NW CROPS & SOILS PROGRAM

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2011 Organic Hop Variety Trial: Preliminary Results

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The goal of the UVM Extension hops program is to develop agronomic recommendations for hop production in the Northeast. Much has changed since hops were last grown in this area in the 1800s, with many new varieties released and a better understanding of cropping science. With this in mind, in August of 2010, UVM Extension initiated an organic hops variety trial at Borderview Farm in Alburgh, VT. The UVM Extension hopyard is trialing 19 publicly-available hop varieties. The goal of these efforts is to find hop varieties that not only grow well in the Northeast and demonstrate disease and pest resistance in combination with high yields, but also present desirable characteristics to brewers. The results and observations presented below are from a first-year hopyard.

MATERIALS AND METHODS

The replicated research plots were located at Borderview Farm in Alburgh, VT on a Benson rocky silt loam. The experimental design was a randomized complete block with three replicates; treatments were the 19 varieties. The hopyard was constructed in the spring of 2010 using 20' x 6" larch, tamarack and cedar posts, with a finished height of 16 feet. Aircraft cable (5/16") was used for trellis wires. A complete list of materials and videos on the construction of the UVM Extension hopyard can be found at www.uvm.edu/extension/cropsoil/hops.

Hop beds (4' in width) were tilled with a moldboard plow, tilled again with a 3-point hitch, 6' rotary tiller, and then planted with two vegetative hop cuttings per hill on 4-August 2010. Hills were distanced 7' apart, and rows were spaced at 10'. Each plot consisted of five consecutive hills. Varieties were evaluated for survival on 12-April and 27-June 2011. In-row rototilling was the primary weed control method, and as the weeds were brought under control, rows were trained with two strings of coir (coconut fiber) per hill, fertilized, and mulched with hardwood mulch. Pro-Gro ® 5-3-4 and Probooster® 10-0-0 were applied to provide 30 lbs plant available N, 40 lbs P, and 80 lbs K ac^{-1}. Boron was also applied at a rate of 10 lbs ac^{-1}. On 7-June, Chilean nitrate (16-0-0) was sidedressed at a rate of 50 lbs N ac^{-1}. All fertilizers were OMRI-approved for use in organic systems, and were applied at rates recommended in the Pacific Northwest (Gingrich et al., 2000).

In late June, three leaves per hill and two hills per plot were scouted for insect and disease pests. The hopyard was scouted weekly in July and August, and pesticides were applied as needed. Potato leafhoppers (*Empoasca fabae*) (Fig. 1) and two-spotted spider mites (*Tetranychus urticae Koch*) were identified in the hopyard and determined to be above economic threshold. Economic thresholds for potato leafhoppers in hops have not been documented, but with an in-depth literature review, it was determined that two leafhoppers per leaf were economically

Figure 1. Potato leafhoppers.

damaging to the hops. Economic thresholds for two-spotted spider mites have been determined in the Pacific Northwest to be 1-2 spider mites per leaf in June, or 5-10 per leaf in July. Pyganic (McLaughlin Gormley King Company, EPA Reg. No. 1021-1771) and Aza-Direct (Gowan, EPA Reg. No. 71908-1-10163) were applied to control insect pests. Pyganic is derived from chrysanthemums and is a botanical insecticide that is labeled for control of leafhoppers in hops. Aza-Direct is a botanical insecticide derived from neem (*Azadirachta indica*) seeds and is labeled for control of mites in hops.

Downy mildew (*Pseudoperonospora humuli*) was identified on var. Cluster in mid-June (Fig. 2), and Regalia (Marrone Bio Innovations, EPA Reg. No. 84059-3), an extract of *Reynoutria sachalinensis (*knotweed*)*, was sprayed over the entire yard three days later using a Fimco 45-gallon trailer sprayer equipped with a hand gun and pulled by a John Deere 20 hp riding lawn mower. Regalia is labeled for use on hops against both powdery mildew (*Podosphaera macularis*) and downy mildew, and is a plant extract that is used to help bolster a plant's natural defense mechanisms. It was applied as per label specifications. Regalia was used in rotation with Sonata (AgraQuest, EPA Reg. No. 69592-13) against downy mildew. Sonata is a biofungicide that uses *Bacillus pumilis* strain QST 2808. It is a preventative product used to control and suppress powdery and downy mildew in hops. All pesticides applied were OMRI-approved for use in organic systems and were applied at rates specified by their labels.

