2017

Hop Crowning Trial Final Report

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NORTHWEST CROPS & SOILS PROGRAM

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UNIVERSITY OF VERMONT EXTENSION
CULTIVATING HEALTHY COMMUNITIES

HOP CROWNING TRIAL FINAL REPORT

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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 either before or at the time that 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 first new growth through mechanical means also 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, 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. To achieve this effect, cutting is performed 0.50 to 1.0 inch below the soil surface. Setting the plant back like this is an advantage for managing disease, but may also reduce the time the plant has to grow vegetatively to the top of the trellis, potentially affecting yield. While crowning is standard practice in other regions, we are still learning about the effects of crowning in the Northeast.

Over the duration of the project, the team at UVM evaluated crowning dates and methods in an attempt to develop best practices in the Northeast for hop production. No crowning and early crowning dates were evaluated each year of the study. Other treatments included late crowning, removing soil and residue from hop crowns, and removing early hop growth with flaming methods to reduce likelihood of downy mildew infection and incidence within the hop yard.

MATERIALS AND METHODS

The replicated research plots were located at Borderview Research Farm in Alburgh, VT on a Benson rocky silt loam. 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. The treatments applied during each year of the study are shown in Table 1. A control treatment was left with no crowning or disturbance in each year of the study. "Early" crowning treatments occurred in mid-late April depending on the early season conditions of each trial year. "Late" crowning treatments occurred as soon as hop shoots had emerged from the ground. "Late" crowning occurred in mid-May. By 2015, our studies had indicated that crowning does result in better hop yields, and that earlier crowning is more effective for this region. We hypothesized that crowning may have an effect on early season soil temperatures. Since crowning disturbs the soil while it is thawing and removes some of the surface debris that could potentially slow the warming of the earth around each hop plant, it was important to determine whether soil temperature might be contributing to better yields. The crowning experiment in 2016 tested whether early season soil temperature was an important factor in hop yield and quality. To test this, one treatment included plants that were crowned according to our standard method, one treatment included plants that were "Uncovered" to increase soil temperature without removing any hop growth. In 2017, a treatment was added to evaluate crowning plants with a flame-weeding technology. The goal was to minimize mechanical cutting that may also spread disease from plant to plant.

Table 1: Crowning trial treatments for each year of the study, Alburgh, VT.

Year	Method	Date
2014	Early crown	14-Apr
	Late crown	12-May
	Control	-
2015	Early crown	23-Apr
	Late crown	13-May
	Control	-
2016	Early crown	18-Apr
	Uncovered	18-Apr
	Control	-
2017	Early crown	25-Apr
	Flame treatment	16-May
	Control	-

Crowning was performed using a Craftsman high-wheel walk-behind trimmer fitted with a circular metal brush-cutting blade fixed with chainsaw teeth (Image 1). Flaming was performed using a walk-behind flame weeder (Image 2).

Image 1: Walk-behind trimmer, left, brush-cutting blade, right.

Image 2. Walk-behind flame weeder, left, in use, right.

Fungicides were sprayed when the forecast predicted downy-mildew-favorable weather with a high degree for risk of infection. Fungicides were sprayed regularly throughout each season from May through August of each growing season (Table 2). The primary pesticides used in the research yard were Champ WG (Nufarm Americas Inc., EPA Reg. No. 55146-1) and Regalia (Marrone Bio Innovations, EPA Reg. No. 84059-3). Regalia is used as a means for broad spectrum disease control whereas Champ is applied specifically for downy mildew control.

Table 2: Yearly spray schedule for Champ and Regalia in crowning trial, Alburgh, VT 2014-2017.

2014			**2015**		
Date	Champ	Regalia	Date	Champ	Regalia
21-May	X	X	21-May	X	
2-Jun	X	X	29-May	X	
9-Jun	X	X	12-Jun	X	
16-Jun	X	X	19-Jun	X	X
24-Jun	X	X	26-Jun	X	X
3-Jul	X	X	6-Jul	X	X
7-Jul	X	X	13-Jul	X	X
14-Jul	X	X	27-Jul	X	X
28-Jul	X	X	14-Aug	X	X

2016			**2017**		
Date	Champ	Regalia	Date	Champ	Regalia
29-May	X	X	1-Jun	X	X
3-Jun	X	X	8-Jun	X	X
5-Jun	X	X	15-Jun	X	X
12-Jul	X	X	10-Aug	X	
21-Jul	X	X			
1-Aug					
9-Aug	X	X			

