REPORT TYPE: PROGRESS REPORT

TITLE: From Ground to Glass: Evaluation of unique barley varieties for western Washington craft malting, brewing and distilling

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ABSTRACT:
This research project was initiated to provide regional agronomic and end-use data for specialty barley producers and end-users in western Washington, and to evaluate for the impact of barley variety on distillate flavor compounds. The long-term aim of the project is to cultivate high value markets for grain based on distinctive end-use qualities such as flavor and mouth feel. This study utilized a breeder-extension-farmer-craft brewer/distiller-food science collaboration to evaluate barley varieties for organic production and value-added processing. We hypothesized that unique flavors exist among the germplasm in the WSU barley breeding program that would be of interest to craft maltsters, brewers and distillers. Nine barley breeding lines and/or varieties were evaluated for valuable agronomic and end-use characteristics important to maltsters, brewers, distillers and farmers. In 2017 and 2018 three replicates of breeding lines (nine in 2017, four advanced to 2018) were grown on field-scale plots in south Puget Sound. These were evaluated for grain and malt quality in 2017, while 2018 evaluation is underway. Micro-malting for malt analysis was completed utilizing two different steep regimes to evaluate the impact of malting regime on subsequent malt quality. Barley from 2017 trials were distilled by Sandstone Distillery and unaged distillate analyzed for flavor compounds using Gas Chromatography Mass Spectrometry (GC/MS) and Liquid Chromatography Quadrupole Time of Flight Mass Spectrometry (LC/QTOF-MS) at the WSU Wine Science Center. Hot barley steeps were evaluated using LC/QTOF-MS for the same varieties grown in western and eastern Washington. Barley lines showed difference in malt quality within lines and in comparison with Copeland as an industry standard malt variety. Several lines were competitive with Copeland regarding grain yield, fine extract (alcohol yield potential), and water sensitivity (need for altered steep regimes in the malt house), with generally higher levels in breeding lines as compared to Copeland of beta glucan. Altered steep regimes improved overall malt performance when adjusting for water sensitivity. Differences were detected based on breeding line, trial location, and distillation conditions. Flavor compounds, as well as their relative incidence and flavor character (spiciness, fruity), could be assigned by breeding line. Sensory panel evaluation protocol is under development for IRB review, and will evaluate the capacity of sensory panelists to detect whiskey flavor differences based on breeding line, and correlation if any between analytical compound analysis and sensory panel descriptions. Whiskey from Sandstone Distillery aged one year will be collected and analyzed in the same manner as unaged whiskey.

PROJECT DESCRIPTION:

Reintroduction of grain production in minor growing regions has been promoted to give non-grain farmers biological tools for managing pests and disease, and to develop marketing relationships among farmers, craft brewers and craft distillers (1, 2, 3). Western Washington has been shown to be a unique agro-ecosystem for the union of regional grain production and end-use product development (4, 5). However, expansion of specialty grain production appears to depend on development and successful marketing of novel attributes. This project addresses specific literature gaps regarding 1) identification of suitable barley cultivars for production and craft brewing and distilling in western Washington, and 2) the impact of barley cultivar on novel flavor attributes in craft beverages.

This project extends WSU breeding efforts through field-scale evaluation of barley cultivars for craft brewing and distilling. Ongoing breeding efforts at WSU have identified barley lines suited to grain production in western Washington while exhibiting specific quality characteristics, predominantly for malting and recently for distilling. Breeding for malting cultivars has historically focused on lines suitable for adjunct brewing, in which malted barley is supplemented by rice or corn. These breeding programs serving large-scale adjunct brewing have emphasized high diastatic power (DP), high free amino nitogen (FAN) cultivars (6). Breeding programs for adjunct brewing emphasize high DP barley because malted barley drives enzymatic conversion of carbohydrate to alcohol. In contrast, the current study is evaluating barley for all-malt (all barley) brewing typically employed by craft brewers. In this case we evaluate for lower DP varieties, and variations in other traits. Characteristics evaluated by the WSU breeding program, and important to craft brewers, include malt quality, percent malt extract, lower DP and FAN, beta glucan content, germination energy, water sensitivity and falling number. Breeding work utilizing these evaluation criteria has identified promising lines that, grown out for field-scale evaluation in this work, will allow for sensory evaluation of distilling and brewing characteristics using analytical tools and sensory panels.

OUTPUTS

<u>OUTPUTS: Overview of Work Completed and in Progress:</u>

Growing trials

- In 2017, three reps of nine barley varieties were grown out in one-sixth acre plots at Hidden River Farms in Montesano, WA, totaling twenty seven plots and 4.5 acres. Breeding lines (numbered) and varieties (named) selected for this evaluation included two hulless types (Havener, 10WA-107.8) and seven hulled types (Muir, 10WA-117.24, 10WA-117.17, 11WA-107.43, 11WA-107.58, 12WA-120.14, 12WA-120.17. Approximately 1,200 lbs per variety was harvested (data below) for distillation and analysis in 2017.
- Approximately 6,000 lbs of grain was needed from a second trial in 2018 to provide a full-size batch (1500 lbs) per variety to Sandstone Distillery for a second year run, and 4,000 lbs of each variety for malting (to ensure sufficient grain for brewer-cooperators). In 2018, three breeding lines (12WA-120.17, 12WS-1240.14, and 10WA-117.17) were advanced to a second trial in Adna, WA. Each variety was grown in triplicate on one-half acre plots amounting to 1.5 acres per breeding line and 6 acres total including Copeland as a replicated check. Larger plots were established in 2018 to provide more barley for

malting, brewing and end-use evaluation. The Adna trial site had lower weed pressure and improved soil fertility, and received higher N application rates to meet yield objectives.

Agronomic data

- Agronomic data regarding breeding lines was collected including yield, height, rust incidence, and percent lodging in the Montesano trial, while and only yield data was collected in the Adna trial (2018) as no significant differences in agronomic performance beyond yield and height were detected. This was due to absence of rust pressure, and conditions conducive to lodging. Neither were detected in the Adna trial.

Malting, grain and malt quality analysis

- Micro-malting, and grain and malt quality analysis were completed on raw barley samples for 2017, and are in progress for 2018. Analyses of all breeding lines and replications were conducted by the USDA ARS Cereal Crops Research laboratory in Madison, WI, but were delayed and results will be returned January 2019. Triplicate samples of 2018 lines have been sent to Wisconsin to allow for malt quality comparisons from the same laboratory.
- Grain samples were also micro-malted and analyzed for grain and malt quality at the Hartwick College Center for Craft Food and Beverage in Oneonta, NY for more rapid turnaround, and to utilize this laboratory that is well-known in the craft malting industry. In 2018, replicated samples will again be analyzed by the Hartwick Center.
- Mini-malting of 20 lb samples of selected 2017 lines was completed at the OSU Barley World Laboratory for small-batch brewing and sensory evaluation work that will occur spring 2019 (described below). Beer sensory evaluation was envisioned as a follow-up outcome of this grant, but may fall outside the final reporting timeframe.
- Roughly 4,000 lbs of three 2018 trial breeding lines and a check is being malted by Gold Rush Malt in Baker City Oregon, allowing quantity for full-scale brewing and sensory evaluation in summer 2019. An agritourism event featuring beer sensory evaluation was identified as a follow-up outcome of this grant, but falls outside the reporting timeframe.

Distillation and distillate analysis

- All breeding lines from 2017 trials were distilled by Sandstone Distillery during winter 2017/18, with intermediate distillation products (low wines) and final unaged product packaged and transported to the WSU Wine Science Center. Flavor compounds were analyzed at the WSU Wine Science Center using GC/MS and LC/QTOF-MS analysis of unaged whiskey from 2017 trials. Results are summarized below. All of the 2017 crop less 2018 seed was required to complete this distillation and analysis.
- Fifteen hundred lbs of barley from 2018 trials is scheduled to be distilled by Sandstone Distillery in December 2018 and January 2019. Compound analysis of unaged and aged whiskey from 2018 barley will be analyzed using GC/MS and LS/Q-TOF/MS at the Wine Science Center. A second and future years of flavor compound analysis will result from

this study, but go beyond deliverables identified for this grant and will fall outside the reporting timeframe.

Sensory Evaluation

- Protocol for a sensory panel to evaluate unaged and one-year aged whiskey from 2017 trials is under development by Dr. Tom Collins and Layton Ashmore, a graduate student in his program. The target date to complete a tasting evaluation is May 2019. The same protocol will be utilized to evaluate whiskey samples from 2018 trials. It is hoped that preliminary results will be available by an extended June 2019 final BIOAg reporting deadline.
- Distillate sensory evaluation will utilize a trained tasting panel at the WSU Wine Science Center. A detectable differences methodology (triangle test) will be used in which panelists taste three samples, two of the same spirit and one different. Reliable difference detection is determined on the basis of panelists differentiating the two same from the one different sample. Where repeatable differences are detected between varieties, panelists develop descriptions that facilitate differentiation based on aroma and flavor. These can be linked to specific associated chemical compounds, such as ethyl esters imparting "fruity" odors (10), among other attribute-compound associations.
- The 20 lb samples of 2017 barley micro-malted by OSU was provided to Dr. Murphy and his graduate student in Pullman, WA. Sensory evaluation will be conducted by a graduate student in collaboration with Dr. Murphy and Dr. Caroline Ross in spring semester 2019, corresponding with graduate coursework. The timeframe for this research step was rate-limited by availability of micro-malting service sat OSU, and the course schedule. Preliminary results may be available by a June 2019 extended final BIOAg reporting deadline.
- Malted barley from 2018 trials will be provided to several cooperating breweries in Olympia, WA. Brewers will produce a single beer from all four varieties (though beer style selected may vary by brewery) for sensory evaluation at the Tumwater Artesian Brewfest, provided suitable protocol can be developed to crowd-source data.
- Aged whiskey evaluation from 2017 trials (>2-year aged) is intended for sensory evaluation at the 2020 Cascadia Grains Conference.
- Aged whiskey from 2017 and 2018 trials will be made available for WSU sensory evaluation/fundraising events, to generate revenue for craft brewing and distilling flavor evaluations in the future.

