2015

Organic Hop Variety Trial: Results from Year Five

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NORTHWEST CROPS & SOILS PROGRAM

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INTRODUCTION

Hops production continues to increase throughout the the Northeast. While hops were historically grown in the Northeast, they have not been commercially produced in this region for over a hundred years. With the lack of regional production knowledge, a great need has been identified for region-specific, science-based research on this reemerging crop. The vast majority of hops production in the United States occurs in the arid Pacific Northwest on a very large scale. In the Northeast, the average hop yard is well under 10 acres and the humid climate provides challenges not addressed by the existing hops research. Knowledge is needed on how best to produce hops on a small-scale in our region. With this in mind, in August of 2010, the UVM Extension Northwest Crops and Soils Program initiated an organic hops variety evaluation program at Borderview Research Farm in Alburgh, Vermont. Since this time, UVM Extension has been evaluating 22 publicly-available hop varieties. The goals of these efforts are to find hop varieties that demonstrate disease and pest resistance, high yields, and present desirable characteristics to brewers in our region. Hops are a perennial crop – most varieties reach full cone production in year three. The results and observations from the first, second, third and fourth years of the hop variety trial can be found online on the UVM Extension Northwest Crops and Soils Hops web page: www.uvm.edu/extension/cropsoil/hops. The following are the results from the fifth year of production.

MATERIALS AND METHODS

The replicated research plots were located at Borderview Research Farm in Alburgh, VT on a Benson rocky silt loam soil. The experimental design was a randomized complete block with three replicates; treatments were varieties. Each plot consisted of five consecutive hills that were distanced 7' apart. Hop rows are spaced at 10'.

The hop yard was constructed in the spring of 2010 using 20' x 6" larch, tamarack, and cedar posts, with a finished height of 16'. Aircraft cable (5/16") was used for trellis wires. A complete list of materials and videos on the construction of the UVM Extension hop yard can be found at **www.uvm.edu/extension/cropsoil/hops**.

Table 1: Training dates from 2013-2015, Alburgh, VT 2015.

Year	Date
2013	20-May to 27-May
2014	19-May to 30-May
2015	20-May to 26-May

Each year, rows are trained with two strings of coir (coconut fiber) per hill, with three to four of the strongest bines trained per string. In 2015, the majority of varieties were trained between 20-May and 26-May. Some plants were behind schedule this year and did not have enough long bines to train during the initial training period. In these cases, bines were trained as they reached appropriate length over the following two weeks. A history of training dates at the UVM hop yard is shown in Table 1. Practices utilized throughout the season are shown in Table 2.

Table 2: Fertility, irrigation and weed management, Alburgh, VT 2015.

Borderview Research Farm - Alburgh, VT	
Soil type	Benson rocky silt loam
Fertilizer (mid May)	100 lbs/acre N
Fertilizer (late June)	50 lbs/acre N
Fertigation	Weekly 1-June to 25-June, 3lbs/acre N
Irrigation	Weekly, 3900 gallons/acre
String-trimming	Bi-weekly, all season
Hand weeding + mulch	Early June
Avenger Herbicide	29-May, 6-Jul

WEATHER

Using data from a Davis Instruments Vantage Pro2 weather station at Borderview Research Farm in Alburgh, VT, weather data was summarized for the months spanning the 2015 hop growing season.

WEED MANAGEMENT

Hand-weeding, herbicide, and mulch were the primary weed control methods. Other weeding methods were studied this year as well in a different trial. Results from the "2015 Hop Weed Management Trial" are available through our website: www.uvm.edu/extension/cropsoil.

Mulch was assorted hardwood and was applied six inches thick and spread 3-4 feet wide. The mulch was applied early enough to smother young weeds that had already germinated and to prevent new germination (Table 2). The total amount of mulch used was equivalent to about 110 cubic yards per acre of hops. Choosing an appropriate type of mulch is very important: the mulch must be at least partially composted, or else it will likely absorb important plant nutrients such as nitrogen, limiting their availability to the hop plants.

Organic OMRI-approved herbicide Avenger (Cutting Edge Formulations, Inc., EPA reg. no. 82052-1) was applied according to the label recommendation of about 5 gallons per acre (before dilution). Avenger was used as a "spot spray" to minimize weed competition. One part Avenger was mixed to six parts water and applied with a 10-gallon electric sprayer unit pulled by a ride-on lawnmower. Avenger is a citrus-based concentrate that removes the plant cuticle on contact, making the plant unable to adequately regulate moisture. It works by direct surface contact only, so all vegetation must be sprayed to be killed. Avenger is meant for all types of weeds, but it is most effective on annual plants and may take multiple applications to kill established perennials such as quack grass.

DOWNY MILDEW MANAGEMENT

Downy mildew (*Pseudoperonospora humuli*) was identified in the hop yard in June of 2011. In the spring of 2013, a majority of the hills were "scratched" as an early season preventative measure against downy mildew. Scratching is a practice initiated in the early spring when new growth has just emerged from the soil. Removal of this new growth through mechanical means helps to remove downy mildew inoculum that has overwintered in the crown. The first shoots have an irregular growth rate and are not the most desirable for producing hop cones later in the season. The top of the crown itself can be removed before new growth emerges to further eliminate overwintering downy mildew. This practice, which was implemented in the hop yard in 2014, is commonly referred to as "crowning". Crowning was performed on 1-May 2015 using a DR trimmer fitted with a modified, toothed metal blade. Crowning dates from past years are shown in Table 3. A section of the hop yard was used to trial different crowning dates. Results from the "2015 Crowning Trial" are available through our website.

Table 3: Crowning dates from 2013-2015, Alburgh, VT 2015.

Year	Date
2013	19-Apr
2014	14-Apr
2015	1-May

Fungicides were sprayed when the forecast predicted weather favorable to downy mildew (warm and moist) (Table 4). There was a weather event favorable to downy mildew at least once out of every week of the growing season (Figure 21).

The fungicides used in the research yard in 2015 were Champ WG (Nufarm Americas Inc, EPA Reg. No. 55146-1), and Regalia (Marrone Bio Innovations, EPA Reg. No. 84059-3). Champ WG is 77% copper hydroxide and works as a control measure against downy mildew in hops. When copper hydroxide is mixed with water, it releases copper ions, which disrupt the cellular proteins of the fungus. Regalia is a broad spectrum bio-fungicide that works by stimulating the plant's natural defenses. All pesticides applied were OMRI-approved for use in organic systems and were applied at rates specified by their labels using a Rear's Manufacturing Nifty Series 50-gallon stainless steel tank utility sprayer with PTO-driven mechanical agitation, a 3-point hitch, and a Green Garde® JD9-CT spray gun. A separate trial studied alternative fungicide options including biological fungicides. The "2015 Biofungicide Trial" is available on our website.

Table 4: Downy mildew spray schedule in the organic hop variety trial, Alburgh, VT 2015.

Date	Champ WG	Regalia
21-May	X	
29-May	X	
5-Jun	X	
12-Jun	X	X
19-Jun	X	X
26-Jun	X	X
6-Jul	X	X
13-Jul	X	X
27-Jul	X	X
14-Aug	X	X

ARTHROPOD MANAGEMENT

Arthropod scouting started in early June. Three leaves per hill and two hills per plot were scouted for insect pests and disease weekly in June, July, and August. Potato leafhoppers (*Empoasca fabae Harris*), two-spotted spider mites (*Tetranychus urticae Koch*), and aphids (*Aphis spp.*) were identified in the hop yard. Beneficial arthropods were also scouted and recorded. Economic thresholds for potato leafhoppers in hops have not been created, but with an in-depth literature review, it was determined that two leafhoppers per leaf may be economically damaging to hops. A fact sheet on potato leafhoppers in hops can be found at: http://www.uvm.edu/extension/cropsoil/wp-content/uploads/PLH-2014-Factsheet.pdf.

Economic thresholds for two-spotted spider mites (TSSM) have been suggested in the Pacific Northwest to be 1-2 spider mites per leaf in June or 5-10 per leaf in July, based on a study done by Strong and Croft in 1995. A fact sheet from Cornell Cooperative Extension on TSSM can be found here: http://nehopalliance.org/wp-content/uploads/2011/08/Article-Two-Spotted-Spider-Mite.pdf.

Of late, some question has arisen on whether these TSSM thresholds are accurate (Weihrauch 2005). It is important to note that spraying to control pests also eliminates many beneficial arthropods that help keep pest populations in check. Always consider carefully whether pesticide application is necessary before spraying. Insecticides have not been applied in the hop yard since 2012. Insecticide controls were not needed in 2015.

IRRIGATION AND FERTILITY MANAGEMENT

The hop yard was irrigated weekly in July and August at a rate of 3900 gallons of water per acre. 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. Fertigation (fertilizing through the irrigation system) was used to apply fertilizer more efficiently. Starting in early June, the hops received 3 lbs ac^{-1} of nitrogen (N) through the irrigation system on a weekly basis until side shoots were observed. At each fertigation application 22 lbs of Ferti-Nitro Plus soy-based organic fertilizer (13.5% N) or 18.8 lbs ac^{-1} of Chilean nitrate (16% N) were applied during irrigation events. The fertilizer was distributed evenly through 3000 gallons of water using a Dosatron unit. In addition to the fertigation, 100 lbs ac^{-1} of N was applied by hand in mid May. Another 50 lbs ac^{-1} was applied by hand in late June. Chilean Nitrate (16-0-0) and Pro Booster (10-0-0) were used to supply N to the hops on those two dates. Total N application (including fertigation) for the season was 165 lbs 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).

HARVEST

Hop harvest was separated by variety and targeted for when cones reached 20-25% dry matter. At harvest, hop bines were cut in the field and brought to a secondary location to be run through a harvester. Yields for each variety represent the mean of 3 replicates.

Harvest date for each variety can be found in the results section in Table 6. Picked hop cones were weighed on a per plot basis, 100-cone weights were recorded, and moisture was determined using a food dehydrator. An online hop moisture calculator is available at http://www.uvm.edu/extension/agriculture/engineering/?Page=hopscalc.html.

One string from each plot for varieties Cascade, Chinook, Newport and Nugget was weighed before and after harvest to determine the weight of the plant relative to the hops. A sample of the bine and cone material from those varieties was sent to the Dairy One Forage Laboratory to be analyzed for macronutrients. Then, based on biomass weight of harvested plants, nutrient removal was calculated on a per acre basis.

Hop cones from all plots were dried to 8% moisture, baled, vacuum sealed, and then stored in a freezer. Hop cones from each plot were analyzed for alpha and beta acids in our lab using spectrophotometry as per the American Society of Brewing Chemists (ASBC) Method of Analysis entitled Hops 6a. Hop Storage Index (HSI) was also measured using the ASBC Method of Analysis detailed in Hops 12. Hop brewing quality data is presented as varietal averages across the trial. The brewing quality of each variety was compared to industry standards.

Yields are presented at 8% moisture on a per string and per acre basis. Per acre calculations were performed using the spacing in the UVM Extension hop yard of 622 hills (1244 strings) per acre.

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.). Pearson correlation coefficients (r) and probability levels for spider mite thresholds developed in the Pacific Northwest, brew values, and growth characteristics were performed across varieties. Pearson correlation coefficients (r) were also used to determine significance between these factors. Correlations were deemed significant at the $p<0.10$ level, and the Pearson correlation coefficient (r) was used to determine the degree of correlation, and whether it was a negative or positive correlation.

RESULTS

Using data from a Davis Instruments Vantage Pro2 weather station at Borderview Research Farm in Alburgh, VT, weather data was summarized for the 2015 growing season (Table 5). The 2015 growing season (March-September) experienced 5692 GDD's, which were 220 more than the 30 year average (1981-2010 data). However, more than half of the higher-than-normal degree days came in August and September. Low April temperatures and dry conditions set the stage for the growing season, and may have had a meaningful negative impact on overall results this year. Once shoots had emerged, the primary growing month of June and part of July were cold and wet, likely further slowing growth (Table 5).

Table 5: Temperature, precipitation, and Growing Degree Day summary, Alburgh, VT, 2015.

