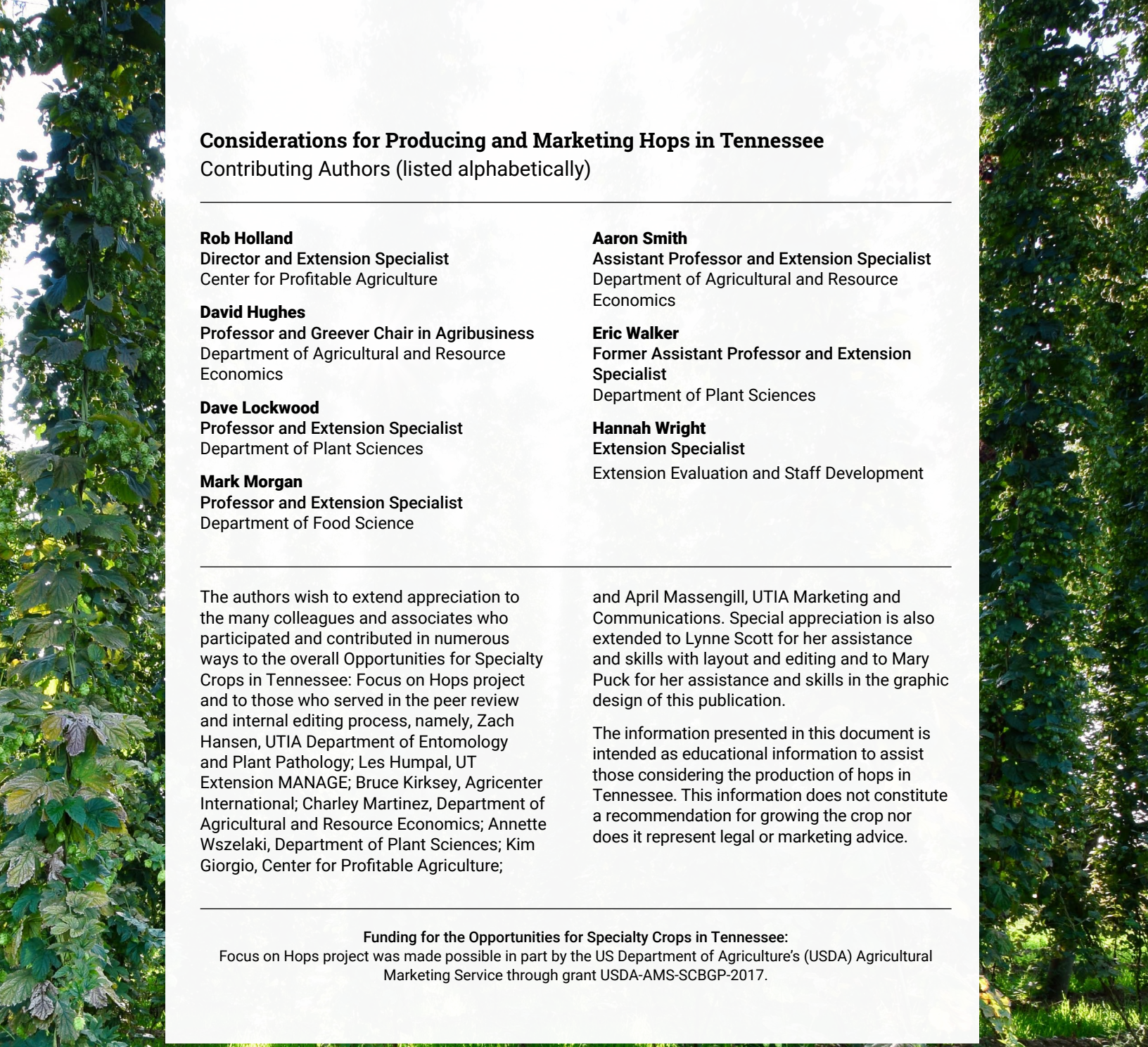
W 912

CONSIDERATIONS FOR PRODUCING AND MARKETING HOPS IN TENNESSEE

UTEXTENSION
INSTITUTE OF AGRICULTURE
THE UNIVERSITY OF TENNESSEE



Considerations for Producing and Marketing Hops in Tennessee

Contributing Authors (listed alphabetically)

Rob Holland
Director and Extension Specialist
Center for Profitable Agriculture

David Hughes
Professor and Greever Chair in Agribusiness
Department of Agricultural and Resource Economics

Dave Lockwood
Professor and Extension Specialist
Department of Plant Sciences

Mark Morgan
Professor and Extension Specialist
Department of Food Science

Aaron Smith
Assistant Professor and Extension Specialist
Department of Agricultural and Resource Economics

Eric Walker
Former Assistant Professor and Extension Specialist
Department of Plant Sciences

Hannah Wright
Extension Specialist
Extension Evaluation and Staff Development

The authors wish to extend appreciation to the many colleagues and associates who participated and contributed in numerous ways to the overall Opportunities for Specialty Crops in Tennessee: Focus on Hops project and to those who served in the peer review and internal editing process, namely, Zach Hansen, UTIA Department of Entomology and Plant Pathology; Les Humpal, UT Extension MANAGE; Bruce Kirksey, Agricenter International; Charley Martinez, Department of Agricultural and Resource Economics; Annette Wszelaki, Department of Plant Sciences; Kim Giorgio, Center for Profitable Agriculture; and April Massengill, UTIA Marketing and Communications. Special appreciation is also extended to Lynne Scott for her assistance and skills with layout and editing and to Mary Puck for her assistance and skills in the graphic design of this publication.

The information presented in this document is intended as educational information to assist those considering the production of hops in Tennessee. This information does not constitute a recommendation for growing the crop nor does it represent legal or marketing advice.

Funding for the Opportunities for Specialty Crops in Tennessee:
Focus on Hops project was made possible in part by the US Department of Agriculture's (USDA) Agricultural Marketing Service through grant USDA-AMS-SCBGP-2017.

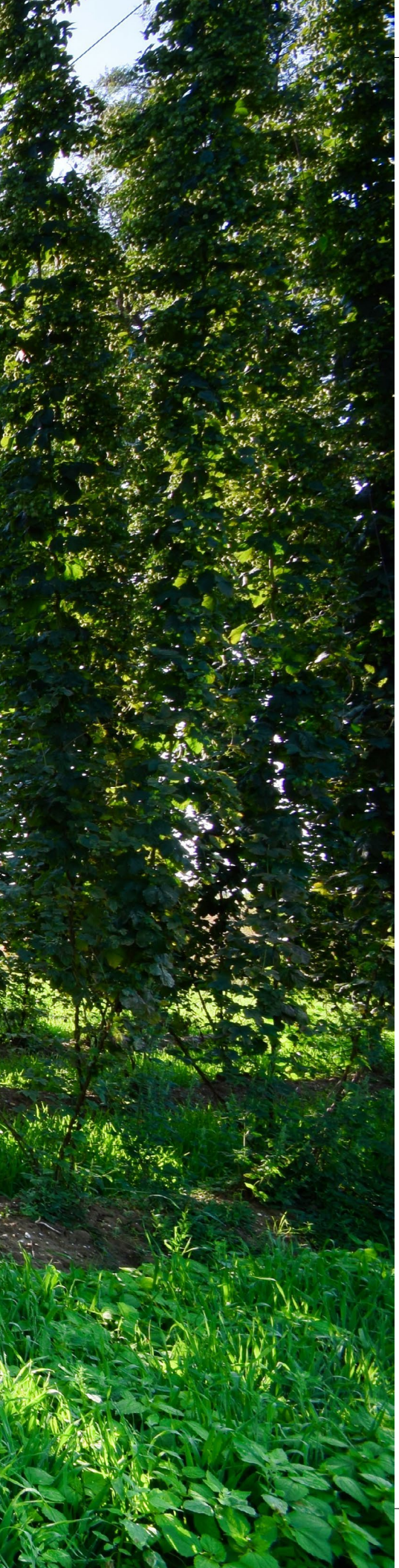
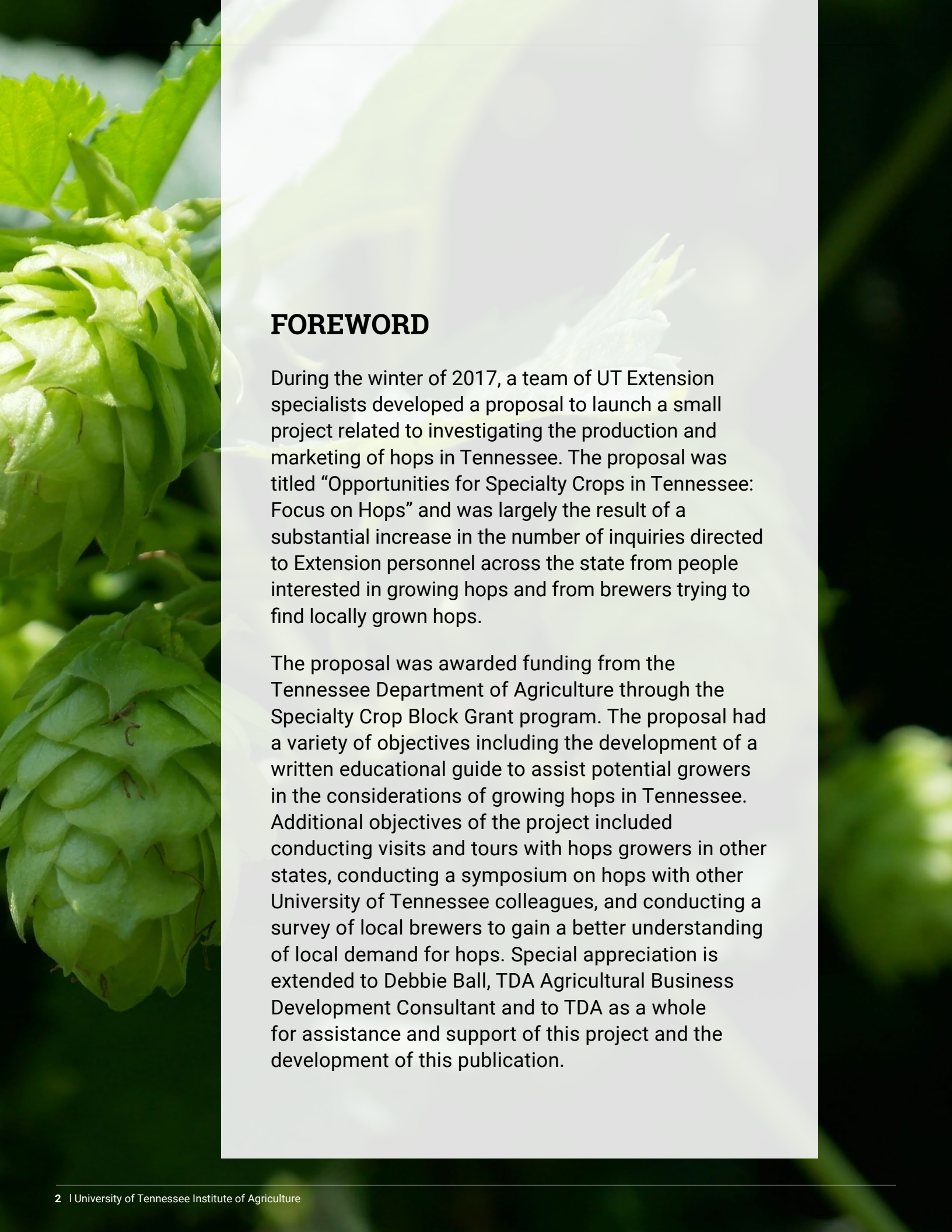


TABLE OF CONTENTS



FOREWORD

During the winter of 2017, a team of UT Extension specialists developed a proposal to launch a small project related to investigating the production and marketing of hops in Tennessee. The proposal was titled “Opportunities for Specialty Crops in Tennessee: Focus on Hops” and was largely the result of a substantial increase in the number of inquiries directed to Extension personnel across the state from people interested in growing hops and from brewers trying to find locally grown hops.

The proposal was awarded funding from the Tennessee Department of Agriculture through the Specialty Crop Block Grant program. The proposal had a variety of objectives including the development of a written educational guide to assist potential growers in the considerations of growing hops in Tennessee. Additional objectives of the project included conducting visits and tours with hops growers in other states, conducting a symposium on hops with other University of Tennessee colleagues, and conducting a survey of local brewers to gain a better understanding of local demand for hops. Special appreciation is extended to Debbie Ball, TDA Agricultural Business Development Consultant and to TDA as a whole for assistance and support of this project and the development of this publication.

INTRODUCTION

Guidelines and considerations can be very helpful when farmers and producers embark on growing new crops. Three of the broadest categories of consideration for growing hops in Tennessee are:

1. Production issues.
2. Estimates of cost.
3. Marketing.

In addition, possible growers of hops should also consider an overall assessment of the crop, implications of the federal Food Safety Modernization Act (FSMA), and industry trends. This publication is intended to address and streamline these primary areas of consideration.

