Hop Production

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Hop Plants: *(Humulus lupulus)*

- Perennials
  - Produce bines (twining stems) from the crown or rhizomes (permanent rootstock) each spring
  - Rhizomes persist in the soil for many years
- Dioecious
  - Male & female flowers grown on separate plants
    - Only the cones produced by the female plants are used in the brewing process
- 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

Hop vs. Hops

- Hop:
  - vine from which hops are obtained
  - 3-to-5 lobed leaves
  - inconspicuous flowers of which the pistillate ones are in glandular cone-shaped catkins

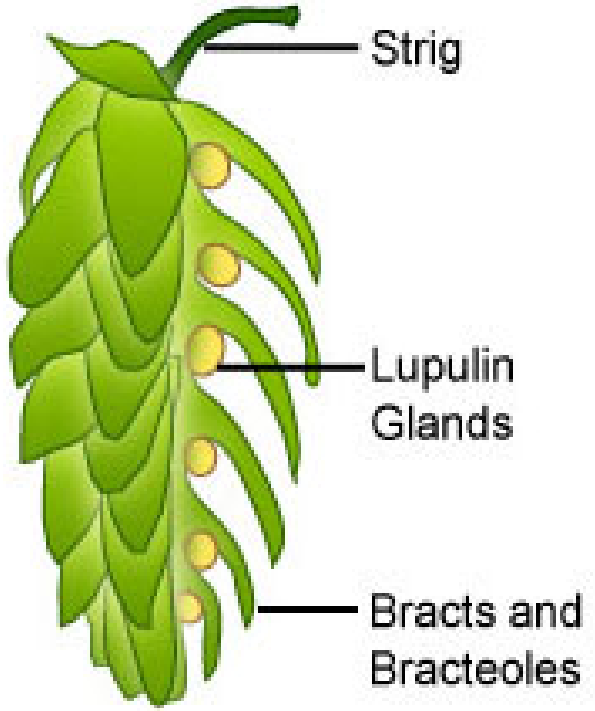
- Hops:
  - ripe, dried pistillate catkins of a perennial north-temperate zone twining vine (*Humulus lupulus*) of the hemp family used especially to impart a bitter flavor to malt liquors

Bine vs. Vine

- Hairy, stiff shoot that climbs by wrapping around a support. (Hops wrap in a clockwise direction).

- Produces tendrils which bind to the support (grapevines)

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.

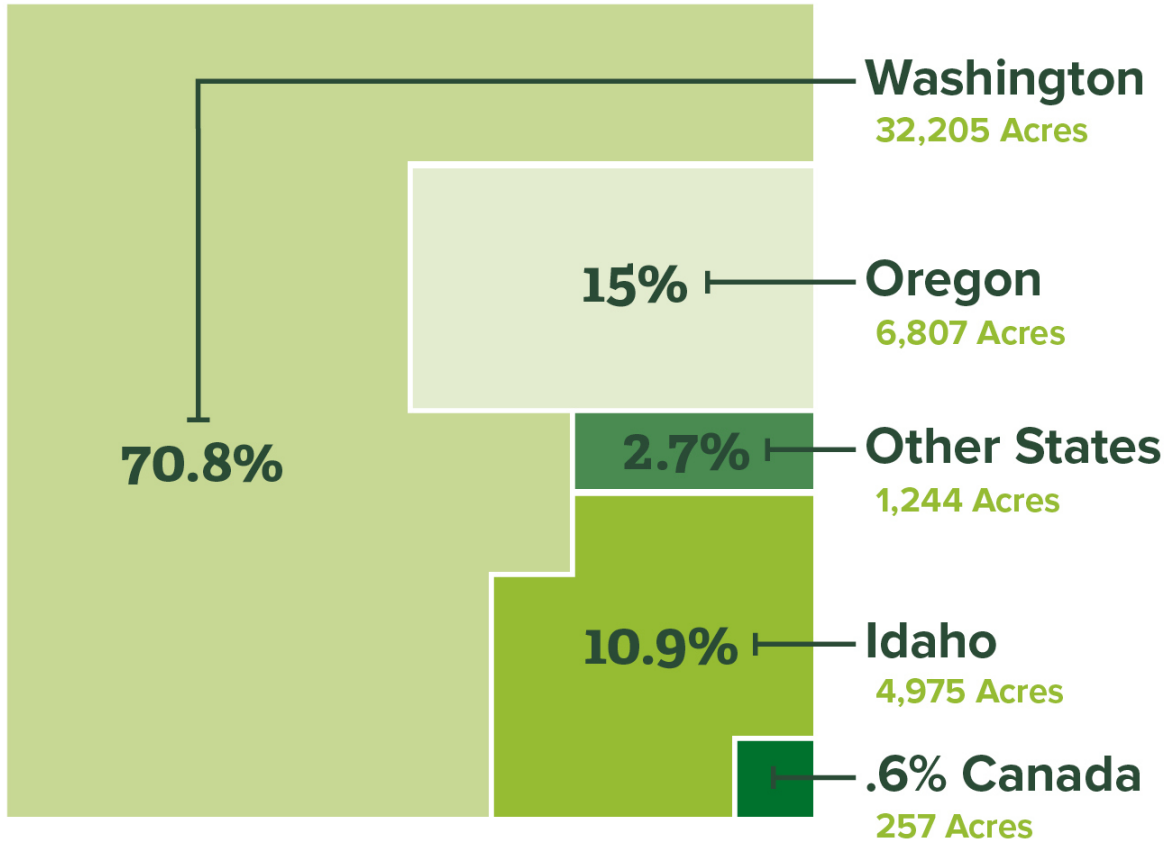
Related terms

Hops

Hop History in the U. S.

