

NORTHWEST CROPS & SOILS PROGRAM



2015 Hop Crowning Trial



Dr. Heather Darby, UVM Extension Agronomist
Julian Post, Lily Calderwood, Julija Cubins, Erica Cummings,
Abha Gupta, Scott Lewins, and Sara Ziegler
UVM Extension Crops and Soils Technicians
(802) 524-6501

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Dr. Heather Darby, University of Vermont Extension
heather.darby[at]uvm.edu

INTRODUCTION

Downy mildew has been identified as the primary pathogen plaguing our northeastern hop yards. This disease causes reduced yield, poor hop quality, and can cause the plant to die in severe cases. Control measures that reduce disease infection and spread while minimizing the impact on the environment are desperately needed for the region. Mechanical control is one means to reduce downy mildew pressure in hop yards. Scratching, pruning, or crowning is a practice initiated in the early spring when new growth has just emerged from the soil.

The first shoots have an irregular growth rate and are not the most desirable for producing hop cones later in the season. Removal of this new growth through mechanical means helps to remove downy mildew inoculum that has overwintered in the crown. The top of the crown itself can be removed to further eliminate overwintering downy mildew. When the top of the crown is removed as well, the practice is typically referred to as “Crowning”. Crowning also reduces the amount of plant material that is above ground and susceptible to downy mildew spores during wet spring conditions that are ideal for infection. Setting the plant back like this is an advantage for managing disease, but also reduces the time the plant has to grow to the top of the trellis, potentially affecting yield. While crowning is known to be effective in other regions, there is no established time frame for crowning in the Northeast. The goal of this project was to evaluate the impact of crowning date on hop downy mildew pressure as well as hop yield and quality. Hops were crowned on an early date before shoot emergence and a later date when shoots were visible. Crowning before emergence is meant to remove downy mildew inoculum living in the crown of the plant. Crowning after shoot emergence can remove inoculum that has moved into the shoots as well as anything in the top of the crown. Removing shoots by other means such as chemical burndown is also known to be effective, but does not affect inoculum living in the crown.



Figure 1: Crowning blade



Figure 2: Modified trimmer

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 10' x 35' plots (each plot had 7 hills). Plots were replicated 3 times. Main plots consisted of two varieties. Cascade served as a moderately resistant cultivar and Nugget served as a downy mildew susceptible treatment. Split plots were two crowning dates. Crowning was completed in 2015 on two different dates, 23-Apr (before emergence) and 13-May (shoot emergence). A control treatment was left with no crowning. Crowning was performed using a DR trimmer fitted with a circular metal brush-cutting blade fixed with chainsaw teeth (Figure 1, Figure 2).

Fungicides were sprayed regularly throughout the season (Table 1). 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). 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.

Table 1: 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

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 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.

Each plot was scouted weekly for basal and aerial spikes, and for leaves infected with downy mildew. Basal and aerial spikes were reported by total number per plant. Leaf scouting was performed by counting 10 leaves at random on the bottom 6 feet of each plant.

Hop harvest was targeted for when cones were at 21-27% dry matter. At harvest, hop bines were cut in the field and brought to a secondary location to be run through our mobile harvester. Picked hop cones were weighed on a per plot basis, 100-cone weights were recorded, and moisture was determined using a dehydrator. The 100 cones from each plot were assessed for incidence of disease by counting the number of diseased cones. Severity was assessed on a scale of 1-10, 10 being worst. All hop cones were dried to 8% moisture, baled, vacuum sealed, and then placed in a freezer. Hop samples from each plot were analyzed for alpha acids, beta acids and Hop Storage Index (HSI) by Alpha Analytics.

Yields are presented at 8% moisture on a per acre basis. Per acre calculations were performed using the spacing in the UVM Extension hop yard crowning trial section of 872 hills ac⁻¹. Yields were analyzed using the GLM procedure in SAS and brew values were analyzed using the PROC MIXED procedure in SAS with the Tukey-Kramer adjustment, which means that each cultivar was analyzed with a pairwise comparison (i.e. 'Cluster' statistically outperformed 'Cascade', Cascade statistically outperformed 'Mt. Hood', etc.). Relationships between variables were analyzed using the GLM procedure.

