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ABSTRACT

Malt barley properties for three cultivars (Harrington, Klagas, and Robust) were evaluated in response to agronomic treatments: cover crops (beans-wheat and peas-oats-vetch), fungicide (Maneb, Tilt 7, and none), or nitrogen (0.0, 18.0, and 36.0, and kg/acre) treatments. In the fungicide study, the cultivar significantly influenced ($p \leq 0.05$) protein content, β-glucan, α-amylase activity, kernel weight, and germination energy. In the nitrogen study, all the measured properties were significantly affected ($p \leq 0.05$) by the barley cultivar. The moisture range of all the barley in this study was relatively low (9.3%–10.5%, wet basis) and within the acceptable range (≤ 14.0%) for malting. The plots not treated with nitrogen had a lower protein content (10.4%–11.0%, dry basis) under beans-wheat (b/w) cover crop. These low protein levels suggested an acceptability for malting. Robust had the highest germination energy (98%). Harrington and Klagas grown under b/w cover crop yielded a heavier kernel weight (40.2–46.4 g/1000 kernels) in the fungicide study.

INTRODUCTION

Barley is the third largest grain crop produced in the United States. During the past five years, between 2.1 and 2.8 million hectares (5.5–6.9 million acres) of barley were planted in the United States (USDA 2003). In 2001, Maine farmers harvested 10,521 hectares (26,000 acres) of barley, which is approximately 1% of the national harvest (USDA-Agricultural Statistics Data Base 2003). Both two-row and six-row barley is produced in the United States. Roughly 65% of the U.S. acreage is planted to six-row barley and the balance is planted to two-row barley. Most barley in the U.S. is grown for malt because of the price premium. Over 70% of the barley varieties planted in the U.S. is acceptable for malting, although 58% is used for feed (U.S. Grains Council 2003). Over 100 million bushels of barley are malted in the United States, most of which is used to make beer. The New England micro-brewery industry has grown rapidly, spurring interest in new local sources of malt. The development of malt barley industry in Maine would provide a new source of revenue for potato farmers who are seeking more profitable rotation crops.

The brewing industry uses both two-row and six-row barley with their standard of quality for the production of malt beverages. According to the U.S. Grains Council (2003), the official U.S. standards for malt barley includes grade identification, type (two- or six-row), protein content, moisture content, kernel weight, foreign material tolerances, germination capacity, and plumpness level. However, additional specifications are normally required in selecting six-row barley to determine diastatic power and α-amylase. Another criterion is β-glucan content, since this polysaccharide can form a highly viscous dispersion that leads to beer filtration problems.

Kendall (1994) summarized the quality factors that need to be considered during selection of barley for malting as follows:

1. acceptable variety,
2. barley can attain 95% germination,
3. less than 5% peeled and broken kernels,
4. moisture content ≤ 14%,
5. kernels have a uniform plumpness, and
6. protein content between 9% and 13%.

The objectives of this project were to identify critical agronomic factors affecting malting quality of barely grown in Maine. Cover crop, fungicide application, and nitrogen application were selected as key factors to be studied.

MATERIALS AND METHODS

Two 2-row cultivars (Harrington and Klagas) and one 6-row cultivar (Robust) grown at Rogers Research Farm, The University of Maine, Orono, were received in individually labeled paper bags (29

cm length × 17 cm width × 42 cm height). All the bags containing barley were stored at ambient temperature until tested for quality.

Experimental Design

A 3 × 3 × 2 factorial design was constructed for both nitrogen and fungicide experiments. The first factor was the barley variety (Harrington, Klagas, and Robust), the second factor was either the level of nitrogen fertilization (0.0, 18.0, and 36 kg/acre), or the fungicide (Maneb, Tilt, and none), and the third factor was cover crops (beans-wheat [b/w] or peas-oats-vetch [p/o/v]). Four replications of each treatment were made within each cover crop for a total of 72 representative barley samples.

