Outline

• Trellis Setup and Hopyard Design
• Hops: Stages of Production/Processing
• Associated Management Practices & costs
• Cost Overview
• Market Outlook
<table>
<thead>
<tr>
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<th>Per Acre</th>
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<th>5 Acre Yard</th>
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</tr>
<tr>
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<td>$ 700.00</td>
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<td>$ 3,500.00</td>
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<tr>
<td>Irrigation^</td>
<td>$ 1,500.00</td>
<td>Includes installation</td>
<td>$ 7,500.00</td>
</tr>
<tr>
<td>Well</td>
<td></td>
<td>Variable</td>
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<tr>
<td><strong>Total Initial Costs</strong></td>
<td>$ 12,588.50</td>
<td></td>
<td>$ 59,102.50</td>
</tr>
</tbody>
</table>

^ For a 5 acre yard: 53 field poles/ac & 27 end poles/ac=265 field poles and 134 end poles or 80/acre

^ 50 gallon/min, 2 inch main (no filtration)-cost is variable depending upon needs, # zones, etc.
Hops: Trellis Design
Climbing bines

- Bine climbs with the aid of “Trichomes”
- In the wild-they climb up companion species
- Commercial production-Requires a trellis system for support
- Typical set-up
  - 18’ tall
  - Plants spaced 3’ x 14’
  - 1000-1200 plants/acre
- Vine wraps around string-clockwise-function of phototropism (light) and thigmotropism (touch)
Conventional High Trellis
Standard Tall Trellis Hopyard Design
Carr creek hops

- 3/16" or 1/4"
- 5/16" - 3/8"
- 28'
- 56'
- 14'
Important to build a Solid Trellis!!
Short Trellis

- 3’ x 8’, 9’, or 12’
- Labor Reduction
- Lower Establishment Cost
- Lower yields
- Ill-adapted varieties
Factors that can impact hop production (growth, yield, and quality) & your net returns

- Environment (temp, day length, soil texture, weather)
- Production Practices
  - Cultivar
  - Soil fertility
  - Disease, pest, and weed pressure and control
  - Training and timing of training
  - Harvest and harvest timing
  - Irrigation
  - Post-harvest processing and storage
Environment

• Grow in a variety of soils from clay to sand
• Prefer well-drained soils
  – Sandy loam or silt loam
• Problem with heavy, poorly drained soils
  – May delay getting into field
  – Increase disease issues/rotting
• Problem with overly sandy soils
  • Hi input costs

Source: Neve, R.A. Hops. 1991
Hops and pH

- pH optimum (6.2-6.5)
- Lime if too low

How soil pH affects availability of plant nutrients
Hop Production Stages

• Stages of Growth
  – Dormancy
  – Spring regrowth
  – Vegetative growth
  – Reproductive growth
  – Preparation for dormancy

• Each stage requires its own unique management regime & associated costs

Source: Jason Perrault, Perrault Farms
FALL/WINTER

Dormancy (October-March)

- In late summer the plant allocates photosynthetically derived starches to the storage roots
- Starch is converted into soluble sugars
- Sugars are the energy needed for spring-regrowth

- In the field
  - Not much happening
  - Planning for next season

Source: Jason Perrault, Perrault Farms
Variety selection

1. What brewers want
2. Yield
3. Disease resistance
4. Location-soil type, etc.

These will affect your bottom line
Spring Regrowth (April-May)

- Increasing day lengths and temperatures signal end of dormancy
- Plants emerge from dormancy
- Initial regrowth occurs—rapidly producing vines unsuitable for production
- Plant uses energy reserves through May, when the starches and sugars reach their lowest points of the year
- Supplemental nutrient management is needed

Source: Jason Perrault, Perrault Farms

Photo credit: Erin Lizotte
## Soil Test Results

**Client:** MICHIGAN STATE UNIVERSITY EXTENSION  
**City:** SUTTONS BAY, MI  
**Date:** 12-Sep-12

### Soil Test Details
- **Crop:** HOPS / HOPS
- **Lab No.:** B0103
- **Total Exchange Capacity (M.E.):** 7.58
- **Desired Ca : Mg, Percent:** 66 : 14
- **pH of Soil Sample:** 7.0
- **Humus Content, Percent:** 1.9

### Base Saturation Percent

<table>
<thead>
<tr>
<th>Element</th>
<th>FOR ORGANIC</th>
<th>FOR CONVENTIONAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium (50 to 70%)</td>
<td>76.15</td>
<td></td>
</tr>
<tr>
<td>Magnesium (10 to 20%)</td>
<td>15.67</td>
<td></td>
</tr>
<tr>
<td>Potassium (2 to 5%)</td>
<td>2.85</td>
<td></td>
</tr>
<tr>
<td>Sodium (.5 to 3%)</td>
<td>0.92</td>
<td></td>
</tr>
<tr>
<td>Other Bases (Variable)</td>
<td>4.38</td>
<td></td>
</tr>
</tbody>
</table>

### Exchangeable Hydrogen (10 to 15%)

### Nitrogen

<table>
<thead>
<tr>
<th>Amendment</th>
<th>Lbs/Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEATHER MEAL 13-0-0 (a)</td>
<td>450</td>
</tr>
<tr>
<td>FEATHER MEAL 13-0-0 (b)</td>
<td>375</td>
</tr>
<tr>
<td>UREA 46-0-0 (c)</td>
<td>40</td>
</tr>
<tr>
<td>AMSULF 21-0-0-24 (d)</td>
<td>125</td>
</tr>
<tr>
<td>CAN 17 N (e)</td>
<td>50</td>
</tr>
<tr>
<td>COMPOST</td>
<td></td>
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</tbody>
</table>

### Sulfate-S

<table>
<thead>
<tr>
<th>Value Found</th>
<th>Lbs/Acre</th>
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<tbody>
<tr>
<td>SULFUR 30-52% (g)</td>
<td>75</td>
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</table>

