



Hop Growing Toolkit for Beginners





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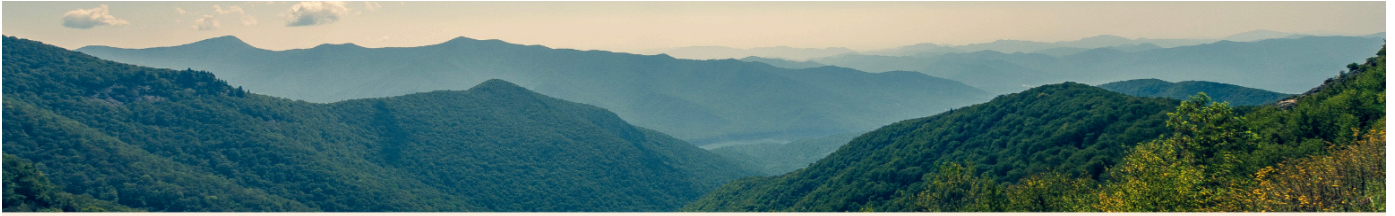
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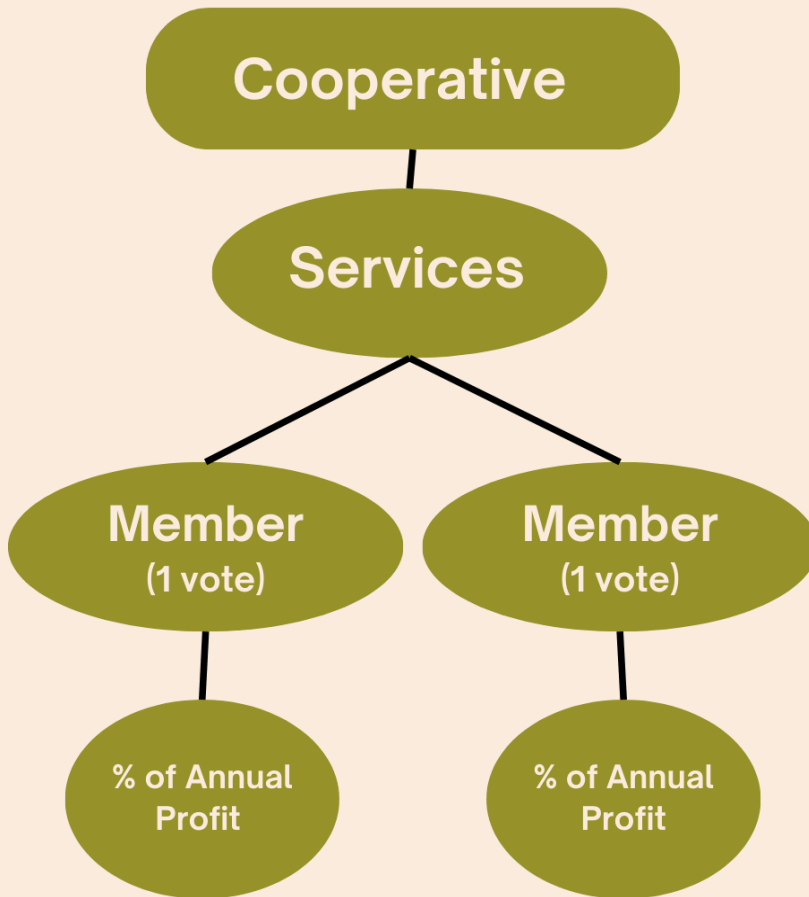
Charleston, WV 25304

(304) 926-0567

Email: info@wvfoodandfarm.org



How it works:



Questions?

Jenn Brown
President
757.897.6724
mountainstatecohop@gmail.com



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- profit sharing
- shared use equipment
- Member owned
- aggregation/distribution
 - marketing
 - sales
 - educational resources/workshops
- collective funding
 - bulk purchasing
 - resourcing
 - economic savings
- improved bargaining power
- reduced costs/increased income
- improved product or service quality
- access to services otherwise unavailable

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PREPARATION



Establish Your Market

As with any new business venture, you should identify your markets and decide how you will sell your product before you get started. There are three different ways to sell hops: wet, whole, and pelleted.



Wet Hops

Wet hops, also known as fresh hops, are freshly picked, undried hop flowers. These hops are kept as cool as possible once they are picked, and delivered to the brewery to be used within 48 hours. Brewing with fresh hops is done in a similar way to brewing with dried hops.



Whole Hops

Whole hops are exactly that, the entire hop cone of a female plant. These are picked, air dried, and then pressed into bales. The bales are then stored in warehouses at around 26°F until needed by a brewer or hop distributor. Hop bales can be different sizes from small 50 pound to large industrial size 200 pound balers.

Because whole hops are minimally processed more of the volatile aromatic compounds, which is what the brewer is after, remain intact. Their natural loose state means that they are more susceptible to oxygen exposure which creates a breakdown in quality that can happen more quickly than in other forms. But as long as you keep whole hops stored correctly, use the freshest hops possible, and reseal unused portions in vacuum-sealed bags; this problem can be mostly avoided.



Hop Pellets

It is after the drying stage that processing for whole hops and pellet hops diverge. Hops bound for the pellet are hammer milled, which creates a powder. This gummy powder is then forced through an extrusion die, turning them into hard shiny pellets, something that looks akin to livestock feed.

The quality of the pellets is critically affected by the temperature and speed, making it extremely important to mill at low speeds and keep the whole process cool by liquid nitrogen or some other means. After milling, the pellets are allowed to cool and harden. These cured hops are then precisely weighed, packaged in vacuum sealed barrier bags, boxed, and set in cold storage until sold.

The outer shell of lupulin resin helps protect the pellets from oxidation giving them a longer storage life, with less chance of damage to quality. Pellet hops are also easier to measure out, work with, and take up less storage space than whole hops.

Identify Local Breweries

You need to identify yourself as a hop grower in the community and reach out to potential buyers. Take some time to visit with local breweries. Small breweries looking for locally-sourced ingredients can be a target population for small-scale hop yards. Ask them:

- What varieties are they interested in?
- What quantity do they need?
- What form do they prefer to purchase their hops?

Alternative Markets

Homebrewers interested in experimenting with hop varieties and brewing-supply shops are other good markets to look into. Contact the homebrewer's association in your area and attend meetings that they host to learn what varieties are preferred. Hops have many health benefits so herbalists or apothecaries may be interested in your harvest. While your hop yard is getting established, these markets can help you sell smaller quantities.



Cooperatives

Reach a larger market by joining a cooperative to aggregate your hops with other growers in the area. A cooperative is a member owned and operated association of people united voluntarily to meet their common economic, social, and cultural needs and aspirations, through a democratically controlled enterprise. Joining a cooperative has many advantages including: shared knowledge, pooled resources, member control, and profit sharing.

There are three main principles that set cooperatives apart from other kinds of business:

- 1.) The user-benefits principle gives members the advantage of economics of size and bargaining power. As members use the cooperative and add value to their products, the cooperative generates profit margins that are then returned to the members. Without the cooperative, these funds would go to other middlemen or processors.
- 2.) The user-owner principle states the people who use a cooperative, own it. Members own the assets.
- 3.) The user-control principle is exercised through voting at meetings and through serving on the board of directors. Members usually have one vote regardless of their equity or how much they patronize the organization. This ensures democratic control of the cooperative and keeps its focus on serving the members, rather than profits for outside investors.



The Mountain State Co-Hop

Hops growers in West Virginia are invited to join the Mountain State Co-Hop which offers:

- Profit sharing
- Aggregation/distribution networks
- Economic savings
- Bulk purchasing
- Educational resources/workshops
- Reduced costs/increased income
- Shared use equipment
- Marketing and sales assistance
- Collective funding
- Resourcing
- Improved bargaining power
- Improved product quality

For more information contact:

Jenn Brown
President
757.897.6724
mountainstatecohop@gmail.com

Market Potential

West Virginia Market

The demand for hops in West Virginia is strong and growing. As of 2023, there are 33 breweries in WV. The majority of these breweries use 1k - 4k pounds of pelletized hops per year, with a few breweries needing 30k - 40k pounds annually. Most brewers prefer dry, pelletized hops; however, there are a few that use wet hops. Current pricing delivered to the breweries is \$8 - \$20 per pound.

Hops Growers in West Virginia as a whole, currently do not produce enough hops to meet the needs of one of these breweries, resulting in a market available for interested growers. In addition, there is a global hop shortage- making selling WV grown hops to breweries in neighboring states a viable option, as not every state grows hops. Stating the demand for hops is limitless is not an overreach.

Projected Yields Per Variety and Process

Variety	Approximate Yield per ¼ acre Wet	Approximate Yield per ¼ acre Pelleted	Approximate Price Per Wet Pound	Approximate Price Per Pelleted Pound	Approximate Profit Per ¼ acre Wet	Approximate Profit Per ¼ acre Pelleted
Cascade	1st year: 137 lbs 2nd year: 275 lbs 3rd year: 412 lbs 4th year: 550 lbs	1st year: 34 lbs 2nd year: 69 lbs 3rd year: 103 lbs 4th year: 138 lbs	\$9	\$9	1st year: \$1,233 2nd year: \$2,475 3rd year: \$3,708 4th year: \$4,950	1st year: \$306 2nd year: \$621 3rd year: \$927 4th year: \$1,242
Centennial	1st year: 106 lbs 2nd year: 212 lbs 3rd year: 318 lbs 4th year: 425 lbs	1st year: 26 lbs 2nd year: 53 lbs 3rd year: 80 lbs 4th year: 106 lbs	\$9	\$10	1st year: \$954 2nd year: \$1,908 3rd year: \$2,862 4th year: \$3,825	1st year: \$260 2nd year: \$530 3rd year: \$800 4th year: \$1,060
Chinook	1st year: 150 lbs 2nd year: 300 lbs 3rd year: 450 lbs 4th year: 600 lbs	1st year: 38 lbs 2nd year: 75 lbs 3rd year: 112 lbs 4th year: 150 lbs	\$9	\$9	1st year: \$1,350 2nd year: \$2,700 3rd year: \$4,050 4th year: \$5,400	1st year: \$342 2nd year: \$675 3rd year: \$1,008 4th year: \$1,350
Columbus	1st year: 139 lbs 2nd year: 278 lbs 3rd year: 418 lbs 4th year: 557 lbs	1st year: 35 lbs 2nd year: 70 lbs 3rd year: 104 lbs 4th year: 139 lbs	\$9	\$6	1st year: \$1,251 2nd year: \$2,502 3rd year: \$3,762 4th year: \$5,013	1st year: \$210 2nd year: \$420 3rd year: \$624 4th year: \$834

Variety	Approximate Yield per ¼ acre Wet	Approximate Yield per ¼ acre Pelleted	Approximate Price Per Wet Pound	Approximate Price Per Pelleted Pound	Approximate Profit Per ¼ acre Wet	Approximate Profit Per ¼ acre Pelleted
Comet	1st year: 139 lbs 2nd year: 278 lbs 3rd year: 418 lbs 4th year: 557 lbs	1st year: 35 lbs 2nd year: 70 lbs 3rd year: 104 lbs 4th year: 139 lbs	\$9	\$11	1st year: \$1,251 2nd year: \$2,502 3rd year: \$3,762 4th year: \$5,013	1st year: \$385 2nd year: \$770 3rd year: \$1,144 4th year: \$1,529
Crystal	1st year: 125 lbs 2nd year: 250 lbs 3rd year: 375 lbs 4th year: 500 lbs	1st year: 31 lbs 2nd year: 62 lbs 3rd year: 94 lbs 4th year: 125 lbs	\$9	\$6	1st year: \$1,125 2nd year: \$2,250 3rd year: \$3,375 4th year: \$4,500	1st year: \$186 2nd year: \$372 3rd year: \$564 4th year: \$750
Williamette	1st year: 137 lbs 2nd year: 275 lbs 3rd year: 425 lbs 4th year: 550 lbs	1st year: 34 lbs 2nd year: 69 lbs 3rd year: 106 lbs 4th year: 138 lbs	\$9	\$10	1st year: \$1,233 2nd year: \$2,475 3rd year: \$3,825 4th year: \$4,950	1st year: \$340 2nd year: \$690 3rd year: \$1,060 4th year: \$1,380
Zeus	1st year: 187 lbs 2nd year: 375 lbs 3rd year: 562 lbs 4th year: 750 lbs	1st year: 47 lbs 2nd year: 94 lbs 3rd year: 140 lbs 4th year: 188 lbs	\$9	\$20	1st year: \$1,683 2nd year: \$3,375 3rd year: \$5,058 4th year: \$6,750	1st year: \$940 2nd year: \$1,880 3rd year: \$2,800 4th year: \$3,760

Site Selection

When considering becoming a hops grower, you need to think very carefully about the site in which you intend to plant. Hops are perennial and do not like to be moved around, consider your hop yard a permanent installation. Hops require a great deal of space. They need to be spaced three feet apart to accommodate their root zone and to provide ample air flow in the yard to aid in the prevention of pest and disease.

There are four key factors to consider when selecting your site: wind direction, sun exposure, water access, and accessibility.

Wind Direction

When considering your site, you need to account for prevailing winds. Hops can grow eighteen to twenty-four feet in a season, once mature. The vegetative mass and height combined essentially create a sail. You will want to position your yard for the wind to blow through your rows instead of against your rows.

Sun Exposure

Hops need ten to twelve hours of sun exposure per day for maximum production. You will want to consider a site with southern exposure that is unencumbered by shade cast from buildings, tree lines, hills, or other obstructions. A cheap and effective way to determine your sun exposure is to create a shade map at the Summer Solstice so that you can observe where the shade encroaches at the peak of the season and select your site outside of the shade line.

Water Access/Management

Hops need approximately thirty inches of rain in the growing season which translates to about sixteen gallons of water per plant per week. Water access is crucial. Running irrigation is the simplest method for ensuring that your yard has enough water throughout the growing season. On the converse, hops do not like to have wet feet so you will also need to consider water mitigation. Amending your soil to be fast draining is a good strategy along with hilling your rows so that any influx of water does not sit on your rhizomes and consequently drown your plants. Slope is also a factor when thinking about how water flows through your yard. There are several techniques you can employ if slope is a factor.

1. **Plant on contour:** When you plant on contour you are accounting for how the water flows through your yard and this will prevent wash out. The hops will also aid in erosion control.
2. **Key Line Aeration:** Key line aeration is a method that cuts through compacted soil to improve infiltration and aeration while redistributing water. Using the key line aeration method on contour lines quickly breaks up compacted soils and allows the water to slow, sink, and spread in the soil.
3. **Furrowing:** By furrowing along your hilled row, you can aid in directing water quickly away from your row to prevent washout.

Accessibility

Hops require a lot of care, attention, and monitoring. It is important to consider the accessibility of your yard for ease of installation, maintenance, harvesting and processing. Some questions to consider are:

- Can you get materials to your yard with relative ease?
- Can you get machinery to the site, through your rows, and around your yard?
- Is it close enough that you will monitor and maintain the yard twice a week at minimum?
- Can you get your harvest to your processing area with ease?

Soil Preparation

Your extension service should provide soil testing services, oftentimes free for residents.

Sampling

You can use a soil probe to obtain soil from multiple locations around the yard. Take samples at a depth of six to eight inches. Collect samples for soil tests from different sections within your yard. Each section should be distinct from the others. Most extension services will conduct a soil analysis.

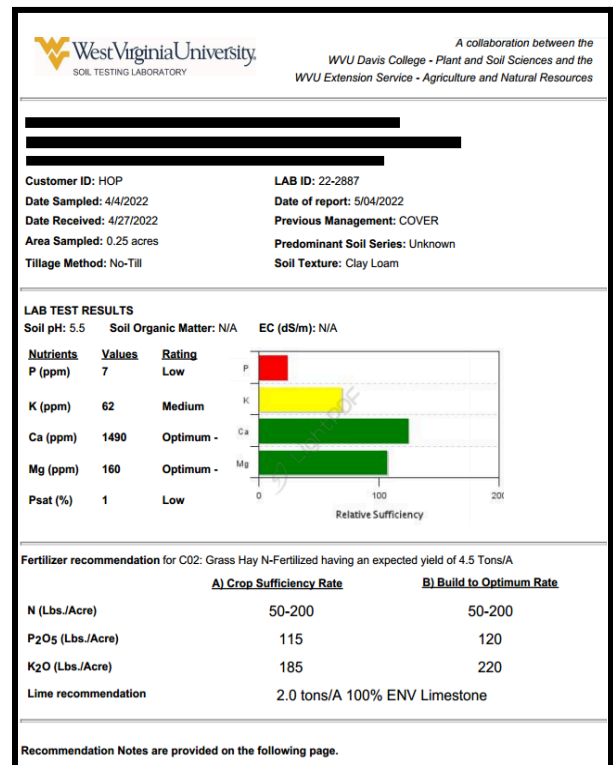
Reading Soil Analysis

Lab reports are divided into four sections: submission information, laboratory test results, fertilizer recommendations and recommendation notes.

Submission Information: The submission information in the top section contains the name, address, county, phone number and email address of the customer submitting the soil sample.

Laboratory Test Results: The results reported include soil pH, content of elemental phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) in parts per million (ppm), and calculated P saturation (Psat). Soil organic matter (SOM) and electrical conductivity (EC) also are available when purchased.

Soil fertility is also reported as low, medium or optimum relative sufficiency. Bar graphs for P, K, Ca and Mg are provided to show the relative sufficiency with 100 indicating the low end of the optimum range. Soils testing in the optimum range should have an adequate supply of that nutrient for the crop to achieve expected yield without adding fertilizer containing that nutrient. Soils testing in the medium range need a small amount of additional fertilizer



nutrient to achieve expected yield. Soils testing in the low range need the indicated larger amount of fertilizer nutrient to achieve expected yield.

The Psat index measures risk for soils testing excessively high in phosphorus, contributing it to surface water and causing pollution. A low P saturation (less than or equal to 15) means that there is low risk for losses to the environment.

The soil organic matter report is the measure of organic matter, which is beneficial for moisture and nutrient availability for plant growth.

The electrical conductivity report measures the salt content in the soil due to excessive fertilization or lack of adequate irrigation in high tunnels. High EC reduces water uptake and can reduce crop yields. When the EC value (1:1, soil:water dS/m) is greater than 0.7, it is recommended to leach the excess salts out of the soil using rainfall or increased irrigation.

Fertilizer Recommendations: Agronomic crop fertilizer recommendations are based on the expected yield for the specified crop when grown on the indicated soil type.

Fertilizer recommendations are reported as N, P₂O₅, and K₂O fertilizer nutrients required to achieve expected yields. These recommendations are reported as pounds per acre or ounces per 100 square feet, depending on the area units provided in the submission.

Two levels of fertilizer recommendations are given – crop sufficiency and build to optimum. The crop sufficiency level is the minimal level of fertilizer that should be used each year to achieve the expected yield. This is the lowest cost fertilizer recommendation and is recommended for land rented on an annual lease. The build to optimum is a higher fertilization rate that will build soil fertility into the optimum soil test range over time.

The lime recommendation is for raising the measured soil pH into the pH range for the indicated crop.

Magnesium (Mg) recommendations are based on optimum health for livestock consuming forage and humans consuming leafy green vegetable crops. Grain crops can tolerate magnesium levels in the medium range, but when grown in rotation with forage crops, the rotation system benefits from magnesium in the optimum range.

Recommendation Notes:

- * Liming recommendations are based on 100% effective neutralizing value (ENV) lime, the part of ground lime that reacts with soil acid within 3-years. Limestone products differ in ENV due to impurities and how finely they are ground. A tool for calculating ENV using label values listed on ground limestone products is available at: https://extapps.wvu.edu/soiltesting/ag_limestone_value.cfm
 - * Split N applications using 50-60 lbs. N/A/harvest. Reduce expected yield by 10-12% for each 50 lbs. N/A applied below maximum recommended N rate.
 - * Applying 50-60 lbs. N/A after last harvest in mid to late September will stimulate tiller bud development and provide N for first harvest the following year.
 - * When yields are lower than indicated yield apply P₂O₅ and K₂O in proportion to actual yield. When taking only 1 cut of hay yielding 2 tons/acre but recommendations are for 4 tons, reduce P₂O₅ and K₂O to one half of the recommended rate. Keep nitrogen application rates for each cut of hay.
 - * Fertilizer recommendations are for topdressing an established stand, based on the indicated yield, with pH adjusted to 6.0 or above, and soil samples take to a 2-inch depth.
 - * Apply the recommended fertilizer rates annually.
 - * Soils testing below Optimum should be tested each fall to track improvement in soil test values.
 - * Soils testing in the Optimum range, receiving annual maintenance applications, should be tested every 3 years.
 - * Fertilizer recommends are for addition of plant nutrients from all sources. Use manures and crop residues to build and maintain soil fertility as much as possible.
- Your soil phosphorus concentration is not an environmental concern. Follow the phosphorus fertilization recommendations provided in your soil test report.

If you have questions about the fertilizer recommendations in this report contact your local ANR county agent, Jennifer Friend, at (304) 624-8650 or jefriend@mail.wvu.edu.