Statistical Analysis

The statistical analyses were performed with Systat statistical software version 6.0.1. (SYSTAT, Evanston, IL). The data were analyzed by analysis of variance (ANOVA) to determine the individual effect and interaction of the three independent variables. Tukey's Honest Significant Different (HSD) test was applied when necessary to determine significant treatment effects. Statistical significance was determined at $p \leq 0.05$.

Moisture Content

The moisture content of the barley grain was determined by a Sartorius (Goetting, Germany) infrared moisture balance (Model YTCL610-D). About 1 g of barley (ground to pass 0.2-mm screen) was placed on the balance. The loss in weight due to moisture lost during infrared heating was monitored until constant. Moisture content was determined as the amount of water removed during heating.

Kernel Weight

A modification of Method Barley-2, D (ASBC 1992) was used to determine the kernel weight of the barley. Determination was simply done by counting 100 representative kernels 10 times. The weight of 100 kernels was recorded and accumulated by increments of 100 kernels up to a total of 1000 kernels. Determination was made in duplicate for each treatment.

Germination Energy

A modified method of germination described by MacGregor et al (1994) was used to determine the germination capacity of the barley. Each determination was done in a petri dish containing a single layer of Whatman No. 1 filter paper. The filter paper in the petri dish was moistened with 4 mL of distilled water. Fifty kernels from the representative samples were randomly selected for each determination and evenly spaced on the blotted filter paper. Each petri dish containing barley was then covered with its lid and incubated in a Bacteriological *Blue M* Incubator (Model "Budget," Blue Island, IL) at 20ºC and 90% relative humidity. The germinated kernels were monitored by recording the number of sprouted kernels after 24, 48, and 72 hours. Percent germination was determined as the number of germinated kernels divided by 50 kernels at a certain period of time. Final germination count in this analysis was at 72 hours from the beginning of incubation.

Protein Content

The Kjeldahl method was used to determine crude protein by estimating the amount of nitrogen in a sample including protein and non-protein nitrogen. An Auto-Kjeldahl system (Tecator), which consists of Tecator Kjeldahl digestion rack, Kjeltec Auto 1030 Analyzer (distillation-titration unit) and 250-mL Kjeldahl digestion tubes, was used to determine the crude protein. All of the reagents and chemicals were purchased from Fisher Scientific (Pittsburgh, PA). The crude protein (CP) was determined as the amount of nitrogen in the sample multiplied by conversion factor of 6.25.

β-Glucan Assay

β-glucan content of the barley was determined by a mixed-linkage β-glucan assay procedure (AACC Method 32-22 1995) using the Megazyme Streamlined Assay Kit (Megazyme Pty Ltd, Wicklow, Ireland).

α-Amylase Activity

α-amylase activity in the barley was determined by modification of AACC method 22-01 (AACC 1995) with the Megazyme Ceralpha Method Kit (Megazyme Pty Ltd., Wicklow, Ireland).

RESULTS AND DISCUSSION

Table 1 shows significant variables in the fungicide experiment. The different types of fungicides applied in this study significantly influenced barley moisture content and a-amylase activity. Barley variety significantly affected protein content, β-glucan, α-amylase activity, kernel weight (R^2 = 0.93), and germination energy (R^2 = 0.80), but not moisture content. Barley that was grown under different cover crops had different kernel weight, moisture, protein and β-glucan levels. There was a significant interaction among all the variables that influenced the weight of the kernels, α-amylase activity, moisture and protein contents.

Table 2 summarizes the significant variables in the nitrogen fertilization experiment. Different levels of nitrogen (0.0, 18.0, and 36.0 kg/acre) applied to the soil resulted in a significant ($p \leq 0.05$) difference in barley protein content (R^2 = 0.81) and a-amylase activity (R^2= 0.82) in the barley. Interestingly, all quality parameters measured were affected ($p \leq 0.05$) by barley variety. Both germination energy and α-amylase activity were not influenced by the type of cover crop under which the barleys were planted. There were significant interactions ($p \leq 0.05$) of all three variables on the moisture content, protein level, and α-amylase activity.