<u>OUTPUTS: Methods and Results:</u>

Methods

Barley breeding lines were grown in randomized complete block designs in 2017 and 2018 trials at two farms in south Puget Sound (Montesano, WA and Adna, WA respectively). Breeding lines (numbered) and varieties (named) grown in 2017 were Havener, 10WA-107.8, Muir, 10WA-117.24, 10WA-117.17, 11WA-107.43, 11WA-107.58, 12WA-120.14, and 12WA-120.17; and in 2018 were 10WA-117.17, 12WA-120.14, 12WA-120.17, and Copeland as a control. The named cultivars were used as 1) check cultivars and 2) to demonstrate an

immediate product available for growers. Selected barley varieties were 2-row types with low to moderate beta glucan and protein content, and possessed quality traits which suggest them as excellent candidates for malting. Wheat and XXX were grown the year prior to field trials at Montesano and Adna respectively. Uniform fertility application and management practices were employed.

Soil at the trial sites consisted of uniform Chehalis silt-loam (fine-silty, mixed, superactive, mesic Cumulic Ultic Haploxeroll, NRCS 2016) at Montesano, and Chehalis silt loam as well as Newberg fine sandy loam (Coarse-loamy, mixed, superactive, mesic Fluventic Haploxeroll, NRCS 2016) at Adna.

Field operations and timing in 2017 and 2018 are summarized in Table 1. In 2017, fields received primary tillage using a _____disk and secondary tillage consisting of four passes with a _____ finishing disk while in 2018, fields received primary and secondary tillage with a vibra-shank harrow followed by spike tooth harrowing. Plot fertility was evaluated prior to planting in both years, and soil samples analyzed by A&L Laboratory in Portland, OR. In Montesano, Stutzman's (4-3-2) organic chicken manure was applied at a rate of 0.7 tons per acre (56 lbs N per acre), and the fields were limed at a rate of 2 tons per acre on. At Adna, 230 lbs per acre of ureasul purchased from Valley Agronomics in Chehalis, WA, was applied at a rate of 75 lbs N per acre. Fertilizer was worked into the ground prior to seeding, and lime was not applied at the Adna trial.

Table 1. Summary of field operations in 2017 and 2018

	Tillage	Fertilizer application	Secondary Tillage	Seeding	Emergence	Tine harrowing	Harvest
2017	4/17	5/8	n/a	5/10	5/17-5/19	5/22 5/27	9/6 9/7
2018	4/10	4/23 4/24	4/25 4/26	4/27	5/5 – 5/7	5/4* 5/10**	8/10 8/13

* *Pre-emergence tine harrowing*

***Post-emergence tine harrowing*

Barley was seeded at approximately 95 lbs per acre with a McCormick-Deering 8-ft seed drill in 2017, and at 110 lbs per acre with a John Deer XX 8-foot grain drill in 2018. In Montesano field plots were harrowed twice after grain emergence while in the Adna trials fields received one pre-emergence and two post-emergence passes, both sites with an Einboch tine weeder with 7 mm tines designed for post-emergence cultivation.

The fields were harvested September 6th and 7th, 2017 in Montesano, and August 10th and 13th, 2018 in Adna. Equipment for harvest. Harvested grain was cleaned with a Clipper 47B to remove weed seed both years. Moisture content was evaluated at harvest in 2017 and three times in 2018: at ten days before harvest, on the day of harvest, and in storage 50 days after harvest. Moisture readings were collected with an AgraTronix MT-16 Grain Moisture Test.

Grain and malt quality analysis was completed at the USDA Grains Research Program in Madison, WI and the Hartwick College Center for Craft Food and Beverage in Oneonta, NY. Grain quality analysis consisted of grain moisture (%), protein (%), test weight (lbs/bu), plump

(% retained on 6/64" screen), thins (5/64"), germination energy (4 ml and 8 ml), RVA and DON. Samples were micro-malted in a Custom Laboratory Products (Milton Keynes, UK) capable of processing sixteen 500g samples per batch. Malted barley was analyzed for malt moisture (%), friability (%), fine extract (% DB), wort color (SRM), beta glucan (ppm), soluble protein (%), protein modification or S/T (%), free amino nitrogen (ppm), diastatic power (L), alpha amylase (D.U.), and pH. Grain and malt quality anlaysis was conducted using official methods of the American Society of Brewing Chemists (http://methods.asbcnet.org/toc.aspx).

Mini-malting of larger, 20 lb samples of selected 2017 lines was completed at the Oregon State University Barley World Laboratory using a Curio Malting (Milton Keynes, UK) MMSG Steep and Germinator and MMK Kiln. Approximately 6-7 kg per selected breeding of malted barley will be utilized by the WSU Barley Breeding and Food Science programs for sensory evaluation in spring 2019.

All 2017 and 2018 (to be analyzed) varieties micro-malted at Hartwick Center utilized a standard steeping regime most adapted to grain with no water sensitivity (Table XY). Water sensitivity is a dormancy mechanism, associated with moisture levels at harvest as well as a genetic component (Aaron Macloed, Personal Communication), which when addressed with altered steeping regimes can improve malt performance. Several 2017 barley varieties malted at OSU exhibiting mild to moderate water sensitivity and received a modified steeping regime (Table XY). This improved malt performance of water sensitive breeding lines, and facilitated the evaluation of steep regime impacts on grain malt quality.

Table Q. Standard and modified steeping regimes for 2017 Montesano trial used at the Hartwick Center and OSU Barley World.

	Entry	Steep	Germ	Kiln
Hartwick Center (standard)	All entries	8 hrs wet (16 hrs air) 6 hrs Wet (14 hrs air) 2 hrs wet @ 14°	96 Hours @ 15°C	6 hrs @ 55°C, 6 hrs @ 65°C, 6 hrs @ 72°C, 4 hrs @ 85°C
OSU (modified, minimally)	Copeland	8 hrs Wet (16 hrs Air) 8 hrs Wet (12 hrs Air) 2 hrs Wet @ 14° C	96 Hours @ 15°C	5 hrs @ 50°C, 5 hrs @ 55°C, ΔT = 9 @ 60°C, 6 hrs @ 72°C, 4 hrs @ 85°C
OSU (modified)	12WA 120.14 & 12WA 120.17	8 hrs Wet (16 hrs Air) 8 hrs Wet (12 hrs Air) 2 hrs Wet @ 14° C	120 Hours @ 15°C	5 hrs @ 50°C, 5 hrs @ 55°C, ΔT = 9 @ 60°C, 6 hrs @ 72°C, 4 hrs @ 85°C
OSU (modified)	10WA 117.17 & 10WA 107.43	5 hrs Wet (19 hrs Air) 5 hrs Wet (15 hrs Air) 2 hrs Wet @ 18°	120 Hours @ 15°C	5 hrs @ 50°C, 5 hrs @ 55°C, ΔT = 9 @ 60°C, 6 hrs @ 72°C, 4 hrs @ 85°C

Agronomic performance of the selected varieties was evaluated for production potential in western Washington based on plant height (cm), barley stripe rust (% leaf infected), lodging (percent of plot area), and yield (lbs per acre clean grain on basis of harvested plot area). Upon harvest, all nine varieties were cleaned through a Clipper 47B to eliminate weed seed. Cleaned

grain was transported to craft distilling cooperator Sandstone Distillery for micro-distillation into new make whiskey.

Unmalted barley was distilled from the Montesano trial by distiller-cooperator Sandstone Distillery in Tenino, WA between October 2017 and January 2018. Starch was converted to fermentable sugars through the addition of added enzymes rather than relying on the addition of malted barley as is done more traditionally. This reduced variation associated with the malting procedure, potentially allowing for greater expression of grain variations. One thousand pounds of each line was ground and deposited as two 500 lb reps into separate reactors utilized both for cooking and fermenting. Mash production consisted of combining grain, enzymes and %00 gallons of water, and heating to 180 degrees F over the course of approximately one hour. An iodine test was administered. Temperatures cooled from 180 to 120 at which point 202 HY and 250 g of GW yeast (get add'l info) were pitched. Fermentation was complete with very little activity after two days.

Fermented mash was distilled directly from the cooker-fermenter reactors by utilizing the reactor as a pot still (Figure 1). The reactors were heated, and alcohol vapor was channeled to a copper Lyne arm and through a water jacket manufactured from a central column wrapped in copper coil through which cold water was circulated. Low wines distillate product was collected in a 100 gallon stainless steel drum. Product was further distilled through two subsequent distillation stripping runs, each with the addition of 100 gallons of water, from which was obtained mid wines and high wines. Each run was completed in approximately five to six hours over the course of three days (one per distillation), with samples collected at each step and recordings taking of alcohol yield in gallons and proof.