- 1648 – Massachusetts Bay Settlement – 45 acres
  - 1st documented commercial hops production in the U. S.
  - Massachusetts remained the largest hop producing state for the next 150 years
- By the mid-1800's. New York was the largest producing state, reaching a peak in the late 1800's
  - Prohibition & downy mildew were credited for the demise
- Hop production shifted to the Northwest

2015 North American Commercial Hop Production



45,488 Total Acres

Hop Production in the U. S. - 2017

- U. S. accounts for 42% or world hop production (#1 in the world)
  - The Northwest produces 98% of the hops produced in the U. S.
  - Washington produces 70% of the hops grown in the U. S.
- U. S. acreage has increased 79.5% since 2012
  - From 2016 to 2017, hop yield jumped 14% due to new plantings coming into production
  - Current market appears to have reached saturation
- Changes:
  - Prior to 2010, ½ the hops grown in WA were alpha varieties (bittering agents)
  - In 2017, U. S. farmers grew 80% aroma or dual-purpose varieties

Tri-Cities Area Journal of Business (Columbia Basin)

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
- Daylength
  - Hops require long daylengths to flower & produce adequate cone yields
- High rainfall/humidity provides ideal conditions for diseases & pests
- Heat

Sample Budget for Hop Yard Establishment

Item	Quantity/Price	Cost
Rhizomes	800 @ $4 each	$3,200
Poles (21 ft)	100 @ $32 each	$3,200
Crushed stone	4 yards	$550
Env. earth anchors	Manta Ray and Duckbill Anchors	$2,200
Drip irrigation	Materials	$800
3/16-inch wire	16,000 ft @ $.09/ft	$1,440
5/16-inch wire	2,000 ft @ $.21/ft	$420
Hop twine	Coconut fiber	$125
Compost	100 yards @ $10/yard delivered	$1,000
Misc. supplies	Wire clamps, staples, etc.	$250
Labor	Hole auger, pole setting, wire	$3,400
Equipment rental	Installing wire	$800
Total		**$17,385***

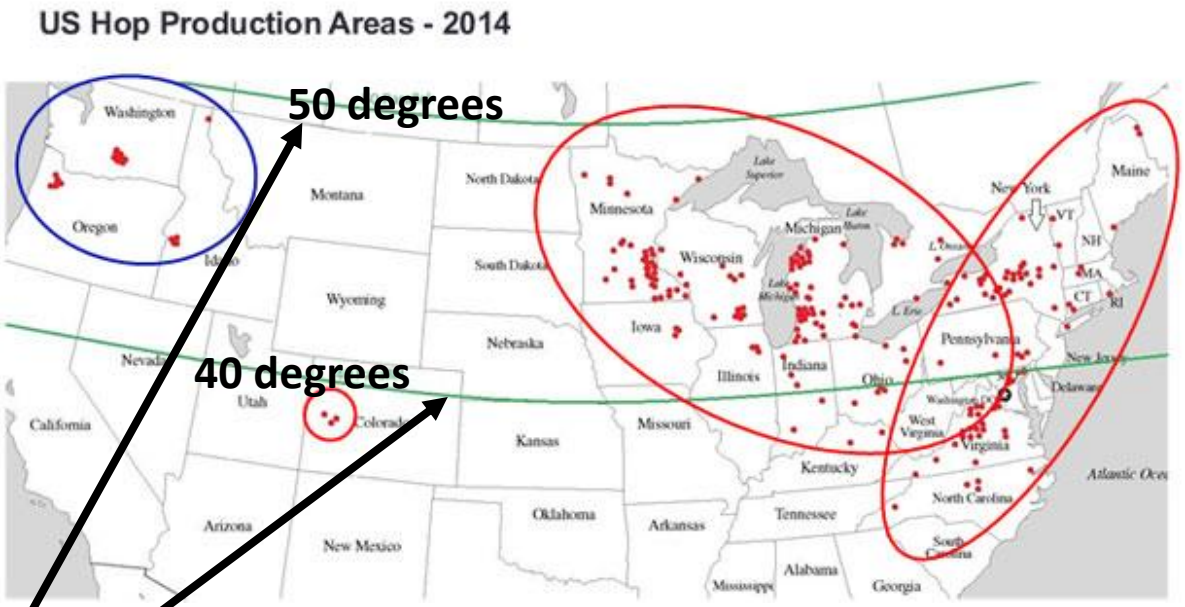
*Note: This figure may be reduced with less expensive products or if a grower chooses to install the hop yard with his/her own equipment and labor.

Growing Hops Successfully

- Location
  - Majority of the world's hops are grown between 35° & 55° latitude in both hemispheres
    - Photoperiod effect - needs long day lengths to flower & produce adequate cone yields
    - Have a specific chilling requirement (needs 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

