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Hops Production in Maryland: 2017-2018 Hops Trial Growing Season Report and Best Management Practices

University of Maryland Extension, in partnership with Flying Dog Brewery, established a half-acre hops yard at the Agricultural Experiment Station in Keedysville, Maryland. Twenty-four hops varieties were selected in consultation with local growers and brewers for Maryland's hot and humid climate. Hops were managed for fertility, irrigation, and other horticultural practices. Insects, disease, and weed pests were controlled using integrated pest management (IPM) principles. Trials were performed to identify varieties best suited for production in Maryland and potential challenges associated with growing and processing hops into a final product. Compared to the Pacific Northwest, the largest producer of hops, Maryland is hotter, more humid, at a lower latitude, and has a variety of insects, diseases, and soil types that pose potential challenges.

As we look forward to continuing this project, we have summarized the first two full years of research and analysis of the hop varieties planted in the trial. In this fact sheet you will find a comparison of the two growing seasons, new findings on each of the top hop varieties, and best practices for establishing and maintaining a hops yard in Maryland.

First Step in Growing Hops is Establishing a Hops Yard

Soil and Site Preparation: In Maryland's climate, it is critical to select the best site possible. This will help to reduce the negative effects of environmental stresses caused by extreme heat, high humidity, and erratic rainfall. You should:

- Select a site with well-drained soil, full sun, good air circulation and accessibility, and clear of frost pockets.
- Test the soil at least one year in advance of planting to ensure time to develop a nutrient management plan and to make the proper fertility and pH adjustments. Pay particular attention to soil acidity, phosphorus, and potassium.
- Be aware of previous crops, potential herbicide carryover, and the existing weed population. You need to control perennial weeds prior to planting to help reduce weed pressure.
- Establish sod between rows in the fall prior to the year of planting to help facilitate future hop yard growth, prevent soil erosion and nutrient runoff, and suppress weeds. Tall fescue is well adapted for this application and will handle equipment traffic better than other sod types (Figure 1).
- Make sure that water is available for drip irrigation.

Figure 1. University of Maryland hops variety trial. Trellises and rows are set-up to mitigate the effects of Maryland's climate and facilitate equipment movement in the hops yard.

Variety Selection: The primary goal of the partnership between Flying Dog Brewery and the University of Maryland is to identify varieties acceptable for Maryland's climate. We are screening 24 varieties in an effort to identify those that might be better suited to be grown in Maryland, while still possessing the characteristics desired for brewers to make high quality beer. Varietal information, such as yield and brewing quality, are discussed later in this publication and is intended to help aid in your selection of varieties.

Trellis: Trellises need to be well anchored and able to support a cable 18-feet high to allow the hops to reach their full potential (Figure 1). Posts should be 4 feet in the ground with plants spaced 3½ feet within a row and 12 feet between rows. Row spacing in Maryland needs to be wider than in commercial hops fields of the Pacific Northwest due to our more humid climate. Wider rows facilitate air movement and help reduce disease. It is important that your row spacing is suited to your equipment and when the plants are fully mature, operations in the hops yard can continue without damaging the plants.

Fertility: All nutrients and soil pH, except for nitrogen, should be addressed based on soil test results prior to planting. For a newly established hops yard, nitrogen should be applied the first week after planting, three weeks later, and then three weeks later, at a total of 75 pounds of nitrogen per acre.

Weed control: Apply glyphosate pre-planting to rows to eliminate all weeds prior to planting. Use a burndown product as needed to control weeds in the row throughout the first season. Avoid burning hops with drift from burndown products.

Planting: From transplants, April through early May.

Irrigation: Regular and consistent watering is essential. Plants can grow 10 inches per day and need water, but should not be overwatered. Adequate moisture in the soil profile must be maintained, but water should not be allowed to puddle on the soil surface, or for the soil in the hop yard to have a muddy texture. Target volume of water for irrigation will vary depending on rainfall and soil type, but irrigation may have to be run as often as four days per week during hot and dry periods.

Training/Pruning: Use one string of coconut coir per plant and encourage all the growth of the plant to climb the string. This will help the plant establish a strong root system and may help to produce a light crop the first season.