Alburgh, VT	March	April	May	June	July	August	Sept
Average temperature (°F)	26.0	43.4	61.9	63.1	70.0	69.7	65.2
Departure from normal	-5.0	-1.4	5.6	-2.7	-0.6	1.0	4.7
Precipitation (inches)	0.8	2.6	1.9	6.4	1.5	0.0	0.3
Departure from normal	-1.5	-0.2	-1.5	2.7	-2.7	-3.9	-3.3
Growing Degree Days (32-90°F)	70	373	930	938	1188	1184	1010
Departure from normal	-54	-16	177	-76	-9	45	154

Based on weather data from a Davis Instruments Vantage Pro2 with WeatherLink data logger. Historical averages are for 30 years of NOAA data (1981-2010) from Burlington, VT.

YIELD

The hop harvest window was from 25-Aug to 16-Sep in 2015 (Table 6). This was a good deal later than the 2014 season, which started in the second week of August and finished in the first week of September.

Table 6: Dry matter and harvest date by Variety, Alburgh, VT 2015.

Variety	Average dry matter	Harvest date
	%	
Cascade	25.7	02-Sep
Centennial	27.2	31-Aug
Chinook	24.8	02-Sep, 03-Sep
Crystal	23.4	25-Aug, 15-Sep
Fuggle	25.9	25-Aug
Galena	24.0	02-Sep
Glacier	24.2	02-Sep
Horizon	28.0	25-Aug
Liberty	21.6	25-Aug, 16-Sep
Mt. Hood	23.2	16-Sep
Newport	28.6	31-Aug, 8-Sep
Nugget	27.0	08-Sep
Perle	22.1	25-Aug
Saaz	23.3	25-Aug
Santiam	23.6	01-Sep, 16-Sep
Sterling	21.4	01-Sep
Tettnang	25.2	25-Aug
Vanguard	26.5	02-Sep, 15-Sep
Willamette	24.8	31-Aug
074	26.5	08-Sep, 11-Sep, 16-Sep

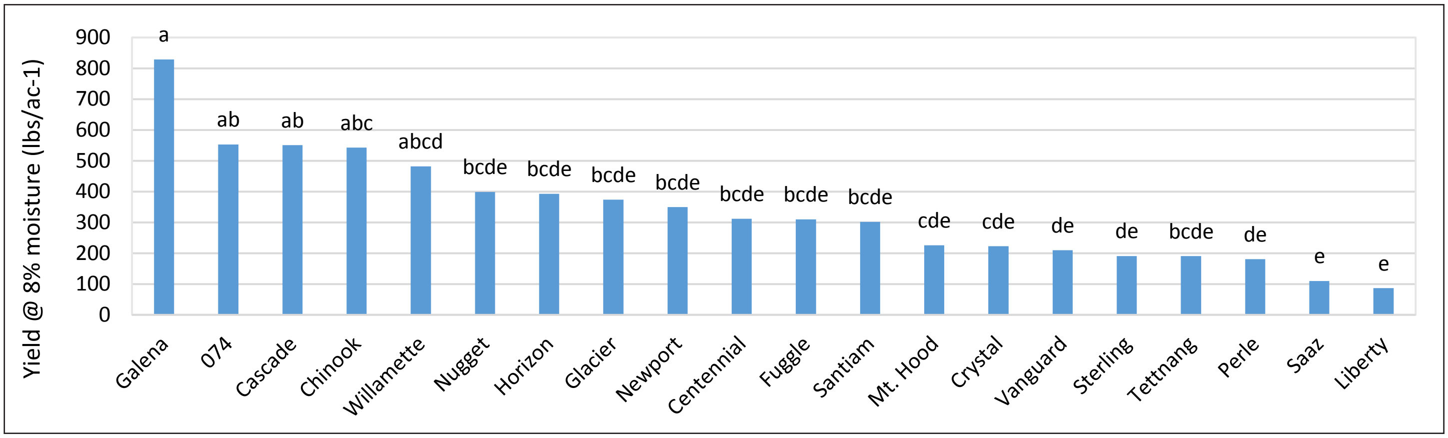

Figure 1: Hop yield in lbs ac^{-1} by variety, Alburgh, VT 2015. *Values followed by the same letter are not significantly different.*

The largest and heaviest cones were produced by 074, Centennial, and Newport (Table 7). Liberty and Glacier had the smallest cones. Galena was the highest yielding variety, producing 0.70 lbs of hops per string at 8% moisture, or 8295 lbs ac^{-1}. Liberty was the lowest yielding variety (Table 7, Figure 1). The top 5 varieties for yield per acre at 8% moisture were Galena, 074, Cascade, Chinook and Willamette respectively (Figure 1).

Table 7: 100 cone weight and yield at 8% moisture by variety, Alburgh, VT 2015.

Variety	100 Cone Weight		Yield @ 8% moisture			
	g		lbs per string		lbs ac^{-1}	
Galena	22.7	bc	**0.67**	a	**829**	a
074	38.7	a	0.44	ab	553	ab
Cascade	21.5	bc	0.44	ab	551	ab
Chinook	19.1	bcde	0.44	abc	543	abc
Willamette	14.7	bcde	0.39	abcd	482	abcd
Nugget	17.5	bcde	**0.32**	bcde	399	bcde
Horizon	17.3	bcde	0.32	bcde	393	bcde
Glacier	8.2	e	0.30	bcde	374	bcde
Newport	24.8	b	0.28	bcde	349	bcde
Centennial	25.0	b	0.25	bcde	312	bcde
Fuggle	12.1	cde	0.25	bcde	310	bcde
Santiam	19.6	bcd	0.24	bcde	302	bcde
Mt. Hood	10.1	de	0.18	cde	225	cde
Crystal	10.9	cde	0.18	cde	223	cde
Vanguard	9.7	de	0.17	de	210	de
Sterling	9.2	de	0.15	de	191	de
Tettnang	10.5	cde	0.15	bcde	191	bcde
Perle	11.9	cde	0.15	de	181	de
Saaz	11.4	cde	0.09	e	110	e
Liberty	7.1	e	0.07	e	87	e
P-value	<.0001		<.0001		<.0001	

*Within a column, values followed by the same letter are not significantly different. Values in **bold** indicate top performing treatments.*

The yield of each variety was quite variable depending on the location of the plot in the hop yard. The wide variation between plots of the same variety can be partly explained by the history of the yard. At the time of the hop yard establishment, each plot contained 5 hills with two crowns per hill. Over the last 3 years, a number of the hills have been killed by disease, insect, or other production pressures (Figure 20). Several of the plots also have hills that have been weakened from environmental and/or pest pressures. For example, the eastern section of our hop yard is shaded during the morning hours, which causes some of the plants in that section to be smaller and perform below average.

Table 8 shows the range in yield for each variety. Because of the variability in plot performance, some varieties have a wide range of yields. For example, while Chinook averaged 543 lbs ac^{-1} across three plots (the fourth highest yield this year), the lowest yielding Chinook plot was 346 lbs ac^{-1}, a yield which 13 other varieties also reached or exceeded in at least one of their plots.

Table 8: Range of yields by variety, Alburgh, VT 2015.

Variety	Yield @ 8% moisture	
	Minimum	Maximim
	lbs ac^{-1}	lbs ac^{-1}
Cascade	547	557
Centennial	311	313
Chinook	346	761
Cluster	578	578
Crystal	154	347
Fuggle	287	331
Galena	667	990
Glacier	227	524
Horizon	251	548
Liberty	58	119
Mt. Hood	191	254
Mt. Rainier	891	891
Newport	116	482
Nugget	268	573
055	339	339
074	298	747
Perle	126	218
Saaz	82	138
Santiam	197	371
Sterling	149	242
Teamaker	325	325
Tettnang	167	214
Vanguard	129	279
Willamette	428	523

BREWING QUALITY

Only seven of the hop varieties met or exceeded the industry standard for alpha acids in 2015 (Table 9, Figure 2). Just over half of the hop varieties met the industry standards for beta acids in 2015 (Table 9, Figure 3). This is much different than the 2014 harvest, in which more than half of varieties met alpha acid standards and all varieties met beta acid standards. In Figure 2 and Figure 3, green bars denote industry averages based on information from Hopunion and USA Hops:

https://www.hopunion.com/hop-varieties/
http://www.usahops.org/userfiles/file/HGA%20BCI%20Reports/HGA%20Variety%20Manual%20-%20English%20%28updated%20March%202011%29.pdf

Table 9: Percent alpha acids, beta acids and Hop Storage Index (HSI) by variety, Alburgh, VT 2015.

Variety	Alpha Acids	Beta Acids	HSI
	%	%	
Cascade	5.5	6.9	0.14
Centennial	8.7	4.0	0.27
Chinook	8.4	3.4	0.25
Cluster	8.4	5.2	0.24
Crystal	5.5	6.2	0.24
Fuggle	3.0	3.0	0.35
Galena	8.8	5.3	0.25
Glacier	3.9	5.9	0.24
Horizon	9.7	6.4	0.23
Liberty	2.3	2.8	0.21
Mthood	4.3	6.9	0.16
Newport	11.7	5.8	0.21
Nugget	15.1	4.5	0.21
O55	10.1	3.4	0.20
O74	10.2	2.9	0.10
Perle	6.8	5.2	0.27
Saaz	2.2	2.8	0.29
Santiam	3.2	6.1	0.22
Sterling	3.7	3.7	0.18
Tettnang	3.2	2.5	0.32
Vanguard	6.5	7.6	0.21
Willamette	8.3	3.9	0.25

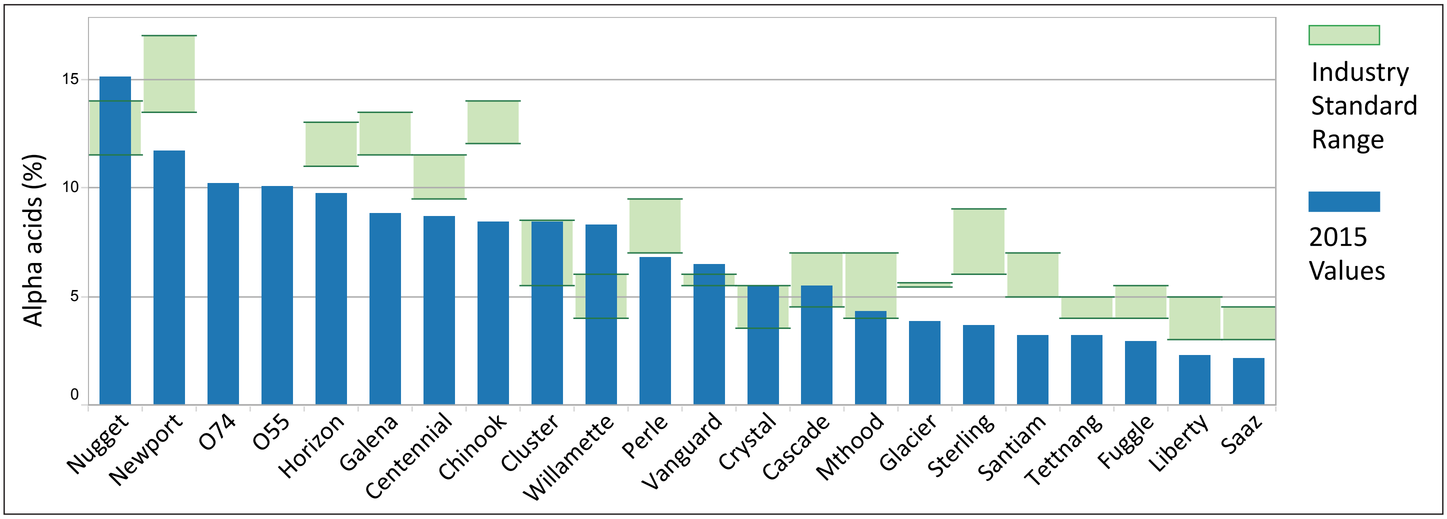

Figure 2: Alpha acid levels for hops from the 2015 harvest, Alburgh, VT 2015. Industry standards based on information from USA Hops and Hopunion. 055 and 074 are experimental varieties and do not have an industry standard.

