Spring Barley Report

Final Project Summary

Briefly describe the timeline of the project, its successes and failures.

Successes/Failures:

1) **Reduce the impact of limiting factors to barley production in Montana.**
   a. **Heat and drought:** By genetically dissecting root development, we have identified genes that have been incorporated into released varieties, MT Endurance and MT Boy Howdy, that have improved yield and quality stability under low water.
   b. **Pre-harvest Sprouting:** Through genetic dissection we have identified genes for dormancy and speed of hydration. By combining these genes we can have some dormancy and still have good malt quality.
   c. **Harvest Damage:** We have identified and are ready to release a hull-less line that is free-threshing without germination issues.
   d. **Biotic stress:** We have a possible future release with good malt quality and stripe rust resistance. We continue to work on scab resistance and bacterial leaf streak.

2) **Improve barley yield and quality to provide an economic advantage for Montana.**
   a. The new release MT Endurance has stable malt quality on dryland under drought conditions.
   b. MT Boy Howdy has been a consistent top yield performer in intrastate and regional nurseries.
   c. MT Bounty the proposed hull-less variety release beats Havener in dryland performance.

3) **Identify new genes for barley improvement.**
   a. Increased grain-fill with greater percent deep roots that are maintained during grain-fill.
   b. Speed of hydration that can be paired with dormancy to maintain malt quality.
   c. Genes increasing malt flavor for brewing industry.

4) **Improve breeding efficiency by**
   a. Testing quality earlier and from more environments and by making marker/trait associations that can be used for selection.
   b. Implementing collection of phenotyping data using a five wavelength and thermal camera carried on a drone. Data collected via drone includes stand count, winter survival, and finally plant water status and canopy temperature as indicators of root development.
   c. Testing for specific food quality traits.

   A challenge is the reduction of trials provided by Research Centers and increased costs. However, thanks to MWBC support we can meet this challenge.

Objectives and Follow-up:

Continue the barley breeding pipeline

The number and goals of the 2022 crosses are noted in Table 1. The end of the breeding pipeline has been very fruitful with 3 lines ready for release. MT Boy Howdy (Haxby/ND24388) was released as a feed line due to agronomic performance especially in dryland (see attached variety release for more information).MT Endurance

Table 1: Spring barley crosses since the inception of the program in 2015

Breeding Goals	2015	2016	2017	2018	2019	2020	2021	2022
High yield, high quality malt and f	90	87	29	39	9	23	36	121
Heirloom malt			75	90	94	76	25	
Food	19	21	23			16	35	14
Forage	12	12	11	14	5	56	50	33
FHB resistance	14	22	13	12	8	23	22	7
Lodging resistance	11	1						
Extended grain-fill	31	12	7					
Spot form of Net Blotch	3	12				14		
Nematode Resistance	4	10	1					
Stem Rust							11	
Stripe Rust				2	4	12	10	14
Bacterial leaf streak							12	
Beer Stalling	6						10	
Acid tolerance			20	11	4			
Spring Total	190	177	181	166	124	197	211	189

(Hockett/ND24388) was released due to stable malt quality performance under dryland conditions (see attached variety release). MT Bounty (MT110065/09WA215.12) is a high β-glucan, non-waxy hull-less spring barley with high yield in dryland that we are making available to end-users for further testing.

Test most advanced crosses

Table 2 and 3 present agronomic data for the Intrastate trials in 2022, while table 4 presents EYT agronomic data.

Table 2: Dryland intrastate 2022

Name	Yield bu/ac	Test Wt lbs/bu	Plump %	Protein %
MT18M11002	73.9	52.3	80.2	11.7
MT19_M034_16	70.4	51.3	80.8	11.5
MT18M11004	69.8	52.6	75	11.9
MT19_M064_04	69.1	51.3	84.4	10.8
Boy Howdy	68.8	52.2	89.1	10.4
MT18M09301	68.6	50.5	90.6	12.1
MT19_M065_05	67.4	50.9	78.9	10.8
MT18M10106	67	52.6	92	10.8
MT16M01801	67	51.3	87.8	10.7
MT17M04801	66.9	52.2	88.2	11.6
MT18M11006	66.8	51.7	79.3	12.3
MT19_M098_17	66.5	51.4	85.1	11.1
MT19_M038_16	66	51.1	71.7	11.4
MT18M11106	65.4	52.4	89.1	12
MT19_M095_04	65.1	52.9	87.8	11.3
MT19_M051_03	64.9	49.4	84.3	11.3
MT19_M046_16	63.7	50.6	70.1	11.8
MT17M01906	63.5	50.6	87.3	11
MT19_M045_08	63.4	51.1	82.4	12.2
MT18M11101	63.4	51.9	81.4	11.7
MT17M01711	63.2	49.8	81.2	11.1
MT18M11103	63.1	49.4	80.2	12
MT19_M075_23	62.8	48.9	80.3	11.3
MT16M02101	62.7	49.4	82.7	10.9
MT19_M061_19	62.3	51.2	91.4	11.3
MT17M05416	62.2	50.5	83.3	11.9
Hockett	62	52.1	83.5	11.7
MT19_M031_18	61.7	50.4	83.1	11.5
MT19_M080_13	61.5	50.7	84.9	11.2
MT19_M022_10	61	50	91.8	11.7
MT19_M067_02	60.4	51.6	92.2	11.2
Buzz	60.2	52.4	89.8	11
MT19_M060_06	59.9	52.4	81.7	11.3
MT19_M064_19	59.9	51.2	77	11.9
MT18M06009	59.4	50.3	90.4	11.2
MT18M10207	59.1	52	95.5	12.1
MT17M05808	58.8	51	85.6	11.8
MT16M09602	58.7	52.9	90.5	11.2
MT17M01908	58.6	52	94.9	11
MT19_M094_04	57.8	51.9	88.9	11.4
MT19_M041_01	57.5	50.8	79.3	11.4
Merit 57	56.7	49.5	74.4	12.1
MT18M06011	55.4	51.8	84.1	11.3
MT19_M045_11	55.2	50.6	85.3	12.2
MT19_M055_03	54.9	52.9	87.9	11.5
MT18M06008	54	51.3	88.2	11.2
MT19_M071_21	53.2	52.9	78.4	11.3
MT18M06012	50	51	92.7	11.1
GRAND MEAN	62.24	51.26	84.81	11.44
LSD	5.44	0.64	3.25	0.34
CV	12.17	1.74	4.13	4.16

