University of Kentucky
College of Agriculture, Food and Environment
Cooperative Extension Service

Center for Crop Diversification System Profile
CCD-SP-2, CCD-CPA-SP-1

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High Tunnel Overview

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Introduction

High tunnels, also known as hoop houses, are relatively simple polyethylene-covered greenhouse-like structures that are passively heated and cooled. Crops grown in high tunnels are usually grown directly in the soil. High tunnels can be used to extend the production season and marketing window of a wide variety of crops beyond what is possible in open field production. In general, high tunnels allow a grower to plant warm-season crops three weeks earlier in the spring than they can plant in the field, and extend the season about four weeks in the fall. The season for cool-season crops may be extended even further, with potential opportunities for year-round production. High tunnels tend to be passively heated and cooled, but many growers install fans and heaters in the structures. They have been used in Kentucky and Tennessee to produce early and late-season vegetables, leafy greens, herbs, cut flowers, brambles and strawberries. Well-vented high tunnels covered with shade cloth can be used to grow some cool-season crops later into early summer.

Photo by Christy Cassady, UK Center for Crop Diversification

High tunnels at the University of Tennessee's Organic Research Farm/ Organic Crops Unit near Knoxville.

In addition to the potential for season extension and off-season production, high tunnels afford a number of other advantages. They provide protection from unfavorable weather conditions, including wind, hail, frost and excessive rainfall. This can help improve the survival rate of perennial crops, as well as result in faster plant growth, higher yields, improved produce quality, fewer culls and more marketable produce for many crops. Insect and disease problems are often less severe in a high tunnel; fewer pests can mean improved organic production potential. High tunnels also provide a sheltered environment for laborers during planting, production and harvest operations.

Between 2012 and 2020, more than 1,200 high tunnels, with over 2.8 million square feet of production capacity, were installed in Kentucky through the USDA Natural Resources Conservation Service (NRCS) Environmental Quality Incentives Program (EQIP) High Tunnel System Initiative.[3] Since 2016, 320 high tunnels have been or are in the process of being installed in Tennessee through the EQIP High Tunnel System Initiative. These tunnels total

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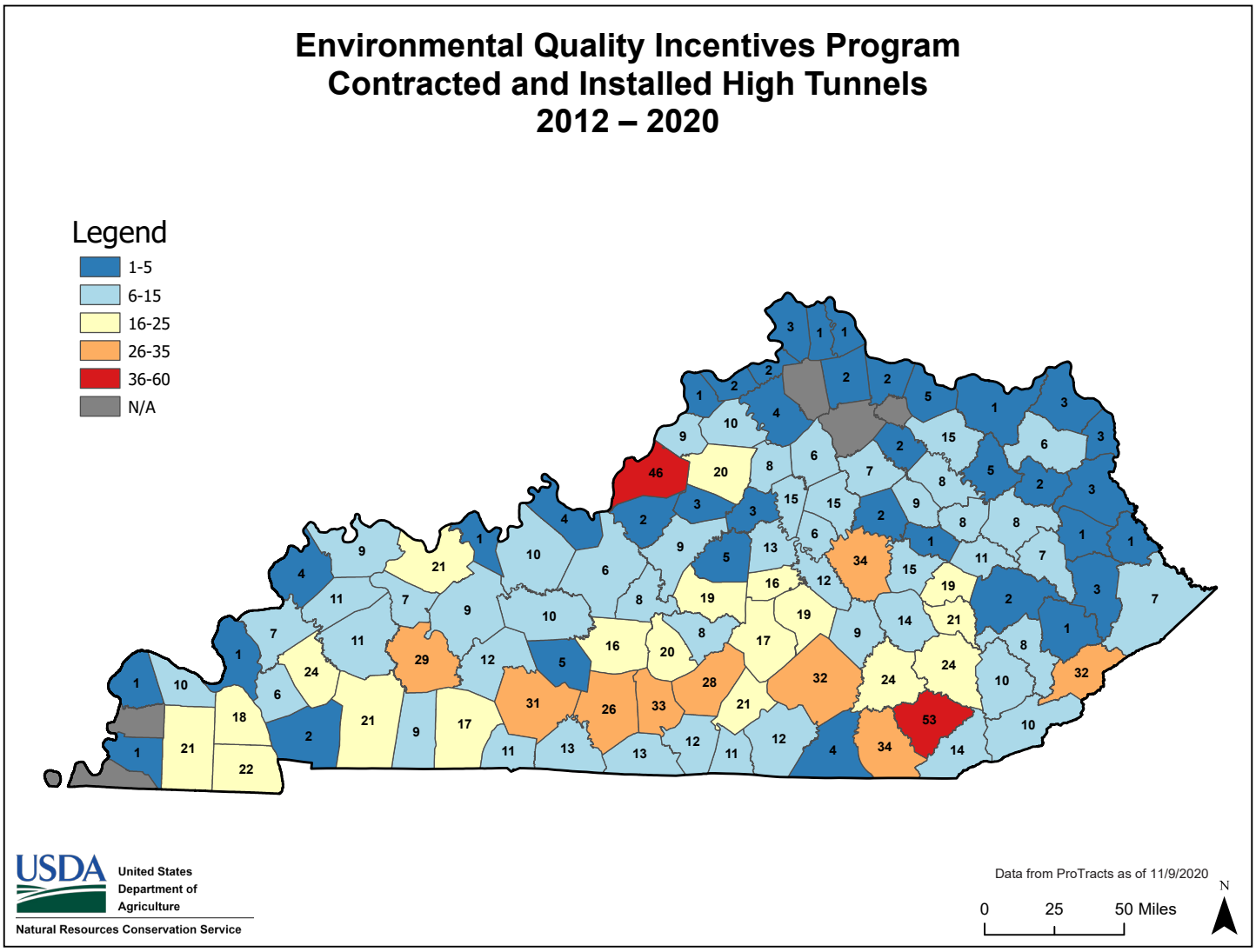
[3]High Tunnel Production and Marketing Survey: Data Summary (CCD-SP-17), University of Kentucky, 2020