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



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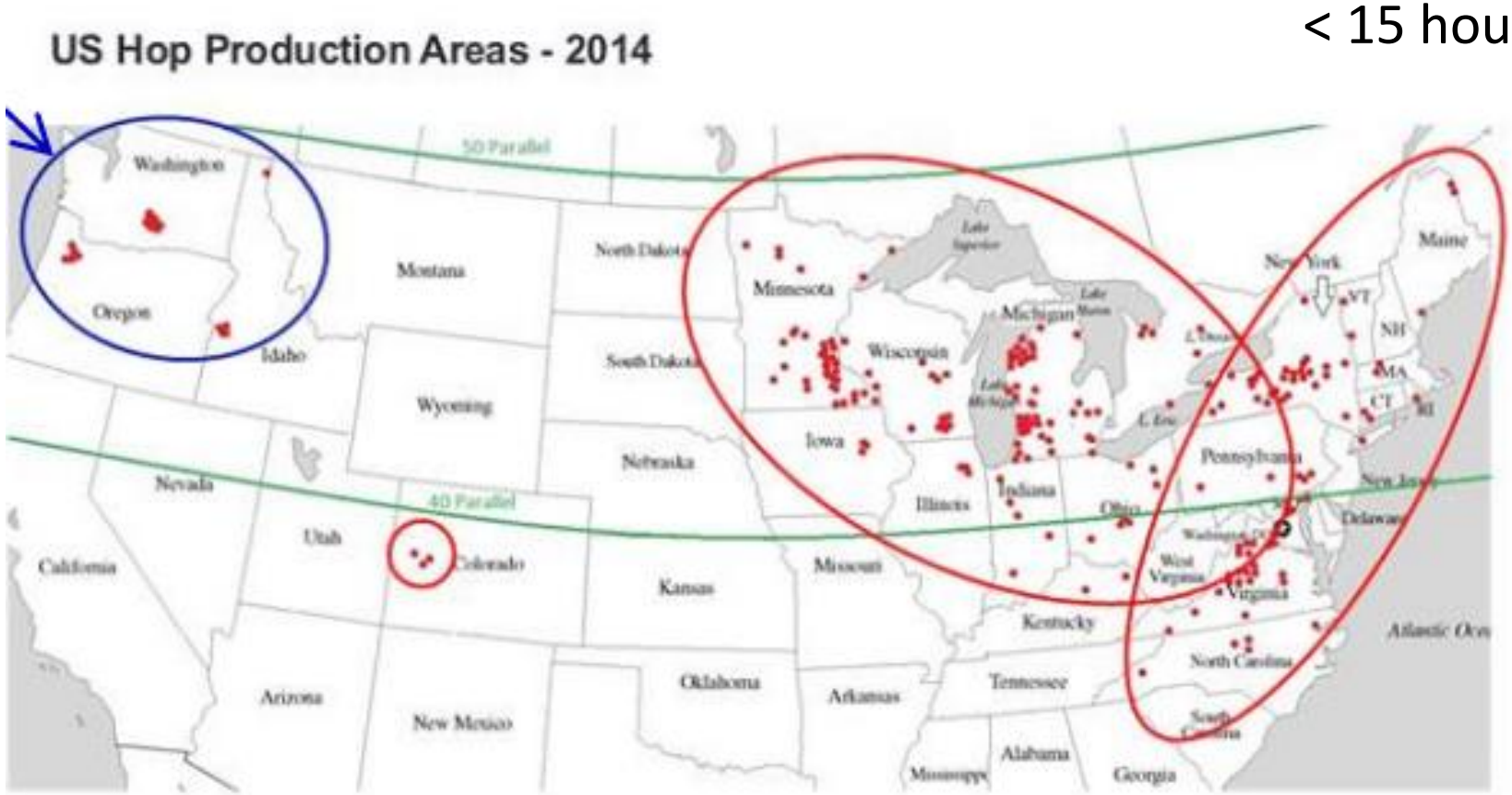
Flowering is controlled by day length

