Received: 15 February 2023 | Accepted: 26 May 2023

DOI: 10.1002/plr2.20316

Journal of Plant Registrations

REGISTRATION

Cultivar

Registration of 'Lontra' malting barley: A two-row, winter-habit cultivar of interest to the craft malting and brewing industries

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Assigned to Associate Editor Jamie Sherman.

Registration by CSSA.

Abstract

'Lontra' (Reg. no. CV-378, PI 702797), experimental designation DH142010, is a two-row winter barley (*Hordeum vulgare* L.) released by Oregon Agricultural Experiment Station in 2023. It is well adapted to the US Pacific Northwest. Lontra is a doubled haploid produced via anther culture and was advanced through fall-planted trials from 2016 to 2021. Lontra was developed with the goal of commercial production as a malting cultivar for the craft malting industry; therefore, it was not tested in the American Malting Barley Association Pilot Program due to the limited number of selections that can be accommodated. Lontra has a solid record of agronomic performance, malting quality, beer quality, and beer sensory.

1 | INTRODUCTION

The development and release of malting barley (*Hordeum vulgare* L.) cultivars geared toward the craft malting and brewing industries offers an alternative to the traditional malting barley assessment pipeline established by organizations such as the American Malting Barley Association (AMBA) and the Canadian Malting Barley Technical Center (CMBTC). As the craft malting and brewing industries grow, they seek opportunities for market differentiation and have actively encouraged barley breeders to develop lines more suitable for their products (Brewers Association, 2014). Additionally, craft maltsters are obliged to secure at least half of their barley from within an ~800-km radius of their facility and need access to locally adapted cultivars (Craft Maltsters Guild, 2022). A few released cultivars have been geared toward craft maltsters, notably the winter-habit 'Avalon' by the Virginia Tech (PI 700308) and the spring-habit 'Butta-12' (PI 692639; Gallagher et al., 2020) by the University of California-Davis, both of which are adapted to areas outside of the primary barley growing regions of the US Mountain-West and the Canadian Prairie. These have both been embraced by craft maltsters with positive comments about their flavor contributions, but these are the exception rather than the rule (Gallagher et al., 2020; Manning, 2022). 'Lontra' (Reg. no. CV-378, PI 702797) was evaluated in multiple environments during selection and has performed particularly well in the Klamath basin on the Oregon and California border. This region has a history of growing malting barley, and while greatly reduced from its peak, there is interest in increasing acreage, especially of winter barley.

Lontra is a selection from a population of doubled haploids developed from two crosses made with the heritage

Abbreviations: AMBA, American Malting Barley Association; ASBC, American Society of Brewing Chemists; CCRU, Cereal Crops Research Unit; FAN, free amino nitrogen; FGDB, fine grind dry-basis; OSU, Oregon State University; S/T, soluble to total nitrogen ratio; UC-IREC, University of California Intermountain Research and Extension Center.

malting cultivar 'Maris Otter' (winter, two-row; Hornsey, 2011) – Maris Otter × 'Violetta' and Maris Otter × '04-028-36', respectively. 'LCS Violetta' is an AMBA-listed, winter, two-row cultivar (Limagrain Cereal Seeds, 2022) and the experimental line 04-028-36 is a winter, two-row selection from Ackermann Saatzucht GmbH & Co. Maris Otter, lauded by brewers for its flavor and brewhouse performance, is arguably the most well-known malting barley cultivar of the 20th century and considered by some to be the "Rolls-Royce" of malts (Simpsons Malt, 2023). Soon after its release in the 1960s, Maris Otter became the dominant winter malting barley in the United Kingdom but over time was surpassed agronomically by contemporary cultivars, eventually falling off the UK's recommended list in 1989 (Hornsey, 2011). While no longer listed, it maintains a small but notable market share and, as of 2020, still made up 1.9% (31,261 t) of all UK malting barley purchases, the largest percentage of any cultivar not currently recommended by the Maltsters' Association of Great Britain (MAGB) (Maltsters' Association of Great Britain, 2019). Current market demand for this and other heritage cultivars has spurred interest in the contributions of these heirlooms to beer flavor and in the potential of capturing these attributes in contemporary cultivars.

Despite the perception that certain malting barley cultivars contribute positively to beer flavor, the scientific evaluation of this connection is fairly novel. Herb et al. (2017) were the first to publish a peer-reviewed study showing that barley genotype contributes to beer flavor, and a series of follow-up studies confirmed and expanded upon this contribution (Bettenhausen et al., 2020; Morrissy et al., 2021; Sayre-Chavez et al., 2022; Windes et al., 2021). This research used a workflow of malting, brewing, sensory, and metabolomics that was developed to expand the evaluation of potential cultivars for the craft malting and brewing industry.