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 2). The 2015 growing season (March-September) experienced 2,657 GDDs, which were 288 more than the 30 year average (1981-2010 data). However, the higher-than-normal degree days came in the very beginning and end of the season, while the critical month of June was cooler than normal. High temperatures in May were not as much benefit to the late crowned plots since half of the growth from that month was cut back. Dry conditions in March and April also set the stage for the growing season, and may have had a meaningful negative impact on overall results this year (Table 2).

Table 2: Temperature, precipitation, and Growing Degree Day summary, Alburgh, VT, 2015

Alburgh, VT	March	April	May	June	July	August	September
Average temperature (°F)	26.0	43.4	61.9	63.1	70.0	69.7	65.2
Departure from normal	-5.1	-1.4	5.5	-2.7	-0.6	0.9	4.6
Precipitation (inches)	0.02	0.09	1.94	6.42	1.45	0.00	0.34
Departure from normal	-2.19	-2.73	-1.51	2.73	-2.70	-3.91	-3.30
Growing Degree Days (50-95°F)	0	80.1	415.9	416	629.7	623.6	491.8
Departure from normal	0	5.1	149.2	-58	-8.8	42.2	158

Figure 3 illustrates the abnormal temperatures experienced in 2015. This year in particular late crowning had detrimental potential for yields because June was so cool. There was just not enough time between shoot emergence and the summer solstice for growth, especially for the late crowning date.

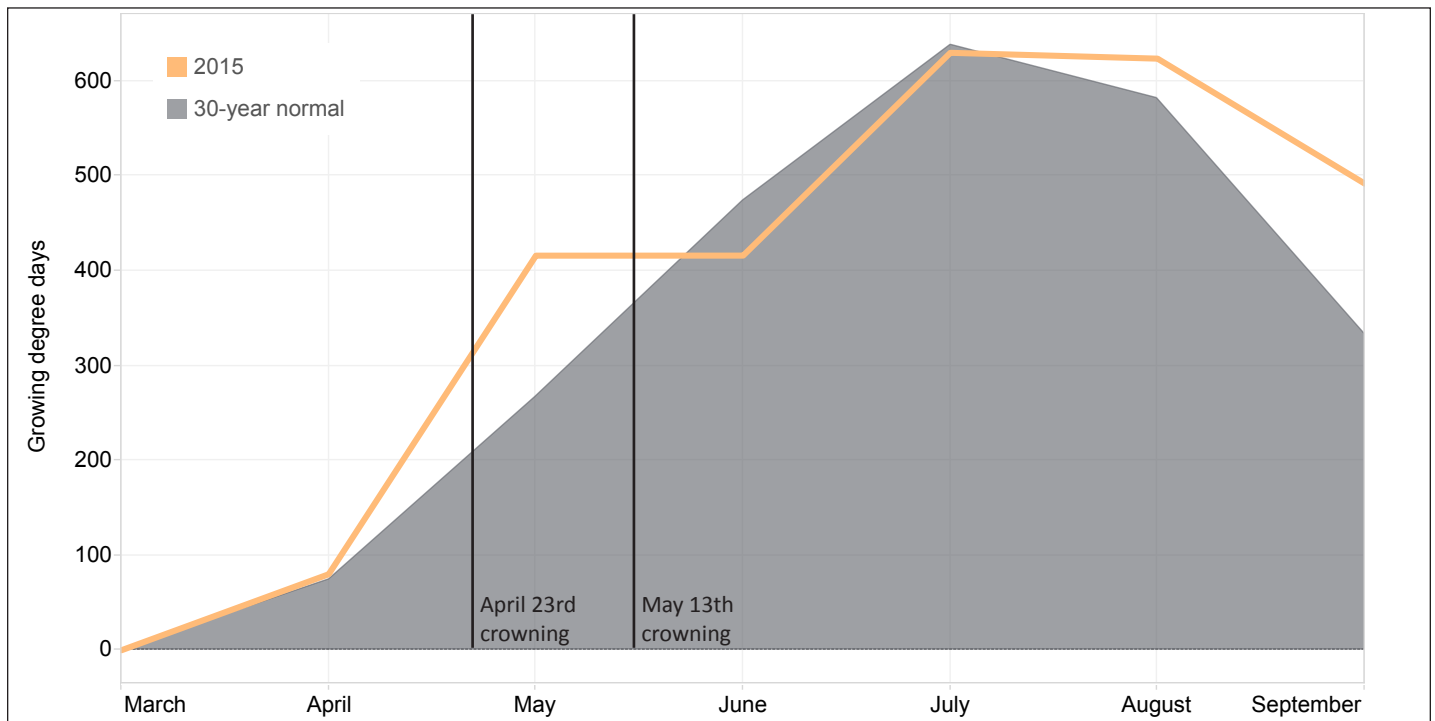


Figure 3: Growing degree days in 2015 compared to the 30-year normal, Alburgh, VT.