Fertigation (fertilizing through the irrigation system) was used to apply fertilizer more efficiently in addition to application of granular fertilizer. Hops were fertigated starting late May-early June using Chilean Nitrate (16-0-0) and Pro Booster (10-0-0) for Nitrogen supplementation. The fertilizer was distributed evenly through 3000 gallons of water using a Dosatron unit. Pro gro (5-3-4) was applied for Phosphorus supplementation as needed. Total N application rates varied between 165-235 lbs ac^{-1} throughout growing seasons with liquid and granular applications taking place between May and June. Fertility was only applied to the 3-foot row that the hops are planted in, and per-acre calculation for fertilizer was based on the square footage of those rows, excluding the 12-foot drive rows in between. All fertilizers were OMRI-approved for use in USDA approved organic systems. Each plot was scouted weekly for downy mildew basal spikes starting in mid-May until the end of the month. Aerial spikes and leaves infected with downy mildew were scouted from June to late August. Insect scouting also took place on a weekly basis as a general practice for monitoring key pest populations including potato leaf hopper, two-spotted spider mite, and hop aphid.

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. Plants were assessed for severity of foliar disease on a 1-5 scale, 5 being worst. 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 downy mildew and other diseases. They were also assessed for severity of browning due to disease on a scale of 1-5, 5 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 the University of Vermont's testing laboratory.

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 (1744 strings) ac^{-1}.

RESULTS

Using data from a Davis Instruments Vantage Pro2 weather station at Borderview Research Farm in Alburgh, VT, weather data was summarized for each growing season from 2014-2017. Over the past four years, we had variable weather which lent to distinctly different growing conditions. The 2014 growing season (March-September) experienced 2257 Growing Degree Days (GGDs), which were 46 more than the 30-year average (1981-2010 data). Precipitation was above average during the growing season (Table 3).

Table 3: Temperature, precipitation and growing degree day summary, Alburgh, VT, 2014.

Alburgh, VT 2014	March	April	May	June	July	August	September
Average temperature (°F)	22.1	43.0	57.4	66.9	69.7	67.6	60.6
Departure from normal	-8.8	-1.8	1.0	1.1	-0.9	-1.2	0.0
Precipitation (inches)	1.70	4.34	4.90	6.09	5.15	3.98	1.33
Departure from normal	-.51	1.52	1.45	2.40	1.00	0.07	-2.31
Growing Degree Days (base 50°F)	0	16	238	501	613	550	339
Departure from normal	0	16	40	27	-27	-31	21

Table 4: Temperature, precipitation and growing degree day summary, Alburgh, VT, 2015.

2015	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	-5.1	-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 (base 50°F)	0	80	416	416	630	624	492
Departure from normal	0	80	218	-58	-10	43	174

The 2015 growing season (March-September) experienced 2657 GDDs, which were 447 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 4).

In the 2016 growing season, there were an accumulated 2653 Growing Degree Days (GDDs), approximately 284 more than the historical 30-year average. While March experienced slightly more precipitation than usual, May through September was unusually dry, accumulating 7.27 inches less rain than in a usual year. Dry conditions reduced disease pressure and significantly reduced yields (Table 5).

Table 5: Temperature, precipitation and growing degree day summary, Alburgh, VT, 2016.

2016	March	April	May	June	July	August	Sept
Average temperature (°F)	33.9	39.8	58.1	65.8	70.7	71.6	63.4
Departure from normal	2.9	-4.9	1.8	0.0	0.1	2.9	2.9
Precipitation (inches)	2.5	2.6	1.5	2.8	1.8	3.0	2.5
Departure from normal	0.29	-0.26	-1.92	-0.88	-2.37	-0.93	-1.17
Growing Degree Days (base 50°F)	32	59	340	481	640	663	438
Departure from normal	32	-16	74	7	1	82	104

In the 2017 growing season there were an accumulated 2411 Growing Degree Days (GDDs) this season, approximately 199 more than the historical 30-year average. 2017 proved to be the wettest year throughout our four year study putting hops at a much higher risk for disease infection for a large portion of the growing season. During critical growth and development periods we experienced rain events averaging 7.39 inches above our 30-year averages despite having late summer months that began to taper off (Table 6).

Table 6: Temperature, precipitation and growing degree day summary, Alburgh, VT, 2017.

