

Basic Hop Physiology & Stages of Production

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HERE'S TO THE MOMENTS

That make brewing beer the best job in the world.

Haas shares your passion for creating flavors that people love. From field to glass, everything we do is to help you brew great beer. Haas is here for your success.

John Eaton, Brewing Manager, Craft Beer Alliance





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FOR YOUR SUCCESS



Getting Started

- Hops... in Michigan?
 - Growing Pains
 - Considerations
- Cultivar Selection



Where to Start?



- Thinking about hops! ...over a beer perhaps?
- There are many things to consider
- Locations of U.S. hop production:
 - Washington: 74%
 - Oregon: 14%
 - Idaho: 10%
 - Other States: 2%
- U.S. hop economic value:
 - \$ 272 million in 2014
 - Crop value has been turbulent

Marketing Year	Total Crop Value
	(x 1,000)
2005	\$102,818
2006	\$118,008
2007	\$179,978
2008	\$325,092
2009	\$337,874
2010	\$214,589
2011	\$203,378
2012	\$186,876
2013	\$232,308
2014	\$271,992

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



Getting Started

Thinking About Hops?

- Agriculture is an important industry in MI!
 - 2nd only to CA in U.S. for crop diversity
 - Although CA leads in U.S. for economic activity generated from agriculture (~\$100 bil.)
 - ... according to Wikipedia

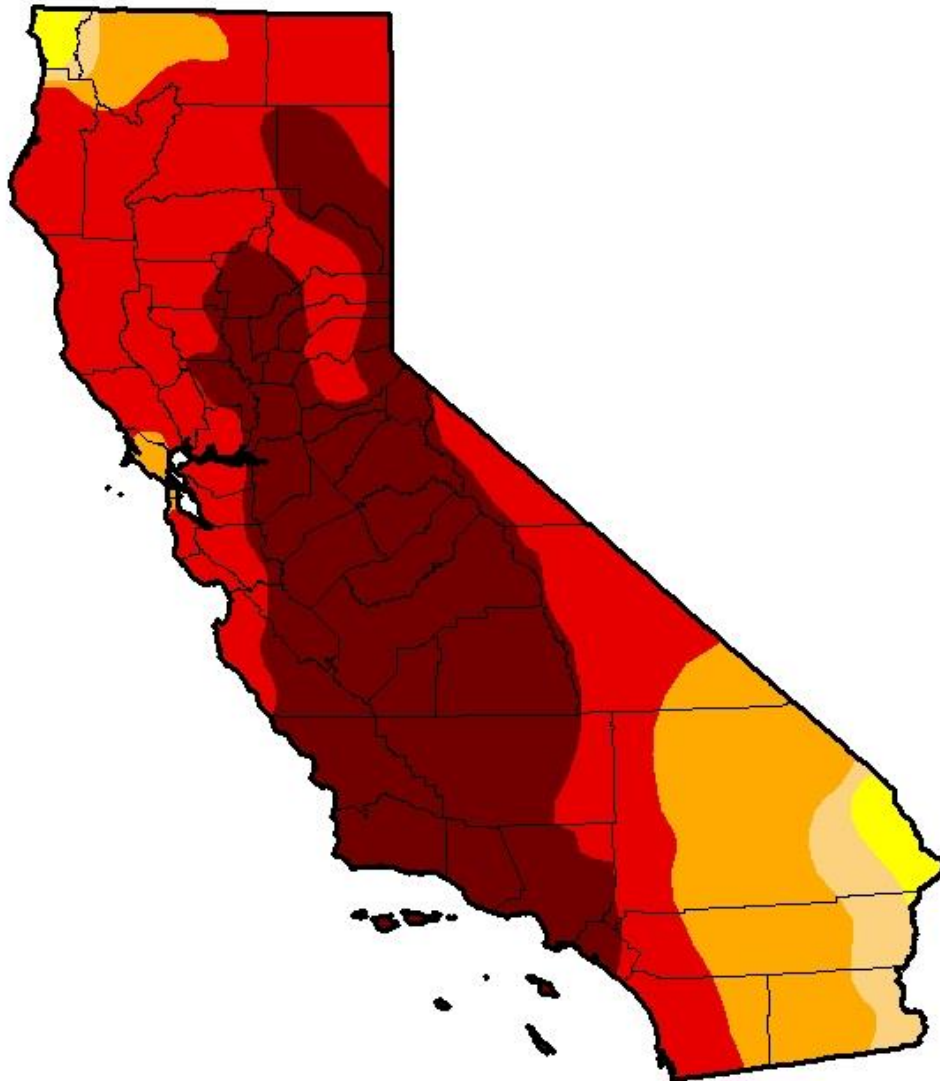


Source: Michigan Ag Council (www.michiganagriculture.com)