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 4) (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. During the season, predicting habitable conditions for downy mildew (humidity/rain events) allowed us to determine our spray schedule such that applications occurred before times of high infection risk. Given the continued moisture throughout the 2015 season, spraying was done as frequently as possible according to fungicide labels.

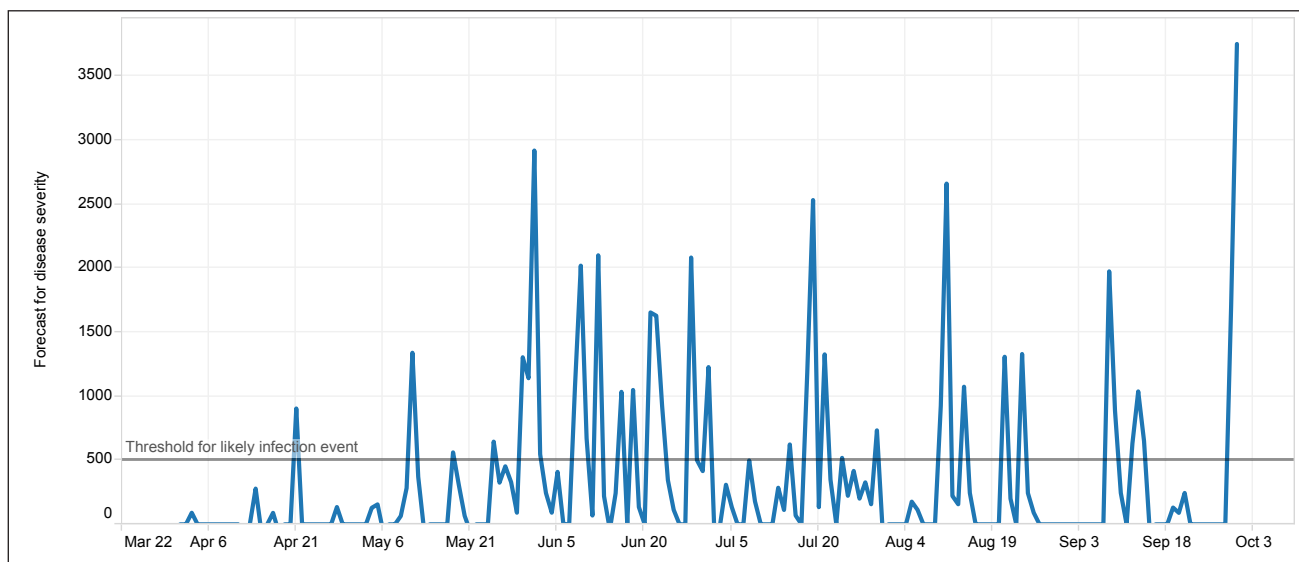


Figure 4: Number of “risk units” according to the disease risk index created by Royle (Gent et al. 2010) Alburgh, VT 2015

Yield by treatment is shown in Figure 5. The early treatments, 23-Apr, yielded highest. When hop plants were crowned prior to spike emergence (23-Apr) the resulting yields was 58% higher than crowning after shoot emergence (13-May) and 35% higher than not crowning at all.