Data and figure courtesy of Kentucky NRCS State Office

642,584 square feet. An additional 101 tunnels totaling 264,800 square feet are tentatively scheduled to be built in Tennessee. See **Pages 11 and 12** for maps indicating the locations of these tunnels.[4] Please note that high tunnels were installed in Kentucky and Tennessee before the EQIP High Tunnel System Initiative began, and many growers still build tunnels without utilizing NRCS financial assistance. Thus these numbers represent only part of high tunnel production taking place in both states.

Marketing and Market Outlook

High tunnels can allow producers to extend the time period over which cash flows are generated from specialty crops. Crops of exceptional quality harvested before traditional open field production has started or after it has ended will bring maximum returns. This extended harvest season should provide high tunnel growers with a marketing advantage. Higher yields of marketable produce per plant or per square foot, compared to field-grown production, are key to high tunnel profitability. High tunnel profitability is very sensitive to price. Crops grown in high tunnels should bring premium prices to sustain profitable high tunnel production.

Early crops can attract customers to a farm enterprise early in the season, giving growers an opportunity to retain those customers throughout the season. Growers need to be aware of other high tunnel production locally, as demand can vary greatly from one area to another. Simple marketing plans can help growers identify the nuances of their local markets and adjust planning and production accordingly.

The costs involved in building and maintaining a high tunnel make this production system more expensive than open field production. Growers can defray these

[4]Due to variability in starting dates for the EQIP High Tunnel System Initiative in KY and TN, as well as variations in mapping between states, some information included here represents different windows of time. We chose to include these for comparison and context, but please note the difference in years reported.

costs by seeking premium prices for out-of-season high tunnel crops, especially if high quality and steady supply are maintained. High tunnels may make it possible for some growers to produce crops they would not otherwise be able to grow in open, unprotected field situations, thus providing additional revenue. Obtaining organic or Certified Naturally Grown certification is another option for adding value to crops grown in a high tunnel and recouping the investment in the structure.

There are a number of marketing options for high tunnel crops. These include:

Direct markets
- On-farm retail markets
- Roadside stands
- Farmers markets
- Community supported agriculture (CSA)
- Internet sales

Local wholesale markets
- Restaurants
- Grocery stores
- Farm to School/institution

Wholesale markets
- Regional wholesalers
- Food brokers
- Produce auctions

Growers who typically sell at farmers markets and use high tunnels to extend their season into fall and winter, when many farmers markets are not open or have limited hours, could generate a subscription list and establish a pickup location or delivery service for their high tunnel crops. Options for notifying customers of product availability and order deadlines include social media and/or an email distribution list. There are a number of options for growers to set up simple online stores for accepting orders and payments. Other options include taking orders by email or phone.

Tunnel Construction

Types of Tunnels

High tunnel establishment and labor costs may vary greatly between farms and regions. Tunnel design, dimensions and construction materials all have an impact on the structure's use and performance. Before building or purchasing any tunnel, it is important to plan ahead to make sure the selected design and size will meet the grower's immediate and future needs. Metal or wood can be used for the structure; metal costs more than wood but lasts longer. Well-constructed, properly maintained tunnels can last for 20 years.

Tunnels are often categorized by the shape of their roofs. The two main types are quonset and gothic.

