UK COOPERATIVE EXTENSION SERVICE
UNIVERSITY OF KENTUCKY — COLLEGE OF AGRICULTURE

Greenhouses and Similar Structures

An Overview

Introduction

Thanks to the pioneering work of Dr. Emery Emmert, "The Father of the Plastic Greenhouse," at the University of Kentucky in the late 1940s and early 1950s, the types of greenhouses available today have become much more diverse. While the traditional glass greenhouse is still with us, we now have many alternative types of structures that can effectively extend the growing season. These range from very simple greenhouse-like structures (low tunnels) to unheated field greenhouses (high tunnels) to traditional heated greenhouses, which can be built to form complexes of 40 acres in size or more.

A greenhouse is a "tool" that can be used to facilitate the growing of plants. Generally, the tool is fitted for the job, and not the other way around. Growers need to determine what plants will be produced before making a decision about the type of greenhouse needed to accomplish the job. Depending on the crops to be grown, a conventional greenhouse may not even be needed. Instead, a simpler structure could more economically extend the growing season into spring and fall. For example, if the primary target is an early start date for farmers markets, row covers or a high tunnel may be quite adequate to handle the job.

Low tunnels covered (top) and uncovered (bottom). Note the supporting hoop at the arrow.

Types of Greenhouse Structures

Low tunnels

Low tunnels are wire or PVC hoops covered with clear plastic or row covers. They are often used in conjunction with black plastic mulch and drip irrigation. The covers are generally in place for only three or four weeks and then removed. Covers protecting bee-pollinated crops should be removed when the first female flowers appear. Besides providing an excellent means of extending the growing season, low tunnels also offer wind protection.

Once hoops are set, the plastic cover is applied with the plastic's edges secured by burying in the soil.

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Modifications have been made on this basic design to allow for daytime ventilation when temperatures within the plastic begin to rise to dangerous levels. While cucurbits are more tolerant of high temperatures, ventilation is a must for some crops such as tomato and pepper. One way to provide ventilation is to simply place slits in the plastic to allow the heat to escape. Rolling up one side of the tunnel is still another way to provide ventilation. An alternative system involves using two narrower sheets of plastic with a seam at the peak of the hoops. This seam is secured by clothespins, which can be removed to open the tunnel for ventilation. Another method, the double hoop system, makes use of two hoops with the plastic sandwiched between them. Because the edges of the plastic are not buried, the sides of the tunnel can be raised and lowered as needed for ventilation.

Interior and exterior of two different high tunnels.

High tunnels

The field greenhouse of Dr. Emmert's day is now generally called a "high tunnel" or "hoophouse." A high tunnel is a hooped frame of walk-in height covered with plastic. Although lacking the precision of the environmentally controlled greenhouse, these simple unheated structures do moderate temperatures, provide soil warming, and protect plants from wind and rain. They are used to extend the growing season earlier in the spring and later into fall for a wide assortment of horticultural crops. Additionally, high tunnels can be used for the winter production of various cool-season crops, such as greens and herbs. University of Kentucky researchers have investigated the use of tunnels for organic brambles and blueberry production, as well.

Tunnels may have a rounded Quonset shape or they may have the peaked roof of a Gothic style high tunnel; they may be a single stand-alone house or form multi-bay tunnels. Sizes can vary from 14 feet to 30 feet wide and from 30 feet to 96 feet long. Frames, which can be constructed of metal pipe, wood, or PVC pipe, are covered with one or two layers of greenhouse-grade polyethylene; those covered with two layers of plastic have an air layer in between, thus offering better insulation and consequently, more cold protection.

High tunnels may be moveable structures that can be relocated to a new site each season or they may be placed in a more permanent location. Moving tunnels to different sites can facilitate crop rotation, help avoid salt buildup in the soil, and prevent the buildup of insect pests and disease pathogens. The soil in moveable tunnels should be worked prior to erecting the structure. Once the structure is in place, tilling can be a challenge. Pennsylvania State University has developed a design in which the end walls are hinged and a small tractor or tiller can be driven in. New Hampshire's system uses plastic mulch to cover the entire soil surface under the tunnel, making tilling unnecessary.

