NORTHWEST CROPS & SOILS PROGRAM

2015 Hop Biofungicide Trial

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2015 HOP BIOFUNGICIDE TRIAL

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INTRODUCTION

Downy mildew has been identified as the primary pathogen plaguing our northeastern hop yards. This disease causes reduced yield, poor hop quality, and in severe cases cause plant death. Control measures that reduce disease infection and have a low environmental impact are desperately needed for the region. Regular application of protectant fungicide sprays is an effective method for managing downy mildew pressure in hop yards. However, regular chemical applications can lead to residual toxicity in the soil and have a negative effect on beneficial organisms. Extended use of protectant and curative fungicides can also lead to development of resistance. The goal of this project was to begin evaluating the efficacy of organic approved biofungicides for control of downy mildew in hops.

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 20' plots (each plot had 4 hills). Plots were replicated 3 times each with two hop varieties: Cascade and Nugget. Cascade served as a moderately resistant cultivar and Nugget served as a downy mildew susceptible treatment. Split plots were four fungicide treatments. The treatments were:

Sil-matrix

The active ingredient in Sil-matrix (Certis USA LLC, EPA Reg. No. 82100-1) is soluble silica. When sprayed preventatively, the silica acts as a physical barrier between the plant cuticle and fungal diseases. It is also used to control mites and insects. For disease, Sil-matrix is primarily intended for controlling powdery mildew. We have not seen any instance of powdery mildew in Vermont; this experiment looked at the product's ability to prevent against other diseases. **http://www.certisusa.com/pest_management_products/biochemicals/sil-matrix_fungicide_miticide_insecticide.htm**

Double Nickel + Cueva

Double Nickel (Certis USA LLC, EPA Reg. No. 70051-108) is a biofungicide intended for use on Powdery mildew, Sclerotinia, Botrytis, Alternaria, Bacterial leaf spot, Bacterial spot and speck, Fire blight, Xanthomonas, and Monilinia. The manufacturer states that it employs 5 methods of action. Double Nickel is for preventative use and was combined with copper-based fungicide Cueva for this experiment. **http://www.certisusa.com/pest_management_products/biofungicides/doublenickel55_fungicide.htm**

Cueva (Certis USA LLC, EPA REG. NO. 67702-2-70051) is a copper soap (combination of copper and fatty acid) for preventative use against fungal diseases. Copper ions disrupt the cellular proteins of the fungus. **http://www.certisusa.com/pest_management_products/biochemicals/cueva_fungicide_concentrate.htm**

Oso

The active ingredient in Oso (Certis USA LLC, EPA Reg. No. 68173-4-70051) is polyoxin D zinc salt. Oso is intended for use on Alternaria, Powdery mildew, and other diseases. It is not marketed for downy mildew. Oso should be applied preventatively. **http://www.certisusa.com/pest_management_products/biofungicides/oso_fungicide.htm**

Champ WG + Regalia

Champ WG (Nufarm Americas Inc., EPA Reg. No. 55146-1) 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. **http://www.nufarm.com/USAg/ChamprWG**

Regalia (Marrone Bio Innovations, EPA Reg. No. 84059-3) is a broad spectrum bio-fungicide that works by stimulating the plant's natural defenses. The active ingredient is extracted from giant knotweed (Fallopia sachalinensis). **http://marronebioinnovations.com/ag-products/brand/regalia/**

All pesticides applied except for Oso were OMRI-approved for use in organic systems. All pesticides were applied at rates specified by their labels.

Champ and Regalia were applied 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. All other sprays were applied with 5-gallon backpack-style hand-pump sprayers.

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 1) (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.