Malting barley cultivars in North America are typically evaluated through a pipeline established by AMBA or the CMBTC to recommend cultivars, which can be challenged by an overload of submissions. While this pipeline is very effective at identifying lines that will meet the needs of the majority of their members, it is not designed for evaluation of niche lines of interest to subsets within the malting and brewing supply chain. Craft maltsters and brewers are interested in novel barley cultivars that provide marketable traits to their consumers (Craine et al., 2022). Working with industry and research collaborators, an alternate path for releasing cultivars relevant to the craft malting, brewing, and distilling industries has been developed. The Oregon State University (OSU) breeding program previously released 'Full Pint' and 'Oregon Promise', based on their positive contributions to beer flavor (Bettenhausen et al., 2020; Hayes et al., 2020; Hayes, 2014). Oregon Promise has also garnered interest for its heirloom heritage as it was a doubled haploid developed from a cross between the notable UK cultivar 'Golden Promise' and 'Full Pint' (Hayes, 2014; Thomas & Swanston, 2011).

Core Ideas

- Lontra malting barley meets the needs and expectations of craft maltsters and brewers.
- Lontra offers a new option for winter-habit malting barley in the Klamath basin.
- Lontra malting barley was evaluated in an alternate pipeline to the existing AMBA evaluation.

Lontra meets many of the commercial desires of the craft industries as it provides four unique attributes: (1) it has shown agronomic success in the Klamath basin, an area of interest to a large California craft-malting operation; (2) it is a daughter of the heritage malting barley Maris Otter, and thus has marketability associated with its parent; (3) it meets malt quality expectations in both pneumatic and floor malting processes; and (4) it has performed well in flavor evaluation trials.

2 | METHODS

2.1 | Breeding and field trials

Crosses of Maris Otter with Violetta and 04-028-36, respectively, were made in 2013 and a population of 85 doubled haploids was developed in 2014 and 2015. Doubled haploids were produced via anther culture following the methods of Cistué et al. (2003). Over the course of 4 years the initial population was culled based on agronomic metrics such as yield, disease resistance, and grain protein content as typical of the program's breeding evaluations. The original 85 selections were grown in the greenhouse and subsequently planted in field miniplots (2.3 m^2). Of these, 47 were selected for a preliminary yield trial (9.3 m^2 plots): 39 of Violetta/Maris Otter and eight of 04-028-36/Maris Otter. Of the 47 initial selections, 10 were selected to advance to a replicated yield trial: 7 of Violetta/Maris Otter and 3 of 04-028-36/Maris Otter. Finally, four selections, two of Violetta/Maris Otter and two of 04-028-36/Maris Otter, were advanced to a trial that included a full suite of agronomic, malting, brewing, sensory, and chemical analysis, the results of which are outlined by Morrissy et al. (2021).

Field trials at various stages were performed primarily at agricultural extension centers: the OSU Hyslop Crop Science Field Research Lab (Corvallis, OR); the Columbia Basin Agricultural Research Center (Pendleton, OR); and the UC Intermountain Research and Extension Center (Tulelake,

CA). Additionally, on-farm trials were held at the Herb Farm (Lebanon, OR). Detailed field trial information and agronomic data collection methodology can be found in previous manuscripts from this research group (Halstead et al., 2022; Morrissy et al., 2021).

2.2 | Malting and malt analysis

A variety of methods and batch sizes were used to produce malt evaluated over the course of life cycle of this cultivar evaluation. Malting batch size is as defined by Morrissy et al. (2022) and is briefly, micro-scale (<1 kg); mini-scale (<150 kg); and commercial-scale. Micro-scale malting was performed at OSU and at the Cereal Crops Research Unit (CCRU) (Madison, WI) using their respective malting protocols. Mini-scale malting was performed in 2019 at OSU and in 2021 at Admiral Maltings (Alameda, CA) and the protocols are outlined in the respective publications by Morrissy et al. (2021, 2022).

Malt analysis was performed either at the CCRU or at Hartwick College's Center for Craft Food and Beverage; each followed American Society of Brewing Chemists (ASBC) methods of analysis (American Society of Brewing Chemists, 2023). All analyses were benchmarked against the AMBA guidelines for all-malt brewing (AMBA, 2020). Malt parameters were used to calculate malt index scores based on the CCRU scoring system (maximum value = 70) (CCRU, 2022). This system assigns a numerical score to the results of each assay based on an established range that reflects the needs of all-malt brewers; the higher the score, the more appropriate the malt is for all-malt brewing.