### Phosphates

<table>
<thead>
<tr>
<th>Desired Value</th>
<th>Olsen Value</th>
<th>Lbs/Acre</th>
<th>Deficit/Surplus</th>
</tr>
</thead>
<tbody>
<tr>
<td>750</td>
<td>636</td>
<td>-114</td>
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</tr>
</tbody>
</table>

### Calcium

<table>
<thead>
<tr>
<th>Desired Value</th>
<th>Value Found</th>
<th>Deficit/Surplus</th>
</tr>
</thead>
<tbody>
<tr>
<td>2062</td>
<td>2309</td>
<td>+247</td>
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</tbody>
</table>

### Magnesium

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<thead>
<tr>
<th>Desired Value</th>
<th>Value Found</th>
<th>Deficit/Surplus</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>285</td>
<td>+35</td>
</tr>
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### Potassium

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<tr>
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<tr>
<td>443</td>
<td>170</td>
<td>-273</td>
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### Sodium

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<tbody>
<tr>
<td>35</td>
<td>32</td>
<td>-3</td>
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### Other Elements

<table>
<thead>
<tr>
<th>Element</th>
<th>Lbs/Acre</th>
</tr>
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<tbody>
<tr>
<td>Boron</td>
<td>0.88</td>
</tr>
<tr>
<td>Iron</td>
<td>411</td>
</tr>
<tr>
<td>Manganese</td>
<td>83</td>
</tr>
<tr>
<td>Copper</td>
<td>1.40</td>
</tr>
<tr>
<td>Zinc</td>
<td>8.50</td>
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### Recommendations

- **NITROGEN:** ENR Value 58
- **SULFATE-S:** Value Found 16
- **PHOSPHATES:** Desired Value 750, Olsen Value 636
- **CALCIUM:** Desired Value 2062, Value Found 2309
- **MAGNESIUM:** Desired Value 250, Value Found 285
- **POTASSIUM:** Desired Value 443, Value Found 170
- **SODIUM:** Desired Value 35, Value Found 32

### Notes

- **Boron:** 14.3% P.P.M.
- **Iron:** 411 p.p.m.
- **Manganese:** 83 p.p.m.
- **Copper:** 1.40 p.p.m.
- **Zinc:** 8.50 p.p.m.

### Additional Information

- **Apply 1 week or so before spring growth begins.**
- **Apply 1 week or so before bloom.**
- **Work into soil immediately or water in with a minimum of 1/2 inch of water.**
- **Apply in early spring.**
- **Apply at bloom.**
- **Apply at bloom.**
- **Sulfur applications including the sulfate form of 50 lbs/acre or more need to be applied at least 6 months prior to next soil sampling.**
- **Apply an additional 250 lbs/acre of Potassium Sulfate (0-0-60) during the growing season.**

**NOTE:** Could use compost here if Ca & Mg levels in the compost are not too high. Should not be applied though without an analysis first to determine the effects this would have on soil nutrient content.
Planting

- Michigan is moving away from rhizomes
  - Disease
  - Reliability
  - New local supplies of certified plants
- Plant starts can be planted throughout the growing season but generally in spring
- Have your trellis and irrigation in place before planting
- Before you purchase quantity, get some sample plants and send them immediately to your University lab
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~ For a 5 acre yard: 53 field poles/ac & 27 end poles/ac=265 field poles and 134 end poles or 80/acre
^ 50 gallon/min, 2 inch main (no filtration)-cost is variable depending upon needs, # zones, etc.
Pruning/crowning
• At least 2000 strings/acre (2 per plant)

• Video

http://roguefarmsblog.wordpress.com/category/crops/hops-crops/
Somewhere In Michigan
Options for stringing

1. W clips
Options for stringing

2. Tie strings to a lower wire
Training

• 3-4 bines
• Clockwise only
• Timing—Cultivar and weather dependent
• Will likely have to re-train
### Table 2. 2013 Hopyard Annual Operating Costs (Per Acre)

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<thead>
<tr>
<th></th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
</tr>
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<tbody>
<tr>
<td><strong>Annual Operating Costs</strong></td>
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<td></td>
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<tr>
<td>Coir (1 string yr 1; 2 strings yr 2+, $.20/ string; clips $80)</td>
<td>$240.00</td>
<td>$480.00</td>
<td>$480.00</td>
<td>$480.00</td>
<td>$480.00</td>
</tr>
<tr>
<td>Labor-stringing (5 workers x 10 hours X $10/hr)</td>
<td>$350.00</td>
<td>$500.00</td>
<td>$500.00</td>
<td>$500.00</td>
<td>$500.00</td>
</tr>
<tr>
<td>Labor-training</td>
<td>$500.00</td>
<td>$750.00</td>
<td>$750.00</td>
<td>$750.00</td>
<td>$750.00</td>
</tr>
<tr>
<td>Pest/Disease Chemicals (insecticide/fungicide/herbicide)</td>
<td>$400.00</td>
<td>$600.00</td>
<td>$600.00</td>
<td>$600.00</td>
<td>$600.00</td>
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<tr>
<td>Fertilizer</td>
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<td>$275.00</td>
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<tr>
<td>IPM Consultant</td>
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<td>$750.00</td>
<td>$750.00</td>
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<td>$750.00</td>
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<tr>
<td>Repairs/Parts/Maintenance</td>
<td>$250.00</td>
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<td>$250.00</td>
<td>$250.00</td>
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<tr>
<td>Machinery/Labor -Stringing</td>
<td>$100.00</td>
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<td>$100.00</td>
<td>$100.00</td>
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<tr>
<td>Machinery/Labor -Fertility</td>
<td>$300.00</td>
<td>$400.00</td>
<td>$400.00</td>
<td>$400.00</td>
<td>$400.00</td>
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<tr>
<td>Machinery/Labor -Mowing/Till</td>
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<td>$100.00</td>
<td>$100.00</td>
<td>$100.00</td>
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<tr>
<td>Machinery/Labor- Spraying</td>
<td>$300.00</td>
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<td>$350.00</td>
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<td>$350.00</td>
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<tr>
<td><strong>Subtotal</strong></td>
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<td><strong>$3,830.00</strong></td>
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<td><strong>$3,830.00</strong></td>
<td><strong>$3,830.00</strong></td>
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<tr>
<td><strong>Harvest</strong></td>
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<tr>
<td>Labor-harvesting (10 hrs, 4 workers-cut, load)</td>
<td>$400.00</td>
<td>$400.00</td>
<td>$400.00</td>
<td>$400.00</td>
<td>$400.00</td>
</tr>
<tr>
<td>Management ($20/hr* 10 hrs)</td>
<td>$200.00</td>
<td>$200.00</td>
<td>$200.00</td>
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<tr>
<td>Machinery ($125/hr)</td>
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<td>$1,250.00</td>
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<td>$1,250.00</td>
<td>$1,250.00</td>
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<tr>
<td><strong>Subtotal</strong></td>
<td><strong>$1,850.00</strong></td>
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<tr>
<td><strong>Total Annual Operating Costs</strong></td>
<td><strong>$2,565.00</strong></td>
<td><strong>$5,680.00</strong></td>
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- Analysis does not include land cost or overhead like interest on loans, taxes, etc.
- Does include per hour rate for machinery, labor, and management that would be charged if hired out (opportunity cost)
- Standard trellis design is 3.5 x 14 ft ~1000 plants/acre
Irrigation