QUONSET tunnels have a rounded roof that generally extends from "ground to ground," giving the structure a semi-circular shape. Quonsets are among the simplest and least expensive tunnels to construct.The tunnel height along the sidewalls, however, limits the types of crops that can be grown in that space. Alternately, the hooped roof may be set on straight sidewalls to increase the vertical growing space along the outer walls. The rounded roof of the quonset tunnel does not shed snow readily, making them more likely to suffer damage from a heavy snow load. Spacing the hoops at closer intervals and/or bracing the bows with cross braces are ways to strengthen the structure. Another alternative is to remove the plastic covering during the winter, at least when significant snowfall is expected. Tunnels constructed from PVC pipe are particularly vulnerable to collapse from snow. Quonset style tunnels may be either single bay or multi-bay. The Haygrove tunnel is an example of a multi-bay, three-season tunnel that can be used to cover larger acreages.

GOTHIC style tunnels have a peaked roof and straight sidewalls. The steeper roof sheds snow and ice more readily than the rounded roof of a quonset tunnel. Additionally, condensing moisture within the tunnel tends to run down the sloping roof to the sides, rather than dripping on the plants below. The straight sides provide more usable growing space along the outer walls than the typical rounded quonset. In addition, the greater height of the gothic tunnel permits the production of taller crops. This height also helps increase air circulation, especially when vents are installed at the gable-ends. Gothic style tunnels are built only as single bay structures.

Endwalls

Endwalls can vary considerably in their design. They may be framed with wood or metal, or they may simply have an unframed plastic curtain that can be rolled up or pulled back. Framed endwalls, which add strength and stability to the high tunnel, are constructed after the tunnel itself is assembled. Fixed endwalls may have just a single or double storm door/

Types of High Tunnels

The two main types of tunnels based on roof shape are gothic (A and B) and quonset (C). Although quonset style tunnels are the least expensive, gothic styles offer several advantages: 1) the straight sides offer more growing space on both sides of the tunnel and facilitate weed management; 2) the additional height allows space for taller crops and offers greater air circulation; 3) condensation runs down the angled roof to the sidewalls, preventing it from dripping on crops; and 4) the slanted roof allows snow and ice to run off the tunnel more readily than does the rounded roof of a quonset tunnel. Quonset tunnels can be set on straight sidewalls to increase the amount of growing space available. Quonset tunnels can be set up as either single bay or multibay, such as a Haygrove tunnel (D).

Movable tunnels (E) can be relocated to a new site each growing season to facilitate crop rotation and to prevent buildup of salts in the soil. A roller and rail moving system or a ski system makes them easier to move.

Photos by David Stalion, UK Ag Communications (screen shots from video, A & E); Steve Patton, UK Ag Communications (B); USDA-NRCS (C); and Mark Williams, UK Horticulture Department Chair (D).

screen door built into one or both ends for worker access. Some framed endwalls have a large rectangular section hinged at the top so that the endwall can be opened. These may completely swing open or fold up accordion style. Others have sliding doors or removable panels. Tunnels in which a large portion of the endwall can be opened or removed not only have better ventilation, but also afford easier access for equipment. Gable end vents installed near the peak of gothic style tunnels offer additional air exchange. The choice of endwall design will depend largely on tunnel size, grower needs, construction costs and personal preference.

Sidewalls

High tunnel sidewalls, also called side curtains, are usually 4 to 8 feet high, and at least 6 feet is recommended. Higher sidewalls offer better ventilation. Sidewalls may be either roll-up or drop-down. Roll-up plastic sidewalls introduce cool air at the ground level of the tunnel and may allow wildlife access. Drop-down sidewalls introduce cool air near the top of the curtain, allowing its temperature to moderate

A sliding door on the endwall of a gothic high tunnel.

Screen shot from video by David Stalion, UK Ag Communications

as it mixes with warm air before reaching the plants at ground level, and can act as a barrier to wildlife entry. Curtains may be raised and lowered with a hand crank or a motor can be installed; the latter is especially helpful for longer tunnels.

Tunnel size

There are a number of factors that should be considered when deciding on the size of the high tunnel. Obviously, the tunnel should be tall enough for workers to walk into comfortably. The size and height of any necessary equipment and machinery should be considered when determining how tall the tunnel needs to be. The amount of maximum vertical space required for the various crops that will be grown in the tunnel is another determining factor for tunnel height. Adequate square footage should be available for planting, producing and harvesting the various crops, as well as for maneuvering small tractors or any other equipment that will be used in the tunnel. Typical tunnels are 9 to 15 feet tall, 15 to 30 feet wide, and 60 to 96 feet long.

