2016

Hop Crowning Trial

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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 is more effective for this region.

While the cause for this increased yield likely has to do with the above benefits of crowning, there is another possible variable 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, and one treatment was left untouched, with no crowning or uncovering.

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. Split plots were two crowning dates. Crowning was completed in 2016 on 18-Apr on one treatment. Plants in a second treatment were uncovered on the same day to increase soil temperature without pruning back any growth. 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).

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

Fungicides were sprayed regularly throughout the season. The pesticides used in the research yard in 2016 were Champ WG (Nufarm Americas Inc., EPA Reg. No. 55146-1), Regalia (Marrone Bio Innovations, EPA Reg. No. 84059-3), Cease (BioWorks, Inc., EPA Reg. No. 264-1155-68539), and Trilogy (Certis USA, LLC., EPA Reg. No. 70051-2). The hop yard was irrigated weekly in June, July and August at a rate of 3900 gallons of water per acre.

Fertigation (fertilizing through the irrigation system) was used to apply fertilizer more efficiently. Starting in late May, the hops received 5 lbs ac^{-1} of nitrogen (N) through the irrigation system on a weekly basis until early July. At each fertigation application, 25 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 on 20-May. Another 100 lbs ac^{-1} was applied by hand on 21-Jun. Chilean nitrate (16-0-0) and Pro Gro (5-3-4) were used to supply N to the hops on those two dates. Total N application (including fertigation) for the season was 235 lbs ac^{-1}. 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. Basal spikes were reported by total number per plot, while 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. In addition, the height of three bines per plot was measured from early May to mid-June to track growth patterns between the treatments.

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}. Yields were analyzed using the GLM procedure in SAS (SAS Institute, 1999) 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.

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, (Gent et al. 2010) (Figure 1). The model was calculated using data from a nearby weather station in Chazy, NY. We found that 28 of the 183 days between 1-Apr 2016 and 30-Sep 2016 exhibited conditions considered likely for downy mildew infection.

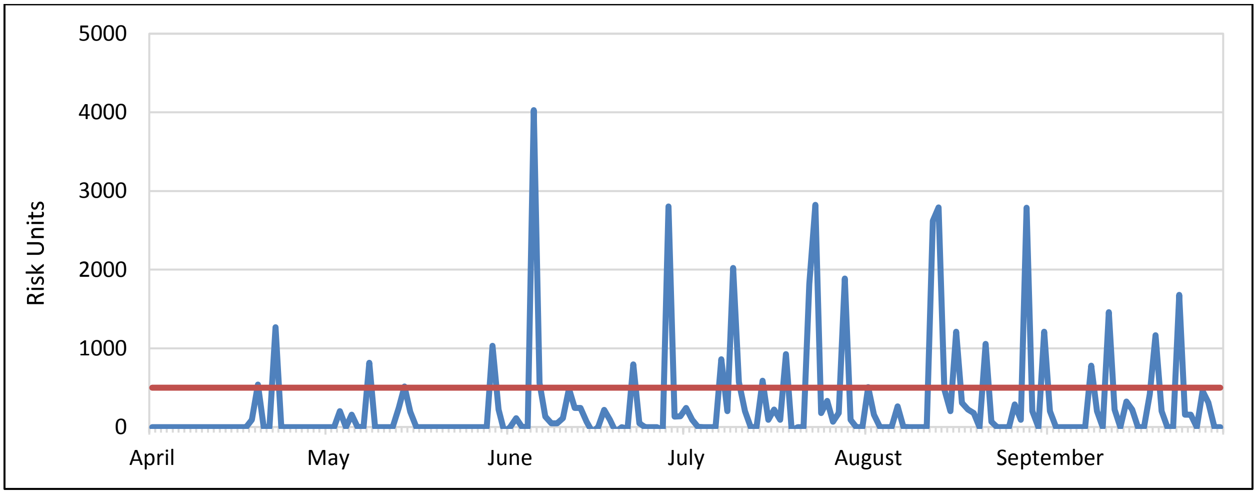

Figure 1. Number of risk units, (Gent et al. 2010), Chazy, NY, 2016.
The red line at 500 risk units indicates an increased likelihood of downy mildew infection.

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Predicting habitable conditions for downy mildew, using humidity and precipitation events, allowed us to determine optimal biofungicide application dates prior to periods of high infection risk.

Dry weather in June allowed us to spray only once during that month. Before and after June, spraying occurred about once every two weeks. Table 1 shows fungicide application dates and products for the 2016 season.

Table 1. Spray schedule in the organic hop crowning trial, Alburgh, VT, 2016.

