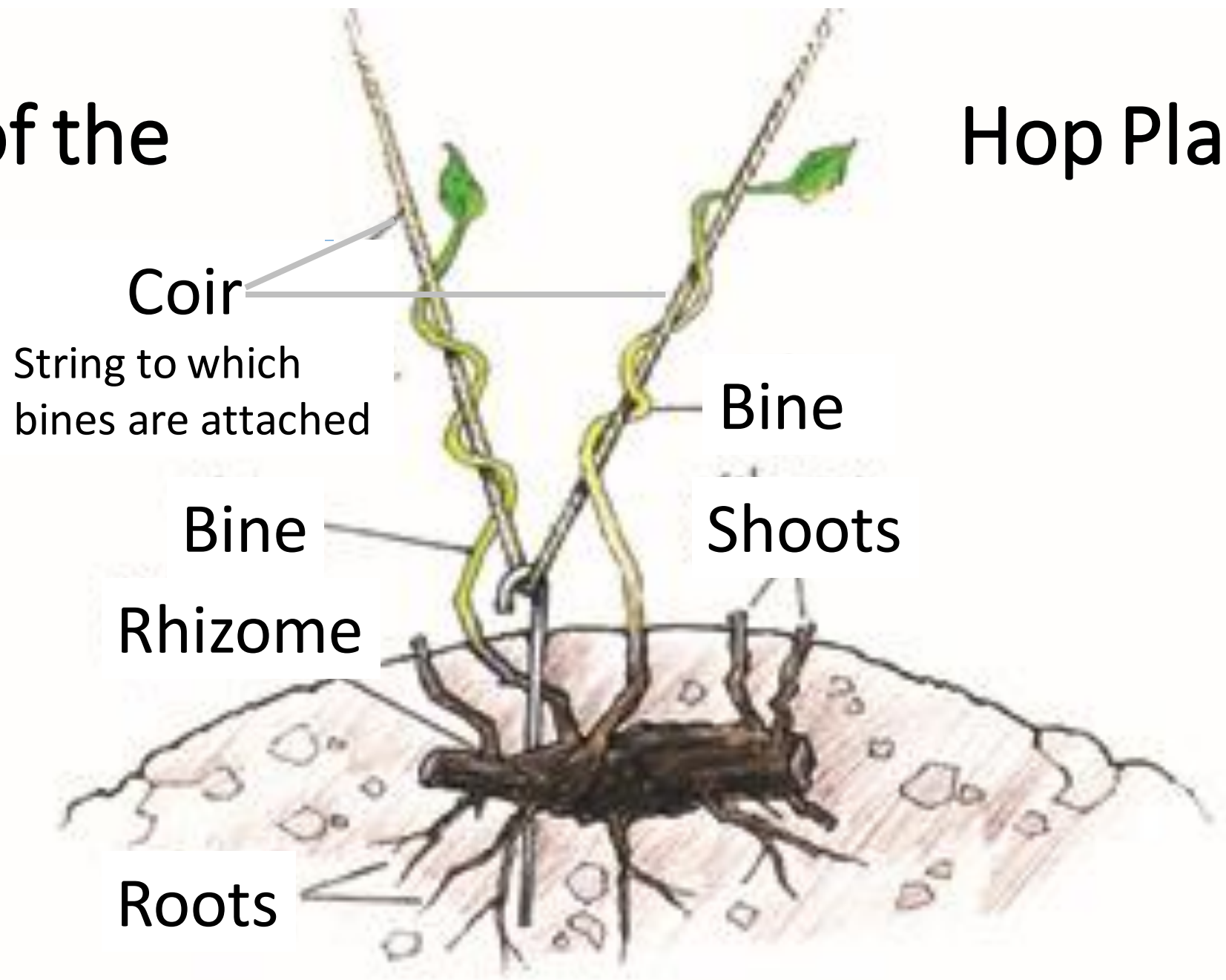


Parts of the

Hop Plant



Hop Plants: (*Humulus lupulus*)



- **Dioecious**
 - Male & female flowers grown on separate plants
 - Only the cones produced by the female plants are used in the brewing process
- **Perennial rhizome**
 - Produce bines (twining stems) from buds on the crown or rhizomes (permanent rootstock) each spring
 - Rhizomes persist in the soil for many years
- **Bines** (aided by trichomes) grow clockwise around strings attached to trellis systems
 - Under right conditions, bines can grow upwards of 2 ft./week,
 - Lateral branches develop on bines & produce clusters of ½ to 4-inch papery green flowers (cones)
 - Triggered by daylength
 - Annual growth habit & dies back to the ground in fall