BRIEF HISTORY OF HOPS

Hops are the flowers of the hop plant. They are used as a preservative and bittering agent, while also adding aromas and flavors to beer. The first documented use of hops in beer production dates to the ninth century (Hornsey, 2003), and the first documented cultivation of hops dates to 736 A.D. in present day Germany (Hornsey, 2013).

The first documented commercial hops production in the United States dates back to 1648, when an estimated 45 acres were grown in the Massachusetts Bay Settlement. Massachusetts remained the largest hops producing state for the next 150 years. By the mid-1800s, New York became the largest hops producing state, reaching a peak in the late 1800s. Prohibition and downy mildew were credited for the demise of the industry throughout the country. Following prohibition, hops production shifted to the Northwest, where growing conditions were much more favorable. Since then the Northwest has dominated hops production in the United States. In 2015 Washington State was estimated to have 71 percent of the North American commercial hops production acreage, estimated to be 45,488 acres, followed by Oregon with 15 percent and Idaho with 11 percent. All the other states combined produced 2.5 percent and Canada produced 0.5 percent. In 2017 the United States was the number one hops producing country in the world, accounting for 42 percent of the world hops production (USA Hops, 2017, http://www.usahops.org).

Over the past few years there has been a substantial amount of interest regarding hops production in the other areas of the United States as a result of the upsurge in numbers of craft breweries throughout the country. Currently, Michigan and New York are the lead producers outside of the Northwest. Other states, including states in the Southeast, also have displayed a growing interest in hops production.

NATURE OF THE PLANT

The hop plant *Humulus lupulus* is a hardy perennial with a long life cycle. The hop plant is made up of rhizomes below ground, annual climbing shoots called bines above ground and flowers that resemble green cones.

Figure 1: Rhizome of a hop plant.

Rhizomes

Rhizomes are essentially underground stems with roots and buds (Figure 1). Rhizomes contain the food reserves necessary to support early growth of the bines in spring. The feeder root system of a hop plant is fairly shallow, being mostly in the upper foot of soil; however, mature plants will have some roots that penetrate more deeply in soils. The actual depth of root penetration varies with soil type.

Figure 2: Bine growing up a coir in a clockwise direction.

Bines

Bines are the aboveground stems of a hop plant arising from buds on the rhizomes in spring. Leaves and, later in the growing season, flowers develop on the bines. As bines grow, they wrap themselves in a clockwise direction around a support (Figure 2). Bines differ from vines in that vines (such as grapevines) have tendrils which grow at the site of buds and attach themselves to a trellis or other objects to support the new growth. Bines do not have tendrils. Instead, they have hooked hairs called trichomes that cling to vertical supports as they grow (Figure 3).

Figure 3: Trichomes are hair-like structures that enable bines to stick to support structures.

Hops

Hops are the flowers (Figure 4) or cones (Figure 5) of female hop plants. They contain alpha and beta acids and essential oils that contribute to the bitterness and aroma in beer.

Hop plants are dioecious, that is, the male and female flowers are borne on separate plants. In hops production, only unpollinated female flower cones are desired for brewing beer, since they produce a greater amount of lupulin. Lupulin are small glands in the hop cone that contain a fine yellowish powder (Figure 6), which produces the bittering and aromatic components essential for beer. Male plants in the vicinity of a hop yard can create problems regarding pollination of the female flowers. Therefore, it is important for hops producers to purchase only female plant material.

Figure 4: A female flower on a lateral shoot

Hop plants respond to light and dark periods. In the first part of the growing season, lengthening of the day stimulates vegetative growth and bine elongation. In midsummer when the summer solstice is reached and daylength begins to shorten, vegetative growth slows down and then ceases, and lateral branches develop and the reproductive phase begins, characterized by the development of 0.5- to 4-inch papery green flowers or cones (Sirrine, 2014).

Figure 5: The cone of a female hop plant

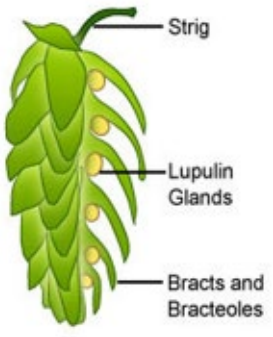


Figure 6: A hop cone sectioned to show the lupulin glands.

SELECTING A HOP YARD SITE

The selection of a site is perhaps the most important decision to be made in hops production. Virtually every aspect of hops production will be impacted, either positively or negatively, by the selection of the site. Site selection for a hop yard will be imperative for long-term success and will impact annual costs and revenue. When selecting a site, consideration should be given to topography, proximity to roads and wildlife, soil condition and depth, proximity to an irrigation water source, proximity to other crops (chemical drift), previous land uses, and accessibility.

During the planning stage of the hop yard, it is important to remember that hop yards, if correctly situated and designed, provide 20-plus years of useful life. If a suitable site is not available using the current farm's land base, strong consideration should be afforded to purchasing a suitable site.

Consult the UT Extension office in your county (find a location at utextension.tennessee.edu) or USDA-NASS for prevailing land values. Land rental or lease arrangements for hops production may be difficult because of substantial establishment costs and long-term investment.

The following are factors for consideration in site selection:

Latitude

Hop plants need long days and short nights during the growing season to flower and produce high cone yields. Latitude determines seasonal daylength, which drives canopy growth patterns and the timing of flower generation. The most desirable range for commercial hops production in both the northern and southern latitudes is from 35 to 55 degrees of latitude. Outside this range, canopy growth and/or flowering will be reduced. The closer the planting is to 55 degrees latitude, the more growth the bines will make before daylength begins to shorten and flowering begins. The state of Tennessee lies between approximately 36.5 degrees north latitude in the north of the state (Blountville, Dover) and 35 degrees north latitude in the south (Chattanooga, Memphis).

Winter Cold and Chilling Requirement

Hop plants transition into dormancy as days shorten in late summer and fall. The onset of dormancy is characterized by a gradual death of shoots and fine roots and a transfer of food reserves to the rhizome where they are stored during the winter months. The hop plant has a chilling requirement with a threshold temperature requirement of 40 to 43 degrees F. In the United States, it is suggested that a minimum cumulative period of 30 to 60 days at this temperature is needed to satisfy the chilling requirement. Failure to achieve adequate chilling could result in uneven and weak growth in spring.

Elevation

Absolute elevation refers to feet above sea level. Relative elevation refers to how high a site is in relationship to the immediate surroundings. Locating the hop yard on a site that is higher than surrounding land is beneficial, since fogs and frosts tend to settle into low areas. Good air drainage out of a hop yard situated on an elevated site will lessen the potential for spring frost damage and the development of certain diseases.

Terrain

The ideal terrain for a hopyard would be one that is level or nearly level. If sloping, it should be gentle and uniform. Under such conditions, construction and maintenance of the trellis will be much easier than on more steeply sloped or undulating sites, and irrigation and pesticide applications also will be more precise. Soil conditions should be more consistent on uniform sites, which would simplify the nutritional management program. Slopes should be no steeper than two to five percent to make working on them easier and less hazardous than steeper, more irregular slopes.

Exposure

If the hopyard is to be situated on sloping ground, exposure must be taken into consideration. South-facing slopes tend to have soils that are thinner, lower in organic matter and are more drought prone. South-facing slopes also get hotter over the winter months and warm sooner in spring than other slopes, especially those with a northern aspect. An east-facing slope offers the morning sun, which is advantageous since the sooner plants dry off following a wetting event, the less potential there is for disease development.

Soil Type

Hops will grow in many different types of soils, ranging from light sands to light clay. However, a light-textured, deep soil that is well-supplied with moisture, yet free from waterlogging, is best. A naturally fertile soil is preferred, but this can be adjusted through pre- and post-plant fertilizer applications.

Soil Drainage

Hops grow best on soils that are well-drained, both internally and on the soil surface. It is highly recommended that water drainage issues be addressed prior to establishing the structure of the hop yard. With certain sites and with certain soils, tile drainage and ditching may be used to turn what might be a marginal site into an acceptable site. If surface drainage is not optimal, constructing and planting on a raised bed or berm may be useful in avoiding standing water against the base of the plant.

Shelter from Wind

A gentle wind is a plus for hop yards, since it encourages airflow, which reduces disease pressure. Prevailing strong winds, however, can cause leaf damage and loss of cone-bearing lateral branches on bines. The tall trellises on which hops are trained can make wind damage especially severe. Locating a site that is sheltered from damaging winds will lessen potential losses.

Water Availability (Irrigation)

Hop plants require a substantial amount of water during their growing season. When selecting a site, it is extremely important to consider the availability and proximity of a water source, whether it is to a well or a community water system. Michigan State University Extension recommends at least 6 gallons of water per day while the plants are growing vigorously. Lack of adequate moisture, especially early in the growing season, could compromise bine growth and potential yield. In view of the high costs of establishing and maintaining a hop yard and the high-water demand of hop plants, supplemental irrigation should be considered as an essential production practice.

HOPS PRODUCTION

Hops production requires substantial labor and capital to establish the hop yard and produce a crop each year. Costs can be divided into the following two primary categories:

- Establishment costs — One-time costs to build the hop yard infrastructure and establish plants.
- Annual costs — Costs incurred each year to produce and market a hops crop.

Currently, only limited information regarding costs is available outside the Pacific Northwest area.

Establishment Costs

Establishment costs published by land-grant universities outside of the Pacific Northwest are highly variable, such as $6,505 for one-quarter acre (North Carolina State University Extension, 2012), $13,668 per acre (Michigan State University Extension, 2014), $15,986 for a one-half acre hop yard (Virginia Tech Cooperative Extension, 2018), and $25,870 for a 2-acre yard (University of Vermont Extension, 2017). In general, hop yard establishment costs can be divided into the following categories: 1) soil preparation, 2) trellis construction, 3) irrigation system installation and 4) plant establishment.

Soil Preparation

Many factors will impact the long-term success of the hop yard, and some are more cost effectively addressed before the trellis system is constructed, the irrigation system is installed, and the hop plants are put into the ground. Augmenting the soil (both deep and shallow) to obtain the desired pH is one of these factors. Similarly, soil fertility should be evaluated and corrected for at multiple depths. Soil tests and corrective action before the yard is established may add to short-run costs, but can save the producer in long-term fertility issues, which may not be easily addressed once the hop yard is established.

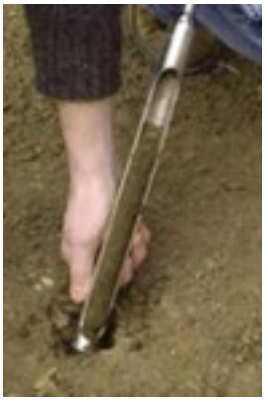


Figure 7: Soil test well in advance of planting.

Soil test the selected hop yard site six months to a year or more in advance of planting (Figure 7). Soil tests can cost $15 to $30 (UT Soil, Plant and Pest Center: Services and Fees https://extension.tennessee.edu/Hamilton/Documents/Agriculture/Soil%20Testing/Soil,%20Plant%20and%20Pest%20Center%20Brochure%20-%202019.pdf) per sample depending on the analysis conducted. Soil sample boxes are available without cost from your county Extension office. (Locate your county office at utextension.tennessee.edu.) Samples can be submitted to the UT Soil, Plant and Pest Center at 5201 Marchant Drive, Nashville, TN 37211 or other private labs for a soil/fertility analysis. Samples should be taken in the upper 15 inches of soil (Darby, 2011). The cost of adjusting soil pH at multiple soil depths will vary based on the existing pH of the site. Applying lime to increase the pH can cost $20 to $30 per ton for lime and tillage/incorporation costs can be $8 to $15 per acre, subject to depth of the soil augmented and the equipment utilized. Soil samples should be analyzed for pH, phosphorus (P), potassium (K), calcium (Ca), organic matter content (OM), and cation exchange capacity (CEC).

Figure 8: Vertical trellis system for hops before spring growth.

The ideal soil pH for hop plant production is 6.5. Phosphorus and potassium should be adjusted to bring them up to the “high” soil test level. Apply the recommended amendments, disk or roto-till to mix them into the upper few inches of soil, and then deep plow to incorporate the amended soil with the subsoil.

Trellis System Construction

The bines of a hop plant can grow from 4 to 10 inches in a day. Because of their vigorous growth, hop plants need structural support from a trellis. There are numerous trellis designs that can be implemented based on the size of the hop yard, owner preference and the selected site. The objective of the trellis system is to support the full weight of mature bines while encouraging vertical growth and cone production. One bine can weigh more than 50 pounds at maturity, and that weight on the trellis system can double due to rain and wind.

When designing the hop yard, consideration should be given to prevailing winds and orientation to sunlight. Maximizing airflow and sunlight will encourage vegetative growth, reduce disease and insect pressure, and assist in reducing annual chemical costs or the need for other controls. Proximity to trees and protection from wildlife damage should also be considered when planning the hop yard.