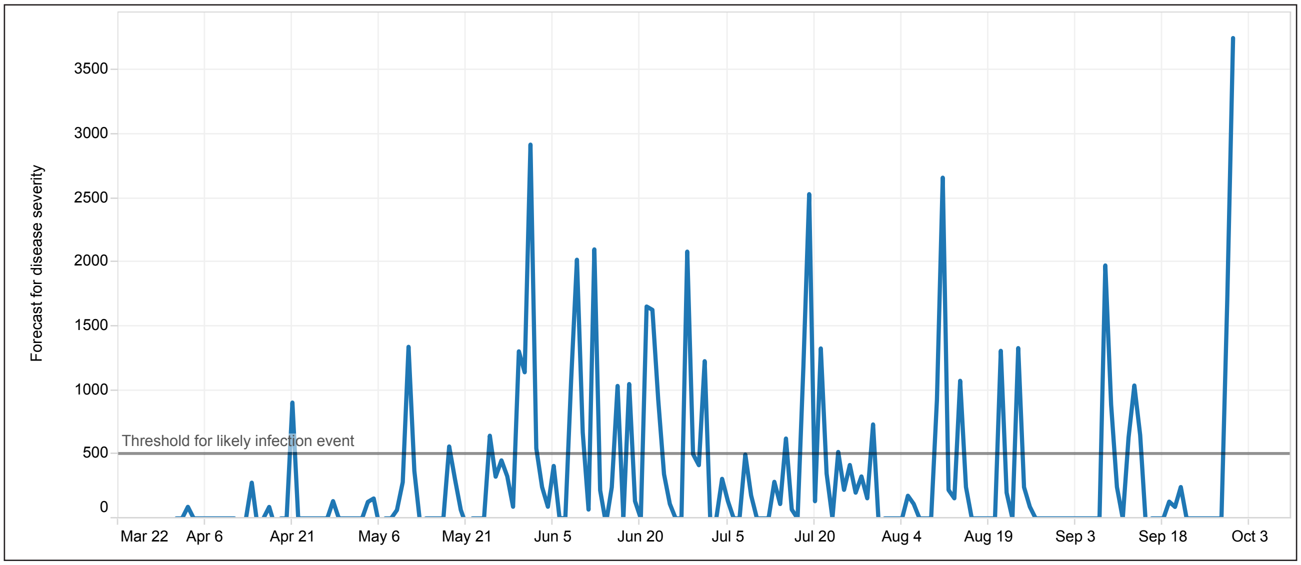

Figure 1: Number of "risk units" according to the disease risk index created by Royle (Gent et al. 2010), Alburgh, VT 2015.

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 cool, wet spring and continued moisture throughout the 2015 season, spraying was done as frequently as possible according to fungicide labels. Table 1 shows fungicide application dates for the 2015 season.

Table 1: Biofungicide application dates, Alburgh, VT 2015.

Date
22-May
29-May
5-Jun
12-Jun
19-Jun
26-Jun
6-Jul
13-Jul
27-Jul
14-Aug

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 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. 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

Overall, hops treated with the copper based fungicides resulted in significantly higher yields than either the Sil-Matrix or Oso (Figure 2). Cone weight was not impacted by the fungicide treatments (Table 3). Interestingly, the hops treated with Champ did not dry down as quickly as the other treatments. This slower dry-down is likely the behavior of a healthier plant. Plots treated with Champ and Regalia yielded highest on average, followed by plots treated with Double Nickel and Cueva (Figure 2, Table 3).