- 75-80% of total annual hop water use occurs after mid-June
- Greatest daily amounts late July-early August
- Majority of roots are in top 4’
- Hops usually extract 50-60% from top 2’, but can extract water from 8’ or below
- Overall use around 30 inches/year, depends on season
- $-right size your well, different zones for different cultivars

Irrigation: Examples

- Loftus Ranches
- Run two drip tubes per row
- 8 gallons per plant per day in hot season (4 on, 8 off, 4 on)
- \(~8000\) gallons/acre
Irrigation: Examples

NWMHRC

- Run one drip tube per row
- .42 gallon emitters every two feet
- RAM tubing
- 30 minute flush, 45 minute fertigate, 30 minute flush (every other day)
- NOT ENOUGH WATER
Fertigation
Vegetative Growth (May-July)

• Critical Stage for the purposes of crop production, occurs from end of May-end of July

• Two Phases:
  1. May-early July: Plant growth mainly in main vine and leaves
  2. July: Bulk of above ground growth occurs in the lateral production (side arms)

• Plant reserves used up
• Plant already determining yield
  • Aggressive management!!
  • Maximize health of plant & growth

Source: Jason Perrault, Perrault Farms
Vegetative Growth (May-July)

• In the Field
  • IPM-monitor, monitor, monitor
  • Pest/Disease/Weed Control
  • Fertility Management
  • Irrigation

Source: Jason Perrault, Perrault Farms
Hop Growing Requirements: Fertility

- Soil Test Before planting
- Tissues Tests and Soil tests
- Recommended fertilization rates:
  - Nitrogen (N) = 150 lbs/acre
    - Mid-April with urea (40-0-0) every 2-3 weeks then later come in with triple 16
    - End in July
    - No more than 25 lbs/acre at one time
  - Phosphorous (P) = 60-100 lbs/acre
  - Potassium (K) = 100 lbs/acre (potash)
- Eg. Yakima Valley
  Highest average yield included a 90 lbs. N/ac as a spring application, followed by 90 lbs. N/ac administered through fertigation, ending in June (180 lbs. of N/ac total)
Weed control
Pests and Diseases

- **Hop aphid** (*Phorodon humuli*)
- **Downy mildew** (*Pseudoperonospora humuli*)
- **Spider Mites** (*Tetranychus urticae*)
- **Powdery mildew** (*Podosphaera macularis*)
- **Potato Leaf Hopper** (*Empoasca fabae*)
Resources for pesticide labels

• Crop data management systems
  – www.cdms.net

• GREENBOOK
  – www.greenbook.net

• Agrian
  – http://www.agrian.com/home/label-lookup/overview#

• New Bulletin
  – http://www.hops.msu.edu
Table 2. 2013 Hopyard Annual Operating Costs and Returns (Per Acre)

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<td>Pest/Disease Chemicals (insecticide/fungicide/herbicide)</td>
<td>$400.00</td>
<td>$600.00</td>
<td>$600.00</td>
<td>$600.00</td>
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<tr>
<td>Fertilizer</td>
<td>$250.00</td>
<td>$275.00</td>
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<tr>
<td>IPM Consultant</td>
<td>$25.00</td>
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<td>Repairs/Parts/Maintenance</td>
<td>$250.00</td>
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<tr>
<td>Machinery/Labor -Stringing</td>
<td>$100.00</td>
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<tr>
<td>Machinery/Labor -Fertility</td>
<td>$300.00</td>
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<tr>
<td>Machinery/Labor -Mowing/Till</td>
<td>$100.00</td>
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<tr>
<td>Machinery/Labor -Spraying</td>
<td>$300.00</td>
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<tr>
<td><strong>Subtotal</strong></td>
<td><strong>$2,565.00</strong></td>
<td><strong>$3,830.00</strong></td>
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<td><strong>$3,830.00</strong></td>
<td><strong>$3,830.00</strong></td>
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<td>Harvest</td>
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<tr>
<td>Labor-harvesting (10 hrs, 4 workers-cut, load)</td>
<td>$400.00</td>
<td>$400.00</td>
<td>$400.00</td>
<td>$400.00</td>
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<tr>
<td>Management ($20/hr* 10 hrs)</td>
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</tbody>
</table>