The most common trellis system used worldwide is the V-trellis (Figure 8). Other systems such as the low trellis have been used in trials; however, they are not widely adapted due to low yields per acre (Bamka, 2017). Vertical trellises and growing systems vary in top height, row spacing, plant spacing, number of strings and bine spacing according to location, variety and intended method of harvest (Dodds, 2017).

The final decision on the design of the trellis system and the spacing of the hop plants is dependent on the variety planted. American types of hops, such as Galena, Willamette, Chinook, Brewers Gold, Columbus and Zeus, tend to be large, robust, high-yielding plants with long laterals (sidearms). They have vigorous root systems that match their bine size and tend to be quite tolerant of different soil types, soil pH ranges and growing conditions. They are often planted 14 feet apart between rows and a minimum of 42 inches between plants within the row (889 plants per acre) to accommodate strong lateral growth. American varieties Cascade and Centennial, however, tend to have shorter laterals and are often planted at a 36-inch spacing within the row (1,037 plants per acre). Trellis poles need to be set close enough to prevent excessive sagging of the cables or wires, which support the canopy as the hop plant grows.

British and Continental types of hop plants, such as the European Noble varieties (Terrnanger, Spalt, Hallertaure and Saaz) and the British Nearly Noble varieties (Fuggles, East Kent Golding, Hersbrucker and Styrian Golding) are genetically different from American types. They tend to be smaller plants with smaller, finer root systems that are not as tolerant of wide differences in soil conditions. Bines tend to have shorter laterals. Cone size and yields per plant also tend to be smaller. Trellis height may be lower and between-row spacing may be closer than with American types.

Top height is determined by the variety and growing conditions. Hop plants need sufficient trellis height to allow bines to complete their annual extension growth and terminate without growing too far above the top wire. Local experience will help to determine this. (In Tennessee, however, there is little local experience to help determine height.) Top height around the world typically varies between 13 and 20 feet for the V-trellis or 10 to 13 feet for a low trellis. The length of cone-bearing laterals also varies among varieties and should be taken into account when deciding on spacing between the bines and between plants.

In Washington State growers often use a V-trellis (Figure 9) having a top height of approximately 20 feet and a between row spacing of 11.5 to 13 feet (Tobin, 2019), as opposed to a V-trellis with a top height of 16.4 feet and 8.2 feet between row spacing, as is often seen in New Zealand. Some commercial hop yards in Australia use a single string, rectangular planting system with a spacing of 6.5 feet between rows and 6 feet between plants within a row (1,117 plants per acre) (Dodds, 2017).

The optimum spacing along the row depends on the number of training strings used for each crown and the hop variety's lateral growth length. Plant spacing in V-trellis blocks in major hop-producing countries ranges from approximately 3 to 5 feet. The goal is to grow a canopy that maximizes available light while still allowing some light penetration around bines.

Trellises must be constructed of good quality materials that will last for many years and be built strong enough to hold the weight of the canopy and the crop even under adverse conditions. High winds will place a substantial additional stress on the trellis, especially once the bines have reached the top, the laterals are developed, and the cones are present.

Poles can be selected using materials that are available; however, long-term integrity of the poles is essential. Pressure-treated telephone poles, cedar poles, black locust poles or pipes can be used in trellis construction. Poles at the ends of a trellis row need to be solidly anchored to prevent the trellis wires from sagging and to increase the strength of the trellis (Figure 10). Pole spacing will have a direct impact on the establishment costs of the hop yard. Spacing poles too far apart, thus providing insufficient support, can result in the trellis system failing under pressure. Additional materials needed include wire rope, eye/shoulder bolts, ground anchors, cable clamps and turnbuckles (Figure 11).

Figure 9: Bines growing on a V-trellis.

Figure 10: Anchors at the ends of rows (Washington State hop yard).

Figure 11: Bolt and wire design, external panel (New York hop yard).

Table 1. Estimated cost to establish a one-half acre hop yard (Trellis Construction)

Trellis Construction		Unit	Quantity	Cost/Unit	Total Cost
Materials	Poles	pole	66	$35.00	$2,310
	Wire Rope	feet	5,830	$0.20	$1,166
	Hardware	panel	60	$20.00	$1,200
					$4,676
Equipment	Auger	day	2	$100.00	$200
	Forklift	day	2	$350.00	$700
	Lift	day	3	$235.00	$705
	Tools			$200.00	$200
					$1,805
Labor	Site preparation	hours	12	$11.63	$140
	Setting poles	hours	36	$11.63	$419
	Anchor installation	hours	20	$11.63	$233
	Wire installation	hours	54	$11.63	$628
					$1,419
Total Trellis Construction Costs					**$7,700**

Source: Modified from Virginia Tech Hop Budget Spreadsheet
Note: Labor wage rate used here is $11.63 per hour and based on the adverse effect wage rate for 2019 in Tennessee. foreignlaborcert.doleta.gov/adverse.cfm

Cost Considerations

Costs for constructing a trellis system will vary based on materials used, prevailing local prices, available equipment and labor costs (Table 1). Modifications to the establishment cost estimates should be made to reflect the specifications/requirements of the individual hop yard. There is significant variation in costs for different locations and trellis designs. However, cutting costs on trellis design, installation and maintenance can result in disastrous losses.

Irrigation System Installation

The goal of installing an irrigation system is to maintain a good soil moisture level throughout the growth cycle without over-irrigating and leaching the soil of nutrients. While the hop plant can send roots down a considerable distance in the right soils, most of the feeder roots will be found in the upper 12 inches of soil (Darby, 2011), and a moisture deficit can develop quickly during the growing season.

Soil moisture should be monitored to a depth of 15 inches. Hop plants can use 25 to 35 inches of water annually, which is less than the typical precipitation in Tennessee (53 inches). However, the timing of rain fall may not provide the appropriate moisture throughout the hop growing season. As such, installing an irrigation system will assist in managing production risk. Lack of sufficient water early in the growing season could result in bines not growing enough to fill the space allocated for them on the trellis, which means that yields will be reduced as well.

Table 2. Estimated cost of establishing a one-half acre hop yard (Irrigation System)

Irrigation System		Unit	Quantity	Cost/Unit	Total Cost
Materials	Mainline (10 ft. 3/4 in. PVC)	sections	20	$2.10	$42
	Laterals (1/2 in. poly)	roll (1,000 ft.)	2	$120.00	$240
	PVC fittings (risers)	fitting	80	$0.49	$39
	Poly tube fittings	fitting	20	$0.54	$11
	Irrigation pump (1 HP)	pump	1	$280.00	$280
	Pump fittings	fitting	4	$8.00	$32
	Pressure regulator	fitting	1	$12.50	$13
	Mesh filter	filter	1	$18.00	$18
	Cistern	cistern	1	$2,000	$2,000
	Drip emitters (2,000 total)	bags	4	$62.50	$250
	Zip ties (4,000 ties)	bags	2	$24.50	$49
					$2,974
Labor	Dig mainline trench	hours	6	$11.63	$70
	Install mainline	hours	30	$11.63	$349
	Zip tie laterals	hours	8	$11.63	$93
	Install drip emitters	hours	14	$11.63	$163
	Cistern and pump setup	hours	5	$11.63	$58
					$733
Total Irrigation System Costs					**$3,706**

Source: Modified from Virginia Tech Hop Budget Spreadsheet
Note: Labor wage rate used here is $11.63 per hour and based on the adverse effect wage rate for 2019 in Tennessee. foreignlaborcert.doleta.gov/adverse.cfm

Figure 12: Irrigation system installed and operational prior to planting.

Figure 13: Drip irrigation is the most cost-effective irrigation system for hops (New York hop yard).

An irrigation system should be considered an essential part of the hop yard. Similar to trellis construction, the irrigation system should be installed and be operational prior to planting. Trickle or drip irrigation systems, where the lines and emitters are laid on the ground or affixed to a low wire on the trellis, are preferred to high volume overhead systems (Figures 12 and 13). Applying supplemental water to the soil surface without wetting the foliage or cones will significantly lessen the potential for diseases to develop.

Farm ponds, creeks and rivers may be viable sources for irrigation water; however, water quality may prohibit the use of surface water in some locations. Additionally, surface water use will depend on the water source's proximity to the hop yard. If surface water is not available, a well or access to county/municipal water may be an option.

Cost Considerations

Cost considerations for irrigation include water source, storage, pump and irrigation method/frequency. Drip irrigation is the most cost-effective system for hops production. Estimated installation costs will vary based on the system design and size requirements. Table 2 depicts an example of the costs that should be considered. NOTE: The cost of establishing a water source or annual pumping costs are not estimated in Table 2.

Figure 14: Transplants (left) or rhizomes (right) can be used for plant establishment.

Plant Establishment

New hop plants should be planted in the spring (mid-April to early May). Hop producers need to decide which method to use to establish the crop. Two common methods of plant establishment are: 1) propagating plants from hop rhizomes or 2) transplants (hop plants propagated by rooting cuttings from actively growing shoots). Whether to purchase rhizomes or transplants depends on the variety of hop, site location and preference (Figure 14). It is strongly recommended for both methods to take all possible precautions to verify the plant material is disease and virus free. Starting a hop yard with clean transplants or rhizomes will provide the greatest probability for a successful stand with fewer initial disease and virus problems, thereby reducing annual chemical costs (Brown, 2012).

Planting more than one rhizome in each hole helps to avoid gaps in rows in case a rhizome does not grow. Some Washington growers use three to four rhizomes per planting hole to guarantee growth. By doing this, they are able to get substantial yields in the year of planting (Tobin, 2019). Position rhizomes either vertically or horizontally in the soil, making sure buds point up. Cover the top of the rhizomes with about 2 inches of soil. Firm soil over cuttings by tamping down with your foot. Plant different hop varieties at least 10 feet apart to help keep them from mixing through underground root suckering (Sirrine, 2014).

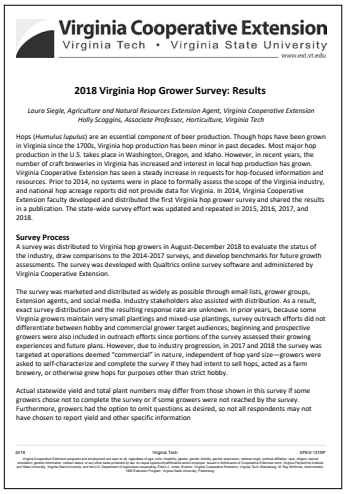
Dormant rooted cuttings or transplants should be planted at the same time as rhizomes. However, if plants are actively growing, it is best to postpone planting until all chance of spring frosts have passed.

Selecting varieties of hops to grow in Tennessee can be a challenging undertaking due to a lack of history of hops production and changing preferences by craft brewers. Additionally, varieties have not been developed for the southeastern climate. Most varieties are developed in the Pacific Northwest and may not be suitable for the humid climate of the Southeast. Varieties are currently being developed for more humid climates; however, limited data/varieties are available at this time.

Table 3. Estimated cost of establishing a one-half acre hop yard (Plant Establishment)

Planting		Unit	Quantity	Cost/Unit	Total Cost
Materials	Transplants	plants	720	$8.75	$6,300
	Mulch	cubic yards	20	$18.00	$360
Labor	Planting	hours	48	$11.63	$558
	Mulching	hours	12	$11.63	$140
Site Prep	Rototilling	acres	1	$15.00	$15
Total Planting Costs					**$7,373**

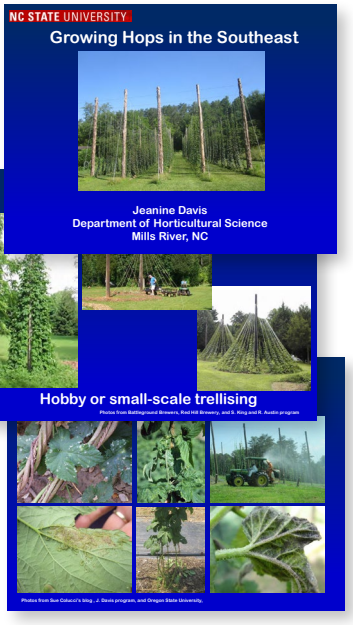
Source: Modified from Virginia Tech Hop Budget Spreadsheet
Note: Labor wage rate used here is $11.63 per hour and based on the adverse effect wage rate for 2019 in Tennessee. https://www.foreignlaborcert.doleta.gov/adverse.cfm


Virginia Cooperative Extension
Virginia Tech • Virginia State University

2018 Virginia Hop Grower Survey: Results


New Crops & Organics

2010-2012 NC Hops Variety Research


NC STATE UNIVERSITY
Growing Hops in the Southeast
Jeanine Davis
Department of Horticultural Science
Mills River, NC
Hobby or small-scale trellising

Currently, producers in the Southeast have grown Cascade, Chinook, Nugget and Galena (2018 Virginia Hop Grower Survey: Results, Virginia Tech, 2018, https://www.pubs.ext.vt.edu/content/dam/pubs_ext_vt_edu/spes/spes-131/SPES-131NP.pdf) Selecting varieties is an important long-term decision. Changes in craft brewers' preferences can dramatically impact the price brewers are willing to pay for hop varieties. Some hop varieties that are in high demand by brewers may not provide the necessary yields in Tennessee to be profitable, or they may have low resistance to diseases, such as downy mildew, making them very difficult to grow in a cost-effective manner.