2.3 | Brewing and beer analysis

Beers were brewed and analyzed with Lontra and other experimental lines in 2020 and 2021 by Deschutes Brewery and Seismic Brewing Co., respectively. Brewing protocols are described by Morrissy et al. (2021, 2022). Analysis of beers was performed using ASBC methods of analysis by the industry partners. Sensory was also performed by the industry partners following their established methods.

2.4 | Statistical analysis

Data were assessed using ANOVA, and mean comparisons were performed using Fisher's Least Significant Difference test. All statistical analysis was performed using the R environment for statistical computing (R Core Team, 2020).

3 | CHARACTERISTICS

3.1 | Agronomics

The 47 doubled haploids selected for a preliminary yield trial in harvest year 2017 at the Corvallis, OR, and Lebanon, OR, field sites were evaluated against a control, 'Wintmalt', an AMBA listed, winter-habit, two-row cultivar (Great Western Malting, 2012). From this, a subset was selected for trials in 2018 and then culled again for another pair of trials in 2019. For 2018 and 2019, trials were replicated (2 per entry) in Corvallis and were planted as a single-replicate in Lebanon. The results of Lontra compared with Wintmalt are shown in Table 1. Average plant height and test weight at both locations across all years were similar for both Lontra and Wintmalt. The 3-year average yield in Corvallis was similar between the two cultivars, but Lontra yielded substantially higher in 2019 while Wintmalt was higher in 2018. At the Lebanon field site, average yield was higher for Lontra, but data are skewed by an overall poor year in 2019 when lodging was problematic for all entries and especially so for Wintmalt. Lontra had higher average grain protein at both locations but was still in specification for all-malt brewing (≤12.0%). From the observations over the 3 years, Lontra appears more resistant to scald (caused by *Rhynchosporium commune*; Avrova & Knogge, 2012) compared with Wintmalt, with a noticeable difference at Corvallis and a slight difference at Lebanon. They both showed some susceptible reactions in 2018, but in 2019 at Corvallis differences were more striking: Wintmalt was 80% susceptible while Lontra was only 13% susceptible. Scald data were not observed at Lebanon in 2019. Lodging and brackling (AHDB, 2023) were also similar between the cultivars, with Lontra slightly less likely to lodge than Wintmalt. Lontra outperformed Wintmalt for plump kernels (~6% higher at each site) and Lontra was only out of specification for 1 station-year.

Lontra was advanced into the Oregon Malt Elite Trials (OMELT) for the 2020 and 2021 harvest years and benchmarked against three AMBA recommended cultivars—'Endeavor', 'Thunder', and Wintmalt (Hayes et al., 2019; Obert et al., 2009). Data from the replicated field trials in Corvallis are shown in Table 2. There was a significant cultivar × year interaction effect for scald, lodging, brackling, and yield and a significant cultivar effect for heading date. Test weight, plump/thin, and protein were only measured on one plot from each entry and thus were not analyzed using statistical tools. Generally, lines performed better in 2021 than 2020 as scald, lodging, and brackling were lower and yields were greater. Lontra outperformed the AMBA checks in 2020 with a 2,808 kg ha^{-1} yield advantage over the next highest line. In 2021 there was minor disease pressure and no lodging, and Lontra yielded similarly to Endeavor but was outyielded by

TABLE 1 Agronomic data of Lontra and Wintmalt from Corvallis, OR, and Lebanon, OR, in 3 years of evaluation. Data from the 2017 set are from a single standard yield trial plot, while data from 2018 and 2019 is the mean of two replicated standard plots.

Harvest Year	Cultivar	Height cm	Heading DOY	Scald % of plot	Lodging % of plot	Brackling % of plot	Plump >6/64″	Thin <5/64″	TW g L^{-1}	Yield kg ha^{-1}	Protein %
Corvallis, OR											
2017	Lontra	82	140	0	0	0	96	1	653	5,149.6	8.4
	Wintmalt	85	n.d.	0	0	0	99	0	654	4,772.3	9.1
2018	Lontra	96	122	45	5	30	93.5	1	653	5,538.6	10.6
	Wintmalt	98	124	53	0	28	90.5	1	675.5	7,227.2	9.3
2019	Lontra	101	117	13	18	13	97.3	0.2	642	7,110.2	10.5
	Wintmalt	92	121	80	35	10	80.1	1.6	578.6	5,214.4	9.8
3-year	Lontra	93	126.3	19.3	7.7	14.3	95.6	0.7	649.3	5,932.8	9.8
Average	Wintmalt	91.3	122.5	44.3	11.7	12.7	89.9	0.9	636	5,738	9.4
Lebanon, OR											
2017	Lontra	95	n.d.	5	0	n.d.	98	n.d.	685	7,548	9.3
	Wintmalt	100	n.d.	20	0	n.d.	99	n.d.	700	7,375	10.3
2018	Lontra	103	n.d.	75	90	n.d.	90	1	686	6,207.7	11.6
	Wintmalt	115	n.d.	75	n.d.	n.d.	87	2	687	6,483.7	9.3
2019	Lontra	105	n.d.	n.d.	70	n.d.	82.7	0.6	649.5	4,855.8	12.2
	Wintmalt	90	n.d.	n.d.	90	n.d.	66.7	1	620.6	2,655.1	11.7
3-year	Lontra	101	n.d.	40	53.3	n.d.	90.2	0.8	673.5	6,203.8	11
Average	Wintmalt	101.7	n.d.	47.5	45	n.d.	84.2	1.5	669.2	5,504.6	10.4

