

Release of Thunder Two-row Winter Barley

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Corvallis, OR 97331

Thunder is a two-row winter malting barley (*Hordeum vulgare* subsp. *vulgare*) developed by Oregon State University (OSU). The variety was released based on its malting quality profile and agronomic performance, primarily under irrigated conditions in southern Idaho. These results warrant commercial assessment of Thunder under irrigated conditions in the Columbia Basin (Oregon and Washington). The Klamath Basin of Oregon and California is also a potential production area. The variety has potential under dryland conditions in Oregon and Washington. In high rainfall environments, west of the Cascades, a comprehensive program of fungicide protection is required for optimum performance. Thunder is on the American Malting Barley Association (AMBA) recommended list for 2019. The “Thunder” was chosen based on the enthusiastic response it has elicited from growers and Great Western Malting. This name is approved by the USDA.

Thunder is a rough-awned, two-row winter barley with short rachilla hairs. It is a doubled haploid derived from the F1 of the cross “Wintmalt” x “Charles”. Wintmalt is a two-row winter barley developed by KWS (Germany). It is the most widely-grown winter two-row malting barley in the Pacific Northwest. Charles, developed by the USDA-ARS program (Aberdeen, ID), was the first winter two-row malting barley variety approved by AMBA. The cross between Wintmalt and Charles was made in 2009 at Oregon State University. Thunder was tested in Preliminary, Advanced, and Elite yield trials by the OSU Barley Program prior to submission to regional trials and the AMBA qualifying program. It passed the AMBA Pilot and Plant Scale Programs and is now on the AMBA Recommended Variety List.

Malting quality

Malting barley varieties must meet stringent requirements for AMBA approval. The two AMBA checks are currently Wintmalt and Endeavor. Endeavor is a successor to Charles, and was also developed by the USDA-ARS program (Aberdeen, Idaho). Thunder meets or exceeds the performance of both checks for adjunct malt specifications. Meeting adjunct malt specifications is the goal of 61% of AMBA members. In malting quality specifications for adjunct malts, higher values are better for plump seed, malt extract, diastatic power, alpha amylase, and free amino nitrogen (FAN). There are no upper limits. There are upper and lower boundaries for grain protein, wort protein, and the soluble/total protein ratio (S/T). Lower values are better for

wort beta-glucan. For all characters except S/T, Thunder is better than the checks, or equivalent, in thirteen micro-malting tests (Table 1). It has a noticeable improvement for malt extract (1% higher than the high check) and wort beta-glucan (126 ppm lower than the high check). The S/T value is just over the AMBA thresholds, as is that of Endeavor. The S/T can be adjusted by minor modifications to the malting protocol. For purposes of perspective, micro-malting quality is summarized for Thunder and the checks from four locations in the national Winter Malting Barley Trial (WMBT) (Table 2). In these data, Thunder comes closest to meeting AMBA specifications. Commercial malting generates the best possible malting quality data, but is only available at large scales. Thunder meets commercial expectations in commercial assessment by Great Western Malting (Table 3).

Agronomic performance

In the overall agronomic summary (Table 4), there are more station years of data for agronomic traits than for malting quality traits. This is due to the limited availability of no-cost malt analyses and the high cost of for-fee analyses. Overall, Thunder is higher yielding than Endeavor and equivalent to Wintmalt. Thunder and Endeavor are both seven days earlier to head than Wintmalt, an advantage for reducing the number of irrigations required and avoiding summer heat stress, which can reduce malting quality. Thunder has the shortest height of the three varieties, usually an advantage for avoiding lodging. In these data, however, Wintmalt had the lowest percentage of lodging. Brackling (a measure of straw breakage at harvest) is highest for Thunder and Endeavor. Brackling can result from uncontrolled fungal diseases and by harvest beyond the optimum date. Brackling is measured only by programs west of the Cascades, a region where - as is noted in the section on abiotic and biotic stress resistance - a comprehensive program of fungicide protection is recommended. Furthermore, in small plot trials, harvest must be delayed until the latest maturing entry is ready. This can penalize early-maturing types, such as Thunder and Endeavor, in terms of brackling scores.