High tunnels do not have any external connections, except for the water supply for trickle irrigation and fertilization. There are two main systems for ventilation. In the most common system the sides of the tunnel are manually rolled up each morning to provide ventilation as temperatures rise within the tunnel. The sides are rolled back down again each evening for cold protection. A system that is becoming more common has drop-down side walls. While high tunnels do not have a permanent heating system, some growers

choose to have a portable heater available for unexpected drops in temperature. Extreme caution must be used when doing this though because an improperly vented tunnel can injure the plants and anyone working inside the tunnel. When vented properly, serious foliar and fruit diseases are often fewer since plant surfaces remain dry while in the protective environment of the high tunnel. Additionally, high tunnels can exclude certain insects, as well as animal pests (such as birds). Fewer diseases and pests can mean reduced pesticide use. High tunnel production results in improved crop growth, quality, and yields compared to plants produced in the field without the tunnel. A combination of an earlier planting date, along with the more rapid ripening that occurs within the tunnel, can result in mature tomatoes as much as one month earlier than field tomatoes.

Exterior of glass-covered conventional greenhouses.

Conventional greenhouses

Conventional greenhouses may be 20 feet or more in width and 100 feet or more in length with frames of aluminum, galvanized steel, or wood. Glazings or coverings are typically glass, rigid clear plastic, or polyethylene. If only a single greenhouse is required, it can be built as a stand-alone unit. However, when multiple houses are needed (either initially or as part of a future expansion) the greenhouses should be gutter-connected for more efficient use.

The greatest advantage to a conventional greenhouse is the ability to completely control the environment to suit the plants being produced. Today this is called controlled-environment agriculture, or CEA. These greenhouses have heat, mechanical ventilation, artificial light, and an irrigation system that can also be used to distribute liquid fertilizer. A monitoring device is essential for determining whether the greenhouse conditions are within the proper range the crop requires. Greenhouses may also have benches, plus various machinery and hand equipment to aid in the production and handling of the crop.

Interior of a polyethylene-covered conventional greenhouse.

Plants grown within a greenhouse may be produced in ground beds, in pots or flats on benches, in hanging baskets, or using hydroponic systems. Winter production of crops will require artificial light and supplemental heat in Kentucky. Because of low natural light and high heating costs, crop production in the middle of winter is generally not economical in the Commonwealth.

Greenhouse conditions that favor plant growth also favor the rapid buildup and spread of insects and diseases. Prevention and careful monitoring are the keys to insect and disease control. Water aeration in the irrigation system can help to reduce water molds. Insect screening on the sidewalls may be necessary for some crops if sidewall ventilation is used. Pesticides must be applied properly and legally. Weed control under benches and around the greenhouse will also help reduce insect pests and disease problems; however, herbicides are not applied inside the greenhouse.

Economic Considerations

Crop production in a conventional greenhouse can be a highly profitable venture. However, it is also a high risk business with significant start-up costs, as well as demanding labor and management. Initial investments include greenhouse construction, production system costs, and equipment. The cost of a production-ready greenhouse, excluding land costs, can easily range from $8 to $30 per square foot.

Low tunnels and high tunnels are relatively inexpensive ways to extend the growing season, requiring little capital investments. Because of their simple design, these structures are not difficult to construct and manage. Excluding labor, the approximate construction cost of a low tunnel may range from $0.25 to $0.50 per square foot. Material and equipment costs for high tunnel construction may range from about $1.00 to $2.50 per square foot; the use of more expensive irrigation and heating technologies are reflected in higher costs per square foot.

Tunnels are not automated in any way, so they will require daily attention and labor to ensure proper ventilation. Both types of tunnels could also require monitoring during heavy storms.