Additional Landowner Information:

Additional reports also sent to: wvu.davis.soiltesting@gmail.com

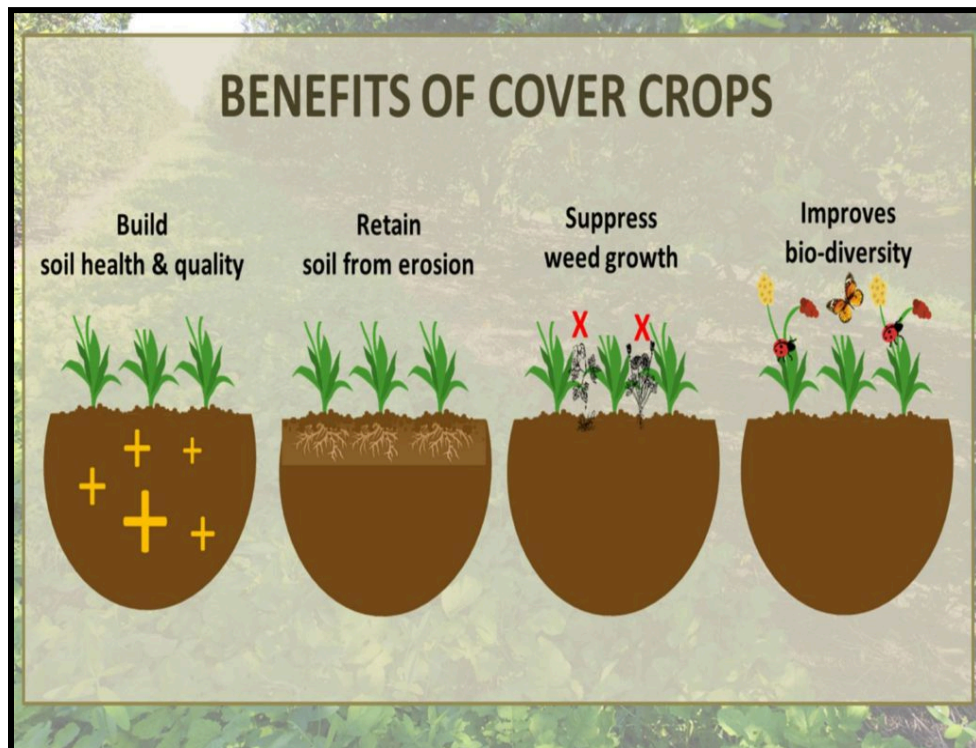
Recommendation Notes: Detailed recommendation notes specific to the crop are provided on the reverse side of the soil test report. These provide valuable management suggestions for the crop.

Nutrient Management Considerations

Hops take up between twenty and thirty pounds of potassium per acre and eighty to one hundred and fifty pounds of nitrogen per acre. Hops are impacted by low boron and zinc. Hop plants will only use about ten percent of its total nitrogen uptake by the end of May. The majority of nitrogen will be consumed during the month of June. The industry standard for the Pacific Northwest is one hundred and twenty pounds of nitrogen applied in the spring and another one hundred and twenty pounds of nitrogen applied from May – mid July. Excessive nitrogen can be damaging to the plant and the environment. Too much nitrogen can cause the plants to grow more succulent in nature which can lead to disease. Excess nitrogen can be washed out of the soil and contaminate aquifers and surface water. You will need to continue to care for your soil. Applications of livestock manure and compost are a great way to manage soil health in your hop yard. It can be worked into the soil and/or used as a mulch. This will add nitrogen and organic matter back into the soil.

Cover Cropping

It is recommended to utilize cover crops at your site before installing your hop yard. Cover crops serve several purposes: It protects your field from water and wind erosion, helps the soil retain moisture, and, when tilled under, adds organic matter to the soil, acting as a green manure. All of which improves the soil tilth, increases the level of biological activity, introduces nutrients back in the soil, fixes nitrogen, and improves aeration in the soil. Suitable cover crops for preparing your hop yard are: winter rye, oats, wheat, vetch, ryegrass, barley, sweet clover, red clover, buckwheat, marigold, sudan grass.

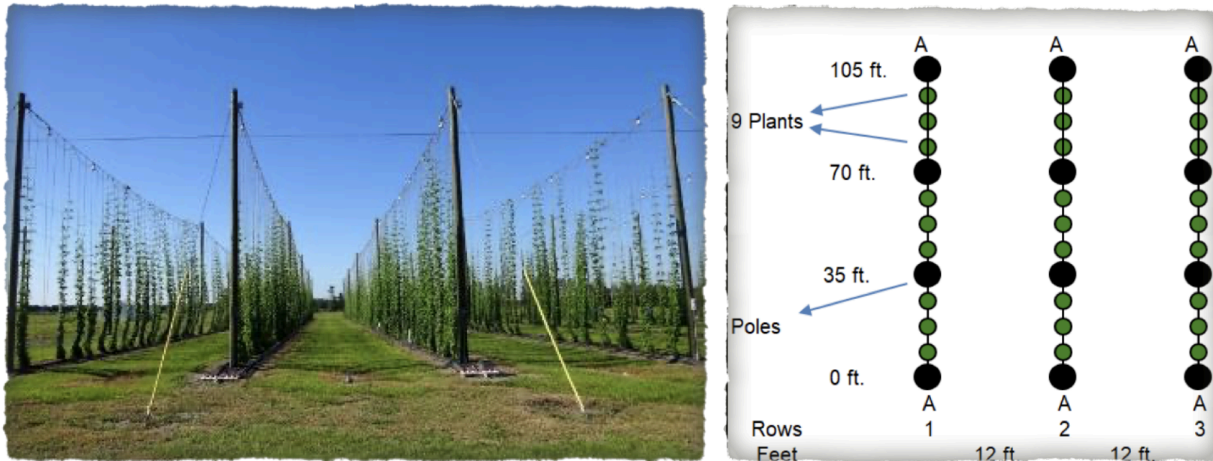


Layout and Spacing

There are different styles of trellis designs for hop yards. Choosing your trellis design is dependent on your site characteristics. The main trellis designs are straight line, in row V-style, and V-style.

Straight Line

Straight line trellis systems can accommodate three to four bines occupying one line in a straight row. The benefits of this design are more airflow, easy harvest, and easy visual inspection. The drawbacks of this design are less yield, more weeds, more watering, and higher potential for mites.



Common layout configurations use pole spacings every thirty-five feet, plant spacing every three to four feet, and have a row width of ten to twelve feet. This style is recommended for yards that are a half-acre or less.



In Row V-Style

This trellis design offers two strings per plant for three to four bines per string totaling six to eight bines per plant, grown in a straight row. The benefit is higher yields with less plants. The drawbacks are harder harvesting, more weeds, more watering, and higher potential for mites.

Common layout configurations are pole spacing every thirty-five feet, plant spacing every six to seven feet, and row width ten to twelve feet. This style is recommended for yards that are a half-acre or less.

V-Style

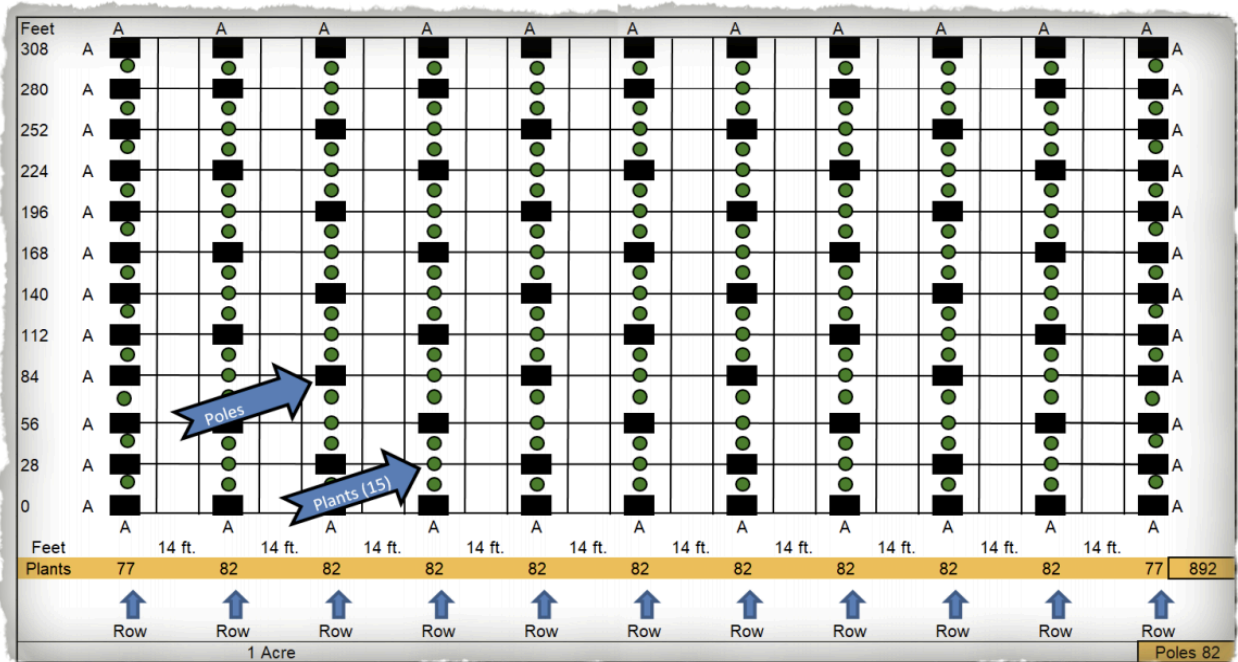
The V-Style trellis system has two strings per plant for three to four bines per string totaling six to eight bines per plant. The plants are trained to grow in rows that angle toward the middle of the alleys. The benefits of this design, if done correctly, are higher yield, less weeds, and less pest and disease. The drawbacks, if not done correctly or managed incorrectly, are greater disease and pest pressure due to lack of airflow.



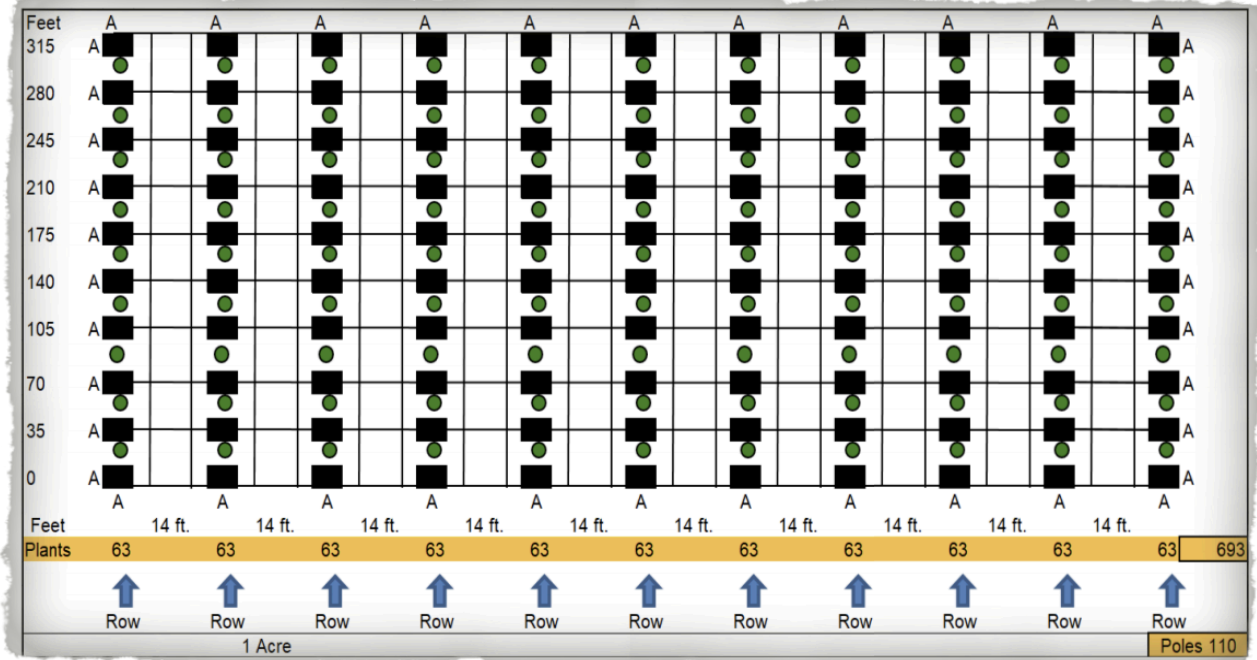
Common layout configurations are on a grid with varied options for patterning. There are a few examples below. Plant spacing is every three to four feet. Row widths are between twelve to fifteen feet. This trellis style is typically found on a half-acre or more hop yard.

V-Style Trellis Layout Options

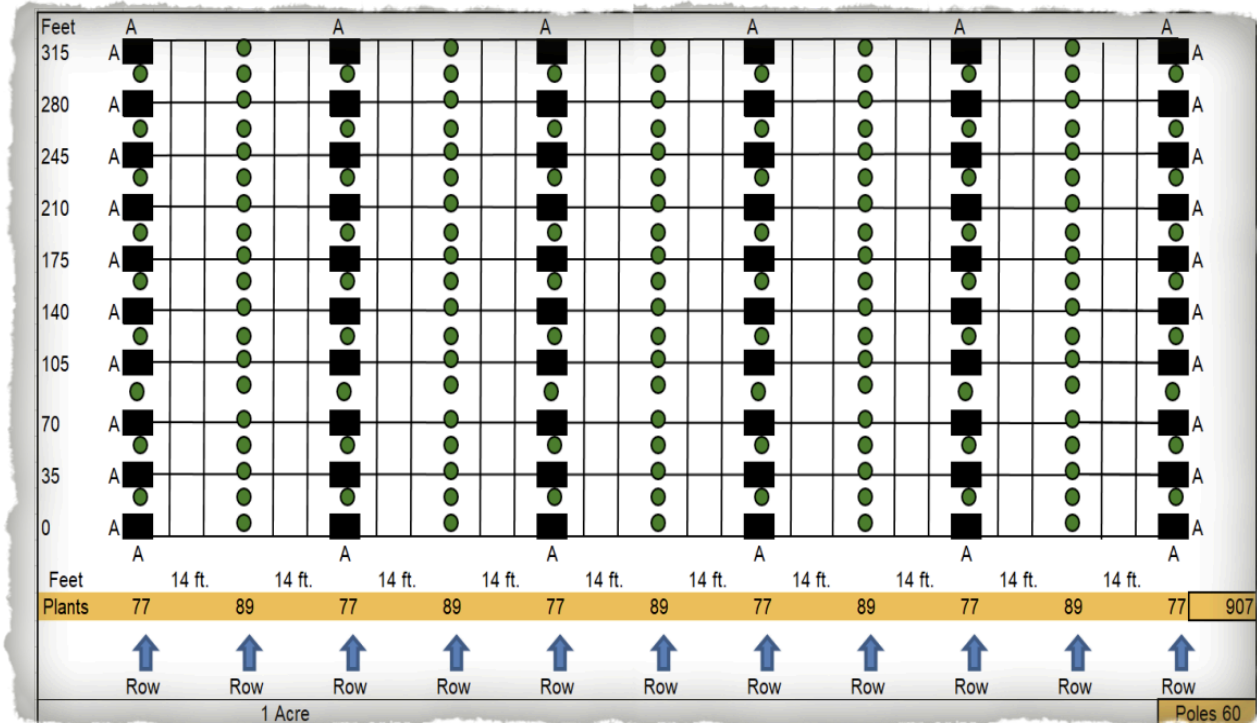
Option 1:



Option 2:



Option 3:



Differences at a Glance

	Straight Line Design	Straight In Line V Design	V Design
# of Poles	110	110	60/82/110
# of Plants	819	572	907/892/693
# of Strings per Plant	1	2	2
Bines per String	3-4	3-4 x 2	3-4 x 2
Yield	0.5-0.75 lbs per plant 410-615 lbs dry per acre	1-1.5 lbs per plant 572-858 lbs dry per acre	1-1.5 lbs per plant 693-1,360 lbs dry per acre
Recommended	1/2 acre or less	1/2 acre or less	1/2 acre or more

Planting

When acquiring your rhizomes or plant starts for your yard it is important to purchase your stock from a reputable source that has clean plants. The place to start your pest and disease management is starting with a clean healthy stock of hops plants.

Once you source your stock, you can purchase all the rhizomes or plant starts you need or there are several options to grow your yard through propagation. Hops plants can be propagated from rhizome division and/or from cuttings.

Rhizomes can be planted before the last frost, while plant starts need to wait until after the last frost and when soil is workable. The soil needs to be well draining so that the hops do not drown and the rhizomes do not rot. When planting, break up about one square foot of soil and add compost or manure. Leave approximately three feet of space between each plant. When planting a rhizome be sure to plant the rhizome with as many buds facing upward. Cover each rhizome with two to three inches of dirt or up to the crown of a plant start. Side-dress the soil with two to three inches of compost or manure. Be sure to add two to three inches of mulch or cover the soil with agriculture cloth. It’s really important to give your plants as much support as possible and weed suppression is crucial. It is also paramount that your irrigation system be installed and operable when you plant, your plants are too young to cope with any sort of drought conditions.

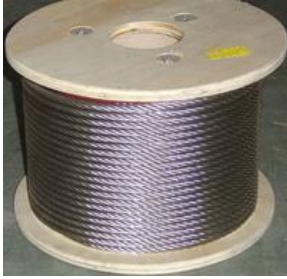
Trellising Materials and Installation

Materials for a hop yard are expensive. It is important to take the time to consider your options. It is also important to consider your installation and whether or not you are going to install it yourself: this is not an easy task. If you are going to have someone install the yard for you, it is recommended that you identify that person before starting down this path.



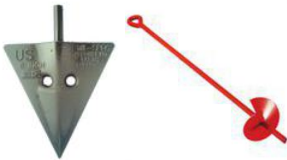
Poles

Poles for a hop yard trellis system are commonly 22 feet long with an average of five inch diameters at the top of the pole. There are several different options for trellis pole materials. The most common lumbers utilized are larch, black locust, tamarack, and honey locust. Larch poles are cheaper than black locust but do not have the same longevity. Larch poles can last ten years or longer with protection applied to the bottom part of the poles that are in the ground. Black locust can last thirty plus years. There are different methods for protecting the bottom ends of the poles, you can wrap them in Rot Block before you install them in the ground or coat them with tar. It is also recommended that you debark the bottom of the poles before installing them in the ground. All of these measures extend the life of the poles.



Cable

Use a high tensile $\frac{1}{4}$ " galvanized 1x7 strand aircraft cable for your hops yard. It is the smallest gauge that can be used to support the weight of your plants. It has a high breaking strength at 6,650 pounds and remains ductile over long periods of work and time.



Anchors

The two most common anchors are helix head ground anchors and arrow head anchors. Helix heads are driven into the ground with a power driver and can hold approximately 4,000 pounds. Arrowhead anchors are driven in the ground to a depth of four feet with a jack hammer and can hold approximately 5,000 pounds. An anchor is needed for every pole at the end of a row.

Hardware

A $\frac{1}{4}$ " guy strand hop tensioner will be needed on every guy wire that connects to an anchor. $\frac{5}{8}$ " x 8' forged eye bolts with washer and nut will be needed at each pole at the end of a row. Post caps are placed at the tops of the poles with staples to protect the pole from the cable rubbing the top. The cable is kept in place with a staple. Rope clips are used in securing the cable at the ends of the rows and explained in further detail in the next section.



Post Cap



Rope Clip



Eye Bolt



Tensioner



Staple

Installation

Poles and anchors need to be installed four feet into the ground and cable needs to be tensioned after install.

The image on the next page shows what a pole looks like at the end of each row.

- Install Pole
- Drill hole through pole six inches from the top
- Install eye bolt with eye pointing into the row
- The hop tensioner will connect to the eye bolt and then the cable is pushed through the hop tensioner

- Once the cable is pulled through, leave about six inches hanging out and then go to the other side. On the other side pull the cable through the hop tensioner. The final tightening will happen with the Havens Grip and a Come-a-Long.
- Next loop the anchor cable around the pole and through the eye bolt and clamp it onto itself with three rope clips.
- On the ground install anchors about ten feet away from the pole.
- Connect the hop tensioner to the anchor end and then pull the cable through the tensioner. Pull tight by hand
- Use the Havens Grip, Come-a-Long, and an extra hook to tighten the anchor cable. The extra hook is hooked into the hop tensioner and then the Come-a-Long is attached to the hook. Then the Havens Grip is attached to the cable approximately five to six feet up and the Come-a-Long is connected to the Havens Grip.
- Tighten the line with Come-a-Long until everything is tight and then release.
- If you have any middle poles in your row you will want to place a pole plate on top of the pole and then the cable on top of the plate. Then hammer a staple to hold the cable in place. Do not hammer the staple all the way into the pole, you will want the cable to move freely below the staple. This helps when weight is distributed with the hops.



Irrigation System

In general, hops require one inch of water per plant per week. In addition to the benefits on plant growth, regular watering can keep plants stress free and sometimes even reduce pest and insect pressure in your yard. Irrigation systems can help to alleviate some of the potential drought stress, but timing of water application is just as important as the amount of water hops are receiving. Hops require most of their water between training and flowering for optimal vegetative growth.

Given these weekly rates, it is often best to apply water in split applications two to three days per week, every other day if possible, and be mindful of rain events throughout the week. Higher amounts may be needed for establishing a new yard. While irrigating with these given rates, you'll be shooting for about one inch per acre (~28,000 gal/ac) of water from irrigation each week during bine and flower growth.