Size will also affect the environment within the tunnel, especially heat retention and air movement. For example, while narrow tunnels are easier to ventilate than wider ones, narrow tunnels also experience more heat loss on cold nights. Long tunnels are more difficult to ventilate, especially if they are wide. Tall, wide houses typically retain heat in winter better than short, narrow tunnels.

Movable vs. Permanent

The high tunnel concept seems to suggest mobility; however, tunnels are often built in such a way that they are difficult to move without considerable effort. As a result, they often remain on the same site for a number of years before being moved to another location (semi-permanent) while others are never moved (permanent).

Typically, permanent/semi-permanent structures have in-ground posts, galvanized steel bows, and rot resistant wood baseboards. Endwalls can be constructed of steel or wood. When tunnels are not moved each year, the grower will need to implement a good crop rotation program as well as a consistent soil testing program. Tunnels that remain in the same location year after year, where either no rotation or a short rotation is practiced, can have high levels of soil pathogens and insect pests, leading to serious crop losses. Fertilizer salt build-up will become a problem unless the plastic covering is removed to allow precipitation to flush salts from the soil. Once in place, soil preparation in these tunnels each year can present a challenge. Hinged endwalls permit easier access for small equipment. When the endwalls are fixed, soil preparation will need to be accomplished by hand or with a small power tiller.

Movable tunnels may be built with PVC bows, which not only makes them lighter, but cheaper to construct. Only quonset style tunnels can be built from PVC. Tunnels built with steel bows but without in-ground

Moving a high tunnel using castors (inset) that roll along a galvanized round pipe below them.

Screen shots from video by David Stalion, UK Ag Communications

posts are easier to move; however, tunnels that sit on top of the ground will be more vulnerable to wind damage unless they are well-anchored. Another way to make the tunnel more mobile is to build it on skids or runners. An important advantage to movable high tunnels is the ability to relocate them to a new site each growing season to facilitate crop rotation. The soil in movable tunnels is worked prior to erecting the structure.

University of Kentucky researchers are experimenting with a low-cost movable tunnel design that can be quickly disassembled and moved to a new site. The PVC bows are fitted over pieces of steel pipe that have been driven into the ground. Tunnels are constructed over already formed beds, making it possible to use traditional tractors and transplanters prior to constructing the tunnel.

Covering

One or two layers of greenhouse-grade polyethylene (4 to 6 mil) are used as the covering. Those covered with two sheets have an air layer in between, thus offering better insulation and more cold protection. Two layers will typically require an inflation fan, which requires access to electricity or installation of a solar system for power. Occasionally growers will insert Styrofoam blocks between the layers of plastic to keep them separated if they do not have electricity to their tunnels. While the second layer of plastic does offer greater heat retention, it also reduces light penetration into the tunnel. A second layer is not necessary in much of Tennessee. Low tunnels or floating row covers can be used within the high tunnel for additional cold protection for tunnels with a single layer of plastic.

Screen shot from video by David Stalion, UK Ag Communications

Row covers are used inside high tunnels to provide additional protection from cold and frost. Hoops are used to prevent leaves from freezing to the fabric.

The cover should be installed in warm, not hot, weather so the plastic will stretch over the frame properly; late spring or early fall are best. Anti-condensate film can be used to prevent condensation from dripping on plants. Additionally, an infrared re-radiate material (infrared blocker) added to the film absorbs and re-radiates heat down to the crop in the evening. As the plastic ages, the amount of light transmitted through it will be reduced. The plastic covering should be replaced approximately every four to five years.

An inflation fan creats a layer of air between two layers of plastic, which provides more protection from cold weather in a high tunnel.

Screen shot from video by David Stalion, UK Ag Communications

To avoid heat-related crop damage during very warm, sunny days, the frame can be covered with shade cloth, which is made from woven fabric or plastic. The shade cloth, which is used either alone or on top of the polyethylene, reduces light intensity and air temperature within the tunnel. The combination of shade and irrigation also keeps soils cooler. Shade cloth can help lessen the frequency of abiotic disorders such as blossom end rot, sunscald and cracking.

Trellising

Some crops grown in a high tunnel may require trellising. Unless the frame has been reinforced to support the heavy load of fruit-laden plants, trellising to the tunnel roof is discouraged. An overhead bracing system can be used to suspend lines for plant support, or a separate trellis system can be constructed inside the high tunnel if needed.

Site selection and orientation

Tunnel location and orientation, in addition to the site soil conditions, are essential to production success. Site selection is more critical when the high tunnel is built to be a permanent structure; however, it is an important consideration even when constructing semi-permanent or movable tunnels.