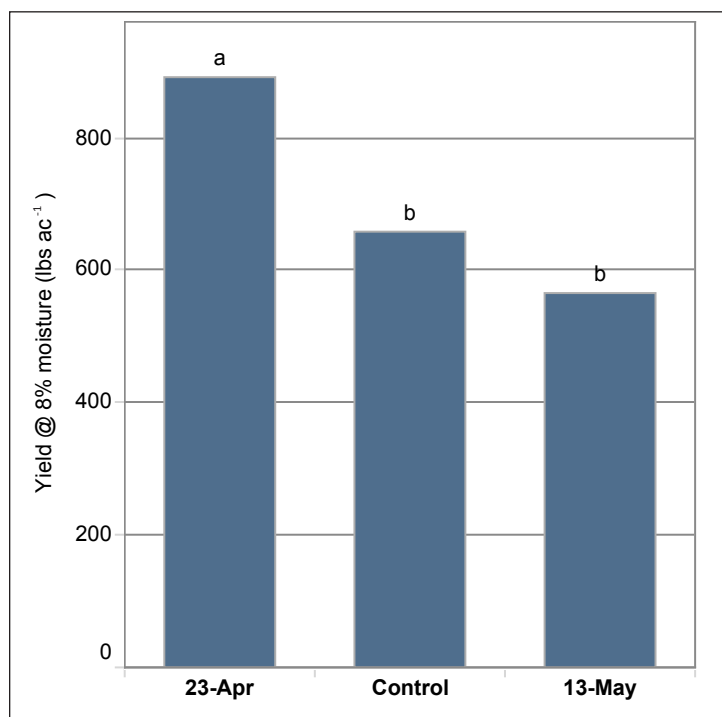


Figure 5: Yield at 8% moisture by treatment, Alburgh, VT 2015
Values followed by the same letter are not significantly different.

Late crowning reduced the height of the plants as well (Figure 6). Interestingly, disease incidence and severity on the cones was not impacted by crowning (Table 3), meaning crowning did not reduce the quantity of cone disease. Cone diseases identified included some downy mildew but also included secondary diseases such as alternaria, phoma, and fusarium.

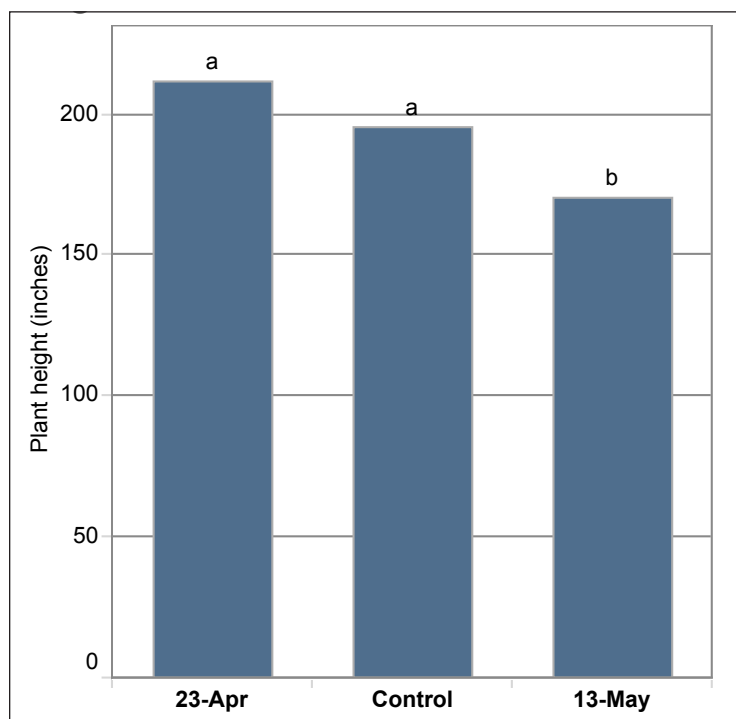


Figure 6: Plant height (inches) by treatment, Alburgh, VT 2015
Values followed by the same letter are not significantly different.

Table 3: Dry matter, yield, disease incidence and disease severity of harvested cones, Alburgh, VT 2015

Treatment	Dry matter		Yield		Height		Disease incidence		Disease severity	
	%		lbs ac ⁻¹		inches		%		out of 10	
23-Apr	24	ab	892	a	211	a	31	a	1.8	a
13-May	25	a	566	b	170	b	36	a	1.3	a
control	24	b	659	b	196	a	33	a	1.7	a
p-value	0.16		0.02		0.03		0.64		0.24	

*Within a column, values followed by the same letter are not significantly different. Values in **bold** indicate top performing treatments. Dry matter is not bolded because there is not a set value for best performance.*

Table 4 shows average number of basal spikes, aerial spikes, and infected leaves by treatment. The late treatment (13-May) had the least amount of disease.