>15 hours for vegetative growth

< 15 hours for fruiting

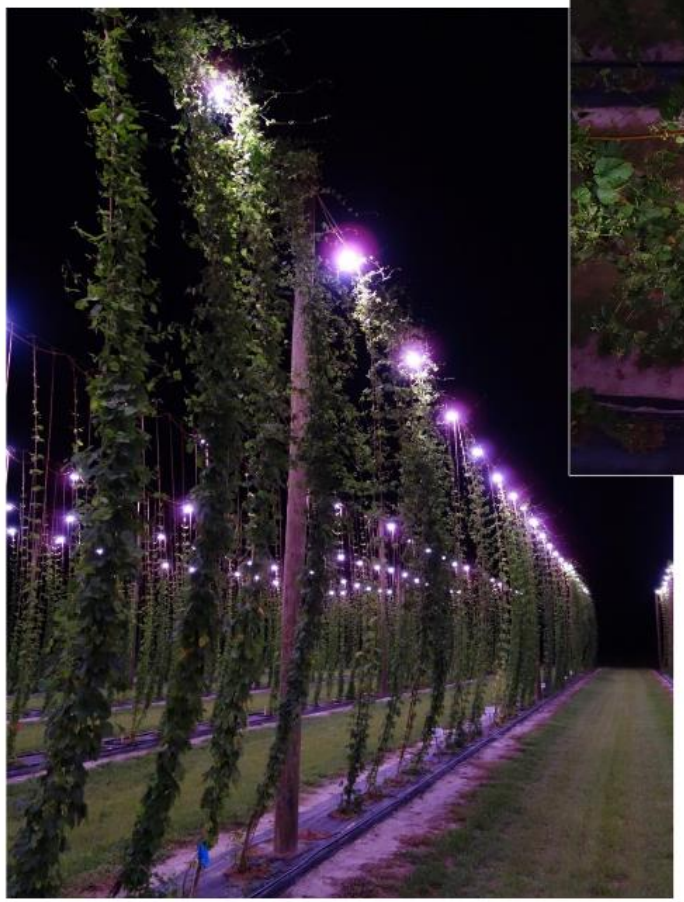


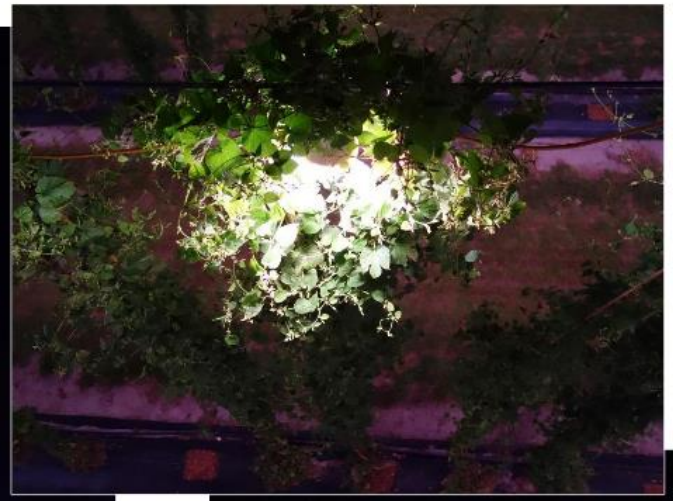
Tampa, FL

- Jan-June: 10-14 hr
- July-Aug: <14 hr

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





Supplemental lighting in the hop yard

Stages of Production

- Determined by photoperiod
  - Shorter day lengths signal maturity
  - Longer day lengths signal vegetative growth
  - Different cultivars respond to different photoperiodic signals
- Length of vegetative growth stages will also vary depending on cultivar and climate
  - Stages of production will take place at different times in PNW than MI
  - Each hop growing region must identify their ‘norm’

Why is height growth limited?

Shoot apex (growing tip)

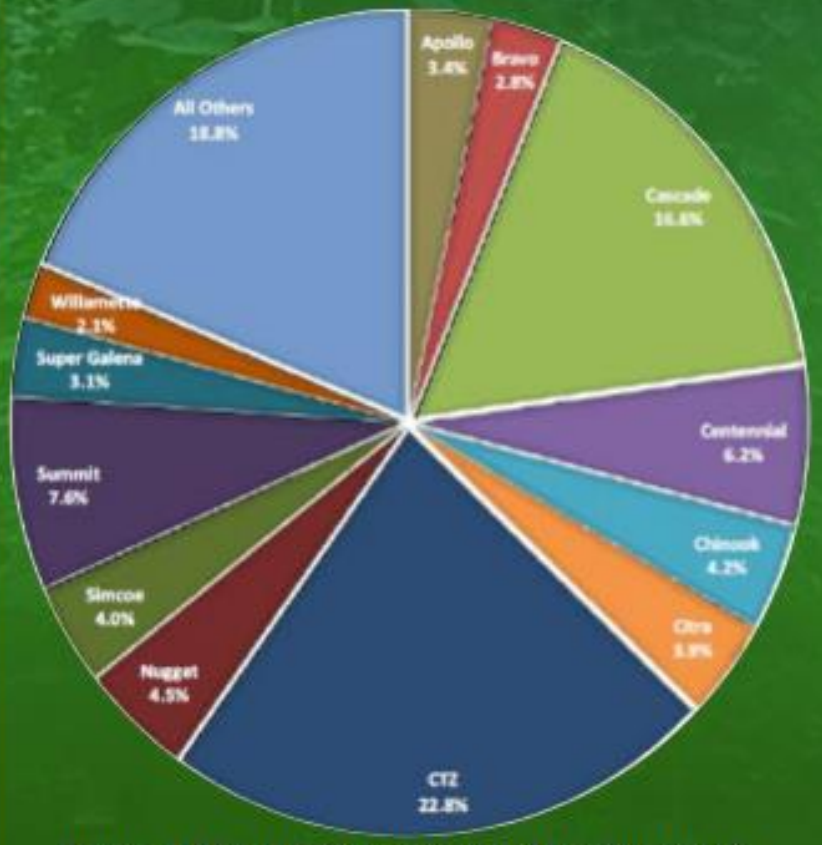
↓

Flower

↓

No more height growth

Getting Started



Source: USDA-NASS, prepared by Hop Growers of America

Cultivar Selection

- What do brewers want?
  - New
  - Local
  - Consistent Quality
- Public versus private cultivars
  - Public: commercially available
  - Private: usually grown on the farm or with select neighbors of the breeder
- Cultivars that seem to do well in NE?
  - Cascade
  - Centennial

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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.