Note: n.d., no data.
Abbreviations: DOY, day of year; TW, test weight.

Thunder and Wintmalt. Notably, Lontra's 2020 yield was the third highest among the eight cultivar × year combinations and its 2021 yield was the fourth highest indicating stable yields between years. In both years, Lontra had the lowest percentage of scald, seeing no effect in 2021. Lontra also was less susceptible to lodging, notable in 2020 where lodging was particularly problematic, but saw similar rates of brackling to the other lines. In 2020, Lontra was the only entry to meet AMBA guidelines for plump and thin, but it did exceed the all-malt guidelines for grain protein. All entries were similar for plump and thin in 2021 and met malting guidelines; Lontra again exceed the protein guideline and was the highest of the four cultivars.

To further assess the cultivar, agronomic quality data relevant to malting (grain protein, kernel sizing, and test weight) and yield were collected in harvest years 2020 and 2021 at the Tulelake field site, an intended production area (Table 3). Lontra was evaluated against two released cultivars, Thunder and Lightning (Hayes et al., 2021), and other elite experimental germplasm from the OSU breeding program, two others in 2020 and four others in 2021. In 2020, grain protein, test weight, and plump (>6/64″) differed significantly between lines, however yield did not differ significantly among the five entries. Lontra was in the higher of two protein groupings (with Lightning) but all entries were suitable for all-malt brewing (≤12.0%). It did separate from all other entries as the least plump grain but was considered acceptable for malting (≥90%). It is notable that there were no significant differences in yield as the evaluation included the AMBA listed Thunder, a cultivar contracted on commercial acreage in the region. Results for the 2021 harvest showed significant separation for protein and yield. Lontra yielded close to the overall year average and out-yielded Lightning but yielded less than Thunder. Overall protein was greater in 2021 but Lontra's grain protein was similar between years. Lontra fell near the average among entries and was only significantly greater than Thunder. However, as with 2020, grain protein for all entries did not exceed 12.0%.

In harvest year 2022, Lontra was planted on a larger scale (0.40 ha) at the University of California Intermountain Research and Extension Center (UC-IREC) but only as a single replicate. This trial was evaluated against a smaller strip of Thunder barley also planted as one replicate at the UC-IREC (Table 4). Both of these large strips were planted with the intention to be harvested for commercial malting trials. The yield for Lontra was higher than the replicated plot average in 2020 but lower than 2021 and generally represents a stable yield performance year over year. Grain protein content was also stable compared with 2020 and 2021. Thunder had a higher yield but showed similar grain protein, plump

TABLE 2 Agronomic data comparing Lontra to three American Malt Brewing Association (AMBA)-listed cultivars from the Oregon Malt Elite Trials at Corvallis, OR, in harvest years 2020 and 2021. Mean separation was performed among parameters that showed a significant year × line interaction and were performed across both years.

Harvest Year	Cultivar	Heading DOY	Scald % of plot	Lodging % of plot	Brackling % of plot	Height cm	Plump >6/64″	Thin <5/64″	TW g L−1	Yield kg ha^{-1}	Protein %
Year × line	interaction	n.s.[†]	***	***	*	–	–	–	–	*	–
2020	Endeavor	106.7	88.3a	78.3a	53.3b	112.0	56.0	11.6	620.6	5,341.6d	11.5
2020	Thunder	107.3	95.0a	33.3b	78.3a	106.0	73.8	5.4	611.2	5,194.7d	12.6
2020	Wintmalt	114.0	51.7b	33.3b	43.3b	105.0	82.3	3.0	585.8	4,865.8d	11.9
2020	Lontra	109.7	15.0c	6.7c	41.7b	114.7	94.1	0.5	632.2	8,150.0bc	12.5
2020 avg.		109.4	62.5	37.9	54.2	109.4	76.6	5.1	612.5	5,888.0	12.1
2021	Endeavor	114.7	15.0c	0.0c	10.0c	104.7	95.3	0.6	697.9	7,846.7c	10.4
2021	Thunder	117.7	6.7 cd	0.0c	9.3c	108.3	98.7	0.2	703.1	9,475.6a	11.8
2021	Wintmalt	122.3	8.3 cd	0.0c	0.3c	104.0	98.2	0.2	711.1	9,081.3a	11.8
2021	Lontra	119.7	0.0d	0.0c	10.0c	105.0	97.4	0.1	657.4	7,876.3c	13.2
2021 avg.		118.6	7.5	0.0	7.4	105.5	97.4	0.3	692.4	8,570.0	11.8