Moisture Content

Moisture content after harvest is important in determining stability during storage. Hough (1985) suggested that barley harvested at moisture contents above 15% should be dried before storage. A low moisture content is not desirable as it cause poor kernel viability. A typical post-harvest treatment of barley is to dry to 12% moisture content and then store at 25°C up to 14 days.

Barley moisture content, shown in Table 3 for the fungicide study and in Table 4 for the nitrogen study, was relatively low (9.3%–10.5%, wet basis). In these studies, drying the barley was not required

Table 1. Summary analysis of variance (ANOVA) of variables varieties, cover crop, and fungicide on quality parameters of barley for malting.

Sources	Moisture content (%, w.b.)	Protein (%)	Germination @ 72 hrs (%)	Weight (g/1000 kernels)	β-Glucan (%, d.b.)	α-Amylase (Ceralpha U/g)
Cover crop (C)	✓[1]	✓		✓	✓	
Fungicide (F)	✓					✓
Varieties (V)		✓	✓	✓	✓	✓
C x F				✓		✓
C x V	✓	✓		✓	✓	
F x V					✓	✓
C x F x V	✓	✓		✓		✓
(R^2)= Coefficient of determination	0.36	0.70	0.80	0.93	0.30	0.74

[1]✓ = Significant ($p \leq 0.05$)

Table 2. Summary analysis of variance (ANOVA) of variables varieties, cover crop, and nitrogen on quality parameters of barley for malting.

Sources	Moisture content (%, w.b.)	Protein (%)	Germination @ 72 hrs (%)	Weight (g/1000 kernels)	b-Glucan (%, d.b.)	a-Amylase (Ceralpha U/g)
Cover crop (C)	✓[1]	✓		✓	✓	
Nitrogen (N)		✓				✓
Varieties (V)	✓	✓	✓	✓	✓	✓
C x N						✓
C x V						
N x V	✓	✓				✓
C x F x V	✓	✓				✓
(R^2) = Coefficient of determination	0.33	0.81	0.85	0.84	0.31	0.82

[1]✓ = Significant ($p \leq 0.05$)

Table 3. Moisture, kernel weight and germination energy of barley malting varieties grown with different fungicide treatments.

Varieties	Fungicide	Cover Crop	Moisture Content [1,2] (%)	Kernel Weight [1,2] (g/1000 kernels)	Germination Energy [1,2] @ 72 hrs (%)
Harrington	None	B/W	10.54 ± 0.63 a	41.44 ± 2.65 a	41 ± 21 a
		P/O/V	9.47 ± 0.42 a	33.13 ± 0.12 a	74 ± 6 a
	Maneb	B/W	10.22 ± 0.38 a	43.02 ± 0.19 a	52 ± 14 a
		P/O/V	9.81 ± 0.16 a	30.75 ± 0.42 a	53 ± 16 a
	Tilt	B/W	10.23 ± 0.30 a	34.77 ± 1.07 a	62 ± 6 a
		P/O/V	9.77 ± 0.29 a	36.79 ± 0.34 a	76 ± 3 a
Klagas	None	B/W	10.34 ± 0.48 a	40.81 ± 2.95 a	78 ± 17 a
		P/O/V	10.26 ± 0.41 a	36.71 ± 1.65 a	56 ± 8 a
	Maneb	B/W	10.40 ± 0.44 a	46.72 ± 3.15 a	64 ± 6 a
		P/O/V	9.72 ± 0.45 a	29.27 ± 0.60 a	61 ± 4 a
	Tilt	B/W	10.11 ± 0.32 a	43.43 ± 1.51 a	77 ± 27 a
		P/O/V	10.07 ± 0.12 a	30.83 ± 2.51 a	80 ± 2 a
Robust	None	B/W	10.10 ± 0.61 a	36.73 ± 2.61 a	96 ± 3 b
		P/O/V	10.13 ± 0.18 a	31.99 ± 0.20 a	94 ± 3 b
	Maneb	B/W	9.87 ± 0.37 a	36.54 ± 4.19 a	98 ± 0 b
		P/O/V	9.52 ± 0.52 a	32.86 ± 1.19 a	97 ± 4 b
	Tilt	B/W	10.20 ± 0.56 a	38.96 ± 0.76 a	90 ± 11 b
		P/O/V	10.09 ± 0.10 a	33.13 ± 0.51 a	94 ± 3 b
HSD[3] ($p \leq 0.05$)			0.71	7.67	48.89