Selected Resources

On the Internet

- Dr. Emery M. Emmert (University of Kentucky)
http://www.uky.edu/Agriculture/CDBREC/anderson/emmert.htm
- Greenhouse Business in Kentucky – A Review of Crops and How to Begin a Business (University of Kentucky, 2002)
http://www.uky.edu/Ag/CDBREC/anderson/greenhousesinkentucky.pdf
- Selected Resources and References for Commercial Greenhouse Operators (University of Kentucky, 2013)
http://www.uky.edu/Ag/CDBREC/anderson/greenhousereferences.pdf
- Center for Plasticulture (Pennsylvania State University)
http://plasticulture.cas.psu.edu
- Cornell High Tunnels (Cornell University)
http://www.hort.cornell.edu/hightunnel/structures/index.htm
- Design Manual for Greenhouses (National Greenhouse Manufactures Association, 2010)
http://www.ngma.com/industry_information.htm
- Economics of High Tunnel Vegetable and Strawberry Production in the Central Midwest (Purdue University, 2007) *7 MB file*
https://www2.ag.purdue.edu/hla/fruitveg/Presentations/econ_summer_crop.pdf
- Greenhouse Structures (University of Arizona, 2001)
http://ag.arizona.edu/ceac/sites/ag.arizona.edu.ceac/files/Greenhouse%20Structures.pdf
- High Tunnels (Kansas State, University of Missouri, and University of Nebraska)
http://www.hightunnels.org/
- High Tunnels (Pennsylvania State University)
http://extension.psu.edu/plasticulture/technologies/high-tunnels
- Season Extension Techniques for Market Gardeners (ATTRA, 2005)
https://attra.ncat.org/attra-pub/summaries/summary.php?pub=366
- Starting a Greenhouse Business (Part 1): Some Basic Questions (Arkansas, 2004)
http://www.uaex.edu/Other_Areas/publications/PDF/FSA-6051.pdf
- Texas Greenhouse Management Handbook: Greenhouse Structures (Texas A&M)
http://aggie-horticulture.tamu.edu/ornamental/greenhouse-management/greenhouse-structures/
- Virtual Grower 3 (USDA-ARS)
http://www.ars.usda.gov/Research/docs.htm?docid=22087

In Print

- *Ball RedBook: Greenhouses and Equipment (Volume 1).* Chris Beytes, editor. 2011 (18th ed). Ball Publishing, Inc.: West Chicago, IL. 800 pp.
http://www.ballpublishing.com/BallPub/_RedBook.aspx

Construction plans & instructions

- Building and Equipment Plans: Greenhouses (University of Kentucky)
http://www.bae.uky.edu/ext/plans/plans_Horticulture.htm

For those plans that cannot be downloaded directly from the Web, contact:

University of Kentucky Plan Service
Biosystems & Agricultural Engineering Dept.
Lexington, KY 40546-0276
Phone: (859) 257-3000 Ext. 111
FAX: (859) 257-5671
e-mail: jpeel@bae.uky.edu

- How to Build a High Tunnel (University of Kentucky, 2005)
http://www.uky.edu/Ag/CDBREC/hightunnel.pdf
- Building and Construction Plans: Greenhouses (Mississippi State University)
http://msucares.com/pubs/plans/books/greenhouses.html
- Design and Construction of the Penn State High Tunnel (Pennsylvania State University, 2002)
http://njsustainingfarms.rutgers.edu/PDF/Design_construction_Penn_State_high_tunnel.pdf
- Greenhouse Plans (University of Tennessee)
http://bioengr.ag.utk.edu/extension/extpubs/PlanList97.htm
- How to Build a Low-cost Hoop House (Kerr Center for Sustainable Agriculture, 2009) *1.6 MB file*
http://www.kerrcenter.com/pdf/hoophouse-howto.pdf
- Portable Field Hoophouse (Washington State University Extension, 2009)
http://cru.cahe.wsu.edu/CEPublications/em015/em015.pdf

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Photos courtesy of Robert Anderson (covered low tunnel & high tunnel interior) and Tim Coolong (uncovered low tunnel), University of Kentucky; USDA-ARS (high tunnel exterior); H.F. Schwartz, Colorado State University, Bugwood.org (glasshouse exterior); and James Locke, USDA (conventional greenhouse interior)
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