Table 3: Irrigated intrastate 2022

Name	Yield bu/ac	Test Wt lbs/bu	Plump %	Protein %
MT18M11004	139.5	54.2	87.5	11.6
MT18M10106	135.3	54.4	94.5	10.3
MT18M11002	134	53.8	89.1	11.6
MT19_M022_10	131.3	52	95.1	10.9
MT19_M034_16	130.7	53.2	89.5	11
MT17M02507	129	53.9	94.1	10.3
MT19_M031_18	128.2	52.8	92.1	11
MT19_M064_04	126.4	51.6	92.3	10.4
MT19_M046_16	126.1	52.3	84	11.4
MT18M09301	125.6	51.5	94.8	11.8
MT19_M098_17	125.6	54.1	93.4	10.7
MT16M01801	125.5	52.9	94.5	10.6
MT18M11103	125.1	51.2	91	11.4
MT19_M095_04	124.6	54.8	92	10.9
Hockett	124.2	54.1	90.6	11.5
MT19_M045_08	123.9	53	89.9	11.4
MT19_M061_19	123.8	52.7	94.4	11
Buzz	122.4	53.3	95.2	10.6
MT19_M045_11	122.4	53	91.6	11.7
MT18M11106	122.2	53.7	94.7	11.4
MT18M11101	121.8	53.1	89.3	11.1
MT19_M041_01	121.2	53	89.9	10.8
MT17M05808	121.1	52.9	92.7	11.6
MT19_M065_05	121	51.4	84.6	10.4
MT19_M051_03	120.7	50.5	87	10.8
MT17M01906	120.1	53	94.2	11.1
MT19_M080_13	119.8	51.6	94.2	11.1
MT19_M067_02	119.5	52.6	95.5	10.9
MT16M02201	119	51.9	95.6	11
MT18M10207	117.9	53.3	97.3	12.1
MT18M11006	117.9	53.3	89.5	11.4
MT17M04801	117.4	54.2	91.3	11.1
MT17M01908	116.6	53.8	96.5	10.5
MT19_M038_16	116.3	52.4	88.8	11
MT19_M075_23	115.3	48.8	85	10.8
MT16M02101	114.4	51.1	87.9	10.9
Merit 57	113.9	51.8	84.4	11.9
MT17M01711	112.9	50.9	86.3	11.1
MT16M09602	112.4	53.8	94.2	10.9
MT19_M094_04	112.3	53.3	92.5	11
MT19_M064_19	109.3	51.9	81.6	11.8
MT17M05416	108.9	52.6	92.1	11.3
MT18M06009	106.5	52.4	94.2	11
MT19_M055_03	106.2	54.7	91.8	10.9
MT19_M060_06	106	52.7	84.8	11.2
MT18M06008	105.5	53.1	93.6	10.7
MT18M06011	103.6	53.4	93	11.1
MT18M06012	100.3	53	96.1	10.8
GRAND MEAN	119.6	52.79	91.27	11.06
LSD	10.32	0.93	3.95	0.3
CV	7.57	1.55	3.8	2.39