2017	March	April	May	June	July	August	Sept
Average temperature (°F)	25.1	47.2	55.7	65.4	68.7	67.7	64.4
Departure from normal	-6.05	2.37	-0.75	-0.39	-1.90	-1.07	3.76
Precipitation (inches)	1.6	5.2	4.1	5.6	4.9	5.5	1.8
Departure from normal	-0.63	2.40	0.68	1.95	0.73	1.63	-1.80
Growing Degree Days (base 50°F)	7	111	245	468	580	553	447
Departure from normal	7	111	47	-7	-60	-28	129

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. Alburgh precipitation data from 8/17/16-10/31/16 was missing and was replaced by data provided by the NOAA for Highgate, VT.

Each season, we calculated the number of days that had ideal downy mildew conditions using a Pacific Northwest forecasting model based on temperature and humidity, (Gent et al. 2010) (Figure 1). The model was calculated using data from a nearby weather station in Chazy, NY. We determined the number of days out of the 183 days between 1-Apr 2016 and 30-Sep 2016 that exhibited conditions considered likely for downy mildew infection based on variable weather conditions. Clearly, 2017 was the most difficult year to manage downy mildew infection.

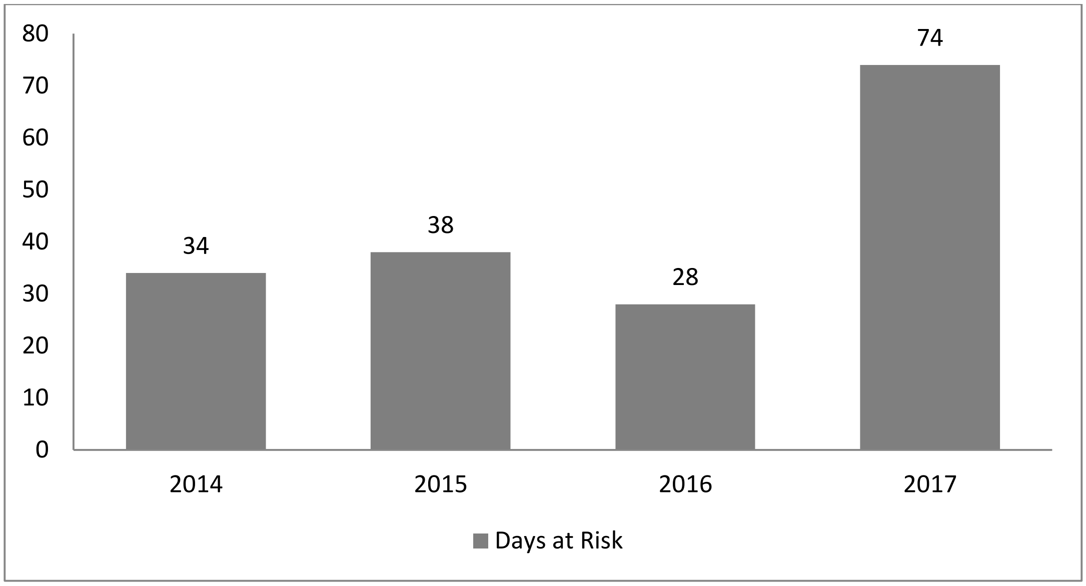

Figure 1: Yearly comparison of days at risk for disease infection.

The abnormally dry weather during 2016 kept disease pressure low throughout the season whereas slightly higher amounts of precipitation during 2014 and 2015 resulted in higher disease incidence and greater severity. Conversely, 2017 experienced extreme wet weather conditions, especially during the early months of the growing season. This of course resulted in heavy disease pressure. Figure 1shows that there were 74 days ideal for downy mildew infection in 2017, which was significantly higher than the previous year which had only 28 days where hops were at risk of infection. Additionally, 2014 and 2015 was also much lower than 2017, having 34 and 38 days at risk.

2014

In 2014, the date at which hops were crowned had little impact on downy mildew, hop yield, and hop quality (Table 7). However, it is worth noting that early crowned treatments have overall higher yields compared to the control and late crowning, though the difference in yield values are not statistically significant. Hops crowned in May also yielded smaller cones compared to the control and early crowning.

Table 7: 2014 Hop yield, 100 cone weight, cone disease incidence, and cone disease severity, Alburgh, VT.