Select a well-drained site in full sun that is near a reliable water supply for irrigation. Access to electricity may also be needed for fans and supplemental lighing. A level surface is generally needed for the high tunnel frame. An exception is the multi-bay Haygrove tunnel, which does not require a level site. Avoid hilltops or other areas subject to high wind. Providing a windbreak can help reduce the threat of wind damage to the tunnel. On the other hand, the site should have good airflow for ventilation. Stay away from low sites that are poorly drained or likely to serve as frost pockets, as well as sites too close to wooded areas. Orienting the house perpendicular to the prevailing wind on the farm will help facilitate cross ventilation in the tunnel. But it is best to orient the tunnel parallel to prevailing winds on sites where strong winds are a concern, which allows winds to hit the doors, not the sides, as the latter can damage the frame. On sites with high winds, it is best to set the ground posts in concrete.

For maximum sun exposure during the fall and winter, the tunnel's ends should be oriented east-west, which allows for more light overall. However, a north-south

Screen shot from video by David Stalion, UK Ag Communications

Sidewalls can be rolled up to provide ventilation.

orientation allows for more uniform light distribution. If you are building multiple tunnels, make sure that they do not shade one another. **When choosing between an orientation that is preferable for protection from the wind and one that is optimal for sunlight, orient for wind protection.**

Place the tunnel on ground that is slightly higher than the surrounding area to prevent water from flowing into the tunnel during heavy rains. It is important to have the ground slope away from the base boards on the outside of the sidewalls. Guttering can be placed on the outside of the tunnel to collect rainwater or direct rainwater away from the tunnel. As a last resort, dig a shallow trench along the outside perimeter to keep water from entering the tunnel.

The floor of the tunnel should be level to prevent uneven growth of crops due to water and fertilizer flowing to a low spot. Grading or deep tillage should be done before construction of the tunnel begins.

Tunnel Management

Temperature and ventilation

High tunnels are passively solar-heated, and nighttime low temperatures may drop to the outside temperature. Row covers used in conjunction with the high tunnel will provide additional cold and frost protection. Because row covers also block sunlight, they should not be left on for prolonged periods during the winter. Placing the row covers over hoops will help to keep tender leaves from freezing to the fabric. As an alternative, a heater can be used when unexpected drops in temperature occur. The type of heater is important, and improperly vented heaters can release air pollutants that can damage the crop and leave residues

on the plastic. Due to rising energy costs, the use of heaters should be limited to short durations. Such additions should be included in the tunnel manufacturer's design and recommendations. A grower who has received NRCS EQIP funds to purchase a high tunnel should check his/her state's NRCS High Tunnel System Conservation Practice Standard to make sure heaters are allowed. NRCS allows the permanent installation of heaters in Kentucky.

High tunnel temperatures cannot be regulated exactly because the tunnel environment is determined by the presence (or absence) of sun for heat and wind for cooling and ventiliation. Temperatures can be manipulated by adjusting the sidewalls as needed. The sidewalls can be left closed in early spring, but may need to be opened as daytime temperatures rise. However, once warmer weather arrives, the sidewalls should be left open. This is generally done manually; however, automatic systems are also available. Removing or opening the endwalls is another way to increase ventilation. During sunny days, temperatures in the tunnels can reach 30 degrees F to 40 degrees F higher than outside temperatures, necessitating that tunnels be adequately vented. Improperly ventilated tunnels will overheat quickly.

Irrigation

Because tunnels prevent natural rainfall from reaching plants, drip irrigation is essential. The irrigation system can also be used to provide fertilization during the season. Iowa State University has developed a system for catching, storing and reusing rainwater run-off for irrigation in a high tunnel. Although it is best to install this system when the high tunnel is built, it can be added to an existing tunnel. To learn more, visit https://store.extension.iastate.edu/product/Rainwater-Catchment-from-a-High-Tunnel-for-Irrigation-Use. Growers must be aware that rainwater catchment in tunnels can pose a food safety risk if the water is not treated, either with a UV filter or properly labeled chemical.

Growers should consider four or more lines of irrigation per bed, even if it is only a single row of crop, as this ensures that the entire bed gets properly wetted and helps prevent salt build-up in the tunnel. Emitter spacing of 8 to 12 inches will work for most transplanted crops, while 4-inch spacing is helpful for crops with long germination times, such as carrots, on well-drained soils. Growers should note that it is much easier to reuse tape in a high tunnel than in the field.

Screen shot from video by David Stalion, UK Ag Communications

High tunnel production requires a much greater investment than growing crops in the field.