**Total Annual Operating Costs**  
$2,565.00  $5,680.00  $5,680.00  $5,680.00  $5,680.00

- Analysis does not include land cost or overhead like interest on loans, taxes, etc.
- Does include per hour rate for machinery, labor, and management that would be charged if hired out (opportunity cost)
- Standard trellis design is 3.5 x 14 ft ~1000 plants/acre
End of July

• Floral Production has commenced
  • Plant shifts energy into cone production
  • Focus on: plant health to maximize cone weight and resin/oil content
  • Water management-July-August most of H2O
  • Nutrient management-cut off N, add K

Source: Jason Perrault, Perrault Farms
Preparation for Dormancy (September)

- Harvest!!!!
- Vines cut (bottom then top)
- Laid down into trailer
- Taken to picking machine
- Cones dried for 8-12 hours (10% moisture)
- Cured
- Baled
- Cold storage

Source: Jason Perrault, Perrault Farms
Harvest Timing

Hops are harvested upon reaching the “technical ripeness” (highest brewing value), not at full or “physiological” maturity. Each variety has its own specific, genetically determined optimal time of harvest. Varies by the weather, location, biological window, and the cutting time.

Harvest time crucially affects:
- $\alpha$-acid contents
- yield
- external quality (color and shine, infection with diseases and pests, shattering)
- aroma (aroma intensity, oil content and composition)
- vigor and vitality of the plant (in the next season)

Economic interest of hop growers, traders and brewers

Results from harvest time studies
- 5 – 8 harvest times (2 dates / week), 4 replications with 20 bines each
- 3- 4-year-trials (climate, health and vitality)
- data for yield, $\alpha$-acid contents, aroma, external quality, shortcomings assessed

# The Right Time to Harvest Optimal Yield and Quality

A. Lutz, J. Kneidl, E. Seigner, and K. Kammhuber

<table>
<thead>
<tr>
<th>August</th>
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<td>22</td>
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</tbody>
</table>

- **Hallertauer Mfr.**
- **Spalter**
- **Northern Br.**
- **Tettnanger**
- **Hall. Tradition**
- **Opal**
- **Saphir**
- **Perle**
- **Spalter Select**
- **Smaragd**
- **Hersbrucker**
- **Hall. Magnum**
- **Hall.Taurus**
- **Herkules**
- **Nugget**

**Legend:**
- Green: optimal harvest time
- Yellow: harvest with restriction possible
Removing the guesswork

Harvest Package $50

• Combining Brewing Values (alpha acids, beta acids, and hop storage index (H.S.I.)) and Dry Matter analysis, the Harvest Package is designed with hop farmers in mind.

• Results provide growers with content and characteristics of their hops and/or fields and can be utilized on an annual basis to establish trends within a given hop variety or lot location.

• Prior to harvest, these results specifically equip growers with the necessary information to plan peak harvest windows and make informed decisions regarding alpha content, hop cone maturity and overall hop quality.

• Require a 200g sample and a minimum 1 day turnaround.
By Hand
Hop Value-Chain

Grow Hops

Hop Harvest

Picking

Drying

Hammer Mill & Pelletizer

Analysis

Conditioning

Baling

Marketing/Sales

Whole cone

Pellets

Cold Storage

Packaging
Transport to the Picker

Degradation potential

- Distance?
- Humidity level?
- Time of harvest (early a.m. or noon)?
- Temperature at harvest?
- Cost

In terms of the drying process picked hop cones can be regarded as a living organism whose basic life processes, particularly respiration, are continuing. They first react to being removed from the plant by a higher intensity of respiration. Rybacek, 1991.
Hop Value-Chain

Grow Hops

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Picking

Considerations

• Acreage
• Speed (bines/hour)
• Drying capacity
• Pelletizing capacity
• Storage
• $$$
• Varieties
• Scheduling!!

http://brewpublic.com/brewpubs/in-hop-pursuit/
Hand Picking

• Not recommended for >1/3 acre
WOLF 170
<table>
<thead>
<tr>
<th>Type</th>
<th>WHE 513</th>
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<tbody>
<tr>
<td>Crop Performance</td>
<td>350 - 510 bines / h</td>
</tr>
<tr>
<td>Length</td>
<td>approx. 17,90 m</td>
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<tr>
<td>Height</td>
<td>ca. 4,70 m</td>
</tr>
<tr>
<td></td>
<td>(at 0,35 m high feet)</td>
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<tr>
<td>Width</td>
<td>approx. 6,80 m</td>
</tr>
<tr>
<td>Performance</td>
<td>approx. 35,0 kW</td>
</tr>
</tbody>
</table>
Used Wolf 2014-2015 price list

- Type 1 $15,000.00 lim. supply
- 140 - 5 drum $23,500.00
- 140/170 - 7 drum $25,500.00
- 220 $40,000.00
- 280 $45,000.00
- 400 $85,000.00
- Pellet mill w/ vac bagger $85,000.00
- Drying floor w/ heater $7,500.00
- Baler $6,500.00

Note: Does not include shipping, build-out, electrical panel

513 video
Modular Hop Oast

Introduction

Hops are commonly harvested at 75-80% moisture by weight, but are ideally pelleted, packaged and stored only after they are dried to 8-10% moisture. To put this into perspective consider that a pound of "dry" hops starts out with about 3 pounds of water (a little less than a half gallon) that has to be evaporated by drying.

In large, commercial hop production whole buildings are dedicated to the careful process of drying hops to the desired storage moisture. Given the nascent, distributed, and small-scale nature of Vermont's resurgent hop industry a different approach is needed. To this end, a modular hop oast has been developed and demonstrated by UVM Extension and Borderview Farm. This oast is designed as an integrated cabinet dryer that holds trays of hops. The drying is accomplished with a fan, heater and controller.

Different hop varieties can be kept separate in the oast by placing them in different trays. A total of 8 trays can be accommodated in each cabinet. Wire mesh is used as the bottom for the trays which allows air flow through the hops.