Drip Irrigation

Drip irrigation excels where watering only the root is desired or when there is inadequate amounts of rain. You want to avoid wetting the plant foliage and much of the soil surface to reduce mildew.



Gallons of water equal to one inch, by row width/ 100' of row				
Row width	acre	gallons	Hours / Inch single .42 gpm, 12" emitter spacing	Hours / Inch double .42 gpm, 12" emitter spacing
1	0.002	62.34	1.48	0.74
2	0.005	124.67	2.97	1.48
3	0.007	187.01	4.45	2.23
4	0.009	249.35	5.94	2.97
5	0.011	311.69	7.42	3.71
6	0.014	374.02	8.91	4.45
7	0.016	436.36	10.39	5.19
8	0.018	498.70	11.87	5.94
9	0.021	561.03	13.36	6.68
10	0.023	623.37	14.84	7.42



There are two application methods for drip irrigation. It can be laid directly on the ground or suspended above the ground by approximately a foot. Laying the drip irrigation directly on the ground is the easiest installation method but does not allow for easy soil management. Suspending the drip irrigation above the soil by approximately a foot is a little harder to install but allows for easier weeding, crowning of the rhizomes, and give you a place to anchor your trellis strings for training your plants.

Fencing

Before choosing a deer fence, consider the following features:

- Fence Height: Deer are great jumpers, capable of leaping 8 feet into the air. While some shorter fences can be effective, if deer are especially interested in your yard, a barrier-style deer fence at least this tall may be best.

- **Repairs:** Any damage incurred to your barrier-style fencing will have to be repaired promptly: A compromised barrier is not effective. Deer are smart enough to find a breach in the fence and enter through it quickly.
- **Pest Prevention:** Depending on the type of fence you build, you can prevent other pests like rodents and small mammals. However, you must select a barrier-style fencing that only has small openings. This can cost more, so decide whether the benefit is worth the extra cost.
- **Gates:** Remember to include a gate or other means of accessing the hop yard.

Types of Fencing

Metal Wire fencing consists of heavy-gauge metal wires running horizontally and vertically that form rectangles, which are attached together at each intersection. It is easy to install, and quite durable when the posts are properly sunken into the ground. If you're willing to pay for a high-end product, metal wire deer fences that have been coated in black polyethylene are the best, as they're more weather-resistant and less visible than standard silver wire options.



Polypropylene Mesh is a type of plastic fencing that's attached to vertical posts to form a barrier, similar to metal wire. This option is the most affordable, but it may look less attractive than some other options. Installing polypropylene mesh tightly—rather than letting it become loose—can help it look more like standard fencing. Keep in mind that deer are powerful animals that can rupture plastic fencing if it isn't strong enough. If you do choose polypropylene mesh, select a grade that has a breaking load of at least 800 pounds. The breaking load figure signifies how strong the product is.

Electric deer fencing consists of a wire (or wires), that carries a mild shock, strung low along a border. Electric fencing is cheap and much less visually obtrusive than mesh or permanent fences, but it's not as effective.

While not quite as effective as a tall barrier fence, the 3D alternative is considerably cheaper. The concept behind 3D fencing is having two parallel fences that provide height, depth and width. This makes deer hesitate before trying to jump the fence, especially because they have poor depth perception because their eyes are on the side of their head. The outer fence can be added to any fence you choose.

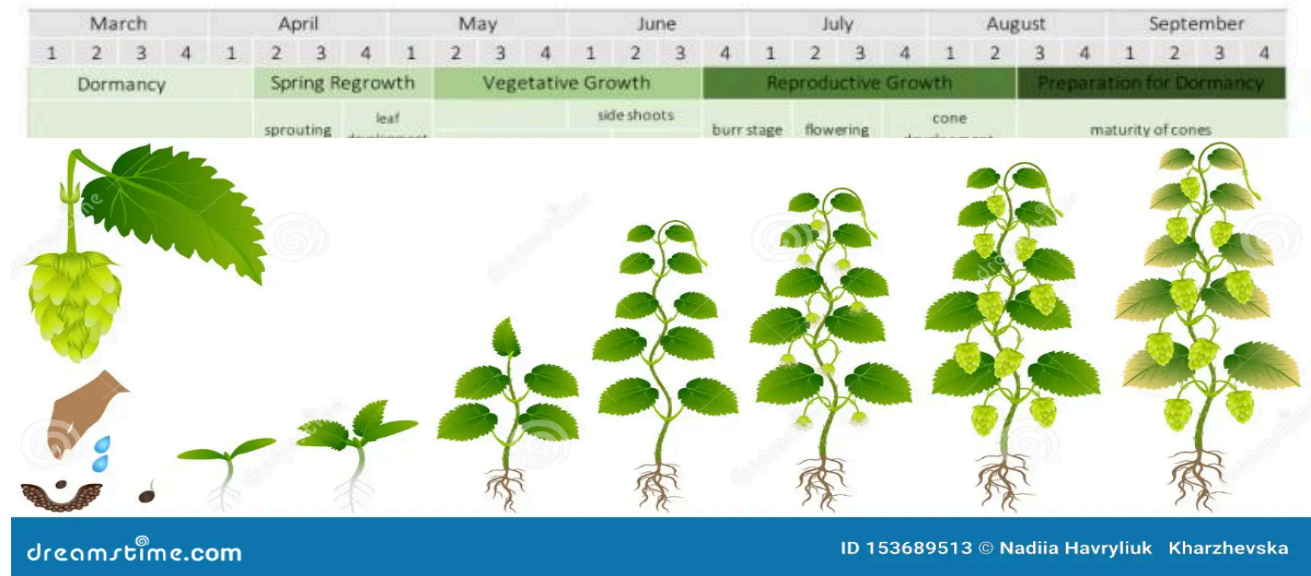


GROWTH AND MANAGEMENT



Growth Stages

Average Michigan hop growth stages based on date.



Stage 1: Leaf development

Stage 2: Formation of side shoots

Stage 3: Elongation of bines

Stage 4: Burr Stage

Stage 5: Flowering

Stage 6: Cone development

Stage 7: Maturity of cones

Stage 8: Entry into dormancy

While knowing when these individual phases occur will help you fine tune the timing of your management practices, hops growth is generally lumped into two phases—vegetative and reproductive. The Summer solstice marks the transition from vegetative growth to reproductive growth.

During the Spring months, hops focus their growth in the main bines, which climb upright, as well as the leaves growing on these bines. As the day length continues to get longer, the plant is pushing to get the main bines as tall as possible. The amount of vegetative growth ultimately determines how much the plant will yield, so it is important to manage plant health aggressively during this time.

By June 21, ideally the main bine has reached the top wire of the trellising system, the length of day gets shorter, and the plants will transition to the reproductive growth phase. The plants may grow a bit taller but vertical growth generally slows. Instead, the plants focus on growing lateral shoots extending from the main bines where the hop cones form. From this point, you'll see the production of burrs which develop into flowers and then cones. After a couple of months, it is harvesting time.

Growing Habits and Needs of Hops

Water

It is important to install your irrigation system at the beginning and to ensure that you use well-draining soil. Young plants cannot tolerate standing water but need frequent light watering to get established. Once your hops are established, they require approximately one and a half inches of water per week.

Fertilizer

Hops require a large amount of nitrogen but uptake most of their nitrogen needs by the Summer Solstice. Around one hundred pounds of nitrogen per acre is removed on average during hop harvest. Approximately seventy-five pounds of nitrogen should be applied per acre in the first year and one hundred to one hundred and fifty pounds per acre in subsequent years. In addition to nitrogen, hops also require a significant amount of potassium (80 – 150 pounds per acre) and phosphorus (20 – 30 pounds per acre). Boron, zinc, iron, and manganese are also important trace minerals for hops. Getting a soil analysis done yearly will help you keep an eye on your soil health.

Sun

Hops require ten to twelve hours of sun exposure per day for quality hop cone formation. They need 120 frost free days to reach the flowering stage (cones).

Early Spring Pruning

In established yards (at least two years old) you should prune the plant and crown material. This can be done by chemical or mechanical means.

Chemical pruning uses a desiccant herbicide to burn back foliage to help limit the spread of virus. With mechanical pruning, you remove any shoots and/or crowning. Crowning removes the top two to five inches of the new wood part of the crown. In place of crowning, scratching removes the material above or just below the soil line with an implement with spinning discs and tongs. Regardless of which method you use, make sure no foliage is left behind after pruning, as this can encourage diseases.

Once hops emerge in the Spring, they should be pruned back to encourage strong secondary shoot growth and reduce disease. Timing of this pruning is critical, as it takes three to four weeks to regrow before they are ready to train. This will also result in a more uniform growth height. If hops have not been pruned by May 1st (due to cool Spring weather) pruning should be skipped for that growing season.



Training

Before training can begin, hops need something to grow along. This is the time to run your strings for your hops to grow up. The strings will attach at the ground and at the top line of your trellis system. There are a few options to choose from including coir, polypropylene (poly) or sisal. Coir strings are made from 100% natural coconut fibers, making them an eco-friendly and sustainable option. The fibers are naturally resistant to rotting, mildew, and pests, ensuring a long-lasting and reliable support system for your hops. Sisal twine is made from individual strands of plant materials twisted together. This kind of twine is naturally biodegradable and comes in various colors and weights. Poly, on the other hand, is a plastic polymer. While it won't biodegrade anytime soon, it has more tensile strength than sisal.



Traditional, commercial hop yards use scaffolding pulled behind a tractor allowing you to hand tie the string at the top line. A pardalera from Schmidt Farm can be used from the ground to tie the strings on the wires above, using sisal twine. (Coir is too thick to be used with the pardalera.)

<https://www.schmidthops.com/inc/sdetail/pardalera--small-home-grower-/6706>

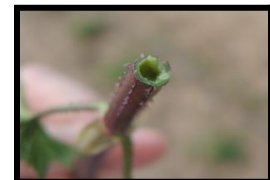


A large nut tied to the end of the coir or sisal and then thrown over the top line works just as well, especially if you have a slope not conducive to tractor use.



After attaching to the top line, the string is either tied to a tension wire that also holds the drip irrigation line above the soil or W clips are used to push the end of the line into the soil a few inches.

Bull shoots are the first and larger bines that emerge on plants and have a hollow center. You will want to cut them back as they are more brittle and less succulent, their leaves will be slightly farther apart.



In most growing seasons training should be done no later than June 1. To train your hops, pick three of the healthiest bines per plant and wrap them in a clockwise direction around each string to encourage growth. All remaining bines and foliage should be pruned back. After the hops are established, (third year of growth) generally they are productive enough to only train two bines per plant. The timing of

training is critical for obtaining maximum hop yields. Most early harvested varieties will benefit from early training dates, whereas a later harvested variety will have higher yields if trained later.



Once bines are 9-12' tall, strip all foliage from 3' down to maximize airflow, and minimize pest and disease. Properly training the hops at appropriate times will maximize your yields.

Weed Control

Weed control in a new hop yard is critical for the successful establishment of the newly planted hops. Tillage or cultivation for annual weed control should be done as shallow as possible to avoid bringing new weed seeds to the soil surface. Weed barriers are another viable option for weed suppression. The weed barrier will be effective for two to three years, after which the rhizomes may grow above the soil surface under the barrier. This would be a good time to transition to heavy mulch and divide your rhizomes.

Organic mulching has you grow a cover crop down your isles then blow the clippings onto the hop crowns when mowing. Chop and drop mulching involves chopping the cover crop, letting it drop, and letting it lay where it lands. Use of organic mulches can have both positive and negative impacts on insect pests and plant pathogens. Synthetic mulches may also be useful to suppress weeds, but are not widely used in conventionally grown hop yards.



Flame weeding is another option that is effective.



Analysis

Tissue testing, also known as petiole testing, can help producers identify deficiencies throughout the critical growth stages. If the results come back that some nutrients are low, growers can apply nutrients for optimal growth. Petiole testing is done when mature hop plants are 5-6 feet off the ground. At the time of sampling, you should take a random sample of about 100 petioles from 15-20 different plants of the same hop variety and repeat the process for all varieties. The full test includes N, P, K, Ca, Mg, S, Zn, Cu, Fe, B and Mn.

Pest and Disease ID and Management

First order of prevention starts with your plants. Select varieties that have resistance to pest and disease. Make sure to thoroughly inspect all new plants coming into your hop yard. Regular pruning and inspection of your yard is another great way to manage and prevent pests and disease.

Pest

Your local Extension service can usually help with identification of pests.

Hops Aphids



Hops aphids spread the carlaviruses and also cause major damage by feeding on the hops. They suck the sap out of the hop plant, depriving it of the nutrients it needs to grow. They also excrete a sticky substance called honeydew. This sticky excretion interrupts the photosynthesis process, can cause sunburn, and provides an excellent medium for sooty mold to take root.

Life Cycle

The eggs overwinter on leaves. Wingless female aphids hatch in the spring and begin asexually reproducing. This cycle persists throughout the season leading to an explosion in population. Both the nymphs and the adults feed on the sap in the leaves with sucking mouthparts. Towards the end of the season some develop wings and migrate up to ¼ of a mile.

Prevention and Control Measure

Monitoring your hop yard on a weekly basis is paramount to pest and disease control. If you spot the problem early you can deploy measures to control the problem quickly. Always check the underside of leaves, this is where a lot of pests like to live.

There are several prevention and control measures that can be used in controlling aphids. Cultural control is a good preventative measure. Making sure to have your yard clean of debris helps to cut down on overwintering pests and removes additional areas for them to thrive. Integrated Pest Management (IMP) is another effective measure. Releasing beneficial insects into your yard will aid in keeping pest populations down. Aphid midges, ladybird beetles, green lacewings, brown lacewings, hoverfly larvae, and trichogramma wasps are all good predators for aphids. Insecticidal sprays may also be necessary. Mixing neem oil, soap, and water deter aphids, is environmentally safe, and does not harm beneficial insects. The neem oil solution can also be utilized as a preventative by having a spray schedule of once a week. If you deploy all aforementioned measures early and often you can keep aphid populations at bay before they become a problem.

Japanese Beetles



Japanese Beetles have large chewing mouthparts. They eat the leaves of hops plants and leave skeletons of the leaves behind. This can be devastating to the plant as it is left with no way to photosynthesize.

Life Cycle

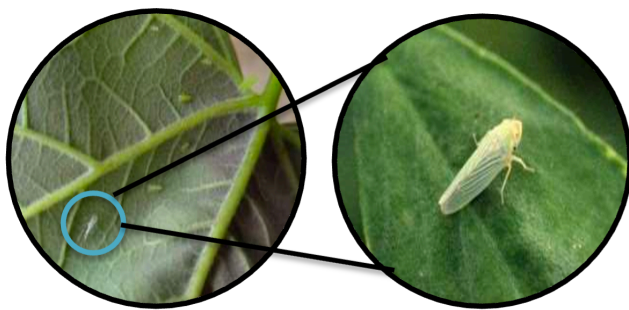
These pests eat and mate at a voracious speed. Two beetles can skeletonize a hop leaf in a day. After a day of eating and mating the female moves to the ground to dig a hole and lay one to three eggs. The next day she resurfaces to eat and mate. She will engage in this process several times during her life cycle, depositing approximately fifty eggs into the soil in her lifetime. The eggs hatch in ten to fourteen days. The larvae are white with distinct brown heads and are shaped like the letter C. They go through a series of molting cycles all while feeding on grass roots. When the temperatures start to cool in the fall the larvae burrow deeper into the soil to overwinter. In the spring they come back to the surface and feed on grass roots for several more weeks before they transform to their pupae stage. From the pupae

stage they grow into adults and ascend to the leafy vegetation of your hops and begin the process all over again.

Prevention and Control Measure

Mechanical control is one means of controlling the population. Japanese beetles are very sluggish in the morning hours and can easily be knocked off the plant by hand into a bucket filled with oil. Biological control is another great way to prevent the problem. Inoculating your soil with milk spores will kill the larvae and prevent adults from emerging in the spring. A couple really thorough inoculations can eradicate the beetles as the spore will continue to proliferate in the soil.

Potato Leafhopper



The Potato Leafhopper has very strong hind legs and wings which enable it to quickly travel large distances in search of food. Potato leafhoppers have sucking mouthparts. They suck the sap from the plants by penetrating the leaf veins. They also secrete a toxin through their saliva that forms a blockage in the leaf vein leading to prevention of nutrient uptake in the plant.

Damage is first seen when the venation of the leaf starts to pale and then the leaves start to curl. The tip of the leaf will yellow and eventually crinkle and turn brown in a V-shape pattern. This prohibits the plant's photosynthesis process.

Life Cycle

These pests cannot overwinter in freezing temperatures so they migrate to the south for the winter. They ride storm surges back north in the spring while carrying fertilized eggs and start to arrive in May. They do the most damage between June-August. The females lay two to three clear gelatinous fertilized eggs on the stems of leaves each day for at least a month. The eggs hatch in seven days to ten days. The nymphs feed in the same manner as the adults and primarily on the underside of the leaves. The time between the egg stage to adulthood is approximately twenty-six days.

Prevention and Control Measure

Early detection is key. Hang sticky cards in your yard to monitor for various pests and inspect your plants on a regular basis, making sure to look on the underside of leaves. Two to three leafhoppers per leaf is the standard threshold. Check twenty to thirty plants scattered throughout the yard per week. Divide the total number of insects you spotted by the total number of plants inspected and if the number is greater than two then it is time to spray insecticide, preferably organic. Do not spray unless you absolutely have to. The organic sprays recommended for potato leafhoppers are pyrethrin which is a biological pesticide derived from chrysanthemum flowers. Use caution because it may affect your beneficial insect population. The best prevention for this pest is predatory insects.

Two-Spotted Spider Mite



Two-spotted spider mites spin a web that looks like a matted layer of whitish webbing just above the surface of the leaves, acting as protection for them while they feed. Adult mites are found on the underside of leaves where they feed off leaves and cones by puncturing the plant and sucking out the sap. This causes the vegetation to weaken and bronze. When their numbers become high, they can cause defoliation. When they feed on cones, they become red, dry, and brittle, rendering them useless.

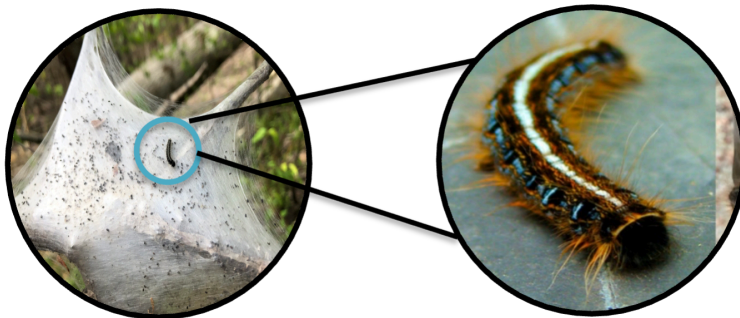
Life Cycle

Two-spotted spider mites overwinter in the hop crowns and cracks in trellising poles. They emerge early in the spring and feed off newly emergent hop plants. The females lay eggs as early as two days after coming out of dormancy. The eggs hatch in just a few days. The larvae mature in as little as three weeks and once mature they begin to breed. Females can lay up to 16 eggs a day and as many as 240 eggs in their lifespan.

Prevention and Control Measure

Start scouting for mites as early as May, the quicker you get a handle on this pest the better off your cones will be. Check the underside of leaves three to six feet off the ground, looking for mites, eggs, webbing, and stippling and yellowing of leaves. Take a magnifying glass when you are scouting, these pests are hard to see with the naked eye. Predatory insects are the best prevention and control measure for this pest. Predatory mites, big-eyed bugs, pirate bugs, ladybird beetles, spiders, and lacewings are wonderful beneficial insects for this pest. If you must spray an organic insecticide make sure that it is selective for mites so that you don't kill your beneficial insects and create a 'flaring' effect.

Tent Caterpillars



Tent caterpillars can cause heavy defoliation and prevent adequate photosynthesis for your plants.

Life Cycle

The larva matures in thirty to forty-two days, depending on weather conditions. Pupation occurs within silken cocoons spun on branches in the leaves. The duration of the pupal stage is from twelve to eighteen days. Adults emerge in late July to early August.

Prevention and Control Measure

The best measure is prevention. Scout your yard at the end of the season and be sure to remove any you find lingering around your yard.

Disease

Your local Extension service can usually help with identification of disease.

Downy Mildew



Downy mildew likes wet conditions. It is a fungus-like parasite that moves through water to penetrate the surface of a plant. It is a type of water mold. Downy mildew lives in hop rhizomes and spreads when rhizomes are harvested from infected hop yards and transplanted somewhere else. The spores can also travel through the wind and on animals, clothes, shoes, and hands of people that have handled infected material. It stunts the growth of hop bines and damages the cones themselves, reducing yield.

Life Cycle

It overwinters in the crown of the hop plant. Infected crowns have reddish-brown to black flecks and streaks in the white crown tissue next to the bark. The infection is then spread through the first emergent shoots during the early season when conditions are wet and favorable for the spores to proliferate and move through the yard. The zoospores love standing water on leaves that are close to the basal spike, producing the sores, because they can swim through the water and enter the plant through the stoma. This is when the disease becomes systemic. If the disease is severe enough it will kill the plant. The cones will brown and dry and be rendered useless.