Note: Letters following values indicate mean separation within groups. Entries using the same letters are not significantly different using LSD. "—" indicates a single replicate dataset and thus was not analyzed.
Abbreviations: DOY, day of year; TW, test weight.
*Significant at the 0.05 probability level. **Significant at the 0.01 probability level. ***Significant at the 0.001 probability level. †n.s., not significant.

kernels, and test weight. Thunder had a high percentage of thin kernels (4.0%) which exceeded the AMBA guideline (≤3.0%).

3.2 | Malting

Lontra was assessed for malt quality beginning with the 2016 harvest year. In the early stages of evaluation, it was assessed under standard malting protocols at the CCRU and benchmarked against AMBA guidelines. Table 5 shows micro malting data from 2016 to 2019 of Lontra compared with Wintmalt. Lontra met AMBA guidelines for all-malt brewing except for seven instances: extract (2018), soluble to total nitrogen ratio (S/T) (2017–2019), diatastic power (DP) (2016, 2019), β-glucan (2018), and free amino nitrogen (FAN) (2019). However, other than extract, these results fit within the range of the AMBA adjunct-brewing guidelines. Wintmalt fell outside of AMBA all-malt guidelines at the same rate over the survey. Lontra-2016 scored highest in the all-malt scoring system (68 out of 70) and Lontra scored higher in each year except for 2018 and over the 4 years had a higher average all-malt score than Wintmalt.

Micro-malting was also performed on samples of Lontra grown at three locations (Corvallis, Pendleton, and Tulelake) in harvest year 2020 to evaluate the effect of growing environment on malt quality attributes. Comparisons between Lontra and Thunder are shown in Table 6. Overall Lontra met AMBA all-malt guidelines for more parameters at more locations than Thunder and average malt quality only exceeded the guidelines for two parameters (S/T and FAN) as opposed to four for Thunder (diastatic power, alpha amylase, S/T, and FAN). The grain grown in Tulelake produced malt that best met the all-malt specifications based on all-malt score, and within the Tulelake site, Lontra produced malt more suitable for all-malt brewing than Thunder. Lontra's all-malt score was higher than Thunder when averaged across all locations. It should be noted that available seed quantity limited malting replicates to one per location, and thus statistical analysis was not performed.

The trend toward slightly higher proteolytic modification in the micro-malts (shown in both Tables 5 and 6) was confirmed in the mini-scale malts produced by Morrissy et al. (2021), with S/T (46.7%) and FAN (210 mg L^{-1}) above the all-malt guidelines but suitable for adjunct brewing. Malts produced in these trials used similar malting protocols as the micro-malts, which were geared toward promoting modification and designed to mimic parameters used by larger malting companies to produce uniform brewing malts. The correlation between steeping regime and overall malt modification is known (Bryce et al., 2010). Given the overall low β-glucan in all entries, these results imply that using an optimized steeping regime can be used to produce malts more in line

TABLE 3 Agronomic data from UC-IREC for harvest years 2020 and 2021. A selection of elite malting lines (2020 – 3; 2021 – 5) and the released cultivars Thunder and Lightning were evaluated for performance in the region.

Cultivar/Line	Protein***	Plump***	TW***	Yield
	%	>6/64″	g L^{-1}	kg ha^{-1}
2020				
DH140963	9.5a	97.2b	683.1 cd	6,494.9
DH141132	9.7a	96.7b	692.5bc	6,902.7
Lontra	10.7b	93.8a	676.2d	6,293.7
Lightning	10.7b	96.9b	706.2a	5,821.5
Thunder	9.4a	97.7b	695.0bc	6,712.2
2021				
DH140963	10.9b	99.0	645.2e	8,338.7b
DH141132	10.9b	97.8	656.3d	7,891.4c
DH141222	11.0b	98.7	680.8a	7,792.8c
DH141225	10.9b	98.9	679.7ab	8,299.0b
Lontra	11.1b	93.6	644.7e	7,590.6c
Lightning	11.7a	98.6	677.3b	7,192.5d
Thunder	10.0c	99.2	669.5c	8,956.8a

Note: Letters following values indicate mean separation within groups. Entries using the same letters are not significantly different using LSD. "—" indicates a single replicate dataset and thus was not analyzed.
Abbreviations: DOY, day of year; TW, test weight.
*Significant at the 0.05 probability level. **Significant at the 0.01 probability level. ***Significant at the 0.001 probability level. †n.s., not significant.