Pest Control: Weekly integrated pest management (IPM) scouting is a must for successful hops production in Maryland. Rapid deployment of control measures can make all the difference between success and failure of a new planting. Growers should be proactive rather than reactive. This consists of walking the rows, observing the overall condition of the plants, looking at vigor, color of foliage, discoloration or browning of leaves, and presence of insects or mites. It is important to examine both the upper and lower surfaces of the leaves with a magnifying glass or hand lens to see mites or early infestations of leafhoppers.

Major arthropod pests include potato leafhopper (*Empoasca fabae*) and spider mite (*Tetranychus urticae*) outbreaks. These pests can show up early in the growing season. Japanese beetles (*Popillia japonica*) may be a pest later in the season and can be difficult to manage with labelled products.

Perennial weeds are the most difficult weeds to manage in a perennial crop like hops. The major weeds of concern in the University of Maryland (UMD) hops yard are bindweed (*Convolvulus arvensis*) and horsenettle (*Solanum carolinense*); both of which are herbaceous perennials. During late winter/early spring dormancy, products such as Scythe® and Pendimethalin can be used. In-season weed control (for hops greater than 6 feet) can be achieved with applications of Goal®, Scythe®, Aim®, and Chateau®. Label restrictions and pre-harvest intervals are major hindrances with weed control in a hops yard.

Hops downy mildew (*Pseudoperonospora humuli*) is by far the most prevalent and significant disease of Maryland hops. This disease thrives in Maryland because of our hot, humid summers. The pathogen overwinters inside dormant buds and will reappear every year when conditions are conducive for disease development. Preventative, scheduled fungicide sprays are critical to keep this disease at bay.

For assistance with pest identification, you may send samples to the University of Maryland Plant Diagnostic Laboratory. Sample submission forms and guidelines are found online at: https://extension.umd.edu/plantdiagnosticlab.

Once Hops Yard is Established, Continued Management is Critical

Optimal Fertility: For an established hops yard, a total of 200 pounds of nitrogen per acre in the form of sulfur-coated urea, per year, should be split-applied into six banded applications. Begin applications starting the first week of May, followed by second week of May, third week of May, fourth week of May, second week of June, and fourth week of June.

Weed control: Apply a burn-down herbicide plus a residual to manage winter annuals and provide spring preemergent weed control.

Irrigation: Regular and consistent watering is essential and follows the same guidelines as establishing a new hops yard outlined above.

Spring Pruning: This can be done mechanically or with a desiccant in early May. Either way, the critical objective is to completely remove all green tissue above the soil to encourage the plant to push up new strong bines (the long, flexible shoots/stems of the hop plant. Unlike vines, bines lack tendrils) from the crown.

Training/Pruning: Two strings per plant in a "V" arrangement, selecting two or three healthy, strong, undamaged bines per string.

Pest Control: Weekly IPM scouting is a must for successful hops production in Maryland. The same pest control measures taken to establish a hops yard outlined above are crucial to maintain a successful crop year-to-year.

For Hops to be a Viable Agricultural Enterprise in Maryland, Hops Production Must be Profitable

In order for hops to be a viable agricultural enterprise in Maryland, hops production must be profitable. With that in mind, the two tables below outline the costs associated with establishing and maintaining the UMD half-acre hops yard (Tables 1 and 2) in order to give growers an estimate for producing hops.

Startup Cost of a ½ Acre Hops Yard		Harvest Equipment Cost of a ½ Acre Hops Yard	
Item	***Cost***	***Item***	***Cost***
Hops rhizomes (plants)	$1,300	Harvester	$28,000
Poles	$4,500	Oast (for drying)	$2,000
Hardware for poles	$1,200	Pelletizer	$5,000
Irrigation	$1,500	Hammer mill	$2,000
Seed (tall fescue), fertilizer, lime, chemicals	$3,500	Liquid nitrogen cooling system	$500
Labor	$6,400	Cooler/storage	$1,000
Total cost	**$18,400**	**Total cost**	**$38,500**

Table 1. Crop budget for the establishment of the half-acre University of Maryland hops yard includes plants, equipment and labor

2017 Seasonal Cost of ½ Acre Hops Yard		2018 Seasonal Cost of ½ Acre Hops Yard	
Item	***Cost***	***Item***	***Cost***
Herbicides	$130	Herbicides	$128
Fungicides	$550	Fungicides	$168
Insecticides and miticides	$300	Insecticides and miticides	$435
Coconut coir string	$175	Coconut coir string	$350
Fertilizer	$120	Fertilizer	$110
Labor	$2,400	Labor	$3,400
Total cost	**$3,675**	**Total cost**	**$4,591**

Table 2. Crop budget for the maintenance of the University of Maryland half-acre hops yard for 2017 and 2018 growing seasons.

