NORTHWEST CROPS & SOILS PROGRAM

Hop Crowning Trial

Final Report Update

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THE UNIVERSITY OF VERMONT EXTENSION

HOP CROWNING TRIAL FINAL REPORT UPDATE

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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 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 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 also reduces 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. So far, our studies have indicated that crowning does result in better hop yields, and that earlier crowning (mid to late April) is more effective for this region.

Over the course of crowning study trials, multiple crowning dates, methods, and practices were tested in an attempt to develop best practices in the Northeast for hop production. Throughout the five year span early crowning dates were maintained while each year also tested other variations on crowning dates and methods. Trials included early crowning, late crowning, uncovering, and flaming as methods to reduce likelihood of downy mildew infection and incidence within the hop yard as well as to improve overall yields as a result.

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. Between 2014 and 2017, four treatments were applied to include early crowning, late crowning, mulch removal (uncover), and flaming. “Early” crowning treatments took place between April 14-23, whereas “Late” crowning treatments took place between May 12-25, each dependent on growing conditions and growing degree days for plant maturity (Table 1).

Table 1: Yearly Crowning Treatments

Year	Method	Date
2014	Crown	14-Apr
	Crown	12-May
2015	Crown	23-Apr
	Crown	13-May
2016	Crown	18-Apr
	Uncover	18-Apr
2017	Crown	25-Apr
	Flame	16-May
2018	Crown	27-Apr
	Flame	11-May

A control treatment was left with no crowning or disturbance. 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 once initial hop shoots emerged and weather conditions permitted use of 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			

2018	
Date	Champ
30-May	X
8-Jun	X
15-Jun	X
27-Jun	X
13-Jul	X
30-Jul	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. 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 five years, we had variable weather which lent to distinctly different growing conditions (Table 3 below).

Table 3: Temperature, precipitation and growing degree day summary, Alburgh, VT, 2016.

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

The 2014 growing season (March-September) experienced 2257 GGD's, which were 46 more than the 30-year average (1981-2010 data). Precipitation was above average during the growing season.

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.

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

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

In the 2016 growing season, there were an accumulated 2653 Growing Degree Days (GDDs) this season, 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 impacted disease pressure and yields.

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

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 five-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.

2018	March	April	May	June	July	August	Sept
Average temperature (°F)	30.4	39.2	59.5	64.4	74.1	72.8	63.4
Departure from normal	-0.66	-5.58	3.1	-1.38	3.51	3.96	2.76
Precipitation (inches)	1.5	4.4	1.9	3.7	2.4	3	3.5
Departure from normal	-0.7	1.61	-1.51	0.05	-1.72	-0.95	-0.16
Growing Degree Days (base 50°F)	1	37	352	447	728	696	427
Departure from normal	1	37	154	-27	88	115	109

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.

In the 2018 growing season, there were an accumulated 2688 Growing Degree Days, 477 more than the historical 30-year average. 2018 was unusually hot and dry accumulating far less rain during the bulk of the growing season (May-Sep) than the average year. Hot and dry conditions impacted disease pressure and yields.

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 that exhibited conditions considered likely for downy mildew infection based on variable weather conditions (Figures 2-5).