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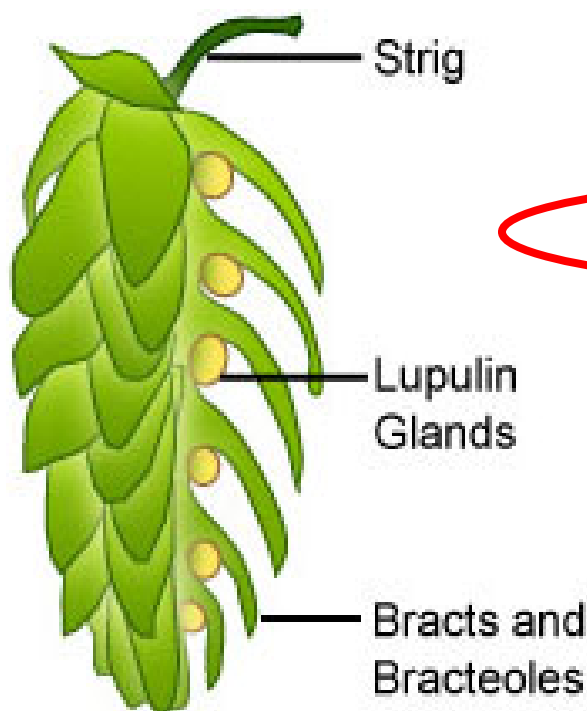
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Cones



Hop Cone Cutaway View

Lupulin Glands

Lupulin glands are the tiny yellow sacs found at the base of the petals of the hop cone.

They contain the alpha acids, beta acids, and hop oils that are so useful to the brewer in adding hop character to beer.

Note that cones from the male hop plant contain relatively few lupulin glands. Therefore, it is the female plant that is in demand to supply hop cones for brewers.

Related terms

[Hops](#)

Growing Hops Successfully

- Location:
 - Majority of the world's hops are grown between 35° & 55° *latitude* in both hemispheres
 - Most hop farming occurs in a narrow latitude band from about 44 to 51° in the Northern Hemisphere.
 - Photoperiod effect - needs long day lengths to flower & produce adequate cone yields
 - Specific chilling requirement (winter temperatures below 40° F for 1 to 2 months for proper growth)
 - Needs sufficient moisture in spring followed by significant periods of summer sun and heat to ensure ample growth and full development of chemical compounds



(Hop Growers of America, 2020)

- Three U.S. states, Washington, Oregon, and Idaho, accounted for more than 95% of harvested acreage in 2019
 - are situated at higher latitudes (44–47°N) relative to Mid-Atlantic states (35–37°N)
 - their growing season is generally characterized by lower relative humidity and less rainfall.
 - Thus, agronomic practices recommended for the PNW may not be applicable to the Mid-Atlantic United States.
 - Hop producers face a number of economically important pests and diseases ([Mahaffee et al., 2009](#))
 - Downy mildew (*Pseudoperonospora humuli*) and powdery mildew (*Podosphaera macularis*),
 - both influenced by climatic factors such as temperature, relative humidity, and leaf wetness, would be of particular concern in Mid-Atlantic United States.



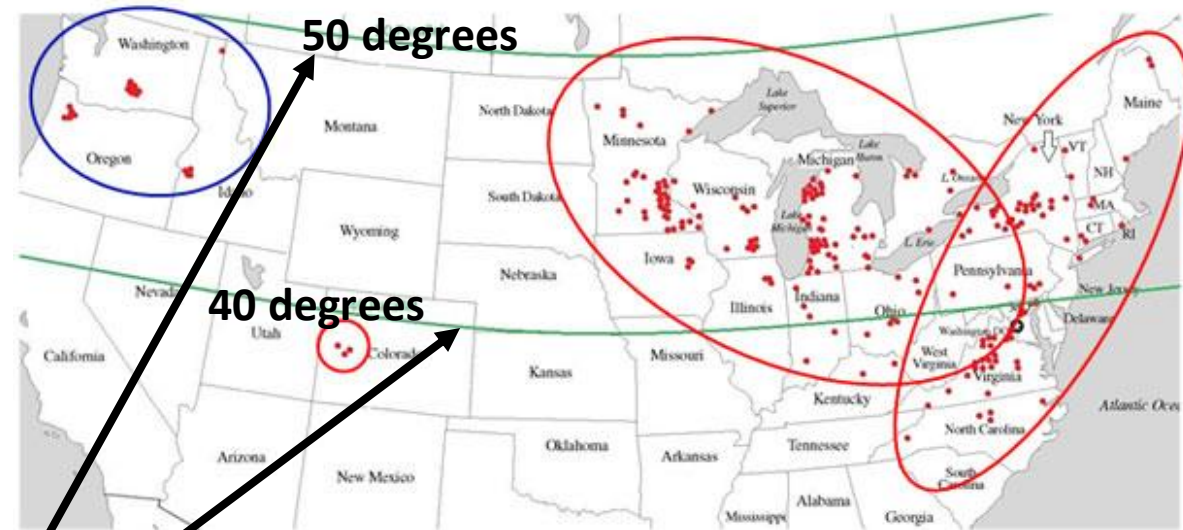
most hops are grown north of the 40th degree of latitude and dried before shipment to brewers, and cultivars grown in Virginia are less productive due to the reduced sunlight at the lower latitude