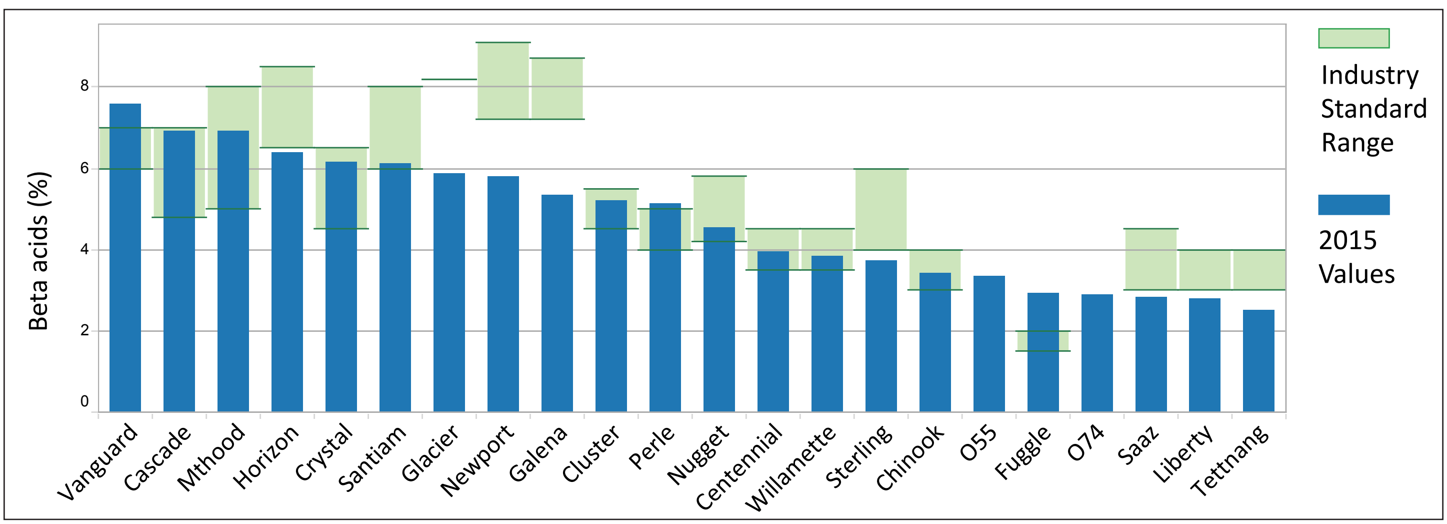

Figure 3: Beta acid levels for hops from the 2015 harvest, Alburgh, VT 2015. Industry standards based on information from USA Hops and Hopunion. 055 and 074 are experimental varieties and do not have an industry standard.

HARVEST YEAR-TO-YEAR COMPARISONS

Yield comparisons from 2013 to 2015 show that this was the first year that overall yield has not increased. The 2015 growing conditions seemed to suit Galena, which experienced a big jump in yield to 829 lbs ac^{-1} from 534 lbs ac^{-1} in 2014 (Figure 4).

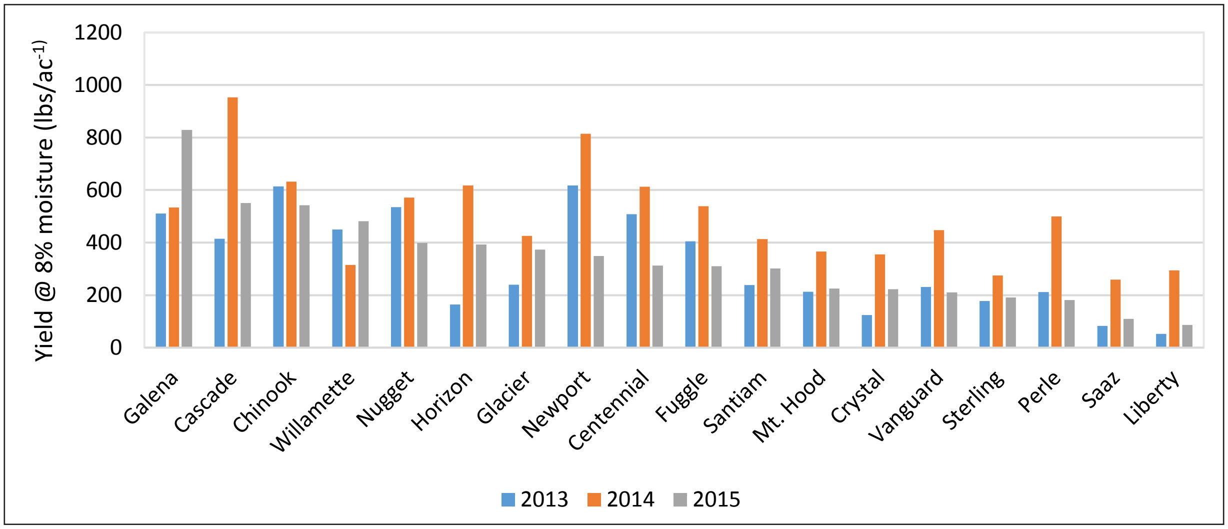

Figure 4: Comparison of 2013, 2014 and 2015 yields, Alburgh, VT.

Alpha acids for many varieties are lower in 2015 than they were in 2014 (Figure 5). Aside from the general trend, higher variability of alpha acids in a certain variety may indicate that the plant's cone quality is more easily impacted by variations in year-to-year growing conditions, the maturity of the plant, or water and nutrient deficiencies.

Some variability was also observed from year-to-year in beta acids, although overall they were relatively consistent (Figure 6).

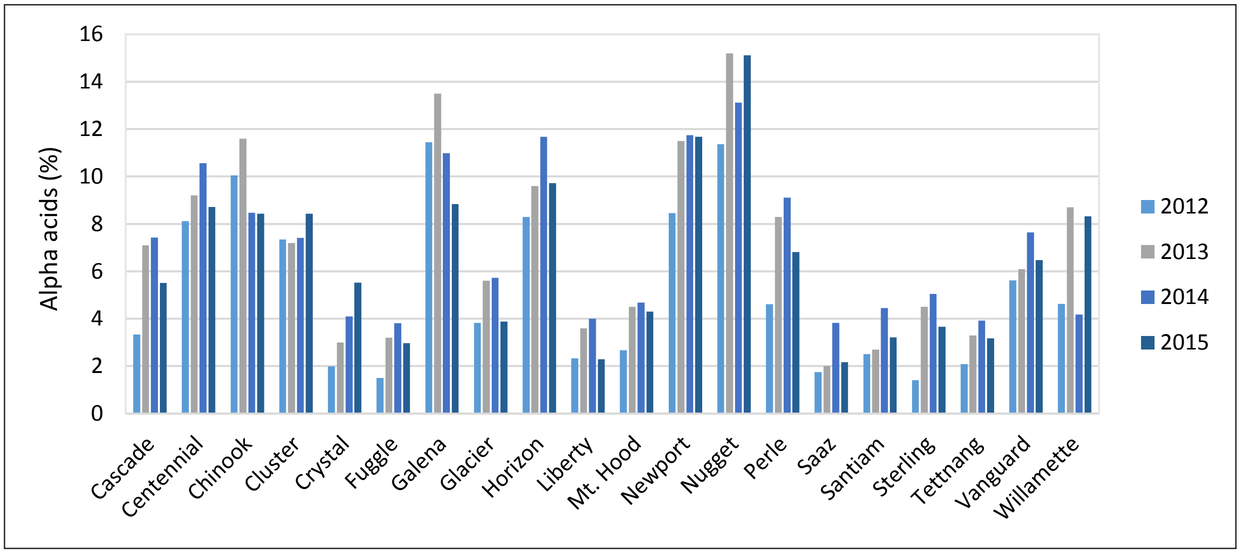

Figure 5: Alpha acid comparison, 2012-2015 harvest, Alburgh, VT.

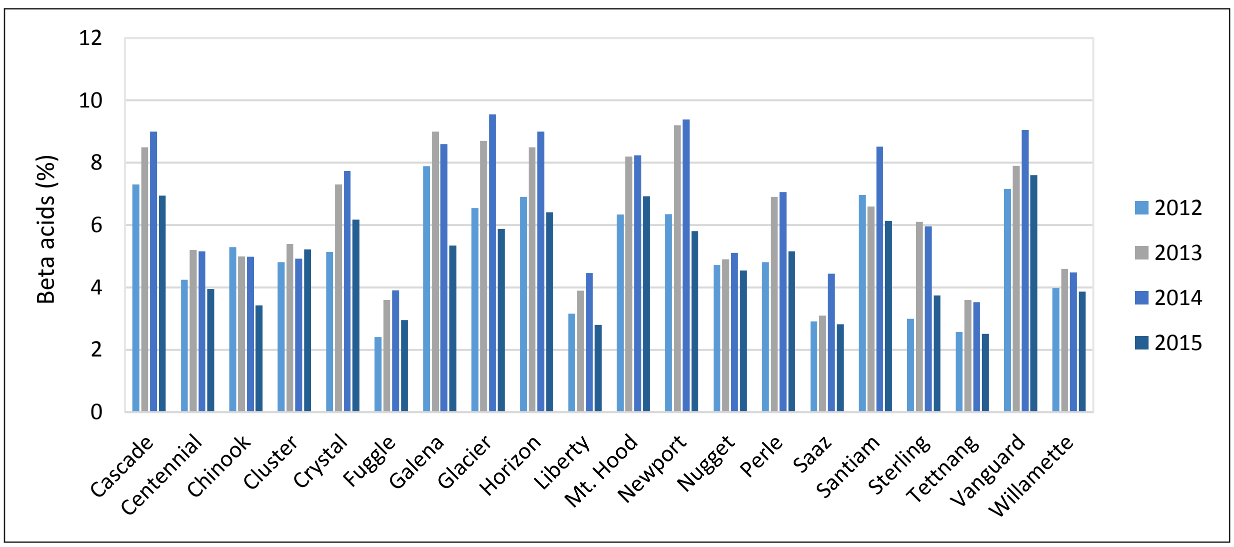

Figure 6: Beta acid comparison, 2012-2015 harvest, Alburgh, VT.

HOP NUTRIENTS

Bine and cone nutrients were measured for Cascade, Chinook, Newport and Nugget. Uptake of macronutrients for hop plants is expected to be 80-150 lbs ac^{-1} of nitrogen (N), 20-30 lbs ac^{-1} phosphorous (P), and 80-150 lbs ac^{-1} potassium (K) (Gingrich et al. 2000). In general, 20-30% of the nutrients are expected to be in the cones. In 2015, the cones had an average of 36% of total nutrients. Table 10, Table 12 and Table 13 show calculated nutrient removal for the bines and cones by variety.

Figure 7 shows total N removal (including bines and cones) by variety in lbs ac^{-1}. Chinook had the highest nitrogen removal at 94.8 lbs ac^{-1} (Figure 7). All varieties except Cascade were within range of expected N uptake, but on the lowest possible end of the range.

The plants sampled here did not represent the whole yard in terms of plant size and yield. On average, the sampled plants represented the healthier plants in the yard. Sampling larger plants helped to get a sense of the nutrient requirements of the plants that we hope to be growing in our hop yard. Table 11 shows the whole plant (bine and cones) dry matter yield per acre for the sampled plants by variety.

Table 10: Nitrogen removal by variety, Alburgh, VT 2015.

	Cascade	Chinook	Newport	Nugget
	lbs N ac^{-1}			
Bine	45.2	64.6	58.8	55.6
Cone	32.8	30.2	26.4	29.2
Total	78.0	94.8	85.2	84.8

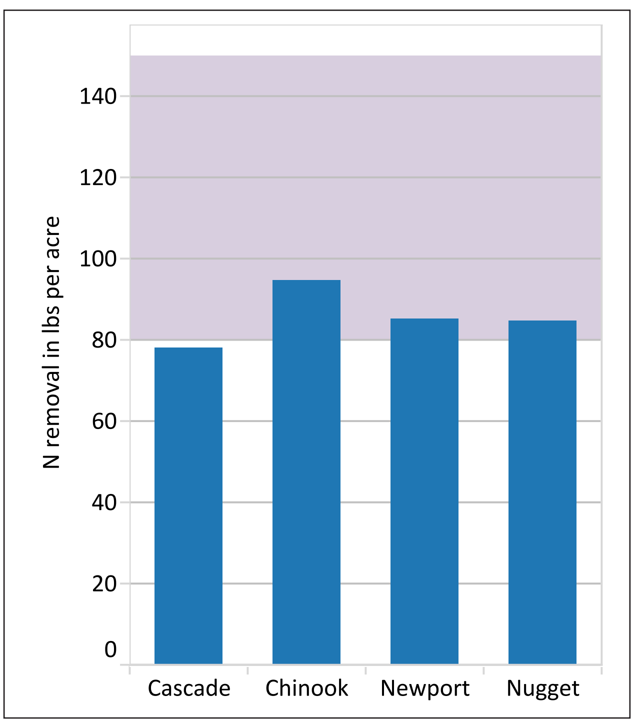

Figure 7: Nitrogen removal by variety, Alburgh, VT 2015.
Purple shaded area shows expected range.

