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Growth and Production of Hops (Humulus lupulus) Varieties in the Helena Valley (MT)

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SIGNATURE PAGE

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ABSTRACT

Hops (*Humulus lupulus*) production has been rapidly increasing in the United States due to the rise in popularity of craft beer. The majority of the hops produced in the United States currently originates from Washington due to the ideal climate conditions and historical infrastructure development. In Spring 2017, we planted commercial varieties of hops and measured their growth over the course of the summer before harvesting in early autumn. Additional varieties were planted in Spring 2018. Average aboveground dry biomass and height measurements were gathered for each plant bi-weekly. No significant difference was found for any of the plants in either year for both average height or average aboveground dry biomass. While Montana has been a top producer of malting barley and has a well-established and expanding brewing industry, it currently lacks commercial hops production. This study aimed to determine if hops can grow as well in the Helena Valley and Montana as they do in Washington, and if a certain variety grows best in Montana. The data gathered from this experiment could provide avenues for breweries to source locally-grown hops. While this project will require several more years of the hops establishing themselves in the field site before they will reach optimal production, we found that hops are capable of being grown in the Helena Valley.

INTRODUCTION

Humulus lupulus (hops) is a perennial, rhizomatous vine in the family Cannabaceae, it is a dioecious plant, meaning the male and female plants grow separately. Hops are used primarily in beer production to add bitterness, aromas, and flavor to the beer (Almaguer et al. 2014). The female cones contain the acids and oils that are important in the brewing process, and the male plants are only used for reproduction (Sirrine 2018). *H. lupulus* plants grow best in a temperate climate with a plentiful source of water, and require temperatures where winter falls below 40 degrees Fahrenheit (Sirrine 2015). These conditions are typically found between 40˚ and 50˚ latitude (Sirrine 2015). When planting hops for the first time they are planted in the spring and then harvested around mid-August before the plants go dormant for the winter. They begin growing again in spring. (DeNoma 2000). For the first few years of establishment, hops are not at their peak height or optimal production rate, but eventually can grow up to twenty-five feet tall. Hops grow and yield the best in soils that drain well and can maintain moisture content such as soils with loam, silt, clay, organic matter, and sand (Sirrine 2015). As with all crops, they can be susceptible to some diseases and pests, which include downy mildew, mold, aphids, and *Verticillium* wilt (Sirrine 2015). Many varieties have been developed to be resistant to many of these issues, however, pesticides are often still used to decrease the effect of the pests and diseases.

Hops have been grown in the United States since the Massachusetts Bay settlement opened a brewery in 1648 (USA Hops 2017). For the following 150 years,

Massachusetts remained the leading hops producer in the country until hops farming increased in neighboring states. In the mid 1800s, New York became the lead hops producer until the crop became prevalent in the West (USA Hops 2017). Powdery mildew struck New York in the late 1920s, which destroyed the hop yards and solidified the Pacific Northwest as the main hops producer in the country (DeNoma 2000). Washington, Oregon, and California became the prominent suppliers of hops in the beginning of the 20th century, and after Prohibition came to an end in 1933, the hops acreage in these states increased further and solidified a major market share. Regions within the Pacific Northwest are ideal for the growth of hops because they have optimal climate, soils, and irrigation, making this area the biggest supplier of hops today (USA Hops 2017). In 2017, Washington produced 73% of hops farmed in the United States followed by Idaho and Oregon, respectively (USA Hops 2018).

According to the USDA National Hop Report, the 2018 total hop production was down 1% from 2017, which experienced a 20% increase from 2016. The 2018 crop was valued at $583 million, down from the 2017 record of $618 million (National Agricultural Statistics Service 2018). In 2018, the national acreage increased by 1% to 107 million pounds, which was up from the 2017 record of 106 million pounds. USA Hops 2017 Hop Harvest Report stated that while the total volume of beer production has decreased, hops production has increased due to high demand (Hintermeier 2017). This is caused by more of the specialty beers being brewed, such as IPAs, which typically require the use of more hops than styles traditionally brewed in the U.S.

Because Montana falls between the desired latitude lines and is near one of the largest hops producing regions in the world, this study sought to determine if hops can grow as well in the Helena Valley and Montana as compared to regions where hops production is abundant. With the information from this study, farmers and breweries would have data as to which varieties grow best in the area, if at all. This would provide an avenue for breweries to work with local farmers to obtain locally sourced ingredients.