TABLE 4 Agronomic data from larger scale evaluations performed at UC-IREC during harvest year 2022. Thunder was planted in a 0.04-ha plot and Lontra was planted in a 0.40-ha plot.

Cultivar	Protein	Plump	Thin	TW	Yield
	%	>6/64″	<5/64″	g L^{-1}	kg ha^{-1}
Thunder	10.8	92.0	**4.0**	646.2	8,002.9
Lontra	11.5	**89.5**	0.6	639.7	6,904.4

Note: Bolded values are outside of American Malting Barley Association guidelines for all-malt brewing.
Abbreviations: TW, test weight.

with the needs of craft brewers. A malting protocol designed to reduce steep out moisture and germinate at lower temperatures should produce Lontra malt with lower proteolytic modification while keeping β-glucan in specification. From previous experience malting this line, depending on year, germination energy, and water sensitivity targeting a steep out moisture of 43–45% has shown to be effective at moderating proteolysis (data not shown).

Finally, to gain a perspective on Lontra's commercial potential for craft maltsters, it was evaluated under floor malting conditions using a mini-scale floor-malting protocol designed for cultivar evaluation by Admiral Maltings. In this assessment Lontra was compared with the AMBA-listed, spring-habit cultivar CDC Copeland (CMBTC, 2015). This cultivar is regularly contracted by Admiral Maltings in the Klamath basin. Both lines were malted to a British Pale Ale-style that mimicked Admiral's "Maiden Voyage" brand malt. Both lines were grown in Tulelake in the Klamath basin but at different field sites–Lontra at the UC-IREC while CDC Copeland was sourced as part of Admiral Maltings' contracted acreage at Cascade Farms. Lontra outperformed CDC Copeland with higher extract and lower overall proteolytic modification, more closely meeting desired specifications (Table 7). Lontra did still exceed AMBA guidelines for S/T and FAN, similar to other trials, but CDC Copeland was out of specification for those parameters as well as α-Amylase and extract. Some of CDC Copeland's malt deficiencies may likely be a result of poor agronomic conditions in 2021 that impacted spring barley more severely than winter (Gous et al., 2015; Wilson, 2020). Lontra grain was more suitable for malting than CDC Copeland with plumper, more homogenous grain. Lontra had a much higher percentage of plump kernels (>6/64″)—94.9% vs. 80.0%—and a lower percentage of thins (<5/64″) – 0.5% vs. 3.8%.

TABLE 5 Micro-malting data from the Cereal Crop Research Unit for Lontra and Wintmalt from harvest years 2016–2019 at Corvallis. Mean comparisons using years as replicates did not reveal any significant differences among the malting data.

Year	Cultivar	Protein %	Extract FGDB%	DP °ASBC	AA 20°DU	FAN mg L^{-1}	S/T %	β-glucan mg L^{-1}	Color °SRM	All-malt Score
2016	Lontra	12.0	83.0	186.0*	62.8	182.0	43.5	55.0	1.7	68.0
	Wintmalt	10.2	81.9	146.0	53.7	**201.0**	**48.1**	**116.0**	1.5	56.0
2017	Lontra	8.5	83.5	108.1	54.4	149.9	**49.6**	14.8	1.8	47.0
	Wintmalt	9.7	82.9	126.1	63.5	169.8	45.9	27.7	1.6	44.0
2018	Lontra	11.3	**80.3**	146.7	45.6	179.9	**50.8**	**145.4**	1.7	29.0
	Wintmalt	9.7	81.9	118.3	51.5	162.7	**52.2**	**136.2**	1.6	40.0
2019	Lontra	11.4	81.7	**177.2**	58.2	**211.9**	**49.2**	28.3	2.0	33.0
	Wintmalt	11.5	**79.5**	**154.9**	58.7	166.7	40.9	32.4	2.4	27.0
4-year	Lontra	10.8	82.1	154.5	55.3	180.9	48.3	60.9	1.8	44.3
Average	Wintmalt	10.3	81.6	136.3	56.9	175.1	46.8	78.0	1.8	41.8
AMBA all-malt	guidelines	≤12.0	>81.0	110–150	40–70	140–190	38–45	<100	1.6–2.8	Max. = 70

Note: Bolded values are outside of American Malting Barley Association guidelines for all-malt brewing.
Abbreviations: AA, alpha amylase; ASBC, American Society of Brewing Chemists; DP, diastatic power; FAN, free amino nitrogen; FGBD, fine grind dry-basis; S/T, soluble to total nitrogen ratio; SRM, standard reference method.