2017-2018 Maryland Hops Trial Progress Report

Because this project is a replicated variety trial, the same hops were studied in both years. Planted in 2016, the following twelve varieties were chosen from discussions with academic and industry experts that identified hops local brewers are interested in or are already using:

- AlphAroma
- Cascade
- Centennial
- Chinook
- Crystal
- Mt. Hood
- Mt. Ranier
- Nugget
- Sorachi Ace
- Southern Cross
- Tahoma
- Ultra

As those discussions extended to farmers who were already growing hops in Maryland, it became clear that there were more varieties with potential for success in this region. The remaining twelve varieties were chosen based on both agricultural and market potential and were planted in 2017:

- Amallia
- Canadian Red Vine
- Galena
- Multihead
- Neo 1
- Newport Southern Brewer
- Teamaker VF
- Vojvodina
- Willamette
- Zeus

Each variety was planted in a block of six plants and replicated three times on a half-acre plot. Plants were spaced widely with 3½ feet between plants and 10 feet between varieties to maximize airflow, a priority in Maryland's humid climate. Data was collected on fertility and irrigation; disease, insect and pest management; harvest timing; levels of acids and oils in the hops; and any other unique aspects of the hop's profile. The lowest-performing varieties, Neo 1 (with no yield) and Multi-head (low plant survival) were removed at the end of 2018 and will be replaced with two prospective local, heirloom varieties.

Horticultural Practices Used for the 2017 and 2018 Crops in the UMD Hops Yard

As an example, a detailed list of the 2018 hops trial production practices are listed in Tables 3 and 4.

Soil Preparation: The soil was prepared in the fall of 2015 with lime to neutralize soil acidity and fertilized with phosphorus and potassium to bring soil test levels to optimum levels. Exact fertility requirements were determined based on a soil test.

Floor Management: Planted rows are maintained as 42-inch wide bare ground with 12½-foot alleys in between rows. Alleys were planted with tall fescue, which suppresses weeds and mitigates erosion while allowing equipment use despite Maryland's frequent heavy rains.

Fertility: Nitrogen was applied as six banded applications of sulfur-coated urea for a target of 200 pounds per acre, per growing season. Sulfur-coated urea was chosen because it is a slow-release form of nitrogen fertilizer. Applications were made approximately weekly, starting in the first week of May and ending in the last week of June.

Stringing: Wires were run parallel to the posts to maximize airflow. One and two-year-old plants were strung with two bines per string. Three-year-old plants were strung with two bines on two strings in a "V" arrangement.

Crowning: Because this is a replicated variety trial, all plants were crowned on the same date. In 2017, plants reached the top wire long before the optimal date of June 21, indicating that final crowning was too early. In 2018, the final crowning was delayed until May 7 and yields improved dramatically, even in the younger plantings.

Weather and Pests Affected Yield in the 2018 Growing Season

Observations of weather conditions in the hops yard began late December, 2017. We saw extreme cold from late December through mid-January with no snow cover and little moisture, which may have contributed to the loss of several Multihead plants. February through April were average for both temperature and precipitation. We saw heavy rain in mid-May that resulted in downy mildew disease development, and a limited opportunity to apply fungicides. Phostrol® was applied, but it did not have adequate conditions or time to dry. At the end of May, there was a heavy infestation of leafhoppers, which blow in every year from the south. The severity depends on the weather patterns, but once they arrive, their population can increase rapidly. They reduce the plant's ability to photosynthesize and need to be managed quickly with an insecticide. That infestation was followed by another round of heavy rain at the beginning of June that resulted in a subsequent round of downy mildew.

The first three weeks of July were extremely hot and dry, causing a two-spotted spider mite outbreak, which required a heavy application of miticide to control. Then, the last week of the month saw 5½ inches of rain, a complete reversal of the weather patterns from the previous three weeks.

From late June through mid-August, there was an abundance of Japanese beetles, which were managed with insecticide applications.

It should be noted that there are very few labeled crop protection products specifically for hops, making it difficult to find the right mix of products. Refer to Tables 3 and 4 to see a list of products used in the UMD hops trial to get an idea of products to use in hops production.

The 2018 season was a reflection of how extreme Maryland's weather can be. Heat and humidity were in full force, which set the stage for a similar amount of insect and disease development as we saw in 2017. Intense care is paramount from the third or fourth week of June to early August, which is a small window for a perennial plant, in order for these plants to thrive.

2018 UMD Hops Yard Production Schedule

Date	*Description of activities and applications*
20-Feb	Solicam DF preemergence herbicide plus Scythe non-selective contact herbicide
10-Apr	Soil drench with Ridomil Gold SL fungicide
2-May	Cleaned debris from rows, applied 50 lbs. nitrogen/A
3-May	Scythe herbicide
7-May	Crowned plants with mower
9-May	30 lbs. nitrogen/A; installed strings
10-May	RANMAN 400SC fungicide
16-May	30 lbs. nitrogen/A
17-May	Phostrol fungicide
21-May	Tanos fungicide plus Champ Formula 2 Flowable fungicide
25-May	RANMAN 400SC fungicide plus 30 lbs. nitrogen/A
30-May	Brigade insecticide/miticide plus Phostrol
4-Jun	Tanos plus Champ Formula 2 Flowable fungicide
12-Jun	30 lbs. nitrogen/A
12-Jun	Aim EC herbicide plus Chateau SW for sucker control
12-Jun	AzaGuard insect growth regulator plus Revus fungicide and Phostrol
15-Jun	Phostrol plus M-Pede insecticidal soap
20-Jun	Phostrol plus RANMAN EC plus AzaGuard
25-Jun	Phostrol plus Tanos plus Champ Formula 2 Flowable plus AzaGuard
26-Jun	30 lbs nitrogen/A
29-Jun	Malathion 5 insecticide plus Phostrol
3-Jul	Phostrol plus AzaGuard
9-Jul	Phostrol plus AzaGuard
16-Jul	Phostrol plus Zeal WDG miticide
18-Jul	Phostrol plus Acramite-50WS miticide
20-Jul	RANMAN 400 EC plus AzaGuard
27-Jul	Phostrol plus AzaGuard
31-Jul	OxiDate 2.0
6-Aug	Phostrol plus AzaGuard
8-Aug	M-Pede
17-Aug	Phostrol plus AzaGuard
2018 totals	*3 herbicide applications* / *21 fungicide applications* / *15 insecticide/miticide applications*

Table 3. Example hops yard production schedule for maintenance of an established hops yard.

Table 4. Crop protection products used in the 2018 UMD hops trial. The products listed in the table are not an endorsement. Be sure to always read and follow the pesticide label.

Crop Protection Products and Rates, 2018 UMD Hops Trial

Class	*Trade Name*	*Active Ingredient*	*Rate*
Herbicides	Solicam® DF	Norflurazon	Depends on soil texture
	Scythe®	Pelargonic Acid	10% solution at 150 GPA
	Aim® EC	Carfentrazone	2 oz/A
	Chateau® SW	Flumioxazin	6 oz/A
Fungicides	Ridomil Gold® SL	Mefenoxam	8 oz/A
	RANMAN® 400SC	Cyazofamid	2.75 oz/A
	Phostrol®	Sodium, potassium, and ammonium phosphites	2.5 pt./A
	Tanos®	Famoxidone + cymoxanil	8 oz/A
	Champ®Formula 2 Flowable	Copper hydroxide	1.33 pt/A
	Revus®	Mandipropamid	8 oz/A
	OxiDate® 2.0	Hydrogen dioxide + peroxyacetic acid	32 oz/100 gal
Insecticide & Miticides	Brigade® 2EC	Bifenthrin	6.4 oz/A
	AzaGuard®	Azadirachtin	16 oz/A
	M-Pede®	Potassium salts	2% solution
	Malathion 5	Malathion	1 pt./A
	Zeal® WDG	Etoxazole	4 oz/A
	Acramite®-50WS	Bifenazate	1.5 lbs./A

Figure 2. University of Maryland hops variety trial harvesting using a mobile hops harvester.