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

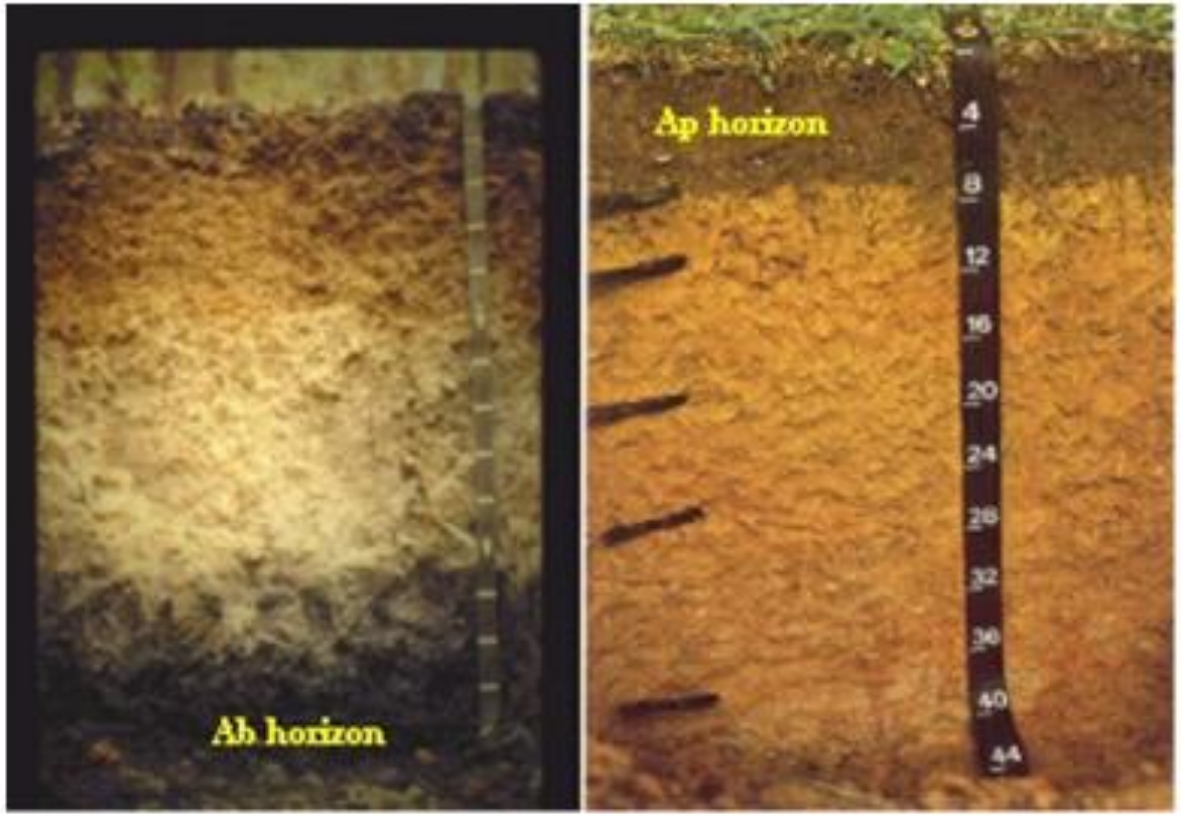
Orchard Site Score Sheet

- Accessibility
- Full sun
- Elevation
- Slope – aspect and steepness
- Soil Characteristics – drainage (internal & surface), potential rooting depth, fertility
- Water – quantity & quality
- Wildlife
- Adjacent agricultural operations

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



Site Preparation

- Soil testing
- Elimination of noxious weeds
- Remove barriers to good air drainage
- Address poor water drainage areas (if applicable)
- Remove wild/abandoned vines near the site

Taking Soil Samples

- **What to Test For:**
  - pH – affects availability of nutrients
  - Phosphorus – only opportunity to adjust P levels in soils (preplant)
  - Potassium – can impact uptake of certain nutrients (Ca, Mg, N)
  - Calcium – calcitic limestone?
  - Magnesium – dolomitic limestone?
  - Organic Matter – can help to determine nitrogen fertilization rates

Sample at 2 depths:
- Upper 8 inches
- 8 to 16 inches

- **What NOT to Test For:**
  - Nitrogen – N levels in soil can change too quickly to be of value
  - Micronutrients – soil testing is of questionable value
  - Macronutrients other than P, K, Ca of Mg unless you have strong reason to suspect a problem

Soil Testing for Hops

- Preplant soil testing
  - Collect soil samples several months or longer in advance of planting
  - Sample areas showing different growing conditions or having a different cropping history separatelyAmend soils based on soil test recommendations in advance of plantingus and potassium (deep incorporation of lime, phosphor
  - There is no economically effective way to raise subsoil pH once the planting is in the ground
  - Phosphorus broadcast on the soil surface will not move down into the soil
  - Potassium varies with soil type in its ability to move down in the soil

Liming Soils – *Preplant* (also for P & K)

Rate for upper 8”
+
Rate for 8 – 16” depth
= **Amt. to apply**

Disk or rototill (mixes lime with soil in upper 4 – 6”)

Plow to put amended soil at the bottom of the furrow

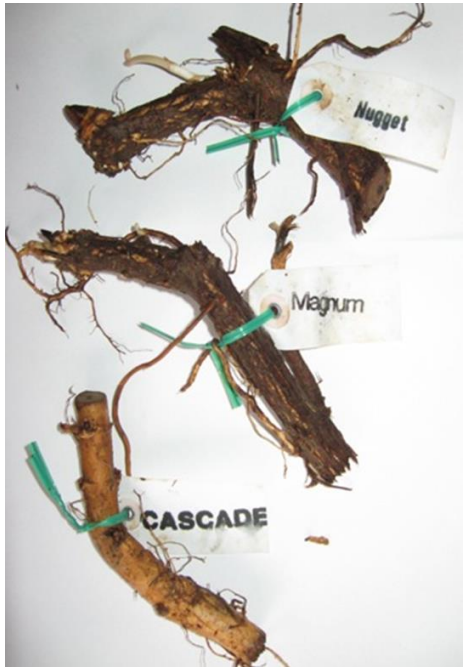
(for high lime rates, apply ~ 2/3 of total & incorporate, apply remaining amount & disk into topsoil)

Orchard Nutrition Management - Stiles & Reid

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)

Stages of Production

Planting a New Crop

Left, Dark discoloration of rhizomes infected with *Pseudoperonospora humuli*.
Right, Healthy rhizome. (C. B. Skotland)

- New commercial hops come from clonal sources; genetically identical to parent material
  - Rhizomes
  - Cuttings
- No matter what form is used, start with virus and disease free

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Hop Plant

- Perennial plant that produces annual bines from a crown & an overwintering rhizome
- In spring, shoots (bines) grow from rhizome buds
- Bines grow in a clockwise direction around strings attached to the trellis
  - Trichomes (stout hairs on bines) enable bines to adhere to supports
  - Bines may grow upwards of 20+ feet in a growing season
  - Bine extension occurs in the early part of the growing season
  - Around the summer solstice, bine extension stops and lateral branches grow off bines
  - Flowers are produced in clusters at the terminal buds
- Hop rhizomes that are only 1 year old will rarely flower or may flower very lightly

Basic Hop Physiology

Aboveground Growth

- Aboveground plant is annual
  - Dies back in fall and plant goes into dormancy
- Bines grow rapidly in ideal conditions:
  - Up to 18-25’ per season
  - Up to one foot per day
  - Wrap clockwise around anything within reach
  - Phototropic (light) and thigmotropic (touch) mechanism
- Lateral ‘side arms’ extend from the bines

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

Stages of Production

- Dormancy
- Planting and Spring Regrowth
- Vegetative Growth
- Reproductive Growth
- Harvest
- Preparation for Dormancy

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Functions of the Trellis

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

- Support the vine 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

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 . . ."