Design

The aim of the design is to use readily available materials and common construction skills and to result in a modular and scalable oast that supports hop growers of various scales. A base module of 4' W x 4' D x 8' H makes use of standard building materials well and allows for convenient sized hop trays. All of the main structure is made with standard construction lumber and plywood. The electrical system is 220 VAC single phase and uses fairly common parts and wiring. The fan motor is 1/4 HP and the fan impeller is 24 inch vane axial design capable of 3250 CFM at 0.7 lwc pressure rise (at 1750 RPM). The majority of air flow is circulation within the cabinet, however in order to dry the hops the humidified air must be removed. Holes are drilled in the top of the cabinet at high pressure and low pressure areas along the impeller resulting in exhaust and fresh air intake respectively. The placement of these holes and the degree to which they are open or covered determines how much "stripping" air is pulled through the cabinet. The heating element is a 3000 Watt bent tubular heater. Although one can dry hops using unheated, ambient air, the addition of well controlled heat to the air allows for quicker drying reducing labor and maintaining higher quality hops.

The comfort level in this oast has been selected to dry 300 lbs of wet hops from 80% moisture to 10% moisture in 8 hours with little to no labor required.

The fan and heater are installed on the ceiling of the cabinet. A PID controller ( inset) rests on top of the cabinet and ensures temperature control.

A proportional-integral-derivative (PID) controller has been used in this system. This type of controller allows the user to set a target temperature and by monitoring the actual temperature in the cabinet using a thermocouple it "zeros" itself on the set point. This differs from a thermostat control which would provide an "average" temperature of the set point but with sometimes wide fluctuations above or below it. The PID controller is always monitoring the difference between the set point and the actual temperature, the historical difference, and the rate at which this difference is changing in order to predictably adjust the heater operation to attain the desired temperature.

The cost of the Modular Hop Oast including design drawings, a bill of materials, and a description of the machine are available for download from http://www.uvm.edu/extension/ncrops/soils/wiki/

A project of University of Vermont Extension; Vermont Agency of Agriculture, Food and Markets; and Massachusetts Department of Agricultural Resources through the USDA Specialty Crops Block Grants Program.

UVM Extension helps individuals and communities put research-based knowledge to work. Issued in furtherance of Cooperative Extension work Acts of May 8 and June 30, 1914, in cooperation with the United States Department of Agriculture, University of Vermont Extension, Burlington, Vermont; University of Vermont Extension, Burlington, Vermont; University of Vermont Extension, University of Vermont Extension, and U.S. Department of Agriculture, Cooperative Extension Service; and U.S. Department of Agriculture, Cooperative Extension Service.
Louvered, multilevel Hop Dryers

• Louvered Dryers are exceptional space savers and easy to use.
• The drying process typically takes place on three levels, on two shelves and in louvered drawer.
• $8k + $4-6k
Yakima, WA
Hop Value-Chain

Grow Hops

Hop Harvest

Picking

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Hammer Mill & Pelletizer

Analysis

Conditioning

Baling

Cold Storage

Packaging

Marketing/Sales

Whole cone

Pellets

SHORT’S BREW

KIND ALE

Wet Hop Ale - From Field to Fermenter

Analysis
Conditioning

Considerations

• Humidity- (In 2 hours you could go from 9% to 13% moisture)
• Throughput and timing
• Space requirements
• Food safety?

• The hops are left in these heaps for 12 hours in a staged process known as “conditioning”.
• The heaps are re-piled for a further 12 hours across the floor in which time the moisture level continues to equilibrate to ensure consistency prior to baling.
• Target moisture level for our hops is around 9.5 % (+/- 1 %) which requires a high level of patience and skill to achieve.
Baling

Considerations

• Timing
• Quantity of hops
• Size
• $$ baler
• Storage
• Transport

“Whole leaf hops are voluminous, but turning them into a bale makes them more compact and stackable, and overall easier to store. It also cuts down on oxidation, which affects brewing quality.”
Mechanical German RB-60 Presses / Balers ~$7k
Hop Value-Chain

Grow Hops

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SHORT'S BREW

KIND ALE

Wet Hop Ale - From Field to Fermenter
Hop Analysis Services

Harvest Package $50
• Combining Brewing Values and Dry Matter analysis

Hop Profile Package $130
• Combining Brewing Values, Oil Content and Volatile Oil Profile analyses, this package is designed to help customers determine the alpha acids, beta acids, hop storage index and oil content of their hops.

Brewing Values $35
• Alpha acids, beta acids, and hop storage index (H.S.I.) values

Dry Matters $20
• Dry matter analysis provides growers with the necessary information to forecast peak harvest windows based on hop cone maturity

Oil Content $20
• Provides a value for the volume of oil in a hop sample

Volatile Oil Profile $100
• Volatile Oil Profile provides a specific value for the most important oil compounds
Pelletizing

Considerations

• Temperature
• Time
• Final product (eg. t-90 or t-45)
• Machine type
• Machine $$
• Facility
Small-scale MI processors
• **Pelletizing**

http://www.youtube.com/watch?v=hn3nc1UBiNY

LM $36,000
350-1000 lbs/hour
Max- 50 C around 120 F

http://www.makepellets.ca/Hophead%202.jpg
Hop Value-Chain

Grow Hops

Hop Harvest

Picking

Drying

Analysis

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Baling

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Marketing/Sales

Whole cone

Pellets

Hammer Mill & Pelletizer
Packaging and Storage

Considerations

- Oxygen and Photosensitivity
  - Hops are photosensitive and, therefore, long exposure to light changes their biochemical structure as is shown by a typical red-brown colour, which is commercially undesirable.