Subsamples of the replicates were collected after the second distillation, resulting in 375 ml "low wines" samples. Subsequently, low wines were combined for a third distillation run and one 375 ml subsample of this final product was collected prior to barreling. All samples were sent to the WSU Wine Science Center in Richland, WA along with 50 ml samples of pre-fermentation mash for each variety. Samples were analyzed for differences among flavor compounds and flavor compound identification by GC/MS and LC/QTOF-MS, the former for volatile compounds and the latter to evaluate flavor precursors and compounds associated with mouth feel. The remainder (unsampled) distillate product was transferred to oak barrels (type & size, retrieving info) at Sandstone Distillery for aging.

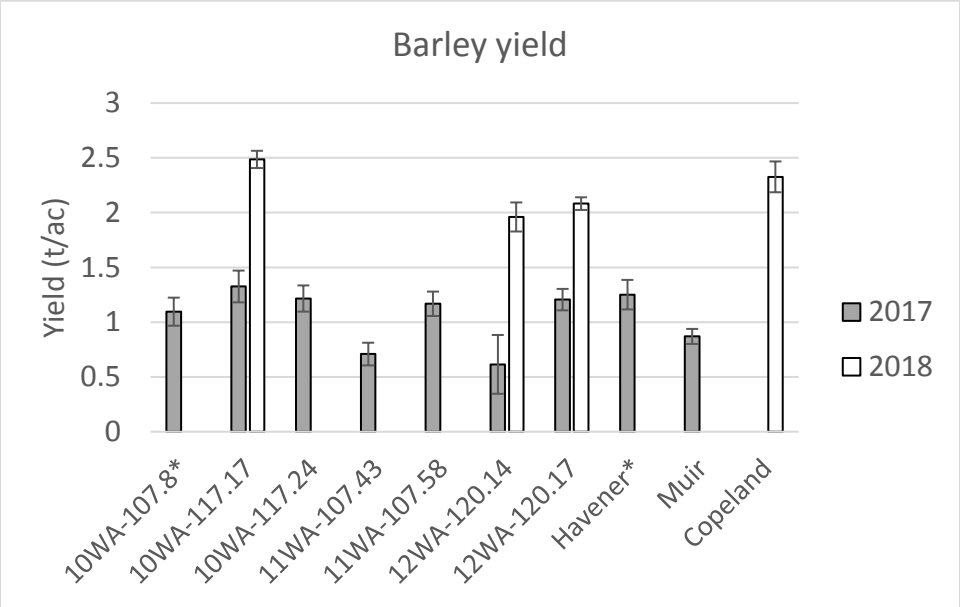
Results

Agronomic data

Yield

Entry	2017 Yield (t/ac)	2018 Yield (t/ac)
10WA-107.8 (hulless)	0.709	
10WA-117.17	1.326	2.486
10WA-117.24	1.168	
11WA-107.43	1.206	
11WA-107.58	0.870	
12WA-120.14	1.216	1.960

12WA-120.17	1.251	2.082
Havener (hulless)	0.615	
Muir	1.096	
Copeland	n/a	2.327



Plant height

Table X.

Entry	**Average height (cm)**
10WA-107.8*	71.7
10WA-117.17	80.7
10WA-117.24	86.7
11WA-107.43	76.8
11WA-107.58	77.2
12WA-120.14	84.9
12WA-120.17	81.0
Havener*	75.0
Muir	75.7

Weed seed load

Weed seed was separated by screen and fan-winnowing for harvested barley in 2017. Mass (g) was obtained as a measure of weed seed load by entry and repetition. This data is collected but not yet analyzed.

Plant development and resistance

Morphological data was collected using a Zadok scale, and development of barley varieties was tracked weekly. Data is available upon request. Rust and lodging observations were made as well, but neither rust incidence nor lodging occurred during the 2017 or 2018 growing seasons.

Plant height

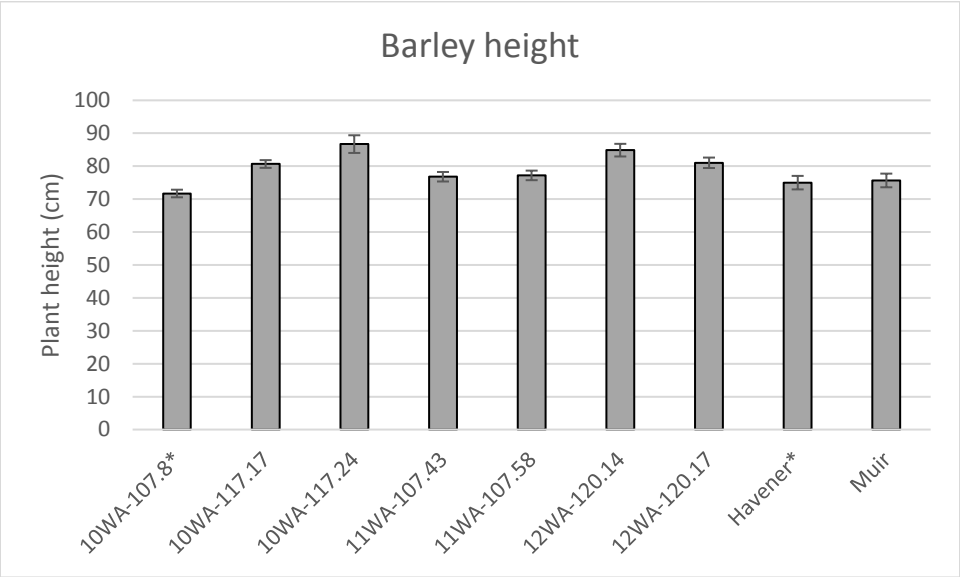


Figure X. Height measurements (in cm) in 2017 trial; to height of spikelet, not counting awns. Plants not straightened out for measurement.

Grain moisture

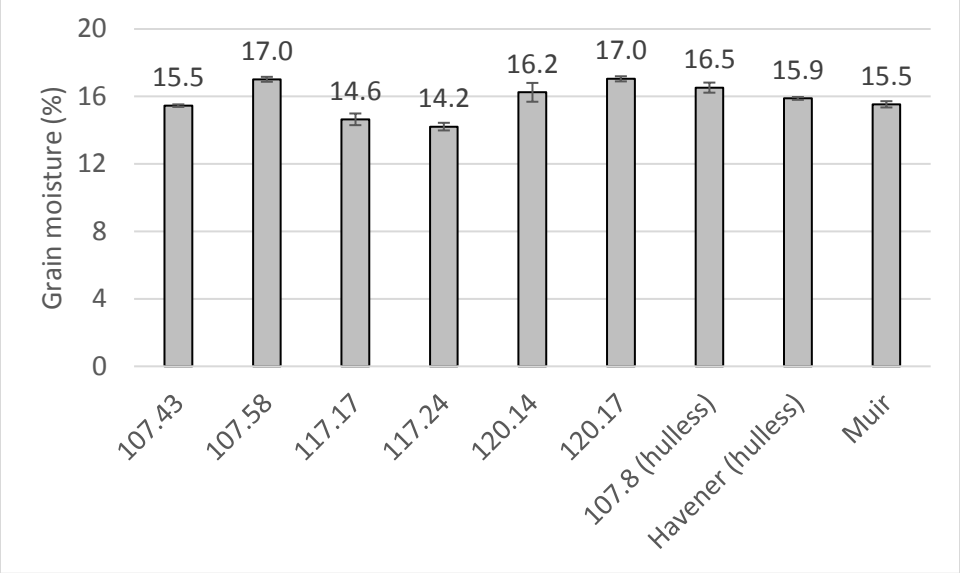


Figure Y. Post-harvest barley moisture (%) of the 2017 Montesano entries

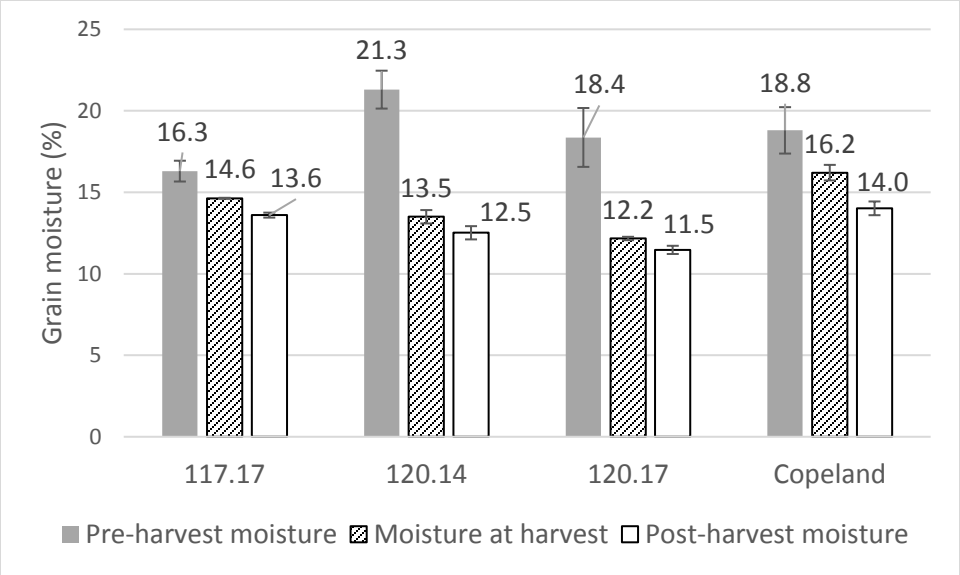


Figure XY. Moisture levels (%) of the 2018 Anda trial entries measured before harvest, at harvest, and in storage after harvest.