Source: ESRI, [ArcGis Online](https://www.arcgis.com/home/index.html)

Growing Conditions:

- Will grow in a variety of soils
 - Optimum: well-drained, deep, sandy loam, pH about 6.5
 - Avoid sites having heavy, poorly-drained soil
- Need supplemental water & nutrients for growth & cone development
- To flower & produce high cone yields –
 - Need long days and short nights during the growing season
 - Winter temperatures below 40° F for 1 or 2 months
 - To achieve this, most hops grown between 40 and 50 degrees latitude

US Hop Production Areas - 2014



Day Length & Latitude

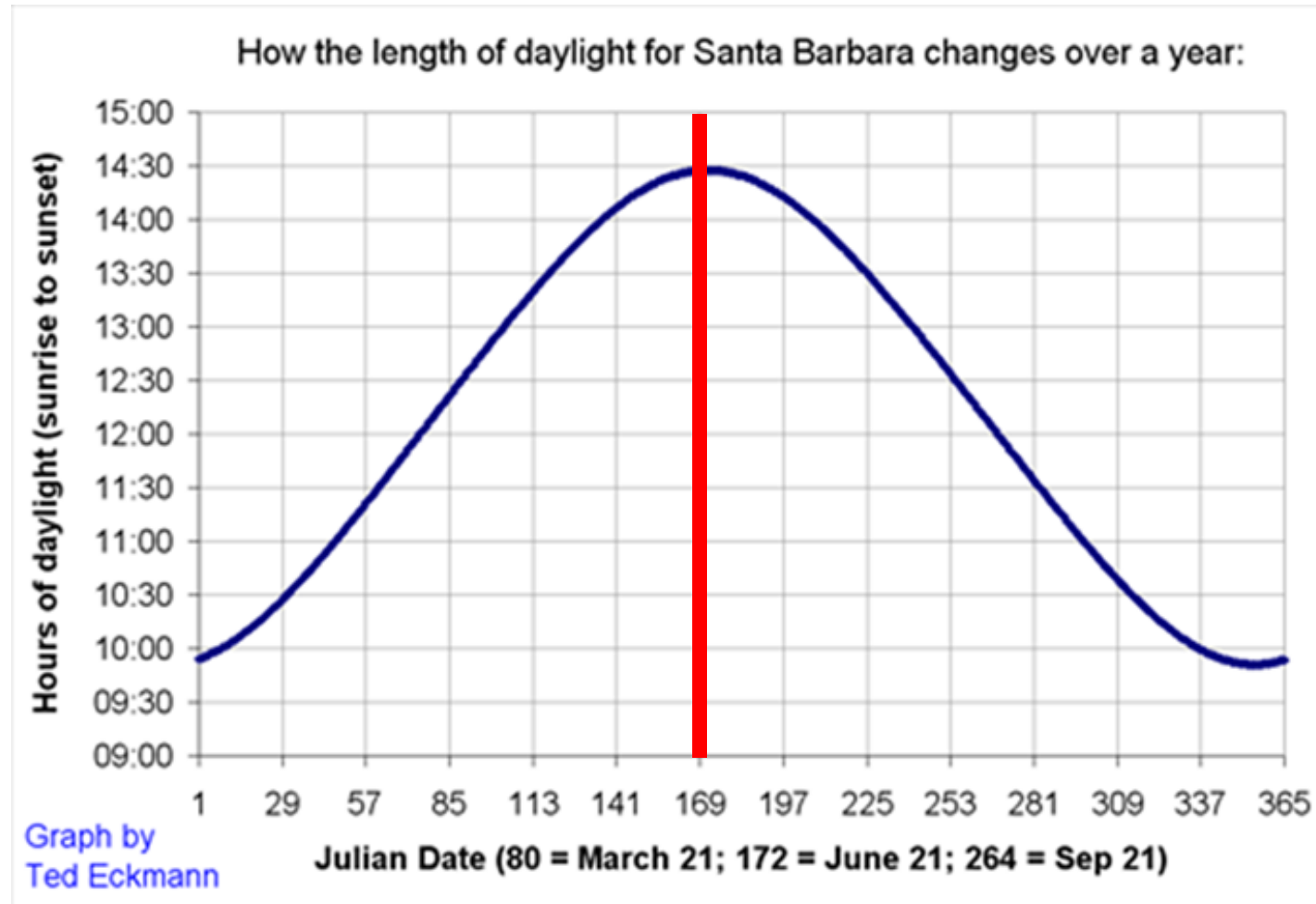
| City | Day length (June 20) | Latitude |
|-------------------------|-------------------------------|----------------|
| Seattle, WA | 15 hr. 59 min. 18 sec. | 47.6° N |
| Rochester, NY | 15 hr. 22 min. 50 sec. | 43.2° N |
| Bristol, TN | 14 hr. 39 min. 57 sec. | 36.6° N |
| Lafayette, TN | 14 hr. 39 min. 24 sec. | 36.5° N |
| Martin, TN | 14 hr. 38 min. 29 sec. | 36.3° N |
| Johnson City, TN | 14 hr. 38 min. 19 sec. | 36.3° N |
| Greeneville, TN | 14 hr. 37 min. 27 sec. | 36.2° N |
| Murfreesboro, TN | 14 hr. 35 min. 37 sec. | 35.8° N |
| Knoxville, TN | 14 hr. 36 min. 9 sec. | 36.0° N |
| Raleigh, NC | 14 hr. 35 min. 7 sec. | 35.8° N |
| Asheville, NC | 14 hr. 34 min. 6 sec. | 35.6° N |
| Memphis, TN | 14 hr. 31 min. 41 sec. | 35.1° N |
| Atlanta, GA | 14 hr. 24 min. 0 sec. | 33.4° N |
| Tallahassee, FL | 14 hr. 6 min. 55 sec. | 30.5° N |

