Final Project Summary

Successes/Failures: We had enough winter material to have across the state in 2021/22 for the first time. Unfortunately, the drought in the fall of 2021 caused germination failure, such that many of the trials were not subjected to winter temperatures and spring germination and development was uneven. However, in Fall of 2022 most locations germinated before snowfall. We included a North Dakota location where, if necessary, irrigation could be provided to ensure germination, but in fall 2022 this was not required. Therefore, we should have good winter survival data in spring of 2023. In 2022, Bozeman we had early canopy closure, high biomass for forages, and high grain yield. Some winter lines are better able to grow out of winter damage than others. It seems none has the cold tolerance of winter wheat check.

Objectives and Follow-up: We will continue to make crosses, advance and evaluate lines. We are continuing to improve cold tolerance through crosses and selection. It maybe that our releases will need to be target only to certain regions of Montana. A goal is to provide regional information on winter barley variety performance so that growers can make informed decisions.

Objectives –

Build the winter barley breeding pipeline

The pipeline starts with crosses and Table 1 lists the number of crosses and goals. We have just completed the 2023 crossing block and will make F2 seed over the summer.

Table 1: Number of crosses and breeding goals for winter barley program

	Breeding Goals	2015	2016	2017	2018	2019	2020	2021	2022
	Forage					8	39	24	60
	Cold tolerance					21	57	17	25
	Malt					45	66	47	35
	Hull-less						3	2	26
	Low GN						2		2
	Feed						4	10	8
	FHB resistance								11
	Stripe Rust							3	5
	Bacterial leaf streak								8
Winter	Total					74	171	103	180

The 180 crosses made in spring 2022 were inbred over the summer 2022 and are in the field as F2s in 2022/23. Table 2 summarizes the winter field trials in 2022 including the available germplasm from other programs fulfilling the objective **Screen available germplasm.**

Table 2: Winter Barley field trials 2022

Winter Trials 2022						
Location(s)	**Trial Name**	**Trial description**	**Goal**	**# of lines**	**Plot size**	**Reps**
BOZ, CARC, NARC, WTARC, Williston	WintMaltIntra	Malt/Grain F5(F3)s	Test lines for survival and grain yield/protein	25	full plot	3, RCB
BOZ	WintMaltPYT	Malt/Grain F6s, F5(F4)s, F5(F3)s, F4(F3)s, and F4(F2)s; Pats Pop 2019/2020	Test lines for survival and grain yield/protein	177 + 3 checks	full plot	1, Augmtd
BOZ, CARC, NARC, NWARC, WTARC, Williston	WintForgIntra	Forage F6(F4)s, F5(F2)s	Test lines for survival and grain yield, forage yield in locations we can travel to	16	full plot	3, RCB
BOZ	WintForgPYT	Forage F6s, F6(F4)s, F5(F3)s, F5(F2)s, and F4(F3)s	Test lines for survival and grain yield, forage yield	99 + 3 checks	full plot	1, Augmtd
Williston	WintF3Williston	Best yielding F3(F1) lines	Test lines for survival	39 + 3 checks	full plot	1, Augmtd
7 locations around North America	WintScab	Winter North American Barley Scab Nursery 2021-22	Screen for scab in 6 environments, screen for cold tolerance in Bozeman	60	shortrow	2
BOZ	OSU vrn+/- panel	vernalization sensitivity panel is 417 total. 140 facultative + 277 winter.	vernalization sensitivity panel from 2020	417	shortrow	1
BOZ	WintIncreases	Vavilov lines with very low seed, Archival matl	Increase or revive lines from storage	30	shortrow	1
BOZ	Breeding Pipeline shortrows	F2s	Evaluate lines, increase seed	122	shortrow	1
BOZ	Breeding Pipeline shortrows	F3s	Evaluate lines, increase seed	113	shortrow	2
BOZ	Breeding Pipeline shortrows	F5s	Evaluate lines, increase seed	232	shortrow	1

Our first goal is to release a feed forage line. Field trials for feed/forage are supported by a USDA grant. However, MWBC was integral in the early stages of this project and so we share data from the trials below. The CARC and WTARC trials were abandoned. Below is reported the remaining trials of 2022. Note that in Bozeman (Table 3) several of the winter barley lines had higher forage yield than the winter wheat check. However, the highest grain yield was for the Limagrains winter barley check, Saturn. Lines with 0 were not harvested due to poor winter survival. The NARC trial shows similar forage yield to winter check. No grain yield was taken due to deer predation. The NWARC trial indicates winter barley lines with lower grain yield than the checks. Forage data was lost due to a technical error by the NWARC staff. From this report, only the Post Farm resulted in complete data. We have been growing winter barley at the Post farm since 2017 and faced difficulties in production the first years as well. This year we have reports that all but NARC (due to lack of moisture) and WTARC (due to late planting) had full emergence before snow. We added the ND trial this year. We are hopeful there will be better results in 2023.