Table 4: 2022 Early Yield Trial Dryland Agronomic Data

name	pedigree	Yield	Test Wt	Plump	Protein	Height	Heading	Maturity
Buzz		89.6	52.7	93.7	10.9	69.3	190	216.5
Hockett		86	51.8	84.4	12.4	68.3	191.3	214.7
Merit 57	Manley/2B80-350//Merit	87.7	50.2	74.5	13.1	66.1	192.4	217.4
LCS Odyssey		103.4	51.9	93.6	12.7	62.6	193.4	219.3
MT20_M118_02	Buzz/MT16M08806	105.9	52.5	91.8	10.8	67.7	192.3	218.9
MT20_M117_10	Buzz/2MS14-3304-022	102.5	52.1	89.6	11.6	71.3	192	216.3
MT20_M124_07	MT16M01704/MT16M0220	99.9	50.7	94.2	11.7	67.6	191.4	217.1
MT20_M038_01	MT124073/Decanter	96.6	53.6	91.7	12.7	75.4	190.2	216.5
MT20_M038_20	MT124073/Decanter	96.1	52.8	90.5	12.8	68.4	192.3	216.1
MT20_M053_02	MT124128/CHARIOT	95.3	52.9	87.3	12.1	71.9	190	215.4
MT20_M033_14	MT100120/JULIETTE	95.2	51.6	90	11.7	68.9	190	218.6
MT20_M081_12	ODYSSEY/BIANCA	94.8	51.5	91.4	12.8	67.9	195	219.3
MT20_M120_05	MT124128/09N2-63	94.8	52	94.1	11.3	69.4	186	216.9
MT20_M079_10	ODYSSEY/ALONDRA	94.2	51	90.3	13	68.3	195	220.5
MT20_M050_03	Buzz/Orca	93.6	53.1	90.5	11.4	72.1	188.7	215.6
MT20_M035_13	MT124016/ROXANNE (WC	93.2	50.1	72.7	11.7	62.8	192.6	216.6
MT20_M081_16	ODYSSEY/BIANCA	93	51.6	90.4	12.5	62.8	193.3	218.6
MT20_M073_12	ND24260/CHARIOT	92.2	52.4	83.2	11.9	60.5	191.3	219.2
MT20_M106_24	MT090190/ND19119	90.8	51.8	94.6	11.5	67.6	189.8	218
MT20_M052_13	MT124128/CARIBOU	90.5	52.3	91.8	11.8	58.2	186.4	215.6
MT20_M106_17	MT090190/ND19119	90.4	53.3	91.9	12	72.1	190.2	216.7
MT20_M074_02	ND24388/AKCENT	90.3	50.5	88.9	11.4	58.7	193	215.8
MT20_M006_07	Buzz/LECHTALER	90.1	50.2	88.6	11.7	66.1	191.6	217.3
MT20_M047_06	Buzz/HALLA	89.4	52.1	90.4	11.3	67.8	190.3	216.2
MT20_M073_08	ND24260/CHARIOT	89.1	52.9	95.3	11.2	64	188.7	218.7
MT20_M035_17	MT124016/ROXANNE (WC	88.7	51.2	67.6	12.2	63.8	191.7	215.5
MT20_M033_01	MT100120/JULIETTE	88.6	51.2	89.2	12.8	71.7	190.7	215.5
MT20_M044_06	Buzz/CHARIOT	88.1	53.6	93	11.2	67.9	188	214.9
MT20_M032_06	MT100120/ALONDRA	87.9	54	94.5	11.6	74.1	190	217.9
MT20_M064_02	MT124134/OLIVIA	87.9	52.8	89.8	12.4	72.8	189.4	217.3
MT20_M063_03	MT124134/ELLICE	87.4	54.3	98.1	11.6	65.8	186.1	216.7
MT20_M062_02	MT124134/CLARK	87	52.4	86.5	11.6	68.8	190.7	215
MT20_M047_16	Buzz/HALLA	86.6	52.8	94	10.8	67.3	188.4	217.9
MT20_M064_13	MT124134/OLIVIA	85.9	52.6	87.9	11.5	66.8	186.3	215.4
FHB-2017-59-2	PINNACLEXMT050187	85.3	52.8	88.1	12.8	68.4	186.7	214.7
MT20_M008_04	ND24388/MAJA-6	85.1	53	95.2	11.7	69.4	190.6	216.9
MT20_M042_04	Buzz/ADORrA	84.7	53.3	83.6	12.3	69.6	189.3	216
MT20_M062_04	MT124134/CLARK	84.2	54.1	93.1	11.5	66	186.7	217.9
MT20_M073_10	ND24260/CHARIOT	84.2	53.6	95.4	11.4	70.1	189	216.9
MT20_M120_02	MT124128/09N2-63	83.8	52.8	93.2	11.1	67.4	186	216.8
MT20_M071_06	ND24260/ALFOR	83.5	54.1	90.8	11	69.4	186.3	216.6
MT20_M063_12	MT124134/ELLICE	83	54.2	95.3	11.8	75.3	190.6	216.6
MT20_M048_10	Buzz/Isaria (WC644)	82.8	53.6	89.4	12	64.2	191.4	217.1
MT20_M068_11	MT124645/TRIUMPH	82.8	51.2	85	13.2	66	192.4	217
FHB-2017-42-3	MT080182XKTYQST55-5	81.3	53.5	86.3	13.5	73.3	192	216.1
MT20_M050_01	Buzz/Orca	80.9	52.4	94.8	11	64.8	186.7	215.5
MT20_M063_01	MT124134/ELLICE	80	52.3	90.2	11.6	61.5	186.6	216.9
MT20_M036_05	MT124073/Alfor	79.9	51.8	86.3	13.3	74.3	191.7	216.4
MT20_M054_02	MT124128/Decanter	79.5	51.4	85.3	11.6	59.7	188.4	216.3
MT20_M103_17	MT124134/MT08024	79.1	51.5	83	12.4	73.1	190.1	214.9
MT20_M102_03	MT100120/Growler	79	49.4	89.1	12.4	67.1	193	216.7
MT20_M075_06	ND24388/FRONTIER	78.3	51.5	94.5	11.3	66.9	186.4	213.8
MT20_M101_07	MT100120/2B11-4149	78.1	51.6	77.4	13.2	58.4	194	218.7
MT20_M118_15	Buzz/MT16M08806	78	50.2	80.6	11.4	59.6	191.2	215.7
MT20_M054_05	MT124128/Decanter	77.5	53.1	94.7	11.9	68	186.4	216.9
MT20_M049_09	Buzz/LARABET	76.9	52.7	89	11.8	66.2	192.3	219
MT20_M057_04	MT124128/STAMM	75.5	53.7	92.6	12.7	72.2	189.4	215
MT20_M048_02	Buzz/Isaria (WC644)	75.4	52.8	81.2	12.3	68.8	191.1	216.8
MT20_M006_08	Buzz/LECHTALER	73.6	51.9	92.9	12.6	65.3	190.5	216.8
MT20_M101_03	MT100120/2B11-4149	71.5	51	80.5	11.9	60.8	192	217.5
MT20_M042_01	Buzz/ADORrA	71.4	51.9	84.9	10.9	65.2	191.6	215.5
GRAND MEAN		87.22	52.28	89.23	11.93	67.74	190.25	216.88
LSD		10.4	1.27	6.36	0.29	6	2.02	1.74
CV		6.39	1.28	3.73	1.31	4.45	0.52	0.42

Table 5 reports the malt quality for the 2022 Intrastate trial from dryland and irrigated. Of note is the high extract of MT Endurance in dryland. A number of lines have good malt quality. Table 6 reports