Flowering is controlled by day length

>15 hours
for
vegetative
growth



Bines



< 15 hours
for
reproductive
growth



Female
flowers

Development of a Bine on a Hop Plant: increasing daylength



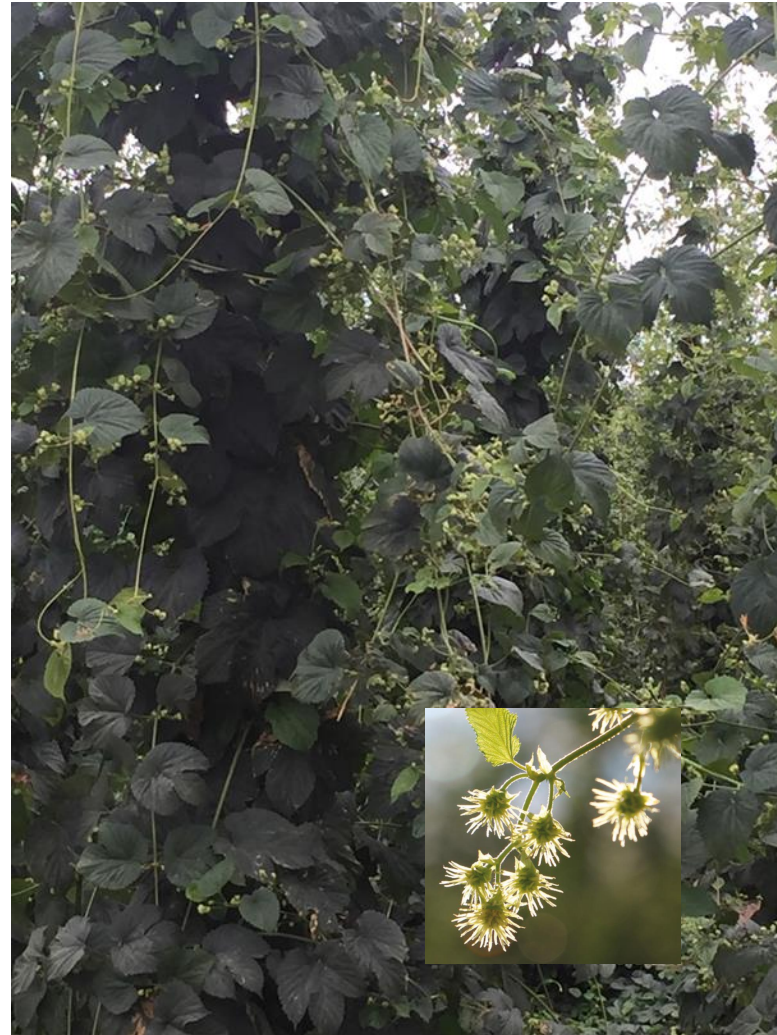
Hop Crown

Hop Rhizome



Decreasing Daylength

Lateral branching → Female flowers → Cones



Hop Varieties

(partial list)