Table 11: Total biomass of plants sampled for nutrient removal, Alburgh, VT 2015.

Variety	Whole plant dry matter
	lbs ac^{-1}
Cascade	2,964
Chinook	3,159
Newport	2,622
Nugget	2,964

Figure 8 shows total P removal (including bines and cones) by variety in lbs ac^{-1}. Newport had the highest P removal at 20.5 lbs ac^{-1} and was the only variety within expected range for P uptake. Newport had the highest K removal as well, with 71.5 lbs ac^{-1} (Figure 9), although none of the varieties met the expected K uptake level.

Table 12: Phosphorous removal by variety, Alburgh, VT 2015.

	Cascade	Chinook	Newport	Nugget
	lbs P ac^{-1}			
Bine	7.1	11.7	14.1	12.5
Cone	6.3	6.3	6.4	7.0
Total	13.4	18.0	20.5	19.5

Table 13: Potassium removal by variety, Alburgh, VT 2015.

	Cascade	Chinook	Newport	Nugget
	lbs K ac^{-1}			
Bine	33.4	47.4	47.9	44.9
Cone	25.9	23.6	23.6	24.1
Total	59.3	71.0	71.5	69.0

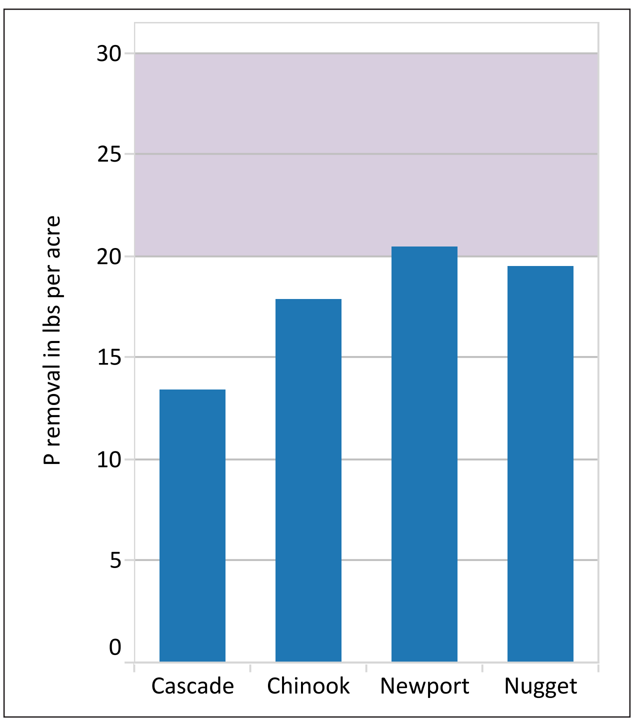

Figure 8: Phosphorous removal by variety, Alburgh, VT 2015. Purple shaded area shows expected range.

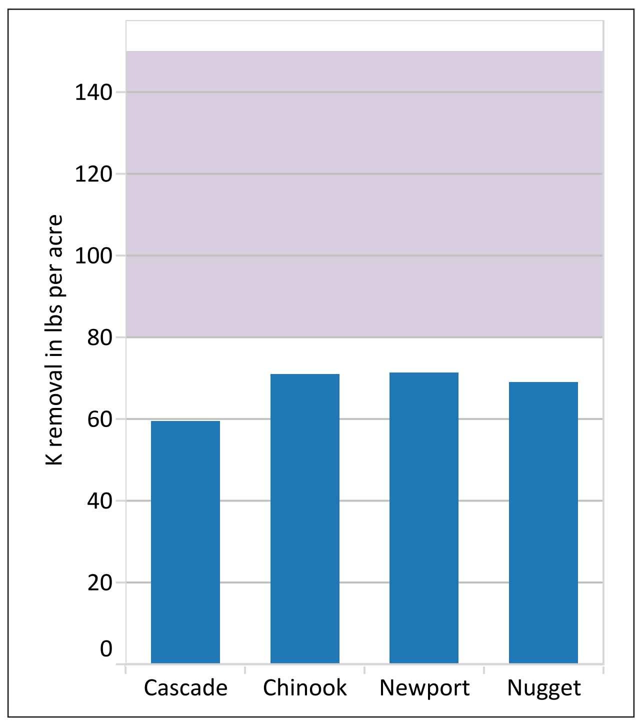

Figure 9: Potassium removal by variety, Alburgh, VT 2015. Purple shaded area shows expected range.

Another way to look at nutrient content is by measuring nutrients in percent of total biomass. Ideally, 3.0% of the total plant biomass at harvest will be N, 0.50% P, and 2.0% K. From this perspective, Newport and Nugget met expected P levels, and Cascade and Newport met expected K levels, but none of the varieties met expected N levels (Table 14).

Table 14: Percent nitrogen, phosphorous and potassium for total hop plant, Alburgh, VT 2015.

Variety	Nitrogen (N)	Phosphorous (P)	Potassium (K)
	%	%	%
Cascade	2.7	0.4	2.0
Chinook	2.3	0.4	1.8
Newport	2.6	0.6	2.1
Nugget	2.2	0.5	1.7

Percent nutrients presented on a dry matter basis.

CONE DISEASE

There was a considerable amount of disease on harvested cones. Incidence of disease varied significantly across varieties: Mt. Hood had an especially high incidence of disease on the cones (91%) and varieties Glacier and Perle had very low incidence (11%) compared to other varieties (Table 15).

The severity of disease on cones was assessed on a scale of severity from 1-10, 10 being most severe. Disease severity varied more than disease incidence (Figure 10, Table 15). Liberty, Saaz and Mt. Hood had the highest disease severity on the cones while Galena, Newport and Perle cones were relatively free of disease.

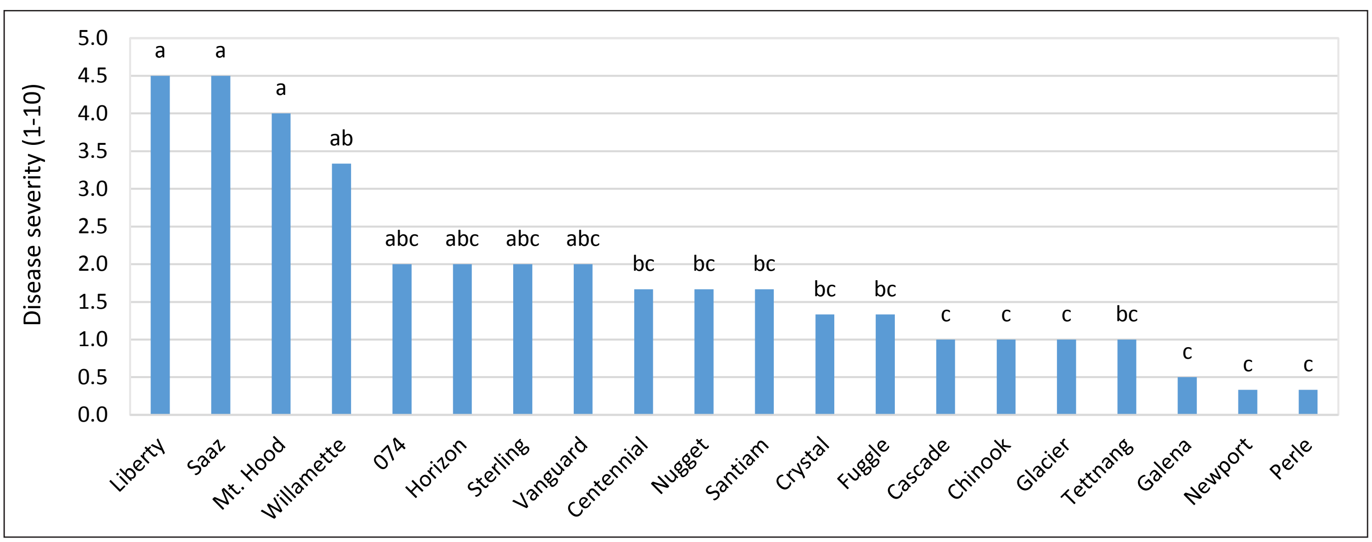

Figure 10: Disease severity 01-10 by variety, 10 being most severe, Alburgh, VT 2015.

Table 15: Disease incidence and severity on harvested cones, Alburgh, VT 2015.

Variety	Disease Incidence		Disease Severity	
	%		out of 10	
Cascade	28	bc	1.0	c
Centennial	50	abc	1.7	bc
Chinook	32	bc	1.0	c
Crystal	19	bc	1.3	bc
Fuggle	26	bc	1.3	bc
Galena	39	bc	0.5	c
Glacier	11	c	1.0	c
Horizon	58	ab	2.0	abc
Liberty	57	abc	4.5	a
Mt. Hood	91	a	4.0	a
Newport	19	bc	0.3	c
Nugget	54	abc	1.7	bc
Perle	11	c	0.3	c
Saaz	50	abc	4.5	a
Santiam	32	bc	1.7	bc
Sterling	42	bc	2.0	abc
Tettnang	46	abc	1.0	bc
Vanguard	61	ab	2.0	abc
Willamette	52	abc	3.3	ab
074	60	ab	2.0	abc
P-value	<.0001		<.0001	

Within a column, values followed by the same letter are not significantly different.

ARTHROPODS

Major pests that are scouted for in the UVM Extension hop yard include two-spotted spider mites (TSSM), potato leafhoppers (PLH), and hop aphids (aphids). We also scout for spider mite destroyers (SMD), a predator of TSSM. No organic pesticides were applied to the hop plants during the 2015 growing season. Pest populations in 2015 were such that spraying was not deemed necessary. Major pest populations throughout the 2015 growing season are shown in Figure 11.

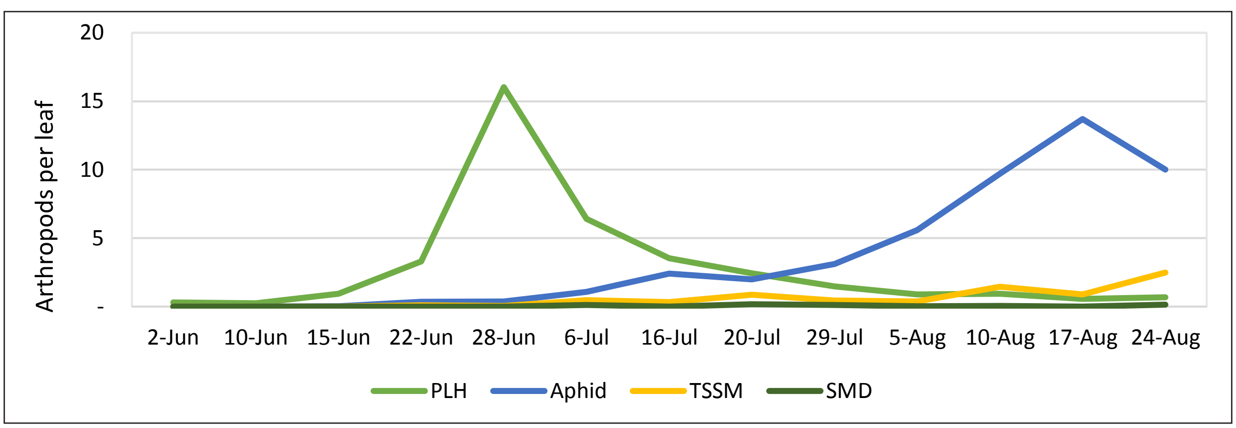

Figure 11: Average number of potato leafhoppers (PLH), aphids, two-spotted spider mites (TSSM) and spider mite destroyers (SMD) per leaf by sample date, Alburgh, VT 2015.

PEST PRESSURE – TWO-SPOTTED SPIDER MITES (TSSM)

Overall TSSM pressure in the hop yard was low in 2015. A slight significant difference was found between hop varieties for the two-spotted spider mite (TSSM) (Table 16, Figure 12). Liberty had the highest levels of TSSM (Table 16, Figure 12).

Table 16: Average number of TSSM and SMD per leaf by variety, Alburgh, VT 2015.