[1]Different letters following values within a column indicate significant differences (Tukey HSD test; $p \leq 0.05$).
[2]Mean values (N = 8) on a dry weight basis.
[3]Honest Significant Difference (Tukey test; $p \leq 0.05$).
B/W = beans-wheat cover crop; P/O/V = peas-oats-vetch cover crop.

Table 4. Moisture, kernel weight and germination energy of barley malting varieties grown with different nitrogen treatments.

Varieties	Nitrogen (kg/acre)	Cover Crop	Moisture Content [1,2] (%)	Kernel Weight [1, 2] (g/1000 kernels)	Germination Energy [1, 2] @ 72 hrs (%)
Harrington	0.0	B/W	10.47 ± 0.19 a	42.41 ± 0.56 b	58 ± 14 a
		P/O/V	9.94 ± 0.37 a	37.13 ± 3.11 a	58 ± 14 a
	18.0	B/W	9.82 ± 0.29 a	42.61 ± 0.88 b	59 ± 16 a
		P/O/V	9.80 ± 0.36 a	37.51 ± 1.13 a	43 ± 24 a
	36.0	B/W	10.23 ± 0.30 a	42.60 ± 1.98 b	39 ± 10 a
		P/O/V	9.94 ± 0.41 a	37.66 ± 3.92 a	51 ± 7 a
Klagas	0.0	B/W	10.09 ± 0.15 a	44.04 ± 0.65 b	76 ± 20 a
		P/O/V	9.84 ± 0.41 a	36.78 ± 0.68 a	48 ± 20 a
	18.0	B/W	10.22 ± 0.27 a	46.38 ± 1.97 b	83 ± 40 a
		P/O/V	10.18 ± 0.38 a	39.59 ± 1.30 a	56 ± 6 a
	36.0	B/W	10.03 ± 0.27 a	40.21 ± 4.33 a	64 ± 14 a
		P/O/V	9.79 ± 0.34 a	38.88 ± 2.51 a	74 ± 3 a
Robust	0.0	B/W	9.91 ± 0.58 a	37.72 ± 1.88 a	96 ± 3 a
		P/O/V	9.95 ± 0.42 a	36.53 ± 2.32 a	94 ± 6 a
	18.0	B/W	10.15 ± 0.32 a	39.49 ± 1.12 a	92 ± 11 a
		P/O/V	9.28 ± 0.68 a	34.80 ± 0.10 a	98 ± 1 a
	36.0	B/W	9.82 ± 0.26 a	38.14 ± 0.45 a	89 ± 1 a
		P/O/V	9.94 ± 0.29 a	32.78 ± 0.74 a	98 ± 3 a
HSD [3] ($p \leq 0.05$)			0.65	8.20	48.25

[1]Different letters following values within a column indicate significant differences (Tukey HSD test; $p \leq 0.05$).
[2]Mean values (N = 8) on a dry weight basis.
[3]Honest Significant Difference (Tukey test; $p \leq 0.05$).
B/W = beans-wheat cover crop; P/O/V = peas-oats-vetch cover crop

after harvest. Although the ANOVA indicated that the barley's moisture content in both nitrogen and fungicide studies was affected by the treatments, there were no differences among barley moisture contents. Robust variety grown under p/o/v cover crop with the medium level of nitrogen application had the lowest moisture content (9.3%, wet basis), while the highest (10.5%, wet basis), was for the Harrington variety under b/w cover crops with no fungicide.