Table 3 Intrastate Forage Trial at Post Farm

pedigree	name	Forage Yield Tons/Acre	ADF	NDF	Grain Yield Bu/Ac	Height cm	Heading Julian	Maturity Julian
check	Ray	4.44	36.6	62.47	nd	112.8	174	nd
Check	Saturn	5.42	36.52	65.13	193.1	92.3	158.7	202
Lavina/Karioka	MTW_19:130-05	5.37	38.77	65.61	141.3	105	160	199.3
LAVINA/Vavilov_13976	MTW_19:131-01	0	0	0	0	0	0	0
LAVINA/Vavilov_13976	MTW_19:131-10	5.88	37.32	62.27	113.6	119.2	159.3	200
LAVINA/Vavilov_19041	MTW_19:132-01	0	0	0	0	0	0	0
LAVINA/Vavilov_19041	MTW_19:132-02	0	0	0	0	0	0	0
Lavina/Vavilov_13976	MTW_19:50-01	5.92	38.2	64.89	117.9	112	160.7	201.3
Lavina/Vavilov_13976	MTW_19:50-03	4.68	35.65	61.02	116.1	110	159	200.3
Lavina/Vavilov_13976	MTW_19:50-07	6.97	37.36	62.88	111.4	123.5	162.7	199.7
Lavina/Vavilov_13976	MTW_19:50-10	5.99	34.33	57.7	105	116.5	161.7	201.7
Lavina/Dicktoo	MTW_19:51-02	5.62	36.85	62.3	162.9	105.8	157.3	198.3
Lavina/Dicktoo	MTW_19:51-05	7.02	39.04	66.21	152.9	115.3	163	203.3
Lavina/Dicktoo	MTW_19:51-06	4.19	38.27	65.03	140.4	102.3	159	202.3
Lavina/Dicktoo	MTW_19:51-09	6.89	38.53	66.35	151.5	120.5	161	201.7
Lavina/Dicktoo	MTW_19:51-10	6.62	37.15	63.26	134	116	163.7	201
	GRAND MEAN	4.69	30.29	51.57	102.51	90.71	131.25	150.69
	LSD	2.26	2.89	4.54	24.82	5.22	0.99	1.6
	CV	28.86	5.73	5.28	14.52	3.45	0.45	0.64

Table 4: Intrastate Forage trial at NARC

pedigree	name	Forage Yield Tons/Acre	ADF	NDF	Heading Julian	Height cm
check	Ray	0.99	34.26	61.04	164.9	76.8
Check	Saturn	0.76	27.05	51.91	161.1	63.1
Lavina/Karioka	MTW_19:130-05	0.71	31.84	59.2	167.8	74.3
LAVINA/Vavilov_13976	MTW_19:131-01	0.65	31.15	57.37	170.1	77.9
LAVINA/Vavilov_13976	MTW_19:131-10	0.93	30.36	55.8	161.5	72.3
LAVINA/Vavilov_19041	MTW_19:132-01	0.49	28.44	51.66	170.6	81.7
LAVINA/Vavilov_19041	MTW_19:132-02	0.22	29.33	53.9	169.5	73.9
Lavina/Vavilov_13976	MTW_19:50-01	0.9	30.99	57.33	163.8	66.6
Lavina/Vavilov_13976	MTW_19:50-03	0.84	30.86	59.15	162.9	68.3
Lavina/Vavilov_13976	MTW_19:50-07	0.79	30.15	56.13	165.2	83.1
Lavina/Vavilov_13976	MTW_19:50-10	0.9	30.01	56.16	164.2	77.3
Lavina/Dicktoo	MTW_19:51-02	0.66	32.32	58.43	160.4	73.9
Lavina/Dicktoo	MTW_19:51-05	0.6	31.16	56.46	170	78.6
Lavina/Dicktoo	MTW_19:51-06	0.66	31.12	57.39	168	72.9
Lavina/Dicktoo	MTW_19:51-09	0.76	30.59	57.82	165.9	76.3
Lavina/Dicktoo	MTW_19:51-10	0.77	30.36	57.15	164.7	76.1
	GRAND MEAN	0.73	30.62	56.68	165.67	74.58
	LSD	0.23	3.38	5.9	3.45	7.65
	CV	18.94	6.62	6.24	1.23	6.04