Figure 2. Downy mildew on var. 'Cluster'.

Drip irrigation was set up in the hopyard at the end of June, and plants were watered as needed, averaging 3,000 gallons a week for a ¾ acre yard of approximately 560 plants. Detailed information as well as a parts and cost list for the drip irrigation system can be found at www.uvm.edu/extension/cropsoil/hops#irrigation.

Figure 3. Hand-harvesting hops.

Hop harvest was targeted for when cones were between 20 and 25% dry matter. Hop bines were cut in the field and brought indoors to be handpicked on a table (Fig. 3). Harvest date by variety can be found in Table 3. Picked hops were weighed on a per string basis, 100-cone weights were recorded, and moisture was determined using a Koster Tester. Hop cones were dried to 8% moisture, vacuum-sealed, and placed in a freezer for storage. A 100 g subsample of hop cones from each plot were sent to Alpha Analytics in Yakima, WA where they were analyzed for alpha and beta acids using spectrophotometry as per the American Society of Brewing Chemists (ASBC) Method of Analysis entitled Hops 6a. Hop Storage Index (H.S.I.) was also measured using the ASBC Method of Analysis detailed in Hops 12.

The data presented is of three replications. Hop brewing quality data is presented as varietal averages across the trial. The quality of each variety in the trial was compared to industry standards. Hill survival was analyzed using a mixed model analysis where replicates were considered random effects. The LSD procedure was used to separate cultivar means when the F-test was significant ($p < 0.10$). Yields are presented at harvest moisture and at 8% moisture on a per hill and per acre basis. Per acre calculations were performed using the spacing in the UVM Extension hopyard of 70 ft^2 $hill^{-1}$, 622 hills ac^{-1}. Yields were analyzed using the PROC MIXED procedure in SAS using the Tukey-Kramer adjustment, which means that each variety was analyzed with a pairwise comparison (i.e. 'Cluster' statistically outperformed 'Cascade', Cascade statistically outperformed 'Mt. Hood', etc.) In all tables, the top performing variety can be found in bold. Varieties that were not significantly lower in performance than the highest variety in a particular column are indicated with an asterisk.

Differences in yield and quality can occur because of variations in soil, weather, and other growing conditions. Statistical analysis makes it possible to determine whether a difference among varieties is real, or whether it might have occurred due to other variations in the field. At the bottom of Table 2, a LSD value is presented for each variable. Least Significant Differences (LSD) at the 10% level of probability are shown in the results. Where the difference between two varieties within a column is equal to or greater than the LSD value you can be sure 9 times out of 10 that there is a real difference between the two treatments.

In the example, hybrid C is significantly different from hybrid A but not from hybrid B. The difference between C and B is equal to 1.5 which is less than the LSD value of 2.0. The asterisk indicates that hybrid B was not significantly lower than the top yielding hybrid, hybrid C. This means that these hybrids did not differ in yield. The difference between A and C is equal to 3.0, which is greater than the LSD value of 2.0. This means that the yields of these hybrids were significantly different from one another.

Variety	Yield
A	6.0
B	7.5*
C	**9.0***
LSD (0.10)	2.0

RESULTS

The 2010-2011 winter in Alburgh provided adequate snow cover, which helped protect the young rhizomes throughout the harsh winter. April and May brought excessive rainfall and floods throughout Vermont. In August, Tropical Storm Irene hit the Northeast, and Alburgh was subject to 70 mph winds and 4" of rain in the middle of harvesting (Table 1).

Table 1. Temperature, precipitation*, and Growing Degree Day summary, Alburgh, VT.