Additional resources on hops varieties for the Southeast are "Growing Hops in the Southeast" a presentation by Jeanine Davis, North Carolina State University, available at newcropsorganics.ces.ncsu.edu/wp-content/uploads/2017/05/201402-Virginia-Hops-Davis-presentation.pdf?fwd=no and "2010-2012 NC Hops Variety Research," North Carolina State University , available at newcropsorganics.ces.ncsu.edu/specialty-crops/nc-hops/varieties.

Newly planted hops may take two to three seasons to produce a full commercial canopy. However, with certain planting practices such as using multiple rhizomes or rooted cuttings per planting site, some production may be recognized in the second year, or in some ideal situations, the first year.

Cost Considerations

In terms of estimated costs, for a 36-foot panel (in-row pole to in-row pole), an estimated 12 potted plants could be planted (12 plants x 60 panels = 720 plants for a one-half acre). Costs will vary based on type of plant material procured, variety selected and transportation costs from the plant provider. For example, Great Lakes Hops currently retails transplants (complete live-rooted plants) for $8.75 to $14.99 per plant (Great Lakes Hops, 2016, https://www.greatlakeshops.com) depending on variety (Table 3).

Annual Production Costs

Annual production costs will vary based on targeted yield; variety; weed, disease and insect infestation; production methods; labor and capital availability; drying and processing systems; and marketing strategies. Annual costs may vary based on production, particularly in the first and second year when limited yield may occur. Annual operating costs can be broken into the following four categories: 1) pre-harvest, 2) harvest, 3) drying/processing, and 4) marketing.

Pre-Harvest

Nutrient Requirements

Based on information reported at the University of Vermont, for every 1,000 pounds of dry matter produced on a per-acre basis, the hops crop will need 30 pounds of nitrogen, 20 pounds of potassium and 5 pounds of phosphorus. The cones will require about one-third to one-half of this total (Darby, 2011). Hop nutrient needs vary depending on soil quality, variety, cultural practices and growing region. Mature plants produce much more canopy and crop compared to young plants, so they remove more nutrients from the soil. Factors that affect replacement nutrient requirements include soil organic matter levels, organic soil amendments, and returning spent bines to the hop yard as compost (Sirrine, 2014).

- **Nitrogen** is the only nutrient that needs an annual application. Amending the soil based on pre-plant soil testing prior to planting should satisfy the first-year needs of the hop plant for all nutrients except nitrogen. In that first year, a total of about 75 pounds actual nitrogen per acre is suggested (Miller, 2015) using multiple applications during spring and early summer (Northeast Hops News, 2017).
- Ground applications of nitrogen should be made over a 12- to 18-inch band on each side of the plants and within the weed-free strip under the plants. Multiple applications of low rates of nitrogen is preferred over a single application at a higher rate. For new plantings, delay the first ground application until approximately 30 to 45 days after planting (Darby, 2011). If nitrogen is applied through the irrigation system (fertigation), consider at least weekly applications of low rates of nitrogen or consider applying nitrogen with the irrigation water for every application up until the time that flowers become evident on laterals. All nitrogen applications should be made prior to flowering. Nitrogen rates may need to be reduced substantially when applications are made through the irrigation system as opposed to broadcasting on the soil surface.
- **Potassium** is estimated to be in the range of 80 to 150 pounds per acre with about one-quarter of this being stored in the cones and the rest in the bines and leaves. Therefore, approximately 75 percent of the potassium needed to grow a crop can be accounted for by returning the bines and leaves to the hop yard as mulch. Perhaps the best time to apply potassium, especially if using a muriate of potash (potassium chloride), is in the fall.
- **Phosphorus** is an essential element for hops production; however, it is needed in much lower amounts than nitrogen and potassium with about 18 to 20 pounds being removed with an average crop. If phosphorus was added and incorporated based on pre-plant soil test recommendations, supplemental applications will probably not be needed and should only be considered if tissue testing indicates a need.

Stringing the Yard

In addition to constructing the trellis system, stringing the hop yard will be required every spring before new bine growth has occurred. (Figures 15 and 16). The bines must be trained to wrap around the strings in a clockwise direction to reach their growth and yield potential (Figure 17). In the first three years, the decision as to how many strings are needed per crown must be made to optimize the use of the available canopy space. For example, depending on location, mature hop yards in Washington State typically carry multiple strings per crown (Figure 18). Once fully established (year four and beyond), the number of strings per crown should be the same from one year to the next.

Figure 15: Stringing a hop yard in the spring (Washington State hop yard).

Figure 16: Pole, wire and coir design end row (Washington State hop yard).

Pruning and Training the Bines

- **Bine pruning** begins in the spring when the first shoots to emerge from the hop crown tend to produce uneven growth which, if trained onto the strings, will result in a weak, non-uniform canopy. Removing the first flush of growth after bines have been growing for about two weeks or when they are about 2 feet high (Sirrine, 2014) will encourage a second flush of stronger, more uniform shoots. Spring trimming may be done manually or by spraying a desiccant herbicide (if one is labeled for hops). Training of this second flush of growth to the bines should begin about three weeks after the first flush of growth is cut or burned down (Tobin, 2019). Stripping leaves from the lower 4 feet of the bines after training promotes better air circulation and lowers humidity levels throughout the hop yard, thus lessening conditions that favor mildew development.
- **Bine** training begins once the second flush of growth reaches about 28 inches in length. Two or three of the strongest shoots should be trained onto each string (coir), wrapping them in a **clockwise** direction to help the bines grow vertically (refer to Figure 2). Once trained, bines will continue to grow on string unaided for the rest of the elongation period.

Figure 17: Hop, bine, coir and wire (Washington State hop yard).

Weed, Disease and Pest Control

- Weeds compete for water and nutrients and will affect hop growth and yield. Weed management in dormancy to early spring is aimed at establishing and maintaining a weed-free strip under the planted row. Hand weeding, mulching and/or application of herbicides will be needed to control unwanted vegetation. Few herbicides, however, are registered for hops, especially in new plantings. Mulches and weed mat may be options for the organic grower. Maintain a 3- to 4-foot-wide weed-free strip (18 to 24 inches weed-free each side of the base) down each row (Figure 19) for the best results (Sirrine, 2014).
- Diseases such as downy and powdery mildew are very problematic in hop yards. Downy mildew is a disease of the foliage caused by a fungus-like organism. It spreads from plant to plant by airborne spores and is one of the most troublesome diseases in hop production. (Quesada-Ocampo, 2018). Downy mildew can cause severe crop damage, and, in some cases, it can cause complete loss of marketable yield due to lost production and greatly reduced cone quality. Infections may begin as early as spring. Once established, the disease can last throughout the growing season. Buds, growing points, cones and leaves are all subject to infection. Symptoms of downy mildew include discolored blotches on the upper leaf surface and mold-like growth on the underside of leaves (Figure 20). Conditions favoring downy mildew infections include high humidity (around 90 percent); extended periods of wetting, such as heavy morning dew, increased rainfall or overhead irrigation; and warm temperatures (appoximately 65 degrees F when moisture is present for at least 1.5 hours).

Figure 18: Commercial hop yard multiple coir strands from one crown (Washington State hop yard).

Figure 19: Maintain a bare area under canopy.

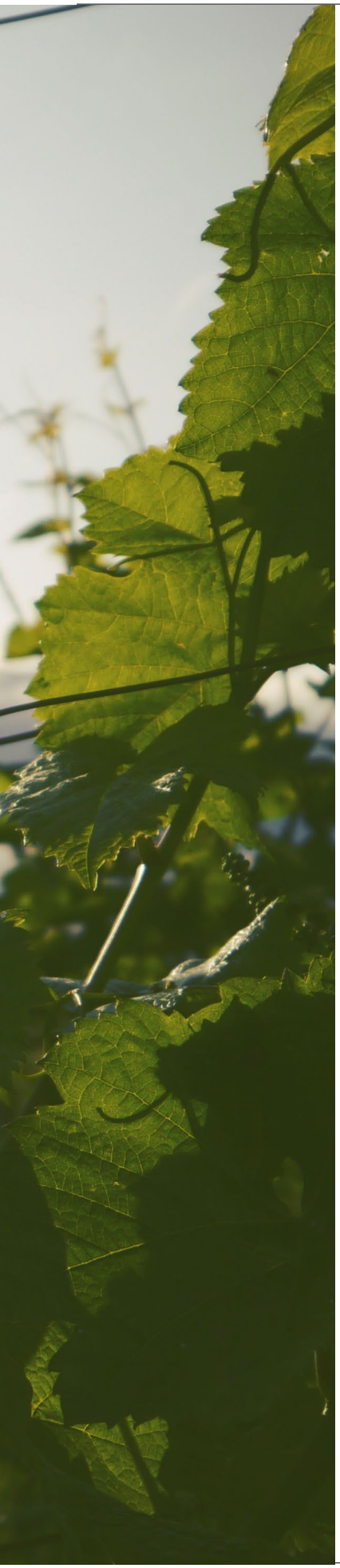


Figure 20: Mold-like spots on the underside of leaves symptomatic of downy mildew.

Photo: D.H. Gent, USDA

Figure 21: Powdery splotches on the topside of leaves symptomatic of powdery mildew.

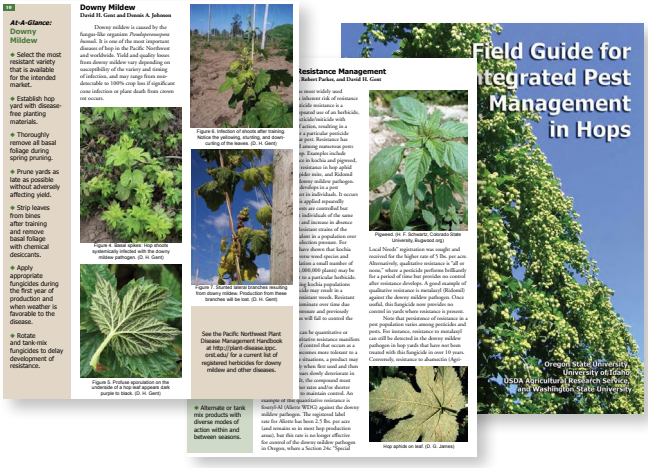
Photo: D.H. Gent, USDA

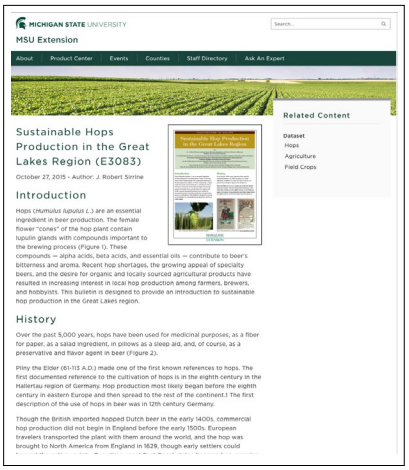
- Powdery mildew, caused by a fungus, is one of the most damaging diseases of Northwest hop yards (Gent and Barbour, 2009), but it also can occur in other hop-producing regions within the United States. Powdery splotches on leaves or stems are symptoms of powdery mildew (Figure 21). The fungus thrives in high-humidity, low-light areas with minimal air circulation.

  Control of downy/powdery mildew involves the following:

  - Timely application of protectant fungicides beginning in spring regardless of the presence or absence of the disease.
  - Use of clean planting stock.
  - Removal of diseased shoots and spikes followed by retraining healthy shoots to take their place.
  - Selection of downy/powdery mildew tolerant varieties, such as Cascade, Fuggle, Magnum, Newport and Perle. (NOTE: There is little information how these varieties will perform in Tennessee and how resistant they will be to downy/powdery mildew considering the Tennessee humidity.)
  - Removal of basal foliage of bines during spring pruning to facilitate good air movement within the hop yard.

- Insect Pests such as mites, aphids and leafhoppers can do serious damage to a hop yard. Aphids and mites feed on leaves and cones, sucking vital nutrients and water from the plant. Leafhoppers defoliate hop plants, giving the leaves a lacey-like appearance. Plants should be scouted (monitored) weekly, and recommended pesticide/miticide applications should be started in early spring to prevent infestation.