Given that distinct varieties grow differently in the Pacific Northwest where hops production is abundant, we hypothesize that the varieties will grow significantly different from one another, and the corresponding null hypothesis is that there will be no difference among the varieties. We also predicted that varieties will grow as well in Helena as in comparison to other major hops producing regions. The goal for this study was to provide information that hops producers could utilize when trying to establish or expand their hops and determine which varieties grow best in the Helena Valley and Montana.

MATERIALS AND METHODS

Hops rhizomes were ordered in Spring of 2017 based on availability and popularity from Yakima Valley Hops and consisted of four different varieties: Willamette, Liberty, Chinook, and Sterling. Willamette hops are known for their citrus, caramel, and elderberry flavors and have a mild, spicy smell. They are commonly used in pale and brown ales (Davis 2018). Liberty hops are mild and slightly spicy (USA Hops 2018). Chinooks are spicy, have medium intensity, supply a full flavor and are used in

pale ales, IPAs, stouts, porters, and lagers (Davis 2018). Finally, Sterlings are herbal, spicy, citrusy, and slightly floral and are used in lagers and Belgian Ales (Davis 2018). The rhizomes were each planted in pots to establish roots and grown for several weeks in a greenhouse before they were transplanted in a field site in the Helena Valley in June 2017.

Research was done regarding the field site that the hops were transplanted into using information from the USDA. According to the USDA, the Helena Valley is comprised mostly of Attewan loam soil (USDA). This type of soil is known for draining well, something hops require in order to grow adequately, and is found in places where there are cold winters and hot, dry summers (National Cooperative Soil Survey 2000). According to U.S. Climate Data, Helena has an average temperature of 23.3°C for April through September, and an average temperature of 5.7°C for October through March. Helena also has an average of 96 cm of snow and 283 mm of rainfall each year. In contrast, the Yakima Valley has an average rainfall of 212 mm per year and receives 58 cm of snow on average. The Yakima Valley has warmer summers and winters with an average of 25.6°C and 8.9°C, respectively (U.S. Climate Data 2019). Montana is known for its extreme weather patterns, which potentially provides an obstacle for growing hops in the area as they prefer moderate temperatures in the spring, dry harvest seasons, and adequate rainfall (Wright Morton 2017).

The four different varieties of hops were arranged into a Randomized Complete Block Design. They were then planted into two rows, with plant and row spacing 1.5 m apart and the two rows 3 m apart. In total, seven Sterlings, seven Chinooks, seven

Liberties, and six Willamettes were planted. A trellis system was built to sustain the weight of the hops as they grew (Figure 1). Once the drip line irrigation system was set up through the use of soaker hoses, they were watered three times a week on Monday, Wednesday, and Friday for four hours each day.

Throughout the growing season of approximately 12 weeks, plant height measurements were recorded biweekly from the base of the plant to the tip of where they grew on the sisal rope. A procedure was set in place to determine any transplant-induced plant death. This procedure consisted of marking the plants as not surviving relocation if they died within two weeks of transplantation without sending up new shoots. Any mortality that occurred after the two-week relocation period was attributed to other factors. The hops were harvested in early September cutting all aboveground vegetative biomass and collecting any cones present and placing them in a separate container. The plants and cones were dried in an oven for 72 hours at approximately 45° and weighed. After harvesting the hops, the yield was calculated by taking the biomass of the cones from each plant. The total dry biomass was also calculated to determine if the weight and height were similar among the plants. The height of each variety was averaged at every date that measurements were taken. After the dry biomass of each hop variety was determined by weighing the individual plants and their cones, each variety was averaged, and an ANOVA test was performed on the four varieties. Survival rates were calculated during the experiment.

The experiment was continued by another research student during the summer of 2018 using the same methods described but adding new varieties to the already pre-

existing ones. Five Galena, six Tettanger, seven Cascade, six Columbus, and six Centennial varieties were planted. The height measurement data of the original plants in their second year of growth was analyzed, however, the average aboveground dry biomass was not accounted for. All height and aboveground dry biomass data was compiled and analyzed using ANOVA tests to determine significance.