	Aug-10	Sep-10	Oct-10	Nov-10	Dec-10	Jan-11	Feb-11	Mar-11	Apr-11	May-11	Jun-11	Jul-11	Aug-11	Sep-11
Average Temperature (°F)	70.4	64.0	50.6	39.9	27.7	22.8	20.8	32.9	46.6	58.7	67.1	74.4	70.4	63.8
Departure from Normal	1.4	3.6	1.8	2.2	2.3	4.6	0.5	2.1	3.1	2.1	1.3	3.3	1.6	5.8
Precipitation (inches)	5.48	4.32	6.73	2.93	3.39	0.90	3.12	3.39	7.88	8.67	3.52	3.68	10.23	5.56
Departure from Normal	1.63	0.86	3.75	0.00	1.52	-1.05	1.71	1.07	5.00	5.35	0.09	-0.29	6.38	2.10
Growing Degree Days (base 32°F)	1192.0	990.5	578.2	243.4	17.1	0.0	0.0	144.2	465.0	826.2	1088.1	1314.4	1120.7	962.6
Departure from Normal	45.0	138.5	57.4	63.4	12.4	0.0	0.0	27.9	120.0	63.6	74.1	103.9	-26.3	110.6

Based on National Weather Service data from cooperative observer stations in South Hero, VT, which is in close proximity to the variety trial.
*Due to missing data from the South Hero station, precipitation from March to July 2011, and average temperature for August and September 2011 are taken from an observer station in Burlington, VT.
Historical averages are for 30 years of data (1971-2000).

Table 2. Hop survival by variety.

Variety	Hill survival	
	14-Apr-11	27-Jul-11
	%	%
Cascade	86.7*	80.0
Centennial	**100***	**100***
Chinook	**100***	93.3*
Cluster	80.0	73.3
Crystal	93.3*	93.3*
Fuggle	93.3*	73.3
Galena	86.7*	80.0
Glacier	**100***	**100***
Liberty	93.3*	93.3*
Mt. Hood	**100***	**100***
Newport	93.3*	93.3*
Nugget	93.3*	93.3*
Perle	**100***	**100***
Saaz	**100***	**100***
Santiam	**100***	**100***
Sterling	**100***	**100***
Tettnang	53.3	26.7
Vanguard	66.7	66.7
Willamette	80.0	80.0
LSD (0.10)	17.6	19.8
Mean	90.5	86.7

* indicates that the variety did not perform differently than the top variety.

Among the varieties ‘Centennial’, ‘Glacier’, ‘Perle’, ‘Saaz’, ‘Santiam’, and ‘Sterling’, at least one of the two plants in every hill survived through the winter and into the end of July. All of the ‘Chinook’ plants also survived the winter, but one plant was lost during the growing season, uprooted by high winds. ‘Tettnang’ and ‘Vanguard’ had very poor survivability (Table 2).

Hop harvest was for 20 to 25% cone dry matter (Table 3). The var. Cluster was the earliest maturing variety and was followed by ‘Crystal’, ‘Fuggle’, Cascade, and Saaz. The latest maturing varieties were Santiam and Sterling. The hop harvest window was from mid-August to mid-September.

Table 3. Dry matter by harvest date and variety.

Variety	Date harvested	Dry matter %
Cascade	24-Aug	22.0
Cascade	26-Aug	22.6
Centennial	2-Sep	23.7
Chinook	2-Sep	23.3
Chinook	6-Sep	23.5
Cluster	11-Aug	19.1
Cluster	12-Aug	18.9
Crystal	12-Sep	21.2
Crystal	14-Sep	21.4
Fuggle	24-Aug	23.6
Fuggle	6-Sep	22.0
Galena	31-Aug	24.0
Glacier	6-Sep	22.1
Glacier	8-Sep	23.1
Glacier	14-Sep	25.8
Liberty	2-Sep	*
Mt. Hood	2-Sep	21.4
Newport	14-Sep	25.1
Nugget	6-Sep	22.7
Perle	2-Sep	25.3
Saaz	24-Aug	23.7
Santiam	6-Sep	19.2
Santiam	14-Sep	22.5
Sterling	13-Sep	21.4
Sterling	14-Sep	23.6
Tettnang	31-Aug	24.3
Tettnang	2-Sep	23.2
Vanguard	31-Aug	26.5
Vanguard	2-Sep	21.9
Willamette	31-Aug	25.6

*Not enough sample to determine percent dry matter.