Pollination within the tunnel

Pollination may present a challenge for some plants grown in a high tunnel. Honeybees do not effectively pollinate crops in this production system since they require UV light to navigate and often become disoriented under the plastic covering. High tunnel growers may need supplemental bumblebee hives if they do not observe sufficient natural pollinator activity within the tunnel. Reportedly, mason bees and alfalfa leaf cutter bees may be used as a supplemental source of pollination.

Pollination of tunnel-produced self-pollinating crops, such as tomatoes, is not adversely affected as long as there is good air movement through the structure. If the tunnel sidewalls need to be kept down for extended periods of time, it may be necessary to promote pollination by vibrating plants, by tapping the crop support system (i.e. stakes or cages), or by using a leaf blower. However, many high tunnel tomato growers utilize bumblebee hives, which are replaced every four to six weeks, to ensure adequate fruit set and yield.

Pest management

Diseases that plague field-grown crops are often less of a threat in high tunnels. However, because of the unique environment within tunnels, growers may encounter different diseases than in the field. Because the tunnel excludes rainfall, the foliage tends to stay dry, resulting in fewer foliar disease problems due to those pathogens spread by rain splash or requiring leaf-wetness for infection. In contrast, powdery mildew and rust diseases, which require high humidity for infection, but not leaf wetness, could become a problem in a tunnel environment.

Insect pests in tunnels differ as well. While the high tunnel presents a barrier to some insects, it is an ideal environment for others, particularly whiteflies and aphids. Mite infestations often become a more seri-

ous problem in a tunnel than in the open field due to the drier tunnel environment. Grasshopper feeding has been known to occur throughout the winter on crops, such as greens, since the ground within the tunnel does not freeze. Without natural predators, such as birds, to help keep insects in check, serious pest infestations may develop very quickly.

Photo by Matt Barton, UK Ag Communications
Harvest labor varies widely among crops.

Due to the relatively high density of plants in tunnels, insects and diseases tend to spread rapidly. Frequent scouting to monitor populations is essential for keeping ahead of potential problems. Pesticides registered for open field production may not be registered for use in the enclosed space of the high tunnel. It is important to always read the label of any product in order to ensure that it is permitted to be used in a high tunnel. In Kentucky, a greenhouse and a high tunnel are considered the same regarding pesticide applications. If the label indicates that a product is not permitted in a greenhouse, it is also not permitted in a high tunnel in Kentucky. In Tennessee, any product can be used in a greenhouse as long as the label doesn't state that it cannot be used in a greenhouse, and a high tunnel is considered a greenhouse.

Weed management prior to tunnel construction is important. Avoid building the tunnel on sites with perennial weeds or high noxious weed populations. Other pre-plant strategies include tillage, crop rotations designed to reduce weed pressure, and weed suppression via cover or smother crops. Once the tunnel is built, plastic or organic mulch can be used to suppress weeds within rows and along tunnel edges. Rototillers and/or hand weeding are used for managing weeds within the tunnel. Having a vegetation-free strip around the outside of the tunnel helps prevent weeds or grass from entering the tunnel from outside.

Tunnels with covers left in place throughout the winter will experience increased rodent activity when these animals discover the warm, sheltering environment that the tunnel provides. Traps can help control rodent populations, and bait stations outside the tunnel, where legally allowed, will also help. Be sure not to use snap traps or bait stations inside the tunnel, as these can pose a food safety risk. Occasionally rabbits, raccoons, groundhogs and deer will also find their way inside a tunnel to feed on the crops when the sides or ends are left open.

Harvest

The protection offered by the tunnel means that crops can be harvested regardless of the weather. Not only are harvesters protected from the elements, but they also do not have to contend with muddy fields or wet produce.

Labor requirements

Labor requirements for establishing high tunnels vary considerably by high tunnel type and system, operator experience, and the useful life of the plastic covering. Average construction times for unheated quonset-style high tunnels of 2,000 to 2,500 square feet range from 65 to 100 hours. Labor times for erecting heated or larger tunnels can move toward 150 hours. Time needed for site preparation, and the amount of time needed for replacing shorter-lived coverings, can greatly impact labor requirements.

Economic Considerations

High tunnels are a relatively inexpensive way to extend the growing season. Excluding labor, the approximate cost of a less permanent high tunnel is $1.30 to $1.50 per square foot. More permanent structures are likely to fall in the $2.50 per square foot range, and high tunnels constructed from kits may cost even more per square foot. Site preparation and the desired level of systems investment for ventilation and heating can increase high tunnel establishment costs. Compared to a traditional production-ready greenhouse, high tunnel structures are not as difficult to construct and require less capital investment per square foot. Greenhouses may be taxed differently than high tunnels as well. High tunnel production, however, does represent a much greater investment than growing produce in the field.