Table 5: 2022 Intrastate Malt Quality in Dry and Irrigated Environments

Name	Dryland						Irrigated					
	Extract	S/T Protein	DP	α Amylase	β Glucan	FAN	Extract	S/T Protein	DP	α Amylase	β Glucan	FAN
	%	%	ASBC	DU	ppm	ppm	%	%	ASBC	DU	ppm	ppm
Endurance	83.4	41.2	130.8	70.6	115.8	183.1	83	36.3	147	75.3	168	177.1
MT19_M067_02	81.6	46.4	130.6	118.6	63.6	214.4	82.4	40.3	126.6	105.2	164.6	195
MT18M06008	81.3	42.1	151.2	87.4	58.9	194.3	82	41.3	149.2	93	109.5	177.5
MT19_M080_13	81.1	37.5	125.5	86.5	117.5	174.8	80.3	34.8	127.4	85.4	213.3	157.9
MT18M06011	81	40.3	153.6	93.3	140.1	160.9	82.5	40.4	166.9	97.6	154.3	183.2
MT17M01908	80.9	38.8	134.3	51.9	150.7	140.5	80.4	35	146.1	62.3	135.1	142.7
MT19_M046_16	80.8	34	129	81.2	211.2	144.1	79.7	34.1	140.6	83	113.9	160.3
Buzz	80.7	41.4	125.3	105.9	80.7	143.1	79.6	37.1	105.2	85.3	394.3	159.9
MT16M02101	80.6	37.9	129	61	195	147.8	80.6	34.7	133.8	74.2	263.9	158.4
MT19_M064_04	80.4	40.7	118.3	98.5	70.3	186.2	81.6	41	114.8	97.2	69.8	172.3
MT18M06009	80.1	37.1	153.9	56.9	56.3	154.6	79.8	35.6	152.4	61.7	149.1	136.5
MT16M01801	79.8	34	119	60.2	572.3	146.4	80.1	35.4	131	66.7	321.9	154.1
MT19_M061_19	79.7	39	142.8	120.1	62.1	207	81.7	41.5	144.2	125.3	43.8	207.8
MT19_M095_04	79.7	38.4	124.5	95.9	70.4	195.4	80.6	40.5	120.4	103.8	131.4	176.3
MT19_M094_04	79.7	36.1	120.2	88.2	467	183.3	79.7	33.4	112	82.3	409.5	160.4
MT19_M045_11	79.5	35	175.7	100.9	97.9	207.1	81.2	35.3	171	109.8	29.7	208.7
MT18M06012	79.4	43.1	135.1	93.5	60.6	211	79.1	37.5	154.5	89.1	138.1	179.4
MT19_M060_06	79.2	35.8	124.9	104.2	87.1	175.1	77.9	29.3	125.7	94.9	319.4	147.8
MT19_M041_01	79.2	37.2	131.8	96.6	184.6	180.7	80.2	39	121.5	93.2	236	178.8
MT17M05416	79	36.7	150.5	87	56.3	188.3	79.1	36.3	152.7	91.9	173.6	169.9
MT17M05808	78.9	34.5	147.3	80.9	128.2	156.5	80	32.5	149.6	97.8	151.9	167.6
MT19_M071_21	78.9	35.1	99.6	111	312.3	162.5	79.2	36.8	95.1	90.3	450.7	167.5
MT17M01906	78.9	29.4	125.1	37.5	476.2	112.2	77.9	28.9	124.4	48.1	344.4	113.3
MT18M11103	78.7	36.1	142.8	73.7	196.7	192.9	79.8	36	141.8	77.5	293.1	182.8
MT17M01711	78.7	32.3	121.5	51.3	360.3	157.9	78.1	32	103.5	41.6	659.2	140.6
MT18M09301	78.6	29.7	119.3	46.1	81	136.9	78.7	29.6	106.2	47.6	131.3	149.7
MT19_M055_03	78.5	34.1	125.4	78.7	204.2	155.3	78.8	35.6	114.9	61.4	537.1	151.2
MT19_M051_03	78.4	31.1	133.8	63.1	58.4	158.9	79.4	31.4	116.2	47.7	168.5	137.6
MT19_M064_19	78.4	33.5	101.2	84.2	59.7	196.3	78.4	31.7	95.5	81.1	94	170.1
MT18M11006	78.3	33.1	107.3	72.4	158.7	159.9	79.7	35.4	117	76.1	124.3	152.3
MT19_M075_23	78	32.8	130.1	74.3	158.6	152.6	80.3	36.9	148.4	85.5	67.8	169
Merit 57	77.9	31.9	172	96.5	175.7	156.7	79.4	33.3	136.7	98.8	289.1	178.4
MT17M02507	77.9	30.3	64.6	44.8	650.8	125.2	78.9	32.5	64.1	51.5	447.2	115.7
MT19_M065_05	77.8	35.5	112.2	83.5	228.3	131.4	78.4	32.6	111.1	87.4	307.2	130.3
MT19_M045_08	77.7	30.5	142.7	87.5	113.9	181.8	79.3	34.8	144.8	95.4	133.2	172.8
Hockett	77.6	31.2	133.1	62.1	540.8	124.7	76.7	25.7	115.3	58.4	907.7	134.7
MT18M11106	77.3	32.9	156	57.2	168.7	149.8	78.5	33.7	145.2	57.5	162.9	162
MT18M11101	77.1	29.2	106.6	57.9	543.7	153	78.7	32.3	114	62.6	609.1	157
MT16M09602	77	29.4	99.1	62.4	669.8	140	80.1	39.6	114.8	72.9	402.8	153
MT19_M031_18	76.8	29.7	129.2	49.5	247.7	137.6	77.1	29.4	111.7	38.2	397.8	123.8
MT18M10106	76.6	31	160	55.4	278.2	125.4	77.3	30.4	149.9	42.7	419.5	115.8
MT17M04801	76.3	28.6	109.8	38.5	448.6	128.4	76	26.5	101.6	40.6	743.5	103.7
MT19_M098_17	76.1	30.3	101.8	50	430.2	122.6	77.7	27.7	106.3	36.5	499	110.4
MT19_M022_10	75.9	32.7	95.6	50.9	225.6	142.4	75.7	29.2	84.5	37.5	749.2	144.2
MT19_M038_16	75.3	28.3	112.2	36.3	349	130.4	75.3	26.8	101.1	27.1	548.2	117.2
MT18M11002	75.2	27.3	104.2	32.2	435.4	106.2	74.5	24.6	100.2	30.8	576	101.4
MT19_M034_16	74.6	24.3	119.1	31.2	452.7	106.2	74.9	25.3	99.9	26.5	577.2	108
MT18M10207	74.3	25.9	125	43.9	549.4	136	76.7	26.9	112.9	40.5	546.8	121.2
MT18M11004	73.7	22.8	94.9	38.9	621.6	105.4	75.8	25.6	86.6	34.9	812.9	125
GRAND MEAN	78.5	34	126.5	71.64	249.85	156.8	79.04	33.52	123.6	70.85	324.3	152.7
LSD	0	0	0	0	0	0	0	0	0	0	0	0
CV	2.57	14.58	16.55	33.33	74.72	18.43	2.5	13.78	18.38	35.3	68.17	17.43