TABLE 6 Micro-malting data from 2020 crop year comparing Lontra to the malting barley cultivar Thunder at 3 locations.

Cultivar	Location	Protein %	Extract FGDB%	DP °ASBC	AA 20°DU	FAN mg L^{-1}	S/T %	β-glucan mg L^{-1}	Friability %	All-malt Score
Thunder	Corvallis	10.6	83.2	**180**	**97.1**	**307**	**58.3**	54	91.5	36
Thunder	Pendleton	10.8	86.0	**166**	**94.5**	**289**	**56.0**	48	92.7	36
Thunder	Tulelake	9.0	85.1	**117**	**84.7**	**254**	**58.9**	37	97.3	42
	Line avg.	10.1	84.8	**154**	**92.1**	**283**	**57.7**	46	93.8	38
Lontra	Corvallis	11.0	84.6	**166**	**75.4**	**240**	**50.1**	71	91.5	36
Lontra	Pendleton	12.0	83.0	**164**	**70.8**	**226**	**45.2**	73	87.2	39
Lontra	Tulelake	10.3	83.8	137	59.3	190	**47.1**	45	90.6	47
	Line avg.	11.3	83.4	156	68.5	**219**	**47.5**	63	89.8	41
AMBA all-malt guidelines	≤12.0	>81.0	110–150	40–70	140–190	38–45	<100	>80a	Max. = 70	

Note: Bolded values are outside of American Malting Barley Association guidelines for all-malt brewing. Friability guideline is not provided by the American Malt Barley Association (AMBA) and an industry recommendation was used in its place (Schoales & Heinrich, 2020). Malting data was reprinted with permission from Halstead et al. (2022).
Abbreviations: AA, alpha amylase; ASBC, American Society of Brewing Chemists; DP, diastatic power; FAN, free amino nitrogen; FGDB, fine grind dry basis; S/T, soluble to total nitrogen ratio.

TABLE 7 Mini-malting data of floor malts produced at Admiral Maltings in 2021. Malts were produced to mimic a commercial-type Pale Ale malt.

Line/Cultivar	Protein %	Extract FGDB%	DP ASBC	AA 20°DU	FAN mg L^{-1}	S/T %	β-Glucan mg L^{-1}	Color °SRM	Friability %
Lontra-floor	10.3	82.8	111	47.4	**194**	**50.4**	48	3.3	92.2
Copeland-floor	10.3	**79.1**	121	**73.6**	**219**	**56.2**	43	4.1	94.5

Note: Bolded values are outside of American Malting Barley Association guidelines for all-malt brewing.
Abbreviations: AA, alpha amylase; ASBC, American Society of Brewing Chemists; DP, diastatic power; FAN, free amino nitrogen; FGDB, fine grind dry basis; SRM, standard reference method; S/T, soluble to total nitrogen ratio.

3.3 | Brewing and sensory

Beers were produced using Lontra in 2020 and 2021 in a series of research projects evaluating the effect of barley cultivar on beer flavor. The first study by Morrissy et al. (2021) assessed Lontra against three of its siblings and Wintmalt, using a single malt, lightly hopped research recipe designed for cultivar differentiation. The beer produced with Lontra met brewhouse performance expectations and performed similarly to the Wintmalt control. In sensory evaluation, the Lontra beer was described as sweet aromatic, sweet, and floral and separated distinctly from its siblings but not from Wintmalt. The second study evaluated the floor malts produced at Admiral Maltings and evaluated Lontra against the spring-habit CDC Copeland using a recipe that more closely resembled the industry partner's offerings (Morrissy et al., 2022). The Lontra malt performed better in the brewhouse with greater mash efficiency and brewhouse yield. Sensory evaluation found the beers had some significant differences for specific descriptors but there was no significant difference in overall preference. Both of these studies indicate that while Lontra can provide some unique flavor attributes to beers, it will generally perform as expected in the brewhouse and sensory evaluation relative to current AMBA recommended cultivars.

