North Carolina Production Guide for Hop Selection NC1601
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Introduction

Hops have been cultivated for a few thousand years as a major ingredient for making beer. In the United States, hop production has been concentrated in states in the Pacific Northwest (PNW) including Washington, Oregon, and Idaho. In recent years, interest and commitment from local growers in establishing commercial hop production in North Carolina have been strong which parallels the growth of the craft brewing industry in the state. Hops, however, are not a traditional crop grown in North Carolina. Hops grown by North Carolina growers and NC State University researchers in Mills River and Raleigh have produced low yields compared to the major hop production areas further north. Dry cone yield of popular hop varieties grown in North Carolina is about one-fifth of that in the PNW (about 400 dried lbs per acre in NC compared to about 1,900 dried lbs per acre in the PNW). A major reason for the low yield is the available market-acceptable hop varieties are poorly adapted to North Carolina. North Carolina is close to the southern most geographic limit (latitude 35^{o} N) considered appropriate for successful hop production. These varieties, bred and selected in the PNW, suffer from poor vegetative growth and/or low flower production in North Carolina. Adjusting cultivation methods, such as cutting down new growth in spring to delay flower initiation, helps control the timing of flower initiation but has a limited impact on increasing cone yield. North Carolina State University started hop breeding in 2016 for developing hop varieties that will grow and develop well in North Carolina with high cone yield, good brewing qualities**,** and acceptable disease resistance.

The North Carolina hop breeding project developed a hop selection named NC1601. Based on the data collected in Mills River, NC, estimated yield of NC1601 is 1,600 to 2,000 dried lbs per acre. NC1601 produces a chemical profile of 11% - 15% alpha acids, 5% – 6% beta acids, 20.3% - 20.6% cohumulone, and 2.5% – 3.6% total oil. NC1601 has been used by about a dozen North Carolina breweries to brew test beer. Feedback on the beer has been very positive according to the brew masters and consumers.

In this production guide, the plant growth and development features and field cultivation methods for NC1601 are described. The information provided is based on the data collected and our experience growing NC1601 on the research station in Mills River, NC, which is in the southern mountains. Results in other areas may vary.

General information on NC1601

Origin of NC1601

Crossbreeding to develop NC1601 was initiated in the summer of 2016 at the Mountain Research Station in Waynesville, NC. The female parent was a commercial hop variety, Southern Brewer, and the male parent, YWA 2, was a plant that had been used decades ago for pollinating hop plants in the PNW to produce seeded hop cones. Dr. Greg Lewis donated the male plant to our program in 2015. Plant NC1601 was selected in 2018.

The NC1601 Hop Plant

NC1601 is a vigorous plant that can grow more than 20 feet tall on the trellis (Figure 1 left and right). Its side arms are 20 – 40 inches long. NC1601 also produces secondary side arms (Figure 1 middle). In most cases, the hop varieties developed in the PNW do not produce secondary side arms when grown in North Carolina. With secondary side arms, a hop plant can produce a higher yield. NC1601 produces medium to larger cones. The harvest time window for NC1601 in Mills River is between mid-August to mid-September.

Figure 1. Left: NC1601 plants at early stage of flowering, middle: secondary sidearms of NC1601, and right: NC1601 at late stage of cone development.

Cultivation of NC1601

Site Selection and Initial Soil Preparation

There are several factors to consider in site selection to start a hop yard including soil drainage and opening to sunlight. A site with sandy loam or well-drained loamy soil is ideal for a hop yard. Well-drained soil may reduce the chances of accumulation of standing water in the hop yard after rainfall. Soil rich in organic matter is especially helpful for the initial establishment of new plantings. When soil is low in organic matter, working in a thick stand of a cover crop or incorporating a good quality compost in the planting rows is recommended.

Lime, phosphorus, and potassium can be incorporated into the beds prior to trellis construction. See the section on Fertility for more information. Soil with a pH of 6.0 to 7.0 is ideal for hop production. The pH value in North Carolina soil is often lower than 6.0 and can be raised by lime application based on soil test results.