For additional resource material on disease and pest management for hops, the following publications are recommended:

- *The Field Guide for Integrated Pest Management in Hops*, (Gent, Barbour, Drewes, James, Parker & Walsh, 2010) is available from the USDA online as a free PDF at www.ars.usda.gov/ARSUserFiles/37109/HopHandbook2010.pdf.
- *Michigan Hop Management Guide* (Lizotte, Sirrine, Miles, Jess, Zandstra. 2020. Michigan State University Extension) is available as a PDF at canr.msu.edu/resources/michigan-hop-management-guide.
- *Sustainable Hops Production in the Great Lakes Region* (Sirrine. 2015. Michigan State University Extension [E3083] is available as a PDF at canr.msu.edu/resources/sustainable_hops_production_in_the_great_lakes_region_e3083.

Irrigation

Watering frequency and run time will depend on the system design, soil type and seasonal conditions. The goal of irrigation is to maintain a good soil moisture level throughout the growth cycle without over-irrigating and leaching the soil of nutrients. Michigan State University Extension recommends at least six gallons of water per plant, per day during June and July when the plants are rapidly growing (Sirrine, 2010).

Fertilization

Precise recommendations for fertilizing hops in Tennessee will be difficult to develop since little to no experience with this crop exists in our area. However, general ideas regarding the proper ranges for various soil nutrients can be developed using information from other areas. A soil test nearly every two years can help monitor the soil pH level and keep it in the optimum range of 6.0 to 6.5. Once the hop yard is established, tissue analysis is preferred over soil test in assessing the actual nutrient status of the crop. Collect plant tissue samples when bines reach approximately half-canopy height. Standards are based on the youngest mature leaf. In some areas, petioles are used instead of leaves.

Pre-Harvest Cost Considerations

Pre-harvest costs include fertilizer; coir; mulch; weed, insect and disease control; plant maintenance; labor; machinery costs; and annual irrigation costs (Table 4). Plant maintenance includes training bines and stringing coir. Since hop production has not been well-established in Tennessee, a great deal of uncertainty exists in estimated costs. For small-scale hop yards, labor can be a substantial cost, since machinery used in large-scale hop yards may be too expensive to obtain. If machinery is available to the producer, it can save labor costs. However, capital recovery and annual repair and maintenance should be considered when establishing an annual production budget.

Table 4. Estimated annual pre-harvest cost for a one-half acre hop yard.

Item	Description	Unit	Quantity	$/unit	Total Cost
Fertilizer	Nitrogen	Pound	37.5	$0.54	$20
Coir		Roll	1	$45.00	$45
Mulch		cubic yard	15	$20.00	$300
Herbicide			1	$56.00	$56
Pesticide			1	$74.00	$74
Fungicide			1	$84.00	$84
Labor	Pre-emergent	$/hour	2	$11.63	$23
	Stringing	$/hour	20	$11.63	$233
	Training/Pruning	$/hour	30	$11.63	$349
	Fertilizing	$/hour	2	$11.63	$23
	Mulching	$/hour	10	$11.63	$116
	Mowing/Weeding	$/hour	40	$11.63	$465
	Spraying	$/hour	12	$11.63	$140
	Pruning	$/hour	50	$11.63	$582
Machinery	Annual Cost		1	$250.00	$250
Irrigation	Annual Cost		1	$150.00	$150
Total Pre-harvest Costs					**$2,910**

Source: Modified from the North Carolina State Hop Budget Spreadsheet
Note: Labor wage rate used here is $11.63 per hour and based on the adverse effect wage rate for 2019 in Tennessee. foreignlaborcert.doleta.gov/adverse.cfm

Harvest

When Are Hops Ready to Pick?

The essential oil content of hops continues to increase beyond traditional harvest dates. Therefore, beers made with a single hop variety, but harvested at different times will have different flavor and aroma characteristics. Correctly timing harvest will optimize these characteristics in the final hop product and, ultimately, the beer (Lizotte, 2020).

The two most common methods used to determine hop cone maturity on the farm are the following:

- Subjective Method — Look, feel and smell (sensory)
  As hop cones mature, they typically go through a subtle color change from green to yellowish. The leaves become papery to the touch, often with brown around the edges and the pale-yellow color of the lupulin glands in the cone changes to a dark yellow/orange hue. Select several cones randomly throughout the hop yard. To test readiness for harvest, squeeze the cone between your hands. If the cone stays compressed, emits a pungent aroma, and leaves a sticky yellow powder on your hands, the yard is ready to harvest (Sirrine, 2012).

- Objective Method — Dry-matter percentage (measured)
  As the hop cone matures, the percentage of dry-matter to green-weight increases by approximately 1 percent every four to seven days depending on the variety. The most common dry-matter harvest target referenced in the literature is approximately 23 percent, although this can range between 20 and 23 percent depending on the variety (Madden and Darby, 2012). Dry-matter tests are easy to do. Basic equipment such as a dryer/dehydrator or microwave and an accurate set of scales are needed. Information on the six-step procedure for doing dry matter tests on hops is available from “Hop Harvest Readiness” from the University of Vermont Extension at blog.uvm.edu/hoppenin/2012/08/24/hop-harvest-readiness.

Figure 22: Bines and the string holding them are cut about 3 feet above the ground to allow the bines to hang straight down.

Figure 23: String (coir) is cut at the high trellis wire and the string plus bine are placed on a truck or trailer for transport to the processing facility.

Figure 24: Cutting down bines on a larger scale.

Figure 25: Small combine used to separate cones from bines.

Figure 26: Larger combine used to separate cones from bines.

Figure 27: In-field combine used to separate cones from bines.

Using a combination of dry matter testing and sensory evaluation will provide the best chance of identifying the right time to harvest.

Harvesting

Harvesting hops generally occurs from mid-to-late August to mid-to-late September, depending on the variety, location and conditions during the growing season. Based on harvest periods for other crops, hop harvest in Tennessee would probably fall somewhere between late July and the end of August.

Proper timing is essential since hops are in prime harvest condition for only seven to 10 days. The hop drying process dictates the timing and speed of the harvest and post-dry processing operations. Harvest is scheduled so the hops are stripped, cleaned, dried, baled and/or pelletized in a continuous process without the need to stockpile green hops, which is undesirable for quality reasons.

Hops are harvested by cutting down the bines (Figures 22, 23 and 24). In very small operations, cones can be removed from the bines by hand or by using a small combine (Figure 25). In larger operations and in commercial hop yards, the cut bines are transported to a processing facility where large combines separate the cones from the bines (Figure 26). Field combines can accomplish this entire process in the field (Figure 27); however, such machines are rare and are very expensive. Regardless of the method used for harvest, both the coir and the bines are cut approximately 3 feet above ground prior to being cut at the top of the trellis. The remaining leaf area below where the bines were cut should still be photosynthetically active and will, therefore, export carbohydrates for storage in the rhizomes. As a result, the rhizomes will be stronger and more tolerant of winter stresses, and spring growth should likewise be enhanced due to stronger rhizomes.

Figure 28: Hop sprayer (New York hop yard).

Figure 29: Cutting bines to be transported to a harvester (New York hop yard).

Figure 30: Hop harvester (New York hop yard).

Figure 31: On-farm hop drier (New York hop yard).

Harvest Cost Considerations

Harvest costs may include labor, equipment (Figure 28) and handling/transportation. Harvest labor is a substantial cost for hop producers. Labor includes cutting bines (Figure 29) and transporting them to a machine harvester (Figure 30) or picking cones by hand.

Hops harvest is labor intensive especially if the hops are hand harvested (stripped by hand from the bines after cutting down from the trellis). Investing in custom harvest equipment is not cost effective due to the low number of acres in hops production in the Southeast (resulting in an inadequate customer base for a custom harvester). Recouping capital investment in machinery specific to hop production is unlikely to be profitable for a small-scale hop production.

Processing

Wet Hops

Harvested hops can be used immediately to brew wet-hopped seasonal ales. Wet (undried) hops are a source of demand held by local brewers in the Southeast. Wet hops must be used within in 24 to 36 hours of harvest due to oxidation of the lupulin.

Drying

Warm temperatures (not to exceed 140 degrees F) will generally result in a higher quality end product. Drying hops to a moisture content of 8 to 10 percent (from a moisture content of approximately 80 percent) is required to prevent oxidations of lupulins and prevent the development of molds and mildews and general spoilage. The online "Hop Harvest Moisture Calculator" (University of Vermont Extension, 2014, uvm.edu/extension/images/engineering/hopscalc.html) is useful for determining moisture levels. Depending on the variety, a mature, well-tended hop bine should produce at least 1 pound of dried hops per year (Sirrine, 2014).

Some producers will dry hops using a hop-drying oven. Harvested hops are placed on a screen and placed in the oven where heated air is blown through the oven for approximately eight hours to dry the hops (Figure 31). This type of drying process requires careful monitoring to ensure the hops do not become scorched. It is important to remember that an entire season's harvest can be ruined in only a few hours during drying. (Gorst Valley Hops web site, 2020, gorstvalleyhops.com/about/hops-processing.)

Dried hops should be stored in a climate-controlled environment to prevent issues such as a rise in moisture content in a humid environment. At present, the Southeast does not have the infrastructure needed to dry hops on a commercial scale. Hops drying for smaller operations would require other methods such as placing the hop cones on screens in a dry room with a dehumidifier.

Hop Harvest Moisture Calculator

STEP 1: Weigh a Sample

Weigh a sample (A) of your harvested hops, making sure to 'tare' the scale before adding the hops, or subtract the weight of the container from the total weight.

Sample (A) Weight: _____ grams

STEP 2: Dry the Sample to 0% Moisture & Re-weigh

Dry out the sample with a microwave, dehydrator, or oven. If using a microwave or oven, stir the sample every minute to prevent scorching! **Weigh frequently: the sample is at 0% moisture when it no longer loses weight.**

Sample (A) Weight at 0% moisture: _____ grams

Harvest Moisture is % moisture (by weight)

Harvest Dry Matter is % dry matter (by weight)

STEP 3: Weigh Another Sample

Weigh a second sample (B) from your harvested hops, making sure to 'tare' the scale before adding the hops, or subtract the weight of the container from the total weight.

Sample (B) Weight: _____ grams

STEP 4: Weigh an Empty Sample Bag & Fill it with Sample (B)

Select an empty sample bag that air can easily pass through (mesh or other permeable material) and weigh it. After you have recorded its weight, fill it with sample (B) and then place it in the oast with the rest of the harvest.

Empty Bag Weight: _____ grams

STEP 5: Choose a Target Moisture Content

Decide on your target final moisture content. In general, hops should be dried to 8-12% moisture, with 8-8.5% being optimum.

Target Moisture Content: _____ % moisture (by weight)

Sample (B) will weigh grams when it reaches % moisture (by weight)

Including the weight of the bag, your Target Weight is grams

Drying Lookup Table

Sample Weight (Undried): _____ grams

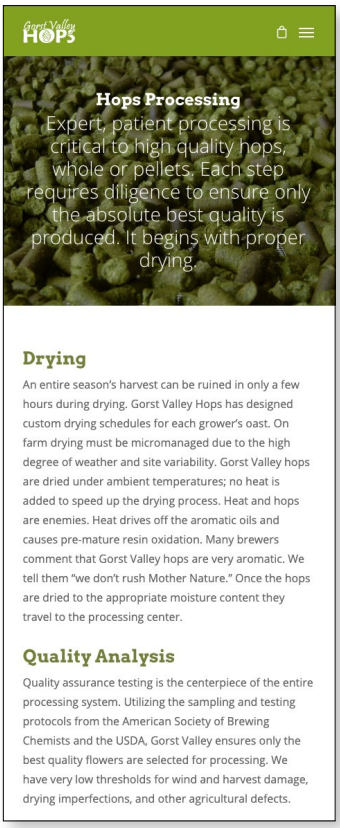
- **Key:**
- Target Harvest Timing
- Your Hops are Over-Dried!
- Optimum Moisture

Download the Hop Harvest Moisture Calculator - Excel version (.xlsx).

Questions?

Pelletizing

Converting hop cones into pellets requires the following eight-step process: 1) harvesting (removing cones, leaves and stems from the bine); 2) separation (removing leaves and stems from cones); 3) drying hops; 4) chemically assaying for acids and oil content; 5) conducting physical quality analysis; 6) pulverizing or milling the cones; 7) pelletizing (compressing the hops powder into cones with uniform density, packaging hops pellets into vacuum sealed and gas flushed oxygen barrier bags); and 8) storing the bags in a low temperature (-4 degrees F) stable environment (Gorst Valley Hops, 2018, https://gorstvalleyhops.com/about/hops-processing). Larger hops operations will bale their hops for ease of shipment, but no operations in the Southeast are large enough to consider baling.