RESULTS

Harvest of September 2017 consisted of 5 Sterlings, 5 Willamettes, 3 Chinooks, and 4 Liberties remaining. Height averages ranged from 20 cm to 133 cm. An ANOVA test was performed on each date to determine if there was any statistical significance among the heights of the varieties (Fig. 2). None of the heights were discovered to be statistically different from one another at any of the dates. In 2018, height measurements were taken at 4 time points throughout the summer (Fig. 3). None of the heights at the dates measured had statistical significance in 2018, in which the plants were on their second year of growth (Table 1). The results from the ANOVA test had p-values of greater than 0.05 for every date in both 2017 and 2018 (Table 1).

In 2017, Willamette had the largest average aboveground dry biomass of 33.5 g, followed by Liberty with 20.15 g, Chinook with 18.9 g, and Sterling with an average of 16.8 g. However, none of the varieties were significantly different from one another in 2017 (p-value=0.66) (Fig 4). Only four plants produced cones in 2017; two Willamette, one Chinook, and one Sterling. In the 2018 growing season, Chinook had the largest aboveground dry biomass (300 g), followed by Liberty, Willamette, and then Sterling. As in the previous year, there were no significant differences in biomass (p=0.30) (Fig. 5). In

2018, more plants produced cones: five Willamette, four Sterling, three Chinook, and two Liberty.

The new varieties of hops planted in 2018 were also analyzed for their average aboveground dry biomass. Cascade had the largest average (32 g), followed by Galena (29 g), Centennial (24 g), Tettanger (17 g), and finally, Columbus (15 g) (Fig. 6). No significant differences were discovered among the varieties ($p=0.70$).

Variety survival was recorded across seasons. All plants that were alive at the end of harvest 2017 survived the winter (Table 2). During 2017, Willamette had the highest survival (83.8%), followed by Sterling (71.4%), Liberty (57.1%), and Chinook (42.9%). In 2018, new varieties were planted, as well as replacements for ones that died during the season of 2017. All hops planted in summer 2018 had 100% survival through Autumn 2018. The replacement hops that were planted in 2018 were not included in the data analysis but had comparable growth to all varieties during their first season (data not shown).

DISCUSSION

In April 2016, there were 59 members of the Montana Brewery Association and over 60 craft breweries all across Montana (Montana Brewers Association, 2016). In April of 2017, a Montana law was passed that increased the number of barrels a taproom can produce annually from 10,000 to 60,000 (Tabish, 2017). Therefore, breweries are able to expand their businesses and brew more beer, which in turn will increase the demand for hops in Montana. With this increase, Montana's beer industry will continue to grow and the need for hops will also rise. The purpose of this

experiment is to provide Montana breweries with locally sourced hops. With the increase of specialty beers, more hops will need to be grown and it could be beneficial to breweries to buy from local markets. In 2011, Montana was one of the top three states that produced the most barley with 31 million bushels (Taylor, Boland, and Brester, 2012). With Montana producing so much barley, brewers have easy access to one of the main ingredients for their beer. If hops can be grown in Montana, then brewers would have close production for not only the barley, but the hops as well.

The height measurements did not show any significant differences at any of the dates in either year (Table 1). Therefore, none of the varieties-Willamette, Sterling, Liberty, or Chinook- grew significantly better than the others in either year. Similarly, the average dry biomass from both years was similar, showing no significant differences. These results conflict our original hypothesis that the four varieties would grow significantly different from one another (Figure 3 and 4). In 2018, 14 plants produced cones, in contrast to four plants the year before, with Willamette producing the most both years. Of the newly planted varieties in 2018, none of average aboveground dry biomasses were statistically significant (Figure 5), however, it was their first year of growth making it difficult to make strong conclusions and extrapolations for a perennial plant.

Willamette consistently had the largest height measurements for the majority of observation dates in both years, the highest survival during the first summer, and the largest dry biomass in 2017, suggesting that Willamette may be well adapted to growing and yielding well in this region. We speculate that in the upcoming years, Willamette

will continue to be a top yielder in this area. In 2018, Chinook was the top producer of average aboveground dry biomass and produced the second highest number of cones for that year, suggesting that it may also be a top yielder in the area.

A hops variety trial performed by the University of Vermont analyzed many different types of hops over the course of six years. In their trial they included Willamette, Sterling, Chinook and Liberty, so I was able to compare the yields from our trial to the trial in Vermont. Their average cone yield for Willamette was approximately 155 g/plant, 182g/plant for Chinook, 42 g/plant for Liberty, and 51 g/plant for Sterling (Darby et al.). This pattern is distinct from the present study because Willamette had the highest cone yield, followed by Sterling, Chinook, and Liberty. These numbers from their study are based off the yield of cones only and these averages exceed our averages from both years. We collected average dry aboveground biomass, which included the weight from the entire plant, not just the cones. Our weights were either near or below the averages of just cones in the Vermont trial. Some reasons for this discrepancy could include the amount of moisture the hops received available soil nutrient levels. Future trials in the Helena Valley should investigate the effect of nutrient supplementation on yield.