2 basic categories

- Bittering (with high alpha acid levels)
 - Magnum
- Aroma
 - Cascade
- Some dual purpose varieties exist
 - Nugget

| Hop Variety | Average Alpha Acid | Ideal Climate/Notes |
|-----------------|--------------------|--|
| Cascade | 4.5-7.0% | Grows well in all climates. Susceptible to aphid. |
| Centennial | 9.5 -11.5% | Grows well in all climates. Susceptible to downy mildew. |
| Chinook | 11.0-13.0% | Grows well in dry, hot climates. Does not grow well in moist climates. Subject to spider mite. Great ornamental hop. |
| Columbus | 14.5-15.5% | Grows well in dry hot climates. Vigorous but susceptible to mildew diseases. |
| Fuggle | 4.0-5.5% | Grows well in damp climates. Suffers a little in hot climates. |
| Glacier | 5.0-6.0% | Grows well in all climates. |
| Golding | 4.0-5.0% | Grows well in mild, moist climates. Does okay in hot climates. |
| Hallertau | 3.5-5.5% | Grows well in mild, moist climates. Suffers a little in dry hot climates. |
| Horizon | 12.0-13.5% | Grows well in all climates. |
| Magnum | 12.0-14.0% | Grows well in all climates. Good resistance to wilt and downy mildew. Susceptible to powdery mildew. |
| Northern Brewer | 8.0-10.0% | Adequate in temperate climates but has difficulty growing when under heat stress. Susceptible to downy mildew. |
| Nugget | 12.0-14.0% | Grows well in all climates. |
| Tettnang | 4.0-5.0% | Grows well in a moderate climate. Suffers a little in hot climates. |
| Willamette | 4.0-6.0% | Grows well in all climates. |

Hops in Virginia – Virginia Places

<http://www.virginiaplaces.org>alcohol>hops>

Virginia is at the southern range for hops, which normally are grown between 35°-55° of latitude

- As one hop grower has noted: Hops are not an easy crop. If you want to grow for the beer industry, and do it easier, grow barley.
- Increased productivity in the Pacific Northwest, with yield of hops/acre as much as **3-10 times greater**, gives growers there a substantial competitive advantage over hops growers in Virginia.

<http://www.virginiaplaces.org>alcohol>hops>



Latitude Longitude Map

90°W

ILLINOIS

KENTUCKY

VIRGINIA

37°N

MISSOURI

36°N

ARKA-
NSAS

**NORTH
CAROLINA**

**SOUTH
CAROLINA**

ALABAMA

MISSISSIPPI

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(Updated on 10th Sep, 2013)

85°W

County Seat :

- | | | |
|-----------------|------------------|------------------|
| 1. Lawrenceburg | 15. Ashland City | 29. Livingston |
| 2. Fayetteville | 16. Tiptonville | 30. Gainesboro |
| 3. Lynchburg | 17. Gallatin | 31. Jamestown |
| 4. Chattanooga | 18. Springfield | 32. Kingston |
| 5. Manchester | 19. Murfreesboro | 33. Loudon |
| 6. Leeburg | 20. Woodbury | 34. Jackson |
| 7. Hohenwald | 21. McMinnville | 35. Dandridge |
| 8. Decaturville | 22. Pikeville | 36. Maynardville |
| 9. Henderson | 23. Dayton | 37. Tazewell |
| 10. Brownsville | 24. Decatur | 38. Rutledge |
| 11. Camden | 25. Smithville | 39. Morristown |
| 12. Waverly | 26. Carthage | 40. Rogersville |
| 13. Clarksville | 27. Lafayette | 41. Erwin |
| 14. Charlotte | 28. Hartsville | 42. Jonesboro |

LEGEND

- State Boundary
 — County Boundary
 ★ State Capital
 ● County Seat



Challenges for Growing Hops in Tennessee



- Lack of established markets
 - Changes are occurring with the popularity of local breweries & potential premiums for locally-grown hops
- Lack of local information (no history of hop production in Tennessee)
 - Most information is adapted from the Pacific Northwest
 - Increasing amounts of information is being generated in the North Central, Northeast and Mid-Atlantic areas

Challenges for Growing Hops in Tennessee



- Growing conditions
 - Sufficient winter cold to satisfy chilling requirements
 - Daylength (15 hours is most desirable)
 - Increasing day length = vegetative growth
 - Decreasing day length =
 - Bine elongation slows, then ceases
 - Lateral shoots develop (more laterals = greater production potential)
 - Flowering followed by cone development
 - High rainfall/humidity provides ideal conditions for diseases & pests
 - Heat