- Package size and quality
  - 3-ply Al-folium bags under inert N2 atmosphere-vacuum sealed

- Cold storage-YES
Cold Storage

- For AB-This freezer keeps the hops stored within at a constant 18-26 degrees Fahrenheit at a 70% relative humidity.

http://www.fwwarehousing.com/divisions/5/cold-storage.html
Marketing and Sales

• What brewers are looking for
  – Quality *Craft* product
  – Consistent supply
  – Sustainable pricing for them
  – Local relationships with hop farms
Further considerations

- Food Safety
- HAACP plan
- Traceability
- Record keeping
  - Yields
  - Lot location
  - Harvest date
  - Quality
  - Climatic conditions

- Food grade facility
  - MDARD
Hops: Cost of Production
Table 1. 2013 Hopyard Preparation and Establishment Costs (Per Acre and Per 5 Acre yard)

<table>
<thead>
<tr>
<th>Land Preparation</th>
<th>Per Acre</th>
<th>Notes</th>
<th>5 Acre Yard</th>
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</thead>
<tbody>
<tr>
<td>Disc</td>
<td>$26.00</td>
<td>$26/acre</td>
<td>$130.00</td>
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<tr>
<td><strong>Establishment</strong></td>
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</tr>
<tr>
<td>Post Holes- digging</td>
<td>$312.50</td>
<td>2.5 hrs * $125/hr (145 hp tractor)</td>
<td>$1,562.50</td>
</tr>
<tr>
<td>Post Holes-placement</td>
<td>$750.00</td>
<td>6 hrs * $125/hr</td>
<td>$3,750.00</td>
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<tr>
<td>Poles-field</td>
<td>$1,590.00</td>
<td>50 @ $30/pole</td>
<td>$7,950.00</td>
</tr>
<tr>
<td>Poles-end~</td>
<td>$1,840.00</td>
<td>46 @ $40/pole</td>
<td>$5,360.00</td>
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<tr>
<td>Earth Anchor</td>
<td>$650.00</td>
<td>50 per acre @ $13 each</td>
<td>$3,250.00</td>
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<tr>
<td>Wire</td>
<td>$1,000.00</td>
<td>Galvanized 7 strand ($800) + #9 ($200)</td>
<td>$5,000.00</td>
</tr>
<tr>
<td>Misc Hardware/supplies</td>
<td>$500.00</td>
<td>staples, etc.</td>
<td>$2,500.00</td>
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<tr>
<td>Labor-poles</td>
<td>$480.00</td>
<td>4 workers- $10/hr x 12 hrs</td>
<td>$2,400.00</td>
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<tr>
<td>Management</td>
<td>$240.00</td>
<td>12 hrs @ $20/hr</td>
<td>$1,200.00</td>
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<tr>
<td>Hop Plants</td>
<td>$3,000.00</td>
<td>($3/plant, 1000 plants per acre; 14' x 3.5')</td>
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<tr>
<td>Labor-planting</td>
<td>$700.00</td>
<td>(70 hrs x $10/hr)</td>
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<tr>
<td>Irrigation^</td>
<td>$1,500.00</td>
<td>Includes installation</td>
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<td>Well</td>
<td>Variable</td>
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<tr>
<td><strong>Total Initial Costs</strong></td>
<td>$12,588.50</td>
<td></td>
<td>$59,102.50</td>
</tr>
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</table>

~ For a 5 acre yard: 53 field poles/ac & 27 end poles/ac=265 field poles and 134 end poles or 80/acre
^ 50 gallon/min, 2 inch main (no filtration)-cost is variable depending upon needs, # zones, etc.
Table 2. 2013 Hopyard Annual Operating Costs and Returns (Per Acre)

<table>
<thead>
<tr>
<th>Annual Operating Costs</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
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<td>Coir (1 string yr 1; 2 strings yr 2 +, $.20/ string; clips $80)</td>
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<td>Labor-stringing (5 workers x 10 hours X $10/hr)</td>
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<td>$500.00</td>
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<td>Labor-training</td>
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<td>$750.00</td>
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<td><strong>$1,850.00</strong></td>
</tr>
</tbody>
</table>

**Total Annual Operating Costs**                                | **$2,565.00** | **$5,680.00** | **$5,680.00** | **$5,680.00** | **$5,680.00** |

- Analysis does not include land cost or overhead like interest on loans, taxes, etc.
- Does include per hour rate for machinery, labor, and management that would be charged if hired out (opportunity cost)
- Standard trellis design is 3.5 x 14 ft ~1000 plants/acre
## Post Harvest Costs

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost 1/acre</th>
<th>Cost 2/acre</th>
<th>Cost 3/acre</th>
<th>Cost 4/acre</th>
<th>Cost 5/acre</th>
</tr>
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<tbody>
<tr>
<td>Picking processing fees ($6/lb.) (energy, supplies, labor, etc.)</td>
<td>$4,500.00</td>
<td>$6,750.00</td>
<td>$9,000.00</td>
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<td>$9,000.00</td>
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<tr>
<td>Transport to processor (variable)</td>
<td>$500.00</td>
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<td>$500.00</td>
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<td>$500.00</td>
</tr>
<tr>
<td>Interest on Equipment (variable)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sales Costs (Commission, transportation, shipping, etc.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subtotal</td>
<td>0</td>
<td>$5,000.00</td>
<td>$7,250.00</td>
<td>$9,500.00</td>
<td>$9,500.00</td>
</tr>
<tr>
<td>Total costs</td>
<td>($2,565)</td>
<td>($10,680)</td>
<td>($12,930)</td>
<td>($15,180)</td>
<td>($15,180)</td>
</tr>
</tbody>
</table>

## Gross Revenue/acre

| Percent of total yield (full production 1500 lbs. dried/acre) | 0% | 50% | 75% | 100% | 100% |
| Total yield in pounds dried/acre                               | 0  | 750 | 1125| 1500 | 1500 |

| Fresh wholecone wet ($5-6/lb.)                                  |     |     |     |      |      |
| Wholecone dried ($10-12/lb)                                     |     |     |     |      |      |
| Pellitized ($14/lb)                                             | 0   | $10,500.00 | $15,750.00 | $21,000.00 | $21,000.00 |