name	pedigree	Extract	S Protein	S/T	DP	a Amylase	B Glucan	FAN
Buzz		78.6	4	35.8	120.7	89	335	163.1
Hockett		75.2	3.4	27.6	130.7	59.2	820.9	137.9
Merit 57	Manley/2B80-350//Merit	77.6	4.3	33	164.9	105.5	217.9	180.7
LCS Odyssey		76.5	3	23.9	103.3	39.2	329.7	132.7
MT20_M073_08	ND24260/CHARIOT	80.9	4.5	39.9	112	114	108.3	189.8
MT20_M044_06	Buzz/CHARIOT	80.2	4	35.9	127.4	112.3	64.3	161
MT20_M047_16	Buzz/HALLA	80.2	4.2	38.5	135.1	114	143.8	163.8
MT20_M054_05	MT124128/Decanter	80.1	4.7	39.6	120.4	124.2	141.2	213.4
MT20_M120_05	MT124128/09N2-63	79.7	4.7	40.9	113.3	50.9	110	159.7
MT20_M073_10	ND24260/CHARIOT	79.7	3.9	33.8	113.8	88.3	439.4	178.2
MT20_M063_01	MT124134/ELLICE	79.7	4	34.5	143.4	103	96.6	171.6
MT20_M050_01	Buzz/Orca	79.6	4.3	40.1	158.5	105.9	96.5	158.9
MT20_M118_15	Buzz/MT16M08806	79.4	4.2	36.9	122.9	90.2	157.8	162.4
MT20_M006_08	Buzz/LECHTALER	79.4	4.4	35.4	151.8	107.6	137.8	198.8
MT20_M062_04	MT124134/CLARK	79.3	4.2	36.6	135.9	101.6	269.4	178.2
MT20_M073_12	ND24260/CHARIOT	79.2	4.2	35	133.2	104.7	151	191.5
MT20_M052_13	MT124128/CARIBOU	79.2	4.3	36.5	122.3	59.9	147.7	187.4
MT20_M064_02	MT124134/OLIVIA	79.2	3.9	31.1	138.8	100.6	424.4	167.9
MT20_M050_03	Buzz/Orca	79.1	3.8	33.7	141.6	92.1	91.4	155.6
MT20_M063_03	MT124134/ELLICE	79.1	4	34	132.4	96.8	235	160.8
MT20_M053_02	MT124128/CHARIOT	79	4.1	34.1	135.2	103.7	156.7	184.3
MT20_M062_02	MT124134/CLARK	79	4.1	35.4	145.3	89.7	368.6	166.6
MT20_M118_02	Buzz/MT16M08806	78.8	4.1	38.1	113.1	87.8	183.3	138.1
MT20_M064_13	MT124134/OLIVIA	78.8	3.8	32.7	122.3	82.5	337.7	165.6
MT20_M047_06	Buzz/HALLA	78.7	4.1	36.6	139.2	111.9	126.1	167.5
MT20_M120_02	MT124128/09N2-63	78.5	4	36.7	95	49.6	131.2	129.3
MT20_M057_04	MT124128/STAMM	78.5	4.2	33.1	118.4	101.9	195.1	182.6
MT20_M042_01	Buzz/ADORrA	78.5	4	36.7	124.8	112.1	61	167.2
MT20_M124_07	MT16M01704/MT16M0226	78.4	3.8	32.4	134.5	51.7	266.6	131.4
MT20_M048_10	Buzz/Isaria (WC644)	78.4	3.9	32.7	143.9	117.3	155.3	169.4
MT20_M075_06	ND24388/FRONTIER	78.4	4.1	36.1	133.8	49.6	754.6	136.8
MT20_M063_12	MT124134/ELLICE	78.2	4.2	34.7	143.9	103.2	231.8	181.8
MT20_M049_09	Buzz/LARABET	78.2	4.3	35.9	128.5	118.7	189.9	183
MT20_M033_14	MT100120/JULIETTE	77.9	3.8	32.3	139.6	57	106.5	137
MT20_M032_06	MT100120/ALONDRA	77.9	3.6	31.3	132.5	53.5	113.2	142.1
MT20_M106_24	MT090190/ND19119	77.8	4.3	36.9	128.5	71.8	105.8	160.1
MT20_M103_17	MT124134/MT08024	77.8	4.6	36.9	156.2	98.5	146.2	166.7
MT20_M081_16	ODYSSEY/BIANCA	77.5	4	31.5	131.2	52.2	118.1	145.1
MT20_M042_04	Buzz/ADORrA	77.5	3.8	30.9	118.8	103.6	190.6	159.3
MT20_M071_06	ND24260/ALFOR	77.5	3.4	31	96.2	83.8	398.7	158.5
MT20_M102_03	MT100120/Growler	77.4	4.9	39.2	189.6	121.1	61.1	192.9
MT20_M048_02	Buzz/Isaria (WC644)	77.4	3.7	30.5	163.4	115.1	151.4	166.5
MT20_M081_12	ODYSSEY/BIANCA	77.3	3.5	27.8	98.9	40.5	202.5	132.5
MT20_M117_10	Buzz/2MS14-3304-022	77.2	4.2	36.4	116.5	91.5	196.9	153.3
MT20_M038_20	MT124073/Decanter	77.1	3.7	29	133.7	67.2	189.3	141.4
MT20_M106_17	MT090190/ND19119	77.1	4.2	35.4	107.6	53.1	188.3	139.6
MT20_M006_07	Buzz/LECHTALER	77.1	3.6	30.8	138.6	89.3	294.5	160.5
MT20_M101_03	MT100120/2B11-4149	77	4	33.9	169.2	61.2	100.4	132.8
MT20_M008_04	ND24388/MAJA-6	76.8	3.9	33.9	152.3	48.4	441.6	140.7
MT20_M054_02	MT124128/Decanter	76.8	3.4	29.1	122.6	70.1	245.9	131.3
MT20_M038_01	MT124073/Decanter	76.4	3.6	28.4	135.2	63	169.1	130.7
MT20_M079_10	ODYSSEY/ALONDRA	76.3	3.4	26.2	119.5	50.5	183	140.4
MT20_M035_13	MT124016/ROXANNE (WC	76.2	3.3	28.4	106.8	41.8	157.7	126.6
MT20_M036_05	MT124073/Alfor	76.2	4.3	32.2	154.2	76.5	140.4	171.8
MT20_M101_07	MT100120/2B11-4149	76.1	3.9	30.1	153.4	46	161.7	127
FHB-2017-42-3	MT080182XKTYQST55-5	75.7	4.3	32.2	144.7	54.9	324.9	189.1
MT20_M068_11	MT124645/TRIUMPH	75.4	3	22.9	110.5	41.3	232.7	135.5
MT20_M074_02	ND24388/AKCENT	75	2.8	24.7	123.8	51.7	691.9	111.6
MT20_M033_01	MT100120/JULIETTE	74.9	3.6	27.8	136.6	35	397	132.6
MT20_M035_17	MT124016/ROXANNE (WC	73.5	2.7	21.3	91.9	37.2	406.7	113.9
FHB-2017-59-2	PINNACLEXMT050187	73.1	2.9	22	107.4	37.1	1024.4	127.2
GRAND MEAN		77.82	3.91	32.91	130.47	78	241.96	156.04
LSD		0	0	0	0	0	0	0
CV		2.11	11.59	13.72	14.46	35.24	76.11	14.51