Table 5: Intrastate Forage trial NWARC

pedigree	name	Grain Yield bu/ac	ADF	NDF	Heading Julian	Height cm	Spring Stand % of Plot
check	Ray	129.7	35.48	61.35	164.9	94.5	100
Check	Saturn	99.3	31.39	57.1	153.1	67.7	62
Lavina/Karioka	MTW_19:130-05	27.5	34.31	59.43	157.4	96.5	68
LAVINA/Vavilov_13976	MTW_19:131-01	25.2	36.03	63.9	160.5	91.2	31
LAVINA/Vavilov_13976	MTW_19:131-10	28.8	34.57	59.16	157.1	98.9	38
LAVINA/Vavilov_19041	MTW_19:132-01	19.3	34.73	60.28	159.9	111.8	49
LAVINA/Vavilov_19041	MTW_19:132-02	19.8	33.43	59.67	157.2	93.1	50
Lavina/Vavilov_13976	MTW_19:50-01	32.9	36.02	63.16	152	98.8	83
Lavina/Vavilov_13976	MTW_19:50-03	38.4	34.4	60.53	152.2	111.3	84
Lavina/Vavilov_13976	MTW_19:50-07	26.8	34.23	59.41	158.9	118.2	59
Lavina/Vavilov_13976	MTW_19:50-10	30.5	35.19	60.1	156.8	106.1	67
Lavina/Dicktoo	MTW_19:51-02	22.8	34.65	59.44	151.7	91.7	81
Lavina/Dicktoo	MTW_19:51-05	76.2	33.93	59.4	158	105	59
Lavina/Dicktoo	MTW_19:51-06	65.3	34.64	59.77	154.7	94.5	61
Lavina/Dicktoo	MTW_19:51-09	60.7	34.83	60.55	155.8	114.6	76
Lavina/Dicktoo	MTW_19:51-10	52.6	33.14	58.33	160.8	103.1	62
	GRAND MEAN	47.24	34.44	60.1	156.94	99.82	64.48
	LSD	17.73	1.89	3.12	3.04	10.79	21.31
	CV	22.51	3.29	3.11	1.14	6.37	19.46

The other statewide trial in 2022 was the feed/malt trial consisting of 25 lines grown in five locations – Post, NARC, WTARC, CARC and Williston ND. Trials that were abandoned were WTARC due to weeds, ND and NARC due to lack of moisture. Winter survival data as % of the plot green at the end of March is reported in Table 6. Note that all the lines had better survival than the two checks. Data for Post and CARC are reported in Tables 7 and 8. The data shows several lines are equal to or better than the checks in both locations. **Test for malt quality:** We malted select lines, but find malt quality still wanting, with experimental lines too low in extract and high in β glucans (Table 7). Table 9 reports a likely cause of poor malt quality, water sensitivity. Water sensitivity is defined as when germination is reduced when grain is submerged in 8 ml of water. Since malting starts with seed submerged in water this problem could explain poor malt quality.

Table 6: Best winter survival of lines in the intrastate trial

Pedigree	Winter Survival (Estimated by % green in plot 3/25)
CHARLES	0.66
Vavilov_13470/Arturio	7.91
Vavilov_13906/Cervoise	7.06
Vavilov_17985/Vavilov_19070	7.72
Vavilov_19070/dicktoo	8.59
Vavilov_20251/Azurel	9.01
Vavilov_22607/Salamandre	5.08
Azurel/Vavilov_13587	7.03
Salamandre/Vavilov_13587	6.38
THUNDER	2.64