To summarize, we hypothesized that the varieties would have significantly different growth because Montana falls within the desired latitude lines for optimal growth where varieties have been shown to have distinct growing patterns. Because of Montana's location, we also hypothesized the varieties' growth would be comparable to themselves in the Pacific Northwest. These data showed no significant differences

among average heights or average aboveground dry biomass for either 2017 or 2018. However, several more years of data are required to make a definitive claim.

The results from the two years of growth are promising that hops can grow in the Helena Valley, but more data are needed. The plants need several years of growth and establishment to reach their full yield potential. We hypothesized that there would be a difference in the varieties and their growth and that hops yields would be comparable to other top producing regions of the United States, but in order to do so we need to keep introducing more varieties and monitor their growth over a long-term period of time to obtain concrete data. Future research should focus on the continued growth of the original plants, adding more varieties of hops, and introducing more variables, such as fertilizer and moisture variability. Testing different variables to find the best combination of variety, moisture, and fertilizer will be vital in offering the most consistent and profitable results to the breweries in Montana.

REFERENCES

Almaguer, C., Schönberger, C., Gastl, M., Arendt, E. K., & Becker, T. (2014). Humulus lupulus- a story that begs to be told. A review. *Journal of the Institute of Brewing*. doi:10.1002/jib.160

Darby, H., Dr., Post, J., Calderwood, L., Cubins, J., Cummings, E., Gupta, A., Ziegler, S. (2017, February). Organic Hop variety Trial Final Report. Retrieved November 19, 2018, from http://www.uvm.edu/extension/cropsoil/wp-content/uploads/2016-Hop-Variety-Trial.pdf

Davis, J., Dr. (2018, June). 2010-2012 NC Hops Variety Research. Retrieved November 19, 2018, from https://newcropsorganics.ces.ncsu.edu/specialty-crops/nc-hops/varieties/

DeNoma, J. S. (2000, January). Hop Genetic Resources. Retrieved July 12, 2017, from https://www.ars.usda.gov/pacific-west-area/corvallis-or/national-clonal-germplasm-repository/docs/ncgr-corvallis-humulus-germplasm/#introduction

Hintermeier, P. (2017, April 9). Market Report April 2017. Retrieved July 12, 2017, from https://www.usahops.org/img/blog_pdf/86.pdf

Montana Brewers Association. (2016, April). The Montana Brewers Association Trail Map. Retrieved July 12, 2017, from http://montanabrewers.org/trail-map/

National Agriculture Statistics Service, Agricultural Statistics Board, & United States Department of Agriculture (USDA). (2018, December 19). National Hop Report. Retrieved April 13, 2019, from https://www.usahops.org/img/blog_pdf/158.pdf

National Cooperative Soil Survey. (2000, December). ATTEWAN SERIES. Retrieved July 12, 2017, from https://soilseries.sc.egov.usda.gov/OSD_Docs/A/ATTEWAN.html

Sirrine, R. (2015, January 26). Michigan Fresh: Growing Hops (E3210). Retrieved February 22, 2019, from https://www.canr.msu.edu/resources/michigan_fresh_growing_hops

Sirrine, R. (2018, October 02). Why are my hops producing male flowers? Retrieved February 22, 2019, from https://www.canr.msu.edu/news/why_are_my_hops_producing_male_flowers

Tabish, D. (2017, April 13). Legislature Approves Bill Raising Brewery Production Limits. Retrieved July 12, 2017, from http://flatheadbeacon.com/2017/04/13/legislature-approves-bill-raising-brewery-production-limits/

Taylor, M., Boland, M., & Brester, G. (2012, April). Barley Profile. Retrieved July 12, 2017, from http://www.agmrc.org/commodities-products/grains-oilseeds/barley-profile/

Wright Morton, L., Gent, D., & Gleason, M. (2017). Climate, Weather, and Hops. Retrieved February 23, 2019, from https://www.climatehubs.oce.usda.gov/sites/default/files/Climate, Weather and Hops.pdf

U.S. Climate Data. (n.d.). Temperature - Precipitation - Sunshine - Snowfall. Retrieved February 23, 2019, from https://www.usclimatedata.com/climate/helena/montana/united-states/usmt0163/2018/1

USA Hops. (n.d.). USA Hops: Hop Growers of America. Retrieved July 12, 2017, from https://www.usahops.org/enthusiasts/

USA Hops: Hop Growers of America. (2018, February 6). Hop Growers of America Releases Annual Stat Pack. Retrieved April 13, 2019, from https://www.usahops.org/news/hga-releases-annual-stat-pack

USDA. (n.d.). Variety Manuel. Retrieved September 12, 2018, from https://www.usahops.org/cabinet/data/USAHops_VarietyManual_2018_Web.pdf

USDA. (n.d.). Web Soil Survey. Retrieved July 12, 2017, from https://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx

TABLES

Table 1**.** P-values from the ANOVA tests performed on the averages of the varieties on each date height measurements were taken. Data are from 2017 and 2018. All p-values are greater than the alpha value of 0.05, meaning no statistically significant results.

Date 2017	P-Value	Date 2018	P-Value
June 26	0.91	May 21	0.64
July 7	0.74	June 5	0.65
July 24	0.30	June 20	0.33
August 7	0.40	July 10	0.91
August 21	0.62	-	-
September 3	0.44	-	-

Table 2**.** Survival rates of the original hops plants planted in spring 2017. Willamette had the highest survival rate, followed by Sterling, then Liberty, and Chinook had the lowest survival rate. All of the plants survived through the winter and sent up new shoots in spring 2018.

Variety	Survival September 2017	Survival Spring 2018
Willamette (n=5)	83.8%	83.8%
Liberty (n=4)	57.1%	57.1%
Chinook (n=3)	42.9%	42.9%
Sterling (n=5)	71.4%	71.4%

FIGURES

Figure 1. The trellis consisted of wooden posts, t-posts, twisted wire and sisal rope.

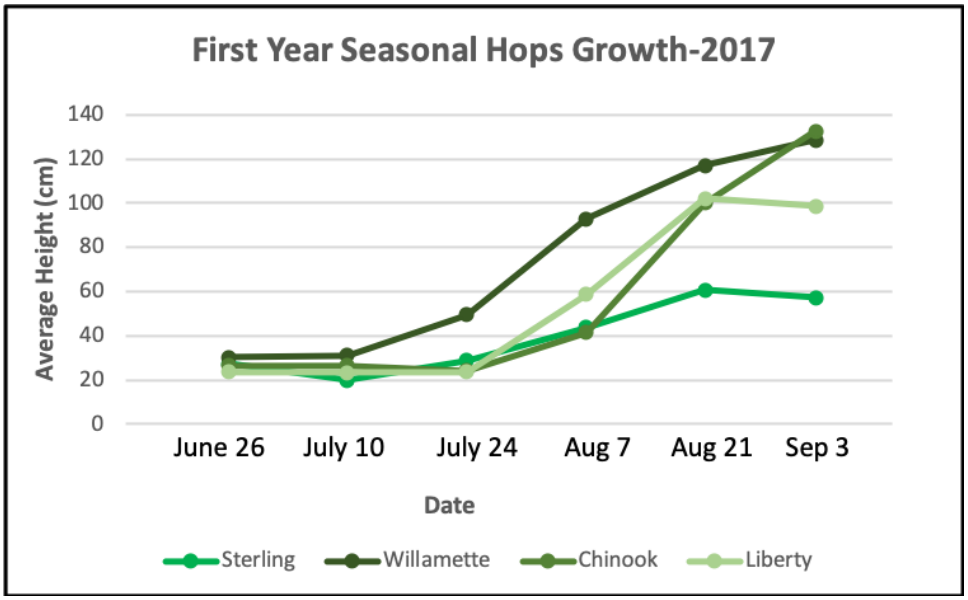

Figure 2. Average height of the varieties throughout the season. Sterling (n=5), Willamette (n=5), Chinook (n=3), and Liberty (n=4) at the end of the growing season. The ANOVA tests at each date resulted in no statistically significant results in the heights.