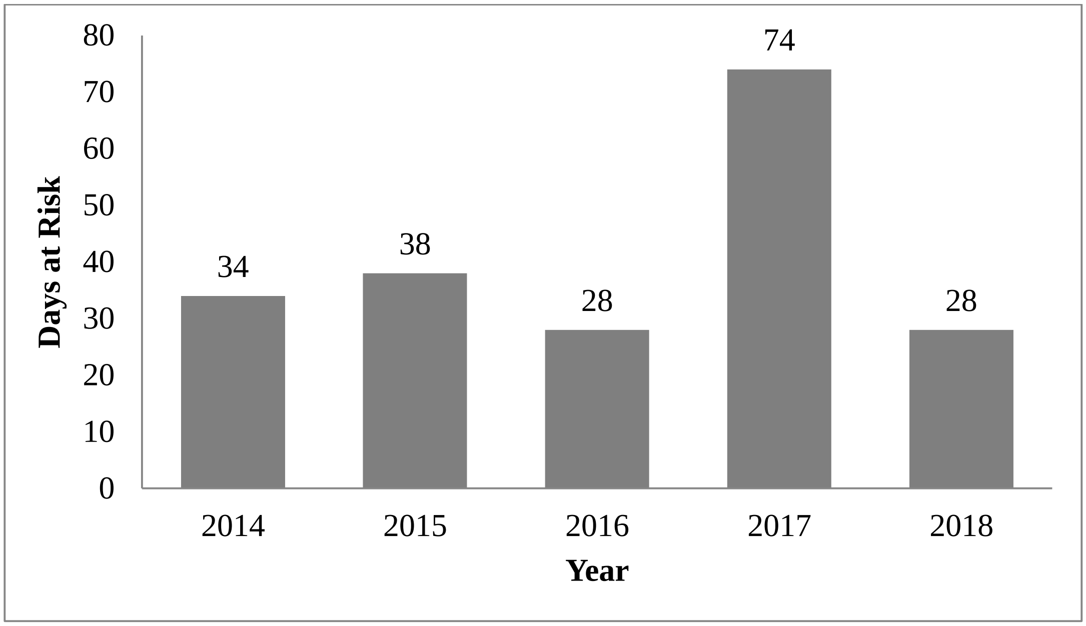

Figure 1: Yearly comparison of days at risk for disease infection.

The abnormally dry weather during 2016 and 2018 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. We welcome dry weather, as in 2016, in the hop yard due to the positive impact that it can have on reducing disease impact. Conversely, 2017 experienced extreme wet weather conditions, especially during the early months of the growing season. This of course resulted in heavy disease pressure.

2014

The date at which hops were crowned had little impact on downy mildew, hop yield, and hop quality (Table 4). 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 4: 2014 Hop yield, 100 cone weight, cone disease incidence, cone disease severity.

	Yields @ 8% moisture	100 cone weight	Cone disease incidence	Cone disease severity
Treatment	lbs ac^{-1}	g	%	1-5
Control	790	17.1*	31	1.8
Crowned Early	868	**17.1**	36	1.3
Crowned Late	788	14.8	33	1.7
Trial mean	816	16.3	35.4	3.89
LSD	NS	1.1	NS	NS

NS= No significant differences in treatments. *Treatments with an asterisk are not significantly different than the top performer in **bold**.

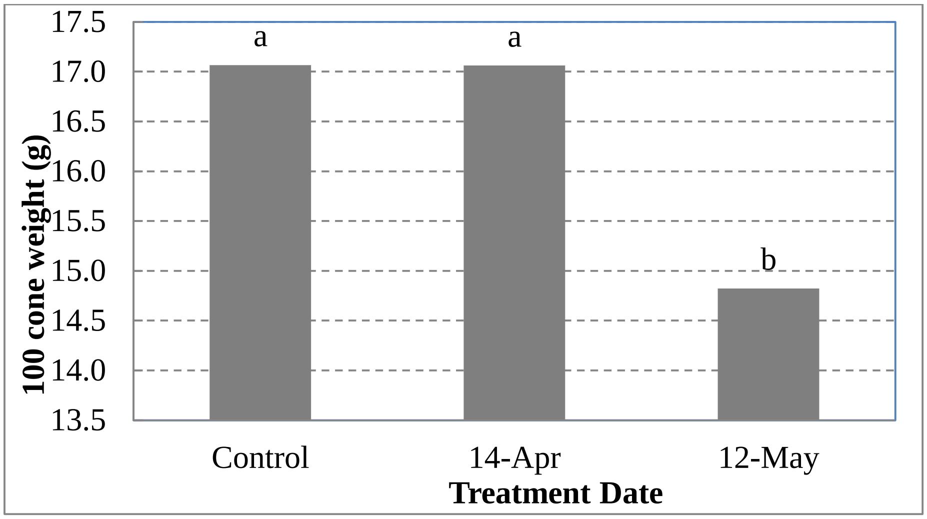

Figure 2: Effect of crowning date on hop 100 cone weight, Alburgh, VT, 2014. Treatments with the same letter are not significantly different from each other.

2015

Disease incidence and severity on the cones was not impacted by crowning (Table 5), 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.

Table 5: 2015 Dry matter, yield, 100 cone weight, cone disease incidence, cone disease severity.