EYT Malt Quality data. Several lines beat Buzz in extract and β glucan.

Table 7: Disease severity of stripe rust and scald of select lines at OSU and UC Davis

| Line | OSU Corvalis | | | UC Davis | | | |
	Stripe rust	Scald	Heading date	Stripe rust 3	Stripe rust 2	Stripe rust 1	Heading date
Baronesse*	0	82.5	118.5	80	80	80	95
Buzz	0	85	100	5	5	5	94
MT16F02902	0	87.5	115.5	60	40	20	95
UC Capay	0	65	97	0	0	0	86
Alba*	0	10	136	0	0	0	115
MT17M00302	0	77.5	120.5	5	0	0	97
MT21_M094_02	0	75	100	0	0	0	101
MT21_M094_04	0	72.5	104.5	0	0	0	93
MT21_M094_05	0	75	99	0	0	0	92
MT21_M094_06	0	65	109.5	0	0	0	92
MT21_M094_08	0	75	108.5	0	0	0	95
MT16M00707	2.5	80	109.5	20	20	20	94
MT17M05508	2.5	77.5	117	60	60	60	94
Robust*	5	80	113	80	80	80	86
Thoroughbred*	35	32.5	126	100	100	100	107

Disease resistance: In 2022, the stripe rust screening nursery performed at OSU and UCDavis indicated that a number of lines resulting from a cross between Buzz and UC1410 are stripe rust resistant (94_-2- 94_08)(Table 7). At least one of these lines has malt quality equal to Buzz 94_06 (Table 8).

Table 8: Malt Quality of stripe rust resistant Buzz (MT21_Y094_06)

Name	Grain Protein	Extract (FG db)%	S. Protein	FAN	B-Glucan	AA	DP	S/T
MT21_Y094_06	11.79	81.11	4.80	235.6	74	92.0	162.7	40.7%
Buzz	11.65	81.62	4.90	228.0	22	123.7	141.8	42.0%
Hockett	12.51	79.43	3.95	176.9	146	80.7	164.3	31.6%
QC Merit 57	13.36	80.13	5.73	328.1	27	145.6	187.3	42.9%

Continue marker assisted selection for barley

We are continuing to screen barley for known genes involved in malt quality stability, including HvNam-1, HvNam-2, HvRBP. We are developing new markers and have begun screening for glycosidic nitrile production, deep roots, maltol, and hydration at steep out. All these markers resulted from student research projects to identify new gene to improve barley.

Identify new genes for improving barley

Currently, we are developing new populations to confirm and more fully characterize the new genes for malt quality and root development. One important goal is to understand the effect of these genes in various environments. For example, will a greater percent deep roots be negative in any environment or will it be beneficial or at least neutral in most environments.

New student projects to identify new genes to improve barley include: 1) genes that attract beneficial microbes that improve agronomics under different field conditions and improve stability of yield and or quality and 2) genes associated with forage and feed performance that can be tracked through high-throughput phenotyping techniques.

Contract with MSU Malt Quality

The MSU malt quality lab has had a productive year. It served 48 third party clients generating a 67% increase in revenue over 2021. The revenue has been used to pay staff, support a graduate student and to add equipment to increase our capabilities, including a new malt unit (increasing our malting capacity by 25%). With the help of several stakeholders we now have permission to brew at MSU, providing a new avenue for research. For the breeding program the malt lab provided data on the following sample: 1294 micro malt, 672 pico malts, 5 malts that were then brewed. Also provided were nitrates on 194 forage samples and estimated % grain protein on 3260 early generation samples. We have also instituted new tests for food barley.