U.S. Drought Monitor California

January 13, 2015
(Released Thursday, Jan. 15, 2015)
Valid 7 a.m. EST



Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	0.00	100.00	98.12	94.34	77.52	39.15
Last Week <i>1/6/2015</i>	0.00	100.00	98.12	94.34	77.94	32.21
3 Months Ago <i>10/14/2014</i>	0.00	100.00	100.00	95.04	81.92	58.41
Start of Calendar Year <i>12/31/2014</i>	0.00	100.00	98.12	94.34	77.94	32.21
Start of Water Year <i>9/30/2014</i>	0.00	100.00	100.00	95.04	81.92	58.41
One Year Ago <i>1/14/2014</i>	1.43	98.57	94.18	89.91	62.71	0.00

Intensity:



The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

Author:

*Richard Tinker
CPC/NOAA/NWS/NCEP*



Getting Started

Thinking About Hops?

- Agriculture is an important industry in MI!
 - 2nd only to CA in U.S. for crop diversity
 - Although CA leads in U.S. for economic activity generated from agriculture (~\$100 bil.)
 - ... according to Wikipedia
- Agriculture, especially when diverse, is a GOOD economic driver
 - Healthy, more buffered, fun
 - Interest in hop production is not surprising



Getting Started

Growing Pains

- Increasing acreage of hops is expensive relative to other crops
 - Labor
 - Pesticides & Fertilizer
 - Equipment
 - Infrastructure (can cost millions of dollars)
 - Picking machine
 - Kiln
 - Cooling/conditioning, baling, and storage



Getting Started

Considerations

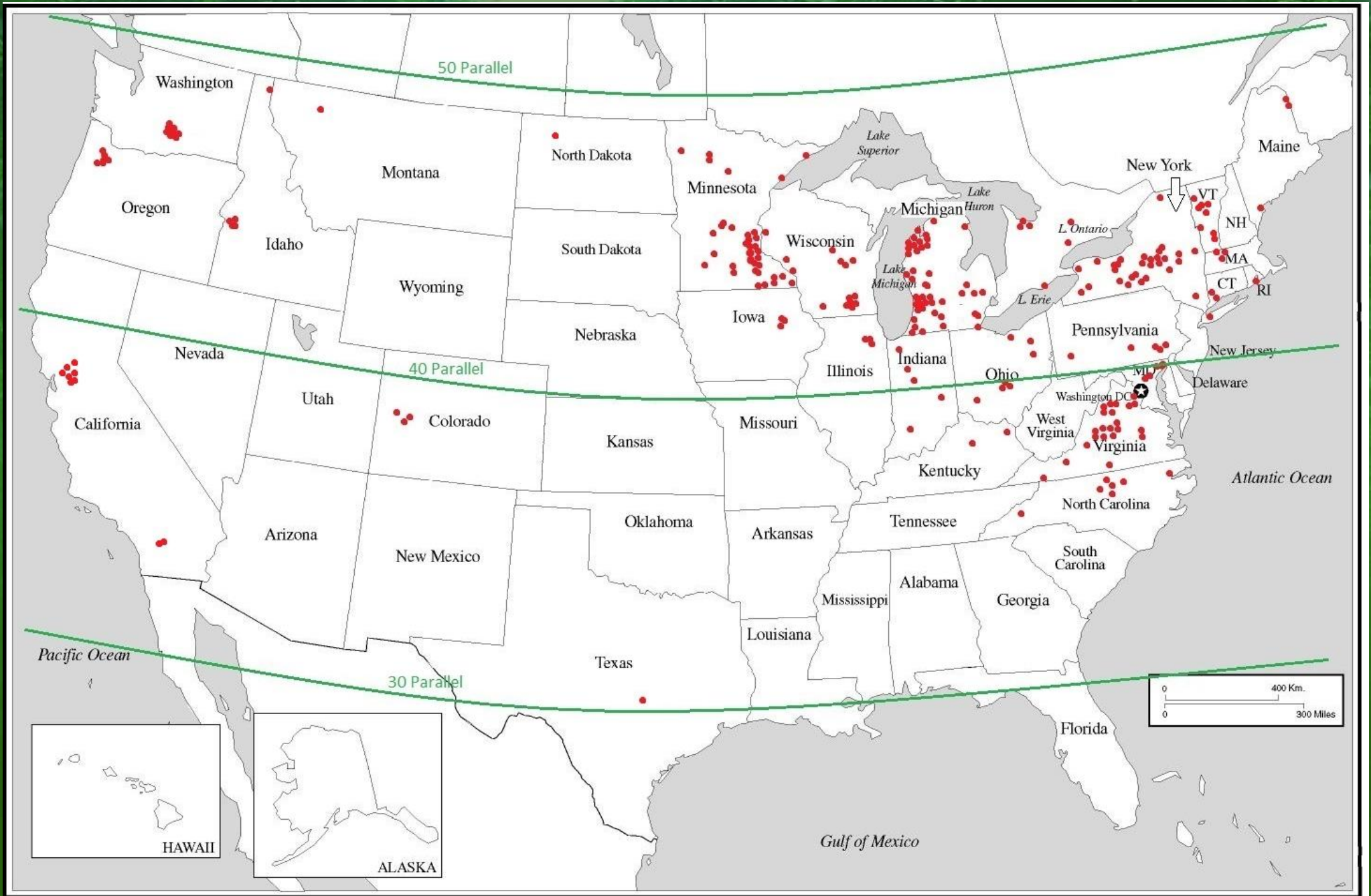
- **Climate**
 - Day length drives production stages (photoperiod sensitive)
 - Latitude determines day length
 - Heat determines growth during each stage
- **Soil type**
 - Physical: soil texture, drainage
 - Chemical: pH and nutrients
 - Biological: microbes, organic matter, etc.
- **Most suitable cultivar?**