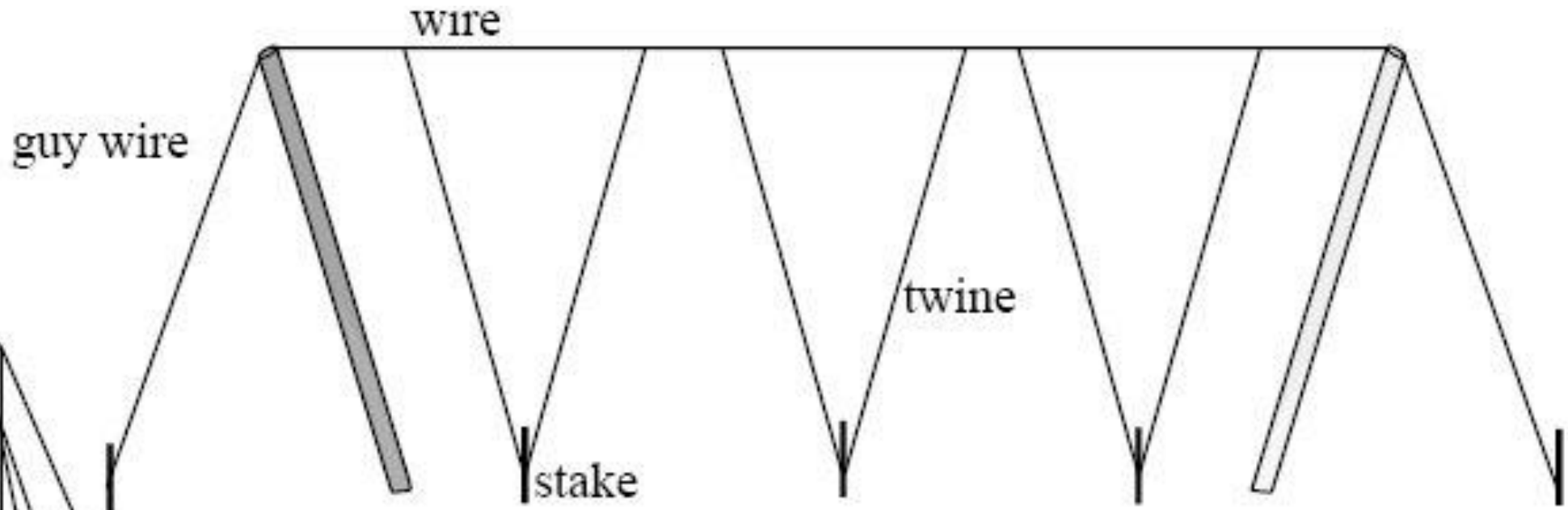
- If you can't get past these – **stop** here to prevent wasting a lot of time and your life savings, otherwise continue reading!

Trellising

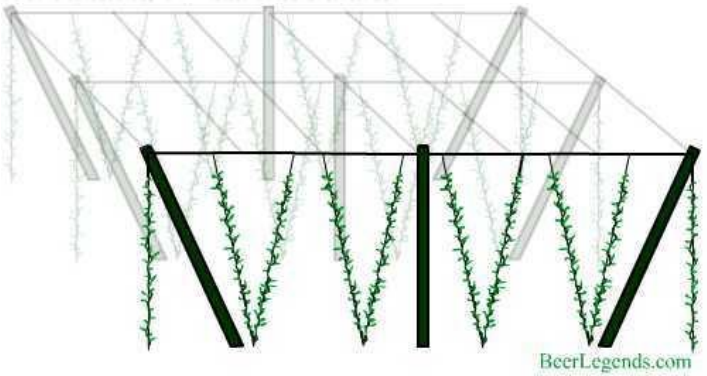
- Most hops trained on tall trellises (18 to 25 ft. tall) to maximize yields
  - Bines most fruitful in a vertical orientation
- Trellis is subject to substantial loads
  - Plant weight = approx. 35 lbs./plant
  - Winds (60 mph wind equivalent to ~ 10 lbs/ft°