Prevention and Control Measure

Make sure that you enter your hop yard with clean hands, clothes, tools, and shoes. Scout your hop yard frequently in the spring, keeping an eye out for primary basal spikes that are infected. Prune them out and destroy them, do not compost anything infected with downy mildew. Make sure to clean your tools between plants, change your clothes and shoes, and wash your hands before you continue any work in your yard. It is a good strategy to do this activity at the end of the day so you can clean everything at the end of the day without the need to reenter your yard. If you know you have downy mildew present in your soil you can get a step ahead and crown your plants. Crowning is when you mechanically remove $\frac{3}{4}$ to 2 inches of the top of the crown. This underground pruning method prevents the hop from sending up an early crop of diseased shoots. It is also standard to cut back early shoots as a preventative measure since they are not the strongest shoot selection. Keeping the area around the base of your plants weed free and pruned of new shoots, after you have trained and selected your primary shoots, is also a good prevention measure for combating downy mildew. As the plant grows and reaches about four feet, start to prune the lower leaves. As the plant advances, continue to strip the lower leaves until the bottom four feet are free of foliage, always keeping about two feet of vegetation. Also, avoiding overhead water is

recommended to prevent standing water on leaves. The preferred irrigation for hop yards is a drip line that is lifted slightly off the ground so that there is room for crowning.

Powdery Mildew



Powdery mildew is one of the most widespread and easily recognized plant diseases. Powdery mildews are characterized by spots or patches of white to gray, talcum-powder-like growth. It is severe in warm, dry climates.

Life Cycle

Powdery mildew thrives in moist environments. Its fungal spores are spread by wind. It overwinters in the soil, leaf duff and underground on the buds of the rhizomes. It makes its first appearance on what is referred to as 'flag shoots'. These emergent shoots appear stunted, pale yellow, and look dusted with white talc. As the spores spread the disease continues to proliferate. It will significantly damage the crop by reducing both the yield and quality of the cones. If the infection gets into the burrs or young cones, it will either kill the cone or deform it. Damaged cones will appear reddish-brown, but sometime will appear normal and then turn brown after drying.

Prevention and Control Measure

Hops need a great deal of nitrogen but providing too much can lead to plant growth that is spongy and succulent, which is a conducive environment for powdery mildew development. Keeping your yard well pruned is a great preventative measure for powdery mildew. Exposure to wind and sunlight will keep the spores from taking hold on the plant's leaves. An effective spray to make for prevention and control is LAB. This is a solution of lactobacillus which will eat the fungus. To produce this spray, soak rice in water for two weeks, ½ cup rice to one cup water. Keep the rice and water mixture covered with a towel. After two weeks, strain the water from the rice. Mix the starch water with whole milk in a 1 (water):10 (milk) ratio. Cover it with a towel and let it sit out at room temperature for two more weeks, at which time it will look like cheese on the top of the mixture and whey on the bottom. Strain the whey off the mixture and discard the 'cheese'. Mix 1/2 tablespoons of the concentrated whey with one gallon of water. You can now use this spray on your plants. Spraying weekly, even if you haven't identified any powdery mildew, goes a long way in preventing an outbreak. You only need to spray during the parts of the season when you know it is usually present, early spring/late fall. It is also important to stop spraying when cones start to form

Verticillium Wilt



Verticillium Wilt is another fungal disease. It is usually present during cone development and appears as yellowing and wilting of the plant moving from the ground up. It can be dormant in the soil or brought in from infected rhizomes and plants, people, and animals.

Life Cycle

This fungus can lie dormant in the soil for four to fifteen years in a mycelial state. Once a host plant becomes present the fungus enters the plant through minor wounds that it has sustained while digging through the soil. From there, the fungus travels through the root and into the plant. The lower leaves will yellow first. Once the plant is infiltrated the fungus will block off the circulation of water and nutrients through the plant tissue and eventually kill the plant. The yellowing starts on the sections of the leaves between the veins and gives the leaves a streaked appearance. Eventually the leaves will brown, curl, and fall off the bine.

Prevention and Control Measure

If Verticillium Wilt is present in your soil choose varieties that are tolerant or choose another location. The only good remedy for ridding your soil of this fungus is to starve it of host plants. Use this area for something that does not act as a host for this fungus.

Apple Mosaic Virus



Apple Mosaic Virus is capable of reducing cone yield and alpha acids by fifty percent. It appears with a yellowing of leaves in an oak-leaf-like pattern.

Life Cycle

Hops viruses have to be present in the plant itself to be a problem. Plant propagation is the primary way this disease is spread.

Prevention and Control Measure

Be vigilant in purchasing clean plants. Humans are a main vector in spreading this disease. Be conscious of having clean hands, tools, and equipment when working in your hop yard.

Carlavirus Complex



Carlavirus Complex is a family of viruses that include hop mosaic virus, hop latent virus, and American hop latent virus. Infection with carlaviruses slows plant growth, making it hard to establish new plantings and reduces yields.

Life Cycle

It has the ability to lie dormant in the plant and then suddenly begins to reproduce at a high rate. Though the virus can be dormant in a plant and the plant be symptom free, it can still spread the virus to other plants. Aphids can also spread this disease.

Prevention and Control Measure

The first step in prevention is purchasing certified clean plants. Controlling the aphid population in your yard is a good preventative measure. The virus is also spread through mechanical cultivation so keeping your tooling clean is crucial. If an infected plant is found, remove the plant and neighboring plants.

Hop Stunt Viroid



Hops Stunt Viroid stunts the plants as well as the cones, significantly reducing the alpha acid content. The plant may appear healthy but will produce fewer alpha acids. When symptoms start to show the plant will appear stunted with curling, yellowed leaves, and small cones. The bines will have trouble climbing because they don't develop trichomes.

Life Cycle

It is a latent viroid and an infected plant can transmit the virus to other plants without showing symptoms for years.

Prevention and Control Measure

The virus is spread through the sap of the plant. Transmission is often due to dirty tooling while pruning. Cleaning your tools often goes a long way in prevention.

HARVESTING AND PROCESSING



Harvesting

When it comes to the perfect timing for hop harvest, various factors come into play. It's not just a matter of waiting for the hops to mature; there are several considerations to keep in mind to determine the optimal time for picking:

Hop varieties: different hop varieties mature at different times. Knowing the specific harvest window for each hop variety is key to getting the best flavor and aroma.

Environmental factors: the climate, weather patterns, and soil conditions have a significant impact on the hop maturation process.

Hop growing regions: the location of the hop farm plays a role in determining the optimal harvest time. Hops grown in cooler climates may take longer to mature than those cultivated in warmer regions. The altitude and latitude of the farm can also influence hop growth and ripening.

Monitor hop growth closely and evaluate the visual signs of maturity to determine the perfect timing for harvest. In the next section, we'll take a closer look at the visual indicators of hop ripeness to guide your harvesting decisions.

Visual Signs

One of the most reliable ways to determine if hops are ready for harvest is to rely on visual cues. As hops mature, they undergo significant physical changes that are easy to spot with the naked eye. Here are some of the key visual signs to look out for:

Appearance: The hop cones should be plump and firm, with a noticeable increase in size compared to earlier stages of growth.

Color: The lupulin glands (responsible for hop oils and aroma) should turn a bright yellow color, indicating that they are at their most potent.



Touch and Smell

When it comes to determining the optimal time for hop harvest, visual cues are not the only indicators of ripeness. Evaluating the aroma and scent of the hops can also provide valuable information that contributes to the quality and flavor of the final product.

Texture: The hop cones should feel papery when gently squeezed, with a slight stickiness when rubbed between your fingers. This indicates that the hop has reached a high level of resin. If the cones are too firm or continue to feel dense, it may be too early to harvest.

Aroma and scent: Take a handful of hop cones and rub them between your palms. If they emit a strong and pungent aroma, it is a good sign that the hop oils and flavors are at their peak. Some of the most desirable hop aromas include floral, citrus, and herbal notes.

Remember, hop aroma and flavor are crucial elements in beer production, and assessing the maturity of the hops through touch and smell can help achieve optimal results.

Harvesting Methods

There are two primary methods for manually harvesting hops (picking by hand) or mechanical.

When picking by hand, wear gloves and long sleeves to avoid skin irritation from the hop plants. Cut the bines down from the top line and lay on a tarp. It is best to get the bines out of the sun as quickly as possible to avoid any excess heat. Gently pull the hop cones off the bines, or use pruning shears to cut away the desired flowers. Be careful not to damage the cones in the process.

If using a hop picking machine, follow the manufacturer's instructions carefully to avoid damage to the hops.



Mechanical Harvesting Options

Harvest Option	Initial Cost (USD)	Crew	Bines/Hr
Hand harvest	0	1	1
Crafty hop Plucker	5,000	1	30-60
Steenl and Hop Harvester 1000	11,800	1	120
Bine 3060	14,250	1-3	20-40
HopsHarvester.com	22,500	2-3	120
Wolverine	29,990	2-3	120
UVM Mobile – Open Source	30,000	4	60-120
Wolf WHE 140	30,000	3	140
Wolf WHE 170	43,500	3	170

Drying

Hops need to be processed as quickly as possible. Once hops are picked, they need to be used or dried within forty-eight hours. Some brewers will use wet hops to create a seasonal beer. If your hops are not dried their efficacy wanes quickly. The lupulin, alpha acids, and beta acids are destroyed by oxygen and heat.



The drying process is a delicate one. Drying them too quickly at too high a temperature or not enough and they are destroyed. If you dry your hops too much they will fall apart and the lupulin will

disintegrate. If the hops are not dry enough, they will oxidize, turn brown and mold, or possibly spontaneously combust. The goal is to dry your cones to a moisture level between 8-10 %. You can achieve this by drying your cones in an environment that is approximately 128 degrees over a period of eight hours. You do not want your hops to get over 160 degrees, this is when you start to break down their oils and acids.

There are several ways you can check the moisture content of your hops to ensure you achieve the desired moisture percentage. There are digital hops moisture meters that take the math out of the process, but are expensive.

Then there is the weights and measures method. Generally, freshly harvested hops have moisture levels between 76-84%. The moisture level needs to be reduced to 8-10%:

- 1.) Start by weighing your sample.
- 2.) Use a dehydrator to dry your sample
- 3.) Weigh your sample throughout the process until the weight no longer changes. This is your bone-dry or dry matter weight.
- 4.) The difference between your starting weight and bone-dry weight is the amount of weight that needs to be removed to reach bone dry.
- 5.) You can use this weight to determine the weight that needs to be removed to obtain an 8-10% moisture content. Make sure that the Oast box sample, that you continually monitor, is near the middle of your drying apparatus so that it is representing the full harvest accurately. If you place your Oast box sample on the edges it may dry quicker than the rest of the harvest. Below is an example of the equation.

Example of percent moisture calculation:

Wet hop sample of 100 grams including the container. The container weighs 5 grams. After achieving 'bone dry' the sample weighs 25 grams including the container. Subtract the weight of the container from the dried sample.

$$\begin{aligned} 25 \text{ grams} - 5 \text{ grams} &= 20 \text{ grams (weight of sample)} \\ 1 - [(20/100) \times 100] &= \text{percent moisture} \\ 1 - [(20/100) \times 100] &= 80 \% \text{ moisture} \end{aligned}$$

Example of calculation of weight based on target moisture:

Calculate the weight needed with the desired percent moisture content (8-10%).

Dry weight/[1-(percent moisture desired/100)] = targeted weight

10%:

$$20 \text{ g}/[1-(10/100)] = 20 \text{ g}/(1 - .10) = 20 \text{ g}/0.9 = 22.2 \text{ g (target weight for 10\% moisture content)}$$

8%:

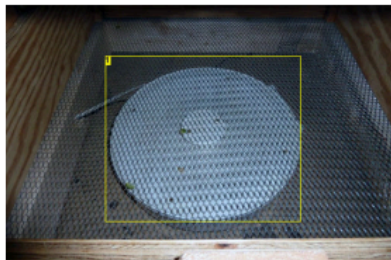
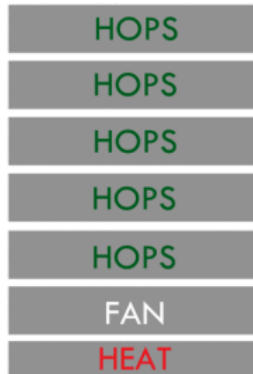
$$20 \text{ g}/[1-(8/100)] = 20 \text{ g}/(1 - .08) = 20 \text{ g}/0.92 = 21.7 \text{ g (target weight for 8\% moisture content)}$$

The original 100 gram sample should weigh between 21.7-22.2 grams to achieve 8-10% moisture content.

A reasonable expectation is a 4:1 reduction in weight. If you start with four pounds of hops then you can expect to have one pound of hops dried to 8% moisture content.

Traditionally hops are dried in Oast houses or Oast boxes. For a small scale grower, we recommend an Oast box.

Small Scale Oast Box



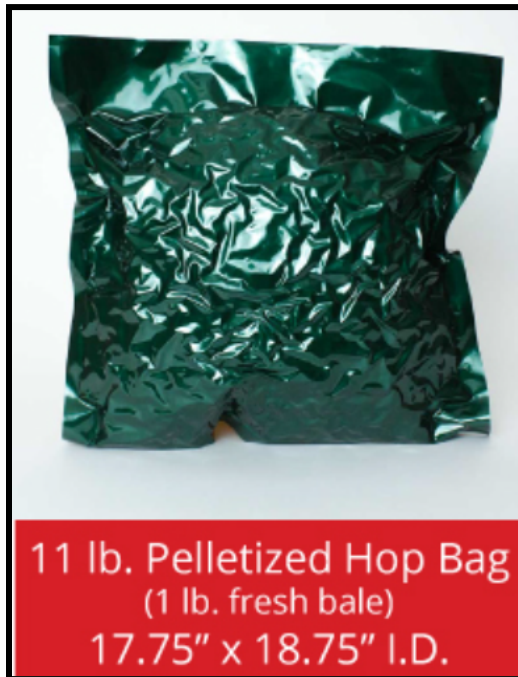
Building your own oast box like the one above is simple with some basic hand tools and knowledge. You can find a free 12-page PDF with step-by-step instructions with pictures at the following link.

Oast Box Instructions <https://www.instructables.com/Hop-drying-oast/>

Comprehensive Hops Analysis

A comprehensive hops analysis is required by most brewers, think of it as a recipe card. It is the baseline for quality control. Comprehensive hops analysis includes terpene, and thiol analysis, aroma analysis, alpha acids, beta acids, total volatile oils, iso-alpha, moisture content, and dry matter assessment.

Storing Dry Hops



Hop Pellets

Pellet hops are the most common way to store hops for breweries, because they allow the hops to be easily transported, measured, used, and stored. Pellets are packaged in a nitrogen-flushed pouch that has been vacuum-sealed for maximum storage length. This eliminates any issues with oxidation and the preservation of the pellet.

Properly vacuum-sealed pellet hops can last up to five years inside the freezer and up to four years in the refrigerator. Vacuum-sealed whole dry hops, meanwhile, will last up to two years in the freezer and six months in the refrigerator. After that amount of time, the aroma and flavor of the hops will start to degrade significantly.

Dried Whole Hops

Hops are dried immediately after they are picked and then put into a vacuum-sealed container for longer-term storage. To store whole hops for any length of time they will need to be dried and frozen as quickly as possible. These can be sealed in the same nitrogen-flushed packages as the hop pellets for a slightly longer storage.

Properly vacuum-sealed, whole dry hops should keep their bitterness and flavor for up to two years in the freezer, six months in the fridge, and about a week at room temperature. After that, the hops will degrade quickly and could even start to mold or ruin.



APPENDIX



Varietal Study

The NE SARE 'Hopping on Hops' varietal research study was conducted by the West Virginia Food and Farm Coalition, analyzing six market identified hops varieties and their proficiency in West Virginia. Varieties studied were Cashmere, Centennial, Comet, Saaz 72, Triumph, and Zeus. The results of the trial suggest that Comet, Saaz 72, and Zeus are the most proficient out of the six varieties tested.

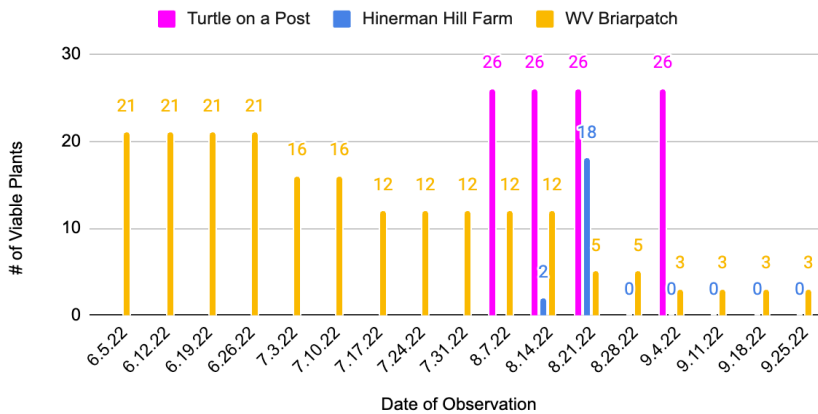
Cashmere 2022/2023

Planting Date:

- 6.11.22 WV Briarpatch
- 6.04.23 WV Briarpatch
- 6.13.22 Turtle on a Post
- 6.25.22 Hinerman Hill Farm
- 8.13.22 Mountain Life Farm

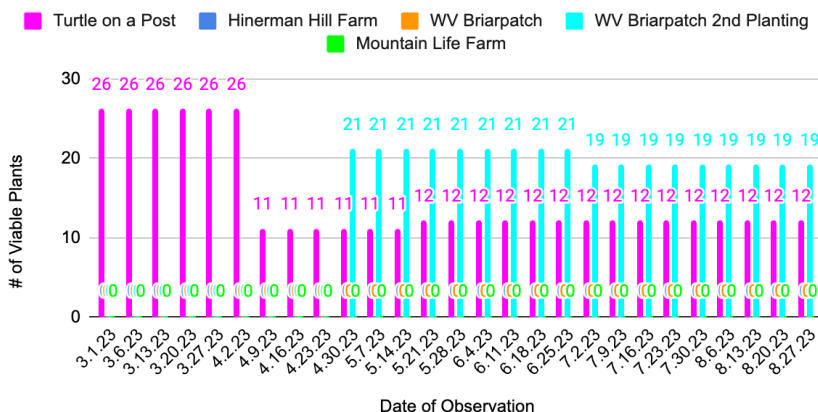
2022

Cashmere: # of Viable Plants (All sites received 27 plants per variety)

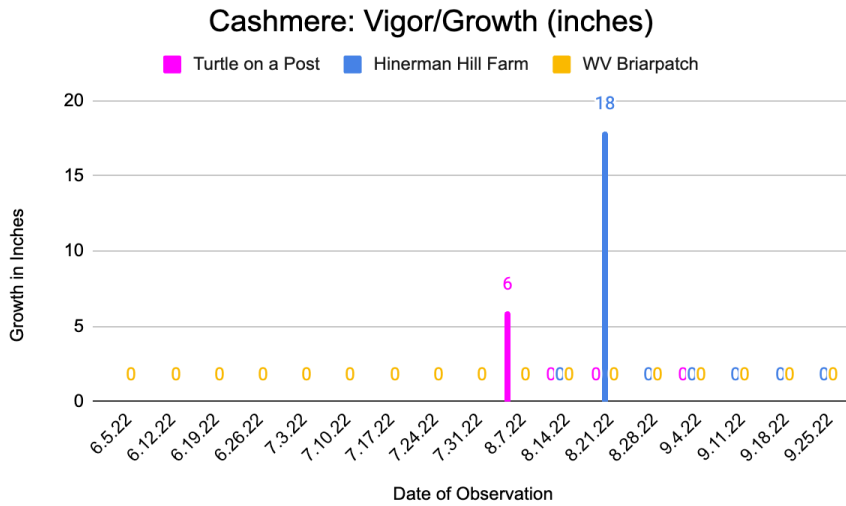


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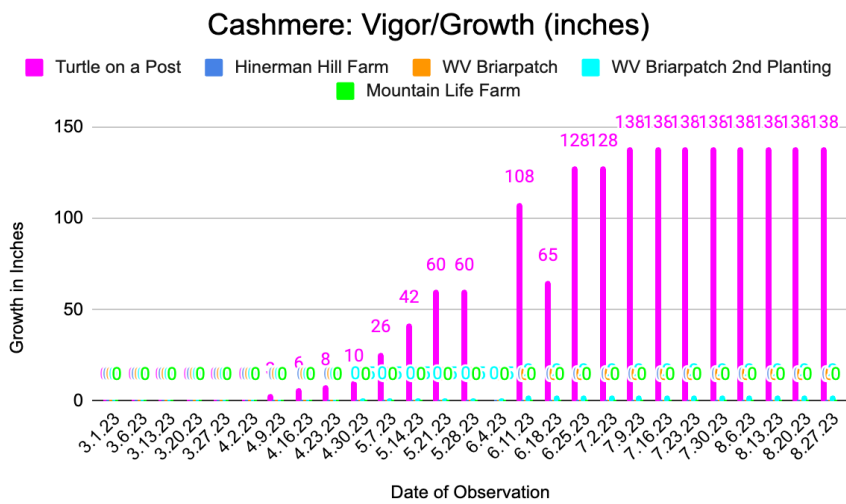
Cashmere: # of Viable Plants (All sites received 27 plants per variety)