Hop Oil

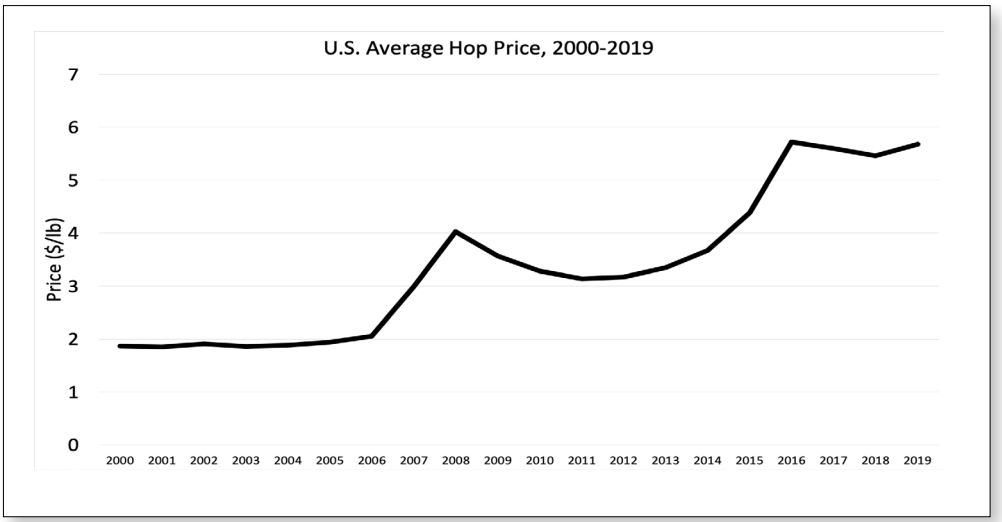
Hop oils contribute to many of the flavor and aroma characteristics in modern craft beers. The oil can be extracted, but it begins to degrade immediately after the cones are harvested. Therefore, the process of extracting the oil requires considerable infrastructure with large fixed costs.

Cost Considerations

Limited infrastructure is available for hop producers in Tennessee; therefore, on-farm drying and processing hops may be required prior to selling. Immediately following harvest, hops should be used either for wet hopping or dried to 8 to 10 percent moisture and stored in a cold, climate-controlled environment. A cold storage environment (approximately -4 degrees F) is necessary since heat causes hops to degrade quickly. Climate controlled storage is an additional capital and annual operating cost producers should consider.

While drying hops is relatively inexpensive and doable by a small operation, pelletizing (or extracting hops oil) requires substantial investment in equipment and consequently must service a fairly large number of acres. Discussions with Virginia growers indicate that a centralized pelleting facility is their biggest need. Many brewers either want pellets or must use pellets (or oil) due to their setup. For example, a survey of Tennessee brewers indicated that many brewers are not set up to accept dried hops and, therefore, require pellets or oil (Best, 2019). Costs for drying will vary based on the system and the energy source used. Pelletizing or baling hops may be required prior to selling, thereby substantially adding to post-harvest costs.

Chart 1: United States average hop price, 2000-2019 (USDA-NASS)



Marketing

Hop Market

Tennessee hop yards are usually quite small (less than an acre), and there is no established hops market. The main disadvantage of the small size of the industry is the lack of industry infrastructure, which is caused by limited opportunities in terms of joint marketing and collaborating with other producers.

As such, producers will need to devote time and resources to market and sell their product. Establishing relationships with local craft breweries and home brewers will assist in obtaining premium prices. Marketing hops online through websites such as The Lupulin Exchange (lupulinexchange.com) may be a cost-effective alternative. Packaging and labeling dried or pelletized hops is an added cost that should be considered. Local brewers may want hops in a specified form (wet, dried, pelletized) or in a particular quantity. Understanding the quantity and quality specifications of the local hops market should be completed prior to starting production.

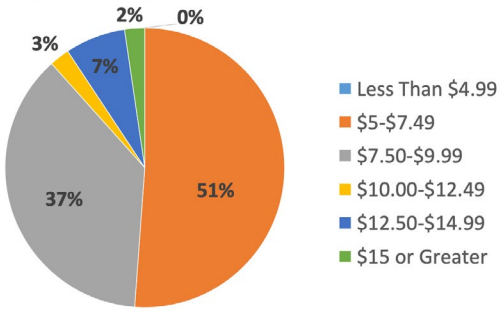
Revenue

Revenue is composed of price and yield, both of which have not been established in Tennessee. Revenue in years one to three may be substantially lower than four or more years, due to lower yields resulting from the time required to establish a mature hop yard.

Prices

Hops prices vary dramatically based on the characteristics of the hop, local supply and demand, and product consistency. The national average price per pound for hops is shown in Chart 1. However, unlike many agricultural commodities, hops are a heterogeneous product. As such, pricing hops will vary due to the characteristics of the hop and the location of production. Working closely with the brewery or home brewer will allow the hops grower to determine the characteristics desired by end users. Contracting hops production with local breweries can offset some of the risk hops producers face. To determine price offerings for varieties by location, producers can visit online markets such as the Lupulin Exchange to view detailed offerings (Chart 2). Online prices need to be evaluated cautiously as substantial variation in the characteristics of the hop, quantity available/required, age and form (dry/pelletized/wet) exist.

Chart 2: Example of price variability in hops: Cascade 2018 price frequency, June 17, 2019. Posted prices the Lupulin Exchange, $/lb.



Yields

The national average hop yield in 2019 was estimated at 1,981 pounds/acre (USDA-NASS, 2019). No publicly available data exists for hop yields in Tennessee and anecdotal evidence is mixed. Hop growers in Tennessee have indicated that limited yield is produced in the first three years and that full yield potential may not be realized until the fourth year. This fact contributes to a significant disadvantage for Tennessee growers compared to growers in other regions. For example, growers in Washington State have indicated that full-yield potential, if established and managed correctly, can be realized in the first or second year. Additionally, for established hop yards in Tennessee, yields are substantially lower than the Pacific Northwest, where producers can achieve yields of greater than 2,000 pounds/acre. Yields reported by Tennessee producers have been less than 1,000 pounds per acre for hop yards that have been established for three or four years. A lack of varieties specific to the region, established production methods, and limitations due to peak daylight hours in the summer contribute to low yields. At this time, the yield potential in Tennessee is still very uncertain.

The Craft Brewing Industry

More than 98 percent of the 57,468 acres of hops grown in the United States in 2018 were used to brew beer. Increased hops demand is tied closely to the growing popularity in the craft beer industry. With the deregulation of home brewing in the United States in 1979, craft breweries, defined as producing 6 million barrels (1 barrel = 31 gallons) of beer or less annually (Brewers Association, 2018), began to emerge (Kain, 2011). There were only eight craft breweries in the United States in 1980, but as of 2018, it is estimated that there were more than 6,000 craft breweries in the United States (Brewers Association, 2018). In 2016, craft brewers collectively produced 24.6 million barrels of beer, which was a 6 percent increase in volume over the previous year. Microbreweries (small-scale breweries with limited production) and brewpubs (a restaurant that brews beer onsite) accounted for 90 percent of growth in the craft brewery industry (Steady Growth, 2017). The number of operating breweries in the United States increased by 16.6 percent, a total of 5,301 breweries, 3,132 of which are microbreweries Steady Growth, 2017).

The state of Tennessee has also had a substantial increase in the number of operating craft breweries, from 24 in 2011 to more than 120 breweries in 2019, based on data from the Tennessee Department of Agriculture, the Tennessee Brewers Association and internet searches. The results of a 2018 University of Tennessee craft brewery survey indicated that continued growth is anticipated in the craft brewing industry (Chart 3).The fast-paced growth of the industry both globally and locally means there is an increased demand for hops, grains and other inputs used to brew beer. Whether growth in the craft industry continues, however, remains uncertain.

Chart 3: Brewery expected sales increase over the next five years. (Based on survey responses of 32 Tennessee craft brewers.)

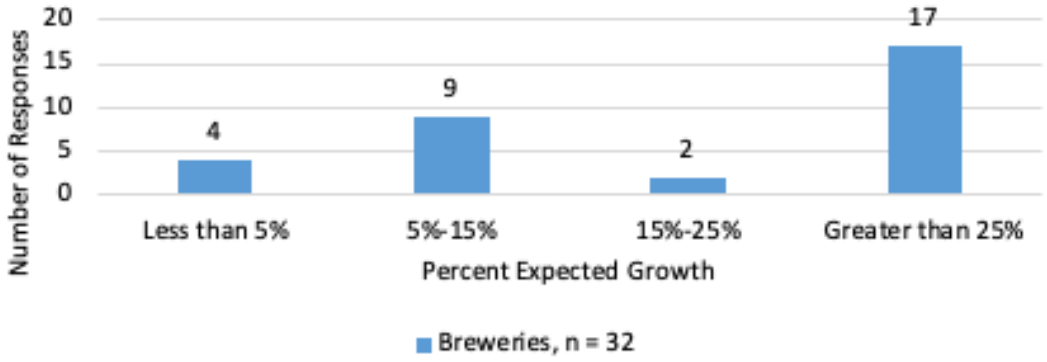
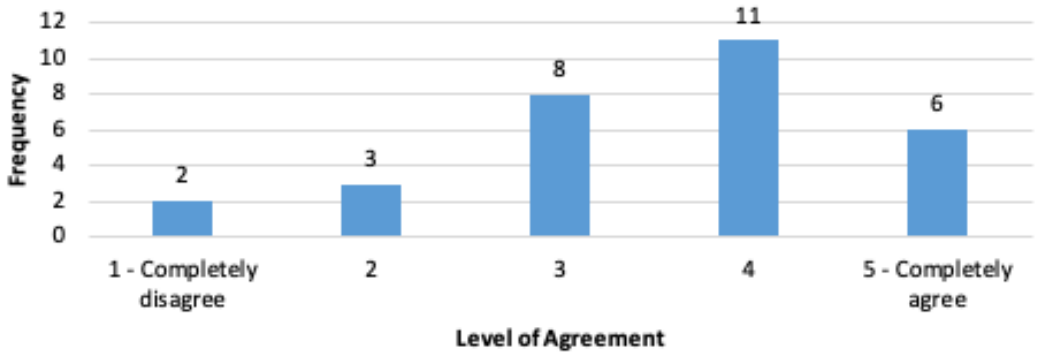


Table 5. Pounds of wet or dry hops used annually by Tennessee craft breweries

	Wet Hops, n = 29	Dry/Pelletized Hops, n = 27
Average	46	2,301
Mode	0	4,000
Max	500	16,500
Min	0	100
Standard Deviation	102	4,072
Total	**1,335**	**62,125**

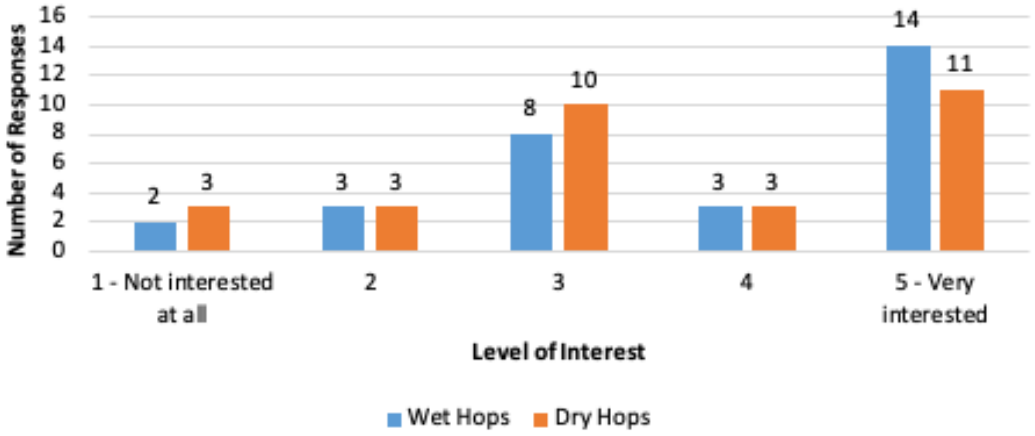
Chart 4: Brewery frequency of responses when asked whether they are only interested in using pelletized hops (with 1 indicating they completely disagree with the statement "I am only interested in using pelletized hops, and 5 indicating they completely agree with the statement).

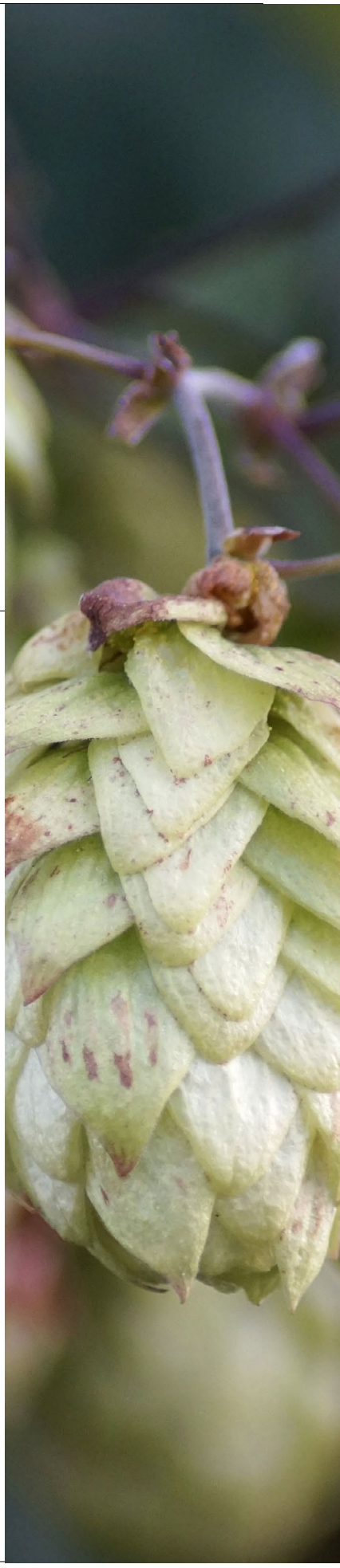


Market Opportunities

A primary market for Tennessee hop growers is selling directly to craft breweries and home brewers. A survey of Tennessee craft breweries indicated that the majority were using dry/pelletized hops rather than wet hops in beer production (Table 5). Additionally, the majority of brewers indicated they preferred using dry or pelletized hops in beer production (Chart 4). Hops used were primarily from the Pacific Northwest (though some hops were used from around the world).

Chart 5: Brewery interest in purchasing Tennessee-grown hops (with 1 being not interested at all and 5 being very interested).





Survey results also indicated that craft brewers were very interested in purchasing Tennessee-grown hops to be used for wet hop brews or dry/pelletized brews (Chart 5).

The demand for high-quality Tennessee-grown hops is evident. Currently, only limited consistent supplies are available for brewers. Nearly half of the respondents who participated in the survey stated that the lack of consistent high-quality supplies was their main reason for not purchasing Tennessee-grown hops.

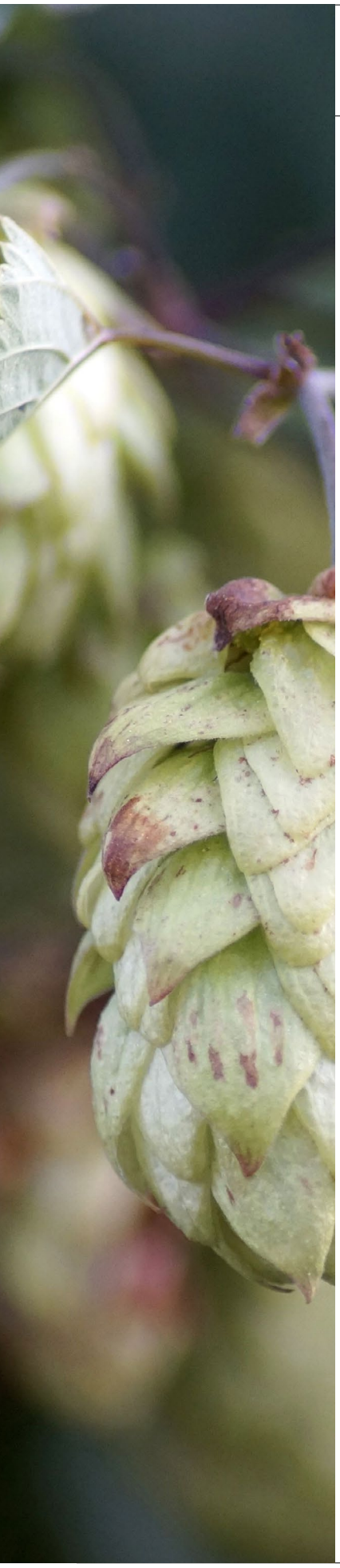
Regional Product Identification

As previously mentioned, the majority of hops produced in the United States are grown in the Pacific Northwest (Washington, Oregon and Idaho). However, in the past two decades, the rise of regional craft breweries has created a demand for locally produced hops. Michigan, New York and Virginia have led the resurgence in East Coast hop production and aided in expanding the production region south.

Many challenges exist in growing hops outside of the Pacific Northwest. Controlling diseases, insects and weeds can be problematic given the hot, humid conditions in the summer. Due to the concentration of hops production, many varieties are developed exclusively for the Pacific Northwest. Limited varieties have been developed specifically for the East Coast or South. Daylight hours can also provide challenges with hops production the farther south the production is attempted.

Agritourism

Small- or medium-scale hops production can be conducive to agritourism as a method to generate additional income or provide cost savings. Location, accessibility, facilities and appearance of the hop yard will determine a business' ability to generate additional revenue from agritourism. Additional revenue may be generated by hosting events such as corporate retreats, weddings, reunions etc. Cost savings can occur from hosting events such as pick-your-own parties in conjunction with a craft brewery or group of home brewers. Pick parties can reduce requirements for labor and build product reputation for marketing purposes.



Industry Trends and Other Considerations

The demand for hops is driven by its use as a flavor additive and preservative in beer production. The recent growth in craft beer production in the United States, with its emphasis on producing a tastier, strongly flavored, and more bitter set of beers, has greatly enhanced the use of hops (as opposed to massed produced beers) and has driven a huge increase in hops production.

Craft beer has a hopping (hop-use rate) typically in the 1.24 to 1.65 pounds per barrel of beer (31 gallons) range. Craft-beer production in 2018 was estimated at 25.6 million barrels at 13.2 percent of the United States beer market volume with a value of $27.6 billion. A dramatic increase from the 5.5 million barrels produced in 2003 (Brewers Association, 2019). Craft beers are more highly valued than their mass-produced counterparts. The average price of craft beer is calculated as being 83.4 percent higher than the average price of other beer sold in the United States. As a result of the growth in the craft industry, hop acreage in the United States has increased from 38,892 acres in 2014 to 57,468 acres in 2018 (Hop Growers of American, 2019b).

While hops are vital to beer production, they constitute a relatively small part of the cost of producing even craft beer. Calculations indicate that around 3.5 percent of revenue in the craft beer industry is devoted to purchasing hops (much less than is spent on malting barley, metal cans and/or glass bottles). The result is there is some leeway in the price that craft brewers can pay for hops, but prices can still have very large and rapid swings. The change in prices is attributed to a desire by craft brewers for different and new types of beer based on hops with varying levels and types of aromas and beta-based bittering. For example, the spot price paid for Citra, a relatively new aromatic variety, rose from approximately $16 per pound in 2014 to a peak of over $23 per pound by the third quarter of 2015, only to decline to around $13 per pound by the end of 2017 (Financial Times, 2019). Production levels of various types of hop varieties can change fairly rapidly; for example, Summit was the third most popular variety in 2013, but had dropped out of the top 10 by 2018, while Citra rose from eighth in 2013, to becoming the most popular variety in 2018. Proprietary varieties, where producers pay the developer for the right of use, have become popular with five of the top 10 varieties in 2018 plantings (Hop Growers of American, 2019).

A slowdown in the growth of the craft-beer industry in the United States (Brewers Association, 2018) and an increase in hops stocks may be a sign of a slowdown in the demand growth for hops (Financial Times, 2019). In terms of evaluating hops, producers rely on alpha and beta acid content, total oils and the hop-storage index. A survey of Michigan brewers indicated that in terms of importance 46 percent saw aroma as very important followed by 32 percent for flavor, 16 percent for analytics and 6 percent judge by color (Malone, 2019).

Wet (undried) hops are a source of demand held by brewers in the Southeast; however, this is a niche market. Wet hops must be used within 24 to 36 hours after harvest, due to the rapid oxidation of the lupine. Wet hops can realize $12 to $14 per pound on an undried basis, but prices are highly variable. Many brewers prize wet hop-based batches as one of their seasonal specialty beers. For example, 17 out of 30 Tennessee brewers surveyed indicated at least some interest in using Tennessee wet hops in their beer production (Best, 2019). In our view, the wet hops market will remain the primary market for Tennessee and probably Southeast hops growers. Another potential local market for Tennessee hops producers is the homebrewers market, which offers the opportunities for high price markups, but where packaging and market access are challenges.

SUMMARY

In summary, the interest in growing and buying high-quality, Tennessee-grown hops has increased in recent years. For the Southeast and especially in Tennessee, many of the historical production challenges and hurdles are being addressed. However, a limited infrastructure exists to support large-scale production and marketing of the crop in the state. In addition, the cost to establish the crop in southeastern states is relatively high, the lack of ideal daylength during the growing season influences relatively low production yields compared to the more northern regions of the country, and the humid environment causes production challenges.

The increase in craft breweries in Tennessee has created demand for locally produced hops; however, the long-term demand and profitability for Tennessee produced hops remains highly uncertain. Prior to considering hops production producers should determine if a viable market for the product (wet, dry, pelletized, extract and/or agritourism) exists in their location. Those considering growing hops in Tennessee must consider the production challenges, cost of production estimates, marketing opportunities, implications of the federal Food Safety Modernization Act (FSMA) and current industry trends discussed in this publication.

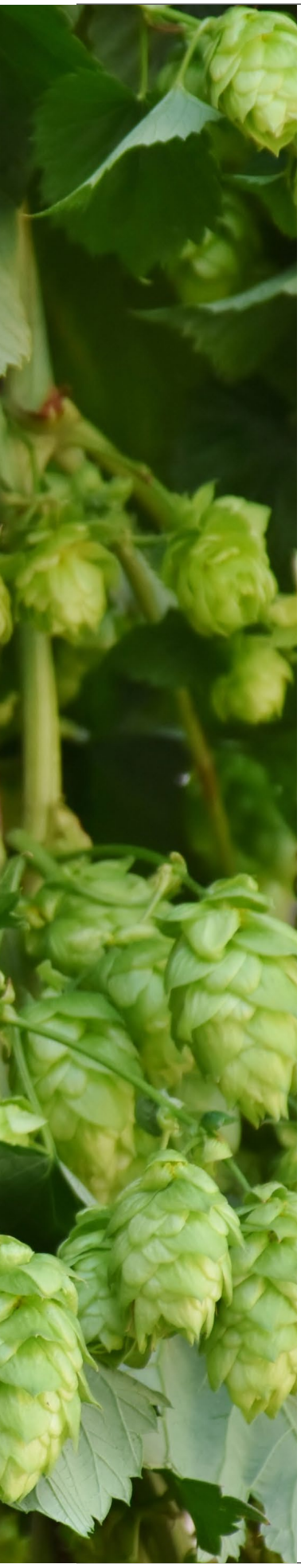
21 CONSIDERATIONS FOR GROWING HOPS

The following 21 bullet points have been assembled as the primary applicable considerations for those considering growing hops in Tennessee:

1. **Hops are generally dried and usually pelletized (or extracted as hop oil) before use.**
2. **Unprocessed (wet) hops can be used immediately.**
3. **Hop varieties can be separated in to two basic categories: bitter (with high alpha levels) and aroma.**
    - Some dual-purpose varieties exist.
4. **Hop plants respond to light and dark periods.**
    - Lengthening of the day stimulates vegetative growth and bine elongation.
    - Following the summer solstice as daylength begins to decline, bine elongation will cease, and lateral branching, flowering and cone development will begin.
    - While the range for commercial hops production in both the northern and southern hemispheres is listed as being between 35 to 55 degrees latitude, only those areas at or near 55 degrees latitude receive a daylength of 15 hours, which is considered optimum for bines to achieve their maximum length and, therefore, their maximum productive potential. In the northern hemisphere, moving south to lower latitudes means that daylengths will be decreased, resulting in decreased bine elongation and reduced yield potential. Tennessee lies between approximately 36.5 degrees north latitude in the north of the state and 35 degrees north latitude in the south.
5. **The hop plant has a chilling requirement of about 400 hours with a threshold temperature of 40 to 43 degrees F.**
    - It is suggested that a minimum cumulative period of 30 to 60 days at this temperature is needed to satisfy the chilling requirement.
6. **The ideal terrain for a hop yard would be one that is level or nearly level.**
    - Hops will grow in many different types of soils, ranging from light sands to clay.
    - Hops grow best on soils that are well-drained, both internally and on the soil surface.
    - The ideal soil pH for hops production is 6.5. Any recommended adjustments to soil pH need to be made prior to planting.
    - Phosphorus and potassium should be adjusted in advance of planting to bring them up to the “high” soil test level.
7. **Only female plants should be planted in or near hop yards.**

21 CONSIDERATIONS FOR GROWING HOPS

8. **There is no such thing as a "one-size-fits-all" trellis for hops.**
    - The hop plant tends to be most productive when grown in a vertical to near-vertical orientation.
    - The most common trellis system used worldwide is the V-trellis.
    - Poles generally are long enough to allow cables at the top be about 18 feet about ground.
    - Hop plants need sufficient trellis height to allow bines to complete their annual elongation without growing too far above the top wire.
    - Consideration should be given to prevailing winds and orientation to sunlight.
9. **Long-term integrity of poles used for the trellis is essential.**
10. **Pole spacing will have a direct impact on the establishment costs of the hop yard.**
    - Pressure treated telephone poles, cedar poles, black locust poles, or pipes can be used in trellis construction.
    - Pole size, depth of set and anchorage must be sufficient to provide good support to the trellis wires.
11. **Hops should be monitored weekly to scout for pest and disease problems.**
    - Hops are susceptible to downy and powdery mildew and to mites, aphids and leafhoppers.
12. **Irrigation allows producers to ensure that hop plants receive consistent water to maximize production.**
    - Hop plants can use 25 to 35 inches of water annually.
    - Watering frequencies and run-time will depend on irrigation system designs, soil type, and seasonal conditions.
        - Monitor soil moisture to a depth of at least 15 inches.
13. **Precise recommendations for fertilizing hops in Tennessee will be difficult to develop since little or no experience with the crop exits in our area.**
    - For every 1,000 pounds of dry matter produced on a per-acre basis, the hops crop will need 30 pounds of nitrogen, 20 pounds of potassium and 5 pounds of phosphorus (University of Vermont).
14. **Weed management from dormancy through early spring is aimed at establishing and maintaining a weed-free strip under the planted row.**
    - Hand weeding, mulching, and/or application of herbicides will be needed to control unwanted vegetation.