## Net Revenue/acre

|                      | $ (2,565.00) | $ (180.00) | $ 2,820.00 | $ 5,820.00 | $ 5,820.00 |

- UVM-$1.60/lb for picking only
- A couple of MI processors- ~$5.50/lb (including a 10% sales commission)
- Ontario $4.50/lb (no sales or marketing)
- Quebec and BC- (they charge 35% of sales amount) or currently $5.50/lb since they are selling for close to $16/lb (including access to mechanized harvester + dryer) and post-harvest services (including pelletization, packaging, commercialization)
- A group in Wisconsin was charging $4/lb just for pelletizing, packaging, and selling.
- **Depends on your assumptions (lbs per acre, cost of labor, payment on debt, etc.), but it looks like things are shaking out at around $5/lb for the process of picking through selling.**
# Cost of Production per pound by variety

<table>
<thead>
<tr>
<th>Hop Variety</th>
<th>Yield (lb/acre)</th>
<th>5 Yr Cost of Production ($/lb)</th>
<th>2 Yr Cost of Production ($/lb)</th>
<th>1 Yr Cost of Production ($/lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ahtanum</td>
<td>1862</td>
<td>3.55</td>
<td>3.78</td>
<td>4.23</td>
</tr>
<tr>
<td>Cascade</td>
<td>1748</td>
<td>3.78</td>
<td>4.02</td>
<td>4.51</td>
</tr>
<tr>
<td>Centennial</td>
<td>1625</td>
<td>4.06</td>
<td>4.33</td>
<td>4.85</td>
</tr>
<tr>
<td>Chinook</td>
<td>1953</td>
<td>3.38</td>
<td>3.60</td>
<td>4.03</td>
</tr>
<tr>
<td>Citra</td>
<td>1428</td>
<td>4.63</td>
<td>4.92</td>
<td>5.52</td>
</tr>
<tr>
<td>Columbus</td>
<td>2250</td>
<td>2.94</td>
<td>3.12</td>
<td>3.50</td>
</tr>
<tr>
<td>Crystal</td>
<td>1600</td>
<td>4.13</td>
<td>4.39</td>
<td>4.92</td>
</tr>
<tr>
<td>US Northern Brewer</td>
<td>1200</td>
<td>5.50</td>
<td>5.86</td>
<td>6.56</td>
</tr>
<tr>
<td>Simcoe</td>
<td>2400</td>
<td>2.75</td>
<td>2.93</td>
<td>3.28</td>
</tr>
<tr>
<td>Sterling</td>
<td>1900</td>
<td>3.48</td>
<td>3.70</td>
<td>4.15</td>
</tr>
<tr>
<td>Warrior</td>
<td>2400</td>
<td>2.75</td>
<td>2.93</td>
<td>3.28</td>
</tr>
<tr>
<td>Willamette</td>
<td>1572</td>
<td>4.20</td>
<td>4.47</td>
<td>5.01</td>
</tr>
</tbody>
</table>

Why variety and yield matter

$\text{Why variety and yield matter}$

$\text{Why variety and yield matter}$

$\text{Cost of Production $/\text{Lb by Average Yield Lb/Ac}}$

$\text{Cost of Production $/\text{Lb by Average Yield Lb/Ac}}$

$\text{5 Yr Cost of Production ($/lb)}$

$\text{2 Yr Cost of Production ($/lb)}$

$\text{1 Yr Cost of Production ($/lb)}$

$\text{R}^2 = .95, p < 0.0001$

$\text{R}^2 = .95, p < 0.0001$
1970-1973 Studied the effect of the date of training

a. Yield
b. Length of cones
c. Number of shoots
d. Density of setting (# cones per 10cm of shoot)
e. Mean length of shoots

May 12 - Highest yield of fresh cones (2.05 kg)
June 1 - Lowest yield (1.26 kg)

Late training reduced the yield by 38.5 % (June 1)
Early training reduced yield by 10.3 % (May 4)

Color of cones poorest with earliest training

Delayed training decreased mean length of harvested cones but increased their setting density

TAKE HOME: the date of training principally affects the yield of cones and their quality

### Post Harvest Costs

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost 1</th>
<th>Cost 2</th>
<th>Cost 3</th>
<th>Cost 4</th>
<th>Cost 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Picking processing fees (($6/\text{lb.})) (energy, supplies, labor, etc.)</td>
<td>$ 4,500.00</td>
<td>$ 6,750.00</td>
<td>$ 9,000.00</td>
<td>$ 9,000.00</td>
<td></td>
</tr>
<tr>
<td>Transport to processor (variable)</td>
<td>$ 500.00</td>
<td>$ 500.00</td>
<td>$ 500.00</td>
<td>$ 500.00</td>
<td></td>
</tr>
<tr>
<td>Interest on Equipment (picking machine, hammer mill, pelletizer)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Sales Costs (Commission, transportation, shipping, etc.)

<table>
<thead>
<tr>
<th>Subtotal</th>
<th>Cost 1</th>
<th>Cost 2</th>
<th>Cost 3</th>
<th>Cost 4</th>
<th>Cost 5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$ 5,000.00</td>
<td>$ 7,250.00</td>
<td>$ 9,500.00</td>
<td>$ 9,500.00</td>
<td></td>
</tr>
</tbody>
</table>

### Gross Revenue/acre

<table>
<thead>
<tr>
<th>Percent of total yield- (full production 1000 lbs. dried/acre)</th>
<th>Cost 1</th>
<th>Cost 2</th>
<th>Cost 3</th>
<th>Cost 4</th>
<th>Cost 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>50%</td>
<td>75%</td>
<td>100%</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total yield in pounds dried/acre</th>
<th>Cost 1</th>
<th>Cost 2</th>
<th>Cost 3</th>
<th>Cost 4</th>
<th>Cost 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>500</td>
<td>750</td>
<td>1000</td>
<td>1000</td>
<td></td>
</tr>
</tbody>
</table>

