College of Agriculture, Food and Environment
Cooperative Extension Service

Controlled-Environment Horticulture Fact Sheet

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Controlled-Environment Horticulture

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EXPERT REVIEWED

Production of fruiting and leafy vegetable crops under protected culture has gained considerable attention in Kentucky in recent years. Although food crop production under protected culture is increasing in popularity, the production of annual flowering bedding plants and herbaceous perennials has a historical presence within the Kentucky horticulture industry. Horticulture production under protection has proven to be successful in Kentucky; however, the infrastructure, systems, technologies, and philosophy of growing under protection has evolved.

To date, the technology-based approach to horticultural crop production is referred to as controlled-environment horticulture (CEH). The CEH approach allows producers to extend or create an artificial growing season by managing and manipulating the growing environment and cultural conditions to elicit favorable plant growth, development, morphological, and physiological responses of horticultural crops.

Structures

Protected culture refers to the practice of producing plants in structures. In Kentucky, many types of structures are used, including nursery tunnels, low or caterpillar tunnels, high tunnels,

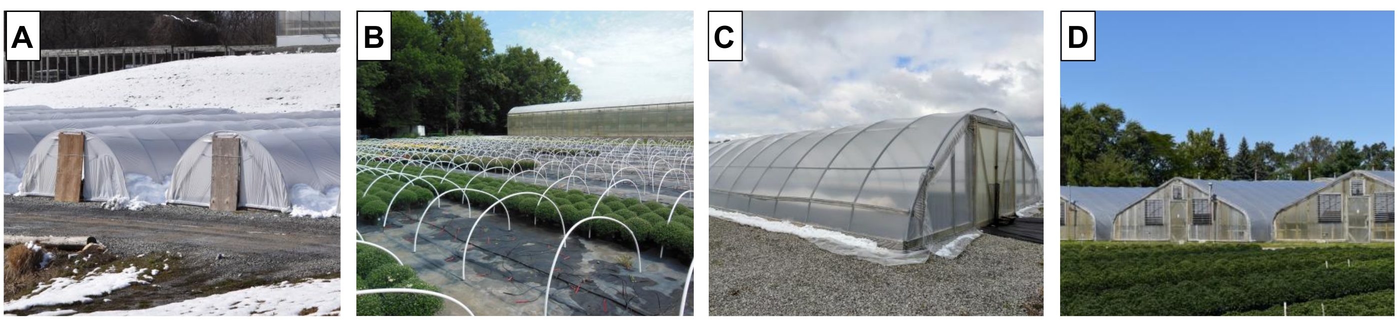

FIGURE 1. Many types of growing structures can be found throughout Kentucky including (A) nursery tunnels, (B) low tunnels, (C) high tunnels, and (D) greenhouses.

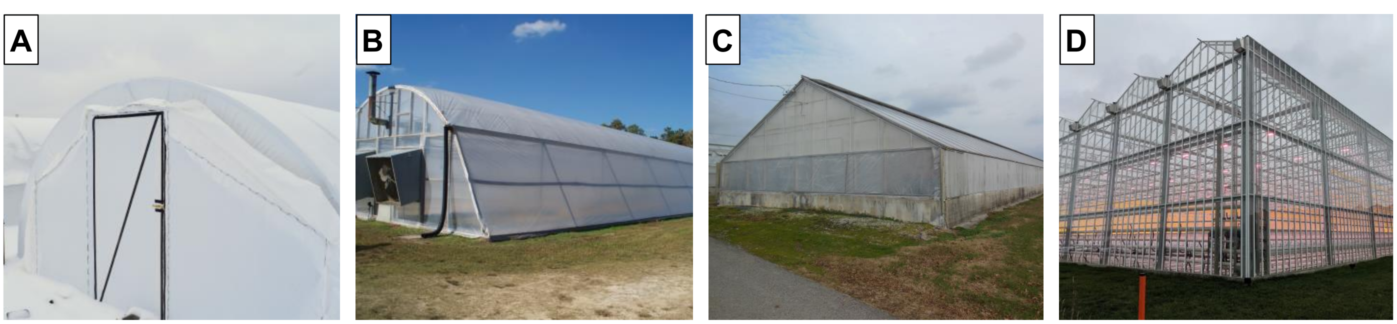

FIGURE 2. Glazing materials are used to cover structures such as (A) opaque poly-film for nursery tunnels and (B) clear poly-films for low tunnels, high tunnels, and greenhouses. Greenhouses may also be glazed with (C) polycarbonate or (D) glass.

and greenhouses (FIGURE 1A–D). These structures are covered with glazing materials which provide protection from the weather. The type, cost, and life expectancy of glazing materials vary with the intent of the structure. Nursery tunnels are often covered with opaque poly-film (FIGURE 2A) while low tunnels, high tunnels, and greenhouses are often covered with clear poly-film (FIGURE 2B). Greenhouses can also be covered with other materials such as polycarbonate or glass (FIGURE 2C–D). Regardless of the glazing material, the crops are protected. The level in which the growing environment in these structures is controlled varies with the

FIGURE 3. High tunnel constructed with a rolling door so machinery can easily access the growing environment.

technology installed. Nursery tunnels, low tunnels, and high tunnels are considered semi-controlled environments with limited to no technology used. These structures are often constructed using endwalls with large sliding or rolling doors that allow equipment access to the growing area (FIGURE 3). The sidewalls may be fixed, but most often are fitted with rolling side curtains that allow users to raise or lower the curtains to cool or vent the growing environment (FIGURE 4). In some instances, users may install low-cost technologies such as drills or solar panels to automate the rolling of the curtains.

Environmental Controls

In greenhouses, other types of technology are deployed. In most greenhouses throughout Kentucky, thermostats control the heating and cooling of the growing environment (FIGURE 5). In high-tech greenhouses, computerized

FIGURE 4. Roll up curtains are used to cool or vent the growing environment.

control systems manage and manipulate the growing environment within grower-defined environmental parameters. These types of systems are often automated and support plants growing in soilless substrates or media by regulating nutrient delivery, moisture, temperature, light, and gases such as carbon dioxide enrichment.

Irrigation Systems

Within greenhouses, production systems vary and include container production (FIGURE 6A) or hydroponics (FIGURE 6B). Plants are grown without soil and are supported by soilless substrates and/or nutrient solutions. Irrigation and nutrient delivery systems must be utilized to support plant growth and development and will vary depending on the crop grown and production system. In general, for hydroponic systems, plants can be irrigated through drip, ebb-and-flood, deep water culture, or continuous recirculation irrigation (FIGURE 7A–D). For container production, plants can be irrigated through drip, overhead, or flood floors (FIGURE 8A–C).

Light Transmission

Adequate light is required for optimal growth, development, and yield. Solar radiation or light from the sun varies by geographical location and over the course of the day, week, month, growing season, and year. These factors will influence the duration (photoperiod) and quantity (intensity) of light the crops will receive. Growers cannot change these natural variations in light. However, there are several practices growers can implement to maximize or reduce light transmission. