NORTHWEST CROPS & SOILS PROGRAM

2018 Hop Harvest Timing

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In the Northeast, hop harvest generally begins in mid-August and continues through mid-September. Harvest date is primarily dependent on the hop variety, but weather can delay or hasten maturation and impact when harvest will occur. In addition to weather, various pests, such as spider mites and downy mildew, can similarly impact harvest timing. The time at which you harvest hops can affect the various qualities of your finished product. Alpha and beta acid content peaks before many essential oils have fully developed. Delaying harvest can provide time for these oils to develop, but increases the amount of time the hops are left vulnerable to disease and late season rainfall which can result in degradation of resins.

Although typical harvest dates are well established for Europe and the Pacific Northwest, the Northeast experiences a distinct climate with unique growing conditions that can greatly impact the various resins and oils in hops. A general window for harvest timing can be gleaned from these other locations, but region specific information is required for producing a fully mature hop cone with the desired aroma and flavor profiles in the Northeast. Traditionally, harvest timing is determined by dry matter and resin content. This method encourages adequate acid production over aromatic oil production, thereby limiting options for end users. To better understand how factors such as cone smell, look and dry matter content correspond to the development of resin and oils, a harvest timing trial was initiated in 2017 in Northfield, MA as a preliminary study and continued into 2018 as a replicated study. We aim to use these data to develop regional harvest timing standards that can assist hop growers in producing the highest quality hops.

MATERIALS AND METHODS

Cascade hops from Borderview Research Farm in Alburgh, VT were collected, analyzed and reported over the harvest period for the study. The hop variety Cascade was chosen for this study because it has aromatic qualities, it is a hop variety that most northeastern hop yards already have in the ground, and it is a non-proprietary hop used by local brewers.

Three plots were randomly designated within the Cascade hops planted in the UVM hop yard. Plots contained 7 hop hills (14 strings) and were marked with ground flags and flagging tape to make sure they were not harvested with the rest of the crop. In 2018, there were 5 collection dates throughout the harvest season falling into the following categories: Early, Normal, and Late (Table 1). The "Early" sampling dates were timed approximately 1 and 2 weeks prior to when Borderview Research farm planned to harvest their Cascade crop. The "Normal" sample was taken during planned harvest for Cascade. Finally, the "Late" samples were taken 1 and 2 weeks after harvest occurred.

Table 1. 2018 Cascade harvest dates.

Harvest Date		
Early	HD 1	20-Aug
Early	HD 2	27-Aug
Normal	HD 3	4-Sep
Late	HD 4	10-Sep
Late	HD 5	17-Sep

Samples were hand-picked from each plant within plots and taken from ground level to the top wire for representative samples as qualities can vary within plants. Each sample was 200g of wet hop cones shipped to Alliance Analytical Laboratories in Coopersville, MI overnight. The collected samples were shipped as wet cones over the five-week period. Alliance Analytical conducted their Brew Quality and Essential Oil packages using the American Society of Brewing Chemists procedures 4c, 12, 13, 14, and 17. Measurements included in this test are percent moisture, hop storage index (HSI), alpha and beta acids, oil content, and volatile oil profile.

Data was analyzed using SAS Version 9.4. For the hop quality data, we conducted a linear mixed model analysis with repeated measures (PROC MIXED). Fixed effects included collection date, replicate, year, and collection date by year. All statistics will be run at the 0.10 level of significance and generated using SAS Version 9.4 (Copyright 2014, SAS Institute Inc., Cary, NC, USA).

Variations in project results can occur because of variations in genetics, soil, weather, and other growing conditions. Statistical analysis makes it possible to determine whether a difference among treatments is real or whether it might have occurred due to other variations in the field. At the bottom of each table, a LSD value is presented for each variable (e.g. yield). Least Significant Differences (LSD's) at the 10% level of probability are shown. Where the difference between two treatments within a column is equal to or greater than the LSD value at the bottom of the column, you can be sure in 9 out of 10 chances that there is a real difference between the two values. Treatments that were not significantly lower in performance than the highest value in a particular column are indicated with an asterisk. In the following example, treatment A is significantly different from treatment C but not from treatment B. The difference between A and B is equal to 200, which is less than the LSD value of 300. This means that these treatments did not differ in yield. The difference between A and C is equal to 400, which is greater than the LSD value of 300. This means that the yields of these treatments were significantly different from one another.

Treatment	**Yield**
A	**2100***
B	1900*
C	1700
LSD	300

RESULTS

Table 2 shows a summary of the temperature, precipitation and growing degree day summary. In the 2018 growing season, there were an accumulated 2688 Growing Degree Days (GDDs), 477 more than the historical 30-year average. The 2018 growing season was unusually hot and dry accumulating far less rain during the bulk of the growing season (May-Sep) than the average year.

Table 2. Temperature, precipitation and growing degree day summary, Alburgh, VT, 2018.

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

This year, we were required to switch labs for hop analysis. In past experiments, Alpha Analytics in Yakima, WA conducted hop oil analysis. Unfortunately, this lab stopped accepting samples in 2018. Hence, we were required to find another lab with the ability to test for essential oils and resins. The lab chosen for the project was Alliance Analytical Laboratories located in Coopersville, MI. Samples were shipped directly to the company and handling was unfortunately inadequate and led to samples becoming moldy. We were able to receive results for brew quality as this test was conducted prior to sample degradation.

Alpha acid, beta acid, cohumulone, colupulone, HIS, and moisture were measured for each harvest date (Table 3). Moisture was variable across all five samples and there was no significant difference between each of the harvest dates. While no statistical difference was noted between Early, Normal, and Late harvest dates, each date would have been deemed “ready to harvest” if using moisture as the sole means of determining harvest timing. Harvesting before aromas fully develop can result in lesser quality hops, making it important to use additional means of measuring hop readiness to determine ideal harvest windows.

Cohumulone makes up a large percentage of total alpha acids and contributes to the bittering qualities of the hops after isomerization in the brewing process. Colupulone makes up a large percentage of total beta acids and would thus contribute largely to hop aromatics and later bitterness in beers after oxidization and conversion to hulupone. Cohumulone and colupulone are presented as a percentage of alpha and beta acids respectively. Cohumulone was highest in HD 4 and HD 3. Colupulone was highest in HD 3 with statistically similar levels shown in HD 4, HD 5, and HD 2.

Table 3. Brewing quality for Cascade hops harvested over a 5 week period in 2018.

Harvest Date	Alpha acid %	Beta acid %	Cohumulone % relative to alpha	Colupulone % relative to beta	HSI	Moisture %
HD 1	4.2	5.6	29.8	47.2	0.22	65.47
HD 2	5.0	6.2	30.0	49.7*	0.09*	76.33
HD 3	7.0*	7.4*	32.0*	**50.3**	**0.04**	64.27
HD 4	6.9*	7.1*	**32.0**	50.1*	0.53	73.07
HD 5	**7.6**	**8.5**	31.4	49.6*	0.12*	74.87
LSD (0.10)	2.0	2.1	0.46	0.86	0.13	NS
Trial mean	6.1	6.9	31.0	49.4	0.20	70.8

* Treatments with an asterisk are not significantly different than the top performer in **bold**.

LSD - Least significant difference. NS – no significant difference.

Normal and Late harvest dates (HD 3, HD 4, and HD 5) had the highest percentage of alpha and beta acids compared to the earlier harvest dates (Figures 1 and 2). Major jumps in both alpha and beta acids occurred after Early harvest dates (HD 1 and HD 2). HD 3, HD 4, and HD 5 had the highest values for brewing qualities.

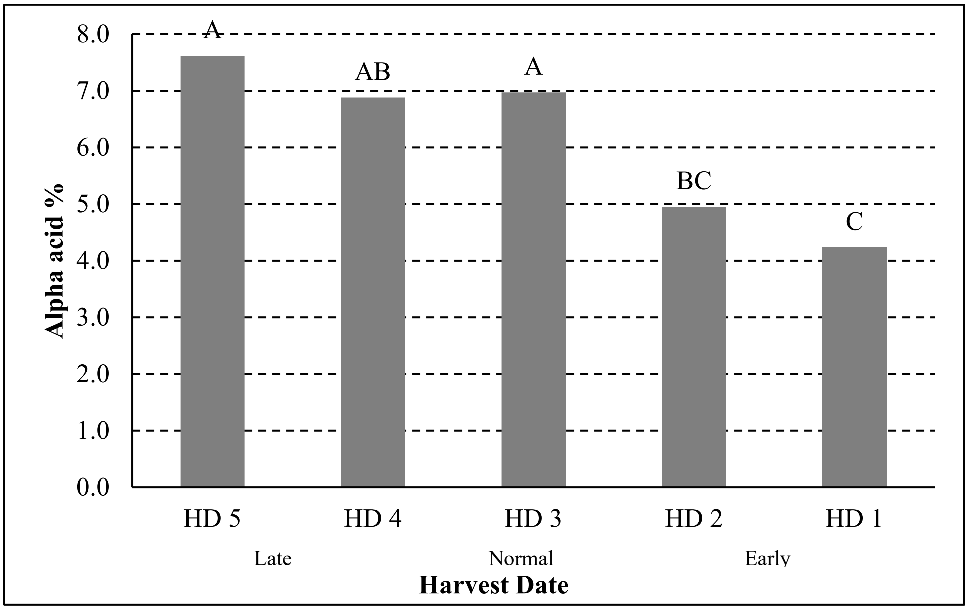

Figure 1. 2018 Alpha acids for Cascade hop harvest dates.

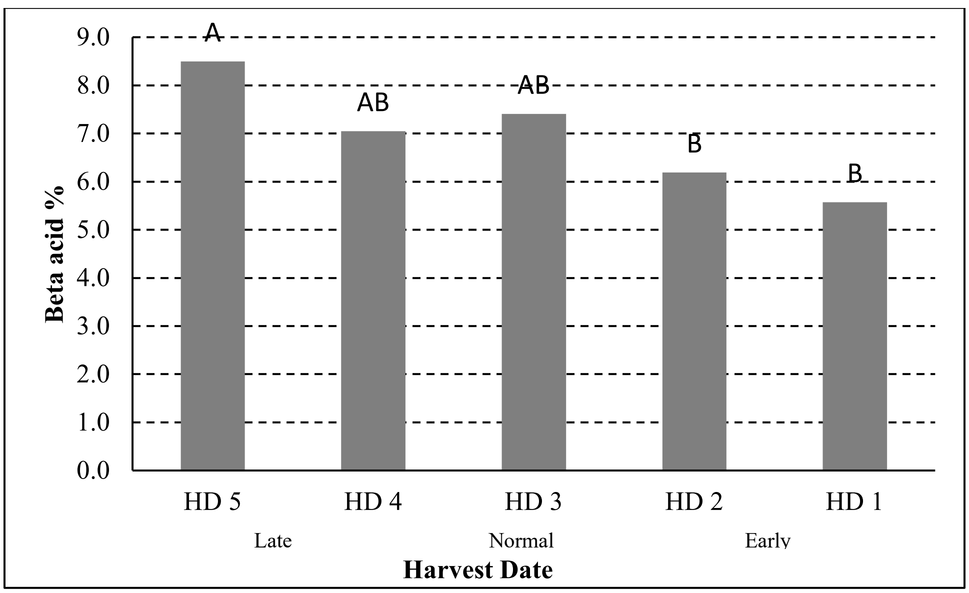

Figure 2. 2018 Beta acids for Cascade hop harvest dates.

HSI measures the potential loss of alpha and beta acid over time; a lower number for HSI means less potential for loss. HSI can also be an indicator of handling and storage practices as the degradation of alpha and beta acids can be accelerated by increased temperatures, exposure to air, and exposure to light. Values for HSI less than 0.40 are generally acceptable but lower values below 0.30 are ideal. Our Normal harvest period (HD 3) also had the lowest HSI showing that resins would be most stable over time for this harvest date (Figure 3). The sample from HD 4 had the highest HSI and would be most subject to alpha and beta acid degradation. This sample may have been subject to improper handling.

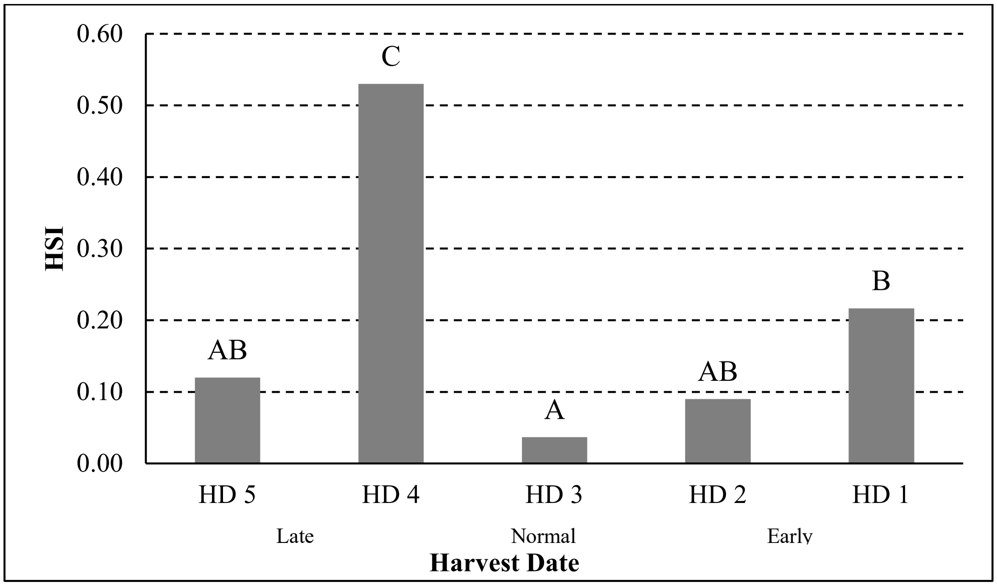

Figure 3. 2018 Hop storage index for Cascade hop harvest dates.

As a whole, Normal and Late harvest dates were all top performers in the trial and exhibited highest values for alpha acid, beta acid, cohumulone, and colupulone. Again due to laboratory error we were unable to test for changes in the hop oil profiles.

DISCUSSION

From the first year of the study (2017), we noticed a general increase in the total analyzed oils from the Early harvest period to the Late harvest period for most varieties of hops; however, we were unable to receive results from this year's harvest for comparison. Resin concentrations peaked for Cascade in the fifth week of our study with dramatic increases going into our normal harvest period. In many cases, delaying harvest could lead to an increase in oil and resin levels contributing increased aromatics in hop cones.

Harvesting too early will also disrupt the various flavor constituents of hops as neither oils nor alpha and beta acids have had the ability to reach peak levels. However, harvesting too late can also reduce brewing quality and aroma through degradation and increased exposure to pests, diseases, and various weather conditions. Later harvested hops are also at risk of accelerated oxidation in storage through the loss of volatile aroma compounds. Later harvested hops usually suffer from shortened storability as do cones that have been damaged by diseases and or pests.

As we continue this study, we hope to determine how harvest timing can impact the various aromatic compounds that help to contribute to aromatic and flavor characteristics for hops. We also hope to provide additional insight on proper harvest timing to accentuate resins and oils in hops for farmers in the Northeast.

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