Harvesting, Processing, and Brew Quality is a Significant Factor for Viable Hops Production in Maryland

For hops production to be a viable enterprise, they must not only be grown in sufficient quantity, but produce a quality product useful to brewers. To explore this, we also focused on demonstrating scalable technologies to provide a high-quality product brewers can use. This meant harvest and post-harvest handling had to be an integral component of this project.

Timely harvest is critical and needs to be performed consistently and within a narrow window of time to ensure maximum quality and comparison of varieties. To facilitate this, Flying Dog's investment in the partnership included joint funding of a mobile harvester (Figure 2). The harvester ensured that each variety was harvested in a timely and consistent fashion, and ensured the yield data collected on each variety was (and will continue to be) consistent (Figure 3).

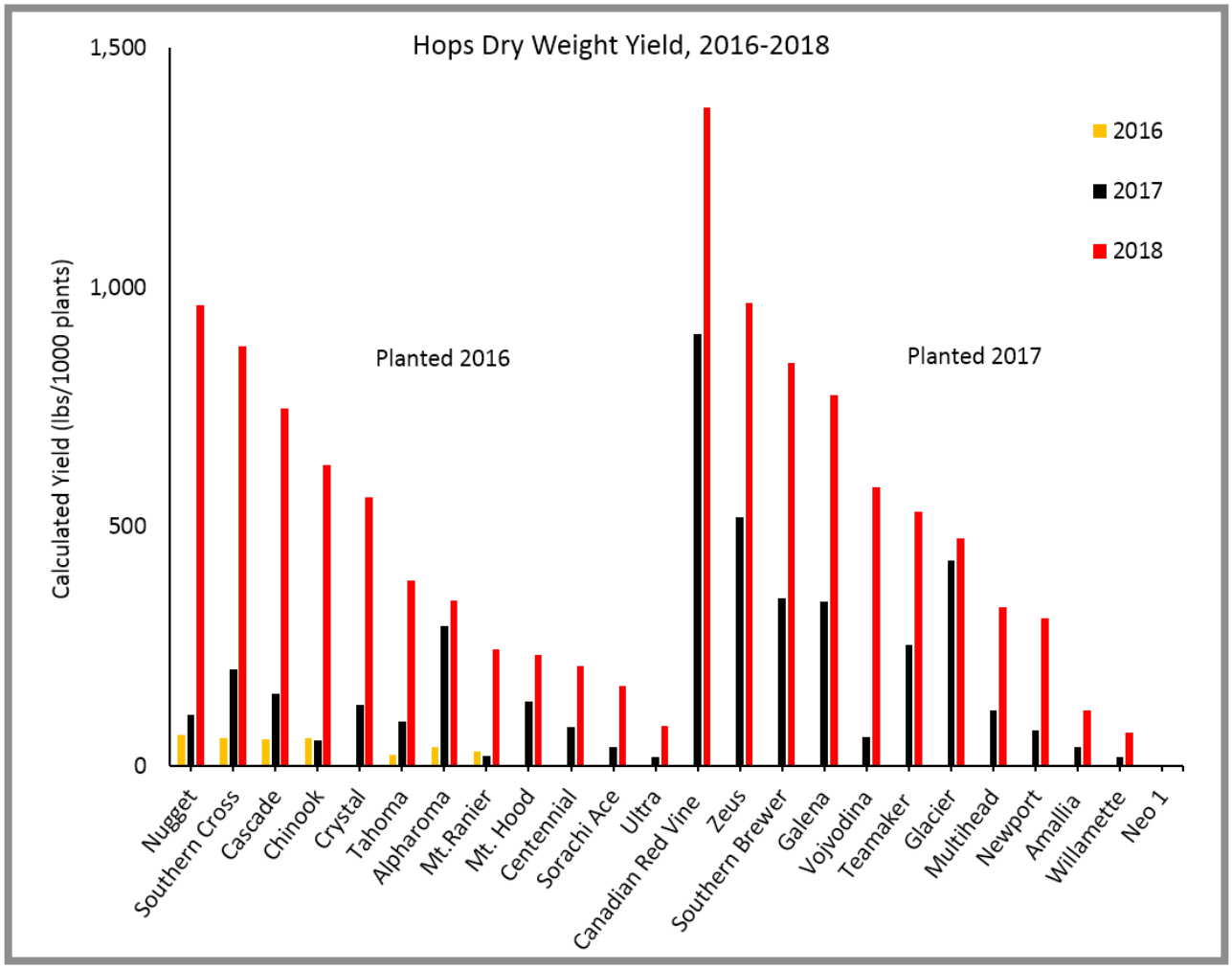

Figure 3. Yield varies greatly by variety and plant age. One acre of hops is equivalent to 1000 plants. Varieties Nugget through Ultra were planted in 2016; Canadian Red Vine through Neo 1 were planted in 2017.

Hops were harvested when the cones reached 25 ± 4% dry matter (determined using a moisture meter). In 2017, harvest ranged from July 29 to September 8, as varieties reached harvestable dry matter at different times. In 2018, in comparison, all varieties were harvested within a 12-day period that stretched from August 12 through August 24. The mechanical harvester was used to harvest the hops and yields were calculated (Figure 3). Several varieties approached or exceeded 1,000 pounds per acre. Once harvested, the cones were dried quickly using an oast (hop kiln) with dehumidifiers to get the moisture out of the hops as fast as possible. Dryer temperature was maintained at 100°F.

Hops Were Processed On-Site at the Research Facility after Harvest