50th Parallel

40th Parallel

30th Parallel



Getting Started



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Getting Started

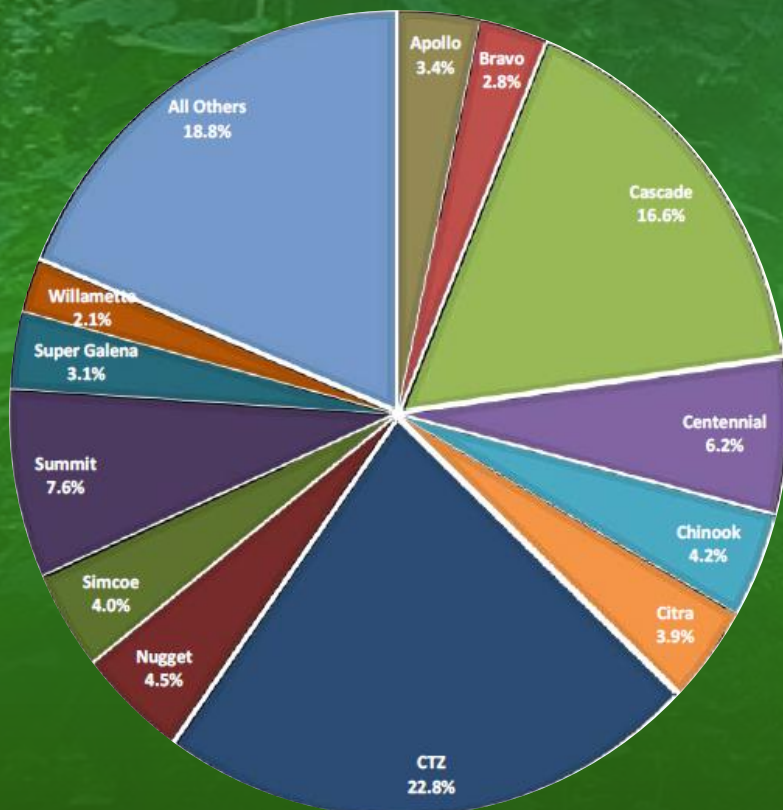
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Getting Started