Treatment	Yield @ 8% moisture	100 cone weight	Cone disease incidence	Cone disease severity
	lbs ac^{-1}	g	%	1-5
Control	790	17.1	31	1.80
Crowned early	868	17.1	36	1.30
Crowned late	788	14.8	33	1.70
Trial mean	816	16.3	35.4	3.89
p-value	NS	0.001	NS	NS

NS= No significant differences in treatments.

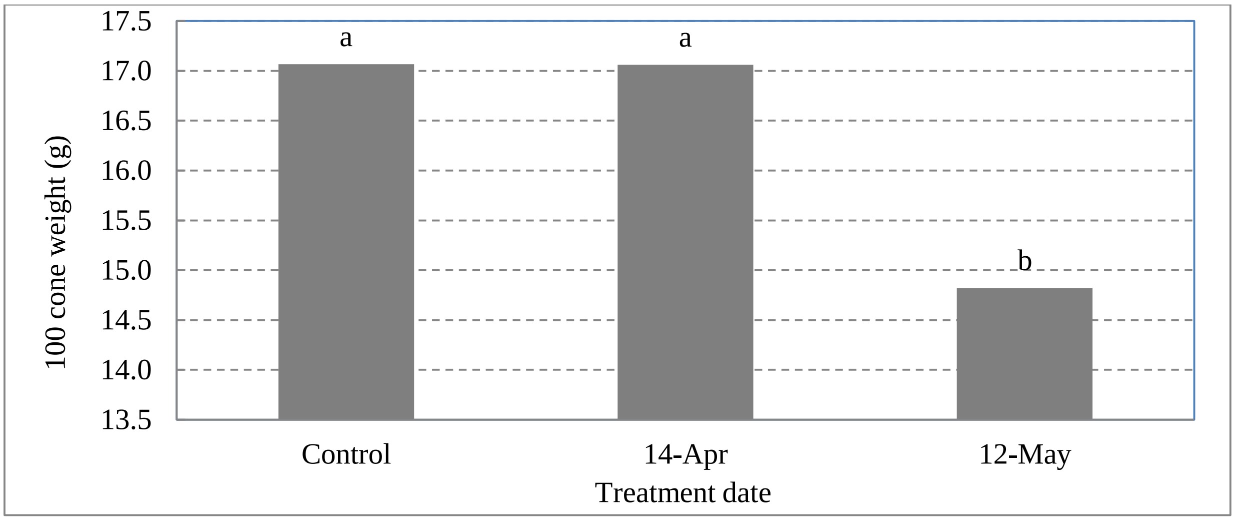

Figure 2: Effect of crowning date on hop 100 cone weight, Alburgh, VT, 2014. Treatments with the same letter are not significantly different from each other.

2015

In 2015, the early treatments, 23-Apr, yielded highest. When hop plants were crowned prior to spike emergence (23-Apr), the resulting yield was significantly higher than crowning after shoot emergence (13-May). While 100 cone weights were not taken this year, it would have been interesting to see if cone size trends remained consistent throughout years. The disease incidence and severity on the cones was not impacted by crowning (Table 8), meaning crowning did not reduce the quantity of cone disease. Cone diseases identified also included some downy mildew but also included secondary diseases such as alternaria, phoma, and fusarium.

Table 8. 2015 Hop yield, cone disease incidence, and cone disease severity, Alburgh, VT.

Treatment	Yield @ 8% moisture	Cone disease incidence†	Cone disease severity‡
	lbs ac^{-1}	%	1-5
Control	659	52.7	2.33
Crowned Early	892	58.8	2.25
Crowned Late	566	53.7	2.33
Trial mean	705	55.1	2.31
p-value	0.02	0.64	0.24

†The 100 cones from each plot were assessed for incidence of downy mildew and other diseases. ‡They were also assessed for severity of browning due to disease on a scale of 1-5, 5 being worst.