	Dry matter	Yield @ 8% moisture	Cone disease incidence	Cone disease severity
Treatment	%	lbs ac^{-1}	%	1-5
Control	24.0	659	52.7	2.33
Crowned Early	25.0	**892**	58.8	2.25
Crowned Late	24.0	566	53.7	2.33
Trial mean	24.3	705	55.1	2.31
p-value	NS	0.02	NS	NS

NS= No significant differences in treatments. *Treatments with an asterisk are not significantly different than the top performer in **bold**.

Yield by treatment is shown in Figure 3. 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.

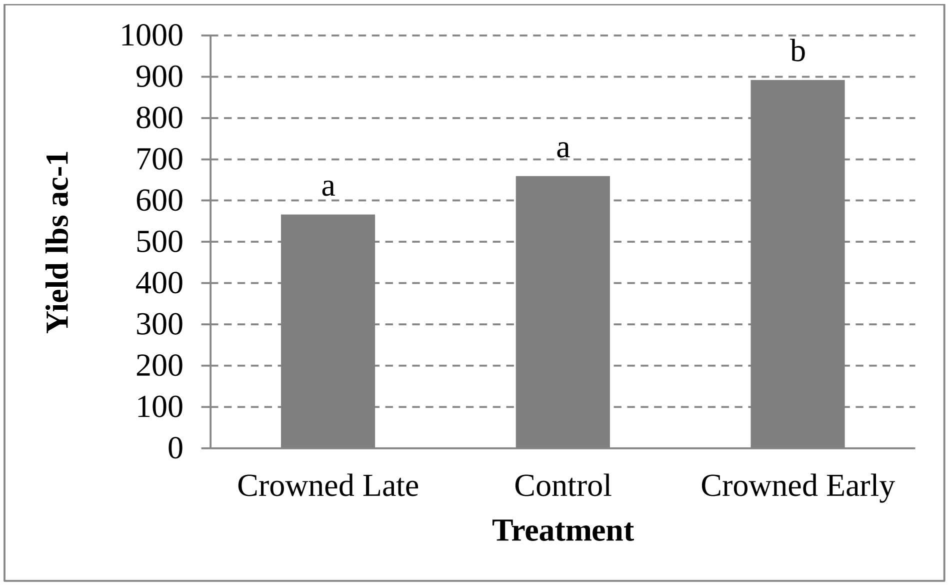

Figure 3: 2015 Yields for early crowning, late crowning, and control treatments. Treatments with the same letter are not significantly different from each other.

2016

This year we eliminated late crowning treatments and included treatment to test the impact of removing the thick layer of mulch had on soil warming and growth from the crown. In prior years of the research study, the early crowning treatment seemed to elevate hop yield but didn't have a major impact on disease. We hypothesized that by crowning, we may be removing the thick layer of mulch and just allowing the soil to warm faster and hop growth to occur earlier in the season. Hence, the goal was to evaluate if just simply uncovering the hop crown would lead to the same results as early spring crowning. The crowing treatment still yielded higher than the other treatments in the study. With a relatively dry season lacking major or significant weather events, we noticed very low disease pressure this year which may have contributed to the similarity in results between treatments (Table 6). 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 6: 2016 Dry matter, yield, 100 cone weight, cone disease incidence, cone disease severity.

	Dry matter	Yields @ 8% moisture	100 cone Weight	Cone disease incidence	Cone disease severity
Treatment	%	lbs ac^{-1}	g	%	1-5
Control	23.2	607	9.90	52.7	2.33
Crowned	22.7	**844**	10.7	58.8	2.25
Uncovered	24.2	663	11.1	53.7	2.33
Trial mean	23.4	705	10.6	55.1	2.31
LSD	NS	0.26	NS	NS	NS

NS= No significant differences in treatments. *Treatments with an asterisk are not significantly different than the top performer in **bold**.

2017

In 2017, we experienced well above normal precipitation which led to very high disease pressure and incidence within the hop yard. Within 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 7). Yield and cone weights were consistently impacted by crowning throughout the study to some effect, whereas other metrics may be influenced by growing conditions. Because of the wet season and high disease pressure, our sample size was significantly reduced and individual plants were analyzed within plot treatments as opposed to entire replicated plots, which could have potentially had an impact on results for the year.