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

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



Basic Hop Physiology

- Phylogeny
 - Roots and Rhizomes
- The Bine and Aboveground Plant
 - Dioecious Flowers
- Components of the Hop



Basic Hop Physiology

Hop Phylogeny

- Family: *Cannabaceae*
 - *Cannabis*
 - *C. sativa*
 - *Humulus spp.*
 - *H. lupulus*
 - *H. japonicas*
 - *H. yunnanensis*
- *H. lupulus* variety we cultivate:
 - *H. lupulus* var. *lupulus*
- Other, infertile varieties:
 - *H. lupulus* var. *cordifolius*
 - *H. lupulus* var. *lupuloides*
 - *H. lupulus* var. *neomexicanus*
 - *H. lupulus* var. *pubescens*

(Neve, 1991)



Basic Hop Physiology

Root System



- Water roots:
 - Grow deep in soil
 - Location of plant's energy reserves
- Crown:
 - Large, central mass of roots
 - Produces many shoots
- Rhizomes:
 - Belowground stems
 - Produce buds that become new spring growth
 - Can be extracted to plant new hop yards
 - More rhizomes can be created by covering bines with soil
- Fine Roots

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



Basic Hop Physiology

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Basic Hop Physiology

Aboveground Growth



Source: www.plantandplate.com

- Aboveground plant is annual
 - Dies back in fall and plant goes into dormancy
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 - Up to 18-25' per season
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 - Phototropic (light) and thigmotropic (touch) mechanism



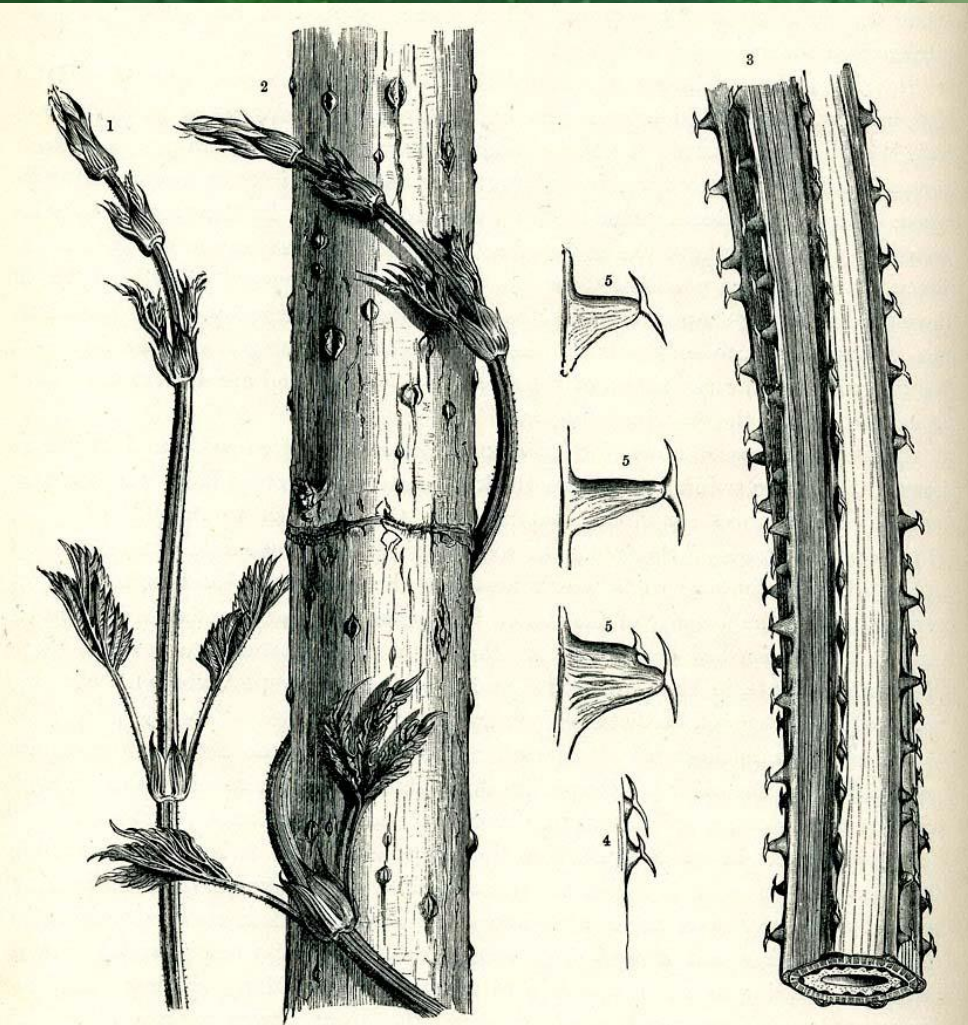


Fig. 160.—Twining Hop (*Humulus Lupulus*).