An innovation, in 2022, is we reduced the number of steeps from 3 to 2. To conserve water, the malt industry would like to reduce the number of water changes and therefore the number of air rest during the steeping process. Certain genotypes are resistant to modification under these conditions. Table 9 compares malt quality performance of Montana lines included in the AMBA trial malted with 2 steep vs 3 steep recipes. Note that the quality differences are emphasized by the 2 steep recipe.

| Table 9: Comparison of MT AMBA trial Malted 2 steep vs 3 steep |

Name	Malt	Grain Protein	Extract (FG db)%	S. Protein	FAN	B-Glucan	AA	DP	S/T
Endurance	2 Steep	12.41	82.72	4.33	188.2	141	89.7	174.7	34.9%
MT18M06011	2 Steep	12.05	81.27	4.23	183.4	142	100.2	164.1	35.1%
MT16M02101	2 Steep	11.78	80.74	3.97	170.7	161	90.3	149.3	33.7%
Buzz	2 Steep	11.65	80.59	4.29	175.9	70	116.8	132.1	36.8%
MT17M01908	2 Steep	12.29	80.05	4.01	155.2	147	73.4	166.4	32.7%
Hockett	2 Steep	12.37	79.65	3.61	153.2	353	89.2	160.3	29.2%
MT17M05808	2 Steep	12.85	78.46	4.29	189.7	76	118.3	185.8	33.4%

Name	Malt	Grain Protein	Extract (FG db)%	S. Protein	FAN	B-Glucan	AA	DP	S/T
Endurance	3 Steep	12.41	83.68	4.89	227.0	50	87.0	175.5	39.4%
MT18M06011	3 Steep	12.05	82.34	5.38	267.0	25	103.0	181.6	44.6%
MT16M02101	3 Steep	11.78	82.32	5.00	229.9	51	95.8	155.7	42.4%
MT17M01908	3 Steep	12.29	81.18	4.76	195.6	59	70.2	168.7	38.7%
Buzz	3 Steep	11.65	81.17	4.93	220.1	31	125.9	137.3	42.4%
Hockett	3 Steep	12.37	80.94	4.30	187.8	157	76.8	168.3	34.8%
MT17M05808	3 Steep	12.85	79.93	5.20	232.4	26	114.2	181.4	40.4%

Forage Barley:

Forage Barley Trials are now being supported by a USDA grant. Since MWBC long supported this effort, we include 2022 results in this report. Table 10 reports agronomic and quality data for the 2022 intrastate trial in five locations. Several lines have forage yields higher than Lavina (tons/acre > 3) and quality better than Lavina (ADF < 33). Some lines are equal to or better than Lavina for grain yield (green highlight), but high grain yield often associates with lower forage yield.

Table 10: 2022 Intrastate Barley Forage Agronomic and Quality Across 5 Locations										
Pedigree	name	Tons/ Acre	ADF	NDF	Yield bu/ac	Test Wt lbs/bu	Protein %	Height cm	Heading Julian	Maturity Julian
MT110009/OR15_5	MT18F00812	3.42	32.32	59.51	62.2	46	14.4	77.8	184.3	207.8
LAVINA/ND24260_3	MT19_F04_02	3.2	31.41	57.56	72.3	48.6	12.5	77.1	180.5	207
LAVINA//Hays/WCC100	MT18F00507	3.18	31.82	58.66	74.7	48.8	13.2	73.8	183.1	207.2
MT103038.4/ND24388	MT18F00714	3.16	31.82	58.71	63.2	48.4	13.7	77.5	182.6	207.3
Hays/WCC100//LAVINA	MT18F00803	3.07	31.54	58.29	80.1	47.5	13.1	73.7	180.7	206.3
HAYBET/ND19119	MT19_F01_01	3.02	32.98	59.35	72	50	12.9	77.6	177.2	208
LAVINA//Hays/WCC100	MT18F00503	3	33.51	60.95	76.3	50.2	13	74.4	182.7	206.5
LAVINA/PI264251	MT18F00607	2.99	32.08	59.48	78	48.9	13	79.7	184.3	207
	Lavina	2.98	33.71	61.2	81.1	49.9	12.6	74.2	180.5	206.7
COWBOY/LAVINA	MT16F02903	2.92	34.72	62.31	75.1	50.7	12.6	84.3	178.5	208.3
MT110061/OR15_5	MT18F00908	2.92	33.35	59.81	61.9	49.4	14.7	79.5	181.3	205.7
COWBOY/LAVINA	MT Cowgirl	2.88	35.38	63.88	73.8	49.8	12.9	80.8	179.8	206.7
	GRAND MEAN	2.87	33.03	60	73.42	49.21	12.88	76.23	179.43	206.88
HAYBET/ND19119	MT19_F01_03	2.84	33.79	59.59	66.7	50.1	12.8	81.8	177.1	207
LAVINA/ND24260	MT17F01612	2.83	32.04	58.01	73.6	50.7	13.1	75	175.7	206.5
	Haymaker	2.79	33.68	60.2	71.8	51.1	13.9	76.5	181.8	205.7
LAVINA/ND24388	MT16F02405	2.76	32.66	58.34	75.5	48.8	11.1	74.4	177.3	207.2
LAVINA/ND24388	MT19_F05_03	2.76	31.97	58.56	67.6	48.8	12.3	73.5	174	206.2
MT103038.4/ND24388	MT19_F07_04	2.75	33.1	59.6	72.5	48	12.5	70.8	175.1	207.2
LAVINA/ND24388	MT17F02410	2.74	32.78	60.16	83.9	50	13	71.5	180.5	207.3
LAVINA/ND24388	MT16F02401	2.68	34.96	63.29	81.2	47.1	11.1	73.9	179.1	208
LAVINA/ND24260	MT19_F03_01	2.67	32.86	60	70.7	48.9	12.5	79.7	177.2	205.5
LAVINA/ND24388	MT16F02406	2.61	34.29	61.47	76.4	50.7	11.9	77.4	180.1	206.3
MT103038.4/LAVINA	MT19_F06_02	2.6	33.5	61.56	72.6	47.8	13.8	68.1	178	207.7
Lavina/ND24260	MT16F01601	2.56	33.09	60.97	79.9	50.2	12.8	76	178.2	207.2
LAVINA/ND24260_3	MT19_F04_01	2.53	32.37	58.58	72.4	49.9	12.5	76.7	176.1	205.8
	CV	16.5	5.1	4.71	9.2	1.18	3.89	5.66	0.6	0.53
	LSD	0.34	1.21	2.03	4.86	0.42	0.4	3.1	0.77	1.26

A single location of an early yield trial is reported in Table 11, indicating continued improvement in forage yield associated with high grain yield, for example MT20_F109_08, unfortunately that line also had higher ADF. MT20_F110_17 had high forage and grain yield and low ADF. Low ADF improves feeding efficiency. A 1% decrease in ADF can increase daily weight gain of steers by 3 %. Therefore, MT20_F110_17 six percent lower forage yield may be compensated for by its nine percent increase in feeding efficiency.