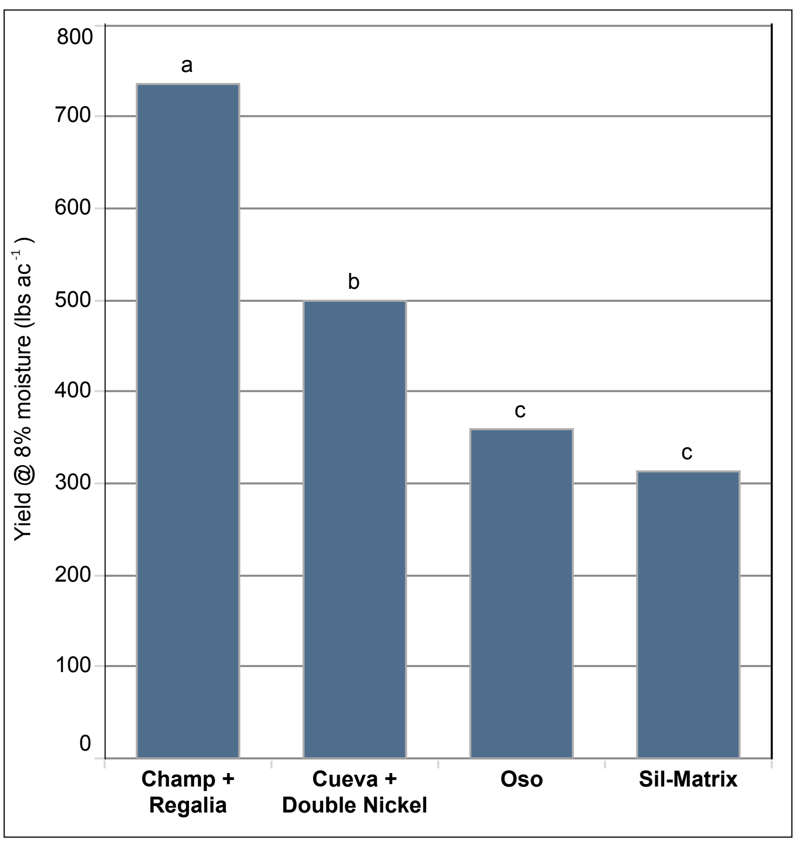

Figure 2: Yield by fungicide treatment, Alburgh, VT 2015
Values followed by the same letter are not significantly different.

At harvest, we noticed discoloration on hop cones (Figure 3). Interestingly, the prevalent diseases identified on harvested cones were not downy mildew. Instead Alternaria and Phoma were the most prevalent disease cultured from cones. Cercospera and Fusarium were also identified but present on cones to a much lesser degree. Hops treated with Champ had significantly lower incidence and severity of disease on the harvested cones (Table 3, Figure 4, Figure 5). Cones treated with Oso and Silmatrix would mostly have been classified as not marketable.

Figure 3: Cones infected with Alternaria and Phoma from least infected to most infected

Table 3: Impact of biofungicide treatments on hop yield and cone disease, Alburgh, VT, 2015

Treatment	Dry matter		100 cone weight		Yield		Disease incidence		Disease severity	
	%		g		lbs ac^{-1}		%		1-10	
Champ + Regalia	24	b	18.6	a	**736**	a	**33**	c	**1.5**	c
Cueva + Double Nickel	26	a	17.0	a	500	b	64	b	2.3	b
Oso	27	a	18.7	a	360	c	85	a	3.7	a
Silmatrix	28	a	18.2	a	313	c	88	a	4.2	a
p-value	0.030		0.840		<0.001		<0.001		<0.001	

*Within a column, values followed by the same letter are not significantly different. Treatments indicated in **bold** had the top observed performance. Dry matter and 100 cone weight are not bolded because there is not a set value for best performance.*