Kernel Weight

Barley kernel weight (g/1000 kernels) of the barley for malting is one of the physical quality factors selected by the maltster and the brewer. Barley kernel weight from all treatments ranged from 29.3 to 46.7 g/1000 kernels in both fungicide and nitrogen experiments (Tables 3 and 4). All mean values of kernel weight in the fungicide study were statistically inseparable with a range of 29 to 47 g/1000 kernels. Similarly, the weight of the Robust kernels was unaffected by nitrogen treatments. Interestingly, kernel weight of Harrington grown after b/w cover crop was consistently heavier than Harrington grown after p/o/v in all nitrogen treatments. A similar trend applies to Klagas at 0.0 and 18.0 kg/acre of nitrogen. There are no established criteria on the kernel weight of barley for malting. Regardless of the treatments applied in this study, Harrington, Klagas, and Robust varieties had an average of 38.3, 39. 5, and 36.2 g/1000 kernels, respectively.

Germination Energy

The ability of barley to completely germinate during malting is essential. Normally, barley taken from storage is analyzed for germination energy (GE), germination capacity (GC) and water sensitivity to predict the steeping and germination conditions (Bamforth and Barclay 1993). Overall, a wide range of germination capacity (39%–98%) was found after 72 hours incubation period (Tables 3 and 4). Robust was the most efficient of all treatments in germination energy (89%–98%) within 72 hours incubation time. However, only Robust under fungicide treatments can be separated from other mean values. All other barley varieties in this study were considered low in germination energy (39%–83%).

Perhaps the low value of GE in this study was due to changes in the embryo that caused a dormancy during storage. Bamforth and Barclay (1993) indicated that the dormant state can be alleviated by several factors, for example, warm storage or oxidizing conditions that may remove inhibitors of germination induced *via* a pentose phosphate pathway.

With regard to the GE, Robust was the only acceptable barley for malting as high germination energy is one of the most critical criteria for the maltster in barley selection. All the varieties used in this study were barley varieties that have been used for malting. Bhatty (1996) reported that malt barley Harrington and Steins cultivars had a high germination energy 98% and 99%, respectively. Therefore, the barley varieties (i.e., Harrington and Klagas) grown in this experiment need further testing for their dormancy.

Protein Content

Protein content of the barley was highly variable, ranging from 11.0% to 16.6% (dry basis) and 10.4% to 15.4% (dry basis) for fungicide and nitrogen studies, respectively (Tables 5 and 6). Bhatty (1996) determined the protein content in malting

Table 5. Protein, β-glucan and α-amylase of barley varieties for malting with fungicide treatments.

Varieties	Fungicide	Cover Crop	Protein [1,2] (%, dry basis)	β-Glucan [1,2] (%, dry basis)	α-Amylase[1,2] (Ceralpha U/g)
Harrington	None	B/W	11.87 ± 0.36 a	6.15 ± 1.27 a	9.33 ± 4.57 c
		P/O/V	14.48 ± 0.61 ab	4.46 ± 1.35 a	6.44 ± 2.50 b
	Maneb	B/W	11.24 ± 0.47 a	5.61 ± 1.37 a	3.53 ± 0.77 a
		P/O/V	14.83 ± 1.30 b	4.37 ± 0.91 a	9.57 ± 5.24 c
	Tilt	B/W	13.33 ± 2.67 a	5.44 ± 1.62 a	9.07 ± 2.05 c
		P/O/V	14.54 ± 0.97 b	4.36 ± 1.28 a	10.26 ± 3.19 c
Klagas	None	B/W	12.27 ± 0.60 a	4.44 ± 1.03 a	4.82 ± 1.70 a
		P/O/V	15.56 ± 0.91 b	4.02 ± 0.47 a	3.08 ± 1.56 a
	Maneb	B/W	11.19 ± 0.27 a	4.85 ± 0.34 a	1.13 ± 0.24 a
		P/O/V	15.69 ± 1.45 b	4.45 ± 0.39 a	3.58 ± 1.21 a
	Tilt	B/W	10.96 ± 0.61 a	5.05 ± 0.97 a	1.97 ± 0.34 a
		P/O/V	16.62 ± 1.51 c	4.53 ± 0.62 a	2.73 ± 1.32 a
Robust	None	B/W	11.44 ± 0.45 a	5.43 ± 1.07 a	0.58 ± 0.66 a
		P/O/V	13.89 ± 0.46 a	5.76 ± 1.10 a	0.32 ± 0.16 a
	Maneb	B/W	12.22 ± 0.98 a	5.90 ± 0.83 a	0.17 ± 0.08 a
		P/O/V	13.63 ± 0.97 a	5.56 ± 1.01 a	0.25 ± 0.13 a
	Tilt	B/W	12.34 ± 1.60 a	4.46 ± 0.99 a	0.14 ± 0.04 a
		P/O/V	14.15 ± 1.80 b	4.42 ± 1.09 a	0.41 ± 0.13 a
HSD [3] ($p \leq 0.05$)			2.04	1.85	2.58