Date	Product
29-May	Champ, Regalia
3-Jun	Champ, Regalia
5-Jul	Champ, Regalia
12-Jul	Champ, Regalia
21-Jul	Champ, Regalia
1-Aug	Cease
9-Aug	Champ, Regalia

RESULTS

The abnormally dry weather this year kept disease pressure low throughout the season. We welcome dry weather like this in the hop yard for that reason, although for this specific project the general lack of downy mildew in the yard made it harder to compare the treatments. Weather data was recorded with a Davis Instrument Vantage PRO2 weather station, equipped with a WeatherLink data logger at Borderview Research Farm in Alburgh, VT. Missing precipitation data from 17-Aug through 31-Oct was supplemented using data provided by the NOAA from Highgate, VT. March, May, August, and September had above average temperatures. Despite the lack of rain, June and July were close to the average temperature. Overall, 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 (Table 2). Dry conditions impacted disease pressure and yields.

Table 2. Temperature, precipitation, and growing degree day summary, Alburgh, VT, 2016.

Alburgh, VT	March	April	May	June	July	August	September
Average temperature (°F)	33.9	39.8	58.1	65.8	70.7	71.6	63.4
Departure from normal	2.89	-4.92	1.84	0.01	0.13	2.85	2.90
Precipitation (inches)	2.51	2.56	1.53	2.81	1.79	2.98	2.47
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

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.

Yield by treatment is shown in Figure 2. The crowned treatments yielded highest, although the difference among the other treatments was not statistically significant.

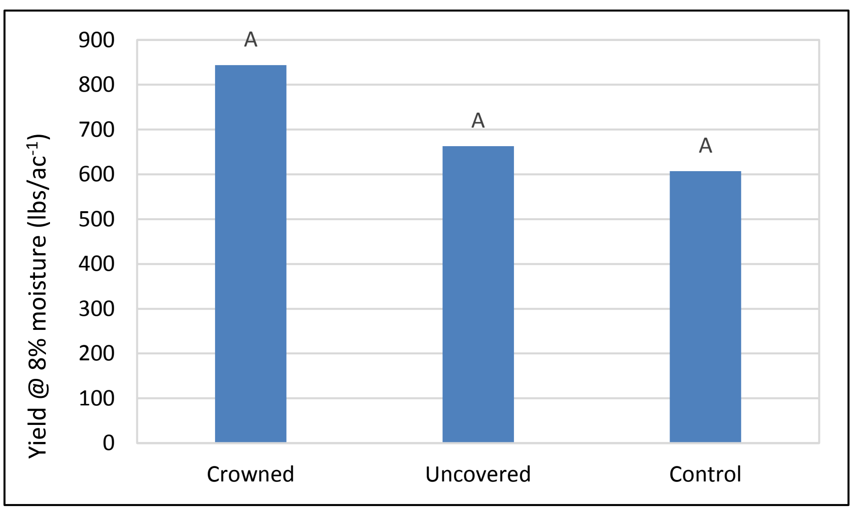

Figure 2: Yield at 8% moisture by treatment, Alburgh, VT 2016.

Figure 3 shows plant heights over time. The plants in the control treatment were taller in the beginning of the season, but by mid-June the other treatments reached the same height.

