	53.3	12	103
DH150720	70.7	14.5	93	54.7	13	81
DH141132	91.4	13.6	92.4	54.3	11	105
DH150120	65.9	14.5	96.4	53.9	13	128
DH150682	78.3	15.4	97.7	53.9	13	116
DH141001	95.9	13.7	95.8	55.1	14	111
DH120304	76.4	14.9	95.8	54.1	13	124
DH141932	82.4	13.7	94.2	54	11	100
DH150683	70.7	13.8	91.5	53.1	13	94
Thunder	83.9	12.2	94	52.9	14	101
DH141515	70.9	14.7	88.6	55	13	113
DH141969	73.9	13.8	87.8	53.9	11	100
DH142000	78	14.3	94.3	54.6	13	86
DH141982	65.5	14.4	87.9	54.3	11	75
DH150115	66	14.2	92.2	54.8	12	90
DH142013	68.2	14.3	94.9	53.2	11	103
DH142010	67.5	13.5	91.7	53	11	94
DH150991	57.8	15.3	95.5	54.2	7	126
GRAND MEAN	76.81974	14.04605	94.25526	53.88684	12.19737	102.90789
CV	20.95736	4.39948	1.44492	0.83224	11.64892	13.34126
LSD	39.14481	1.50252	3.31142	1.09043	3.45475	33.38184

CARC WINTER DATA 2020						
	YIELD	SPRING PLANT			YIELD	SPRING PLANT
Line	BU/AC	COUNT/FT^2		Line	BU/AC	COUNT/FT^2
MarisOtter	83.1	7		DH141132	92.5	14
Wintmalt	81.1	17		DH150120	90.5	11
Charles	110.4	9		DH150682	81.6	16
DH141364	86.3	14		DH141001	82.2	17
DH141000	81.7	14		DH120304	80.1	6
DH141077	77.4	14		DH141932	95.9	14
DH141217	63.9	11		DH150683	89.7	10
DH140088	69.1	11		Thunder	85.1	10
DH130939	74.9	6		DH141515	78.8	7
DH141947	108.5	9		DH141969	72.7	8
DH130910	79.2	6		DH142000	71	16
DH141221	77.3	8		DH141982	84.6	9
DH141222	81.2	14		DH150115	78.2	10
DH141944	95.8	14		DH142013	68.8	11
DH141225	75.2	14		DH142010	88.4	15
DH140963	81.8	11		f3fam50B	61.5	6
DH150686	69.8	8		f3fam51B	68.8	7
DH150157	96.6	11		SC85942	78.6	15
DH141917	75.4	11		DH160990	60.4	16
DH151006	79.9	11		DH161022	65.3	12
DH141940	80.8	11		DH161440	69.3	6
DH150720	81.8	11				
				GRAND MEAN	80.34729	11.12403
				CV	14.49449	36.4415
				LSD	22.55086	7.8496

CARC Till vs no Till

Comparing barley in till vs no-till treatments at CARC in 2020 had similar results to 2019.

	CARC Till No-till 2020					
	Plant Counts	Plant	Yield	Test	Protein	Plumps
	Spring	height (in)	bu/ac	weight (g)	%	%
no-till	10.84	21.35	58.37	56.88	11.91	92.73
till	9.95	22.92	67.91	56.51	12.63	91.49
T test pvalu	0.27	0.00	0.00	0.00	0.00	0.04

Plant counts surviving the winter were not significantly different, although trending toward higher numbers in no-till. On average tilled plots had higher plant height, yield and protein. While no-till had higher test weight and plumps. This indicates that conserved moisture due to no-till had a bigger impact on seed size than yield. A dryer year might result in different effects of no-till.

Test for malt quality

Because winter material must be planted early in fall and we had a delayed harvest, it was impossible to get malt data to make decisions before planting. The malt quality lab tested winter lines from 2019 early in 2020 for malt quality. Note none of the material tested was adequate malt quality. All were too low in Extract, most were too high in beta glucan, and many too low in enzyme alpha amylase. The poor quality will likely be fixed by crossing with good malt quality spring barley. We have made a number of crosses with our spring malt advanced lines.