Table 7: 2022 Winter Barley Feed/Malt Post

pedigree	name	Yield bu/ac	Height cm	Plump %	Extract %	S/T Protein %	DP ASBC	α Amylase DU	β Glucan ppm	FAN ppm
Check	Saturn	195.7	89.6	nd	nd	nd	nd	nd	nd	nd
Check	Charles	154.8	94.9	95.3	81.5	43.2	152.6	82.1	80.7	222.9
Check	Thunder	160	94.5	97.4	81.1	44.5	181.3	98.5	86.7	255.8
Buzz/Maris Otter	MTW_19:57-01Bulk	110.8	97.2	nd	nd	nd	nd	nd	nd	nd
Vavilov_17985/Vavilov_19070	MTW_19:17-01Bulk	68.6	121.3	85.6	73.9	28.6	105.3	25.7	1221.9	136.4
MT124128/Vavilov_17642	MTW_19:59-01Bulk	80.8	132.3	nd	nd	nd	nd	nd	nd	nd
Salanandre/Vavilov_13587	MTW_19:68-01Bulk	138.9	120.4	95.8	74.3	24.2	100.3	33.3	580.8	150.6
Vavilov_13470/Arturio	MTW_19:05-01Bulk	174.8	106.7	70.1	73	23.9	115.1	27.5	1041.3	117.3
Bearpaw/Dicktoo	MTW_19:37-01Bulk	141.6	125.6	nd	nd	nd	nd	nd	nd	nd
Vavilov_20251/Azurel	MTW_19:24-01Bulk	163.1	117.6	62.7	75.4	31.7	89.2	35	728.3	146.8
MT16M02204/Salanandre	MTW_19:64-01Bulk	152.6	93.8	nd	nd	nd	nd	nd	nd	nd
MT16M02204/Karioka	MTW_19:63-01Bulk	157.3	95.7	nd	nd	nd	nd	nd	nd	nd
Gigga/Vavilov_19917	MTW_19:48-01Bulk	84.1	118.7	nd	nd	nd	nd	nd	nd	nd
Vavilov_13906/Cervoise	MTW_19:08-01Bulk	91.3	124.2	69.7	73.4	30.3	111.3	21.3	1024.6	124.5
MT16M02204/MARIS OTTER	MTW_19:61-01Bulk	130.5	105.9	nd	nd	nd	nd	nd	nd	nd
MT124128/Salanandre	MTW_19:60-01Bulk	126.5	86.1	nd	nd	nd	nd	nd	nd	nd
Charles/Salanandre	MTW_19:40-01Bulk	146.2	98.7	nd	nd	nd	nd	nd	nd	nd
Azurel/Vavilov_13587	MTW_19:32-01Bulk	109.7	130.5	85.1	73.6	25.5	98.5	28.5	818.7	137.6
Buzz/Maris Otter	MTW_19:57-02Bulk	128.4	100.4	nd	nd	nd	nd	nd	nd	nd
Vavilov_19070/dicktoo	MTW_19:20-01Bulk	150.5	116.3	85.9	70.7	24.4	85.9	16.9	1319.2	113
MT124069/Maris Otter	MTW_19:54-01Bulk	176.5	102.2	nd	nd	nd	nd	nd	nd	nd
Vavilov_22607/Salanandre	MTW_19:26-01Bulk	164.5	100.5	83.3	74.8	26.5	128.3	31.9	945.5	147.6
Bearpaw/MarisOtter	MTW_19:35-01Bulk	111.3	108.5	nd	nd	nd	nd	nd	nd	nd
MT16M08806/MARIS OTTER	MTW_19:65-01Bulk	136	101.8	nd	nd	nd	nd	nd	nd	nd
NH05H31/MARIS OTTER	MTW_19:67-01Bulk	155.7	102.4	nd	nd	nd	nd	nd	nd	nd
	GRAND MEAN	136.4	107.43	83.09	73.62	26.66	104.08	27.77	922.63	133.92
	LSD	26.18	4.33	7.24	1.99	2.83	9.03	2.35	196.35	7.41
	CV	10.33	2.35	5.08	1.52	5.97	4.88	4.77	11.96	3.11