EQIP High Tunnel System Initiative

The USDA-NRCS EQIP High Tunnel System Initiative offers financial and technical assistance to growers interested in pursuing high tunnel crop production. In fiscal year 2021, participant financial assistance

in Kentucky ranged from $2.55 to $3.80 per square foot. For details on the EQIP High Tunnel System Initiative in Kentucky, click here. For fiscal year 2021 in Tennessee, participant financial assistance ranged from $2.62 to $3.14 per square foot. For details on the program in Tennessee, click here. You may contact your local NRCS service center to learn more about the High Tunnel System Initiative, including current financial assistance rates and how to submit an application, by clicking here.

Selected Resources

- The Agriculture Building and Equipment Plan List - Greenhouse Plans (University of Tennessee) http://web.utk.edu/~ggrandle/Programs/PlanList97.htm#Greenhouse%20Plans
- High Tunnels (University of Tennessee video) https://ag.tennessee.edu/news/VideoReleases/Pages/High-Tunnels.aspx
- High Tunnel Strawberry Production in Tennessee (University of Tennessee, 2013) https://extension.tennessee.edu/publications/Documents/SP754-A.pdf
- Year-Round Production: See the Light at the End of the (High and Low) Tunnel (University of Tennessee) http://www.organics.tennessee.edu/pdf/Yearroundproduction_alw.pdf
- The Tennessee Vegetable Garden Season Extension Methods (University of Tennessee, 2016) https://extension.tennessee.edu/MasterGardener/Documents/W346-F.pdf
- North Carolina State Growing Small Farms Season Extension (N.C. State Extension) https://growingsmallfarms.ces.ncsu.edu/growingsmallfarms-seasonextension/
- Rainwater Catchment from a High Tunnel for Irrigation Use (Iowa State University, 2012) https://store.extension.iastate.edu/product/Rainwater-Catchment-from-a-High-Tunnel-for-Irrigation-Use
- High Tunnel Manual (Penn State University, 2003) https://extension.psu.edu/high-tunnel-manual
- Cornell High Tunnels (Cornell University) https://blogs.cornell.edu/hightunnels/
- Alternative Cropping Systems for High Tunnels (Penn State University, 2015) https://extension.psu.edu/alternative-cropping-systems-for-high-tunnels
- Small-scale Field Grown and Season Extension Budgets (Penn State University, 2020) https://extension.psu.edu/small-scale-field-grown-and-season-extension-budgets
- High Tunnel Lettuce Variety Trial, Fall 2014 (University of Tennessee) https://www.cefs.ncsu.edu/ncgt/Eastern-TN-High-Tunnel-Organic-Trials-FINAL.pdf
- High Tunnel Production and Marketing Survey: Data Summary (CCD-SP-17) https://www.uky.edu/ccd/sites/www.uky.edu.ccd/files/HTsurvey.pdf
- Covers Under Cover: Managing Cover Crops in High Tunnels (CCD-SP-16) https://www.uky.edu/ccd/sites/www.uky.edu.ccd/files/CoversUnderCover1.pdf
- Cool-Season Cover Crops for High Tunnels in the Southeast (CCD-SP-18) https://www.uky.edu/ccd/sites/www.uky.edu.ccd/files/cool-season_covercrops.pdf
- Warm-Season Cover Crops for High Tunnels in the Southeast (CCD-SP-19) https://www.uky.edu/ccd/sites/www.uky.edu.ccd/files/warm-season_covercrops.pdf
- Cover Crops Under Cover (PowerPoint presentation) https://ag.purdue.edu/hla/fruitveg/Presentations/02Cover%20Crops%20Under%20Cover_Annette%20Wszelaki_February%2012,%202019.pdf
- Movable High Tunnels (University of Kentucky video) https://www.youtube.com/watch?v=-GZ_p5cP96E&t=148s
- Monitoring Energy Balance and Airflow Characteristics in a Naturally Ventilated High Tunnel (Transactions of the American Society of Agricultural and Biological Engineers (ASABE) 60(5): 1683-1697. (doi: 10.13031/trans.12080) @2017) https://elibrary.asabe.org/abstract.asp?aid=48478&t=1&redir=&redirType=