Timeline for Planting Hops

- Site selection – most important decision you will make
 - “Live where you farm, don’t farm where you live”
- Site preparation – begin a *minimum* of 6 months to one year in advance of planting
 - The success or failure of a planting is often determined before the first plant is set
- Order plants well in advance of the time to plant
 - Use reputable nurseries
- Build the trellis prior to planting
- Have the irrigation system installed and operational before planting

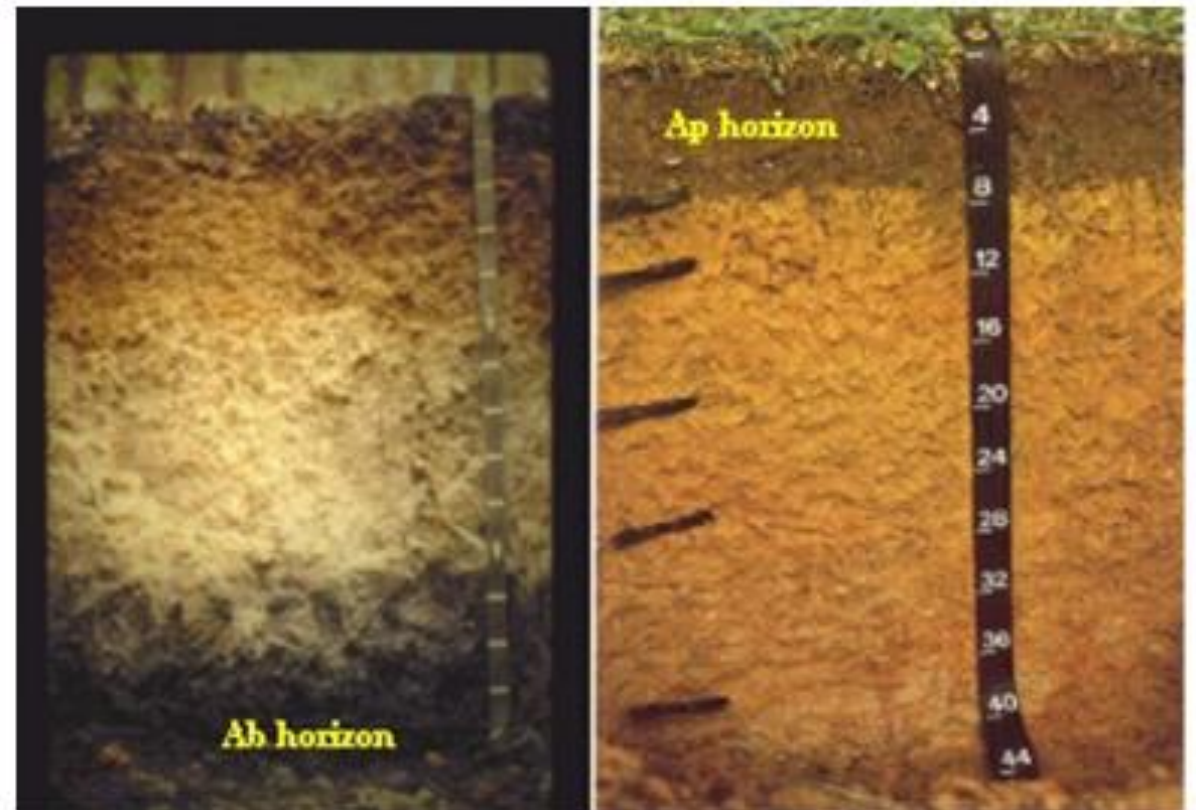
Hop Yard Site Score Sheet

- Full sun
- Elevation in regards to immediate surroundings (air drainage)
- Terrain – level to slightly sloping (2 to 5%), uniform
- Soil Characteristics – drainage (internal & surface), potential rooting depth, fertility
- Water – quantity & quality
- Wildlife
- Adjacent agricultural operations (especially if considering organic production)

Soils for Hop Production

- Sandy loam - avoid heavy, poorly drained soils
- Deep – minimum rooting depth 30 to 36 inches
- Well-drained (internal & surface)
- pH 6.0 to 6.5
- Medium to high fertility