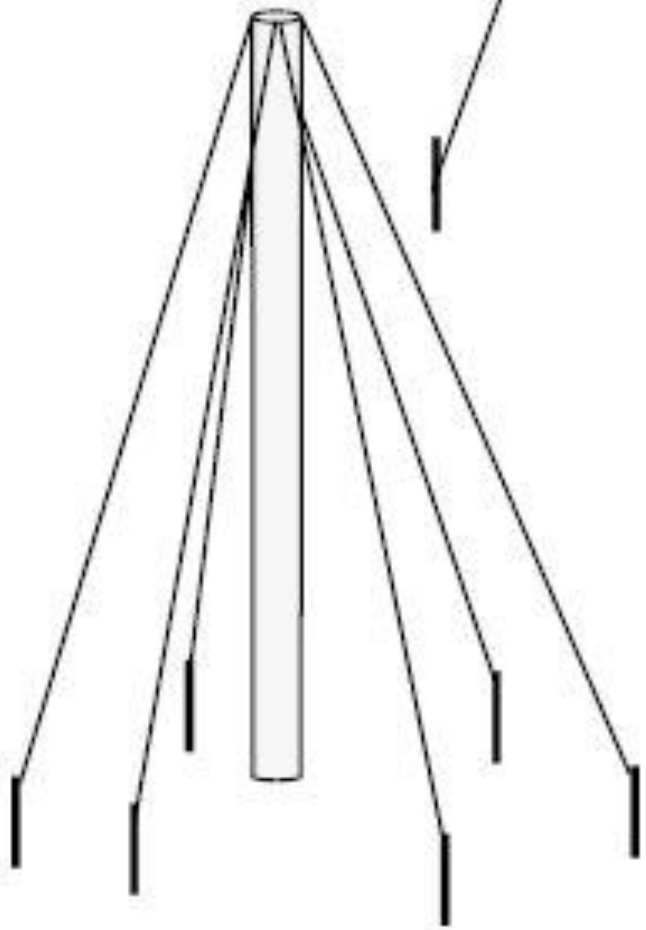
The Trellis

- Heavy poles set with 3 to 4 ft. below ground & 18 to 20 ft. above ground
- Poles spaced every 30 to 60 ft.
- High tensile heavy gauge wire or cable suspended between poles
- Earth anchors to tighten wires at each end of row
- Strings attached to the wire to the ground near a plant and back to the wire in a “V” shape
  - 2 bines will be attached to the strings by wrapping in a clockwise manner on each side of the plant (total of 4 bines/plant)



Typical hop trellis. End poles are installed at an angle and secured by guy wires. Note there are two twines per hop hill. Height should be about 18 feet.





Tent training: Multiple twines around a single pole.

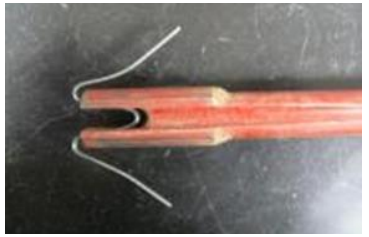
Trellis Strings for Bine Support

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

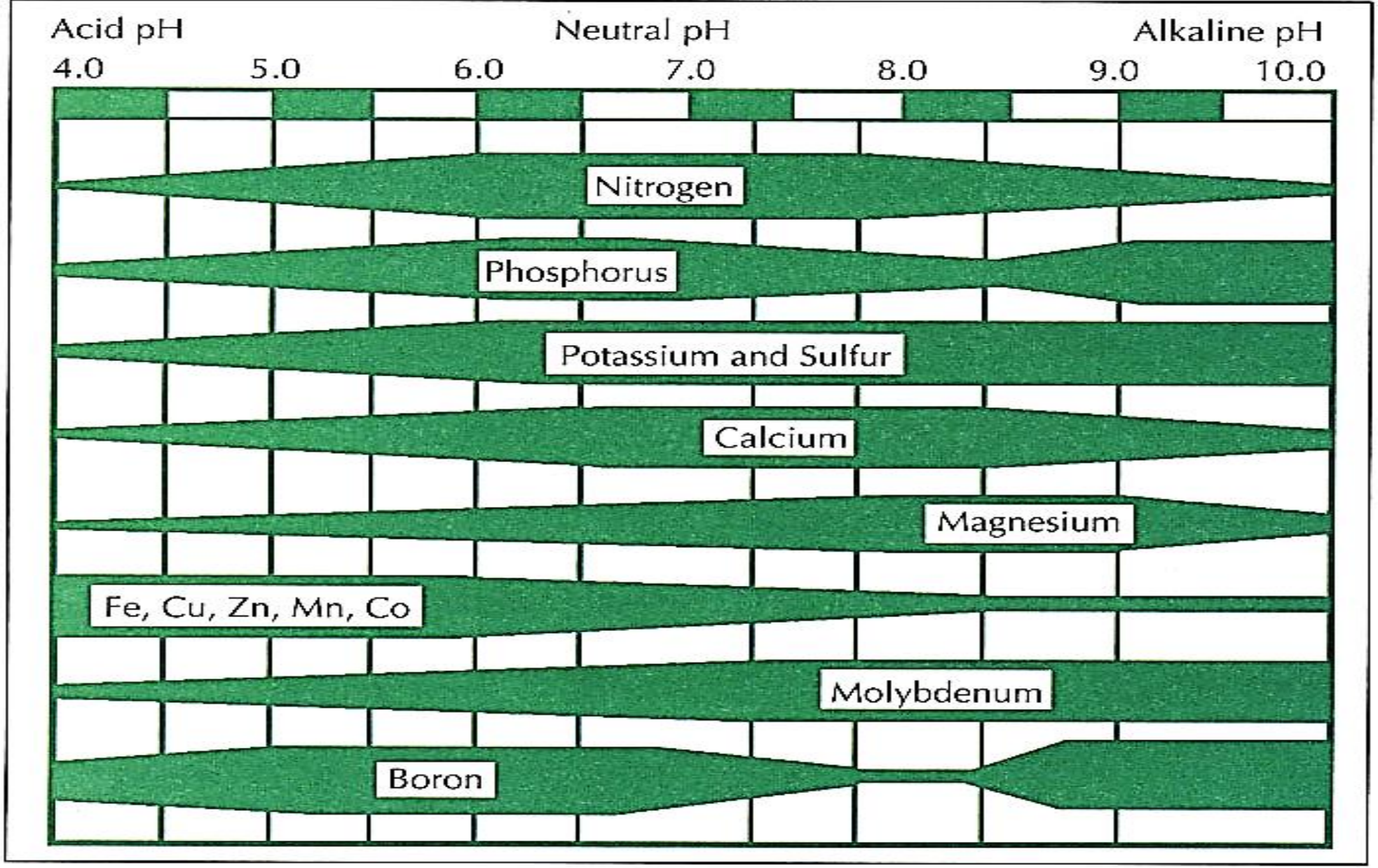
Irrigation

- 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

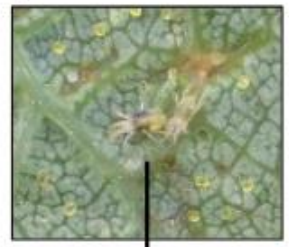
Fertilizing hops

- 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

Effects of Soil pH on Nutrient Availability



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

Hop Aphid

Defining features:
- Light green
- Pear shaped
- Cornicles (butt tubes)