Table 8:2022 Winter Barley Feed/Malt CARC

pedigree	Name	Adj Yield	Protein	Heading	Test Wt
Check	Saturn	26.8	13.7	178.3	49.7
CHARLES	Charles	39.2	13.4	180.8	52.4
check	Thunder	43.5	13.5	179.7	51.3
MT124128/Salanandre	MTW_19:60-01Bulk	50.3	14.5	177.6	53.6
MT124069/Maris Otter	MTW_19:54-01Bulk	50	12	181.1	51.6
Buzz/Maris Otter	MTW_19:57-01Bulk	48	12.5	180.5	55.4
Salanandre/Vavilov_13587	MTW_19:68-01Bulk	47	14.4	179.3	53.1
Buzz/Maris Otter	MTW_19:57-02Bulk	47	14.1	181	55.7
Bearpaw/Dicktoo	MTW_19:37-01Bulk	43.7	13.4	186.8	53.4
Vavilov_13470/Arturio	MTW_19:05-01Bulk	41.6	11.5	179.2	49.4
Vavilov_19070/dicktoo	MTW_19:20-01Bulk	39.6	13	177.3	53.4
Vavilov_20251/Azurel	MTW_19:24-01Bulk	39.4	14	185.8	49.1
Azurel/Vavilov_13587	MTW_19:32-01Bulk	38.3	12.9	181.1	53.7
Vavilov_13906/Cervoise	MTW_19:08-01Bulk	37.8	11.5	184.2	51.7
Vavilov_22607/Salanandre	MTW_19:26-01Bulk	36.8	14.3	179.4	52.2
Vavilov_17985/Vavilov_19070	MTW_19:17-01Bulk	34.7	11.8	178.2	53.2
MT16M02204/Karioka	MTW_19:63-01Bulk	33.5	11.2	178.5	55.6
NH05H31/MARIS OTTER	MTW_19:67-01Bulk	31.7	14.8	181.2	51.7
Charles/Salanandre	MTW_19:40-01Bulk	31.6	14.5	183	51.9
MT16M02204/Salanandre	MTW_19:64-01Bulk	31.4	13.9	183	55.2
MT16M08806/MARIS OTTER	MTW_19:65-01Bulk	30.5	13.6	179.4	54.7
MT16M02204/MARIS OTTER	MTW_19:61-01Bulk	29.1	13.4	179.8	54.8
Bearpaw/MarisOtter	MTW_19:35-01Bulk	25.7	15	181.4	53.9
Gigga/Vavilov_19917	MTW_19:48-01Bulk	25	12.5	175.6	53.7
MT124128/Vavilov_17642	MTW_19:59-01Bulk	24.4	14.9	178.3	54.6
	GRAND MEAN	37.07	13.37	180.43	53
	LSD	15.03	1.71	2.79	2.11
	CV	22.1	6.91	0.88	2.17

Table 9: Germination of winter lines, indicating water sensitivity that could cause malt quality issues where germination is less in 8ml when compared to 4ml test.

Name	Pedigree	1000 Kernel Weight (g)	4ml % germ	8ml % germ	Water Sensitivity
MTW_18:26-01Bulk	Vavilov_22607/Salamandre	51.7	99.0	98.7	0
MTW_18:68-01Bulk	Salamandre/Vavilov_13587	50.8	98.0	98.0	0
Charles	Charles	48.3	100.0	100.0	0
Thunder	Thunder	46.9	98.0	100.0	-2
MTW_18:20-01Bulk	Vavilov_19070/Dicktoo	43.6	49.7	30.3	19
MTW_18:17-01Bulk	Vavilov_17985/Vavilov_19070	41.7	36.0	21.7	14
MTW_18:08-01Bulk	Vavilov_13906/Cervoise	41.1	49.3	35.7	14
MTW_18:32-01Bulk	Azurel/Vavilov_13587	41.0	89.3	85.3	4
MTW_18:24-01Bulk	Vavilov_20251/Azurel	40.5	89.3	82.3	7
MTW_18:05-01Bulk	Vavilov_13470/Arturio	39.2	96.0	98.0	-2

Project Outcomes/Impacts:

The ultimate goal of this project is to release a winter variety for Montana. We have moved toward that goal by having locations around the state and in ND where we have some survival. It might be that some locations in Montana may never be able to support winter barley. We are moving forward to improve cold tolerance. We will continue to characterize winter survival so that we can at least give growers good data on possible winter barley success.

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.

The chart below compares yields for two different trials (one spring and one winter), in two locations (Bozeman and CARC). Note the average difference in yield is not significant in the winter trial between the two locations, while the averaged difference in yield between the two locations is more

than 50 bu/ac for the spring trial. This difference is due to differences in available moisture for the spring trial but not for the winter trial, indicating a significant improvement in yield potential across dryland locations.

	GRAIN YIELD (BU/AC)			
HABIT	WINTER		SPRING	
LOCATION	BZN	CARC	BZN	CARC
AVG 2020	76.8	80.3	118.6	49.2
CV	20.1	14.5	10.2	14.4

Certification

Authorized Representative: 

Sign Date: 3/23/2023

Title: Associate Professor