Positioning the hop yard to receive full sunlight throughout the day is important for hop plant growth and development especially for the short day lengths in North Carolina during the growing season. Sites with tall trees growing nearby should be avoided since that could shade the plants in the morning or late afternoon. In addition, morning sun is useful in evaporating dew and moisture from the leaf surface where mildew spores can be present.

Trellis Construction

Although there are many ways to construct a hop yard trellis, there are two commonly used systems.

- The simplest and least expensive is the **single strand trellis**. This consists of tall, sturdy posts topped with a single strand of wire strung tightly between them. This top wire is called the vine line. The strings the hop bines climb are attached to the vine line. A single row of plants is grown directly underneath the vine line. There can be a single string per plant or the plants can be trained to a V with both two strings per plant leading to the single wire. This simple system is commonly used by beginning hop farmers in non-traditional growing areas, such as North Carolina.
- In the major production areas in the PNW and Michigan, **high density V-trellises** are constructed. They are more expensive and complex, but they are also capable of supporting much more production than a single strand system. In this system the vine lines are supported by cross wires and the vine lines are attached to a double stranded bridle wire that runs along two opposite sides of the exterior of the hop yard. There are two vine wires per row of plants, with the plants in a row between the vine wires. The plants are trained to a V with one string trained to one vine wire and another string trained to the vine wire on the opposite side of the plant row.

More information on hop trellis design and construction can be found in this PowerPoint from the University of Vermont:
https://www.uvm.edu/sites/default/files/media/SSchmidt_Hop_Yard_Trellis_DesignV5.pdf and this one from Michigan State University:
https://www.canr.msu.edu/uploads/234/78941/Hop_Intro_-_2_Hopyard_Preplant_Preparation_and_Setup_-_Dan_Wiesen.pdf.

NC1601 will need a trellis with top wire that is 18 to 20 feet high. With a regular in-row planting spacing of 3.5 feet, NC1602 grown on a single top wire trellis may be difficult to harvest with a hop harvester because the longer side arms of NC1601 tend to get entangled with the adjacent bines and are difficult to separate. We experienced this in our hop yard in Mills River. Our trellis has a single top wire and the in-row spacing is 3.5 feet and 12 feet between rows (Figure 2 left). As shown in Figure 2 (middle), the adjacent NC1601 plants were entangled because of its longer side arms on a trellis with a single top wire. So, a V-trellis system (Figure 2 right) is recommended for commercial production of NC1601. With a V-trellis system, between-rows spacing should be about 14 feet. With the same in row spacing, a V-trellis can prevent adjacent bines from growing together as much and allow more sunlight penetration between strings.

Drip irrigation is usually installed when the trellis is constructed. See section on Irrigation for more information.

Figure 2. Hop trellises and NC1601 plants. Left: Single top wire trellis in Mills River, middle: adjacent bines of NC1601 plants grow together because of the longer side arms, and right: hop V=trellis double top wires in the Pacific Northwest (By A. Balet - Own work, CC BY 3.0, https://commons.wikimedia.org/w/index.php?curid=6301453).

Obtaining Planting Material and Planting

Three types of vegetative propagation materials are available for hops. These include rhizomes cut from established hop plants, rooted softwood cuttings, and micropropagated plants (from tissue culture). Because NC1601 is a new release covered by intellectual property rights, when it is commercially available, growers will need to purchase planting materials from a licensed nursery. Hop plants are susceptible to a number of viruses, viroids, and fungal diseases. Buy rhizomes and plants from a licensed and inspected nursery that have their propagation material tested regularly for these diseases. Consider buying from nurseries that purchase their foundation material from the National Clean Plant Network https://www.nationalcleanplantnetwork.org/.

Trellises should be in place before planting. In North Carolina, field transplanting can take place in April to May or in August. Rhizomes are planted in early spring. Rooted plants are set after all danger of frost has past. An in row spacing of 3.5 feet between plants is recommended for this variety.