Table 7: 2017 Dry matter, yield, 100 cone weight, cone disease incidence, cone disease severity.

Treatment	Dry matter	Yield @ 8% moisture	100 cone weight	Cone disease incidence	Cone disease severity
	%	lbs ac^{-1}	g	%	1-5
Control	23.3	1073	13.8	86.4	2.95
Crowned Early	24.1	**1308**	**15.8**	88.8	2.50
Flamed	n/a	n/a	n/a	n/a	n/a
Trial mean	23.6	1161	14.5	87.3	2.78
p-value	NS	0.155	0.089	NS	NS

NS= No significant differences in treatments. *Treatments with an asterisk are not significantly different than the top performer in **bold**.

Figure 4 (below) 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.

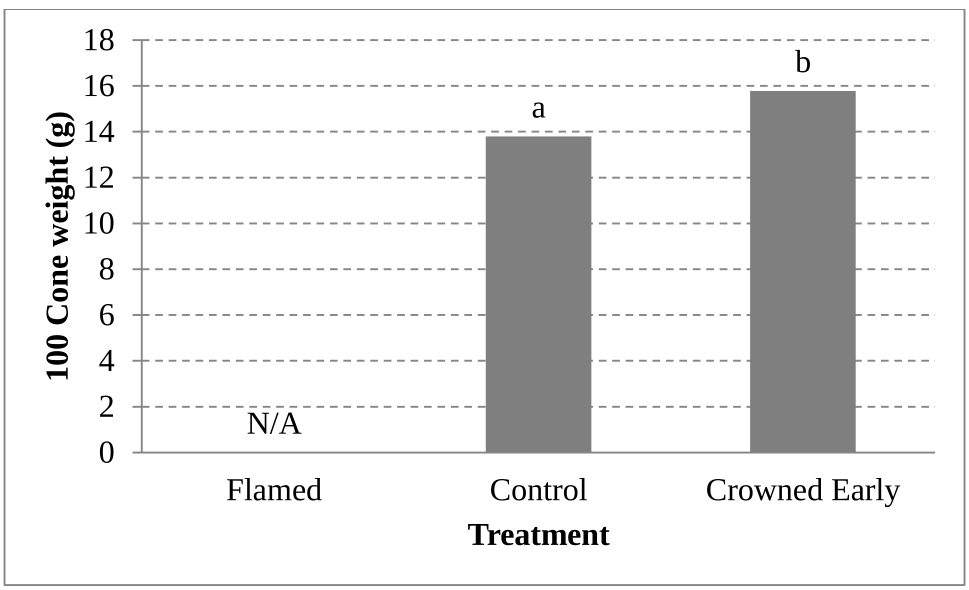

Figure 4: 2017, 100 Cone weights for flamed, early crowned and control treatments. Treatments with the same letter are not significantly different from each other.

2018

In 2018, we experienced well below normal precipitation and higher than normal temperatures which led to decreased disease pressure and severity across all samples (Table 8).

Table 8: 2018 Dry matter, yield, 100 cone weight, cone disease incidence, cone disease severity.

Treatment	Dry matter	Yields @ 8% moisture	100 cone weight	Cone disease incidence	Cone disease severity
	%	lbs ac^{-1}	g	%	1-5
Control	24.8	642*	**14.2**	63.7	2.00
Crowned Early	25.1	584	13.0*	70.3	2.00
Flamed	24.6	**786**	11.4	73.3	1.50
Trial mean	24.8	671	12.9	69.1	1.83
LSD	NS	189	2.36	NS	NS

NS= No significant differences in treatments. *Treatments with an asterisk are not significantly different than the top performer in **bold**.

Yield by treatment is shown in Figure 5. The flamed treatment, 11-May, yielded highest. While there was not a significant difference in yield between crowning and control treatments this year, crowning did have the lowest yield compared to control and flamed treatments.