Cluster outperformed all other varieties, averaging 0.74 lbs/hill or 460 lbs/acre at 8% moisture (Table 4). 'Liberty' was the worst performing variety, although statistically no different from Centennial, Crystal, Fuggle, Glacier, Mt. Hood, Perle, Saaz, Santiam, Sterling, Tettnang, and Vanguard (Figure 4).

Table 4. Yield of 19 hop varieties at harvest and 8% moisture.

Variety	Yield at harvest moisture		Yield at 8 % moisture	
	lbs/hill	lbs/ac	lbs/hill	lbs/ac
Cluster	**3.58***	**2227***	**0.74***	**460***
Galena	1.87	1166	0.49*	303*
Newport	1.54	958	0.41	257
Willamette	1.60	993	0.41	256
Cascade	1.71	1062	0.41	255
Nugget	1.40	870	0.35	217
Chinook	1.20	747	0.30	190
Glacier	0.87	539	0.22	138
Mt. Hood	0.53	329	0.12	76.7
Centennial	0.44	273	0.11	70.0
Vanguard	0.37	227	0.09	58.9
Crystal	0.37	232	0.09	53.5
Santiam	0.31	193	0.06	40.4
Fuggle	0.12	77.5	0.03	19.6
Tettnang	0.08	50.3	0.02	12.0
Perle	0.07	43.2	0.02	10.9
Sterling	0.05	32.2	0.01	7.6
Saaz	0.05	28.4	0.01	7.3
Liberty	0.02	11.8	0.00	0.4

* indicates varieties that are statistically similar to the top performing variety with respect to yield.

Brewing values for select varieties are presented in Table 5. Some varieties did not produce sufficient yield to be tested for brewing characteristics. Alpha acid percentages for Cluster, Cascade, 'Galena', and Vanguard fell within industry averages. 'Nugget' and 'Willamette' exceeded industry alpha acid averages (Figure 5). Beta acid levels for Centennial, Cluster, Crystal, Mt. Hood, 'Newport', Nugget, and Santiam all fell within the industry averages. Cascade, Chinook, Fuggle, and Willamette all had beta acid levels higher than industry averages (Figure 6).

Table 5. Brewing values by hop variety

Variety	Alpha acids %	Beta acids %	H.S.I.
Cascade	4.7	7.4	0.20
Centennial	8.2	3.6	0.27
Chinook	9.9	4.1	0.24
Cluster	6.3	5.1	0.20
Crystal	2.1	6.2	0.19
Fuggle	3.2	2.6	0.25
Galena	12.5	6.9	0.21
Glacier	3.6	6.7	0.21
Mt. Hood	3.3	7.1	0.22
Newport	10.3	7.6	0.21
Nugget	14.4	4.6	0.23
Saaz	1.0	1.2	0.20
Santiam	3.0	6.8	0.20
Vanguard	5.9	4.7	0.20
Willamette	8.4	4.1	0.23