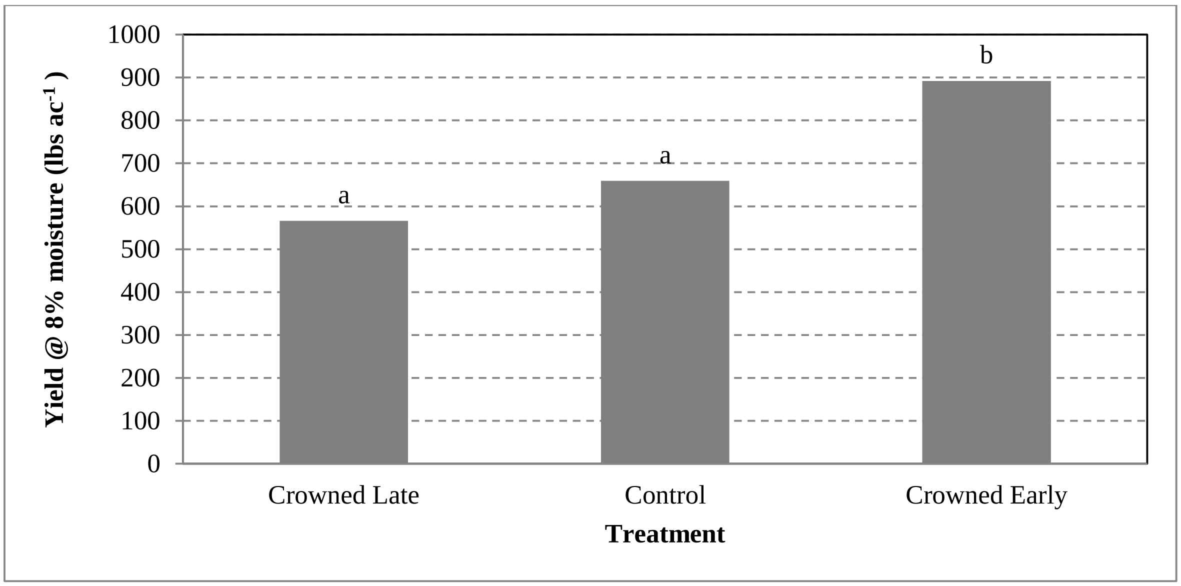

Figure 3: 2015 Hop yields for early crowning, late crowning, and control treatments.

2016

This year we eliminated late crowning treatments and included an uncovered treatment to test the impact of a soil warming effect on the crown and subsequent hop growth. With a relatively dry season lacking major or significant weather events, we noticed very low disease pressure this year (Table 9). From the past years of this study, we have noticed some key differences in cone weight and yield that occur as a result of early crowning that were lacking, perhaps due to climatic conditions.

Table 9: 2016 Hop yield, 100 cone weight, cone disease incidence, and cone disease severity Alburgh, VT.

Treatment	Yield @ 8% moisture	100 cone weight	Cone disease incidence†	Cone disease severity‡
	lbs ac^{-1}	g	%	1-5
Control	607	9.90	52.7	2.33
Crowned	844	10.7	58.8	2.25
Uncovered	663	11.1	53.7	2.33
Trial mean	705	10.6	55.1	2.31
p-value	0.26	0.57	0.41	0.91

†The 100 cones from each plot were assessed for incidence of downy mildew and other diseases. ‡They were also assessed for severity of browning due to disease on a scale of 1-5, 5 being worst.

2017

In 2017, we experienced well above normal precipitation which lead to very high disease pressure and incidence within the hop yard. During this wet season, we continued to notice trends on the significant impact of crowning on cone weights, in addition to some less significant impacts on yield and cone disease severity (Table 10). The flaming treatment was unsuccessful in this year but will be evaluated again in 2018.

Table 10. 2017 Hop yield, 100 cone weight, cone disease incidence, and cone disease severity Alburgh, VT.

Treatment	Yield@ 8% moisture	100 cone weight	Cone disease incidence†	Cone disease severity‡
	lbs ac^{-1}	g	%	1-5
Control	1073	13.8	86.4	2.95
Crowned early	1308	15.8	88.8	2.50
Flamed	n/a	n/a	n/a	n/a
Trial mean	1161	14.5	87.3	2.78
p-value	0.155	0.089	.454	0.120

†The 100 cones from each plot were assessed for incidence of downy mildew and other diseases. ‡They were also assessed for severity of browning due to disease on a scale of 1-5, 5 being worst.

Figure 4 shows the difference in control, flaming, and early crowning treatments on 100 cone weights. Flaming, perhaps in conjunction with adverse growing conditions resulted in plant death for the majority of plants receiving the treatment, whereas early crowning once again resulted in heavier cones.

