More information online at
www.SARE.org/Season-Extension

High Tunnels and Other Season Extension Techniques

Photos *(clockwise)*: **Drip irrigation is used in this solar-heated greenhouse on Santa Cruz Farm in Española, N.M.** - *Santa Cruz Farm* **String beans in Mississippi farmer Hattie Thompson's high tunnel.** - *USDA* **To adjust temperature, high tunnel covers can be raised so that air may flow in and out.** *-Jerry DeWitt*

SPURRED BY ENTHUSIASM FOR FRESH, local agricultural products, farmers are increasing the availability of their crops beyond the traditional outdoor growing season. Premium prices and an extended income stream are some of the advantages farmers pursue with season extension techniques. Main strategies for creating extended-season sales include: growing in greenhouses, high tunnels (or "hoop houses") or under temporary row covers; storing non-perishable crops for sale in the off season; or minimally processing crops.

Commercial high tunnel production has increased rapidly in recent years because these structures promote increased crop quality and productivity, and extend the growing season. This leads to rapid payback on investment. The growing environment inside a high tunnel is different from the field, and thus crop management differs in many key areas. Visit *High Tunnels and Other Season Extension Techniques* (www.SARE.org/Season-Extension) for in-depth information on season extension strategies for your farm.

TYPES OF STRUCTURES

SEASONAL STRUCTURES THAT PROTECT crops from cold temperatures and inclement weather vary widely in size, shape, materials and purpose. The following are common types.

Row covers are sheets or strips of synthetic, breathable fabric of various weights and mesh diameters. Sometimes greenhouse plastic is also used. These materials are placed over individual rows, with or without supporting wire hoops, or over entire fields. "Floating" row covers are unsupported, laying directly on the plant leaves as the crop grows.

Low tunnels and **caterpillar tunnels** are seasonal structures covered with the same materials as row covers, but with rigid supports such as metal or plastic tubing, or electrical conduit. Low tunnels are typically 2 to 3 feet high and cover the width of a growing bed. Like row covers, they protect cold-hardy crops in winter and spring plantings from cold and wind. Low tunnels are increasingly used for pest management also.

Caterpillar tunnels are three-season structures and are typically 6 to 8 feet high and 10 to 20 feet wide. They are usually held in place with ropes anchored to the ground. Ventilation must be managed manually. Caterpillars and low tunnels differ from high tunnels in that they are removed when not in use, are much less durable and are much more portable. They represent a lower investment than high tunnels.

High tunnels, or **hoop houses**, are simple greenhouse-like structures over bare ground,

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SARE's website features dozens of publications, videos and other educational materials on a wide range of topics, including cover crops, local food systems, small ruminants and more. Visit www.SARE.org/resources.

Written by Vern Grubinger, Northeast SARE

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Kansas State's high tunnel series includes videos on designing a high tunnel, what to plant, basic and intensive management considerations, and additional high tunnel resources.

Visit www.SARE.org/Season-Extension/Kansas-High-Tunnels.

without the elaborate heating and cooling systems of a greenhouse. They rely primarily on passive solar heating and passive ventilation. High tunnels generally have steel pipe frames set into the ground and are covered with one or two layers of greenhouse-grade plastic. They are irrigated using drip systems, hand watering or small sprinklers. Roll-up sidewalls, usually hand cranked but sometimes automated, provide ventilation in a high tunnel. They may also have end-wall vents (louvers) or ridge vents. Crops grow in the ground, raised beds or containers. The ground may be bare, or it may be covered with landscape fabric, plastic mulch or an organic mulch such as straw. Guides for high tunnel design and construction are abundant; check out the Types and Construction section online for Extension guides with detailed high tunnel plans, including photos and designs.

Smaller high tunnels may be Quonset shaped (half-circle frame) while larger tunnels are Gothic shaped (peaked frame). Gothic frames shed snow well. Both designs are best with internal bracing to provide stability during wind or snow. Ground posts must be securely anchored to ensure structural stability. Multi-bay high tunnels are built side by side to cover more acreage with less exposed surface area. They require gutters and structural reinforcement to handle rain and snow shed from the top of the bays. Multi-bay high tunnels are generally not considered four-season structures in regions with snowy winters, as they cannot bear a snow load.

Greenhouses tend to be similar in size to high tunnels or larger, often with more structural strength. They may or may not have a permanent foundation. They are covered with one or two layers of greenhouse plastic, rigid polycarbonate or glass. Greenhouses have supplemental heat from a furnace or boiler, and automated ventilation with fans and/or louvers. As greenhouse heating, cooling and irrigation are automated, full electrical service is required.

Special Considerations for High Tunnel Production

THE GROWING ENVIRONMENT INSIDE A high tunnel varies in many important ways from field production, and those differences will influence the way crops are managed.