Variety	TSSM		SMD	
	# per leaf		# per leaf	
Liberty	2.05	a	0.21	a
Saaz	1.36	ab	0.03	a
Crystal	1.00	ab	0.18	a
Vanguard	0.95	ab	0.05	a
Santiam	0.87	ab	0.03	a
Sterling	0.87	ab	0.15	a
Newport	0.81	ab	0.10	a
Centennial	0.69	ab	0.03	a
055	0.57	b	0.03	a
Galena	0.44	b	0.05	a
Mt. Hood	0.38	b	0.03	a
Tettnang	0.38	ab	0.04	a
Horizon	0.37	b	0.00	a
Nugget	0.36	b	0.05	a
Chinook	0.28	b	0.00	a
Perle	0.28	b	0.08	a
Fuggle	0.26	b	0.03	a
Cascade	0.23	b	0.00	a
Glacier	0.21	b	0.00	a
Willamette	0.15	b	0.03	a
074	0.14	b	0.00	a
Teamaker	0.08	b	0.00	a
P-value	.0023		.1667	

Within a column, values followed by the same letter are not significantly different.

Table 17: Average number of TSSM and SMD per leaf by sample date, Alburgh, VT 2015.

Sample Date	TSSM		SMD	
	# per leaf		# per leaf	
2-Jun	0.00	c	0.00	b
10-Jun	0.00	c	0.00	b
15-Jun	0.00	c	0.00	b
22-Jun	0.10	c	0.00	b
28-Jun	0.06	c	0.00	b
6-Jul	0.47	bc	0.11	ab
16-Jul	0.33	c	0.00	b
20-Jul	0.87	bc	0.17	a
29-Jul	0.44	bc	0.13	ab
5-Aug	0.39	c	0.01	ab
10-Aug	1.44	ab	0.06	ab
17-Aug	0.90	bc	0.00	b
24-Aug	2.49	a	0.14	ab
P-value	<.0001		.0009	

Within a column, values followed by the same letter are not significantly different.

Populations of TSSM and SMD differed significantly by sample date (Table 17, Figure 13). TSSM populations peaked in the hot, dry part of the season on 24-Aug.

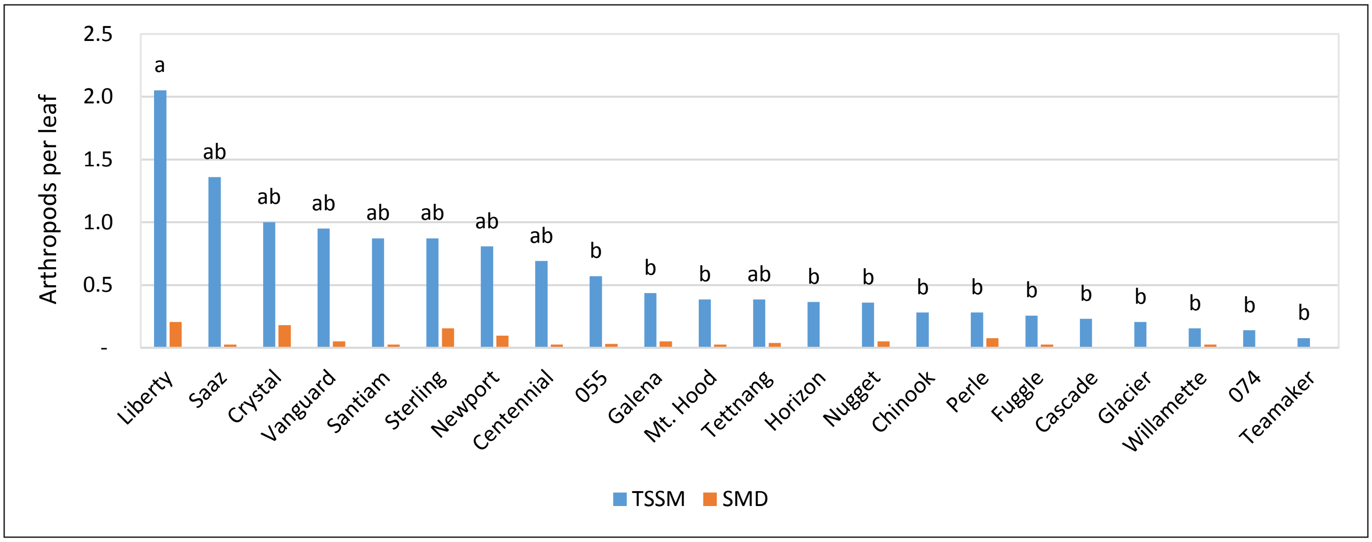

Figure 12: Average number of two-spotted spider mites (TSSM) and spider mite destroyers (SMD) per leaf by variety, Alburgh, VT 2015.

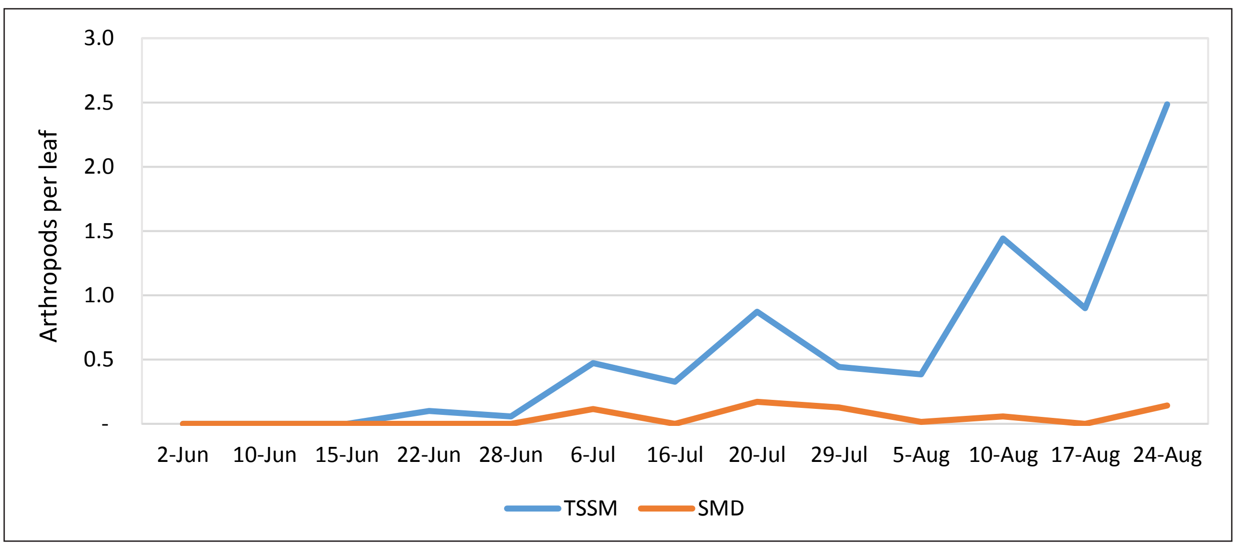

Figure 13: Average number of two-spotted spider mites (TSSM) and spider mite destroyers (SMD) per leaf by sample date, Alburgh, VT 2015.

PEST PRESSURE – POTATO LEAFHOPPERS (PLH)

PLH pressure was very high in 2015 in comparison to other years. Average number of PLH varied significantly by hop variety, with Saaz hosting the highest populations and 074 and Horizon the lowest (Table 18, Figure 14).

Table 18: Average number of PLH per leaf by variety, Alburgh, VT 2015.

Variety	PLH	
	# per leaf	
Saaz	6.82	a
Liberty	5.92	ab
Newport	5.37	abc
Mt. Hood	5.13	abc
Cascade	3.97	abcd
Nugget	3.90	abcd
Santiam	3.90	abcd
Perle	2.95	abcd
Teamaker	2.92	abcd
Sterling	2.74	abcd
Fuggle	2.64	abcd
Willamette	2.33	bcd
Crystal	2.21	bcd
055	2.06	bcd
Tettnang	2.04	abcd
Vanguard	1.82	bcd
Galena	1.74	bcd
Glacier	1.67	bcd
Chinook	1.51	cd
Centennial	1.46	cd
074	1.20	d
Horizon	0.87	d
P-value	<.0001	

Within a column, values followed by the same letter are not significantly different.

Table 19: Average number of PLH per leaf by sample date, Alburgh, VT 2015.

Sample Date	PLH	
	# per leaf	
2-Jun	0.31	de
10-Jun	0.24	e
15-Jun	0.93	cde
22-Jun	3.30	cd
28-Jun	16.03	a
6-Jul	6.41	b
16-Jul	3.54	c
20-Jul	2.44	cde
29-Jul	1.49	cde
5-Aug	0.89	cde
10-Aug	0.93	cde
17-Aug	0.57	de
24-Aug	0.67	cde
P-value	<.0001	

Within a column, values followed by the same letter are not significantly different.

Potato leafhoppers arrived in early June, peaking at the end of June (Table 19, Figure 15). A significant difference was found between sample dates for PLH.

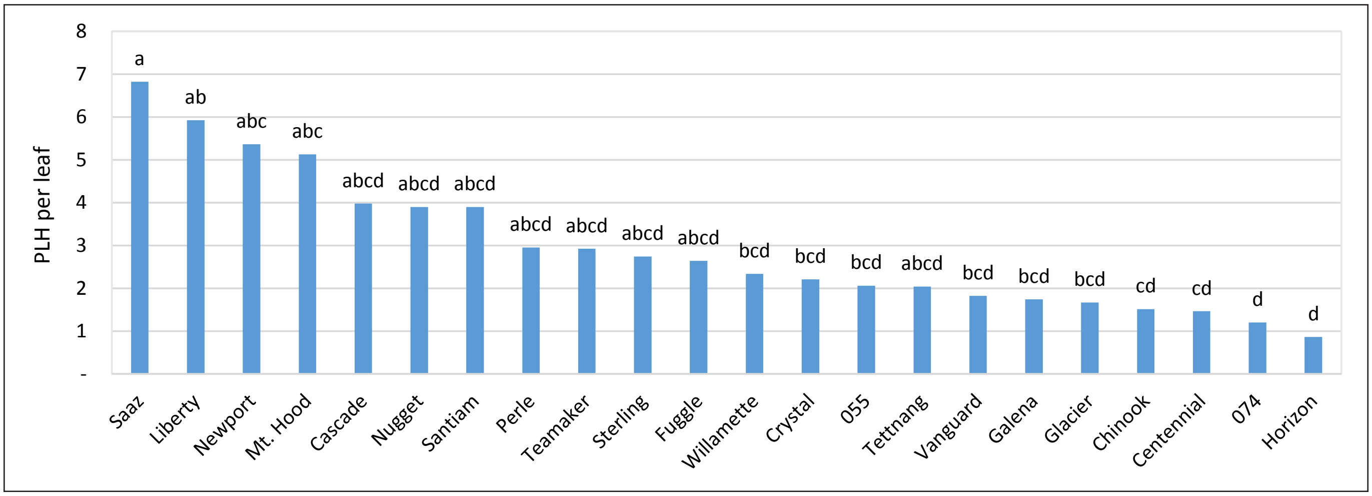

Figure 14: Average number of potato leafhoppers (PLH) per leaf by variety, Alburgh, VT 2015.