In 2017, the hop cones were placed in the oast immediately following harvest and dried to 8% moisture within 24 hours. They were frozen in sealed bags using a liquid nitrogen system until they could be processed in the hammer mill and then run directly into the pelletizer. The pellets were not heated above 110°F during pelletization, which required close attention. Once pelletized, they were placed in vacuum-sealed bags and frozen.

Most of the same processing techniques were used in 2018 to maintain best practices for processing hops and to minimize the number of variables in this project. However, because the hops needed to be harvested in a shorter timeframe in 2018, cones were vacuum-packed and stored in a freezer once they were dried. This kept them stable in between processing runs while we finished the harvest. Once harvest was complete, the cones were processed cold, which improved efficiency because the cones did not heat up as fast during the pelletization process; an unexpected discovery that came out of the necessity of a shorter harvest period.

Hops Chemical Analysis Provides Insight into Brewing Properties of Hops

Samples of both dried cones and final pellets were sent to the Enology Analytical Services Laboratory at Virginia Tech for a complete analysis of oils and acids (Figures 4 and 5). A typical brewer's evaluation of hops in Yakima Valley does not include any of this quantifiable data—they are evaluated solely from a sensory standpoint.

However, because this is a research-based project, we want to make sure the sensory analysis of UMD's varieties matches up with quantifiable data on the composition of these hops. For the most part, our evaluations are aligning with the aromas and flavors that are typically associated with each hop oil. In the long term, this will help us identify patterns of oil compositions based on the ideal profiles for each variety.