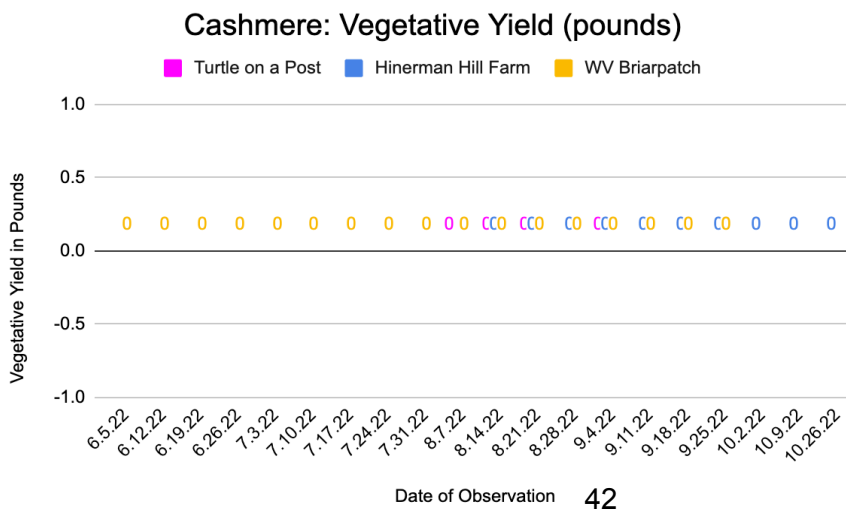
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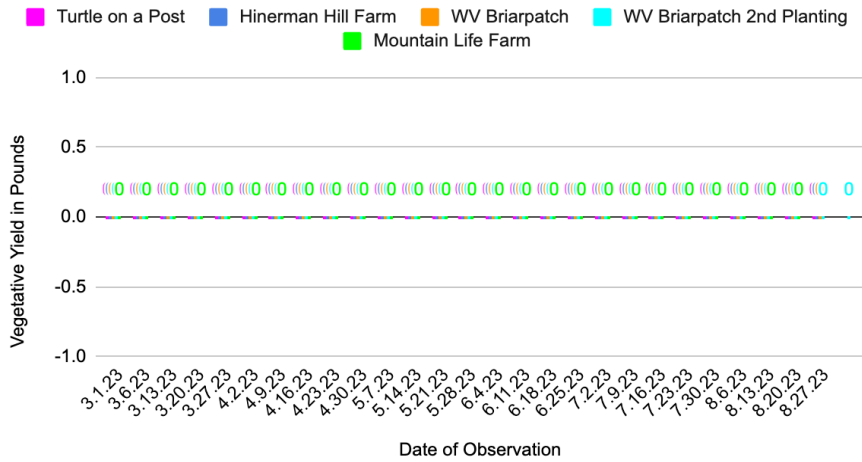


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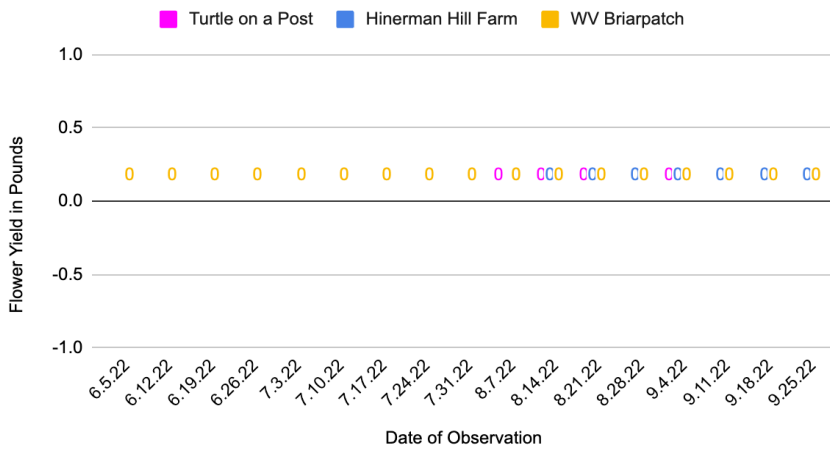
2023

Cashmere: Vegetative Yield (pounds)



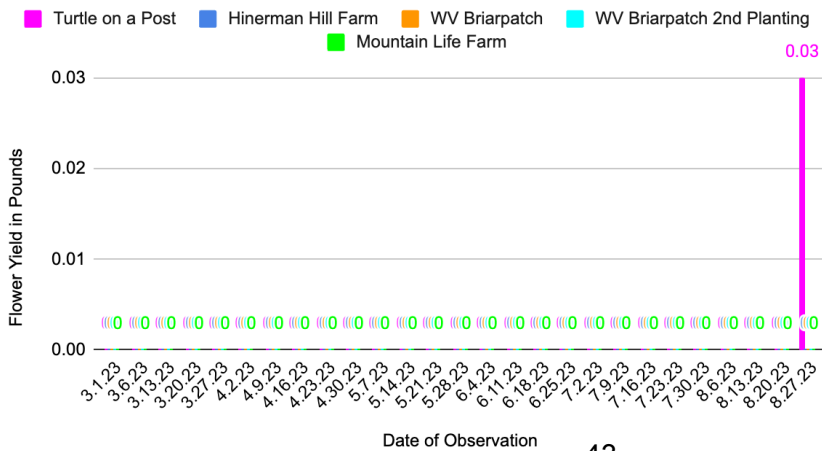
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Cashmere: Flower Yield (pounds)



2023

Cashmere: Flower Yield (pounds)



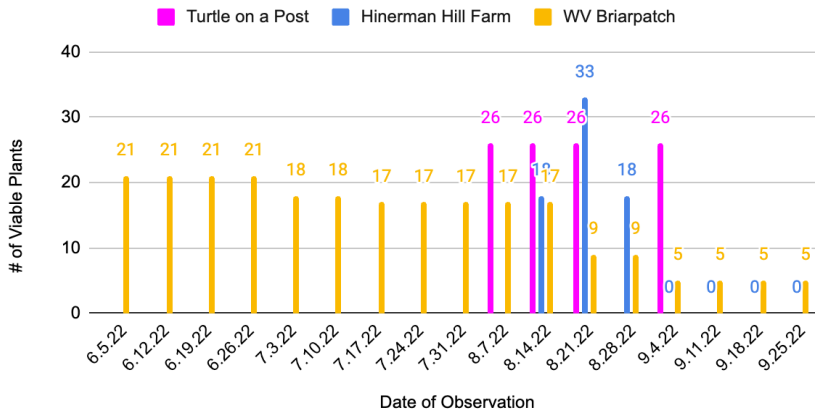
Centennial 2022/2023

Planting Date:

- 6.11.22 WV Briarpatch
- 6.04.23 WV Briarpatch
- 6.13.22 Turtle on a Post
- 6.25.22 Hinerman Hill Farm
- 8.13.22 Mountain Life Farm

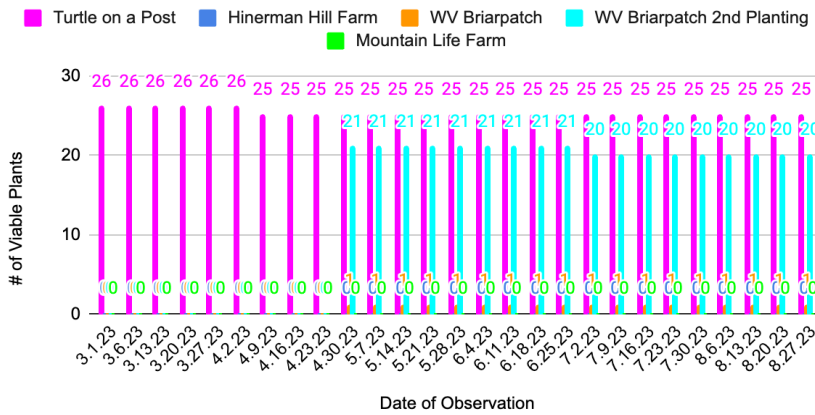
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Centennial: # of Viable Plants (All sites received 27 plants per variety)

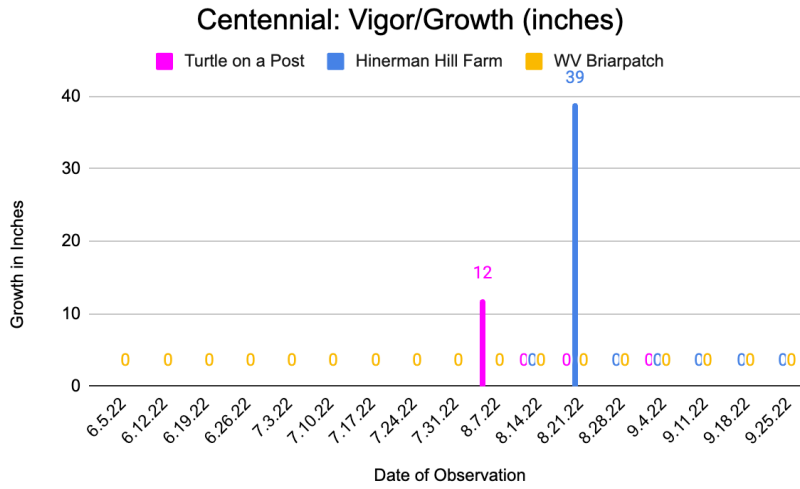


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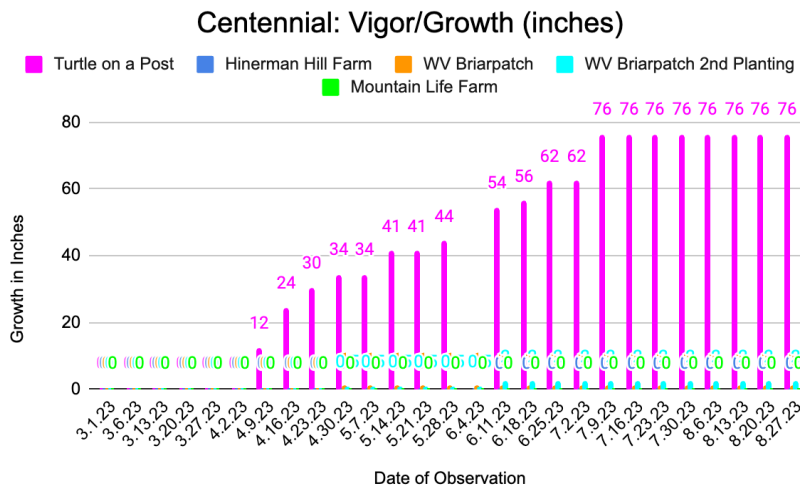
Centennial: # of Viable Plants (All sites received 27 plants per variety)



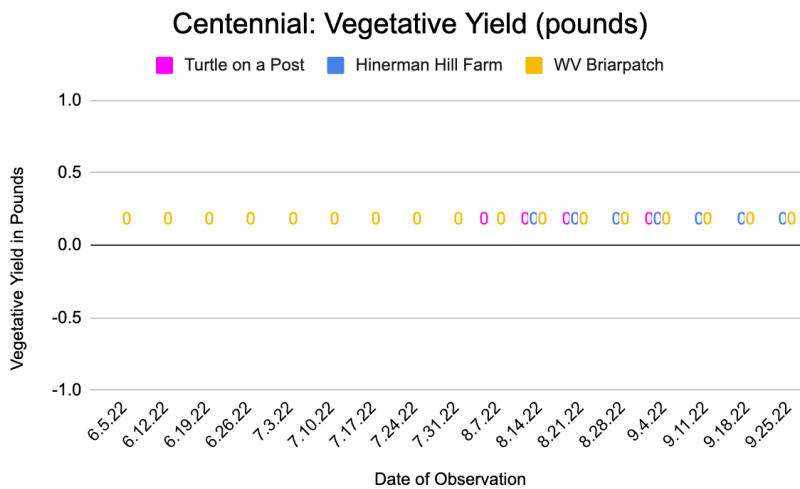
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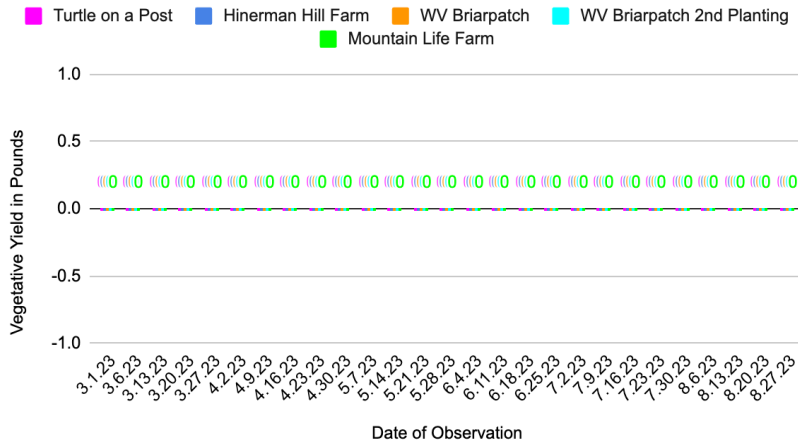


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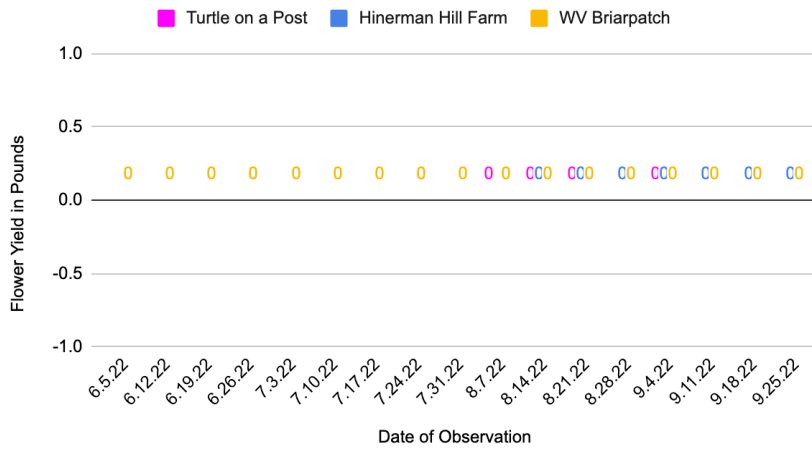
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Centennial: Vegetative Yield (pounds)



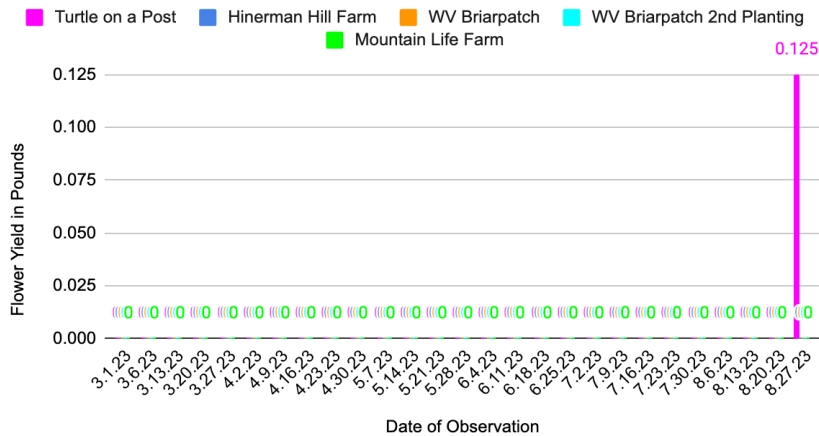
2022

Centennial: Flower Yield (pounds)



2023

Centennial: Flower Yield (pounds)



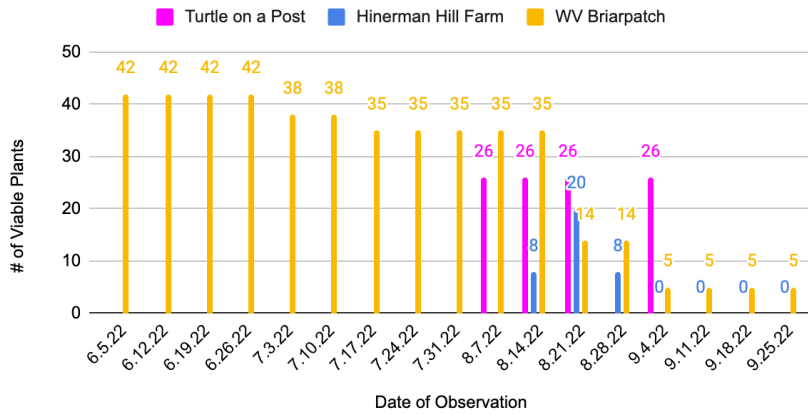
Comet 2022/2023

Planting Date:

- 6.11.22 WV Briarpatch
- 6.04.23 WV Briarpatch
- 6.13.22 Turtle on a Post
- 6.25.22 Hinerman Hill Farm
- 8.13.22 Mountain Life Farm

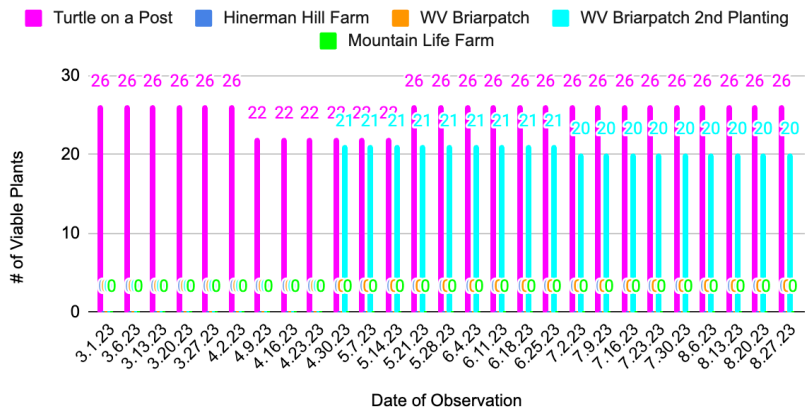
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Comet: # of Viable Plants (All sites received 27 plants per variety)

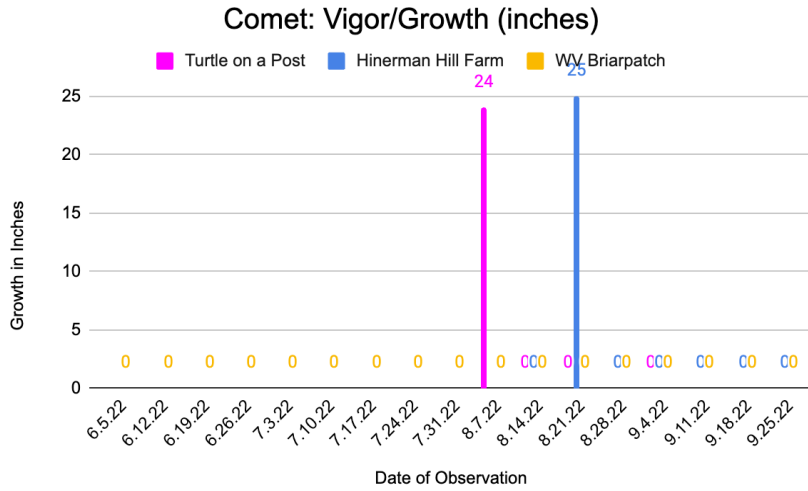


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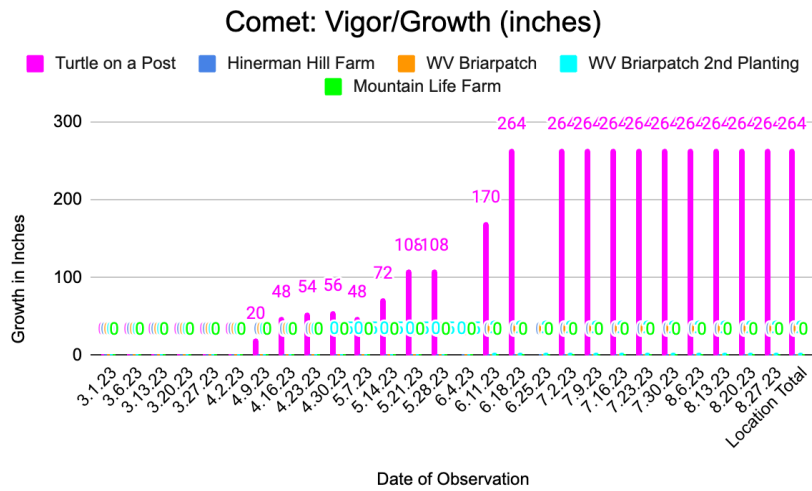
Comet: # of Viable Plants (All Sites received 27 plants per variety)