When do they appear?
- Migrate to hop plants in May
- Thrive in cool, wet conditions

Sooty mold:
- Sugary secretions from hop aphid can lead to fungal growth

Can lead to sooty mold

Feeding damage:
- Feeding can remove water and vascular tissue
  - Leaf wilt and curl (reduced photosynthesis)
  - Unmarketable cones (limp and brown)

Management:
- Increase natural enemy habitat
  - Lady beetles, lacewings, parasitoid wasps
- Use of pesticides if populations remain high after flowering
- Populations tend to decrease in hot, dry weather

Potato Leafhopper

Causes hopperburn

Defining features:
- Bright green
- Bullet shaped
- Side-to-side scuttling

When do they appear?
- Variable- they arrive on wind currents from southern US as temperatures rise

Hopperburn:
- V-shaped leaf chlorosis and browning
- Decreases photosynthetic abilities

Management:
- Give them something tastier (trap cropping)
  - Red clover and alfalfa
- Varietal selection
  - Susceptible varieties: Liberty, Mt. Hood, Fuggle, Tettnang, Santium, Newport
- Increase natural enemy habitat
  - Minute pirate bugs, damsel bugs, big-eyed bugs, lacewings, lady beetles, spiders, parasitoid wasps

Japanese Beetles & Cutworms

Diseases of Hops

Powdery mildew

Downy Mildew

Verticillium Wilt

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

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

Stages of Production

Dormancy

- Onset:
  - Can be September through November
  - Shoots and fine roots die
  - Storage roots thicken and accumulate starch
  - Large resting buds develop
- Fieldwork:
  - Contain overgrown roots
  - Apply pre-emergent herbicides and compost
  - Work the ground
  - Set up new hop yards

Stages of Production

Spring Fieldwork

- Pruning mature hop yards from March through April (if necessary)
  - Mechanical, then chemical
  - Goal is to prepare consistent shoot length for training and to prevent disease
- Simultaneous weed control
- Dry fertilizer application
- Twining
- Irrigation
- Training

Stages of Production

Spring Fieldwork: Training

- Critical component of maximizing yield
  - Too early = early bloom risk
  - Too late = not achieving max yield
  - Train new, soft shoots
  - ~3 bines per string, but varies depending on cultivar
- Additional bottom-growth is controlled with desiccant later in season

Stages of Production

Vegetative Growth

- Typically May through July
  - From May to early July, most growth is in main bine
  - In July, bulk of growth occurs in lateral production
- Yield is determined in the plant very early, and adding fertilizer at this stage is essential

Stages of Production

Summer Fieldwork: Pests, Diseases and Weeds

- Major challenges to quality are pests and diseases
  - Other issues, while impacting yield, may not impact quality as much
- Healthy plants have more defenses
  - Fertilize
  - Irrigate
  - Spray
- Scout fields constantly, every day

Stages of Production

Reproductive Growth

- Typically late July through August
  - Trained vegetative growth ceases and is concentrated on hop cones
  - Mature cones can account for up to 50% of aboveground biomass
- Cannot increase number of cones
  - Maintaining plant health will maximize cone weight and quality
    - Fertilize
    - Irrigate
    - Spray

HAAS®

Stages of Production

Harvest

- Timing determined by cone moisture
  - Usually mid-August to early October depending on region
  - Dry matter measurements are scaled to ratios of oil or alpha content over time and weight
- Many harvest methods
  - Most common: cut and transport strings and bines to a stationary picking machine
  - Other methods: field strippers, mobile harvesters…
  - Still used in addition to a stationary cleaning facility or picking machine

Stages of Production

Preparation for Dormancy

- Begins at harvest
  - Typically end of August through September
- Signaled by short days
- Material migration shifts to roots
  - Peaks by October
- Keeping roots healthy is important at this stage
  - Preventing drying (irrigating)
  - Preventing damage

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


Field Guide for Integrated Pest Management in Hops
Oregon State University
University of Idaho
USDA Agricultural Research Service
and Washington State University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EXPERT REVIEWED
PURDUE EXTENSION
Hops Production in Indiana
Integrated Pest Management Guide for Hops in Indiana 2014
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Natasha Cerruti,
Lori Hoagland
Purdue Horticulture and Landscape Architecture
Rick Foster,
John Obermeyer
Purdue Entomology
Foreword
This guide will help growers select practices to manage weeds, diseases, and insects in hops in Indiana. It also lists pesticides registered for hops in Indiana if their use is warranted.
The recommendations in this guide use integrated pest management (IPM), which helps growers make management decisions that are economically sound and that have minimal impact on the environment. IPM management principles use the most economical means of managing a pest, which may involve cultural, mechanical, or chemical controls.
Please note that while the pesticide products listed in this publication are approved for use on hops, they have not been tested for effectiveness on hops in Indiana.
Reference to products in this publication is not intended to be an endorsement to the exclusion of others that may be similar. Individuals using such products assume responsibility for their use in accordance with current directions of the manufacturer. Information presented in this publication does not supersede pesticide label directions. To protect yourself, others, and the environment, always read the label before applying any pesticide — always remember that the label is the law.
We strongly recommend that anyone applying pesticides to crops for sale be a licensed applicator. Anyone who purchases or applies restricted use products (RUPs) — see Table 7 — must be a licensed applicator. Details about pesticide licensing are available from the Indiana Office of State Chemist, oisc.purdue.edu.
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