21 CONSIDERATIONS FOR GROWING HOPS

15. **Hop harvest in Tennessee will probably fall somewhere between late July and end of August.**
    - The timing depends on several factors:
        - Hop variety,
        - Weather,
        - Cone moisture content, and
        - Any pest or disease issues.
    - Hops are only in prime condition for about seven to 10 days.
    - Hops are ready for harvest when:
        - The outside scales feel papery and dry and
        - The inside lupulin is dark yellow.
16. **Hops production requires substantial labor and capital to establish the hop yard and produce a crop each year.**
17. **Cost can be divided into two primary categories:**
    - Establishment costs: One-time costs to build the hop yard infrastructure and establish plants.
    - Annual costs: Costs incurred each year to produce and market hops.
18. **Establishment costs published by land grant universities outside of the Pacific Northwest are highly variable.**
19. **General hop yard establishment costs can be divided into three primary categories:**
    - Trellis construction
    - Irrigation system
    - Plant establishment
        - Two common methods of plant establishment are:
        - Propagating plants from hop rhizomes and
        - Transplants (hop plants propagated by rooting cuttings from actively growing shoots).
20. **Revenue may be highly variable due to uncertainty in yield and price.**
21. **Alternative sources of income such as agritourism may be available for hop producers in Tennessee.**

REFERENCES

Austin, R., S. King, J. Davis. *2012. 2010-2012 North Carolina Hops Project Enterprise Budget.* North Carolina Extension. https://newcropsorganics.ces.ncsu.edu/specialty-crops/nc-hops/enterprise-budget/

Bamka, William. 2017. *New Jersey Commercial Hops Production FAQs*. Rutgers University, New Jersey Agricultural Experiment Station. https://njaes.rutgers.edu/fs1276

Best, S. 2019. "Estimating Production of Brewery and Distillery Spent Grains in Tennessee and Identifying Sustainable Uses." Unpublished Masters' Thesis, University of Tennessee, Department of Agriculture & Resource Economics.

Brewers Association. 2018. "History of Craft Brewing." Internet site: https://www.brewersassociation.org/brewers-association/history/history-of-craft-brewing/. "Statistics by State." Internet site: https://www.brewersassociation.org/statistics/by-state/?state=TN. "Craft Beer Defined." Internet site: https://www.brewersassociation.org/statistics/craft-brewer-defined/

Brown, D. 2013. Determining When Hops Are Ready to Harvest. Michigan State University Extension

Brown, D. and R. Sirrine. 2012. Purchasing hops for planting. Michigan State University Extension. https://www.canr.msu.edu/news/purchasing_hops_for_planting

Bullen, G. and R. Allen. 2017. "Small-Scale Commercial Hops Production in North Carolina." North Carolina State Extension. Web Access: https://newcropsorganics.ces.ncsu.edu/wp-content/uploads/2017/05/North-Carolina-Hops-Enterprise-Budget-Narrative.pdf?fwd=no

Comparing and selecting hops (web page). Brew Your Own. (n.d.) Retrieved from byo.com/resources/hops

Darby, H. 2011. *Fertility Guidelines for Hops in the Northeast.* University of Vermont Extension

Dick, J, K. and G. Bresowar. 2018. "Using Phototherapy to Delay Flowering and Increase Vegetative Growth in Hops." Poster Presentation Southeast Hops Conference, Blacksburg, VA.

Dodds, Kevin. 2017. *Hops: A Guide for New Growers*, First edition 2017. NSW Department of Primary Industries (Australia). https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/712717/hops-guide-for-new-growers.pdf

Financial Times. 2019. "US craft beer slowdown sends hops market from boom to bust." April 23. https://www.ft.com/content/0f678bd6-0cc7-11e8-839d-41ca06376bf2

Gent, D. H., J. Barbour, A. Drewes, D. James, R. Parker, & D. Walsh (eds.). 2009 *Field guide for Integrated Pest Management in Hops.* Moxee, WA: Washington Hop Commission. Retrieved from https://www.ars.usda.gov/ARSUserFiles/37109/HopHandbook2010.pdf.

Gorst Valley, Hops, 2018. "Drying to Processing: Method Overview." Presentation at Southeast Hops Conference, Blacksburg, VA.

Hopnology. Training and Crop Yield. 2018. Presentation at Southeast Hops Conference, Blacksburg, VA. http://www.hopnology.com/

Hop Union. (n.d.) "Hop varieties: A Hop for Every Flavor and Style" (webpage). Retrieved from https://shop.yakimachief.com/

Hornsey, I. S. 2003. *A History of Beer and Brewing*. Royal Society of Chemistry. London.

Hornsey, I.S. 2013. *Brewing*. Royal Society of Chemistry. London.

Kain, E. 2011. "The Rise of Craft Beer in America." *Forbes*. Internet site: https://www.forbes.com/sites/erikkain/2011/09/16/the-rise-of-craft-beer-in-america/#55002dee7344

Lizotte. E., R. Sirrine, T. Miles, L. Jess, B. Zandstra. 2020. *Michigan Hop Management Guide*, Michigan State University Extension. Available as a PDF at https://www.canr.msu.edu/resources/michigan-hop-management-guide.

Madden R., and H. Darby. 2012. "Hop Harvest Readiness" What's Hoppening: Musings from the Hop Yard Blog. University of Vermont Extension. https://blog.uvm.edu/hoppenin/2012/08/24/hop-harvest-readiness

Michigan State University Extension. (2014). "Growing hops in Michigan and the Great Lakes Region" (website). Michigan State University Extension. https://www.canr.msu.edu/hops/

Miller, Steve. "Fertilizing Commercial Hop Fields in New York." https://www.uvm.edu/sites/default/files/media/SMiller_Fertilizing_Commercial_Hop_Fields_in_New_York.pdf.

Miller. S., R. Sirrine, A. McFarland, P. Howard, T. Malone. 2019. "Beer as a Means of Economic Development: An Economic Impact Analysis of the Michigan Value Chain." Michigan State University Extension. Available as a PDF at https://www.canr.msu.edu/resources/beer-as-a-means-of-economic-development-an-economic-impact-analysis-of-the-michigan-value-chain

Noble Hops. 2020 "What Are Noble Hops." https://noblehops.com/what-are-the-noble-hops/

Northeast Hops News. April 2017. "Instructions on how to grow hops." Cornell University Cooperative Extension, Madison County. http://madisoncountycce.org/agriculture/hops-program

Post, J. 2017. Cost of Growing Hops in the Northeast. University of Vermont Extension. https://www.uvm.edu/sites/default/files/media/Cost_of_Growing_Hops_in_the_NE_Jan2017.pdf

Qu, L. and J.M. Davis. 2019. "Growing Hops for the Southeastern US." Poster at Southeast Hops Conference, Asheville, NC.

Quesada-Ocampo, L. 2018. "Hop Downy Mildew." North Carolina State Extension, https://content.ces.ncsu.edu/hop-downy-mildew

Siegle, L. and H. Scoggins. 2018. *2017 Virginia Hop Grower Survey Results*. Virginia Cooperative Extension. Presentation at Southeast Hops Conference, Blacksburg, VA. https://www.pubs.ext.vt.edu/HORT/HORT-289/Hort-289.html

Siegle, L. and H. Scoggins. 2019. *2018 Virginia Hop Grower Survey: Results*. Virginia Cooperative Extension, SPES-131NP. https://www.pubs.ext.vt.edu/content/dam/pubs_ext_vt_edu/spes/spes-131/SPES-131NP.pdf.

Sirrine, R. 2014. "Michigan Fresh: Growing Hops." Michigan State University Extension. E3210. Web access: https://www.canr.msu.edu/resources/michigan_fresh_growing_hops.

Sirrine, R. 2015. *Sustainable Hops Production in the Great Lakes Region*. Michigan State University Extension [E3083]. https://canr.msu.edu/resources/sustainable_hops_production_in_the_great_lakes_region_e3083

Sirrine, R., E. Lizotte, D. Brown, T. O'Brien, and A. Leach. 2014. "Estimated Costs of Producing Hops in Michigan." Michigan State University Extension. E3236. Web Access: https://www.canr.msu.edu/uploads/234/71501/MI_Hops_cost_of_production_Bulletin-E3236.pdf.

Smith, R.M. 2018. Future of Florida Hops Just Got a Little Brighter. July 30. https://www.growingproduce.com/vegetables/future-florida-hops-just-got-little-brighter/?utm_source=realmagnet&utm_medium=newsletter&utm_campaign=gpweeklynews+08042018&utm_content=An%E2%80%A6

"Steady Growth for Small and Independent Brewers." 2017. *Brewers Association*. Internet site: https://www.brewersassociation.org/press-releases/2016-growth-small-independent-brewers

Tobin, Dave. 2019. Personal communication.

USA Hop Growers of America. 2019a. Historic Overview. https://www.usahops.org/enthusiasts/

USA Hop Growers of America. 2019b. USAHops 2018 Statistical Report. Yakima, WA. January. https://www.usahops.org/enthusiasts/stats.html

United States Department of Agriculture - National Agricultural Statistics Service (USDA-NASS). 2019. Quick Stats - National Hop Yield. Web access: https://quickstats.nass.usda.gov.

University of Tennessee, Soil Plant and Pest Center Services and Fees brochure. Available at https://extension.tennessee.edu/Hamilton/Documents/Agriculture/Soil%20Testing/Soil,%20Plant%20and%20Pest%20Center%20Brochure%20-%202019.pdf.

University of Vermont Extension. 2014. Hop harvest moisture calibrator (interactive web page). Burlington: University of Vermont, UVM Extension. Retrieved from https://www.uvm.edu/extension/images/engineering/hopscalc.html

Virginia Cooperative Extension. 2016. GAPs and FSMA- an Overview for Hop Growers in Virginia. Retrieved from https://www.pubs.ext.vt.edu/content/dam/pubs_ext_vt_edu/HORT/HORT-237/HORT-237-PDF.pdf on June 12, 2019.

Virginia Cooperative Extension – Hops Budget. Web Access: https://ext.vt.edu/agriculture/commercial-horticulture/hops.html.

Virginia Hops Enterprise Budgets and Financial Statements. 2018. Virginia Tech Cooperative Extension. Web site: https://ext.vt.edu/content/dam/ext_vt_edu/topics/agriculture/commercial-horticulture/hops/files/VA-Hops-Budget_FINAL.xlsx

GLOSSARY

Alpha and beta acids: Compounds in hops that serve as bittering agents in the beer.

Bine: Annual, succulent shoot arising from a bud on the rhizome.

Coir: Twine or yarn made of fibers from the husks of coconuts. Coir is strong and resists rot. In hops production, coir twine is tied to wires or cables at the top of the trellis posts and extended to the ground near a rhizome where it is pegged down. Bines use coir for support as they grow.

Cone: Unfertilized female flower formed on laterals growing on bines. Cones contain the lupulin used in beer making.

Crown: A young hop plant propagated by rooting cuttings from actively growing shoots.

Dioecious: Having male and female flower parts on separate plants as opposed to monoecious where both male and female sex organs are on the same plant. The hop plant is dioecious.

Essential oils: Components in hops that give aromas to beer.

Lupulin: Yellow gland in a hop cone where the alpha and beta acids and essential oils used in beer making are found.

Rhizome: Underground stem from which roots and bines grow. Rhizomes also contain energy reserves that support early season shoot (bine) growth.

Trellis: The support structure for bines growing from hop rhizomes. It consists of poles and connecting cables. Coir is tied to these cables at the top of the trellis and extended to the ground.

Trichomes: Hair-like structures on bines that allow it to cling to support structures such as coir as the bines elongate.

UTIA.TENNESSEE.EDU

W 912 20-0218 07/20 Programs in agriculture and natural resources, 4-H youth development, family and consumer sciences, and resource development.
University of Tennessee Institute of Agriculture, U.S. Department of Agriculture and county governments cooperating.
UT Extension provides equal opportunities in programs and employment.