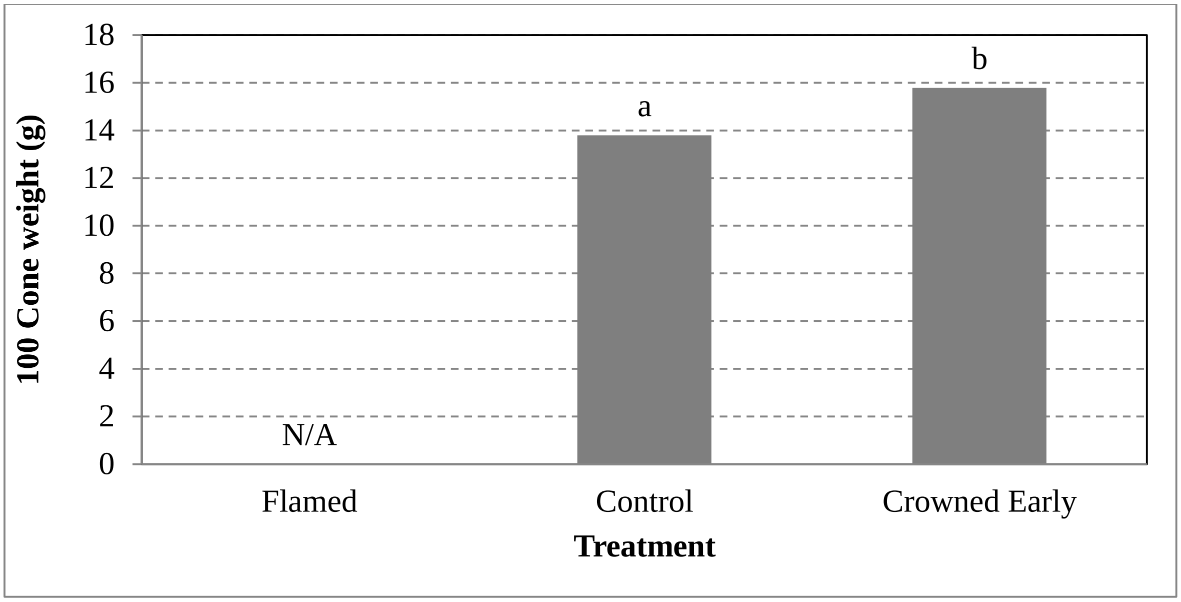

Figure 4: 2017, 100 Cone weights for flamed, early crowned and control treatments.

Summary 2014-2017

When evaluated across all years of the project, there appeared to be minimal impact of crowning on hop performance. As shown in Table 11, hop yields were slightly improved when early crowning performed. The impact on 100 cone weight as well cone disease was not statistically significant.

Table 11. Hop yield, 100 cone weight, cone disease incidence and cone disease severity Alburgh, VT, 2014-2017.

	Yield @ 8% moisture	100 cone weight	Cone disease incidence†	Cone disease severity‡
Treatment	lbs ac^{-1}	g	%	1-5
Control	872	14.4	65.3	2.74
Crowned Early	**1001**	15.3	59.1	2.56
Trial Mean	930	14.8	62.5	2.66
p-value	0.116	0.321	0.671	0.953

†The 100 cones from each plot were assessed for incidence of downy mildew and other diseases. ‡They were also assessed for severity of browning due to disease on a scale of 1-5, 5 being worst.

Table 12 shows the impact of crowning on alpha acids, beta acids, and hop storage index for both Cascade and Nugget hops. While neither alpha acids, beta acids, nor HSI are significantly different amongst treatments, there seems to be some impact on beta acids across both hop varieties.

Table 12: Alpha acids, beta acids, and HSI for both Cascade and Nugget Hops, Alburgh, VT, 2014-2017.

	Alpha acids	Beta acids	HSI
Treatment	%	%	
Control	9.52	5.87	0.250
Crowned early	9.74	6.10	0.242
Trial mean	9.62	5.97	0.246
p-value	0.919	0.121	0.907

DISCUSSION

While increased pressure from downy mildew in this region gives us more to gain by crowning to remove overwintering 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. Our research from the past four seasons indicates that there are benefits to crowning and that it is important to implement this practice as early as possible in the spring. Crowning can help to remove overwintering inoculum and to aid in warming the crown for plant growth. Early crowning appeared to to improve yields, whereas late crowning, flaming, or uncovering appeared to have negative or marginal impact on our hops. This trial has also 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. Hence the decision to implement crowning in the northeast climate will likely be a year by year decision.

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