Irrigation

Hop plants grow rapidly and require consistent and adequate access to water for good growth and yield. First-year plantings require frequent irrigation throughout the growing season. Hop yards with mature plants typically require 1-2 inches of water per week depending on soil type; this may need to be doubled during hot, dry periods. Hops are deep rooted and it is important to ensure the moisture is percolating deep into the soil. Consider using tensiometers placed at 6

and 12 inches deep to help monitor this. The most critical periods for water are when the plants first start to grow in early spring and again when flowers initiate through cone growth.

Drip irrigation is the preferred method of watering the hop yard, either using drip tape laid directly on the ground or tubing with emitters that is suspended 10-18 inches above the ground. It is important to minimize application of moisture on all the above ground parts of the hop plants to reduce disease pressure, therefore, the use of overhead sprinklers is not recommended. The most effective way to deliver water is with emitters leading directly to the crown of the plant.

Fertility and Fertilization

Before planting and every fall thereafter, collect and submit soil samples to the NC Department of Agriculture and Consumer Services (NCDA&CS) Agronomic Division. Soil sample submission forms, instructions, and information on how to understand your soil test report can be found online: https://www.ncagr.gov/divisions/agronomic-services/soil-testing. Your local cooperative extension agent can provide you with more information on this process.

Nitrogen (N)

The first-year hop yard with this variety requires 75-100 lbs of nitrogen per acre, increasing by year three to about 150 lbs per acre. Nitrogen can be applied in split applications, one in the spring after plant emergence and again in early summer (early to mid-June in Mills River) around the beginning of flowering. Nitrogen fertilization is generally not recommended for hops after flowering.

Phosphorous (P) and Potassium (K)

A soil test is important in determining P and K fertilization. Data generated in Oregon (https://extension.oregonstate.edu/catalog/pub/fg-79-hops-fertilizer-guide) suggests that when the soil test P is above 30 ppm, P fertilization is not recommended. For K fertilization, the soil test K should be below 200 ppm. Because North Carolina soils and environmental conditions are so very different from those in Oregon, following recommendations from the NCDA&CS soil-testing lab or your local state agronomist is highly recommended.

Micronutrients

Boron is often a limiting trace mineral in North Carolina soils. When a soil test indicates that boron level is 1.5 ppm or lower, boron should be applied at the rates recommended from the soil test. If excessive amounts of boron are applied, plant damage may occur.

Weed Management

It is important to have the planting rows (about 2 feet wide) clear of weeds that can compete with the hops and lower yields and possibly harbor downy mildew spores and other pests. For small-scale production, one method is lay silt fencing or woven polypropylene weed fabric on each side of the plant crowns. We do not recommend covering the area directly around the crown of the plants. We installed three-foot wide silt fencing along the length of the planting rows on both sides, and secured it in place with u-shaped landscape pins. The plant rows can be covered by double ground hardwood mulch to suppress weed growth. Weed suppression

between rows can be mowed grass or cover crops, such as clover. In major production areas, where the land is flat and soil erosion is not a concern, clean culture through cultivation and herbicides is used.

Bine Management

Cutting Back

NC1601 emerges in spring relatively later than most other commercial hop varieties. The plants typically emerge around April 10 in Mills River, about two weeks later than 'Cascade'. We remove the early shoots by cutting them all the way to the ground around April 25. If the plants have not been pruned by May 1st, skip doing it for that year and select shorter shoots to train. Pruning too late will reduce yields.

This cutting back (pruning) of the first shoots plays a role in producing more uniform shoot development, delaying flowering, and reducing pressure from some diseases, such as hop downy mildew. It is important to delay hop flowering in North Carolina because hop plants begin growing early in spring. Without cutting back, NC1601 can flower before the end of May in Mills River. With cutting back, NC1601 flowers around June 10th in Mills River. The recommended timing for hop to flower is about June 20. In the PNW, early season pruning, mechanically or chemically, is used mostly for reducing hop downy mildew and powdery mildew pressure in the growing season. The mechanical pruning method called crowning (crown pruning) is to remove a portion of the crown about 1 inch below soil surface, which includes the buds formed in the previous season and the new growth in the current season if the practice is conducted after emergence. First year plants should not be pruned.