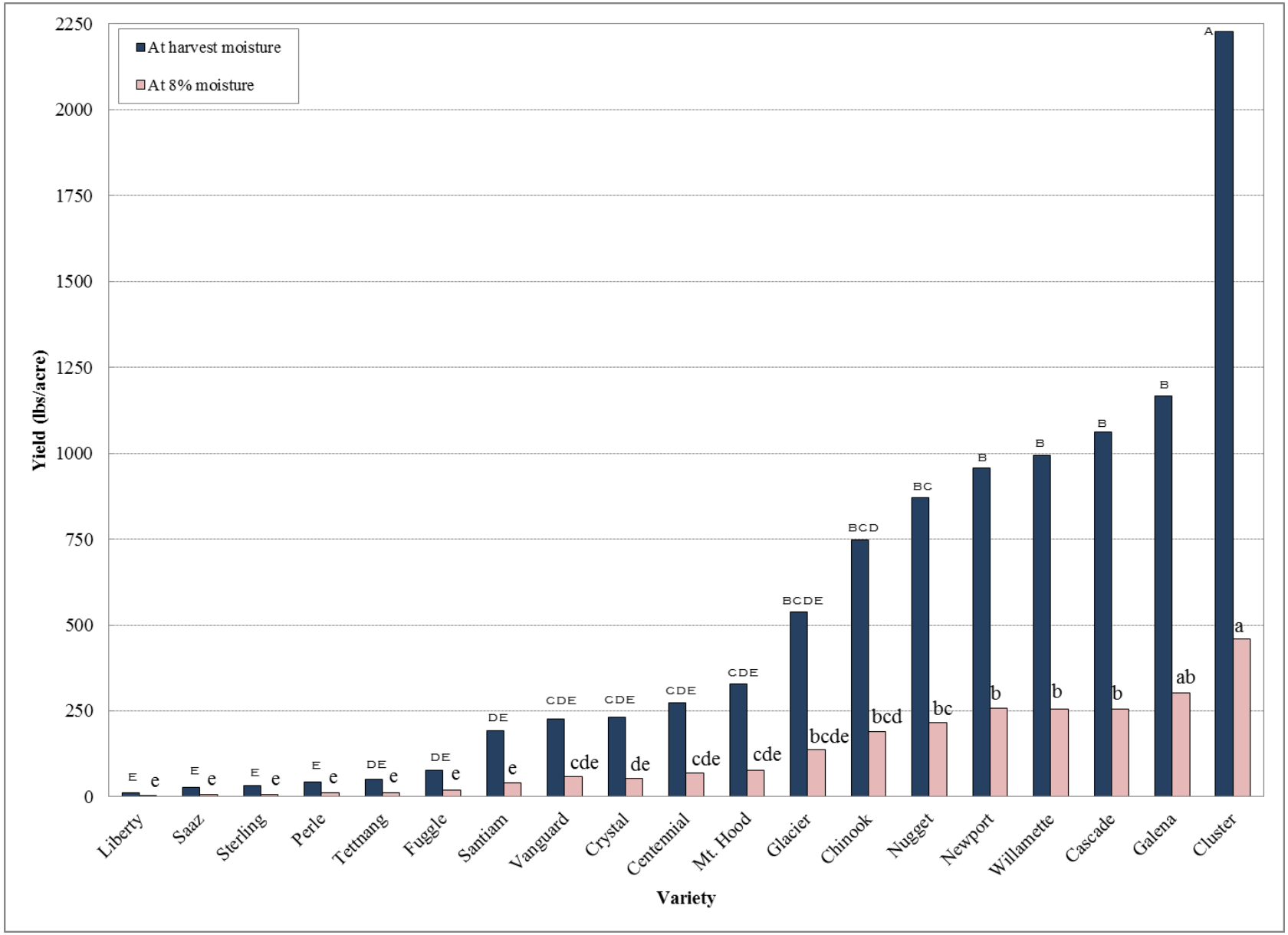

Figure 4. Yields of 19 hop varieties evaluated by UVM Extension. Varieties with the same letter are not statistically different from each other.