Table 11: 2022 Early Barley Forage Agronomic and Quality

Pedigree	Name	Tons/Acre	ADF	NDF	Yield bu/ac	Test Wt lbs/bu	Height cm	Heading Julian	Maturity Julian
COWBOY/LAVINA	MT Cowgirl	4.97	33.74	60.54	113.6	52.1	86.5	186	214
Lavina/PI274631	MT20_F110_19	4.83	31.79	55.94	110.1	51.7	89.3	184.3	214.7
Lavina/PI467813	MT20_F109_08	4.78	35.31	63.44	121.5	52	82.1	184.7	216
Lavina/PI467819	MT20_F109_18	4.72	34.49	60.96	118.1	50.8	80.6	185	214.3
Lavina/PI274630	MT20_F110_17	4.46	31.66	57.89	117	52.6	85.5	185	214.3
Lavina/PI274620	MT20_F110_04	4.45	33.8	60.6	111.1	52.4	82.8	185.3	215.3
Lavina/PI467809	MT20_F109_04	4.43	36.31	65.2	111.5	50.9	85	184.7	215
Lavina/PI274629	MT20_F110_12	4.3	31.82	57.28	110.3	52	79.4	184.3	215
Lavina/Atlas	MT20_F097_01	4.28	33.86	60.62	110.4	52.5	85.7	185	215.7
Lavina/PI5799625	MT20_F111_15	4.19	33.31	59.59	116.2	51.6	84.8	185.3	215.7
Lavina/Totem	MT20_F098_01	4.16	33.79	60.07	118.4	51.2	79.3	184.7	214.3
Lavina/PI274627	MT20_F110_10	4.16	35.45	62.73	115.6	52.8	85.6	184.7	215.3
Lavina/Totem	MT20_F098_24	4.14	34.15	60.24	121.2	53.8	82.7	184.7	214.3
Lavina/clho7079	MT20_F108_12	4.11	34.39	61.56	93.9	50.4	87.6	184.3	214.3
	Haymaker	4.08	35.06	62.09	103.9	52.2	85.4	185.7	215.3
Lavina/PI5799627	MT20_F111_21	4.05	32.34	57.54	107	52.7	85	185.7	215
Lavina/PI5799622	MT20_F111_10	3.97	34.38	62.34	104.7	50.9	85.3	184.7	215.3
	Hays	3.95	35.16	63.37	124.1	53.2	76.6	184	215
Lavina/PI274623	MT20_F110_07	3.88	34.43	60.92	123.5	52.4	82.3	185.7	215.7
Lavina/Atlas	MT20_F097_20	3.86	34.02	60.9	106.3	51.8	91.9	184.3	215
Lavina/PI548113	MT20_F099_10	3.84	34.93	62.83	110.3	51.4	76.8	183.7	215.4
Lavina/PI467821	MT20_F109_22	3.83	35.09	61.61	125.8	50	77.8	183	215.7
Lavina/PI5799630	MT20_F111_25	3.73	33.47	58.53	111.8	49.2	90.9	184.7	215.7
Lavina/PI548109	MT20_F099_04	3.71	32.1	56.69	100.4	53.2	83.5	183.3	215
Lavina/clho7080	MT20_F108_13	3.69	34.32	62.77	122.8	53	76.5	184	215.3
Lavina/PI548108	MT20_F099_02	3.66	32.45	58.6	111.5	53.2	81.2	185.7	215.3
	Lavina	3.63	33.62	60.52	115.5	50.5	79.8	184.7	215
Lavina/Totem	MT20_F098_08	3.62	33.54	58.61	74.1	51.6	78.3	185	215.7
Lavina/Totem	MT20_F098_05	3.6	34.17	60.29	76.1	52.3	86.5	184.7	214
Lavina/PI548115	MT20_F099_14	3.56	33.86	61.01	104.9	52.8	84.6	184	215.3
Lavina/PI548110	MT20_F099_05	3.55	33.5	60.23	111.9	53.5	83	185.7	215
Lavina/PI467814	MT20_F109_10	3.46	33.56	61.05	116.6	51.8	85.7	184	214.3
Lavina/Totem	MT20_F098_28	3.41	35.51	63.39	109.1	52	79.1	184	215
Lavina/Atlas	MT20_F097_07	3.26	34.32	62.7	110.8	49.9	66.5	186	216
Lavina/Totem	MT20_F098_03	3.09	32.95	59.51	102.4	49.8	73.9	185.3	214.4
Lavina/clho7086	MT20_F108_24	3.07	32.69	58.32	94.8	51.7	80.4	184	214.7
	GRAND MEAN	3.96	33.87	60.57	109.93	51.83	82.44	184.71	215.04
	LSD	0.79	2.91	4.99	26.03	1.32	4.59	2.36	1.5
	CV	12.13	5.28	5.06	14.47	1.55	3.4	0.78	0.43

Project Outcomes/Impacts:

The primary goal of the Montana State Barley Breeding, Quality and Genetics is to Build Better Barley for the economic benefit of Montana stakeholders. We do this by developing varieties that have higher yield, quality stability, resilience to abiotic and/or biotic stress,

quality advantages, as well as require fewer inputs, and are suitable for new markets. New barley varieties must reduce production risk factors, thereby enhancing barley competitiveness.

Certification

Authorized Representative: *Jamie D. Sherman*

Sign Date: 3/23/23

Title: Associate Professor