1 Free end of a shoot recently emerged above the ground. 2 Shoot of Hop twining round an elder-stem; natural size. 3 A portion of the Hop stem magnified. 4, 5 Single, anvil-shaped climbing-hooks detached from the stem; more highly magnified.

Anton Kerner von Marilaun (1895)



Source: <http://beyondthehumaneye.blogspot.com/2011/09/hooked-on-hops.html>

Basic Hop Physiology

Colorized scanning electron microscope image of hop trichome.

Photographed at Ludwig Maximilians University, Munich, Germany by Dr. Andre Kempe



Basic Hop Physiology

Aboveground Growth



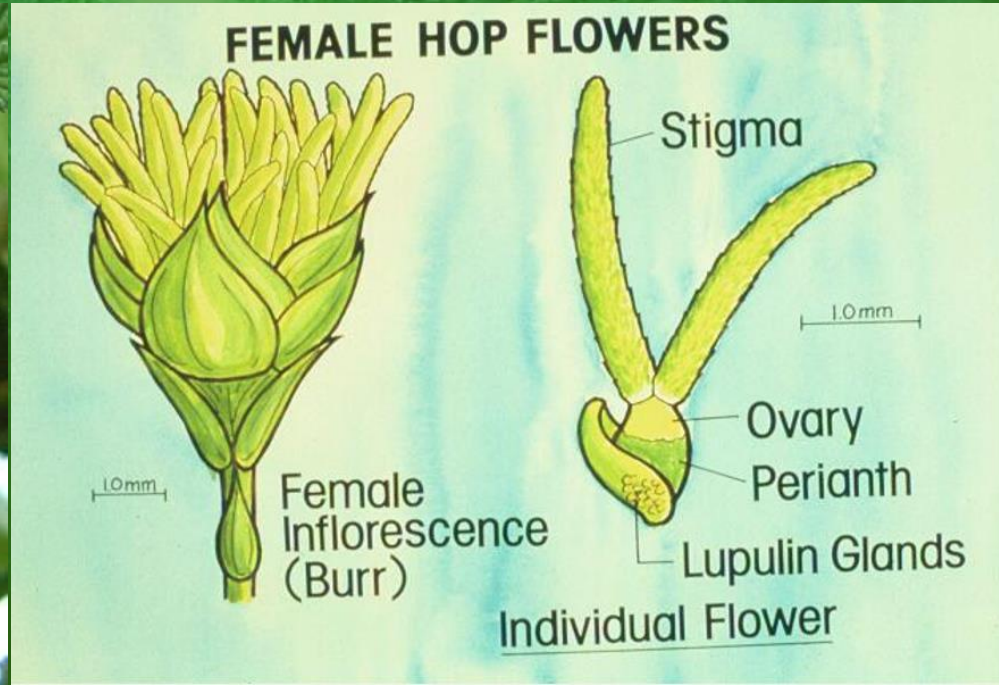
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- Bines grow rapidly in ideal conditions:
 - Up to 18-25' per season
 - Up to one foot per day
 - Wrap clockwise around anything within reach
 - Phototropic (light) and thigmotropic (touch) mechanism
- Lateral 'side arms' extend from the bines



Basic Hop Physiology

Reproduction/Flowering

- Dioecious: plants are either male or female



Basic Hop Physiology

Flowers

- Dioecious: plants are either male or female (there are some exceptions)
- Female plants produce commercially valued strobiles, or hop cones
- Male plants are valued for breeding
- Pollination undesirable in commercial fields:
 - Seeds
 - Increased cone size