[1]Different letters following values within a column indicate significant differences (Tukey HSD test; $p \leq 0.05$).
[2]Mean values (N = 8) on a dry weight basis.
[3]Honest Significant Difference (Tukey test; $p \leq 0.05$).
B/W = beans-wheat cover crop; P/O/V = peas-oats-vetch cover crop.

Table 6. Protein, β-Glucan and α-amylase of barley varieties for malting with nitrogen treatments.

Varieties	Nitrogen (kg/acre)	Cover Crop	Protein[1,2] (%, dry basis)	β-Glucan[1,2] (%, dry basis)	α-Amylase[1,2] (Ceralpha U/g)
Harrington	0.0	B/W	10.39 ± 0.58 a	5.18 ± 1.02 a	2.28 ± 1.14 a
		P/O/V	12.22 ± 0.51 ab	5.70 ± 1.00 a	4.14 ± 3.17 a
	18.0	B/W	12.02 ± 1.04 ab	5.89 ± 0.82 a	6.79 ± 2.89 b
		P/O/V	13.72 ± 0.60 b	5.84 ± 1.51 a	8.98 ± 1.68 b
	36.0	B/W	13.08 ± 0.41 b	5.36 ± 1.47 a	9.94 ± 3.09 c
		P/O/V	14.51 ± 0.90 c	5.67 ± 1.00 a	5.32 ± 1.04 a
Klagas	0.0	B/W	10.83 ± 0.71 a	4.15 ± 1.00 a	0.85 ± 0.41 a
		P/O/V	13.18 ± 0.48 b	4.88 ± 0.49 a	2.29 ± 1.54 a
	18.0	B/W	12.41 ± 0.34 b	4.22 ± 0.54 a	1.56 ± 0.28 a
		P/O/V	13.46 ± 0.44 c	5.57 ± 0.52 a	1.70 ± 0.47 a
	36.0	B/W	14.87 ± 1.42 c	4.12 ± 1.00 a	2.61 ± 1.37 a
		P/O/V	15.35 ± 1.41 c	5.44 ± 0.56 a	2.78 ± 1.03 a
Robust	0.0	B/W	10.98 ± 0.87 a	4.86 ± 0.98 a	0.22 ± 0.11 a
		P/O/V	12.29 ± 0.62 b	5.98 ± 0.46 a	0.52 ± 0.47 a
	18.0	B/W	12.00 ± 0.46 b	3.98 ± 1.26 a	0.09 ± 0.09 a
		P/O/V	13.92 ± 0.45 bc	5.51 ± 0.34 a	0.32 ± 0.16 a
	36.0	B/W	13.26 ± 0.43 b	5.95 ± 1.98 a	0.33 ± 0.38 a
		P/O/V	15.04 ± 0.48 c	5.68 ± 0.36 a	0.52 ± 0.15 a
HSD[3] ($p \leq 0.05$)			1.30	1.82	3.90

[1]Different letters following values within a column indicate significant differences (Tukey HSD test; $p \leq 0.05$).
[2]Mean values (N = 8) on a dry weight basis.
[3]Honest Significant Difference (Tukey test; $p \leq 0.05$).
B/W = beans-wheat cover crop; P/O/V = peas-oats-vetch cover crop.

barley and hull-less barley as 15.3% and 16.0%, respectively. Harrington and Klagas varieties grown after p/o/v cover crop contained a higher protein content than those grown after b/w regardless of which type of fungicide applied. Robust variety grown after p/o/v cover crop with Tilt fungicide had a higher protein content than other treatments with the same variety.