The South Central Idaho Extension data from irrigated trials (Table 5) show the potential of Thunder where available data indicate that it is most adapted. Thunder has a ~ 900+ lb/acre yield advantage over the checks, together with excellent test weight, earliness, short plant height, lodging resistance, good grain protein, and a high percentage of plump kernels. The area represented by these trials is where Thunder has been tested by Great Western Malting for commercial potential. In a broader sample of irrigated environments (Table 6), Thunder maintains an edge over the checks for all agronomic traits.

Under higher rainfall dryland conditions (Table 7), the limited data available indicate that Thunder is higher yielding than the checks and has excellent test weight, kernel plumpness, and short plant height. Lodging was not observed. The potential of Thunder in the region represented by these trials (e.g. Pendleton and into the Palouse) merits assessment. Under even drier conditions (Gilliam County, OR) in 2018, Thunder had a 240 lb/acre yield advantage over Wintmalt and met all other agronomic criteria for malting barley (Table 8). Endeavor was not included in this trial. Malting and malt analyses of this grain are in progress.

Thunder, and the checks, can potentially produce high quality malting barley west of the Cascades and in regions beyond the intended area of adaptation. In 13 station years of testing in western Oregon (Table 9), Wintmalt maintained a slight edge over Thunder for all traits.

Thunder, in turn was generally superior to Endeavor. At 18 sites across the US in the WMBT (Table 10) Endeavor has a slight advantage over Thunder and Wintmalt for most traits. At Bonner's Ferry, ID, Thunder was higher yielding than Endeavor and slightly higher yielding than Wintmalt. Other attributes were similar, except for lodging, where Thunder had the highest value. A lodging percentage of 21%, while not ideal, is acceptable.

In summary, Thunder is agronomically competitive with the checks under all production systems. It is superior to the checks under irrigated conditions in South Central Idaho, warranting commercial assessment with irrigation elsewhere in the Pacific Northwest (e.g. the Columbia Basin, Central Oregon, and the Klamath Basin of Oregon and California). The limited data available indicate that Thunder merits commercial assessment under dryland conditions. West of the Cascades, the agronomic data indicate that a comprehensive program of fungicide protection is recommended for maximum yield and quality.

Resistance to abiotic and biotic stresses

Winter injury is the principal threat to fall-planted malting barley. In most trials, Thunder and the checks had no issues with winter survival. Results from trials where differential injury was observed are shown in Table 12. In the South Central Idaho Extension trials, Thunder had the highest average survival, followed by Endeavor and then Wintmalt. The reverse was true across other irrigated breeding trials. In this data set, the advantage of Wintmalt over Endeavor and Thunder was due to two environments: Oakley, ID and Hermiston, OR. At these locations and years, the lowest temperatures were -12°F and -9°F, respectively. In the dryland data set, Wintmalt had the higher survival, followed by Thunder and Endeavor. At Mt. Vernon, WA, Wintmalt had the highest winter survival. However, survival issues were likely due to factors other than temperature. The lowest temperature at this location was 20°F. At Ithaca, New York, Thunder, Endeavor, and Wintmalt had comparable survival values. In the TCAP LTT trial, a set of 882 winter and facultative barley accessions were evaluated at 23 locations around the world. Averaged across the 8 environments where there was differential winter survival, Thunder was superior to Wintmalt and Endeavor. Across all environments, Wintmalt had the highest average survival: a 1% advantage over Thunder and a 9% advantage over Endeavor. Winter survival was 100% in all the western Oregon trials.

In summary, the causes of winter injury will likely vary with environment and can include absolute low temperature, frost heaving, and/or snow mold. Therefore, it is reasonable to focus on winter survival data from target areas of adaptation. It is also important to establish an acceptable threshold for winter injury: 50% damage may be acceptable in many circumstances, due to the ability of barley to tiller profusely in response to reduced inter-plant competition. Thunder is not a breakthrough in winter survival, but it is competitive with current varieties. Growers are encouraged to use agronomic practices that enhance the likelihood of survival, such as maximizing surface residue and planting into deep furrows.