Basic Hop Physiology

The Hop Cone

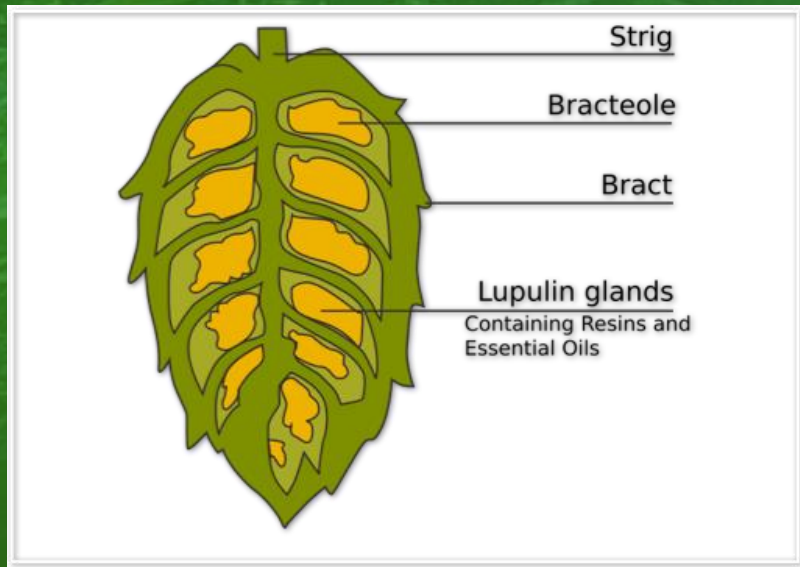
- Hop cones contain the commercial value of the plant



Basic Hop Physiology

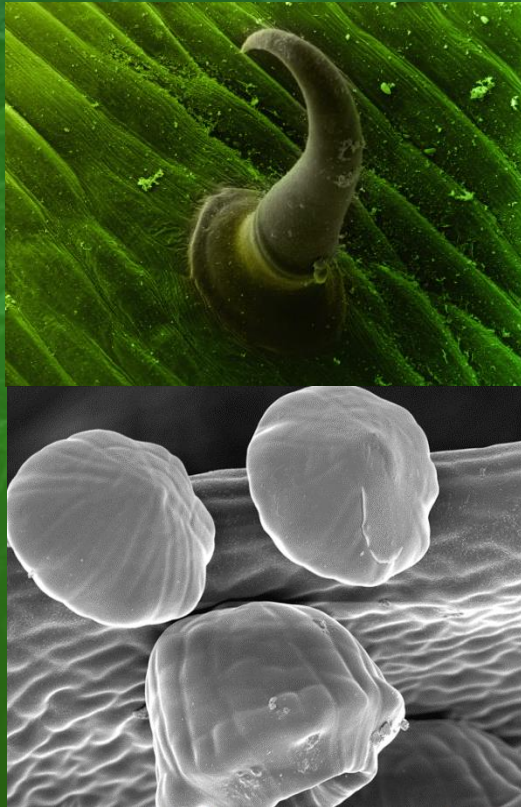
The Hop Cone

- Hop cones contain the commercial value of the plant
- Amazing phytochemical content in lupulin glands!
 - 200+ essential oil compounds
 - Important alpha acids, beta acids and other uncharacterized components