Poor Vs. Good Internal Drainage





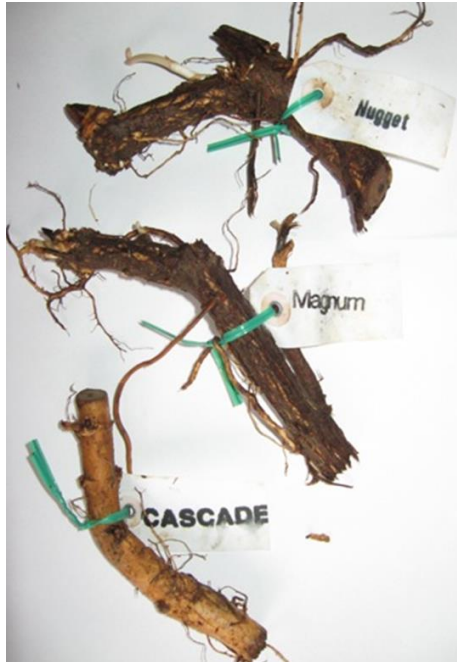
Hops Production Timeline

- 1st year (planting)
 - Expect no yield to a very modest yield
 - Setting more than 1 plant/rhizome/site will help boost early yields
- 2nd year (1 year after planting)
 - Modest to moderate yield
 - As rhizomes develop, yield potential will increase
- 3rd and succeeding years
 - Full yield potential
 - What is a “full crop”?
 - Do NOT expect the same as reported for the Yakima Valley
 - S. E. trials have often yielded about 1/4th of this amount (~500 lbs. cones/acre)

Planting: Rhizomes vs. Propagated Plants

Purchase disease-free propagated plants

- Tissue culture
- Virus indexed



Rhizomes – be sure to purchase from a reputable source
(risk of spreading diseases & viruses if digging from an existing hop yard)

Planting

- Timing: late winter to early spring
- Rhizomes:
 - Cut into 6-to 8-inch lengths & transplant immediately into hop yards or put in pots and place in a greenhouse.
 - Lay plants horizontally with bud side up and 1 to 2 inches below the soil surface
- Softwood cuttings:
 - Take from a stem with 1 or 2 nodes & 2 leaves and with 2 to 3 ½ inches of wood beneath the nodes.
 - Plant in a nursery and grow one season before transplanting to the hop yard

Functions of the Trellis

The trellis is a long-term investment. It should be built to last the life of the vineyard

- Support the bine and the crop
- Expose fruit and foliage to sunlight
- Open canopy to air movement and spray penetration
- Facilitate ease of vineyard operations
 - Pruning, thinning, pest control, harvest

Trellising

- Most hops trained on tall trellises (18 to 25 ft. tall) to maximize yields
 - Bines most fruitful in a vertical orientation
- Trellis is subject to substantial loads
 - Plant weight = approx. 35 lbs./plant
 - Winds (60 mph wind equivalent to ~ 10 lbs/ft²)



Selecting the Right Trellis Design

- Some thoughts to immediately **discard**:
 - “Poles are expensive so let’s really space them out”
 - “don’t need such long poles if I don’t put ‘em 3 feet in the ground”
 - “This thinner wire should work . . .”
 - “the rows have to be really wide ‘cause I got a big tractor”
 - “let’s grow 10 varieties in 4 rows”
 - “we won’t need irrigation”
 - “fertilizer is just too expensive.”
 - “healthy hop plants don’t get bugs or disease.”
 - “I’m gonna plant the hops first and then put in the trellis and irrigation . . .”
- If you can’t get past these – **stop** here to prevent wasting a lot of time and your life savings, otherwise continue reading!



Trellis Strings for Bine Support



Coir strings (Hop Yarn)



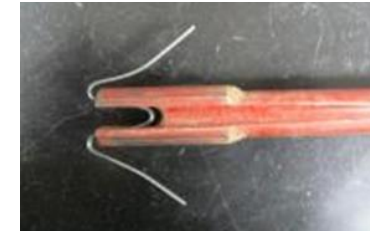
“W” clips



Tool for Installing
“W” clips



“W” clip, string
& tool



Inserting the “W” clip



Training the Bines

- Every year:
 - When vines are 1 ½ to 2 ft. in length, select 4 vines from each rhizome to keep & remove all others
 - Train 2 vines up each of the 2 support strings on the trellis by wrapping in a clockwise direction.
- Beginning the 3rd year:
 - Remove old vines if present
 - Prune back new shoots to control time of crop maturation & yields and to help reduce disease issues
 - Once vines reach ~6 ft. in height, strip leaves & lateral shoots off the lower 3 ft. to facilitate better air circulation and improve mildew control success

Plant Development: pruning back 1st vines to emerge



- 1st shoots to emerge in spring tend to grow unevenly which can result in poor canopy fill
- Trim or burn off 1st flush shoots after ~ 2 weeks or when the vines are ~ 2 ft. high
 - This promotes a 2nd flush of shoot growth which is stronger & more uniform

Training 2nd flush vines onto Coir



- About 3 weeks after the 1st flush of bine growth was cut or burned back & vines from the 2nd flush of growth are about 28 in. long,
 - Start training the strongest 2 – 3 shoots per crown onto each string by:
 - Wrapping in a clockwise direction
 - Removing other shoots
- Once trained, vines tend to grow on the string unaided