The principal fungal disease threats to fall-planted barley in the Pacific Northwest are scald (incited by *Rhynchosporium commune*), stripe rust (incited by *Puccinia striiformis* fsp. *hordei*) and leaf rust (incited by *Puccinia hordei*). These diseases are generally most prevalent west of the Cascades. Severe epidemics of leaf rust in the region are a new, if occasional, phenomenon. No disease was reported from the Southern Idaho Extension trials. Considering all the

environments where disease was reported (Table 13), Thunder, Endeavor, and Wintmalt are susceptible to scald and leaf rust. Thunder, Endeavor, and Wintmalt would be considered resistant/moderately resistant to stripe rust. Data from the Regional Barley Stripe Rust trial (Table 14), however, indicate that Thunder can develop higher stripe rust disease severities (similar to those of the Baronesse, the moderately susceptible check). Wintmalt and Endeavor were not included in these trials.

Barley Yellow Dwarf Virus (BYDV) can be a serious disease of fall-planted barley. Determining levels of resistance to this disease can be challenging when relying on natural and even infestations of the aphid vector. One approach is to assess germplasm planted very early in the fall, when aphid flights are most likely to occur. Under these conditions, Thunder - when compared with other the recently released variety “Buck” and the average of advanced breeding lines - displayed the lowest level of symptoms in 2017 and was slightly above average in 2018 (Table 15). Endeavor and Wintmalt were not included in these trials.

Preliminary data are available on diseases not yet endemic (Fusarium Head Blight (FHB)) or reported (race TTKSK (aka UG99) of stem rust) in the Pacific Northwest. With only one environment of data available, Thunder was more resistant to FHB than Endeavor and Wintmalt (Table 16). At the seedling stage, Thunder is resistant to stem rust race TTKSK with an infection type of 0;1- (under controlled conditions). At the adult plant stage the disease severity was 25% compared to the wheat check (Jagger) at 100% under field conditions in Kenya.

In summary, Thunder is comparable to the checks in terms of resistance to pathogens most prevalent west of the Cascades. Growers of fall-planted malting barley in this region are encouraged to use insecticide seed treatments for control of BYDV and foliar fungicides for control of scald, stripe rust, and leaf rust. Organic growers need to consider the risks of producing Thunder, and the commercially available checks, west of the Cascades. In all environments, disease resistance is an excellent insurance policy and future variety releases will have higher levels of resistance to the endemic diseases.

Seed production of Thunder

Breeder’s seed was produced from head row purification blocks at Hyslop Farm in 2017 and 2018. The 2017 seed was used for Research Foundation seed production at Burley, ID. The block was inspected and certified by the Idaho Crop Improvement Association and used to plant Registered seed at Burley in the fall of 2018. The 2018 Breeder’s seed was sent to Washington Crop Improvement for Foundation seed production and was planted at Othello, WA in the fall of 2018.

Licensing and royalties

Thunder is recommended for release with non-exclusive licenses. Release with non-exclusive licenses is a condition for receipt of research funding from the American Malting Barley Association. There will be a one-time application fee of \$250 for each non-exclusive license. Those interested in a license should contact Denis Sather at the OSU Office of Commercialization and Corporate Development (denis.d.sather@oregonstate.edu). Thunder can only be sold as a class of certified seed with a royalty of \$0.03/lb., except for the fall of 2019. In the fall of 2019, the sale of common seed will be allowed by Golden Valley Warehouses, Inc.

(Burley, Idaho) in order to meet production needs of Great Western Malting for the 2020 harvest. The \$0.03/lb royalty will be paid on sale of this seed. The reason for this exemption is that there will not be sufficient volume of certified classes of seed to meet the projected demand of Great Western Malting. The amount of common seed sold in 2019 by Golden Valley Warehouses, Inc. will not exceed 450 tons. All grain harvested in 2020 must be disposed of by malting or feeding, unless permission is obtained - in writing – from OSU to use the seed for other purposes, including re-planting.

Variety protection

Plant Variety Protection will not be sought for Thunder because the malting barley supply chain is based on sale of certified seed. By specifying that all seed sales must be a class of certified seed (except for fall, 2019) we will ensure that growers will be purchasing seed from the seed dealers with non-exclusive licenses. It is possible that some growers would elect to purchase certified seed, grow out the seed, and retain seed for future feed production. Given the availability of other feed varieties and the generally low price of feed barley – as compared to malting barley – the potential loss of revenue is not significant. The variety will be protected by Federal Seed Law and OSU recognized as the owner of the variety. Furthermore, Oregon, Idaho and Washington state trademarks will be applied for that specify the variety and only be sold under the name of “Thunder”.