Basic Hop Physiology

The Hop Cone



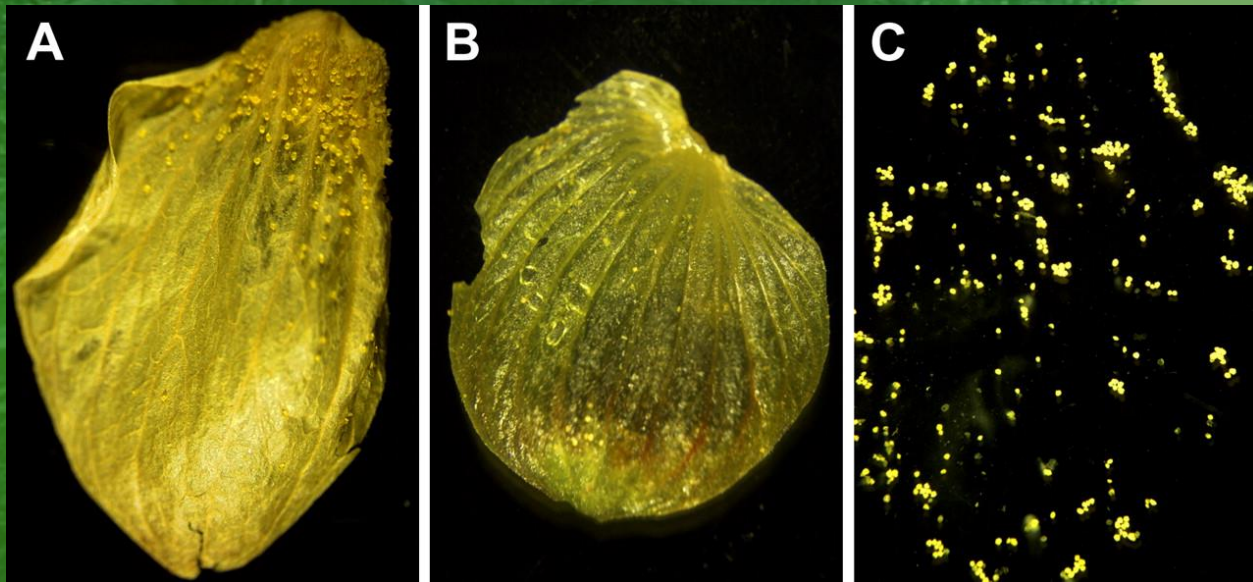
Source: www.plantrichome.org

- Hop cones contain the commercial value of the plant
- Amazing phytochemical content in lupulin glands!
 - 200+ essential oil compounds
 - Important alpha acids, beta acids and other uncharacterized components
- Lupulin glands are actually modified trichomes (glandular trichomes)



Basic Hop Physiology

The Hop Cone



Source: American Society of Plant Biologists (www.plantphysiol.org)

- Lupulin glands account for 20-30% of cone weight

Stages of Production

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



Stages of Production

- **Determined by photoperiod**
 - Shorter day lengths signal maturity
 - Longer day lengths signal vegetative growth
 - Different cultivars respond to different photoperiodic signals



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'



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



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

Planting a New Crop

- 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



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

Stages of Production

Planting a New Crop



- Several hop yard schemes
 - Most common in U.S.: 18.5' tall x 14' between rows x 3.5' between plants
 - Many other layouts:
 - Row spacing: between 7' and 14'
 - Between plant spacing: at least 1'
 - Low-trellis options

Stages of Production

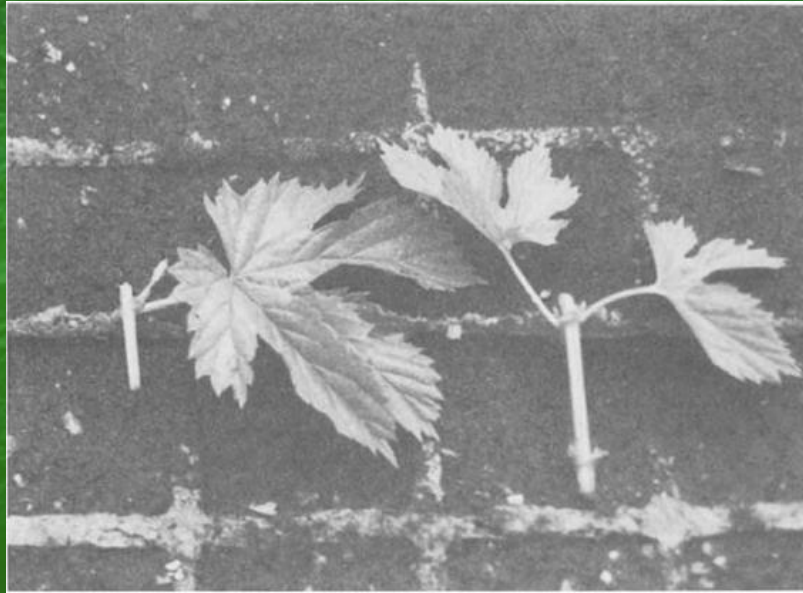


Planting Rhizomes

- Rhizome pieces and crowns can be planted directly into new fields
 - Low temperatures are ok
- Rhizome pieces can also be propagated in pots
 - Planted later in season (usually after frost)
 - Requires “hardening-off” period before planting
 - More expensive



Stages of Production



Cuttings prepared for propagation (Neve, 1991)