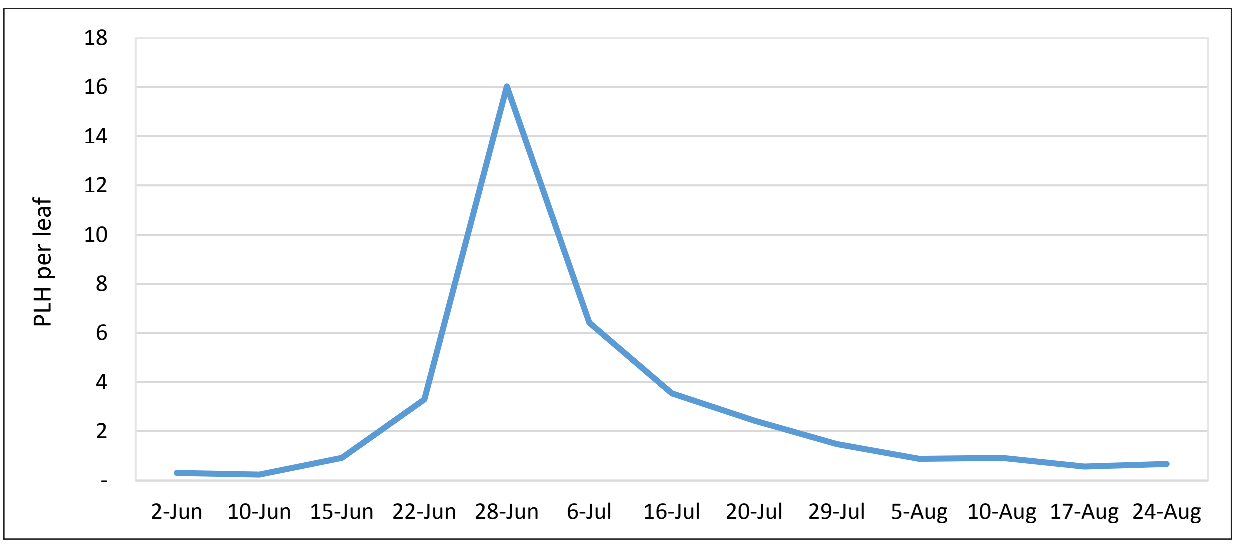

Figure 15: Average number of potato leafhoppers (PLH) per leaf by sample date, Alburgh, VT 2015.

PEST PRESSURE – APHIDS

Aphid populations reached a fairly high number at the end of the 2015 season. However, there was no evidence that they negatively impact yield or quality. There was little significant difference by variety across the 2015 season (Table 20, Figure 16). Willamette had the highest average population of aphids, while Fuggle had the lowest. Aphid populations were the highest from early July to harvest time (Table 21, Figure 17).

Table 20: Average number of aphids per leaf by variety, Alburgh, VT 2015.

Variety	Aphids	
	# per leaf	
Willamette	6.97	a
Galena	6.59	ab
Centennial	5.56	ab
Glacier	5.49	ab
074	4.38	ab
Santiam	4.26	ab
Newport	4.23	ab
Tettnang	4.23	ab
Saaz	4.21	ab
Chinook	3.85	ab
Horizon	3.65	ab
Nugget	3.64	ab
055	3.51	ab
Liberty	3.38	ab
Crystal	3.05	ab
Mt. Hood	3.00	ab
Teamaker	2.81	ab
Vanguard	2.54	ab
Cascade	2.03	ab
Sterling	1.97	ab
Perle	1.10	ab
Fuggle	0.79	b
P-value	.0579	

Within a column, values followed by the same letter are not significantly different.

Table 21: Average number of aphids per leaf by sample date, Alburgh, VT 2015.

Sample Date	Aphids	
	# per leaf	
2-Jun	0.00	e
10-Jun	0.00	e
15-Jun	0.01	e
22-Jun	0.36	e
28-Jun	0.37	e
6-Jul	1.09	e
16-Jul	2.40	de
20-Jul	2.00	de
29-Jul	3.11	de
5-Aug	5.59	cd
10-Aug	9.71	bc
17-Aug	13.70	a
24-Aug	10.01	b
P-value	<.0001	

Within a column, values followed by the same letter are not significantly different.

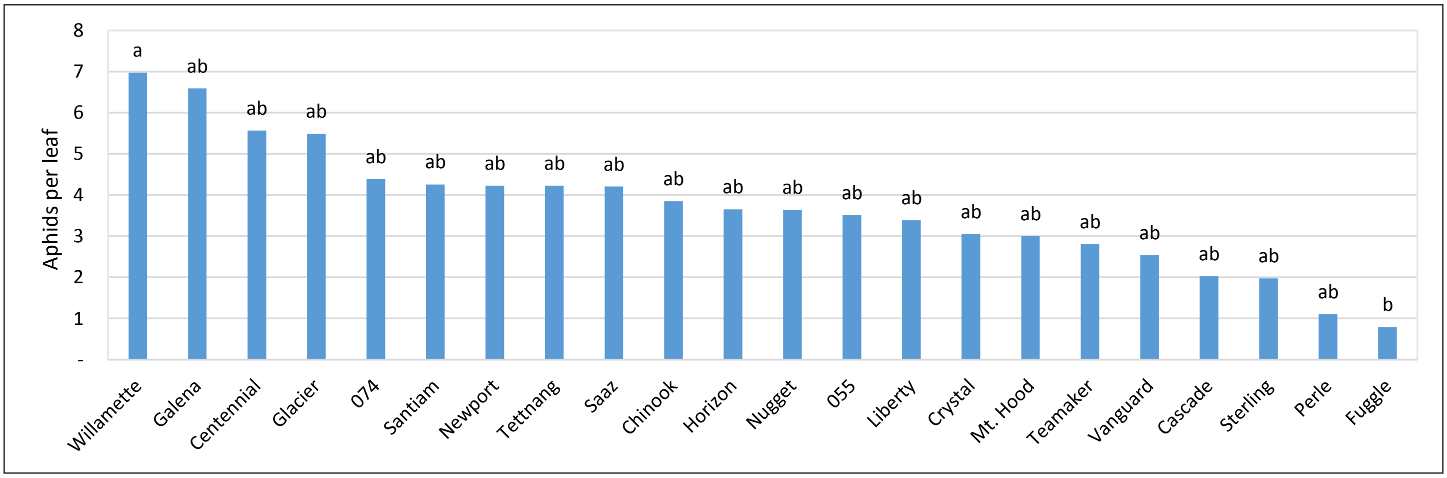

Figure 16: Average number of aphids per leaf by variety, Alburgh, VT 2015.

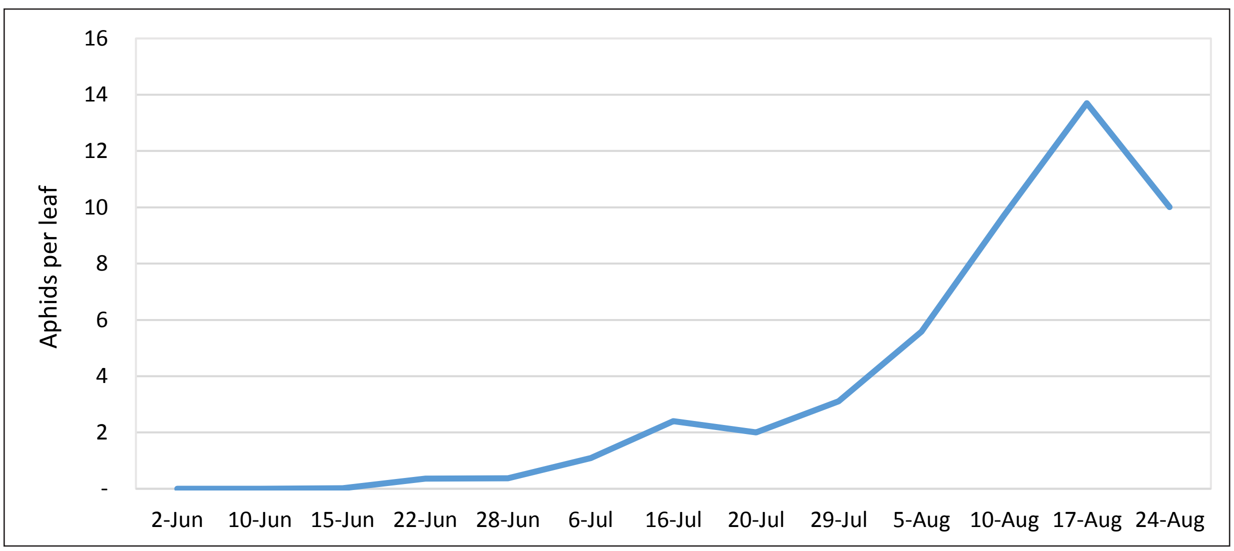

Figure 17: Average number of aphids per leaf by sample date, Alburgh, VT 2015.

DISCUSSION

YIELD

Organic hop yield was much lower in 2015 than in 2014. It is the first year since the yard was established that yields have not increased. Four varieties produced above 500 lbs ac^{-1} (at 8% moisture) in 2015. In comparison, there were eight varieties that produced over 500 lbs ac^{-1} in 2014, five in 2013, and one in 2012. No variety reached 1000 lbs ac^{-1} in 2015, while in 2014 there were four varieties that had yields over 1000 lbs ac^{-1} in at least one of their three plots. With 5 years of learning experience behind us, we still feel positive that higher yields can be achieved in the Northeast, but as with any other agricultural crop, some years don't go as planned. This year the hops were slow to reach the top of the trellis. Low April temperatures and dry conditions left hop plants with a very slow beginning. Once the shoots had emerged, the primary growing month of June was cold and wet, likely further slowing growth. Although June was very wet, all other months were below average for rainfall. A more aggressive crowning strategy in 2015 could also have contributed to the slow start this season.

There is no doubt that meeting nutrient needs is still a challenge, and that we have some difficult pests to manage. However, improved management techniques continually show promise in enabling plants to reach their maximum potential. While yields in the Vermont research hop yard are consistently lower than standard yields in the Pacific Northwest (PNW), the difference is not the same across varieties, e.g. top performing varieties in Vermont are different from top performing varieties in the PNW (Figure 18). This suggests that continued cultivation of varieties that are successful in this region, or breeding of new Northeast-specific varieties, could help to close the gap between Northeast and Northwest yields.

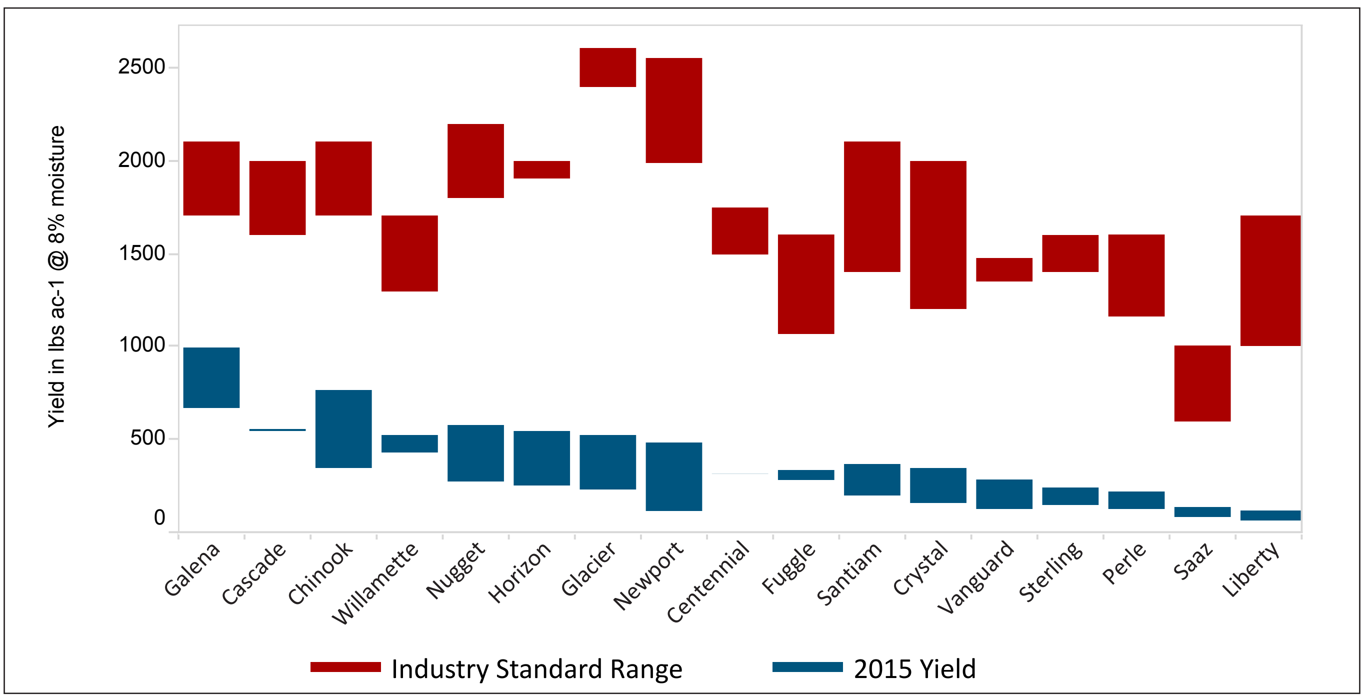

Figure 18: Range of yields in UVM hop yard compared against standard yields in the Pacific Northwest.