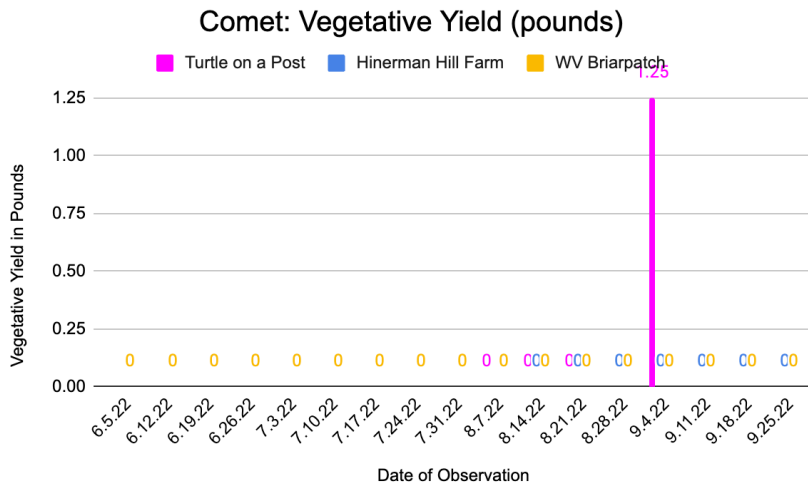
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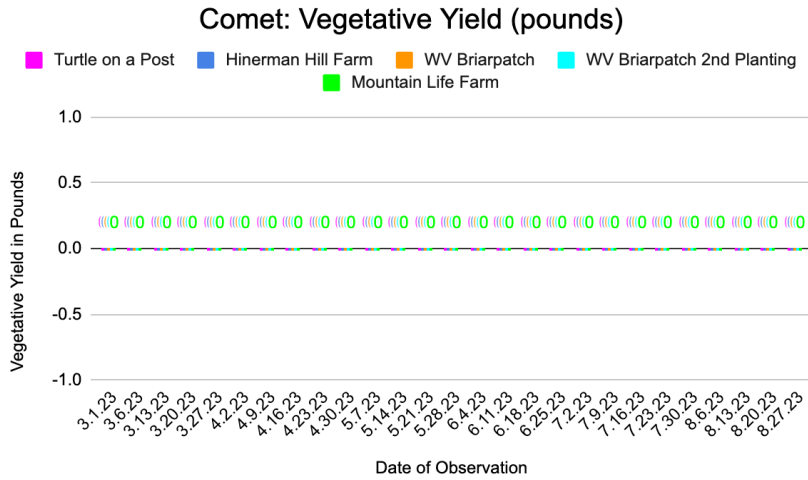
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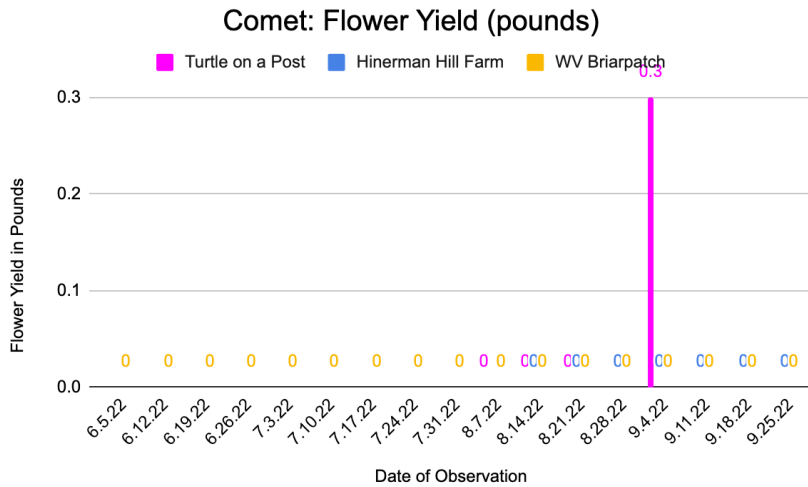
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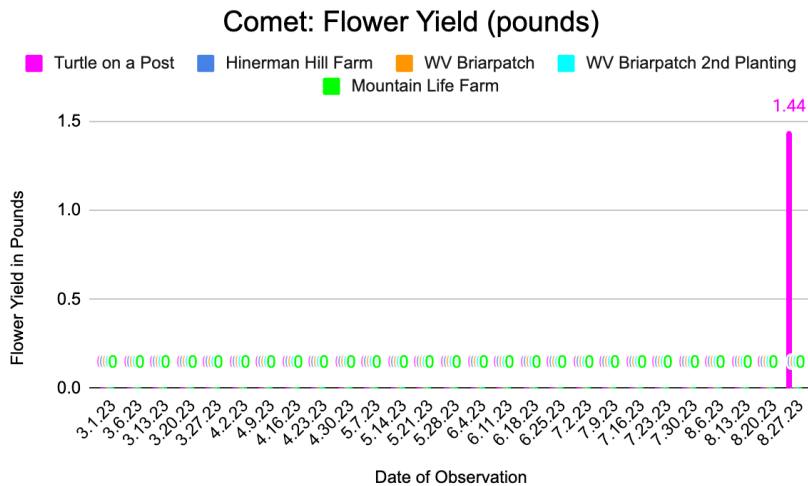
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2022



2023



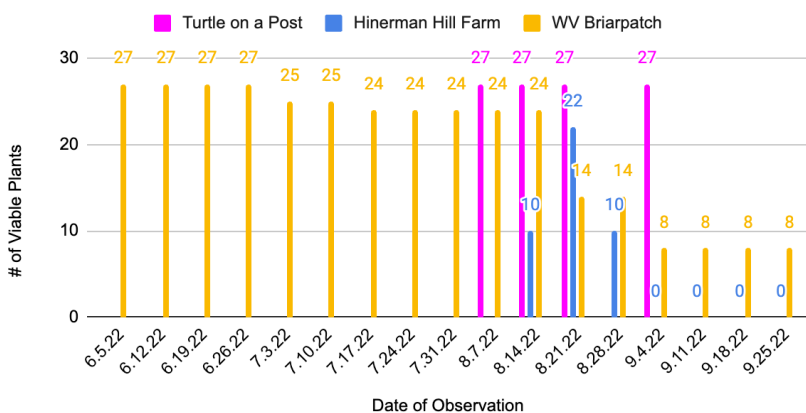
Saaz 72 2022/2023

Planting Date:

- 6.11.22 WV Briarpatch
- 6.04.23 WV Briarpatch
- 6.13.22 Turtle on a Post
- 6.25.22 Hinerman Hill Farm
- 8.13.22 Mountain Life Farm

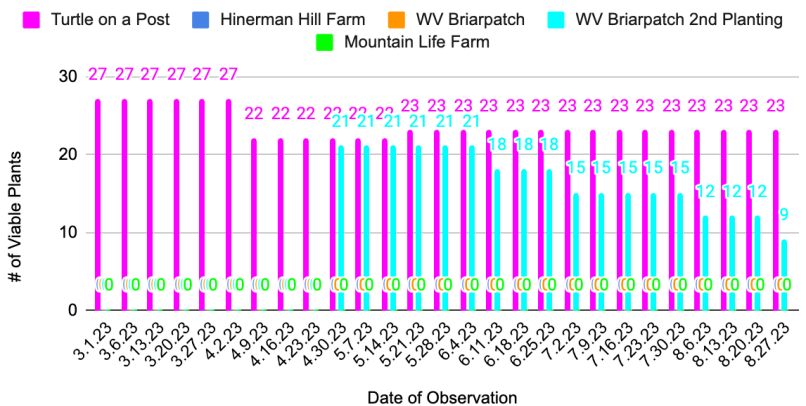
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Saaz 72: # of Viable Plants (All sites received 27 plants per variety)

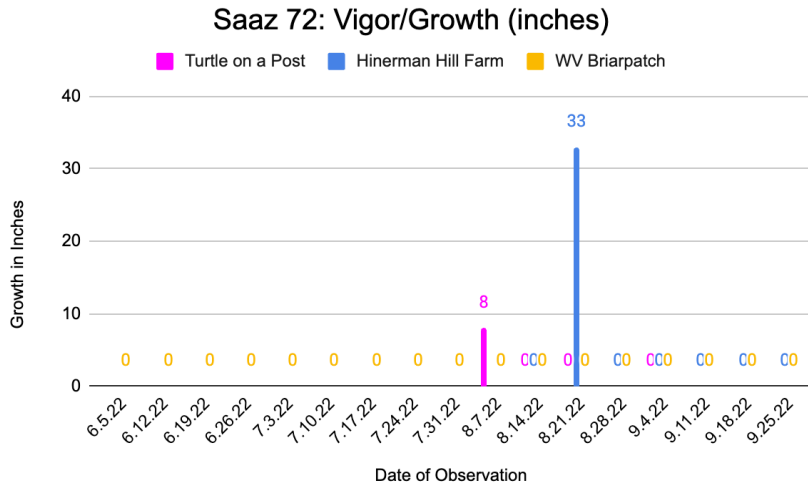


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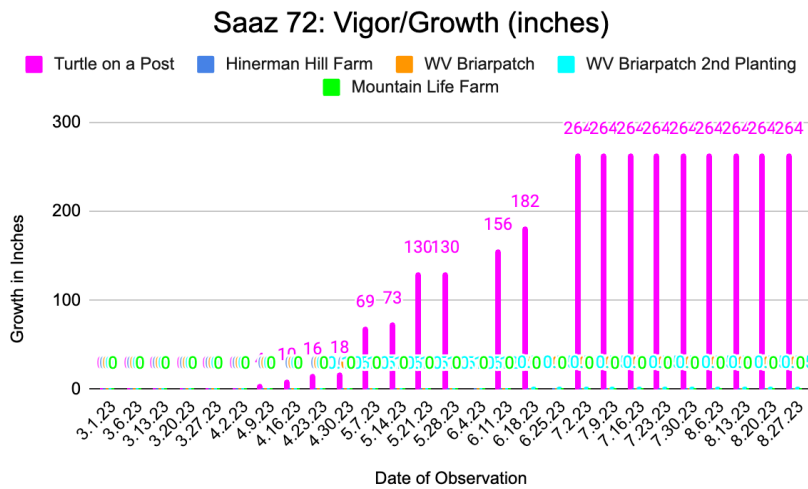
Saaz 72: # of Viable Plants (All sites received 27 plants per variety)



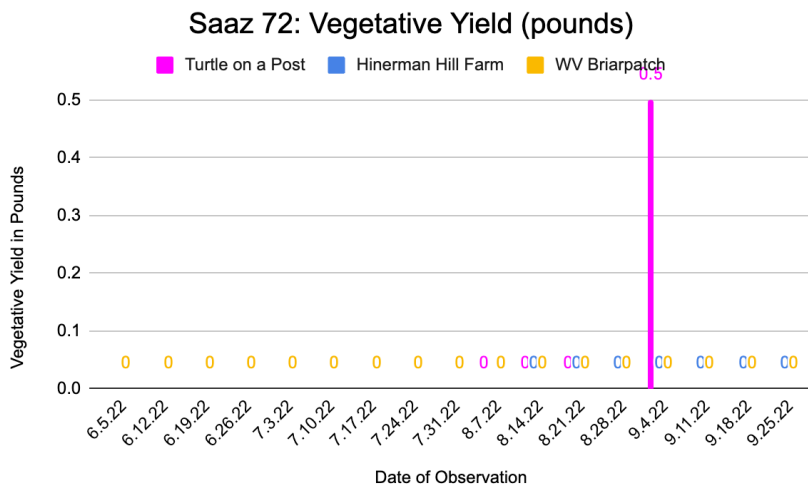
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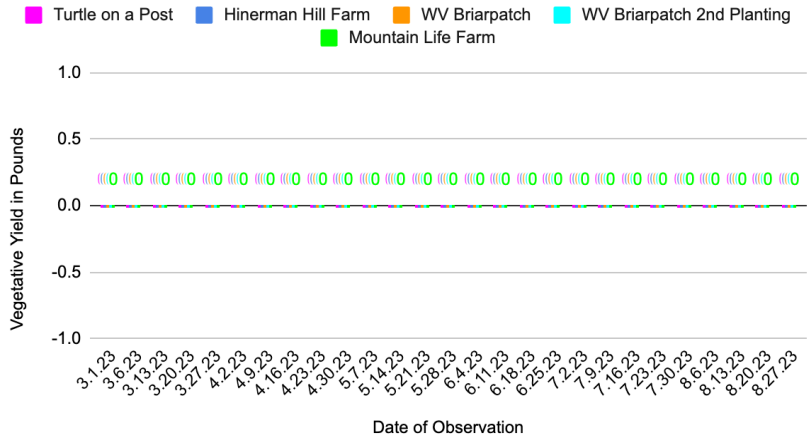


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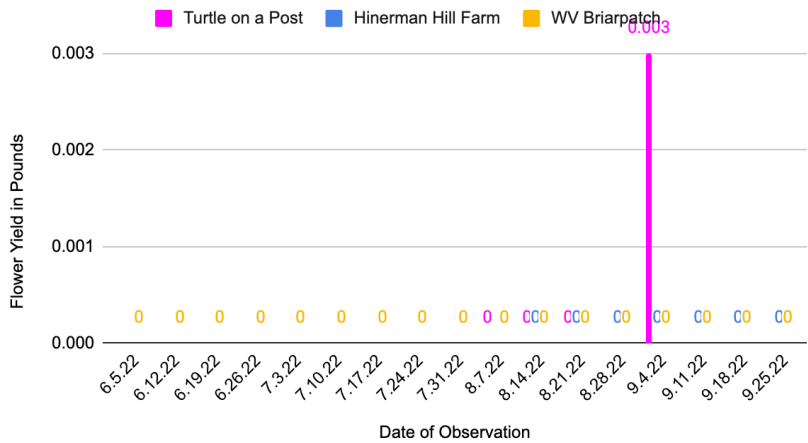
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Saaz 72: Vegetative Yield (pounds)



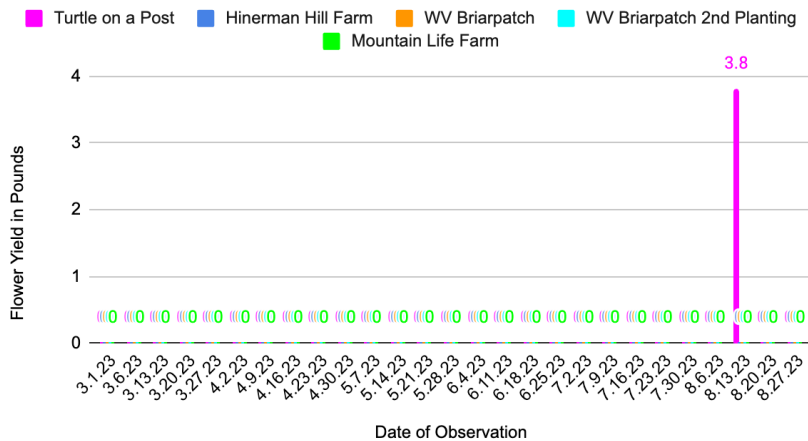
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Saaz 72: Flower Yield (pounds)



2023

Saaz 72: Flower Yield (pounds)



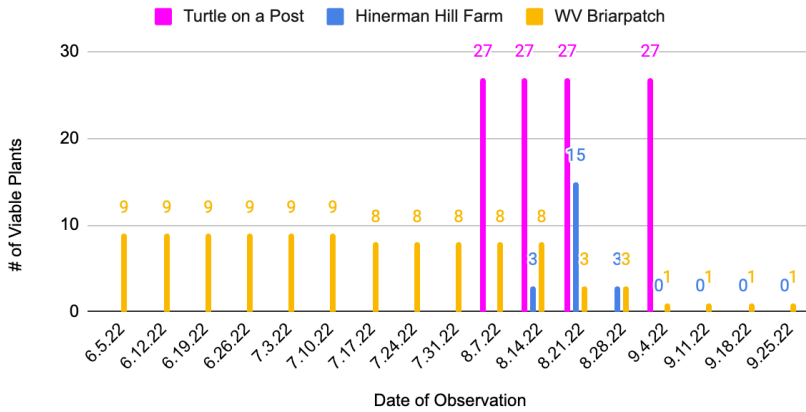
Triumph 2022/2023

Planting Date:

- 6.11.22 WV Briarpatch
- 6.04.23 WV Briarpatch
- 6.13.22 Turtle on a Post
- 6.25.22 Hinerman Hill Farm
- 8.13.22 Mountain Life Farm

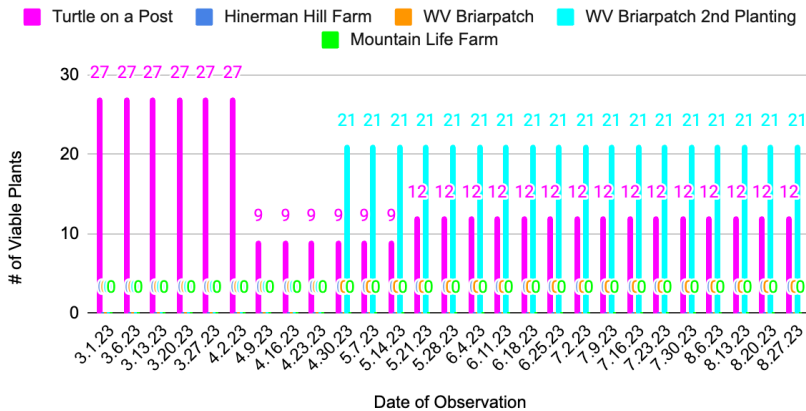
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Triumph: # of Viable Plants (All sites received 27 plants per variety)

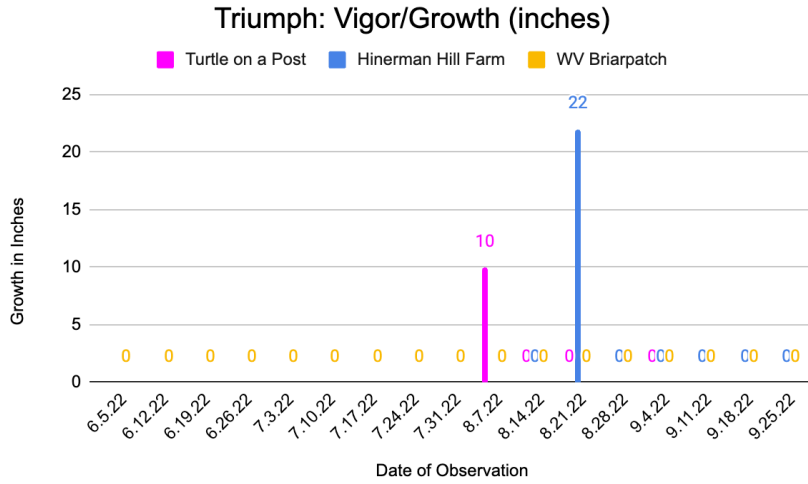


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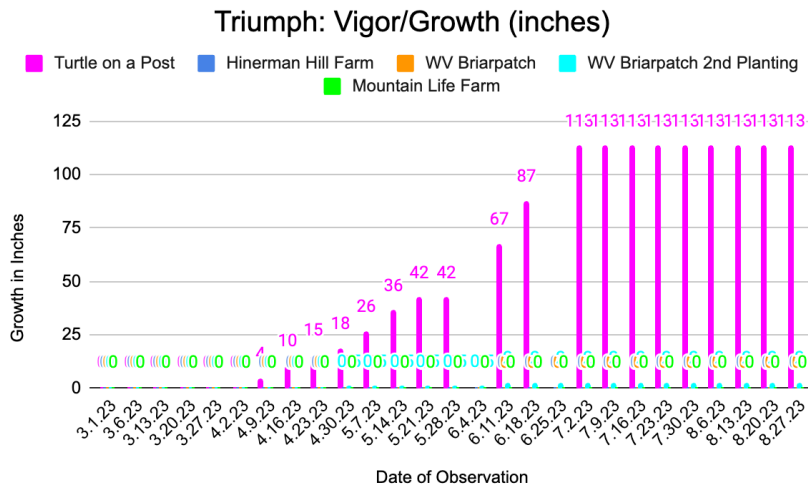
Triumph: # of Viable Plants (All sites received 27 plants per variety)



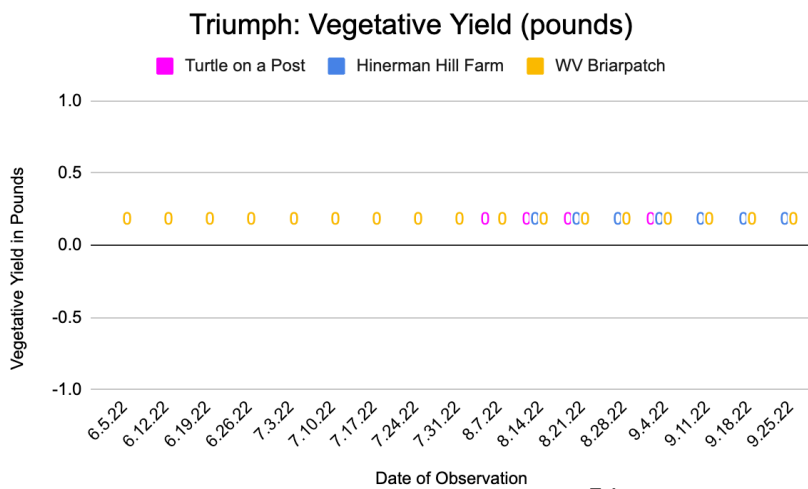
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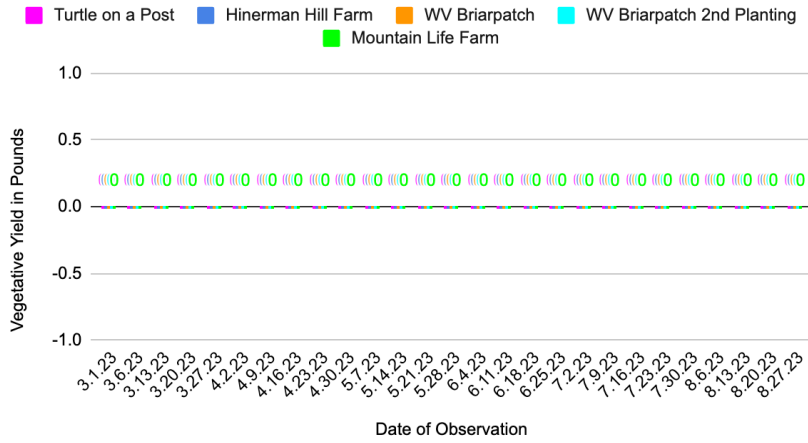