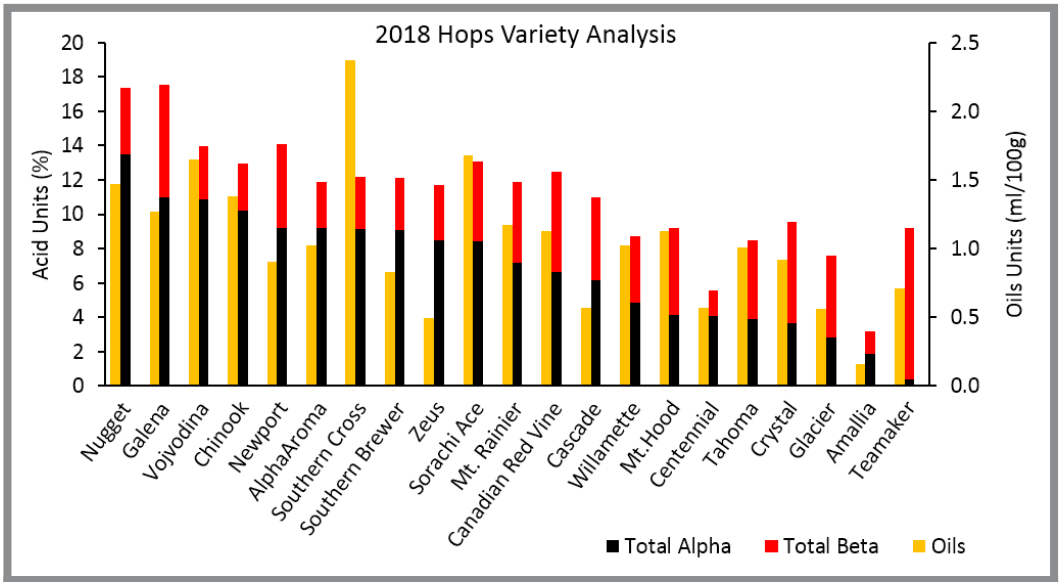

*Figure 4. In the long term, hops analysis will help UME researchers identify patterns of oils and acids based on the ideal profiles for each variety. *Yields for Neo 1 and Ultra were insufficient for lab analysis.*

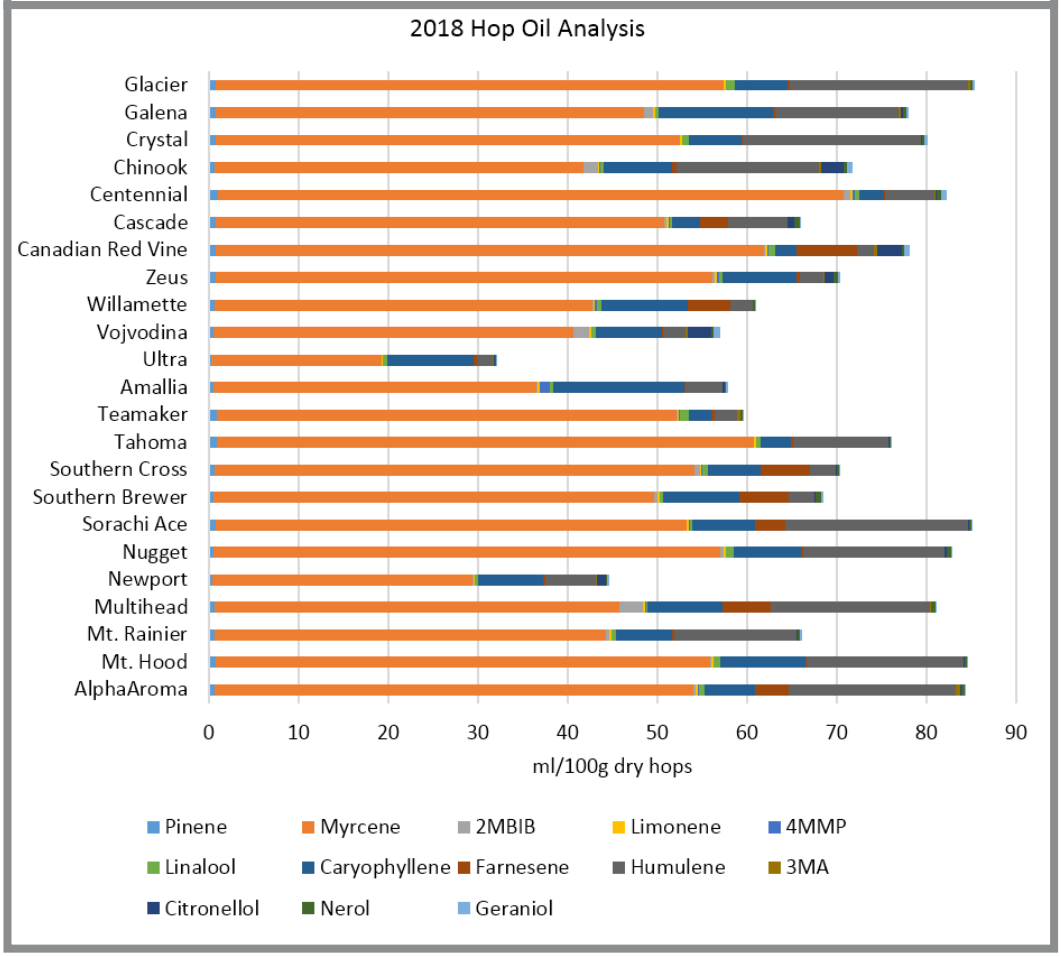

Figure 5. The combination of oils gives each hop variety a unique aroma and brew qualities.