Cultivar Selection and Variety Trials. The desirable characteristics of crop cultivars/varieties for high tunnel production are much the same as field production: good yield, high quality and pest tolerance. However, depending on the season, high tunnel cultivars/varieties must be able to thrive in higher temperatures and relative humidity, tolerate freezing, or have their day-length requirement met. Thus, the best field cultivars/varieties are often not ideal for use inside a high tunnel. Pest pressure is also different, so tolerance to diseases or insects that are not prevalent outdoors may be a consideration. In the Cultivar Selection and Variety Trials section online, a good primer is the video *What to Plant*, part of a Kansas State series on high tunnel vegetable production (see sidebar).

Fertility Management. In a high tunnel, plant growth may start earlier, last longer and/or lead to a significant increase in biomass and yield. Thus, nutrient needs may vary from field production, so plan fertilization accordingly. In addition, salt accumulation is a greater concern in a high tunnel because rainfall does not leach nutrients from the soil. Carefully monitor soil fertility status, including soluble salts, and conduct plant tissue analyses when making fertility decisions. Soil test annually, as pH can rise quickly in the absence of rain.

Pest Management. Many foliar diseases are eliminated from high tunnels, as rain and soil splashing are eliminated. However, due to higher

Photo courtesy Santa Cruz Farm in Española, N.M.

PHYSICAL PEST EXCLUSION IN GREENHOUSES

Insect pests love Alabama, with its hot, humid climate and long growing season. For vegetable growers who want to use fewer pesticides but face the risk of major crop losses, and especially for organic growers, who cannot use conventional chemicals at all, pests are a huge problem.

But help is coming in the form of new pest management techniques and improved outreach, being delivered to farmers by Alabama Extension Entomologist Ayanava Majumdar.

Physical pest exclusion is one new tool Majumdar is bringing to farmers. Typically accomplished by growing crops inside structures covered with a shade cloth akin to mosquito netting, the strategy showed promise on Will Mastin's farm, where he tested it in 2013 with a SARE farmer grant. Inside the protected structures he lost less than 20 percent of a tomato crop to pests, whereas in the open field his loss was nearly total.

"We almost don't even have to worry about caterpillars inside of these structures anymore. It used to be a constant scouting routine," says Mastin, who grows produce for local markets around Baldwin County. "And so it saves us labor, it saves us pesticide usage and we can focus on planting, harvesting and doing the things that we need to be doing instead of just trying to take care of our crops from the bugs constantly."

Visit www.sare.org/mastin to hear Will Mastin describe his experiences with shade cloth and share some tips.

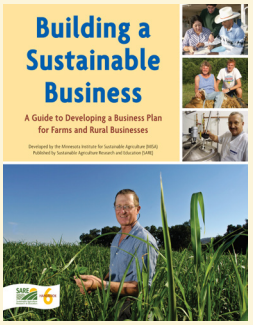
Will Mastin stands inside one of his high tunnels that he covered with shade cloth to protect his crops from certain pests.
- Photo by Candace Pollock, Southern SARE

humidity levels, a handful of diseases become more severe inside; thus proper ventilation is critical. Higher temperatures, the exclusion of rain and a humid microclimate inside the plant canopy can promote certain insect pests, especially if there is little or no fallow period. Aphids, thrips, spider mites and whiteflies are common insect pests inside high tunnels. The good news is that high tunnels are an excellent setting for using biological control agents due to the high value of the crops, the enclosed space (if ventilation openings are covered with mesh screens) and controlled environmental conditions that improve persistence. The Pest Management section online includes resources on such high tunnel pest management strategies as tomato grafting for disease resistance, beneficial insects, physical pest exclusion and biofumigation.

Water Management. To take full advantage of a high tunnel, one must precisely control the supply of water to crops. Use drip irrigation to deliver water directly to the root zone, without wetting the foliage. This helps avoid foliar diseases and the washing off of foliar bioinsecticides. When there is plenty of light, high temperature and low humidity, crops will use a lot of water, but be careful not to overwater, as excessively wet soil can be difficult to dry out. Use soil-moisture monitoring devices to match the amount and timing of water to the crop's needs. Consider providing soluble fertilizers through the drip system to "spoon feed" crops.

Temperature Management. In some high tunnels, the sun may satisfy all energy needs, with the soil acting as a nightly heat reservoir. Other high tunnels may have supplemental or emergency heating systems. High tunnels in colder climates where heat-loving crops are produced on the "shoulders" of the growing season will typically have furnaces or boilers to maintain the optimal temperature for growth. Understanding the temperature requirements of the crop, and then ventilating or heating to maintain that temperature, is critical. Important energy conservation measures for high tunnels range from sealing cracks around doors and ventilation louvers to installing night-time heat curtains. Low tunnels can be instrumental in retaining heat stored in the soil during the night. Some high tunnels are also using renewable fuels to provide heat, such as biodiesel, shell corn, wood and solar hot water collectors. For low-growing crops, heating the soil with circulating water pipes below ground may be more efficient than heating the air inside the tunnel. The Temperature Management section of online includes resources on the important topics of energy conservation and alternative energy strategies.