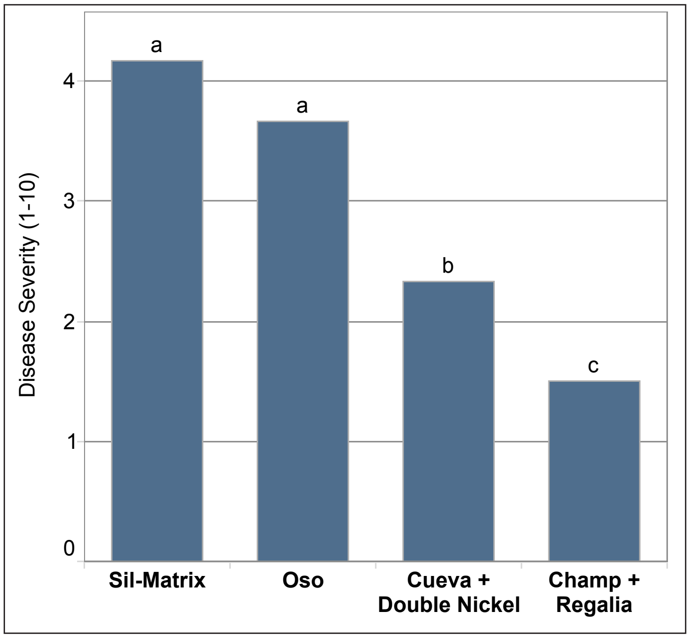

Figure 4: Disease severity (1-10) on harvested cones by fungicide treatment, Alburgh, VT 2015. *Values followed by the same letter are not significantly different.*

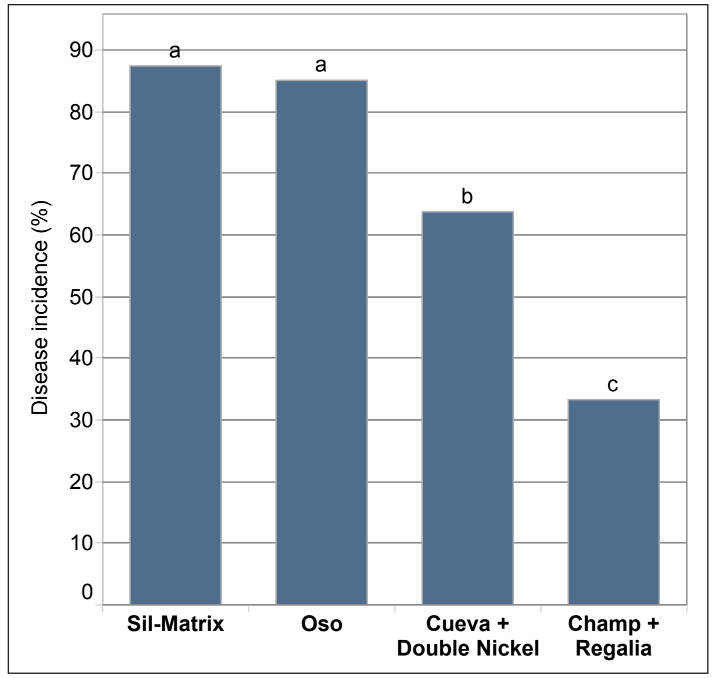

Figure 5: Disease incidence on harvested cones by fungicide treatment, Alburgh, VT 2015. *Values followed by the same letter are not significantly different.*

Table 4 shows average severity of Phoma and Alternaria by treatment, and highlights that Oso provided significantly better control of Alternaria compared to other treatments. Phoma was not supressed by any of the treatments.

Table 4: Secondary disease severity on harvested cones by treatment, Alburgh, VT 2015

Variety	Alternaria		Phoma	
	severity (1-5)		severity (1-5)	
Sil-Matrix	3.4	a	2.6	a
Champ + Regalia	2.8	ab	2.9	a
Cueva + Double Nickel	2.8	ab	2.3	a
Oso	2.1	b	2.8	a
p-value	0.048		0.591	

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

Across the length of the season, average number of infected leaves was lowest in the two copper treatments (Figure 6). Comparing the copper treatments, Champ was more effective at protecting the plant from downy mildew (Figure 6). What's the difference between the two formulations? Copper can be toxic to plants if too many copper ions are released at the same time, so these fungicides are each formulated in a way that slows the release of these ions, but in different ways. Champ includes elements that "fix" the copper ions, and Cueva includes a fatty acid that holds them in suspension. Ions are released each time the formulation becomes wet.