Planting Softwood Cuttings

- Softwood cuttings are typically one or two nodes
- Generally not preferred over direct planted or potted rhizomes
 - Weaker tissue
 - Requires more time and resources
- Used to increase acreage of new cultivars with limited parent material
 - Can get thousands of new plants from one

Stages of Production

Spring Regrowth



- Onset:
 - Typically March through May
 - Signaled by increasing day length and temperatures
 - Storage roots are depleted as shoots emerge rapidly from over-wintered buds



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 vines 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



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



Stages of Production

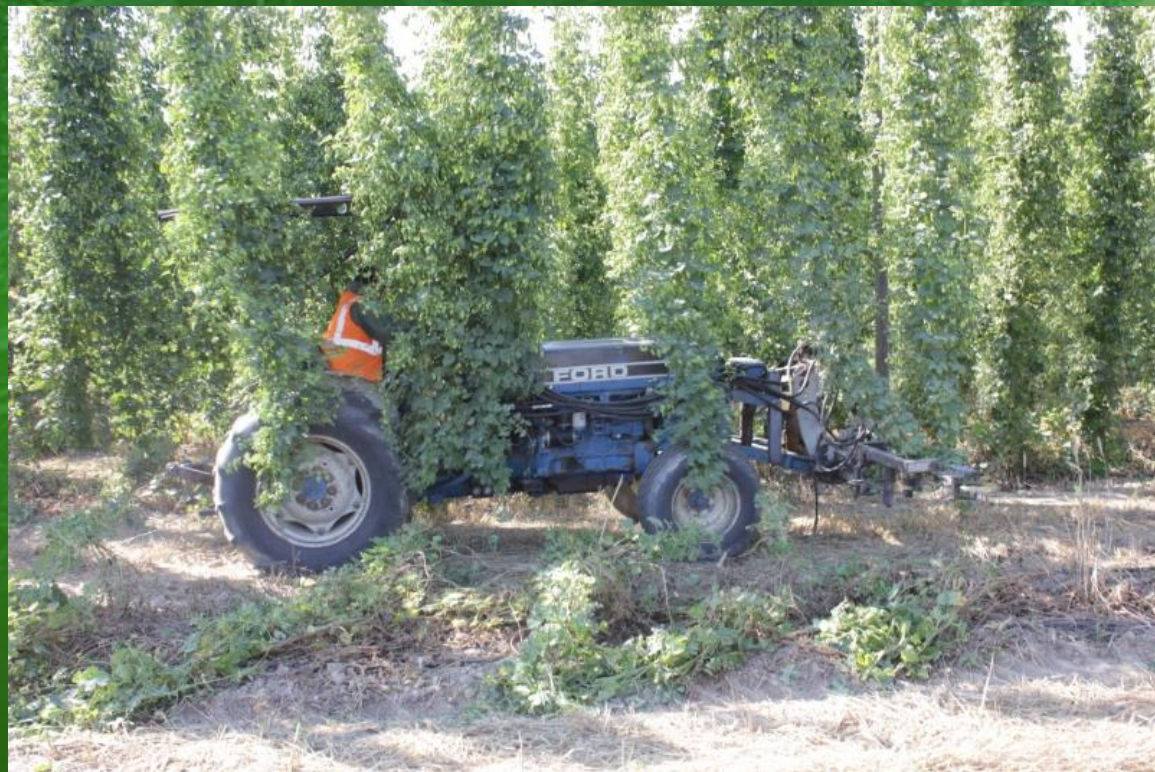
Harvest



- 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

Harvest



Stages of Production

Harvest



Stages of Production

Harvest

- Hops are picked and cleaned in one facility...



Stages of Production

Harvest



- Hops are picked and cleaned in one facility...
- Dried in the kiln...

Stages of Production

Harvest



- Hops are picked and cleaned in one facility...
- Dried in the kiln...
- Cooled and baled...

Stages of Production

Harvest



- Hops are picked and cleaned in one facility...
- Dried in the kiln...
- Cooled and baled...
- Then shipped to cold storage before downstream processing

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

Take Home Message

- **Quality is the #1 goal:**
 - Value is realized in quality
- To achieve **consistent** quality, know your plants and your environment
 - Stages of production are determined by photoperiod, while growth in each stage is regulated by climate
- The management decisions you make will depend on your region
- Next steps are to collect information





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Thank You!