Training

Hop is a vining plant that needs vertical support to grow upward and produce more yield. Training hops involves manually wrapping the bines around a string in a clockwise direction to encourage and guide vertical growth. Coir twine, made of coconut husks is the most widely used material for stringing hops due to its strength and durability. NC1601 is ready for training early to mid-May when the bines are at least 12 inches in length. Of the dozens of bines shooting up from the crown, three of the most uniform and vigorous ones are trained clockwise around the twine. The remaining bines are cut back to the ground. In Mills River, we either secure twine on the bottom wire used to suspend the irrigation line or staple it down into soil with M clips.

Stripping Leaves and Controlling New Growth

When plants reach about 4-6 feet tall, stripping the lower leaves from the three chosen bines begins and is continued until harvest time. This is also a good time to prune away additional shoots that emerge throughout the season and scout for disease and insect pests. This practice keeps the space just above the crown free of foliage and allows for good air circulation. Thick foliage close to the soil surface can harbor moisture for disease to flourish. As the bines grow taller, more leaves can be stripped from the base of each bine, up to three feet high off the ground. For small-scale production, this work can be done by hand, but it is labor intensive. In large commercial yards, this is done with herbicides.

Disease and Insect Management

Hop Downy Mildew

Hop downy mildew is caused by the fungal pathogen *Pseudoperonospora humuli* and is one of the most important diseases of hops in the US and other hop growing areas worldwide. Total yield loss can be caused by severe hop downy mildew damage. Hop downy mildew spores survive and sporulate in prolonged moist, warm environments and can overwinter as oospores and mycelium in the crown and buds of the plant. Leaf, stem, and cone surfaces must have moisture present for sporulation and infection to occur. The optimal temperature range for infection is 60-68° F with night temperatures no lower than 41° F. Leaf infection can occur in as little as 1.5 hours at optimal temperatures. All parts of the hop plant are susceptible to hop downy mildew. NC1601 is susceptible to hop downy mildew, but to which degree has not been evaluated. Field observations indicate that its level of susceptibility is comparable to the hop variety Zeus.

The presence of downy mildew on leaves appears interveinal (between the veins of the leaf), angular shaped, yellow lesions becoming brown and necrotic (Figure 3. left). The underside of the leaf has dark purple to black blotches containing the sporangium. Young infected shoots are termed “spikes” and harbor the downy mildew inoculum. Spikes are identified by discoloration, stunted growth, small down turned leaves, and reduced spacing between internodes (Figure 3. right).

Figure 3. Hop downy mildew infected hop leaves (left) and shoot spikes (right).

Downy Mildew Management

Regular scouting of the hop yard combined with forecasting for downy mildew is essential to take preventative measures. Mildews and other plant pests can develop resistance to chemicals that are routinely applied. It is essential to implement a spray program of fungicides with alternating modes of action. Additionally, full coverage of the foliage with the fungicide is essential to the efficacy of the product. All fungicides and other agrichemicals must be applied according to the label instructions. If growing organically, there are fewer products available for implementing an alternating spray schedule. There is a list of fungicides recommended for hop downy mildew

control with spray instructions in the Southeastern U.S. Vegetable Crop Handbook https://content.ces.ncsu.edu/southeastern-us-vegetable-crop-handbook.

Other diseases commonly found in hop yards include powdery mildew, Alternaria cone disorder, Verticillium wilt, Fusarium canker, viruses, and viroids. Information on these diseases and control can be found in the Field Guide for Integrated Pest Management in Hops https://www.canr.msu.edu/uploads/234/71503/hop_field_guide_third_edition.pdf. We have not observed these diseases in our hops in Mills River.