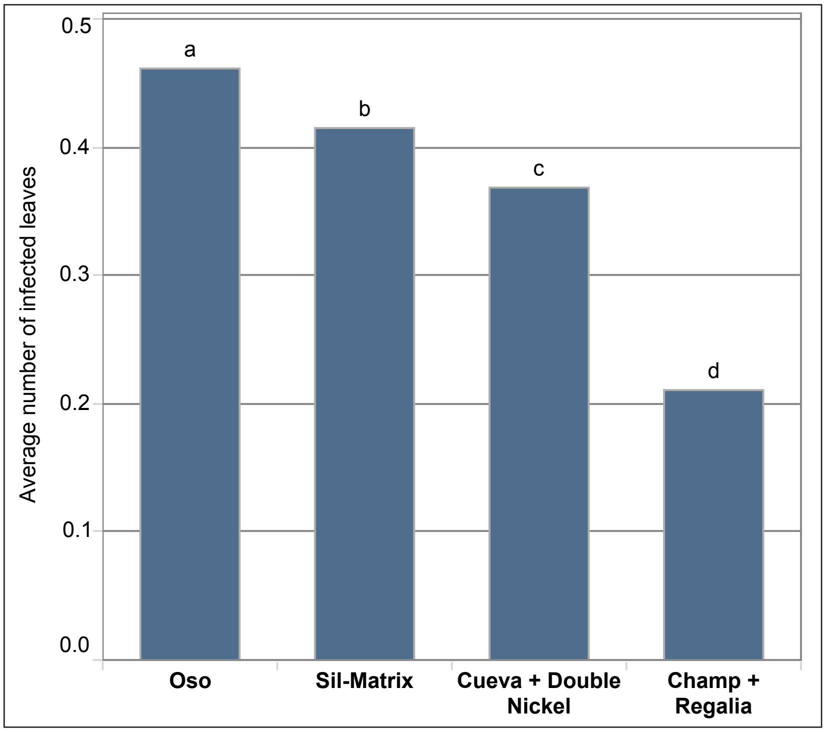

Figure 6: Average number of infected leaves by treatment, Alburgh, VT 2015. *Statistical significance was determined by performing a square root transormation of the data. Values followed by the same letter are not significantly different.*

Figure 7 shows the number of infected leaves and aerial spikes over the course of the season. Notice that the number of infected leaves peaks earlier than aerial spikes. Downy mildew infection periods were highest in June and July and dropped off quite significantly in August. This was likely due to the drier conditions in August.

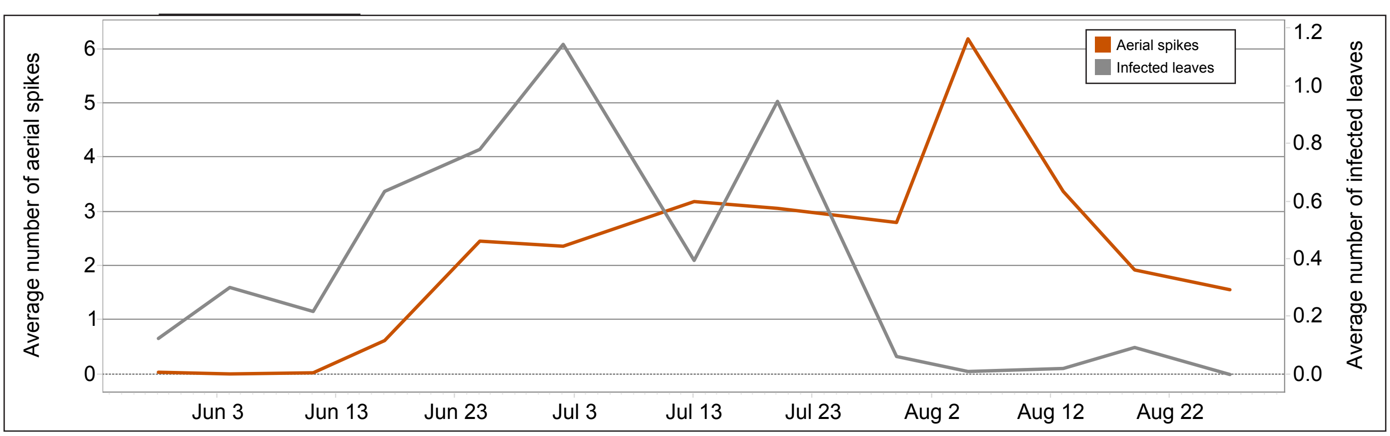

Figure 7: Average number of aerial spikes and leaves infected with downy mildew by date, Alburgh, VT, 2015