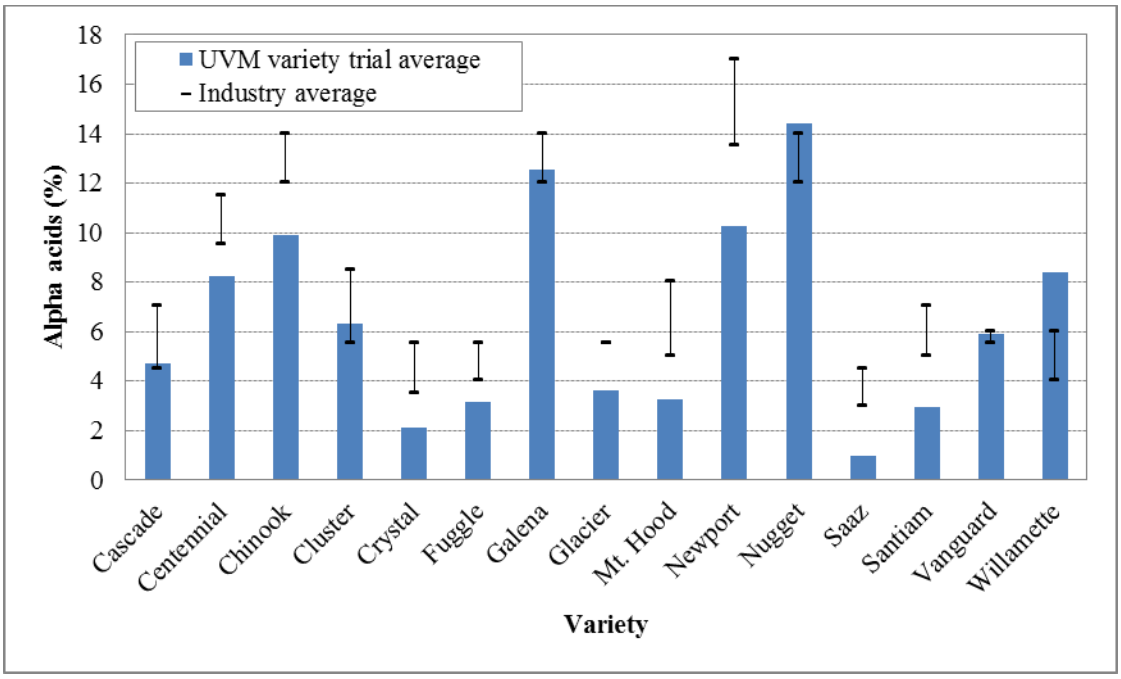

Figure 5. Alpha acid levels from the UVM Extension hopyard compared to industry averages presented by Hopunion CBS, LLC and Yakima Chief, Inc.

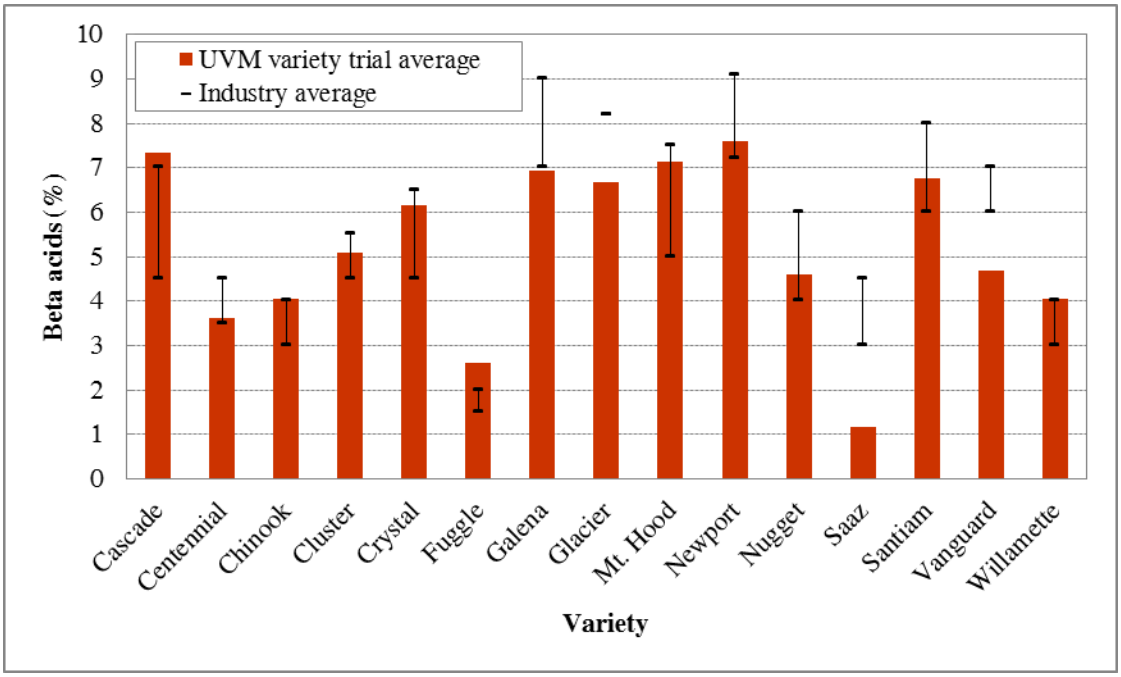

Figure 6. Beta acid levels from the UVM Extension hopyard compared to industry averages presented by Hopunion CBS, LLC and Yakima Chief, Inc.

DISCUSSION

Traditionally, hops are propagated by rhizome, which are planted in the early spring. Rhizomes can often carry diseases like Verticillium wilt, hop latent virus, and downy and powdery mildew. Unbeknownst to the grower, these diseases can easily be transplanted into a new hopyard. In an effort to minimize the possibility of this, the UVM Extension hopyard was planted with vegetative cuttings. The cuttings were propagated and sent across the country in a refrigerated truck, arriving in early August 2010. Some plants were adversely affected by the long distance traveled, some were too close to the refrigerator unit, and all plants arrived heavily infested with two-spotted spider mites. This, combined with a late planting, resulted in reduced plant vigor. Soil saturation from the soggy October in 2010 and the spring floods of 2011 reduced the amount of oxygen in the soil and promoted root rot, which was the main cause of low winter survival in the hopyard (Table 2). Approximately half of the plants that did not survive from April to July of 2011 were impacted by root rot and highly susceptible to breakage at the soil surface. High winds in the area caused these plants to easily uproot and die. Cluster, while yielding well in 2011, is particularly susceptible to downy mildew, and infected hills will often die outright. In the UVM Extension hopyard, one hill of Cluster was lost in this exact manner. The hill already presented poor vigor due to root rot, and was subsequently lost to a downy mildew infection that had spread to the crown.

Weed pressure was combatted by first rototilling the beds, and only when the weeds were under control were the hops trained, resulting in varied training dates among the same varieties. Although not closely monitored, it appeared that late trellised hops did not produce as much biomass as hills that were trained earlier in the season. In addition, late trellised hops were more susceptible to growing point damage when the long bine was trained around the coir twine. It was also noted that plots of the same variety which were trained on different dates showed dry matter variability at harvest.

Figure 7. Leafhopper damage, called "hopper burn."

On August 28th, 2011 Tropical Storm Irene hit the Northeast. While Borderview Farm had minimal damage overall, the high winds caused physical damage to the hops. Sidearms were torn off of many plants, impacting yield, and some bines became detached from the crown and were not harvested, also affecting yield. Throughout the yard, the high winds caused premature dry-down and browning of the cones, which impacted quality.

Figure 8. Two-spotted spider mite damage in hops.

The UVM Extension hopyard is located within a grass/alfalfa field. After the first cut of forage was harvested, significant damage caused by potato leafhoppers was noticed in the hopyard (Fig. 7). Leafhoppers pierce the leaf tissue and suck out water and nutrients. The saliva that is left behind by this action can block the leaf veins, preventing nutrients from reaching the tips of the leaf and in the end causing leaf necrosis. To the best of our

knowledge, there are no established economic threshold levels for leafhoppers in hops. Reviews of threshold levels for raspberries, potatoes, and alfalfa, resulted in the establishment of a threshold level of two leafhoppers per leaf. An informational article on potato leafhoppers in hops can be found on the UVM Extension Northwest Crops and Soils Team website.

The UVM Extension hopyard was planted in August of 2010, putting the yard at a stage of maturity between one and two year old plants in the 2011 growing season. First-year yields are generally assumed to be approximately 30-50% of a mature yard's yield. Some varieties, such as Cluster and Galena, yielded well for first-year plants. Other varieties, namely Santiam, Fuggle, Tettnang, Perle, Sterling, Saaz, and Liberty, did not thrive nor yield well. However, continued evaluation of variety performance will determine overall suitability for this region.

Hops, like grapes, have *terroir*. Their brewing characteristics and oil content are reflective of their microclimate. Hops grown on the East Coast, even though genetically the exact same, will not be like hops in the Pacific Northwest due to different soils and different climates. Hops grown in the Northeast will present unique brewing characteristics. It is important to evaluate hops in different locations to develop geographically specific profiles for varieties that grow well in those areas. Analysis of the varieties in this trial will help brewers understand the quality profile for this region. Continued data collection will help build a more accurate view of varietal profiles.

ACKNOWLEDGMENTS

The UVM Extension Crops and Soils Team would like to thank Borderview Research Farm and staff for their generous help with the trials. We would like to thank Katie Blair, Chantel Cline, Amber Domina, Savanna Kittell-Mitchell, and Laura Madden for their assistance with data collection and entry. This work is made possible through the USDA Organic Agriculture Research and Extension Initiative Grants Program; Vermont Department of Agriculture, Food, and Markets; Massachusetts Department of Agricultural Resources; and the Specialty Crops Block Program.

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