### Fresh wholecone wet (\$5-6 /lb.)

<table>
<thead>
<tr>
<th>Wholecone dried ($10-12/lb)</th>
<th>Cost 1</th>
<th>Cost 2</th>
<th>Cost 3</th>
<th>Cost 4</th>
<th>Cost 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pellitized ($14/lb)</td>
<td>$ 10,500.00</td>
<td>$ 14,000.00</td>
<td>$ 14,000.00</td>
<td>$ 14,000.00</td>
<td></td>
</tr>
</tbody>
</table>

### Net Revenue/acre

<table>
<thead>
<tr>
<th>Cost 1</th>
<th>Cost 2</th>
<th>Cost 3</th>
<th>Cost 4</th>
<th>Cost 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>$ (2,565)</td>
<td>$ (180)</td>
<td>$ 1070</td>
<td>$ (1180)</td>
<td>$ (1180)</td>
</tr>
</tbody>
</table>

What if your maximum yield is 1000 lbs/acre?
## What if price drops to $10/lb?

### Post Harvest Costs

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<tr>
<th>Item</th>
<th>0</th>
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<td>-</td>
<td>-</td>
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<td>-</td>
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<th>75%</th>
<th>100%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total yield in pounds dried/acre</strong></td>
<td>0</td>
<td>750</td>
<td>1125</td>
<td>1500</td>
<td>1500</td>
</tr>
</tbody>
</table>

#### Fresh wholecone wet ($5-6/lb.)

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>$7,500</th>
<th>$11,250</th>
<th>$15,000</th>
<th>$15,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wholecone dried ($10-12/lb)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pellitized ($10/lb)</strong></td>
<td>0</td>
<td>$7,500</td>
<td>$11,250</td>
<td>$15,000</td>
<td>$15,000</td>
</tr>
</tbody>
</table>

### Net Revenue/acre

|                              | ($2,565.00) | ($3,180) | ($1,680) | ($180) | ($180) |
• **Other potential issues**
  
  – Seed, stem, leaf content. How much is docked?
  
  – Hand picking-increases labor costs
    
    • one bine per hour?
    
    • 1000 hours to do one acre
    
    • ten people-100 hours -2 weeks?
    
    • $10,000 in labor alone
  
  – How do you become a millionaire farming?
  
  – Start with $2 million, pretty soon you will have $1 million
Hops: Markets
U.S. BEER SALES 2013

**Overall Beer**
-1.9% 
196,241,321 bbls

**Craft Beer**
17.2% 
15,302,838 bbls

**Import Beer**
-0.6% 
27,539,358 bbls

**Export Craft Beer**
49% 
282,526 bbls

**Overall Beer Market**
$100 Billion

**Craft Beer Market**
$14.3 Billion
20% Dollar Sales Growth

**Craft**
7.8% Share in 2013 
15,302,838 bbls

**Import**
27,539,358 bbls

**Domestic**
153,399,125 bbls

Source: Brewers Association, Boulder, CO
US Craft Beer Hopping Rates (TTL Pounds / TTL BBL)

<table>
<thead>
<tr>
<th>Year</th>
<th>Hopping Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>0.93</td>
</tr>
<tr>
<td>2009</td>
<td>0.95</td>
</tr>
<tr>
<td>2010</td>
<td>1.12</td>
</tr>
<tr>
<td>2011</td>
<td>1.185</td>
</tr>
<tr>
<td>2012</td>
<td>1.28</td>
</tr>
<tr>
<td>2013</td>
<td>1.296</td>
</tr>
<tr>
<td>2014</td>
<td>1.31 (est.)</td>
</tr>
</tbody>
</table>
Aroma Hop Acreage as % TTL US Acres

2003: 25.3%
2004: 22.2%
2005: 22.2%
2006: 20.3%
2007: 21.8%
2008: 19.8%
2009: 20.9%
2010: 26.0%
2011: 41.6%
2012: 31.9%
2013: 62.7%
Concerns on the Horizon?

• Hop Usage
  – At 20% share, craft hop usage is 2/3 of current national production – even without increase in usage/bbl

• Hop Varieties
  – Larger scale only part of the challenge
  – Issues like growing windows necessitate further investment
Getting to 20/20 - Hops

• 25% increase in hop volume
• Greater increase in acreage/resources
  – 30% increase in acres
  – Acreage needed greater than hop increase
    • Aroma vs Alpha
    • Starting to run out of acres to switch
    • More resource intensive
  – $10K an acre + processing ($5K)
    • Capacity is fine – but harvest windows tightening
    • “New” acres cost more
Getting to 20/20 - Hops

• 12,000 new acres?
• $180 million *minimum* in acreage investments?
• Growers get it, but more work
• 25 million more pounds of hops
  – Pelletizing infrastructure
  – Storage (even 25 cents a pound adds up)
  – New technologies/products
• Hop Hunter anyone?
Getting to 20/20 - Hops

• Other investments may double cost
  – Collective half a billion $’s not out of the picture
• Will new areas help?
• Yes, but at the margins
  – Lack of scale
  – Higher cost
  – Uncertain demand
  – More fragmented
2013 Beer Sold in MI (bbls)

All Beer: 6,257,864 bbls

All Craft Beer: 452,000, 7.2%

MI Craft Beer: 297,000, 4.7%
Growth in Michigan's Craft Beer and Hop Supply Chain Sectors

- Number of Craft Breweries
- Acres of Hops in Commercial Production

Year: 1991 to 2020
TAKE HOME MESSAGES

- Quality is crucial, brewers want pellets
- Do not skimp on establishment
- Post-harvest very important
- Hi initial and annual costs
- Don’t underestimate the amount of labor required
- Need for picking and processing equipment if you plant >1/3 acre
- Line up supplies well in advance
- How will you sell your hops and to whom?
- You will need a price premium to do organic
http://www.hops.msu.edu
Harvesting, drying, conditioning, and baling video-WOLF