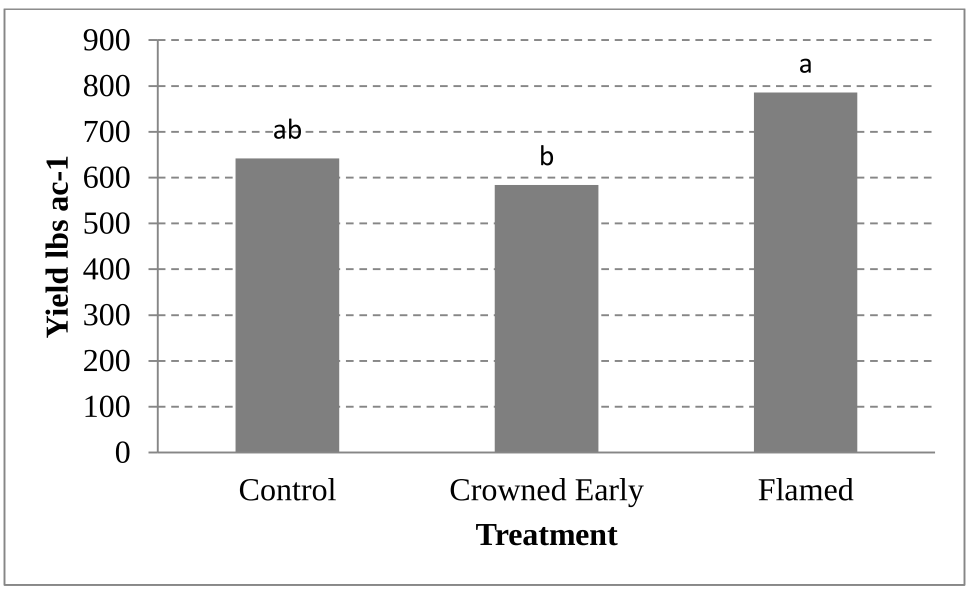

Figure 5: 2018 Yields for control early crowning, and flamed treatments. Treatments with the same letter are not significantly different from each other.

Figure 6 shows the difference in control, flaming, and early crowning treatments on 100 cone weights. Flaming resulted in significantly smaller cone sizing on hop plants despite having highest yields in the 2018 trial.

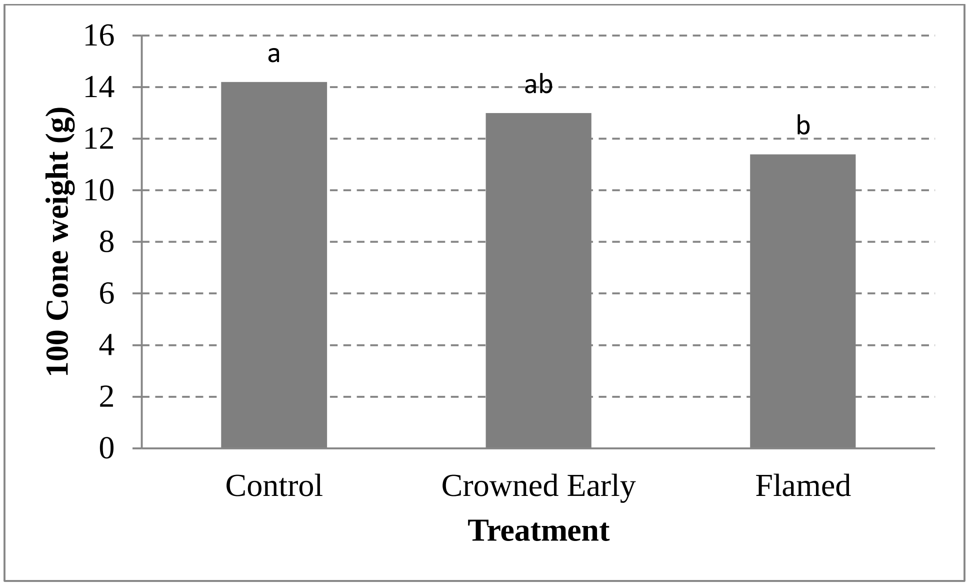

Figure 6: 2018, 100 Cone weights for flamed, early crowned and control treatments. Treatments with the same letter are not significantly different from each other.

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 five 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 helped to improve yields, whereas late crowning or uncovering appeared to have negative or marginal impact on our hops. We also experienced increased yields on flamed treatments this year perhaps helping to not only reduce potential overwintering inoculum but also potential bull shoots which would have produced fewer cones and reduced yields. 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.

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