Irrigation

- Irrigation:
 - Can improve yield & quality of hops
may positively affect alpha acid concentration
- Hops require ~ 27 to 32 inches of water during the growing season
- 2 critical periods for adequate growth:
 - In spring as the hop plant begins growth
 - Just before flower initiation through cone development
- Supplement rainfall to get 1.0 to 1.5 inches of water/week during dry conditions
- 1st year hop plantings require more frequent watering, but at lower amounts



Fertilizing hops

- Do not base fertilizer rates on postplant soil test results
 - The correlation between soil test results and the actual nutrient status of the plant can be very poor
 - The value of postplant soil testing is to monitor soil pH
 - Soil pH can affect the availability of nutrients to plants
- Use plant tissue testing to determine the actual nutrient status of the plant and to aid in formulating a fertilizer program for the crop
- Split apply or fertigate N for best results

Diseases of Hops

Powdery mildew



Downy Mildew

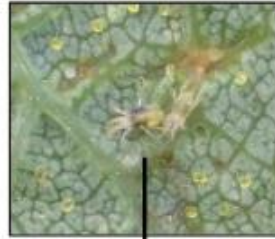


Verticillium Wilt

Two Spotted Spider Mite

Defining features:

- Very small
- Two black spots on back
- Webbing on underside of leaf



Can cause
leaf
stippling

When do they
appear?

- Prefer hot, dry
conditions



Damage:

- Leaf stippling
- Feeding on cones
 - Dry, brittle, and
browning cones
- Quality and yield
reduction

Management:

- Sufficient irrigation
to reduce dust



Regular scouting is
key to monitoring
hop pests!

Hop Pocket Pest Guide

A pocket guide to the
major hop pests in Vermont

Julija Cubins

Crop and Soil Field Technician

Dr. Heather Darby

UVM Extension Agronomist

NORTHWEST CROPS & SOILS PROGRAM



UNIVERSITY OF
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CULTIVATING HEALTHY COMMUNITIES



Ready to Harvest



Harvest

- Variety & management dependent (mid-Aug. through late September in Michigan) Harvest date decisions based on variety, cone moisture content, weather, disease & pest issues
- Hops are in prime harvest condition for a short time (7 to 10 days)
 - Premature harvest = loss in yields & flavor in the current season & potential reduced yield in subsequent years
 - Harvesting past prime = reduced aroma & brewing quality, shattering & discoloration





Harvesting Hops

- Cut the coir about 3 ft. above the ground to allow bines to hang free
- Remaining leaf area below where bines were cut contributes to stored energy reserves in rhizomes to support next season's growth

Removal of Hop Cones from Bines



Timing of Harvest

Subjective Method

- Look, feel and smell (sensory)
- As hop cones mature,
 - color will change from green to yellowish
 - Leaves become papery to the touch, often with brown around the edges
 - The yellow color of the lupulin glands will intensify
- Monitoring for changes in aroma:
 - Rub several hop cones between your palms & sniff the crushed hops
 - Immature hops have a “green grass” or “hay-like” smell
 - Over-mature hops can smell like onion, sulfur or garlic
- A cone that is crushed by hand stays compressed when the pressure is removed & leaves behind a sticky residue & a strong aroma



Objective Method

- Proper timing is essential – hops are only in prime condition for about 7 to 10 days
- As the cone matures, the % dry matter to green weight increases by around 1% every 4 – 7 days depending on variety.
- The most common dry matter harvest target found is about 23% (ranges from 20 to 23% depending on variety)
- Timing depends on several factors:
 - Variety
 - Weather
 - Cone moisture content
 - Insect or disease issues in the hop yard
 - A combination of dry matter testing & sensory evaluation is best

Harvested Hops:

- Wet hops can be used immediately to brew seasonal ales
 - Use fresh hops within 48 hours of harvest
or
 - Store in a sealed plastic container in the refrigerator
 - Do not freeze fresh/undried hops
- Dried hops can be vacuum packed and stored in a freezer for later use

Post-Harvest Hops Care

- Dry cones to reduce moisture from about 80% down to 8 to 12% for storage
- Following drying,
 - allow cones to cool purge
 - Bale
 - Pelletize
 - Nitrogen purge
 - Frozen storage



Fun Facts...

889 plants or “hills” make up one acre of hops, if planted on a standard 3.5 foot by 14 foot spacing.

In the Pacific Northwest, yields average about 2,000 pounds of dried hop cones per acre on mature hop yards, or a little over two pounds per hill (yields vary depending on variety and location).

Hops are typically sold in 200-pound bales.

A bale will yield between 135 - 800 barrels of beer (31 gallons each), depending on the recipe.

Resources