Grain and malt analysis

Table YY. Grain quality analysis for Montesano trials (2017)

Entry	Yield (t/ac)	Protein (%)	Moist. (%)	Test weight (lbs/bu)	Plump (>6/64 %)	Thin (<5/64 %)	Germ. (Energy, 4mL %)	Germ. (Energy, 8mL %)	RVA
Copeland	n/a	9.8	14.9	51.8	99.1	0.1	100	90	202
Havener* (hulless)	0.615	10.8	15.6	53.2	98.1	0.1	85	61	169
Muir	1.096	9.2	15.0	58.4	92.1	0.4	100	83	128
10WA-107.8* (hulless)	0.709	9.9	14.9	50.1	98.4	0.3	100	82	200
10WA-117.17	1.326	10.0	14.6	50.7	99.0	0.1	96	60	165
10WA-117.24	1.168	10.0	15.0	52.9	99.1	0.1	97	80	160
11WA-107.43	1.206	10.6	15.5	52.4	98.9	0.1	97	71	201
11WA-107.58	0.870	10.1	15.4	50.6	98.7	0.3	96	90	180
12WA-120.14	1.216	10.3	16.9	49.7	99.1	0.1	97	87	176
12WA-120.17	1.251	10.3	13.4	48.9	99.6	0.0	100	91	140

Table ZZ. Malt quality analysis for Montesano trials (2017) utilizing a generalized steeping regime developed for Copeland (for steeping regime see Appendix I)

Description	Malt Moist. (%)	Fria-bility (%)	Fine Extract (% DB)	Wort color (*SRM)	ßeta-Glucan (ppm)	Soluble Protein (%)	S/T (%)	FAN (mg/L)	Diastatic Power (°L.)	Alpha Amylase (D.U.)
Copeland	3.7	94.9	81.9	2.44	75	5.14	49.9	232	131	58.5
Havener*	4.0	63.8	89.1	1.60	726	4.02	41.9	149	67	30.5
Muir	3.9	82.0	80.3	2.10	216	4.05	41.3	153	101	41.9
10WA 107.8*	4.3	70.1	83.6	1.82	622	4.47	41.4	171	76	36.4
10WA 117.17	3.8	84.5	80.6	1.60	340	4.03	40.7	156	94	31.0
10WA 117.24	3.5	70.9	78.8	1.69	730	3.75	37.5	138	90	25.3
11WA 107.43	4.0	73.2	82.4	1.57	471	4.08	40.8	157	86	33.9
11WA 107.58	4.0	69.8	80.3	1.71	483	4.15	39.2	164	87	36.1
12WA 120.14	3.8	82.0	81.7	2.49	195	4.80	47.5	217	98	46.1
12WA 120.17	3.7	81.8	81.1	2.39	228	4.64	45.0	202	95	39.0

Gray: varieties advanced in 2018 trials
Orange: control, target high quality
Yellow: 2nd highest quality
Green: 3rd highest quality

Table QQ. Malt quality analysis for Montesano trials (2017) utilizing a modified steeping regime developed by variety (for steeping regime see Appendix II)

Description	Malt moist. (%)	Fria-bility (%)	Fine extract (%)	Coarse Extract (%)	Color (°SRM)	Beta glucan (ppm)	Soluble Protein (%)	S/T (%)	FAN (ppm)	Diastatic power (°L)	Alpha amylase
			FGDB	CGDB			Protein			Power	Amylase
	%	%	%	%		mg/L	%	%	mg/L		D.U.
10WA 117.17	4.8	89.1	79.5	78.3	1.84	99	4.13	40.9	151	106	47.8
10WA 107.43	5.3	87.9	81.5	80.0	1.87	95	4.22	37.7	155	101	47.6
12WA 120.17	5.1	84.4	80.9	79.8	2.49	130	4.54	42.4	190	100	56.7
12WA 120.14	5.4	86.1	81.5	80.6	2.79	127	4.83	44.7	208	102	60.9
Copeland	4.8	87.5	81.3	80.5	2.20	85	4.79	44.4	193	122	64.8

Flavor compound analyses (following pages)

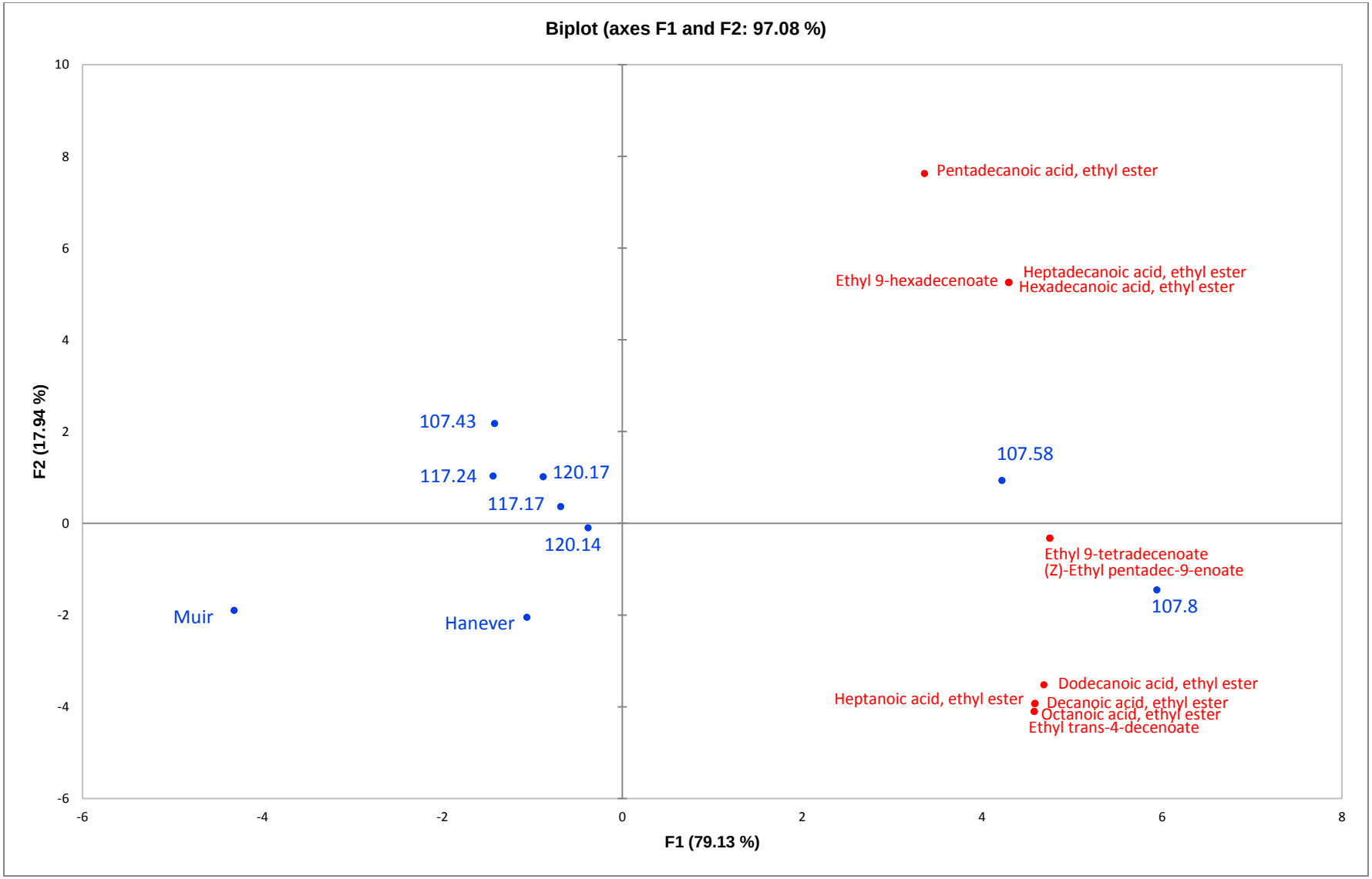


Figure 1. PCA biplot of key volatile compoundsin whiskies made from WSU barley breeding trials. As whiskies from strains 107.58 and 107.8 were distilled using a different still than the remaining whiskies, the separation in PC1 (79.1%) is explained by differences in the stills.