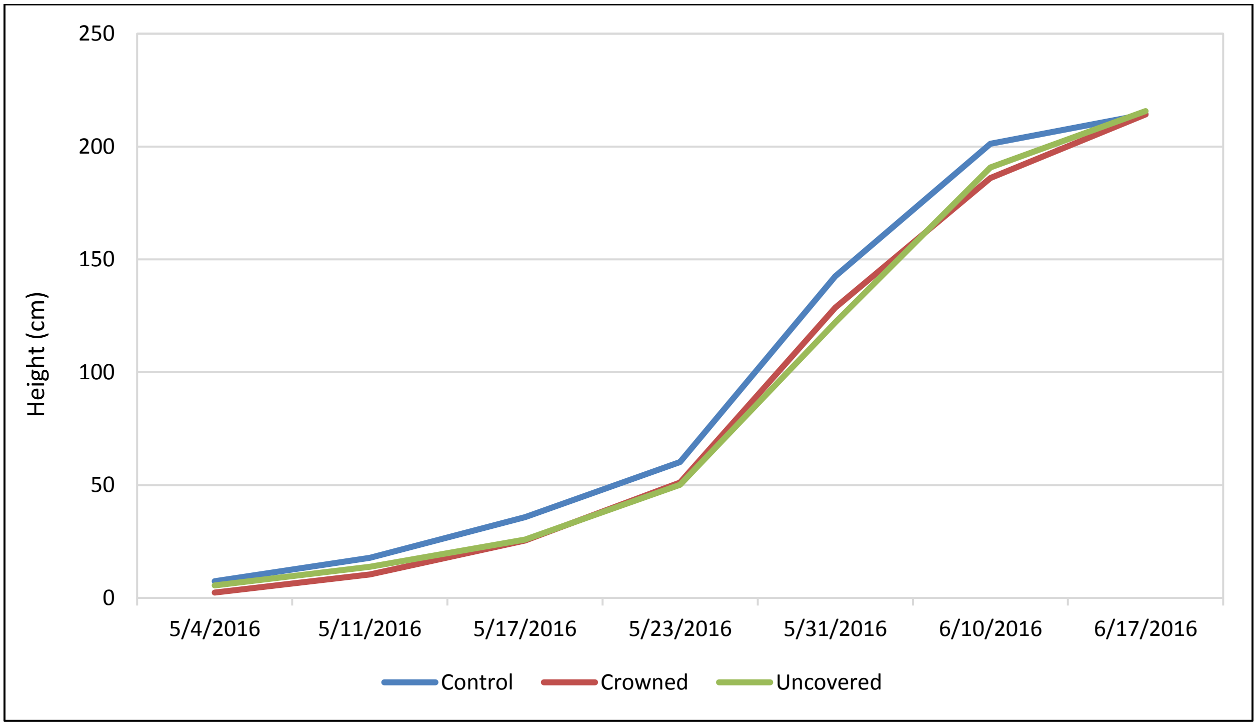

Figure 3: Plant height by date and treatment, Alburgh, VT 2016.

As shown in Table 3, neither dry matter, yield, nor 100 cone weight were statistically different among the treatments.

Table 3. Dry matter, yield per acre at 8% moisture, and 100 cone weight, Alburgh, VT, 2016.

	Dry Matter		Yield		100 Cone Weight	
Treatment	%		lbs ac^{-1}		g	
Control	23.2	a	607	a	9.90	a
Crowned	22.7	a	**844**	**a**	10.7	a
Uncovered	24.2	a	663	a	11.1	a
Trial mean	23.4		705		10.6	
p-value	0.47		0.26		0.57	

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

Treatments did not differ in the incidence or severity of cone disease or foliar disease incidence (Table 4).

Table 4. Cone disease incidence, cone disease severity, and foliar disease incidence, Alburgh, VT, 2016.

Treatment	Cone Disease Incidence		Cone Disease Severity		Foliar Disease Incidence	
	%		1-5		1-5	
Control	**52.7**	**a**	2.33	a	2.25	a
Crowned	58.8	a	**2.25**	**a**	1.83	a
Uncovered	53.7	a	2.33	a	**1.58**	**a**
Trial mean	55.1		2.31		1.89	
p-value	0.41		0.91		0.59	

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

Table 5 shows average number of basal spikes, aerial spikes, and infected leaves by treatment. While there were slight differences here, the treatments were not statistically different.

Table 5. Basal spikes, aerial spikes, and leaves with downy mildew, Alburgh, VT, 2016.

Treatment	Basal spikes		Aerial spikes		Leaves	
	per plot		# per plant		# per plant	
Control	**2.11**	**a**	0.069	a	0.010	a
Crowned	2.83	a	0.071	a	0.029	a
Uncovered	3.11	a	**0.051**	**a**	**0.010**	**a**
Trial mean	2.69		0.064		0.017	
p-value	0.64		0.72		0.078	

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

Table 6 and Table 7 show alpha acids, beta acids, and hop storage index (HSI) by treatment for Cascade and Nugget, respectively. For Cascade, alpha and beta acids were statistically similar. HSI was not quite significantly different, but indicated an advantage toward the crowned plots. Alpha and beta acid values for Nugget treatments were statistically higher in the uncovered treatments, while HSI showed little difference.

Table 6. Alpha acids, beta acids, and hop storage index for Cascade hops, Alburgh, VT, 2016.

Treatment	Alpha Acids		Beta Acids		HSI	
	%		%			
Control	4.87	a	6.21	a	0.252	a
Crowned	5.16	a	7.06	a	**0.211**	**b**
Uncovered	**5.67**	**a**	**7.90**	**a**	0.232	ab
Cascade mean	5.2		7.1		0.232	
p-value	0.7260		0.4071		0.1074	

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

Table 7. Alpha acids, beta acids, and hop storage index for Nugget hops, Alburgh, VT, 2016

Treatment	Alpha Acids		Beta Acids		HSI	
	%		%			
Control	11.38	b	3.86	c	0.241	a
Crowned	12.84	a	4.19	b	**0.235**	**a**
Uncovered	**13.27**	**a**	**4.45**	**a**	0.241	a
Nugget mean	12.5		4.2		0.239	
p-value	0.0067		0.0014		0.7880	

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

DISCUSSION

Very low disease pressure this year likely contributed to the similarity in results between treatments. Our research from the past three seasons indicates that there are benefits to crowning, and it is important to implement this practice as early as possible in the spring. This trial has confirmed that crowning does have a positive effect on yield compared to the control and uncovered treatments, although the results this year were not statistically significant. Higher alpha and beta acids and slightly better yield performance in the uncovered treatments over the control suggest that uncovering the plants early in the season may have had a positive effect on their growth as well, although likely not as much as crowning did. We know that all plant growth has a strong relationship to temperature, so it makes sense that helping the plants reach temperatures adequate for growth as early as possible will benefit them.

Other crowning methods scratch the entire length of the plant bed instead of targeting individual plants as we did in the UVM hop yard. That strategy is likely more effective, and we plan to test its efficacy with new equipment this coming growing season.

WORKS CITED

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

ACKNOWLEDGEMENTS

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