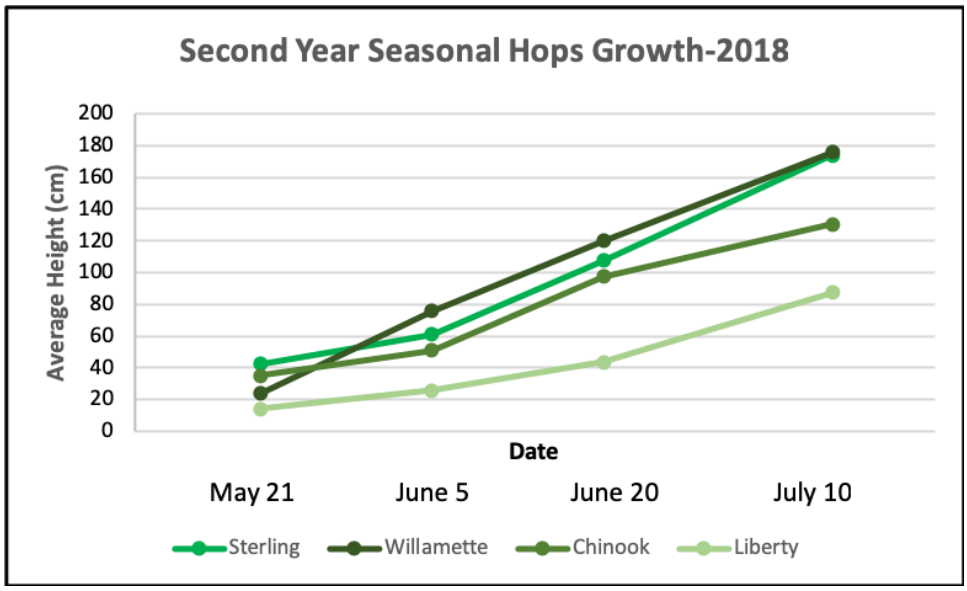

Figure 3**.** The average heights of the varieties on the indicated dates throughout 2018. This image represents the hops second year of growth. Sterling (n=5), Willamette (n=5), Chinook (n=3), and Liberty (n=4) at the end of the growing season. The ANOVA tests performed at each date yielded no statistically significant results regarding the heights.

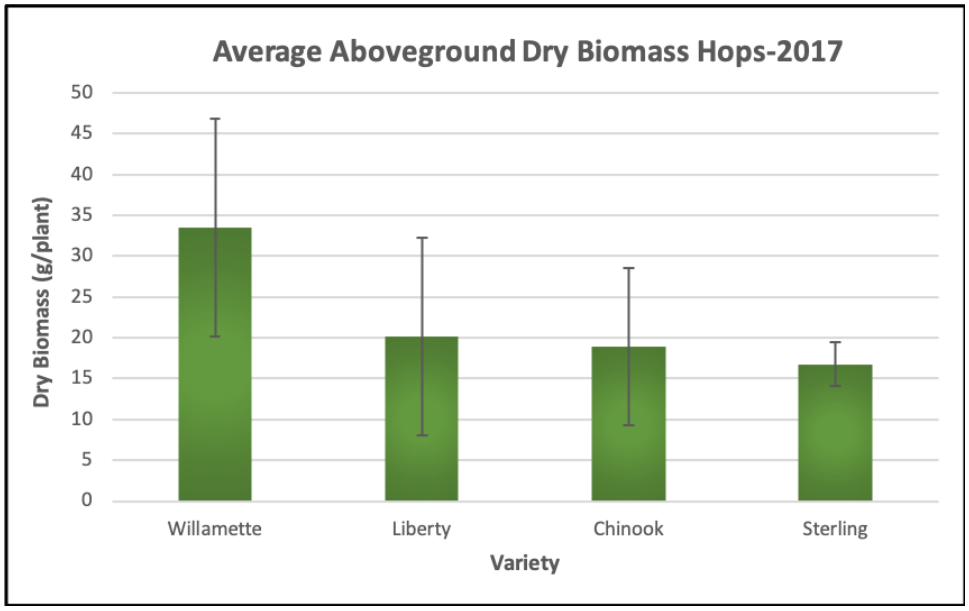

Figure 4. Average aboveground dry biomass of each variety at the time of harvest. Willamette (n=5), Sterling (n=5), Liberty (n=4), and Chinook (n=3). No statistical significance was found from the ANOVA test. Error bars $\pm$ 1 SE.

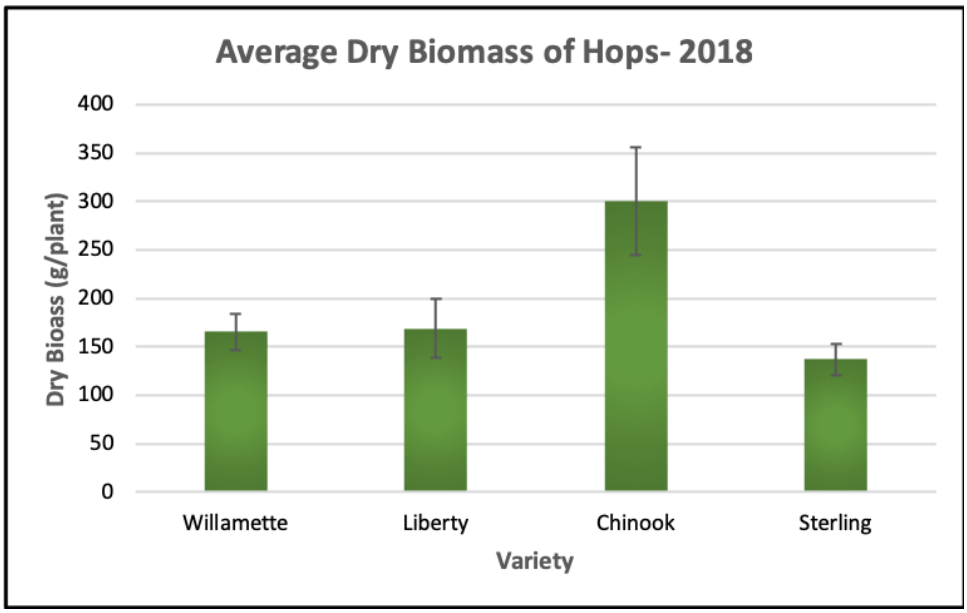

Figure 5. Average aboveground dry biomass of the hops in their second year of growth. Willamette (n=5), Sterling (n=5), Liberty (n=4), and Chinook (n=3). No statistical significance was discovered from an ANOVA test. Error bars $\pm$ 1 SE.

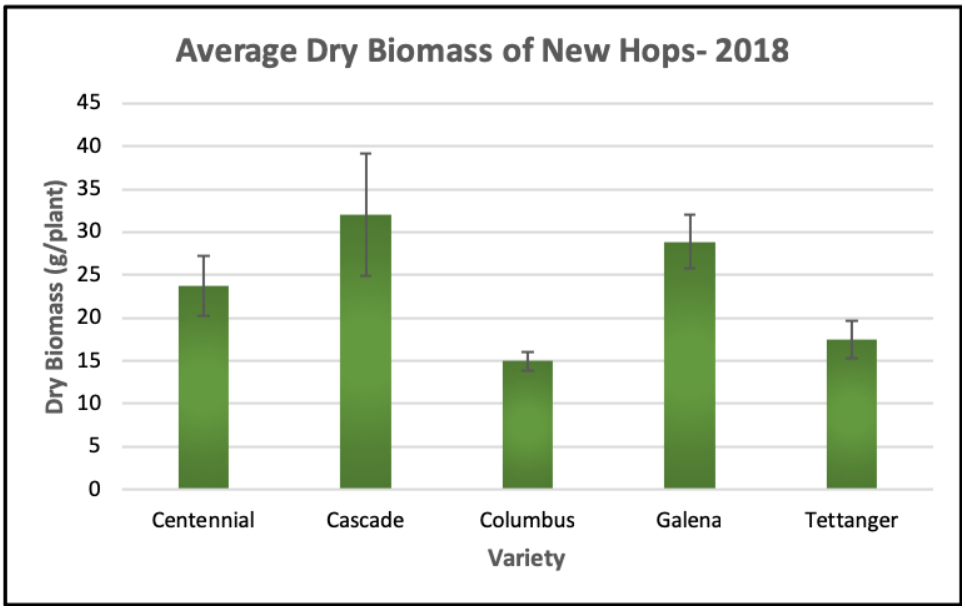

Figure 6**.** Average dry biomass of the newly planted hop varieties in 2018. These plants were in their first year of growth. Centennial (n=6), Cascade (n=7), Columbus (n=6), Galena (n=5), and Tettanger (n=6). An ANOVA test resulted in no significant differences among the varieties in their average aboveground dry biomass. Error bars $\pm$ 1 SE.