Notice of the release and deposition in seed repositories

A variety release for Thunder will be submitted to the Journal of Plant Registrations and seed will be deposited with USDA collections, as required for such releases.

Acknowledgements

The development of Thunder was supported by the American Malting Barley Association, Great Western Malting, the Oregon Agricultural Experiment Station, and the Oregon Wheat Commission.

In the following tables, mean values across station years (environments) are followed by ranges across the same environments. Thunder is identified by its experimental designation – 10.0777

	Plump on 6/64"	Barley Protein	Malt Extract	Wort Protein	S/T	DP	Alpha- amylase (20°DU)	Beta- glucan (ppm)	FAN (ppm)
Line	(%)	(%)	(%)	(%)	(%)	(°ASBC)	(20°DU)	(ppm)	(ppm)
10.0777	95.0	10.8	82.9	5.40	53.4	156	112.4	38	270
	87.7 - 99.1	8.9 - 14.1	80.1 - 84.7	4.72 - 6.89	46.9 - 61.7	114 - 216	94.8 - 133.1	15 - 89	220 - 338
Endeavor	82.6	10.9	81.8	5.14	51.7	160	99.9	164	239
	62.9 - 95.6	9.4 - 13.5	80.0 - 83.7	4.42 - 6.29	44.2 - 59.7	103 - 222	83.6 - 114.7	51 - 357	206 - 294
Wintmalt	95.3	10.8	81.0	4.20	41.9	143	57.2	72	170
	88.8 - 98.9	8.8 - 14.6	77.7 - 83.1	3.55 - 5.19	34.6 - 48.1	120 - 183	48.9 - 65.0	28 - 150	146 - 203
Station Years	13	13	13	13	13	13	13	13	13

	Plump on 6/64"	Barley Protein	Malt Extract	Wort Protein	S/T	DP	Alpha- amylase (20°DU)	Beta- glucan (ppm)	FAN (ppm)
Line	(%)	(%)	(%)	(%)	(%)	(°ASBC)	(20°DU)	(ppm)	(ppm)
10.0777	87.9	12.9	80.9	5.92	47.5	177	125.5	43	333
	80.6 - 96.5	11.3 - 14.0	78.7 - 83.2	5.50 - 6.37	44.5 - 52.3	120 - 232	97.7 - 143.8	21 - 79	299 - 357
Endeavor	81.4	11.2	81.9	5.33	50.0	150	108.0	117	279
	64.0 - 91.6	10.6 - 12.0	79.5 - 83.3	5.23 - 5.55	45.3 - 53.7	104 - 218	97.9 - 117.2	64 - 195	270 - 298
Wintmalt	85.5	13.2	78.2	4.80	37.3	186	76.2	123	221
	78.8 - 94.6	12.0 - 14.9	74.7 - 81.4	4.18 - 5.50	35.0 - 41.5	172 - 197	54.8 - 109.4	87 - 178	174 - 311
Locations	4	4	4	4	4	4	4	4	4

	Malt Extract	DP	Alpha- amylase (20°DU)	Total Protein	Wort Protein	S/T	Beta- glucan (ppm)	FAN (ppm)	Plump on 7/64	Friability
Line	(%)	(°ASBC)	(20°DU)	(%)	(%)	(%)	(ppm)	(ppm)	(%)	(%)
10.0777	81.1	161	71.3	11.80	5.92	50.3	70	248	85.5	83.5
	80.2 - 81.8	146 - 169	62.8 - 78.9	9.97 - 13.2	5.01 - 6.45	41.3 - 57.4	49 - 113	178 - 297	76.3 - 89.6	77.4 - 93

The protein and percent plump are based on malt, not grain (as in Tables 1 and 2) and the percent plump in on a 7/64 rather than a 6/64 screen

	Yield	Test Wt	Heading Date	Height	Lodging	Brackling	Protein	Plump
Line	(lbs/ac)	(lbs/bu)	(Julian)	(inches)	(%)	(%)	(%)	(% on 6/64)
10.0777	5433	49	119	35	33	44	10.9	89.6
	1138 - 9571	38.4 - 55.7	96 - 144	19 - 44	0 - 90	8 - 90	8.4 - 14.3	48 - 99
Endeavor	5182	50	119	37	32	45	10.8	74.7
	1147 - 10221	40.9 - 55.2	85 - 146	25 - 48	0 - 100	13 - 90	8.5 - 13.8	46 - 96
Wintmalt	5430	49	126	36	22	22	10.5	89.2
	555 - 9230	37.4 - 55.9	109 - 149	24 - 45	0 - 100	0 - 57	7.9 - 14.6	47 - 99
Station Years	51	45	32	49	32	18	21	32