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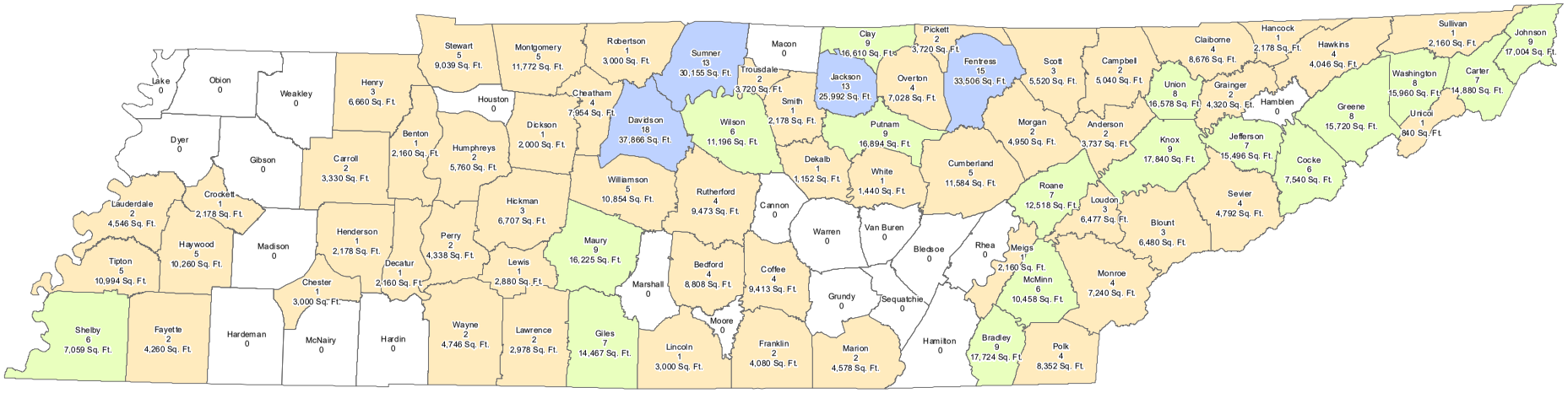
Photos courtesy of Christy Cassady, UK Center for Crop Diversification; David Stalion, Steve Patton and Matt Barton, UK Ag Communications; USDA-NRCS; and Mark Williams, UK Horticulture Department Chair **Aug. 2021**

High Tunnel Systems - Applied In Tennessee (2016-2021)



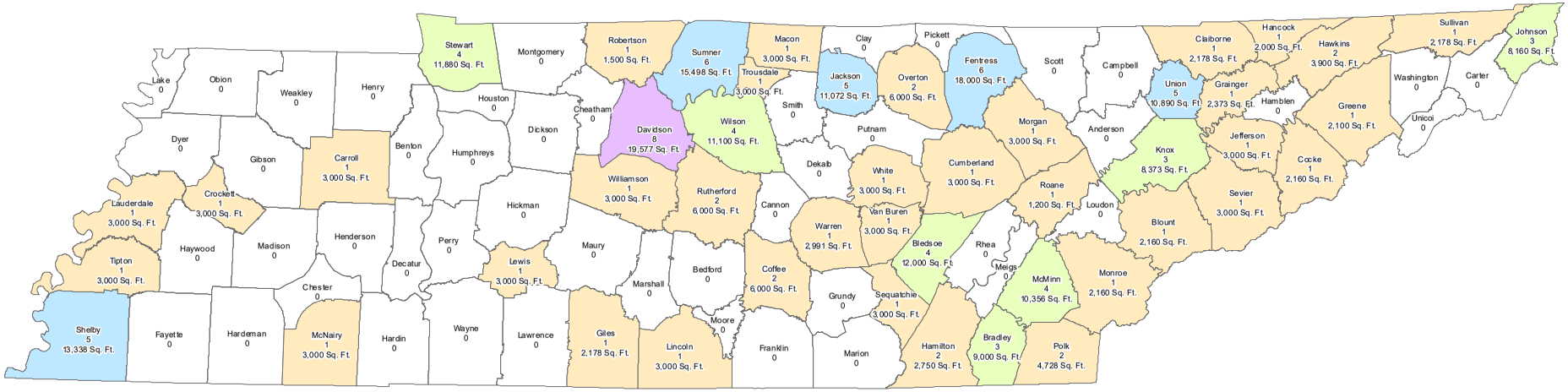
1st No. = High Tunnels Systems - Number Applied
2nd No. = High Tunnel Systems - Sq. Ft. Applied

High Tunnel Systems Number Applied By County

- 0
- 1 - 5
- 6 - 10
- > 10

Source: USDA-NRCS - Intergrated Data for Enterprise Analysis
Practice Summary Report (5/1/2021)

High Tunnel Systems - Planned In Tennessee



1st No. = High Tunnels Systems - Number Planned
2nd No. = High Tunnel Systems - Sq. Ft. Planned

High Tunnel Systems Number Planned By County

- 0
- 1 - 2
- 3 - 4
- 5 - 6
- >6

Source: USDA-NRCS - Intergrated Data for Enterprise Analysis
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