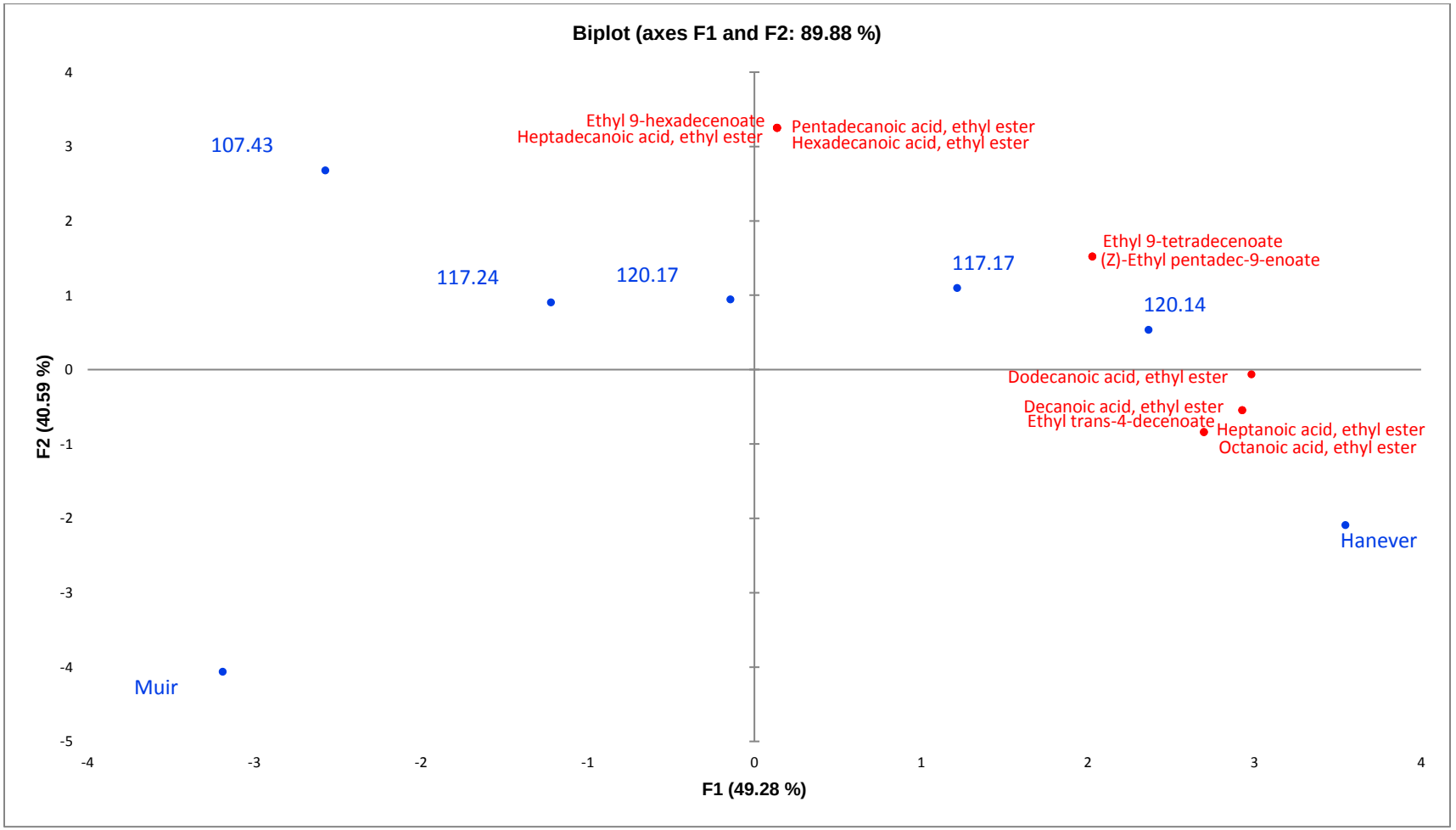


Figure 2. PCA biplot of major volatiles in whiskies made from WSU barley breeding trials with whiskies made from 107.58 and 107.8 removed. The major volatiles in these whiskies are typical yeast byproducts (fatty acid ethyl esters), potentially masking differences amongst the barleys.

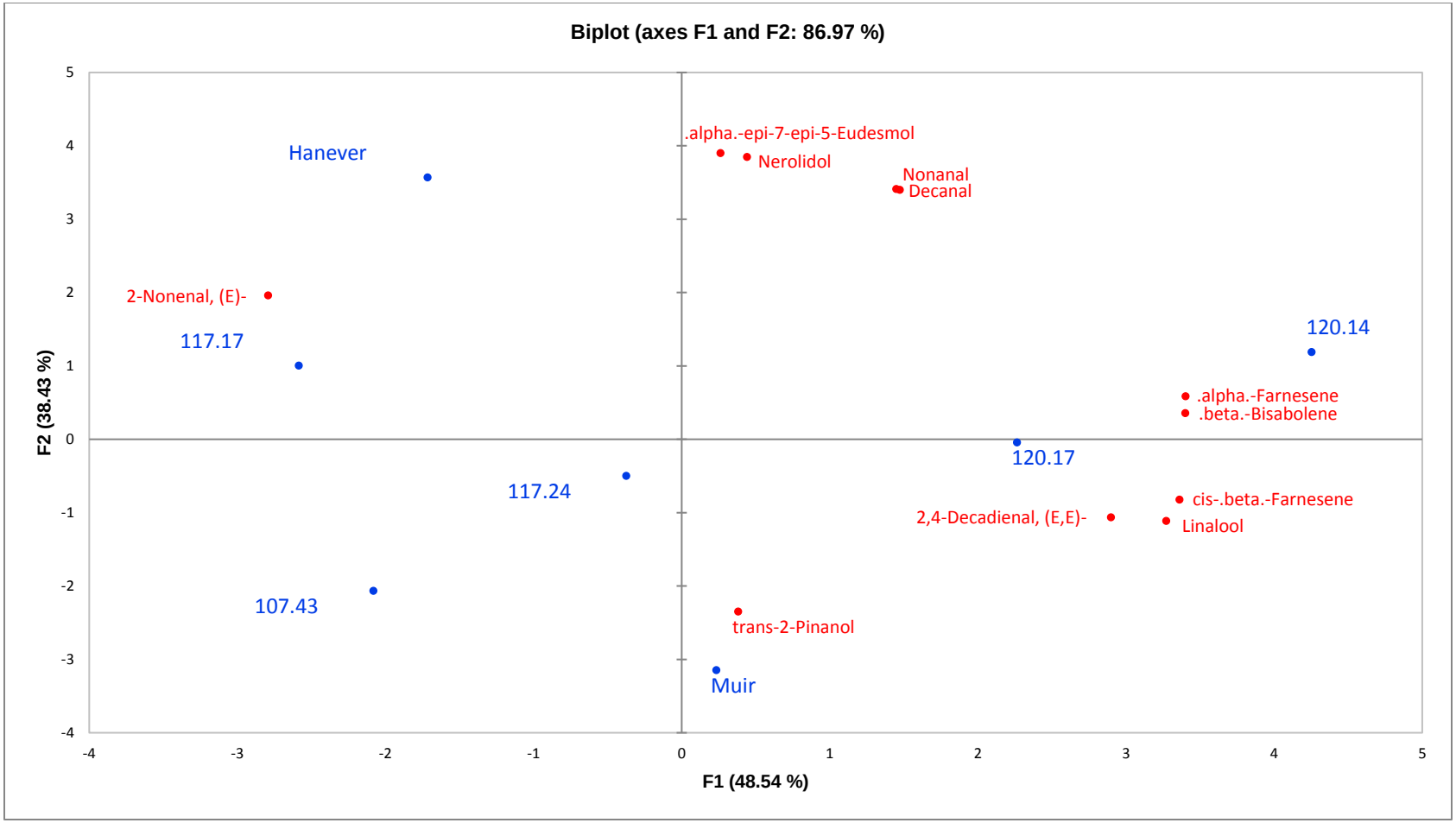


Figure 3. PCA biplot of key plant-derived volatiles in these whiskies. It should be noted that *S. cerevisiae* is also capable of producing some terpenes, however it would be expected contribution is minor and equivalent across all trials. Most variance is driven by presence of farnesene derivatives (α-farnesene, cis-β-farnesene, β-bisabolene, PC1, 48.54%) which were present in higher concentrations in the 120 strains compared to the 117 or 107 strains. Separation in PC2 appears to be driven by the presence of oxidation products (nonanal, decanal, trans-2-nonenal, PC2, 38.4%).