Table 4: Basal spikes, aerial spikes, and infected leaves by treatment, Alburgh, VT 2015

Treatment	Basal spikes		Aerial spikes		Infected leaves	
	# per hill		# per hill		# per hill	
23-Apr	0.29	a	1.75	b	0.35	b
13-May	0.26	a	1.31	a	0.17	a
Control	0.28	a	2.15	b	0.45	b
p-value	0.73		0.002		0.001	

*Within a column, values followed by the same letter are not significantly different. Values in **bold** indicate top performing treatments. Statistical significance was determined by performing a square root transformation of the data.*

Figure 7 and illustrate the difference between treatments for infected leaves and aerial spikes, respectively. In general, the later crowning treatment resulted in reduced primary infection inoculum sources (basal and aerial spikes) and in-season disease infection (infected leaves).

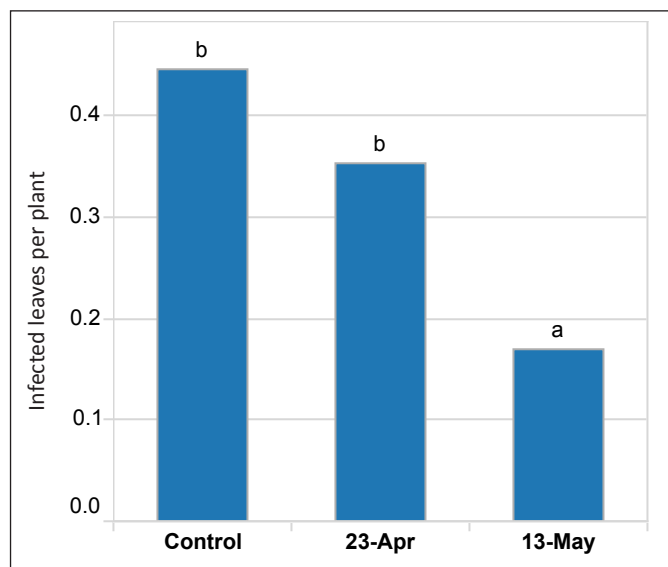
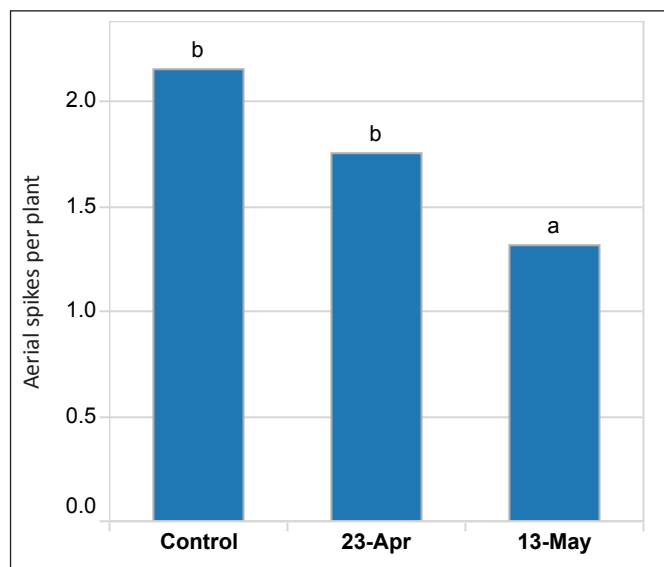


Figure 7: Infected leaves by treatment, Alburgh, VT 2015

Statistical significance was determined by performing a square root transformation of the data. Values followed by the same letter are not significantly different.



Aerial spikes by treatment, Alburgh, VT 2015

Statistical significance was determined by performing a square root transformation of the data. Values followed by the same letter are not significantly different.

Figure 8 shows leaf infection by treatment over time. The late treatment (13-May), had consistently lower leaf infection levels throughout the season.