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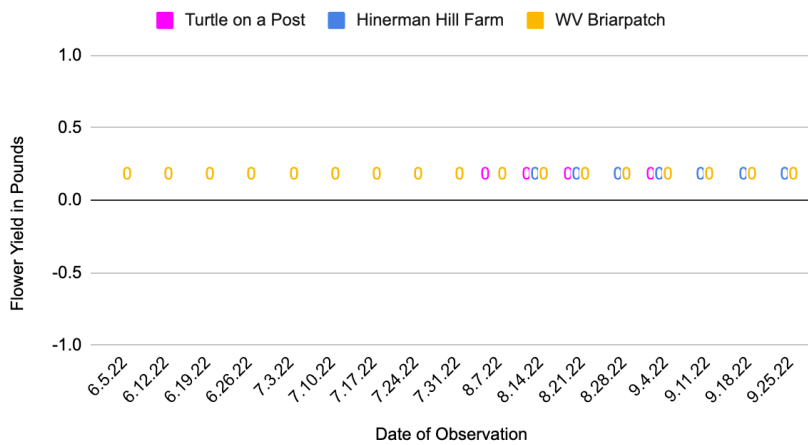
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Triumph Vegetative Yield (pounds)



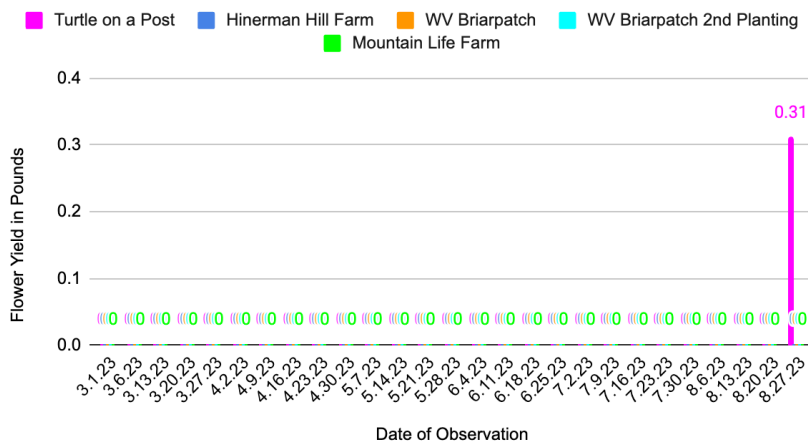
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Triumph: Flower Yield (pounds)



2023

Triumph: Flower Yield (pounds)



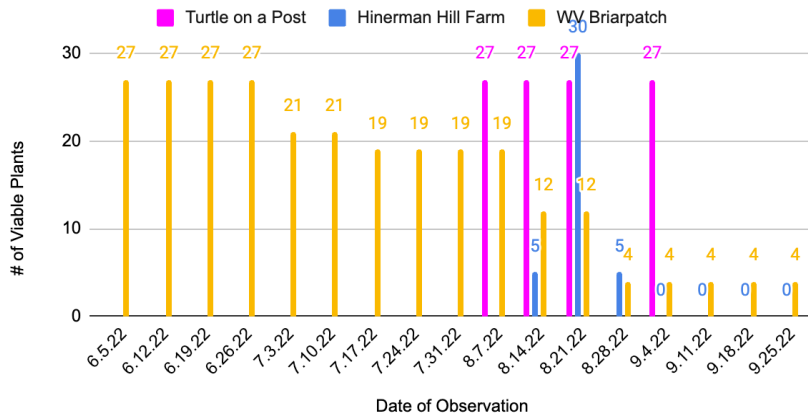
Zeus 2022/2023

Planting Date:

- 6.11.22 WV Briarpatch
- 6.04.23 WV Briarpatch
- 6.13.22 Turtle on a Post
- 6.25.22 Hinerman Hill Farm
- 8.13.22 Mountain Life Farm

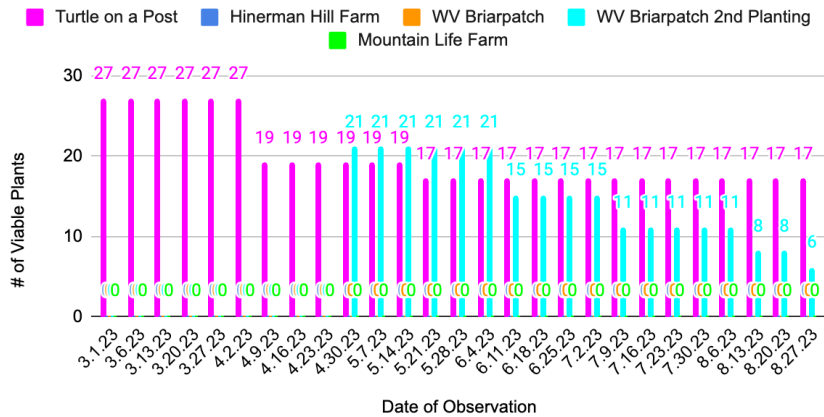
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Zeus: # of Viable Plants (All sites received 27 plants per variety)

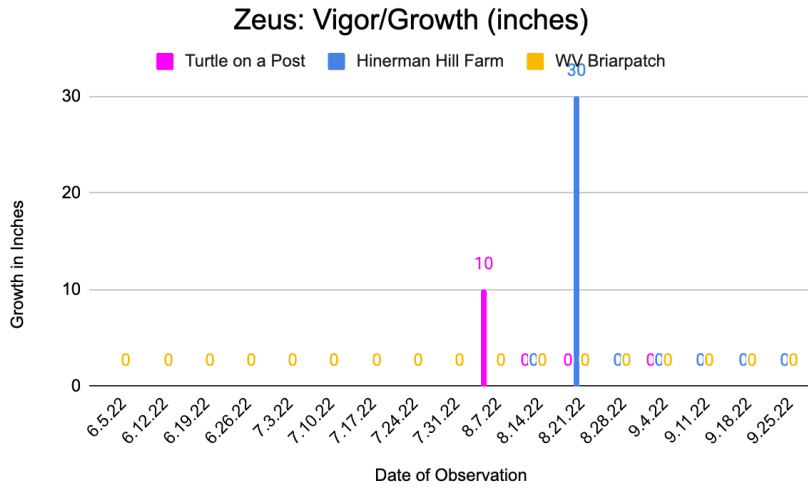


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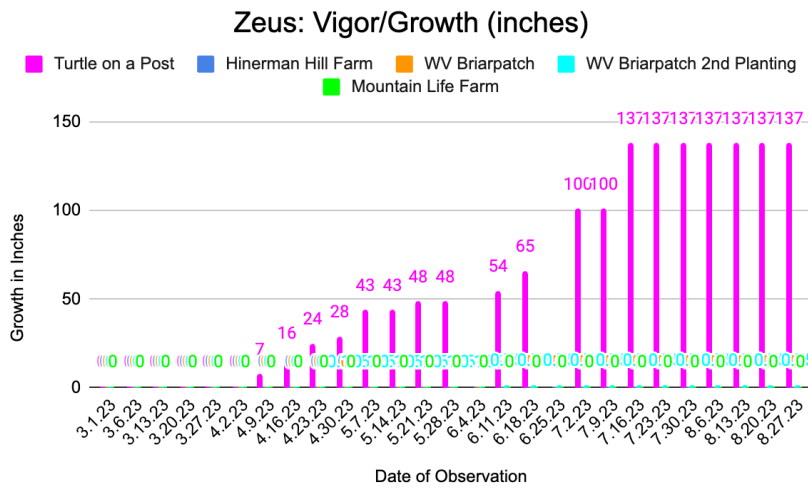
Zeus: # of Viable Plants (All sites received 27 plants per variety)



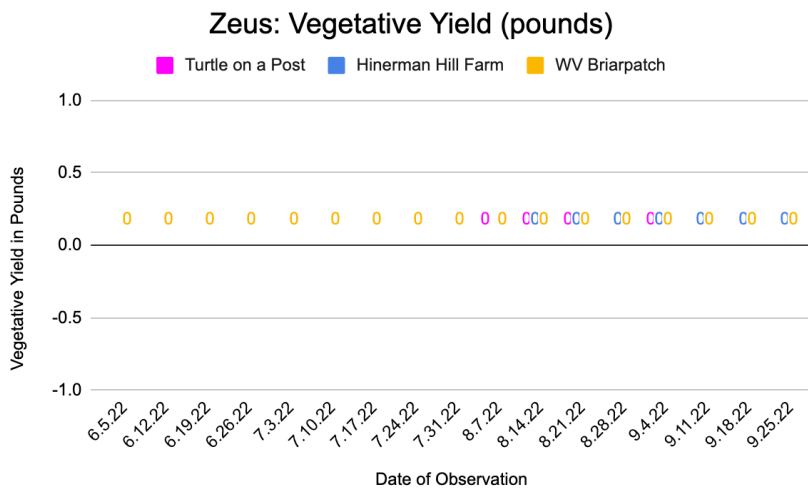
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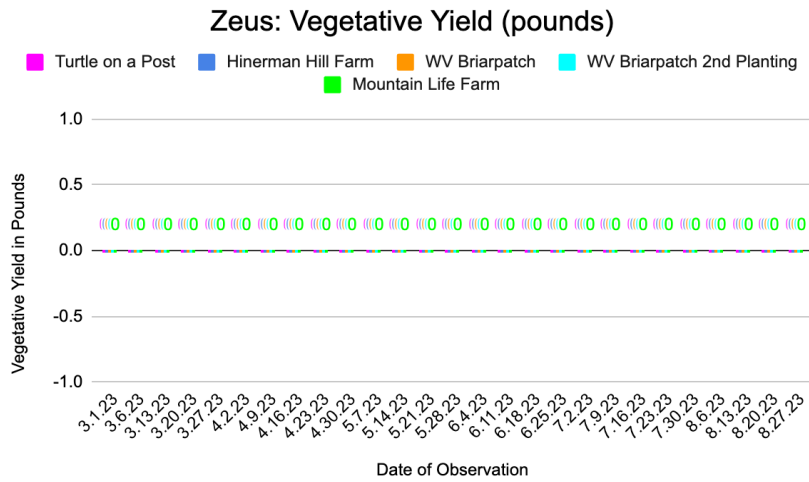
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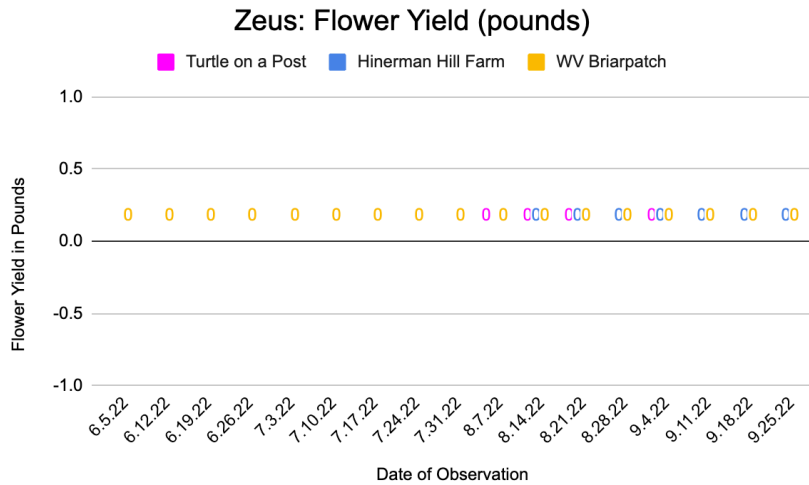
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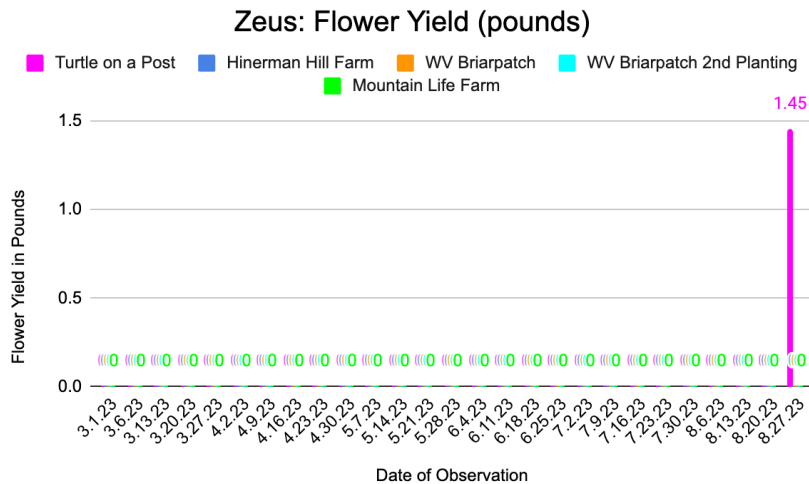
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2022



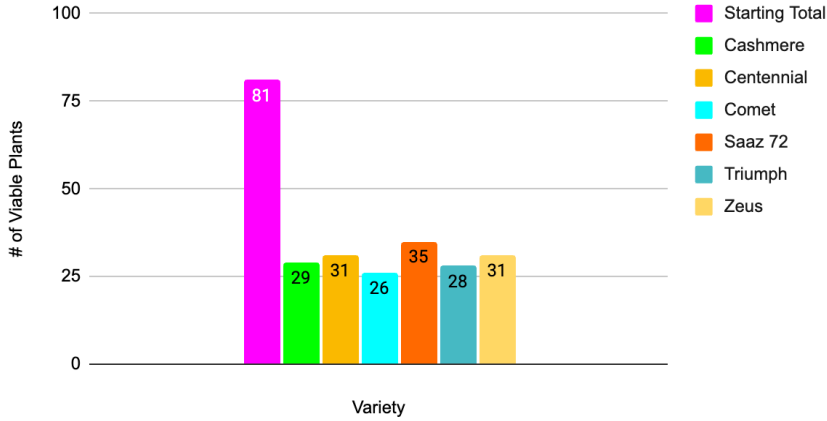
2023



Varietal Comparison 2022/2023

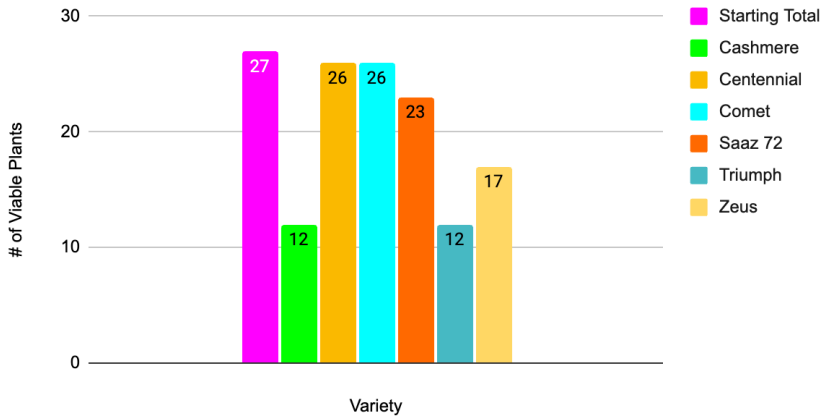
2022

Variety Comparison: # of Viable Plants (81 plants in total amongst 3 sites)



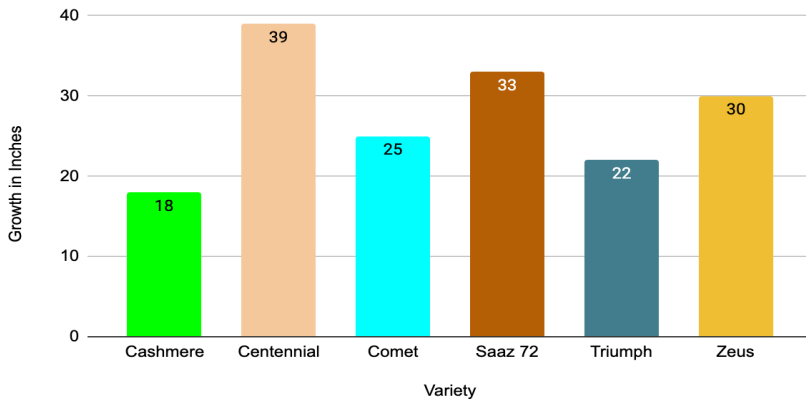
2023

Variety Comparison: # of Viable Plants (27 plants per variety at each site)

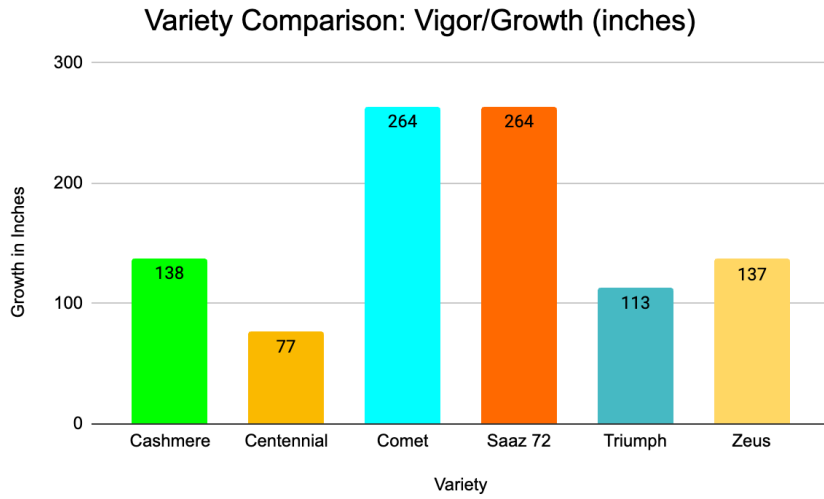


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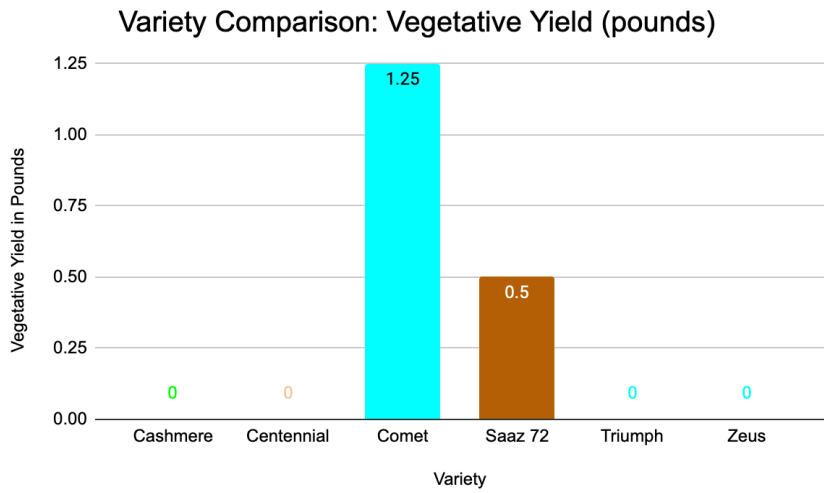
Variety Comparison: Vigor/Growth (inches)