Table 5 shows hop brewing quality values for Cascade plants by treatment and Table 6 shows values for Nugget plants. The fungicide treatments did not signficantly impact hop quality in this experiment.

Table 5: Alpha acids, beta acids and HSI for Cascade plants by treatment, Alburgh, VT 2015

Treatment	Alpha acids		Beta acids		HSI	
	%		%			
Sil-Matrix	4.7	a	7.1	a	.23	a
Oso	4.5	a	7.0	a	.22	a
Cueva + Double Nickel	4.3	a	6.8	a	.22	a
Champ + Regalia	3.7	a	6.6	a	.23	a
p-value	0.113		0.594		0.642	

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

Table 6: Alpha acids, beta acids and HSI for Nugget plants by treatment, Alburgh, VT 2015

Treatment	Alpha acids		Beta acids		HSI	
	%		%			
Champ + Regalia	14.5	a	4.9	a	.24	a
Oso	13.7	a	4.8	a	.24	a
Cueva + Double Nickel	13.1	a	4.9	a	.24	a
Sil-Matrix	12.4	a	4.6	a	.25	a
p-value	0.125		0.580		0.845	

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

DISCUSSION

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. 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.

Although biological forms of control are promising as elements of a downy mildew control program, it is clear that sprays containing copper were more effective in this trial. We would like to continue to explore other options for biological control and using biological sprays in conjunction with copper products like Champ. It is important to find alternatives to allow organic producers to rotate downy mildew fungicide treatments.

We also learned that other diseases are more prevalent than downy mildew post-harvest. More information is needed to determine whether they are having a negative impact on the cones and how best to manage them.

This trial provides an insight into how important it is to keep up with a fungicide regime; yields were dramatically different between the most and least effective treatment. If there had been plots with no treatment at all, the difference between those and the high-performing treatments would likely have been even greater. The importance of fungicides was also evident in the sharp rise in cone diseases at the end of the season. The time between the last spray application (14-Aug) and harvest on 15- and 16-Sep is likely when most of the infection in Figure 3 and Table 4 took place.

WORKS CITED

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

Other fungicides registered for use in Vermont are listed in Table 7. Regulations change frequently. Always read the label on the product for accurate information on where the product can be applied and how to use it safely. The following PNW handbook provides more information about fungicide options: **http://pnwhandbooks.org/plantdisease/hop-humulus-lupulus-downy-mildew**

Table 7: Fungicides labeled for use on hops in Vermont, 2015

Brand Name	Active Ingredient	Restricted use	Certified Organic
Champ Formula 2	Copper hydroxide	No	No
Champ WG	Copper hydroxide	No	Yes
C-O-C-S WDG	Basic copper sulfate, copper oxychloride	No	No
Cueva	Copper octanoate (copper soap)	No	Yes
Cuprofix Ultra 40D Disperss	Basic copper sulfate	No	No
Kocide 2000	Copper hydroxide	No	No
Nordox 75 WG	Cuprous Oxide	No	No
Curzate 60DF	Cymoxanil	No	No
Tanos	Famoxadone, cymoxanil	No	No
Agri-Fos	Mono- and di-potassium salts of phosphorous acid	No	No
Aliette WDG	Aluminum tris (o-ethyl phosphonate	No	No
Flint	Trifloxystrobin	No	No
Pristine	Pyraclostrobin	No	No
Sonata	Bacillus pumilus	No	No
Regalia	Reynoutria sachalinensis	No	Yes
Actinovate	Streptomyces lydicus	No	Yes

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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