4 | CONCLUSION

Lontra malting barley is a new cultivar that meets the requirements of craft maltsters and brewers. It is the third line from OSU, after Full Pint and Oregon Promise, to be released primarily for its unique contributions to malt and beer, but without evaluation via the AMBA-pipeline. Lontra was derived from a cross with the heritage malting barley Maris Otter and thus has market interest due to pedigree alone. Agronomically, it performs similarly to the AMBA-listed cultivars Endeavor, Thunder, and Wintmalt, and performs well in the Klamath basin, a target growing environment. Notably, Lontra appears to have improved resistance to scald over the AMBA checks. Malting assessments found that under standard malting protocols it will meet AMBA adjunct brewing guidelines and most of the all-malt guidelines, but under standard malting protocols, it is likely to exceed some those related to proteolytic modification (FAN & S/T). However, compared with the AMBA-check cultivars malted under the same protocols, it produced superior all-malt scores in nearly all site years. Using malting conditions to temper proteolytic modification (e.g., reduced grain moisture at germination on-set), Lontra is likely to meet the specifications for all-malt brewing. A multi-location trial found that Lontra produced superior malt quality compared with Thunder across three locations, with the best malt coming from grain grown in the Klamath basin. Unique to this evaluation was its assessment under a floor-malting protocol and in brewing evaluations where it outperformed the AMBA-listed CDC Copeland for malt quality. The release of Lontra provides a new option for growers in the Pacific Northwest that are interested in planting winter barley for the craft industry.

5 | AVAILABILITY

The production of certified classes of seed is proceeding as follows. Breeder seed was produced from head row purification blocks at Hyslop Farm, near Corvallis, OR, in 2021. Approximately one-quarter of an acre of this seed was planted in the fall of 2022 in Othello, WA, by Washington State Crop Improvement Association to produce foundation seed. This seed will be harvested in 2023. Seed for one acre (~50 kg) will be saved for planting a second round of foundation seed increase in the fall of 2023. The balance will be available for sale as foundation seed and can be used to produce registered and/or certified classes of seed.

Lontra was released with a nonexclusive license. There is a one-time application fee of $250 for each nonexclusive license. Those interested in a license should contact Denis Sather at the OSU Office of Commercialization and Corporate Development (denis.d.sather@oregonstate.edu). Lontra seed, for planting purposes, can only be sold as a class of certified seed with a royalty of $0.03/lb (approximately $0.67/kg). The $0.03/lb royalty will be paid on sale of this seed. All grain harvested from the certified production must be disposed of by malting or feeding, unless permission is obtained in writing from OSU to use the seed for other purposes, including replanting.

U.S. Plant Variety Protection (PVP) will not be sought for Lontra due to the special status of malting barley in the United States, where the malting barley supply chain is based on sale of certified seed. By specifying that all sales for planting purposes must be a class of certified seed we will ensure that growers will be purchasing seed from the seed dealers with nonexclusive licenses. There is not an open market in the United States for malting barley not grown from a class of certified seed: the risk to the maltster is too great. The cultivar will be protected by Federal Seed Law and OSU recognized as the owner of the cultivar. Furthermore, Oregon, Idaho and Washington state trademarks will specify that the cultivar can only be sold under the name of Lontra. Seed of Lontra has also been deposited into the USDA-ARS National Laboratory for Genetic Resources, where it will be available immediately upon publication.

AUTHOR CONTRIBUTIONS

C. Morrissy: Data curation; formal analysis; investigation; writing—original draft; writing—review and editing. **T. Filichkin**: Data curation; investigation. **S. Fisk**: Data

curation; formal analysis; investigation; writing—review and editing. **L. Helgerson**: Data curation; investigation. **C. Davenport**: Data curation; investigation; methodology. **R. Silberstein**: Data curation; investigation. **D. Culp**: Data curation; investigation. **P. Hayes**: Conceptualization; methodology; project administration; resources; supervision; writing—review and editing.

ACKNOWLEDGMENTS

We would like to thank the following for contributions to this work: Dr. Daniela Carrijo, Margaret Halstead, and other members of the OSU Barley Project for contributions throughout this process. Dr. Harmonie Bettenhausen at the Hartwick College Center for Craft Food and Beverage for collaboration and support of all barley, malting, and beer flavor work. The teams at Admiral Maltings, Deschutes Brewery, pFriem Family Brewers, Seismic Brewing Co., and other industry partners who have supported this and similar work on beer flavor.

This research was initially supported by the Brewers Association and subsequently by the Oregon State University Agricultural Research Foundation Barley Research Fund.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

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How to cite this article: Morrissy, C. P., Filichkin, T., Fisk, S. P., Helgerson, L., Davenport, C., Silberstein, R., Culp, D., & Hayes, P. M. (2023). Registration of 'Lontra' malting barley: A two-row, winter-habit cultivar of interest to the craft malting and brewing industries. *Journal of Plant Registrations*, 1–10. https://doi.org/10.1002/plr2.20316