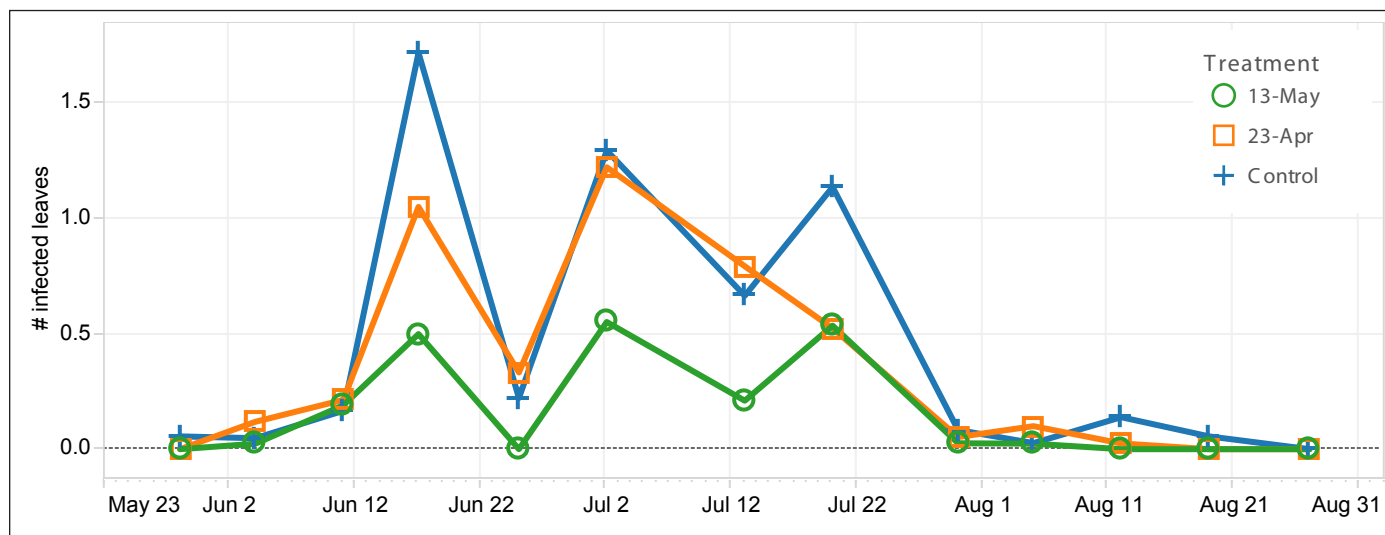


Figure 8: Leaf infection by treatment and date, Alburgh, VT 2015

Table 5 and Table 6 show alpha acids, beta acids, and Hop Storage Index (HSI) by treatment for Cascade and Nugget respectively. For cascade, alpha acids were highest in the late (13-May) crowning date. Beta acids for Cascade were somewhat closer together, although the early (23-Apr) crowning date had the highest values. Values for Nugget treatments were not statistically different from each other. This shows a significant interaction between variety and crowning treatment: While crowning of Cascade increased alpha and beta acids compared to no crowning, Nugget was not impacted significantly by crowning treatment.

Table 5: Alpha acids, beta acids, and Hop Storage Index (HSI) for Cascade plants by treatment, Alburgh, VT 2015

Date	Alpha acids		Beta acids		HSI	
	%		%			
23-Apr	5.2	b	7.2	a	.21	a
13-May	6.2	a	6.6	ab	.21	a
Control	4.1	c	6.3	b	.22	a
p-value	0.014		0.193		0.291	

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

Table 6: Alpha acids, beta acids, and Hop Storage Index (HSI) for Nugget plants by treatment, Alburgh, VT 2015

Date	Alpha acids		Beta acids		HSI	
	%		%			
23-Apr	15.0	a	4.8	a	.24	a
13-May	15.4	a	4.8	a	.23	a
Control	14.5	a	5.0	a	.24	a
p-value	0.651		0.619		0.594	

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

DISCUSSION

While increased pressure from downy mildew in this region gives us more to gain by crowning to remove downy mildew, our much shorter growing season makes the timing of this practice tricky. If we crown too late, we risk leaving too short a window for plants to reach the top of the trellis by late June. This trial has confirmed the risk of crowning too late: crowning seems to be helping to manage downy mildew pressure, but crowning after shoot emergence clearly reduced yield by shortening the growing window. While the early crowning date did not have an advantage on in-season disease, it seems to have some advantage to yield, even over the control. One possibility is that the early crowning allowed the soil to warm up more quickly by removing mulch and generally aerating the soil surface. Insulating material such as mulch and compaction could be causing the soil to stay cool longer into the spring even when air temperatures are rising. This could present a big opportunity to get a head start by making sure the soil is exposed to warm temperatures as early as possible.

WORKS CITED

Gent, D., Ocamb, C., & Farnsworth, J. (2010). Forecasting and Management of Hop Downy Mildew. *Plant Disease*(94), 425-431.

ACKNOWLEDGEMENTS

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 Hillary Emick, Lindsey Ruhl, and Dan Ushkow for their assistance with data collection and entry. This work is made possible through funding provided by the USDA Hatch Initiative and The Environmental Protection Agency.

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