HIGHEST AND LOWEST YIELDING VARIETIES

Although there is some year-to-year variation in variety performance, trends over the history of the UVM hop yard show certain varieties that consistently perform among the best, and varieties that consistently perform among the worst. Table 22 shows varieties that ranked in the highest yields in 2013, 2014 and 2015, and the lowest yields in 2013, 2014 and 2015.

Table 22: Best and worst performing varieties, Alburgh, VT 2013-2015.

High yield	Low yield
Cascade	Crystal
Centennial	Liberty
Chinook	Saaz
Galena	Sterling
Newport	

BREWING QUALITY

Alpha acids from this year's harvest were, on average, lower than last year (Figure 5). Beta acids met the industry standard for half of the varieties, also lower on average than last year (Figure 6). These results are consistent with general lower performance in 2015 (Figure 1). Many different factors influence acid content. Lewis and Thomas (1982) found that high temperatures during flower initiation in the end of May and early June can cause high alpha acid levels, as this is when resin glands are initiated. Murphy and Probasco (1996) linked later harvest dates to lower alpha acid content. See the harvest section of this report for more information on acid levels.

Hops, like grapes, have terroir (unique characteristics based on their specific soil and climate). Hop varieties grown on the East Coast, even though genetically the exact same as varieties grown in the Pacific Northwest or Europe, will not be like hops elsewhere due to different soils and different climates. Hops grown in the Northeast will present unique brewing characteristics. It is important to note that the hops from the UVM Extension research hop yard were only evaluated for alpha acids, beta acids, and HSI. No essential oil profiles were analyzed as it was cost-prohibitive. Further research is needed both at an industry-wide level and in the Northeast on the development of essential oils in hops, ranging from agronomic factors that affect essential oil development to the relationship between those essential oils and the final brewed product. Brew values produced in this trial will help brewers understand the quality profile displayed in this region. Continued data collection will help build a more accurate view of varietal profiles in the Northeast.

NUTRIENT MANAGEMENT

Hops are considered "heavy feeders", meaning they require a lot of nutrients. Split applications of volatile nutrients such as nitrogen (N) are highly recommended, particularly on lighter soils. Slow release amendments such as manures, composts, and various meals (blood, alfalfa, oilseed, etc.) will release plant available N (PAN) over time, but only under the right conditions. Hop N needs are greatest in the month of June and into early July when the plant is growing quickly (Figure 19). Split applications should be timed for early spring at training, and again in early- to mid-June.

The fertigation system in the UVM Extension hop yard, added in 2014, is intended to add available N more efficiently by applying fertilizer directly over the plant. Unfortunately, there are few rapidly available sources of N approved for use in organic farming systems and ready for application through a drip line, and they are expensive. This year we experimented with Chilean nitrate as a cheaper organic N source, which dissolved well in ground-temperature water. It is important to stop fertilizing when side arms begin to develop, because adding N after that time can divert the plant's focus to bine growth and away from cone production.

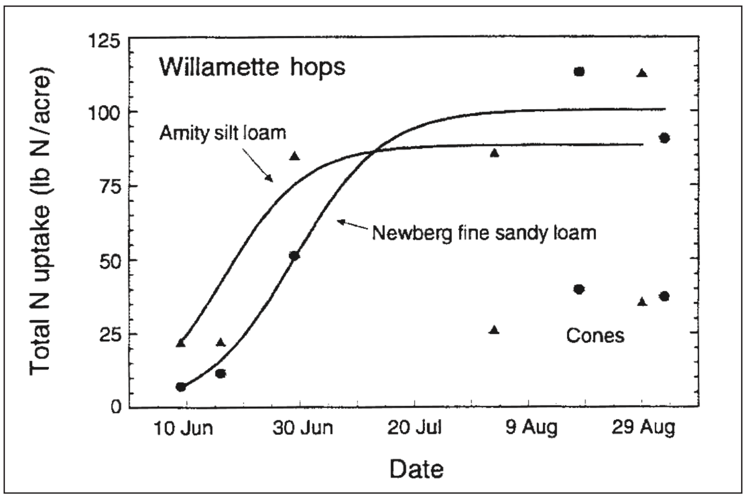

Figure 19: Rate of nitrogen uptake over time, Gingrich et al. 2000.

About 165 lbs ac^{-1} of total N were applied in 2015. Next year we will aim to apply more N, as the nutrient analyses still point to N deficiency in the hop plants. It appears that we are losing between 40 and 50 percent of what we are applying during the season. This means that we may need to add as much as twice the plant N requirement in order for it to reach target levels, although it is important to remember that extremely wet weather in June likely led to above normal N leaching. There may be other ways to increase efficiency of N utilization, such as increased use of the fertigation system or different application timing.

IRRIGATION

As hop production in the Northeast continues to evolve, it is becoming more and more apparent how essential irrigation is to obtaining high yields. Hops need 30" of water during the growing season, and while we often receive that much precipitation over the course of a year in the Northeast, it is not necessarily at the time when hops need it most. The summer of 2015 had frequent rain in the month of June, but below average precipitation during the rest of the season. Although plants seemed to have adequate water for most of the summer, dry conditions in May could have contributed to our slow start. In a study by Aroostook Hops in Maine, three-year-old Nugget plants with drip irrigation had three times the yield of the plants that were not irrigated (Delahunty and Johnston, 2011). Plants that are weakened due to water stress are also more susceptible to pest damage.

HILL SURVIVAL

In addition to yield performance, it is also useful to look at plant health over time. While quantity and quality of cones is often a good indicator of plant health, it may not always correlate to long term success. Figure 20 shows hill failures by variety over the five-year lifetime of the UVM Extension hop yard. Hill failure can occur for many reasons. For example, one Cascade plot in our hop yard receives more shade than the rest of the yard. However, for varieties like Cluster and Tettnang that have had significant failure, it is likely that they are not well suited for Vermont's specific climate and/or pest pressure.

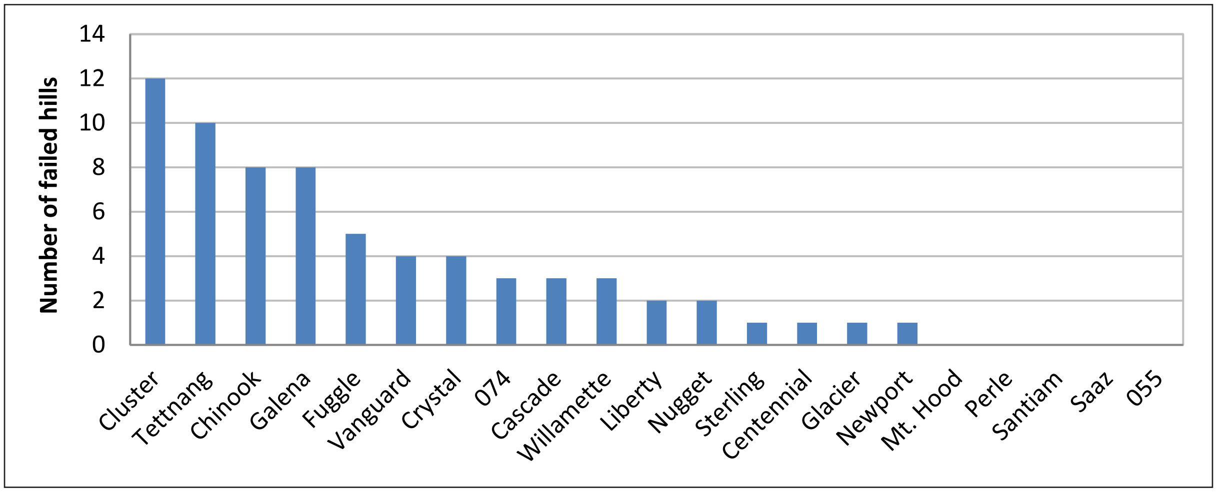

Figure 20: Hill failures by variety, Alburgh, VT 2010-2015.

HARVEST AND PROCESSING

This was the second year in the UVM Extension hop yard that the mobile harvester was used for the entire crop instead of harvesting some plots by hand. In past years, for a ¾ acre hop yard, it took 7 motivated individuals approximately a month to harvest the entire yard by hand. That shows just how economically unfeasible it is to hand harvest, especially with short windows of opportunity for optimum harvest dry matter. The mobile harvester does a wonderful job in ensuring the cones stay intact and do not lose quality. In a 2012 comparison, we did not see any yield loss when comparing mobile harvesting to hand harvesting.

Table 23: Harvest window from 2012-2015, Alburgh, VT 2015.

Year	Date
2012	16-Aug to 18-Sep
2013	21-Aug to 9-Sep
2014	11-Aug to 5-Sep
2015	25-Aug to 16-Sep

As noted earlier, harvest was targeted for when the cones reached between 21-27% dry matter. Varieties reached appropriate dry matter and were harvested from 25-Aug to 16-Sep. Past harvest windows are shown in Table 23. Limitations in equipment availability and labor always make for some shuffling in harvest date, but hops were generally harvested on time this year. Our harvest timing on the East Coast is likely different than standards for the PNW and there is no literature for harvest date in the Northeast.

Paying close attention to dry matter and harvesting within the 21-27% window has worked well. Murphy and Probasco (1996) have found that a 2% increase in dry matter can result in a 9% increase in production. Alpha acid content and essential oil levels are also affected by harvest timing. Total essential oils continue to develop well beyond normal harvest dates, whereas alpha acids degrade as harvest date is pushed back (Murphy and Probasco, 1996). In fact, Bailey et al (2009) found that late-harvested hops rated better in aroma quality, and beers brewed with late harvested hops were also rated better, described as more palate-full with a more pleasant bitterness, and more intense hop flavor and aroma.

HOP DOWNY MILDEW AND OTHER DISEASES

The moist growing season we experienced in 2015 created a habitable environment for fungal pathogens. Hop downy mildew is prevalent in most, if not all, hop yards in the Northeast. The pathogen has been systemic in our research hop yard in Alburgh since 2012. During the 2015 growing season, we documented the presence of disease on a number of basal and aerial spikes in addition to the assessing the severity of new infection on hop leaves. This information can be found in our "2015 Crowning Trial" and "2015 Biofungicide Trial". It is possible to manage downy mildew in our region; however, management requires a multi-pronged approach which includes crowning, meticulous forecasting, fungicide applications, and removal of infected plant material.

This season, we calculated the number of days that had ideal downy mildew conditions using a Pacific Northwest forecasting model based on temperature and humidity (Figure 21) (Gent et al. 2010). We found that 38 of the 183 days between April 1, 2015 and September 30, 2015 exhibited conditions considered likely for downy mildew infection. Predicting habitable conditions for downy mildew allowed us to determine our spray schedule such that applications occurred before times of high infection risk (humidity/rain events).

Given the cool, wet spring and continued moisture throughout the 2015 season, spraying downy mildew fungicides that contained copper as the active ingredient was required as frequently as possible according to fungicide labels. Spraying fungicides is currently necessary to produce high quality hops in our region and so we plan to continue monitoring the temperature and humidity to predict favorable downy mildew conditions accurately for our area.

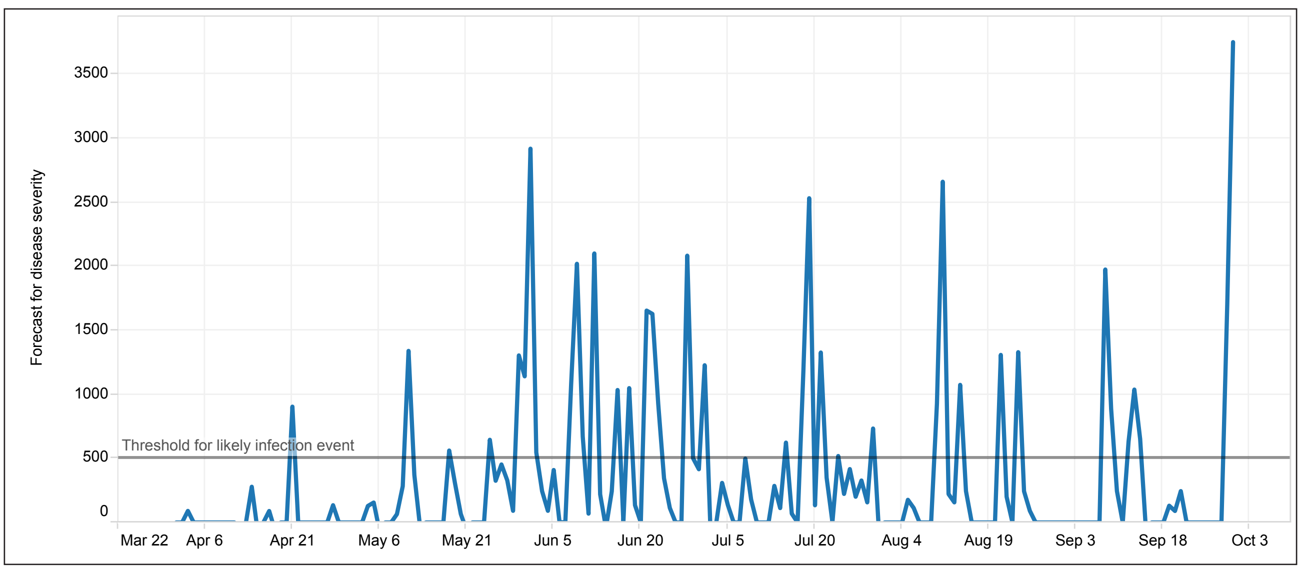

Figure 21: Number of "risk units" according to the disease risk index created by Royle (Gent et al. 2010), Alburgh, VT 2015.