Within a week of processing, Flying Dog Brewery received all of the hops from 2018's harvest, except for the sub-samples sent to Virginia Tech for testing. To mimic how a brewer would use the hops in the typical brewing process (without brewing an individual beer with each), Flying Dog replicated its dry-hopping process by adding the hops to a light lager set to the same temperature as a dry hop. From there, Flying Dog's trained sensory team did an aroma evaluation of the pelletized hops. Each evaluation was performed blind, and panelists selected the top two hops out of five groups. Not only did the team evaluate aroma notes, they also noted the intensity of the aroma (Table 5).

Flying Dog's final analysis of each hop variety combines the aroma and dry hops evaluations, with the dry hops evaluation weighted heavier because it is a better indication of how the hops will perform in a beer. What was most interesting to the brewer was that Flying Dog's team evaluation of the hops aligned with the hop oils break-down data from the lab analysis.

- ***Sorachi Ace***: Lemon, citrus, and spice profile mimics what is expected from this variety grown in other areas of the United States.
- ***Amallia***: No yield in 2017, but the 2018 harvest brought a unique combination of tropical fruit and earthiness.
- ***Canadian Red Vine:*** While this hop had the best yield in 2017 and 2018, the profile is a less-desirable combination of onion, garlic, and herb.

In comparison, the top-rated brewing hops from the 2017 harvest were Vojvodina, Glacier, Mt. Hood, Newport, Southern Brewer and Southern Cross. Vojvodina, Glacier, Southern Brewer and Southern Cross remained on 2018's list, but Mt. Hood and Newport were replaced by Amallia, Canadian Red Vine, and Sorachi Ace. The profile differences from 2017 to 2018 show how drastically some hop varieties can change as they reach maturity (Table 5).

Hops Sensory Analysis, 2018 vs. 2017

2018		2017	
Variety	***Description***	***Variety***	***Description***
Vojvodina	Tropical, citrus	Vojvodina	Green, melon
Southern Cross	Citrus, fruit	Southern Cross	Fruit punch
Southern Brewer	Citrus, melon, resin	Southern Brewer	Tangerine, resin
Glacier	Pine, fruit, spice	Glacier	Pine, resin
Sorachi Ace	Citrus, lemon, spice	Mt. Hood	Fruit and herb
Amallia	Fruit, earth, berry	Newport	Pineapple, green apple
Canadian Red Vine	Onion, garlic, herb		

Table 5. Profile differences from 2017 to 2018 demonstrate how significantly some hop varieties can change as they mature.

The top-rated hops for brewing from the 2018 harvest were:

- ***Vojvodina***: Floral and melon aromas in 2018 and 2017, with the addition of a tropical and citrus pop in 2018.
- ***Southern Cross***: In 2017, this hop exhibited a fruit punch profile, but 2018 brought more distinct citrus notes.
- ***Southern Brewer***: This variety is traditionally used for bittering, not flavor or aroma; however, this variety when grown in the UMD trial, possessed brew qualities that align with the most popular hops coming out of the Pacific Northwest. Citrus, melon, and resin dominate its profile.
- ***Glacier***: Dominant fruit and pine with subtle herbal and floral notes in 2018, compared to much more prominent resinous notes the year prior.

Suggested Readings & Resources:

- *Field Guide For Integrated Pest Management in Hops.* Third Edition (2015). https://www.usahops.org/cabinet/data/Field-Guide.pdf
- *Evaluation of Hops Production in Maryland as a Sustainable Agricultural Enterprise* (2019). Northeast SARE grant report. https://projects.sare.org/sare_project/one18-315/
- Hops in Maryland. University of Maryland Extension: https://extension.umd.edu/carroll-county/agriculture/hops-maryland
- Hops Marketing. Maryland Rural Enterprise Development Center. https://extension.umd.edu/mredc/specialty-modules/hop-production

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