Marketing and Economics. Thousands of commercial high tunnels are in use around the country because they make economic and marketing sense for many growers. High tunnels generally allow for improved pest control, making them a good option for organic production. However, carefully consider the potential costs and returns prior to getting into high tunnel farming. A possible avenue of support is through the USDA Natural Resources Conservation Service, which offers financial assistance for high tunnel construction. The net profit from high tunnel crops ranges from just a few cents per square foot up to several dollars per square foot, depending on yield, production expenses and grower skill. Labor is a special consideration. Be aware that high tunnel farming is relatively labor intensive and requires skill, and that such labor must be available to perform tasks in a timely fashion to ensure profitability. The



Use SARE's *Building a Sustainable Business* to help you plan for season extension on your farm.

Download the book for free at www.SARE.org/Business.

Find guides on building a walk-in cooler and retro-fitting an existing structure, developed by a Massachusetts nonprofit, at www.SARE.org/season-extension/MA-cooler.

Photo by Lewis Jett, West Virginia University

Marketing and Economics section online includes resources on both high tunnel production and general business planning, which may be of help.

Storing Crops

STORING FIELD CROPS SUCH AS CARROTS OR potatoes can lengthen their marketing window, which is another approach to season extension. The length of time that crops can be stored is a function of their postharvest physiology as well as pre-storage activities, including how they are produced, harvested and handled. Optimal storage conditions vary among crops. Five common sets of storage conditions for vegetable crops are:

- Cold and moist = 32°F and 90-95 percent relative humidity (RH).
  Ex: beets, cabbage, carrots, parsnips, turnips.
- Cold and dry = 32°F and 65-70 percent RH.
  Ex: garlic and dry onions.
- Cool and moist = 45°F and 90 percent RH.
  Ex: potatoes for table stock.
- Warm and moist = 57°F and 85-90 percent RH.
  Ex: sweet potatoes.
- Warm and dry = 55°F and 50-70 percent RH.
  Ex: winter squashes, including pumpkins.

Storage options include cold cellars or root cellars, walk-in coolers and cold rooms fitted with air conditioners and temperature-override controllers. Cold cellars are a low-cost, low-energy-use option, but may lack the environmental control of other options. Walk-in coolers use refrigeration systems and are widely found on wholesale farms, supermarkets and other places that handle large volumes of fresh produce. Cold rooms are widely used on farms with small volumes of storage produce.

Air conditioner temperature-override controllers such as CoolBot™ units allow residential air conditioners to provide cooling in small-scale storage units. These units require a sealed, well-insulated storage room to be effective, and they may have trouble cooling down produce with a lot of field heat in it.

Light Processing of Crops

FIELD CROPS CAN BE PRESERVED AND SOLD in the off-season through light processing techniques such as canning, dehydrating or freezing. To learn more about processing, see the Food Safety and Food Processing sections of SARE's *Farm to Table: Building Local and Regional Food Systems* (www.sare.org/local-food).

HIGH TUNNELS PROVIDE A COMMUNITY BOOST IN WEST VIRGINIA

For years, high tunnels have been popping up throughout many cold Northeastern states but in West Virginia they were not as common.

Until 2008 that is, when West Virginia University Extension Specialist Lewis Jett and his colleagues turned their attention to the technology, which has since proved invaluable not just for local farmers, but for local communities as well.

That year, Jett received a SARE grant to begin a four-year project that taught hundreds of farmers and Extension educators how to use high tunnels successfully. The grant was a major impetus for the leap in adoption the state has recently seen: Whereas no more than 20 high tunnels were in use in 2007, there were more than 150 by 2012.

A state benefits from having a hundred new high tunnels because it means more healthy, locally raised food options are available to consumers. In West Virginia, schools have been particular beneficiaries. "It's really helped our farm-to-school program," Jett says. "That used to be an unattainable option for growers, but now that we have tunnels in place, it's really an option."

Jett, who provides technical assistance to the West Virginia Department of Education's Farm to School program, says that the majority of the 75 to 100 participating farmers are now using high tunnels to help them meet cafeterias' seasonal demand.

Terry Hudson, who uses two high tunnels on a two-acre vegetable farm outside Charleston and collaborates with Jett on education projects, has fully embraced the potential of high tunnels to support local schools. One of his two tunnels is essentially a classroom, where he hosts both periodic field trips and regular visits from small groups of children with mental and physical disabilities. In his second tunnel, Hudson grows commercial crops year-round, using intensive, carefully timed rotations: He raises high-value crops like tomatoes, peppers and eggplants in warmer months and leafy greens and root vegetables through the winter. By selling at farmers' markets and to restaurants, he nets about $13,400 per year from that high tunnel.

"We have unique micro-climates here–early and late freezes and frosts, strong winds and heavy snow," Jett says. "These tunnels have really demonstrated that you can buffer the crop against our erratic climate and consistently grow a good crop."