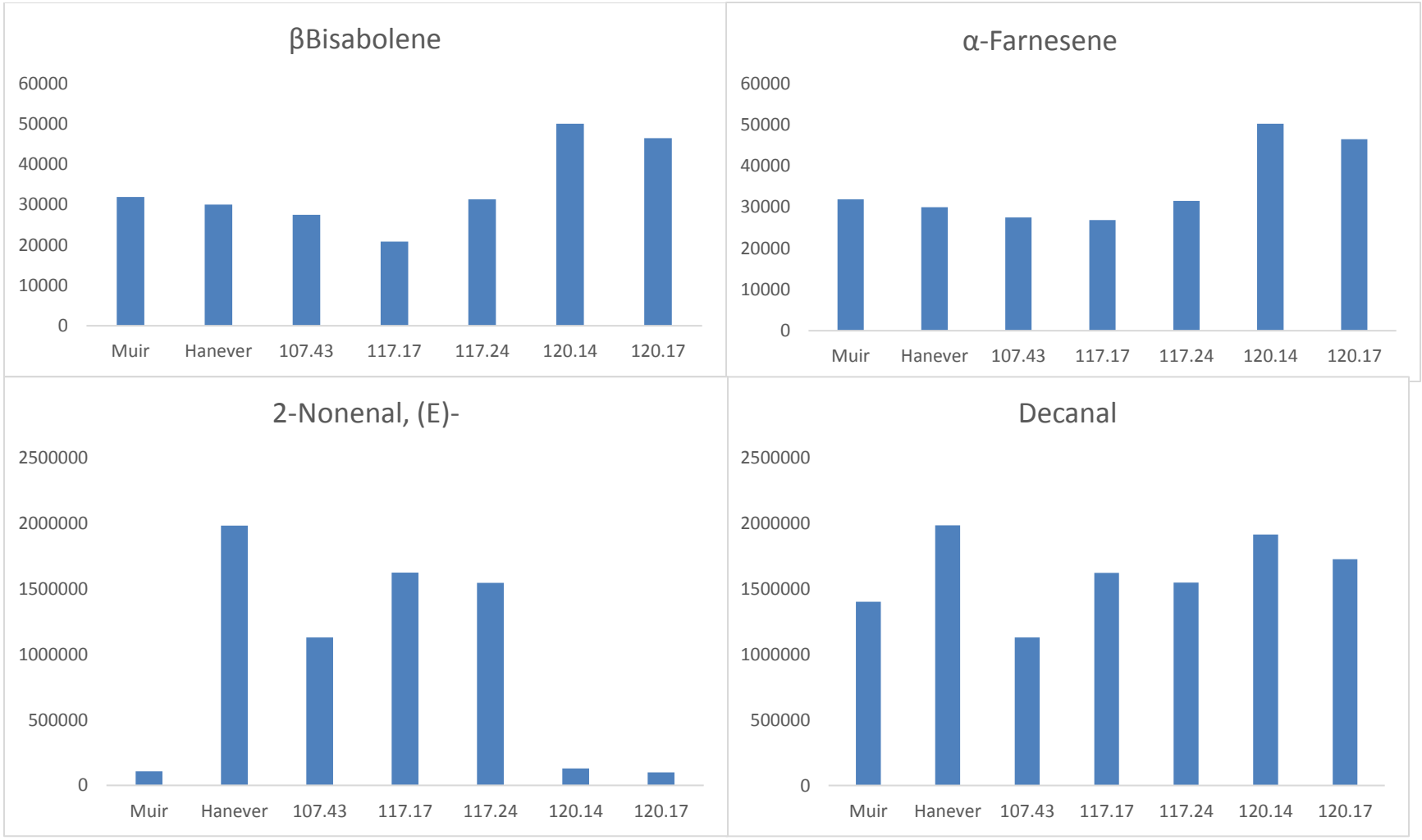


Figure 4. Difference in key volatiles in whiskies made from WSU barley breeding trials. Terpene content (β-bisabolene, top left and α-farnesene, top right)is higher in whiskies made from 120 strains while trans-2-nonenal (bottom left), an oxidation product known for causing off-flavors associated with "wet newspaper" and "cardboard" was higher in the 117 strains. These differences could be attributed to yeast, barley, or the distillation process.

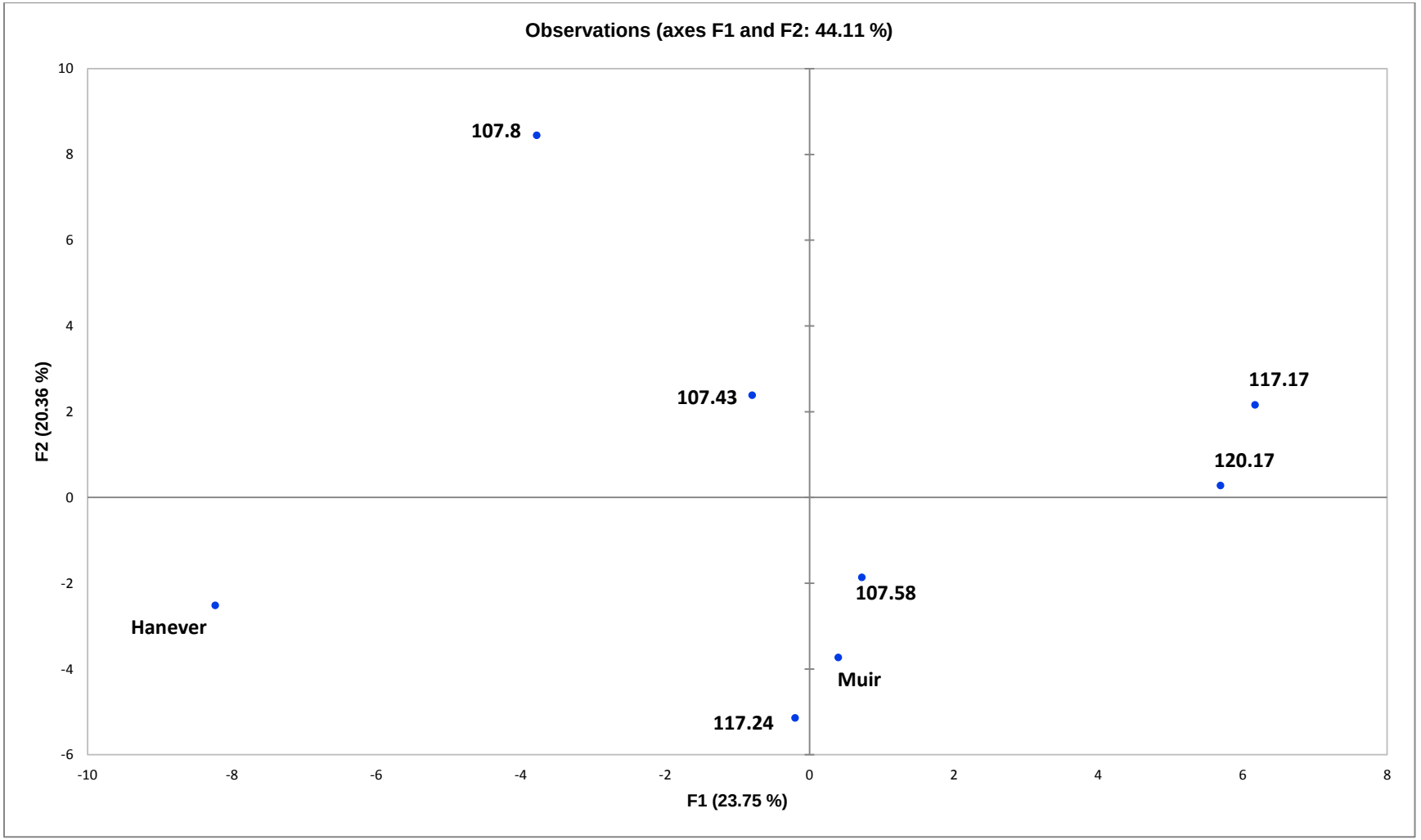


Figure 1. PCA scores plot of barley cultivar steeps from the 2017 harvest of the WSU barley breeding trials. Barleys were ground and steeped in DI water at approximately 40°C for one hour. Approximately 10mL of each steep was placed in to headspace vials and analyzed by HS-SPME-GC/MS.

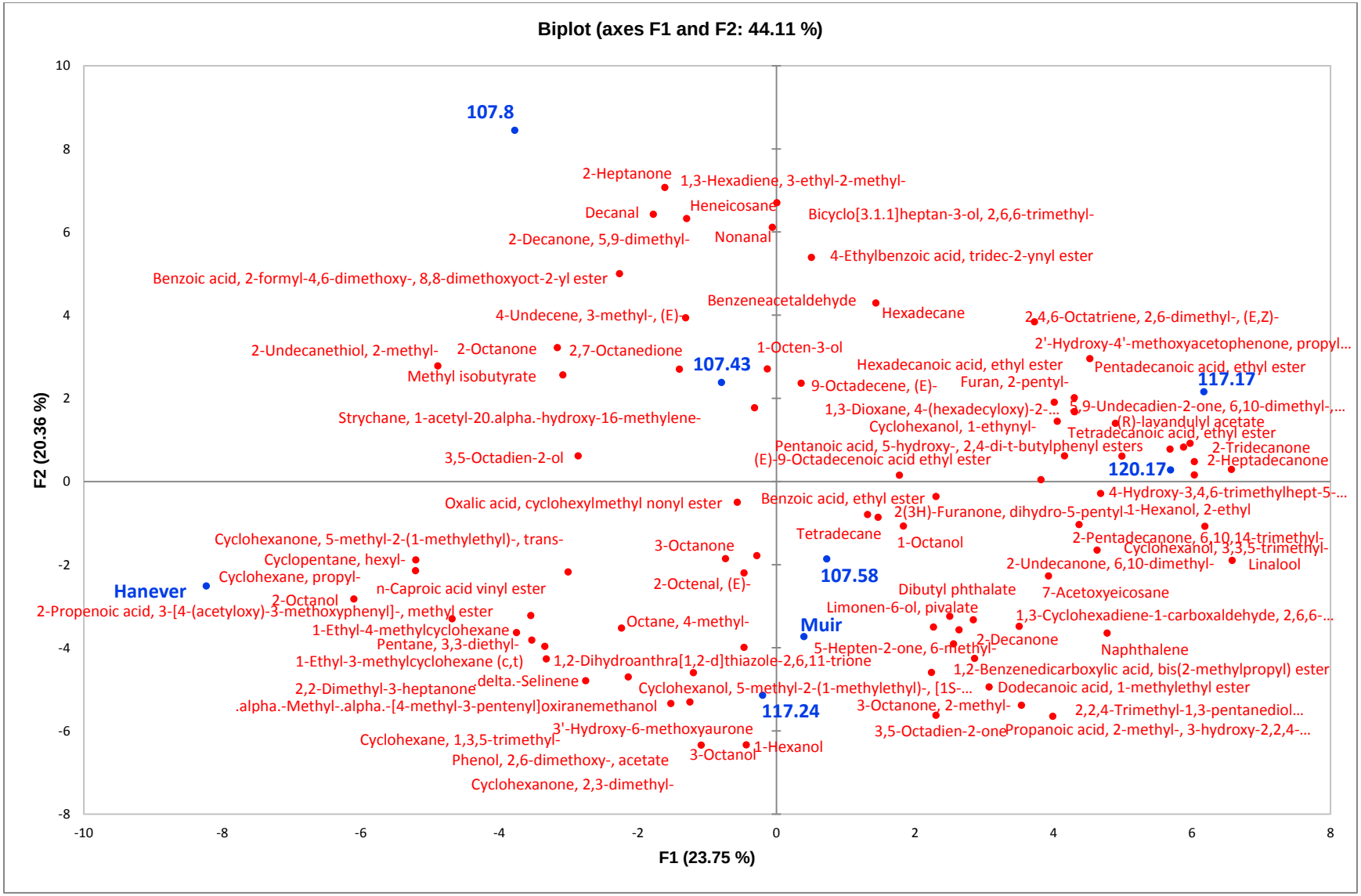


Figure 2. Biplot of barley steeps with associated compounds used to derive the PCA plot in Figure 1.