Agronomic performance of 10.0777 and check cultivars in the irrigated University of Idaho Southern Extension trials .							
	Yield (lbs/ac)	Test Wt (lbs/bu)	Heading Date (Julian)	Height (inches)	Lodging (%)	Protein (%)	Plump (% on 6/64)
10.0777	7591	51.3	139	32	23	11.1	93.5
	6408 - 8736	51.1 - 51.5	130 - 151	28 - 33	0 - 59	10.6 - 11.5	91.4 - 97.0
Endeavor	6540	51.7	142	37	31	11.1	81.6
	5390 - 7728	50.2 - 52.7	131 - 155	32 - 43	0 - 88	10.7 - 11.5	76.5 - 91.2
Wintmalt	6664	50.5	143	34	24	11.3	90.1
	4694 - 8784	49.3 - 51.1	134 - 156	30 - 37	0 - 64	10.4 - 12.4	89.5 - 91.3
Station Years	5	3	5	5	5	3	3

Agronomic performance of 10.0777 and check cultivars across 11 irrigated environments.							
	Yield (lbs/ac)	Test Wt (lbs/bu)	Heading Date (Julian)	Height (inches)	Lodging (%)	Protein (%)	Plump (% on 6/64)
10.0777	7728	51.5	133	39	45	13.6	90.9
	5375 - 9571	48.0 - 55.0	125 - 144	31 - 44	0 - 90	12.9 - 14.3	73.0 - 98.0
Endeavor	7211	52.9	133	42	53	13.5	81.0
	4299 - 8578	50.8 - 55.2	126 - 144	33 - 48	0 - 100	13.2 - 13.8	45.6 - 95.6
Wintmalt	7318	50.8	138	39	43	12.5	88.0
	4429 - 9230	48.1 - 52.8	129 - 148	33 - 45	0 - 90	11.5 - 13.5	67.7 - 98.5
Station Years	11	10	6	10	6	2	8

Agronomic performance of 10.0777 and check cultivars across 3 dryland environments*						
	Yield (lbs/ac)	Test Wt (lbs/bu)	Height (inches)	Protein (%)	Plump (% on 6/64)	
10.0777	4890	51.5	37	11.2	94.3	
	4213 - 6002	48.3 - 53.8	32 - 40	8.5 - 13.9	90 - 98	
Endeavor	4762	53.0	41	11.2	78.7	
	3457 - 6041	51.1 - 54.3	36 - 43	8.5 - 13.8	66 - 96	
Wintmalt	4490	50.4	38	11.6	87.3	
	3218 - 5510	45.7 - 52.8	33 - 41	9.6 - 14.6	71 - 97	
Station Years	3	3	3	3	3	

* (Pendleton 2014, 2015; Pullman 2014)

Agronomic and grain quality parameters from Rattray Ranch, Condon, Oregon 2018.				
Variety	Yield (lbs/ac)	Test Wt (lbs/bu)	Protein (%)	Plump (% on 6/64)
10.0777	2600	51.4	8.6	98
Wintmalt	2360	49.6	9.2	96

Agronomic performance of 10.0777 and check cultivars across years and locations in Western Oregon.								
	Yield (lbs/ac)	Test Wt (lbs/bu)	Heading Date (Julian)	Height (inches)	Lodging (%)	Brackling (%)	Protein (%)	Plump (% on 6/64)
10.0777	5875	51.9	111	39	30	46	10.0	91.0
	3928 - 8047	48.7 - 55.2	103 - 124	31 - 44	0 - 70	8 - 90	8.4 - 11.3	79 - 99
Endeavor	5466	52.0	107	40	28	45	10.0	71.5
	3294 - 7348	50 - 54.4	96 - 115	30 - 45	0 - 93	13 - 90	8.7 - 12.1	52 - 92
Wintmalt	6147	51.3	117	39	15	23	9.7	92.8
	3943 - 9154	44.9 - 54.8	110 - 125	35 - 44	0 - 57	0 - 57	7.9 - 11.8	78 - 99
Station Years	13	13	8	13	11	12	11	13