Without nitrogen application, all varieties grown after b/w cover crop had a low protein content (dry basis): 10.39%, Harrington; 10.83%, Klagas; 10.98%, Robust. By increasing the nitrogen level from 18 to 36 kg/acre in the b/w cover plots in which Klagas was grown, the protein content increased from 12.4% to 14.9% (dry basis). Similarly, an increase in protein content from 13.7% to 14.5% (dry basis) was also seen with Harrington variety grown under p/o/v cover crops. Despite the wide range of protein content in this study, all barley varieties at particular treatments can produce a protein in the acceptable range (9.0%–13%, dry basis).

β-glucan

The cell walls of barley may interfere with the brewing process if they are insufficiently degraded during malting. One of the primary concerns is the presence of β-glucan or arabinoxylan. β-glucans can form a viscous dispersion that interferes with beer filtration and increases the likelihood of haze formation in the finished products (Duffus and Cochrane 1993). Although β-glucan may be depolymerized during malting by β-glucanases, a high initial amount of this polymer in barley grain may result in a relatively high residual amount after malting. Barley varieties rich in these compounds may be rejected for malting (Hough 1985).

β-glucan of the barley in the fungicide study ranged from 4.0%–6.0% on a dry weight basis, but

no significant differences were found. This suggested that all treatments including the varieties in this study had a similar influence on β-glucan content. Similarly, the nitrogen study resulted in a narrow range (4.0%–6.0%, dry basis) of β-glucan for all treatments.

Interestingly, the lowest (4.0%, dry basis) and the highest (6.0%) amount of β-glucan in this study were both in Robust under nitrogen and fungicide treatments, respectively. Bhatty (1996) reported that β-glucan in hull-less barley and malting barley was 4.9% and 4.4%, respectively. Over all, the means of β-glucan (5.0%) for all varieties in this study suggested acceptability for malting.

α-amylase

α-Amylase activity in malting barley is normally determined before and after the malting process. The level of α-amylase is expected to greatly increase (≥ 200-fold) after malting. The level of α-amylase activity in unmalted barley should be relatively low so that the starch is not damaged or hydrolyzed before malting. Bhatty (1996) compared the α-amylase activity between unmalted and malted barley. It was reported that the activity of unmalted barley (Harrington) was 0.1 Ceralpha U/g, and, after malting the α-amylase activity was greatly increased to 288 Ceralpha U/g.

In this study, the α-amylase activity was only determined in the barley before malting, since the University does not possess malting facilities. The α-amylase activity ranged from 0.14 to 10.26 Ceralpha U/g in the fungicide study (Table 5). Harrington grown with Tilt fungicide resulted in the highest levels of a-amylase activity (9.1–10.3 Ceralpha U/g). On the other hand, Tilt fungicide application resulted in the lowest α-amylase activity (0.14 Ceralpha U/g) for Robust, and there was a significant fungicide x variety interaction. The activity of a-amylase and perhaps other enzymes in the barley grain may have been partially activated during storage. Harrington contained a high α-amylase activity (9.94 Ceralpha U/g) when grown under b/w cover crop. Robust and Klagas, which had a lower activity than Harrington, were undifferentiated for α-amylase activity.

Criteria for α-amylase activity in the barley before malting is not well defined. Although lower activity was defined in this study as the acceptable level, documentation of the actual development of α-amylase activity in each barley variety during malting would give a better evaluation. However, this study suggested that Robust and Klagas are acceptable for malting because of their lower α-amylase activity.

CONCLUSIONS

Despite the high variation among the cultivars for barley grown in Maine, generally all the varieties were in the acceptable range for malting. However, determination of quality parameters after the malting is necessary for the assurance of high-quality barley. Other barley varieties for malting should be grown in Maine and examined similarly for a wider comparison study. These findings do suggest that acceptable malt barley can be grown in Maine.

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