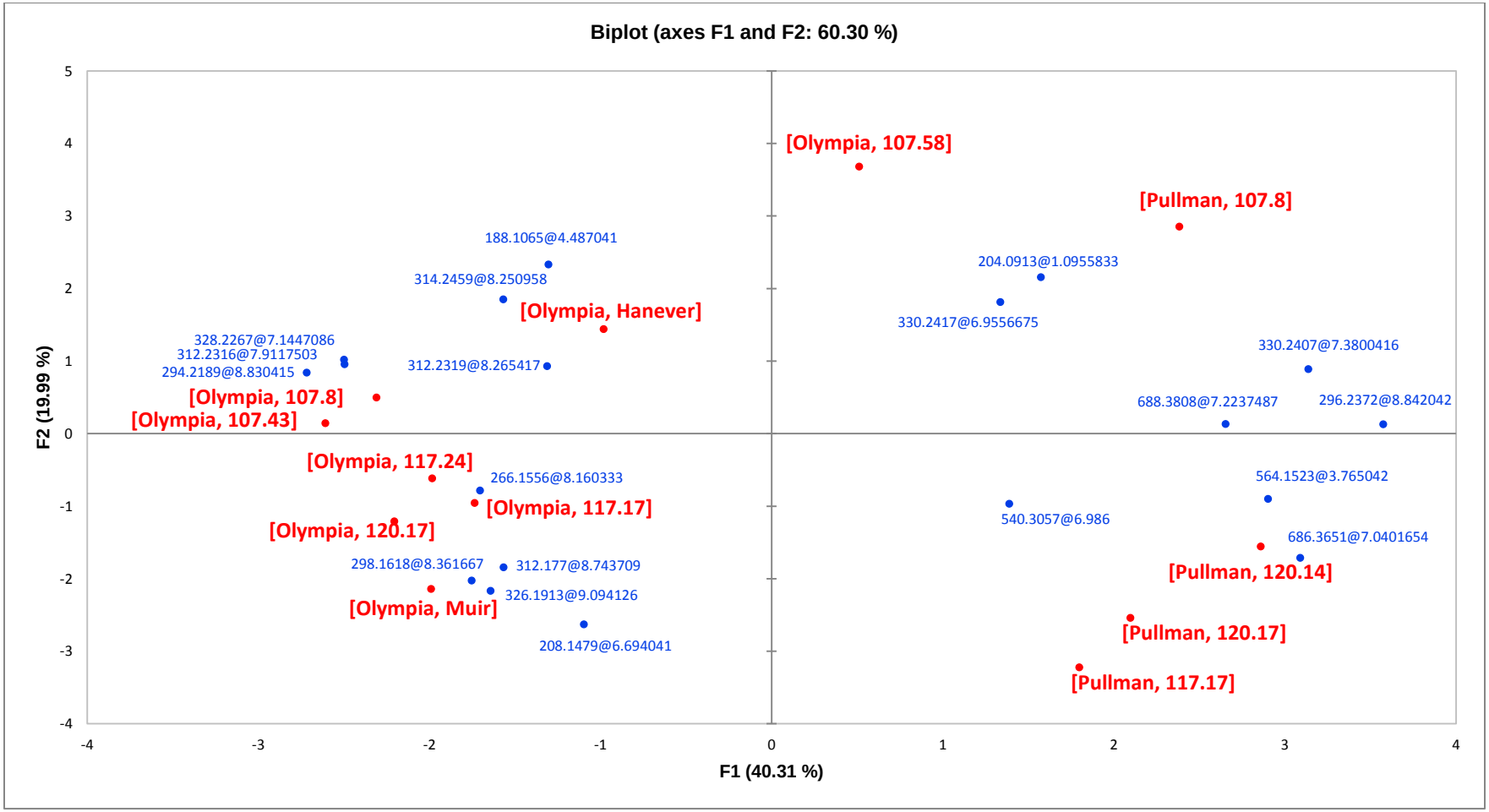


Figure 1. Biplot of LC-QTOF barley hot water steep data for strains grown at two different sites (Pullman, Olympia) from 2017 breeding trials. PC1 (x-axis) represents 40.31% of the variance of the data, and is driven by growing site. Peaks of interest are likely glycosylated flavonoids, which provide mouthfeel characteristics and long chain fatty acids which esterify during beer and spirit production, adding to aroma and flavor. Separation in PC2 is driven by the presence or absence of the 208.1479m/z peak, which tentatively identified as a terpene compound associated with the strains Muir, 120.17, 120.14, 117.17, and 117.24 grown at both locations. Remaining strains (Hanever, 107.58, 107.8, 107.43) are more closely associated with a shorter chain fatty acid (188.1065m/z) which provides aroma when esterified during fermentation and brewing/distillation.

Publications, Handouts, Other Text & Web Products:

- A field day hand-out was developed for the Montesano (2018) event, attached below
- A field day hand-out was developed for the Adna (2019) event, attached below
- A local online newspaper covered the barley variety trial field day: http://www.thurstontalk.com/2017/08/11/wsu-barley-breeding-craft-malting-brewing-distilling-field-walk/
- Notice and coverage of the variety trials were featured in the July and August 2017, and May and July 2018 Thurston County Extension *Ag Sounder* Newsletter: https://extension.wsu.edu/thurston/agriculture/farming-news-resources/ag-sounder-newsletter/
- Project webpage: https://extension.wsu.edu/thurston/specialty-grain/
- Related findings from grain infrastructure field trip to Port of Skagit partially funded by this project: https://s3.wp.wsu.edu/uploads/sites/2056/2018/10/Skagit-Tour-2018_Notes-1.pdf
- Grain grower survey funded in combined trials-infrastructure project ($10,500) by Port of Olympia for this project, and supported by WSU undergraduate internship funding: https://s3.wp.wsu.edu/uploads/sites/2056/2018/10/Grain-grower-survey-results-1.pdf
- Grain buyer survey funded in combined trials-infrastructure project ($10,500) by Port of Olympia for this project, and supported by WSU undergraduate internship funding: https://s3.wp.wsu.edu/uploads/sites/2056/2018/10/Grain-buyer-survey-results.pdf

Outreach & Education Activities:

- A field day was held July 18th, 2017 at Hidden River Farms and July 19th at Reisinger Farm, and was attended, respectively, by 25 and 20 farmers, brewers, distillers, agronomy professionals and students. Evaluations of the field day were collected:
    - In 2017, among 45 attendees and 23 evaluations, 78 percent reported moderate increase to greatly increased knowledge of topics (agronomic performance, brewing/distilling performance, opportunity to grow barley, opportunity to buy, using local barley for craft beverages) and 70 percent report they will use information from field day. The 2018 evaluations have not been analyzed.
- Trials and proposal for funding a grain handling facility presented to Port of Olympia Commissioners in 2017 and was funded ($10,500) in 2018.
- A successful proposal was presented to Thurston County in 2018 for Lodging Tax funds ($5,000) to host a community tasting evaluation of beer from Thurston County barley (event flyer below)

OUPUTS

Extension bulletin – Growing malting barley in western Washington for craft brewing and distilling	Started 2018
Barley malting data: Extension publication – Ground to glass; barley varieties for craft brewing	No, go with referred journal
Project results will be presented at the Cascadia Grains Conference	2019

Community sensory evaluation, public agri-tourism event with City of Tumwater and Visitor and Convention Bureau; community sensory presentation	Planned for August 2019
Distillate analysis: conference proceeding at Cascadia Grains Conference and extension publication – Growing and marketing barley for the craft brewing and distilling industry	January 2018
Field days: western Washington barley production for craft brewing, distilling and feed	2018, 2019
Refereed scientific journal as data permits	2020

- Recorded presentation to WSU Food Systems Team, First Fridays webinars: https://www.youtube.com/watch?v=xNEtY2bS6E0
- **Additional outputs not in original grant: local popular press, newsletter entries, webpage: https://extension.wsu.edu/thurston/specialty-grain/ (2017, 2018)
- Grain buyer and grower surveys. This project was intended to lead to support of a feasibility study for a grain handling facility. Preliminary survey work was completed as a specific related output of this project: https://extension.wsu.edu/thurston/specialty-grain/ (links at bottom of page).

IMPACTS

Short-term

30 growers attend field days and are aware of opportunity to grow barley in western WA	25 20	x
10 local government decision-makers more aware of brewing/distilling using local grain	12 of 10	x
Growers have agronomic information about performance of available barley varieties	2017, 18 field days, 2019 summary	/x
Growers and craft brewers, distillers have end-use data on available barley varieties	2018 field day hand-out. More in 2019	/x
Research results used in ongoing grain mill feasibility study with local land trust	2018 survey work, WSU intern & Port Oly funding	x
Farmer are interested in grain network, want to experiment with integrating grain-veg-livestock*	20+ farmers	x

- Local officials with increased knowledge:
- *This work dovetailed with 2018 survey work focused on establishing a grain network and grain handling facility in south Puget Sound. Over 20 grain farmers completed the survey, as well as 15 local grain buyers.
- A team of local food system representatives toured Port of Skagit grain handling facilities and businesses in July 2018. Visited The Bread Lab, Skagit Valley Malting, met with Port of Skagit executives, Cairnspring Mill, Skagit Valley Brewing Academy
- Working on a non-binding Letter of Intent with two Ports, two EDCs, two Conservation Districts, WSU Thurston and Lewis Counties, Cities of Tumwater, Tenino, Chehalis,

Olympia on “collaboration for planning and development of regional grain and food system infrastructure”

- Working with Port of Chehalis on 2019 funding for grain storage facility planning and design project.