Agronomic performance of 10.0777 and check cultivars from the Winter Malting Barley Trial (WMBT) 2016.								
Line	Yield (lbs/ac)	Test Wt (lbs/bu)	Heading Date (Julian)	Height (inches)	Lodging (%)	Brackling (%)	Protein (%)	Plump (% on 6/64)
10.0777	4447	46.5	121	31	28	63	11.8	90.5
	2327 - 9257	38.4 - 53.2	96 - 144	22 - 42	0 - 89	40 - 87	10 - 13.6	82.9 - 96.7
Endeavor	4536	48.4	121	34	29	66	12.5	75.7
	1732 - 10221	40.9 - 54.8	85 - 146	25 - 47	0 - 100	43 - 88	12 - 13	56 - 94.3
Wintmalt	4278	47.5	130	33	18	28	10.5	91.3
	555 - 8432	37.4 - 53.4	109 - 149	25 - 43	0 - 100	23 - 33	10 - 11	85 - 97
Locations	18	14	13	18	12	2	2	6

Agronomic performance of 10.0777 and check cultivars in the University of Idaho cereal extension trials grown in Bonners Ferry, ID.								
	Yield (lbs/ac)	Test Wt (lbs/bu)	Height (inches)	Lodging (%)	Plump (% on 6/64)			
10.0777	6406	51.7	28	14	97.2			
	5808 - 7536	50.7 - 52.8	24 - 31	0 - 23	96 - 99			
Endeavor	4672	53.1	32	3	96.1			
	4176 - 5424	51.4 - 54.1	28 - 34	0 - 10	95 - 98			
Wintmalt	6100	51.9	31	0	97.8			
	5328 - 7392	50.5 - 52.9	27 - 34	0 - 0	96 - 99			
Station Years	3	3	3	3	3			

Winter survival (%) in seven different data sets in which there was differential winter survival.								
Line	South Idaho Extension	Irrigated Breeding Trials	Winter Malting Barley Trial	Dryland (Pendleton, OR)	Wetland (Mount Vernon, WA)	Ithaca, New York	TCAP LTT*	Average
10.0777	91	66	93	80	45	71	46	69
	68 - 100	40 - 95	84 - 100	-	40 - 50	43-95	0 - 100	0 - 100
Endeavor	85	70	86	73	47	71	21	61
	35 - 100	43 - 100	61 - 96	-	44 - 50	47-93	0-80	0 - 100
Wintmalt	79	85	90	93	79	74	34	70
	41 - 100	72 - 100	73 - 98	-	73 - 84	63-97	0 - 95	0 - 100
Station Years	5	5	5	1	2	3	8	29
* See text for definition								

Disease response of 10.0777 and check cultivars - west of Cascades			
	Scald	Stripe Rust	Leaf Rust
Line	(%)	(%)	(%)
10.0777	61	7	74
	35 - 90	0 - 13	40 - 92
Endeavor	77	2	72
	45 - 100	0 - 10	53 - 92
Wintmalt	47	13	55
	12 - 92	0 - 30	40 - 68
Station Years	14	7	4

Barley stripe rust severity of 10.0777 & checks in the Barley Stripe Rust Screening Trial						
Barley Stripe Rust (%)						
Line	Corvallis, OR		Davis, CA		Mt. Vernon, WA	Mean
	2016	2018	2016	2018	2016	
10.0777	50	17.5	5	60	30	33
Full Pint*	0	0	0	10	0	2
Baronesse**	30	15	30	60	30	33
Robust ***	53	45	75	85	50	62

(*susceptible, **moderately resistant, and ***resistant)

Barley Yellow Dwarf (BYDV) resistance of 10.0777 compared to the variety Buck and the trial average*.		
Line	Plot basis	Flag leaf
	(% plot infected)	(% incidence)
	2017	2018
10.0777	22	12
Buck	43	4
Trial average	62	11

*Early-planted fall trials. Corvallis, OR.

Fusarium head blight index and deoxynivalenon (DON) accumulation for 10.0777 and check cultivars. Warsaw, VA. 2017		
Line	FHB (index)	DON (ppm)
10.0777	7.1	1.52
Endeavor	31.4	7.34
Wintmalt	8.9	1.80