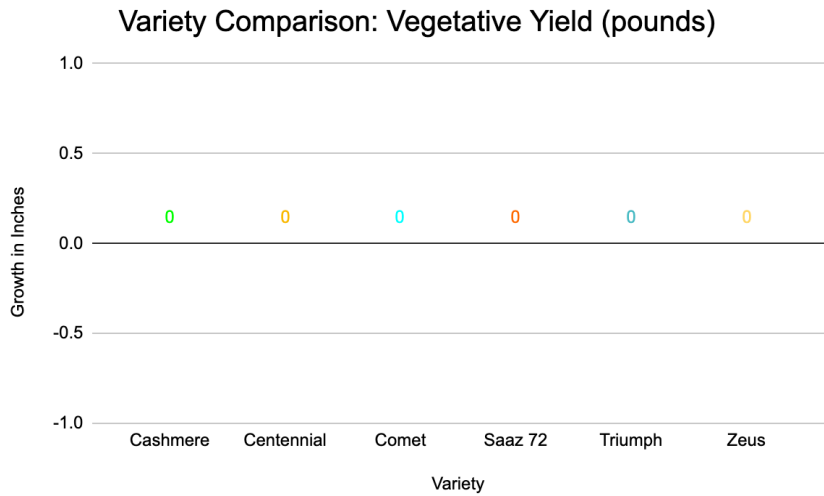
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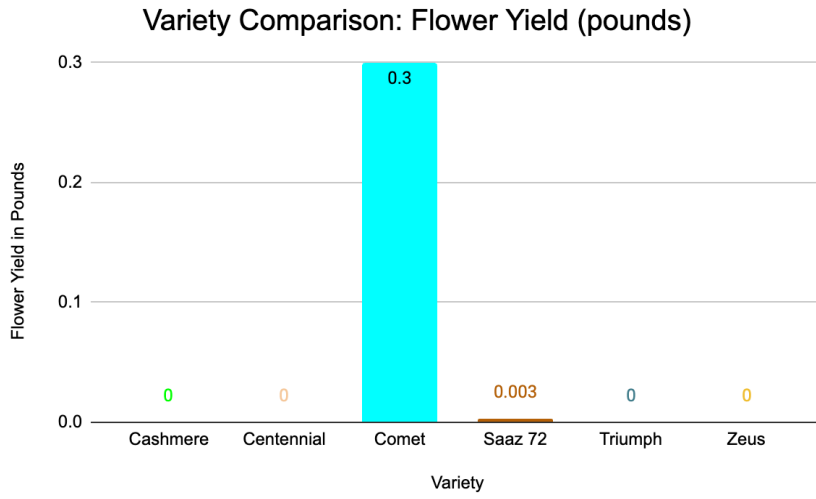
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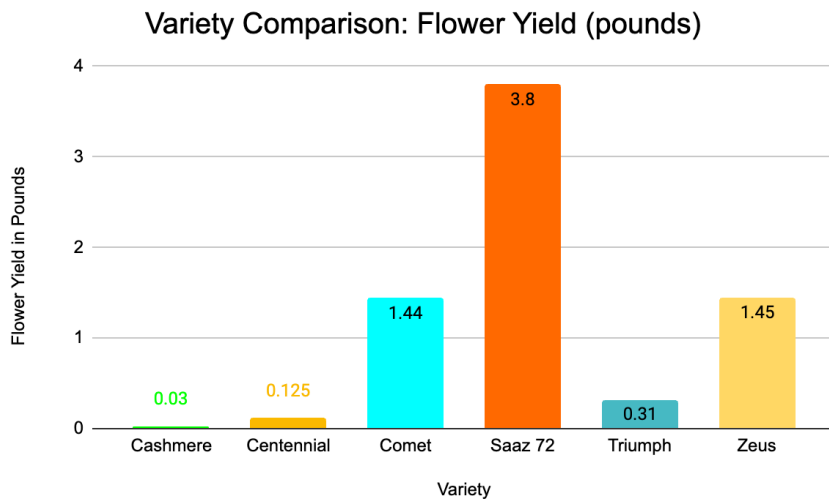
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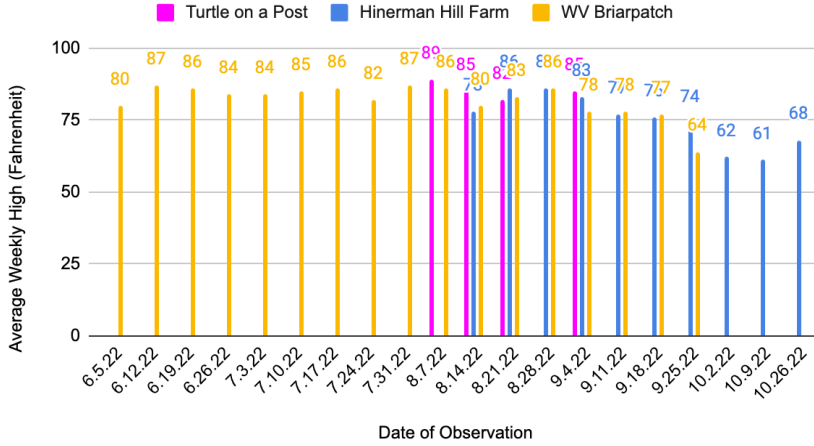
2023



Weather and Climate Data 2022/2023

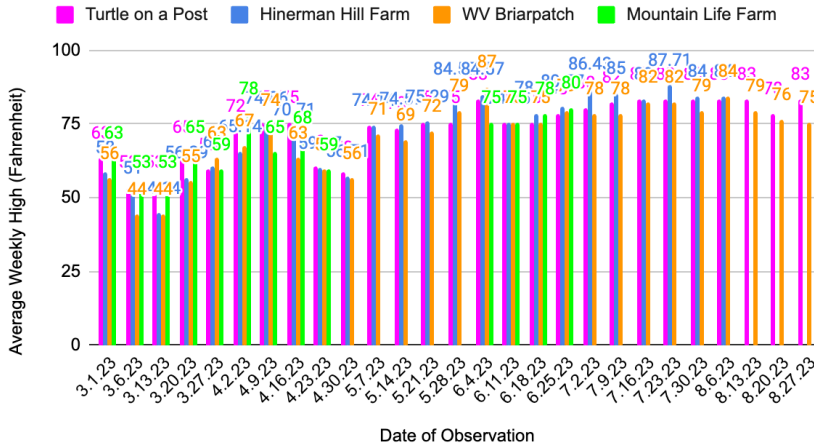
2022

Weather & Climate Data: Average Weekly High



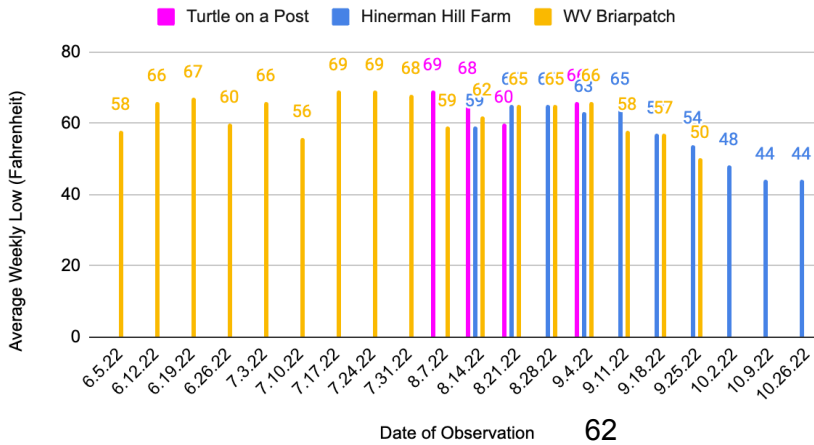
2023

Weather & Climate Data: Average Weekly High

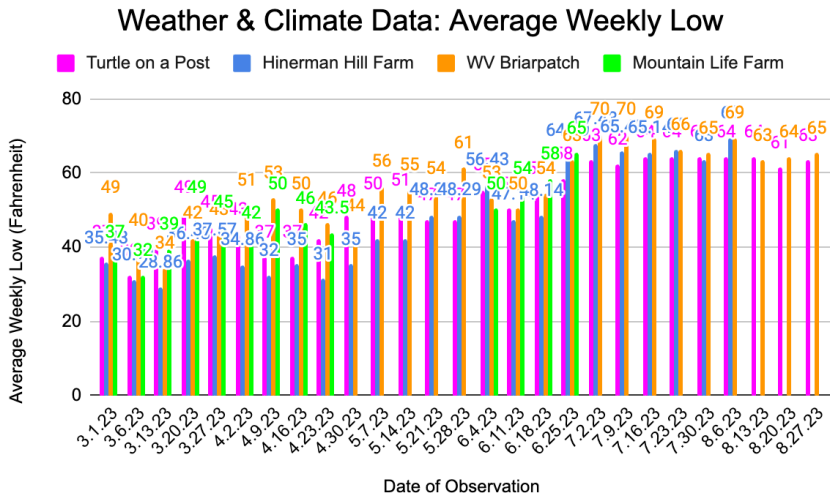


2022

Weather & Climate Data: Average Weekly Low

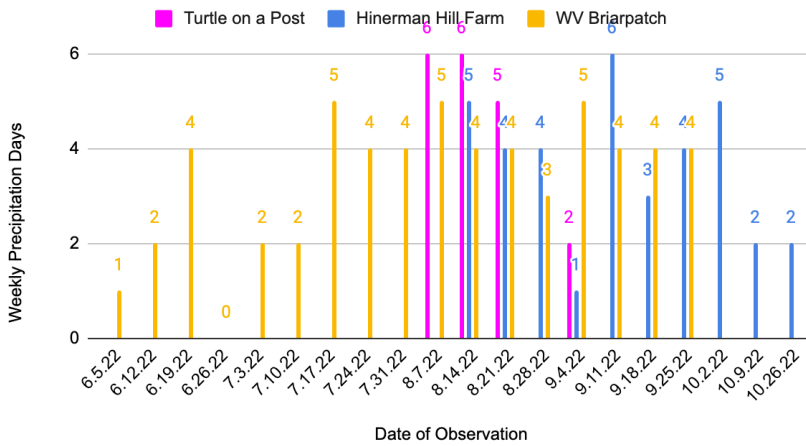


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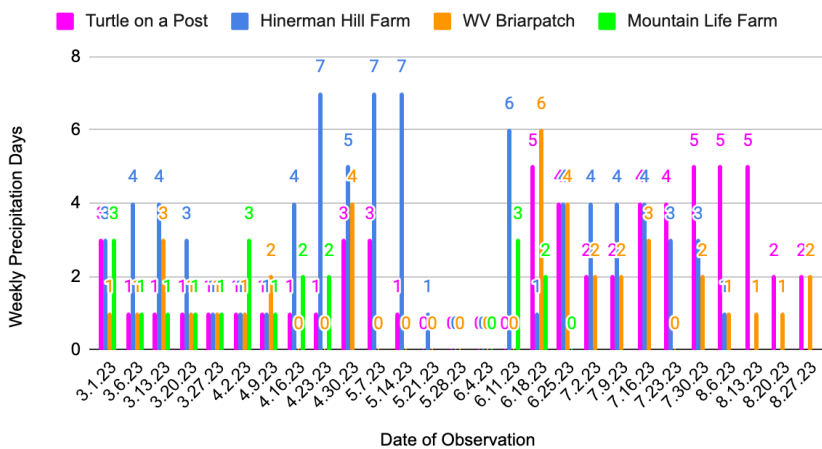
2022

Weather & Climate Data Precipitation Days (out of 7 days)



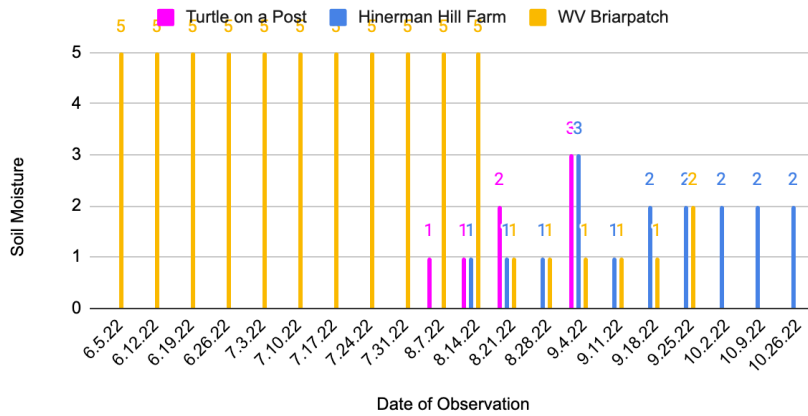
2023

Weather & Climate Data Precipitation Days (out of 7 days)



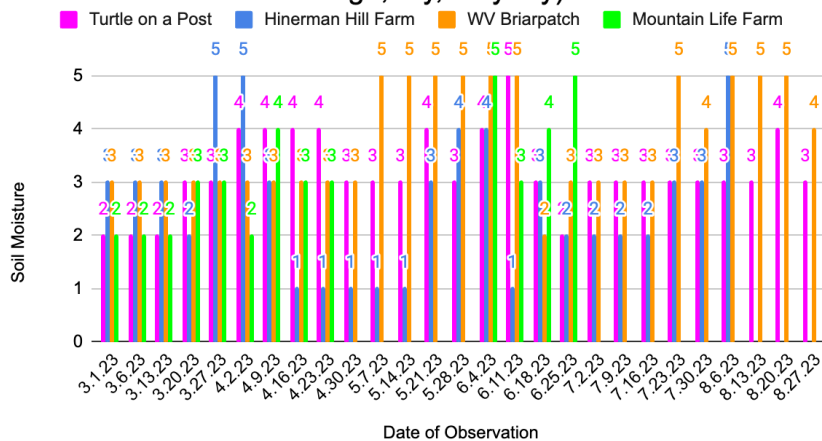
2022

Weather & Climate Data: Soil Moisture (1-5 saturated, wet, average, dry, very dry)



2023

Weather & Climate Data: Soil Moisture (1-5 saturated, wet, average, dry, very dry)



Locations 2022/ 2023				
	Turtle on a Post	Hinerman Hill Farm	WV Briarpatch	Mountain Life Farm
Address	157 Middletown Rd, Shinnston WV Harrison Co.	2412 Little Sandy Rd. Bruceeton Mills, WV Preston Co	6371 Saltwell Rd. Bridgeport, WV Harrison Co	1194 Sugar Camp Rd. Shinnston, WV Harrison Co
Latitude/Longitude	39.372794,-80.20299 1	39.61656, -79.665690	39.344110, -80.228130	39.36515, -80.229240
Elevation	1,002.19'	1876.6'	1083.7'	1,211.3'
Growing Zone	6a	6a	6a	6a

Pest and Disease Pressure 2022/2023:

Pest and Disease Pressure 2022:

- Turtle on a Post:
 - Pest:
 - 9.4.22 caterpillars on Comet and Saaz 72 varieties. Cashmere appears dead.
 - Measure Taken:
 - Disease:
- Hinerman Hill Farm:
 - Pest:
 - 8.14.22-9.4.22 Japanese Beetles. They ate the leaves down to the bine. The bines appeared like woody sticks and were defoliated.
 - Measure Taken: inoculated milky spore to soil.

Pest and Disease Pressure 2023:

- Turtle on a Post:
 - Pest:
 - 7.2.23 Japanese beetles and caterpillars
 - Measure Taken: pulled most of the damage off, plucking pests off plants
 - 8.13.23 spider mites
 - Disease:
 - 6.4.23 downy mildew
 - Measure Taken: stripped off infected leaves, sprayed neem oil
 - 6.11.23 downy mildew
 - Measure Taken: sprayed LAB (Lactic Acid Bacteria)
 - 6.18.23 downy mildew
 - Measure Taken: sprayed LAB (Lactic Acid Bacteria), last spraying of LAB, hops are starting to burr
 - 6.25.23 downy mildew
 - Measure Taken: pulled off most of the infected leaves, Triumph: had the least amount of downy mildew, Zeus: had the worst amount of down mildew
- Mountain Life Farm:
 - Pest:
 - 4.9.23 Prevention Measure: applied milky spore and nematode spray as preventative (sent wrong nematodes, will apply again)
 - Disease:

Fertilizers and Amendments 2022/2023:

Fertilizers and Amendments 2022:

- WV Briarpatch:
 - Fertilizers:
 - 6.26.22-8.14.22 and 9.18.22-9.25.22 Miracle Grow
 - Application Rate: 0.25 tsp per gallon
 - Method: soil drench
 - 5.25.23
 - Application Rate: 1 tsp per plant
 - Method: side dress
 - Amendments:

Fertilizers and Amendments 2023:

- Turtle on a Post:
 - Fertilizers:
 - 4.26.23 Bone Meal N 13%
 - Application Rate: 0.5 tsp per plant
 - Method: side dress
 - 5.25.23
 - Application Rate: 1 tsp per plant
 - Method: side dress
 - Amendments:
- WV Briarpatch:
 - Fertilizers:
 - 4.30.23 Horse manure
 - Method: manually added to each hole for new plantings
 - Amendments:

Cultural Practices 2022/2023:

Cultural Practice 2022:

- WV Briarpatch:
 - applied a hay mulch

Cultural Practice 2023:

- Turtle on a Post:
 - 4.9.23 Triumph didn't get fully pruned back at the end of 2022 season as others did. 1st mow of the season 4-12-23
 - 4.16.23 started weeding yard
 - 4.23.23 weeded all rows

- o 5.9.23 cut bull shoots, trained hops
- o 5.28.23 training some slower growing hops
- o 6.4.23 training some slower growing hops
- Mountain Life Farm:
 - o 4.9.23 repaired fencing and ordering more fencing

Observations 2022/2023:

Observations 2022:

- Hinerman Hill Farm:
 - o Observations:
 - experienced heavy rain washing rhizomes out of the rows and transferring them to the bottom of the hop yard. Their yard is on a slope. They need water mitigation.

Observations 2023:

- Turtle on a Post:
 - o Observations:
 - 3.1.23 Weekly precipitation 0.8 inches.
 - 3.6.23 Weekly precipitation 0.07 inches.
 - 3.13.23 Weekly precipitation 0.34 inches.
 - 3.20.23 Weekly precipitation 0.57 inches.
 - 3.27.23 Weekly precipitation 0.61 inches.
 - 4.2.23 Weekly precipitation 0.34 inches.
 - 4.9.23 Weekly precipitation 0 inches.
 - 4.16.23 Weekly precipitation 0 inches.
 - 4.23.23 Weekly precipitation 0.5 inches.
 - 4.30.23 Weekly precipitation 1.29 inches.
 - 5.7.23 Weekly precipitation 1.4 inches.
 - 5.14.23 Weekly precipitation 0.6 inches.
 - 5.28.23 Weekly precipitation 0 inches.
 - 6.4.23 Weekly precipitation 0 inches.
 - 6.11.23 Weekly precipitation 0 inches.
 - 6.18.23 Weekly precipitation 1.5 inches. Hops are just starting to burr.
 - 6.25.23 Weekly precipitation 1.8 inches.
 - 7.2.23 Weekly precipitation 0.2 inches.
 - 7.7.23 Comet has cones
 - 7.10.23 Most are branching
 - 7.15.23 Weekly precipitation 1.08 inches.
 - 7.15.24 Saaz 72 cones started. Triumph and Zeus started branching.
 - 7.30.23 Monthly precipitation 4.75 inches.
 - 8.12.23 Monthly precipitation 4.5 inches.
 - 8.19.23 Monthly precipitation 1.5 inches.

- 8.20.23 Cashmere: 0.05 oz (1 plant) 0.05 oz per plant, Centennial: 2 oz (3 plants) 0.66 oz per plant, Comet: 23 oz (22 plants) 1.04 oz per plant, Saaz 72: 61 oz (17 plants) 3.5 oz per plant, Triumph: 5oz (9 plants) 0.55 oz per plant, Zeus: 23.2 oz (12 plants) 1.93 oz per plant
- Hinerman Hill Farm:
 - Observations:
 - 4.2.23 water damage from previous season, still seeing no growth
 - 7.23.23 Water damage from the previous season, still seeing no growth. 100% loss
- WV Briarpatch:
 - Observations:
 - 4.30.23 no measurable rain. Zeus and Saaz 72 do not like the sun. They are not growing as much as the other varieties.
 - 5.7.23 conditions are turning dry. no measurable rain. Zeus and Saaz 72 do not like the sun. They are not growing as much as the other varieties.
 - 5.14.23 minimal growth. turning bushy.
 - 5.21.23 conditions are turning dry. no measurable rain. Zeus and Saaz 72 do not like the sun. They are not growing as much as the other varieties. minimal growth. turning bushy.
 - 5.28.23 conditions are turning dry. no measurable rain. Zeus and Saaz 72 do not like the sun. They are not growing as much as the other varieties. minimal growth. turning bushy.
 - 6.4.23 dry, no measurable rain; conditions are dry. Zeus and Saaz do not like the sun. They are not growing as much as the other varieties.
 - 6.11.23 dry, no measurable rain; conditions are dry. Zeus and Saaz do not like the sun. They are not growing as much as the other varieties.
 - 6.18.23 dry, no measurable rain; conditions are dry. Zeus and Saaz do not like the sun. They are not growing as much as the other varieties.
 - 6.25.23 average conditions. Zeus and Saaz do not like the sun. They are not growing as much as the other varieties.
 - 7.2.23 average conditions. Zeus and Saaz do not like the sun. They are not growing as much as the other varieties.
- Mountain Life Farm:
 - Observations:
 - 4.2.23 0.4 inches of rain.
 - 4.9.23 0.2 inches of rain.
 - 4.16.23 0.47 inches of rain.
 - 4.23.23 0.59 inches of rain.
 - 6.25.23 100% loss

Resources:

Mountain State Co-Hop is a member owned cooperative that started as a hop growers' cooperative, and expanded to add value added producers. The cooperative sells hops to West Virginia breweries and its value-added products online to in-state and out-of-state wholesale and retail markets. By joining you not only become part owner, you gain group marketing and sales, along with distribution. You can utilize shared use equipment, bulk purchases, workshops and educational events. If you would like more information about Mountain State Co-Hop please check out our website (coming soon) or email mountainstatecohop@gmail.com.

Oast Box Instructions:

<https://www.instructables.com/Hop-drying-oast/> 12 page PDF on how to build an oast box

Hops Moisture Calculator:

<https://www.uvm.edu/extension/images/engineering/hopscalculator.html>

Soil Testing: <https://extension.wvu.edu/natural-resources/soil-water/soil-testing>

Tissue Analysis:

<http://dairyone.com/wpcontent/uploads/2014/01/Tissue-AnalysisGuidelines-Field-Crops-Vegetables-Hop.pdf>

Materials: <https://www.schmidthops.com/>

How To Build a Small Scale Hops Picker Toolkit: coming soon.....

West Virginia Food and Farm Coalition: <https://www.wvfoodandfarm.org/>

NE SARE: <https://northeast.sare.org/>

Book: The Hop Grower's Handbook. The Essential Guide for Sustainable, Small-Scale Production for Home and Market. Laura Ten Eyck and Dietrich Gehring

Classes: Michigan State University offers a self-paced course on growing hops: 'Hop Production in Midwest and Eastern North America'