Medium term

15 Local brewers/distillers/feed purchasers are provided research result publications	Working on summary for local circulation, 2019
Brew/distillate from local barley featured in three regional agri-tourism marketing materials	Planned for Tumwater Artesian Brewfest tasting
100 community members attend events, increase awareness brewing/distilling with local grain	Tumwater Brewfest tasting event
Local craft brewing and distilling initiative in City of Tumwater uses information to promote development of Craft Brewing and Distilling Center	Materials in blog posts, SPSCC to utilize grain for education, City Tumwater support on Brewfest event
Consumers are willing to pay a small premium for local craft beer, spirits	TBD. Possible to evaluate with flavor at Brewfest???
One local distillery regularly sources organic barley	1 sources barley, no organic available
Local agri-tourism organizations (VCB) and jurisdictions (City of Tumwater) are interested in matching funds to support community sensory panel agri-tourism event	Thurston County matched, VCB in-kind support, Tumwater in-kind support

Long term

Ed material on organic barley for Craft Brewing-Distilling available through WSU	In progress
Integrating grain into crop rotation including in cultivating success advanced course	TBD
Small-scale grain mill is established for mixing feed, brokering sales	In dev. at Kirsop Farm, with local land trust and WSU support
A local grain equipment cooperative is established to farms to integrate grain production	Fledgling, several local farms clean grain on shared Clipper and 1 farm dried 300+ tons of feed barley and peas on shared equipment
Barley is used in intensive vegetable crop rotation for feed and brewing-distilling to close nutrient loops, integrate crops-livestock, and break pest and disease cycles	TBD

A field trial is established to evaluate the impact of grain-vegetable crop rotation on specific pest and/or disease severity or population	TBD

ADDITIONAL FUNDING APPLIED FOR / SECURED

- Port of Olympia - $10,500
- Thurston County Lodging Tax - $5,000
- WSU Barley Breeding program (contribution) - $5,000
- Considering applying with Lewis County WSU for Distressed County funds for grain facility in Lewis County with Port of Chehalis
- Considering supporting (not leading) legislative request for capital improvements at Port of Chehalis grain handling facility

GRADUATE STUDENTS FUNDED

Graduate student at WSU Wine Science Center – research support forthcoming $7,000
Undergraduate intern secured in 2018 – $2,500

RECOMMENDATIONS FOR FUTURE RESEARCH

Short-medium term project continuation:

Funding for a second year of trials in 2018 was secured to produce more barley for additional micro-malting tests. This allowed shipment of 1,500 lbs of each line/variety to Sandstone Distillery, and 4,000 lbs of each line/variety for malting. Future research this will enable includes:

- Community sensory evaluation of beers brewed with 4 different lines/varieties
- Whiskey flavor compound analyses
    - Year 2017 and 2018 flavor compound analysis of unaged whiskey
    - Year 2017 and 2018 flavor compound analysis of aged whiskey
    - Sensory evaluation (unaged whiskey) – years 2017 and 2018 product
- Panel sensory evaluation of whiskeys distilled with each line/variety
- Beer flavor compound analysis on
    - Barley steeps (unmalted)
    - Malted barley steeps
    - WORT compound analysis
    - Beer compound analysis

Recommendations for future research coordination:

1. Small-scale research malt facility in south Puget Sound, located at Craft Brewing and Distilling Partnership Zone in Tumwater, WA. Partner with South Puget Sound Community College Craft Brewing and Distilling program (and others?) to house and manage. Co-operate/management MOA among WSU Barley Breeding Program, County Extension, The Bread Lab, and the WSU Food Systems Team.
2. Coordinated malting barley research team in western Washington combining research and extension personnel involved in Cascadia Grains Conference, The Bread Lab, County

Extension, craft beverage industry partners, malting industry partners, education partners (SPSCC and SVC), and farmer partners. With public partnerships at Ports, Counties and Cities.

Ground to Glass: Evaluation of Barley Varieties for Craft Brewing, Distilling and Malting

Thurston County
Washington State University Extension

An On-Farm Field Day
July 18th 4:30 – 7pm (reg./food at 4pm)
Hidden River Farms
627 Wynoochee Valley Rd
Montesano, WA 98563

Come learn about grain production in western Washington, and varieties being evaluated in a field-scale 4.5-acre replicated trial at Hidden River Farms. Nine varieties/breeding lines are being evaluated for valuable agronomic (yield, leaf rust) and end-use qualities important for malting, brewing and distilling. Varieties are also being evaluated for feed quality. Hidden River Farms is an 88-acre organic, integrated grain-hog operation. Hogs are pasture-raised and fed barley, wheat and peas grown on site. Grain is raised organically on Nisqually silt-loam soil along the Wynoochee River outside of Montensano, WA.

Participants will learn about:

- Field-scale performance of new barley breeding lines for western Washington
- Farmer experiences growing grain for feed in western Washington
- Barley breeding lines specifically suited to the needs of craft brewers, micro-maltsters, and local distillers
- Distiller and brewer perspectives on regional grain production
- Current information on impact of grain variety on spirit flavor attributes, and how this study is contributing to this research
- Potential for developing locally-distinctive whiskey

Evan Mulvaney (Hidden River Farms) owns and operates Hidden River Farms. **Stephen Bramwell** (Ag Extension, WSU) coordinates field research in Thurston County. **Kevin Murphy** (Crop & Soil Sciences, WSU) is the Barley and Alternative Crop Breeder at WSU. **Tom Collins** (Wine & Distillate Science Specialist, WSU) is an expert in chemical analyses of the distilling process at the Ste. Michelle Wine Estates, WSU Richland Wine Science Center.

Registration and Event Details
Registration opens at 4pm prior to the tour. **Light refreshments** will be served. Dress appropriately for summer heat with hat, sunglasses, sunscreen. There is **no registration fee**. **Please RSVP** to Stephen Bramwell, Thurston Co. Extension: bramwell@wsu.edu 360.867.2161

Ground to Glass: Evaluation of Barley Varieties for Craft Brewing, Distilling and Malting

An On-Farm Field Day

WASHINGTON STATE UNIVERSITY EXTENSION

July 19th 4:30 – 7pm (reg./food at 4pm)
653 Bunker Creek Road
Adna, WA 98532

Port of Olympia

Come learn about results from the 2017 barley variety trials, and continued 2018 trials. Last year, nine varieties/ breeding lines were evaluated for agronomic, grain quality, and malting quality, and for unique whiskey flavors. All nine were distilled by project partner Sandstone Distilling. Unaged product was analyzed for flavor compounds at the WSU Wine Science Center by distillate researcher Tom Collins. Malt analysis was conducted at the Hardwick Center for Craft Brewing and Distilling. We'll take a look at these results, and learn about (and see) the top-performing varieties selected to grow out in the 2018 trials. Product from 2018 will be again distilled at Sandstone, as well as malted and brewed by a regional brewery this winter (for community tasting next summer??). See you on July 19th!

Participants will learn about:

- Grain and malt quality results from 2017, as well as potential unique flavors among western Washington barley malt
- Field-scale performance of new barley breeding lines
- Current WSU breeding for brewers, micro-maltsters, and distillers
- Distiller and brewer views on locally-distinctive products
- Current information on the impact of grain variety on spirit flavor attributes, and how this study is contributing to this research

Bill Reisinger (Adna host farm) and **Brian Thompson** (field manager). **Stephen Bramwell** (Ag Extension, WSU) in Thurston County. **Kevin Murphy** (Crop & Soil Sciences, WSU) Barley and Alternative Crop Breeder. **Tom Collins** (Wine & Distillate Science Specialist, WSU) an expert in distillate analyses at WSU Richland Wine Science Center.

Registration and Event Details

Registration opens at 4pm prior to the tour. **Light refreshments** will be served. Dress appropriately for summer heat with hat, sunglasses, sunscreen. There is **no registration fee**.

Please RSVP to Stephen Bramwell, Thurston Co. Extension: bramwell@wsu.edu 360.790.9308

WASHINGTON STATE UNIVERSITY EXTENSION

Extension programs and employment are available to all without discrimination. Evidence of noncompliance may be reported through your local Extension office. Reasonable accommodations will be made for persons with disabilities and special needs who contact Stephen Bramwell; 360.867.2161; bramwell@wsu.edu at least two weeks prior to the event.

Homegrown Beer: A Community Tasting of Local Beers from South Puget Sound Barley



Support your Local Farmer: Malt is the Next Frontier in Beer

farmers + barley + breweries + WSU research

=  ...flavor from Ground to Glass

*August 19th at the Tumwater Artesian Brewfest: **Join craft brewers in Thurston County and WSU Extension for a community tasting evaluation of four beers brewed from four varieties of barley. Register your tasting results as part of this crowd-sourced, community tasting research.*

Cheers!

Registration forthcoming. Contact for info: bramwell@wsu.edu
https://extension.wsu.edu/thurston/specialty-grain/

Thurston County
Washington State University Extension