Insect Pests

Insect pests such as Japanese beetle, two-spotted spider mites, aphids, and leafhoppers can sometimes do serious damage to hop plants. In Mills River, we have observed Japanese beetle damage to NC1601 plants. We have not noticed damage by other insects to NC1601 in our Mills River hop yards.

For comprehensive hop disease and insect management, it is recommended to consult The Field Guide for Integrated Pest Management in Hops https://www.canr.msu.edu/uploads/234/71503/hop_field_guide_third_edition.pdf. and the Southeastern U.S. Vegetable Crop Handbook https://content.ces.ncsu.edu/southeastern-us-vegetable-crop-handbook.

Harvest and Post-harvest Handling

Determining Cone Maturity

Moisture content in the cones is often used to determine the time for hop harvest. As hop cones mature, their moisture content declines. A moisture content between 75% and 80% (dry matter between 20% and 25%) is considered the optimum time for harvest. It typically takes 4 to 7 days for dry matter to increase one percent during mature time. This allows a time window for harvesting. Harvest of NC1601 in Mills River is typically between early August and early September.

Subjectively, hop harvest time can be determined by observing, feeling, and touching. Mature hop cones will feel papery to the touch and not regain their cone shape so quickly when squeezed. Under-mature cones will be spongy and resilient, staying true to form after being squeezed. Upon opening the cone, the internal lupulin glands at the mature stage should be bright yellow and sticky.

Harvest

In hop harvest season, the hop growing industry in the PNW has the equipment to mechanically harvest thousands of acres of hop bines. Large stationary hop harvesters then remove the hop cones from the bines.

We hand harvest our research plots. In our hop yard in Mills River, we can lower and raise the top wire of hop trellis by using a winch to facilitate hop harvest, and then harvest each cone by

hand. This is very, very labor intensive and would not be economically feasible on any scale. We also have a portable hop harvester (by HopsHarvester https://hopsharvester.com/) powered by the tractor PTO may be used to facilitate harvest of NC1601 (Figure 4). We still cut the bines off in the hop yard manually, but then feed them through this small harvester to separate the cones from the bines. For large hop yards, the bines can still be cut manually but a large, stationary harvester to separate the bines from the cones, such as a Wolf Hop Harvester https://wolfharvester.com/wolf-hop-harvesters/ may be employed. Used hop harvesters are often available for sale in the US.

Figure 4. A portable hop harvester by HopsHarvester.

Wet Hops

Some breweries may use wet hops to brew beer. To prevent oxidation of the lupulin, wet hops should be used as soon as the cones have been harvested. In the case that wet hops cannot be used sooner, they should be stored in a cooler for not more than 48 hours.

Drying Hops

To maintain the quality of the essential oils and other chemicals that are required for beer quality, hop cones should be dried immediately after harvest to reduce the moisture content to 8%-10%. Temperature for drying hops should not exceed 140° F. In hop production regions in the PNW, oast houses or hop kilns are used to dry large quantities. Dried hops are often pelletized or baled in large-scale production. This video (https://www.youtube.com/watch?v=052zE_vTkUA) from YouTube demonstrates large-scale hop harvest, drying, and baling processing.

For research, we use a small drier with shelves and forced hot air (Figure 5) to dry our hops. After harvest, we immediately deliver the cones to the drier set at about 130° F for 10 to 24 hours depending on the size of load.

Figure 5. A small hop drier with shelves and forced hot air. Front (left) and back (right). Plans for this drier can be found at https://newcropsorganics.ces.ncsu.edu/wp-content/uploads/2016/11/herb_dryer_leaflet-1.pdf?fwd=no

Dried hops should be properly stored for optimum quality preservation because hops oxidize quickly. It is recommended that hops be stored under freezing temperature (30 to -5° F) and away from exposure to air. For small quantities, dried hops can be vacuum-sealed and stored in the freezer chamber of a refrigerator.

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