At harvest, we noticed discoloration on hop cones (Figure 22), an indication of secondary disease. The secondary diseases identified on the cones included Alternaria and Phoma sp. Cercospera. Fusarium was also identified but present on cones to a much lesser degree.

Figure 22: Cones infected with Alternaria and Phoma from least infected to most infected.

TWO-SPOTTED SPIDER MITES

Timing is important when developing integrated pest management strategies. Annual tendencies should allow you to predict when certain pests will likely show up, or rapidly increase in number. Weather conditions can help gauge what pests will be more prevalent at certain times. For example, TSSM thrive in hot and dry conditions, usually later in the growing season (late July to harvest time). In contrast, aphids prefer cool and wet conditions such as those experienced throughout the 2015 growing season.

TSSM were not a very significant pest in the UVM Extension research hop yard, but they have been in the past. Strong and Croft (1995) established TSSM thresholds of 1-2 mites per leaf in June, or 5-10 per leaf in July if no predators are present. Further studies performed more recently by Weihrauch (2005) suggest that hops may be able to tolerate >90 mites per leaf without suffering economic loss.

Significance was determined between hop varieties for TSSM and mite destroyers (Table 16). Differences between varietal susceptibility to TSSM are well known, and have a genetic component. Research has indicated that there are differences in TSSM fecundity living on host plants of differing varieties, and that varieties have different susceptibilities to TSSM (Peters and Berry, 1980b). Peters and Berry (1980a) found that leaf characteristics such as hair and gland density affected TSSM oviposition rates, development rates, and sex ratios. Regev and Cone (1975) found that varieties vary in the susceptibility to TSSM based on their chemical differences, namely levels of farnesol.

APHIDS

The hop aphid was much more abundant from 2013 to 2015 than in previous years; in 2011 and 2012 very few aphids were observed in the hop yard. During these years the weather was drier and hotter than average throughout the entire growing season. Aphids prefer a cool, wet climate and in 2013-2015 cool and/or wet conditions were experienced throughout much of the growing season. Even though populations were high at some points throughout the season, they were not large enough to warrant pesticide usage, based on our discretion. This example illustrates how important insect scouting can be. If outbreaks had persisted or increased further, there is a chance that our hop cones could have been impacted by sooty mold. Aphids have the ability to secrete a sugary solution, called “honey dew,” directly into hop cones. This secretion provides a perfect habitat for sooty mold. Sooty mold can cause significant economic damage to hop cones, and is the reason that aphids must be watched closely in a hop yard.

Research shows that certain hop varieties are more susceptible to aphids than others (Campbell 1983, Dorschner and Baird 1988, Weihrauch and Moreth 2005). Kralj et al. 1998 shows a relationship between high essential oil content and higher susceptibility to aphids, suggesting that the aphids feed on certain essential oils and are attracted to those plants with more available.

POTATO LEAFHOPPERS

The fact that PLH may prefer certain hop varieties over others is a new discovery. Potato leafhoppers, native to the eastern United States, are not an economically problematic pest in the major hop growing regions of the world. However, the UVM Extension hop yard is located within a grass/alfalfa field where these pests already live. 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 causing leaf necrosis. In severe cases, this is referred to as "hopper burn." Many plants were affected by hopper burn this year, as PLH populations were unusually high.

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, although whether this will translate as an acceptable PLH threshold level for hops remains to be seen. An informational article on potato leafhoppers in hops can be found on the UVM Extension Northwest Crops and Soils Program website: http://www.uvm.edu/extension/cropsoil/wp-content/uploads/PLH-2014-Factsheet.pdf. At this time, it is unknown what draws leafhoppers to certain varieties or perhaps repels them from another. There are physical differences between hop leaves by variety, as demonstrated by research on TSSM (Peters and Berry, 1980a). These physical differences are known to provide resistance to PLH in alfalfa, potato and dry bean plants. Leafhopper-resistant alfalfa varieties have been developed and reduce the need for pesticide application. These resistant varieties have dense hairs that exude a chemical that deters leafhopper nymphs.

We now have enough data to see trends over time in regard to plant resistance to PLH. Figure 23 shows incidence of PLH by variety over the past four seasons. As hop production continues to grow in this region, PLH will likely remain a major pest problem. PLH resistant/tolerant hop varieties would reduce pesticide use if these varieties were grown by local farms.

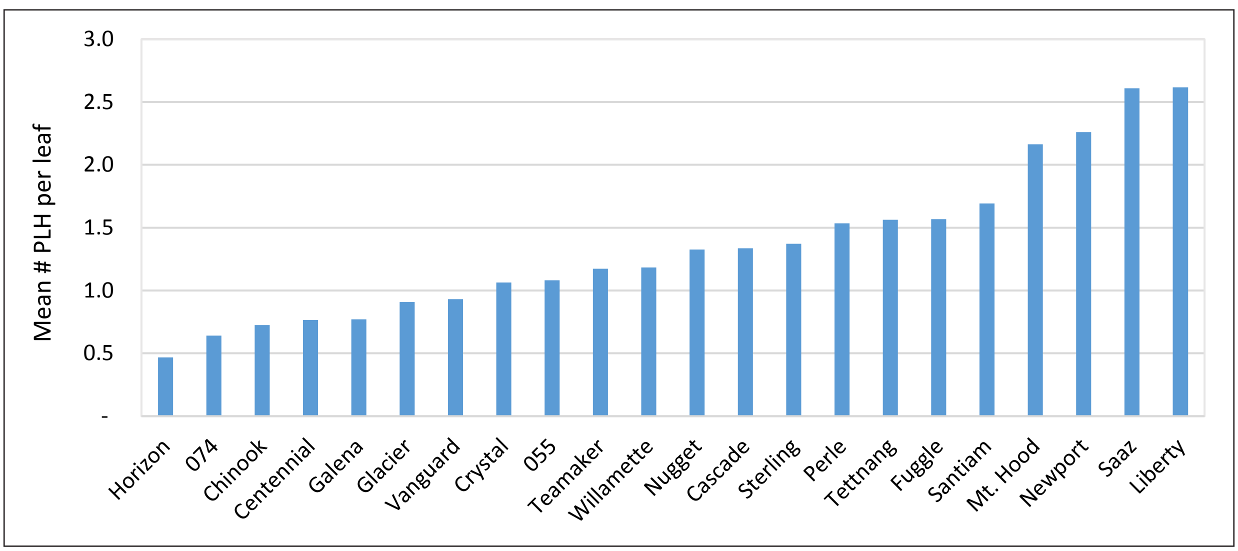

Figure 23: Number of PLH found per leaf by variety. Average over the years 2012-2015, Alburgh, VT 2015.

A relationship was found between alpha/beta acid levels and the number of PLH (Figure 24, Figure 25). As alpha and beta acid levels increase, average number of PLH per leaf decreases. At this stage it is undetermined whether this is an indicator of PLH preferring lower alpha varieties, or if PLH cause lower alpha acid content in hops. Other possibilities for varietal preference among PLH include hop growth characteristics or nutrient levels acting as a deterrent or attractant. UVM Extension continues to look into the interaction between PLH and hops.

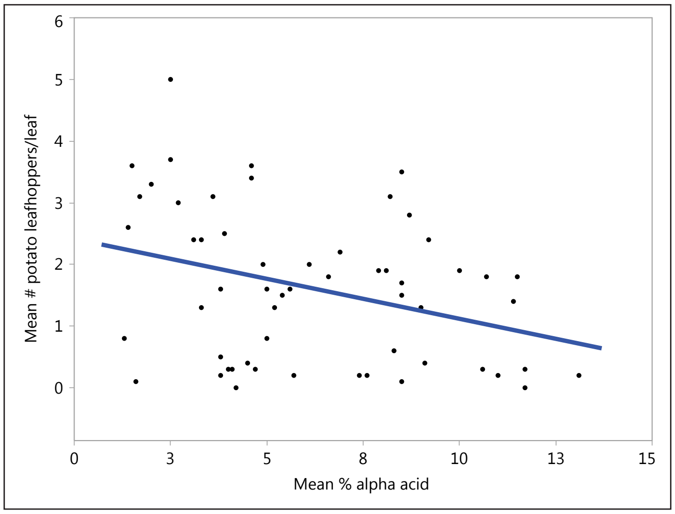

Figure 24: Relationship between alpha acid levels and average # of PLH per leaf, Alburgh, VT 2014.

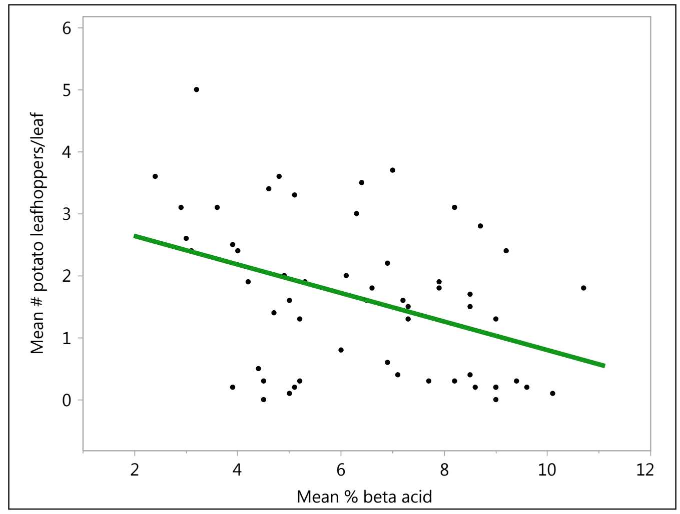

Figure 25: Relationship between beta acid levels and average # of PLH per leaf, Alburgh, VT 2014.

Natural enemies and insecticide applications impact pest populations. Natural enemies are present to varying degrees in Northeast hop yards and once established they can stabilize pest populations as suspected at the Borderview Farm research site. Insecticides have the opposite effect, as they kill natural enemies and increase the risk of a two-spotted spider mite and PLH outbreaks. General scouting efforts over time at the Borderview Research Farm have shown that monitoring of pests and judicious application of insecticides can allow natural enemies to increase in northeast hop yards and minimize/stabilize pest pressures.

Table 24 highlights the pest to natural enemy ratio at Borderview Research Farm over a 3 year period. In 2012, broad-spectrum insecticides were implemented to control PLH and as a result the pest to natural enemy ratio increased. In 2013 and 2014, insecticides were not sprayed at the research yard and the pest to natural enemy ratio declined significantly. The increase in natural enemies resulted in adequate arthropod control and no chemical controls were necessary. If farms in the northeast monitor natural enemy and pest dynamics on their individual farms, insecticide applications may be mostly eliminated or greatly minimized on hops.

Table 24: Pest to natural enemy ratios calculated from number of pests and natural enemies on hop plants for 2012, 2013, and 2014, Alburgh, VT.

Ratio: Pests to Natural Enemies		
	Vacuum Samples	Sticky Traps
2012	4.19:1	0.50:1
2013	2.55:1	0.72:1
2014	2.12:1	0.74:1

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Any reference to commercial products, trade names, or brand names is for information only, and no endorsement or approval is intended.

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Notes

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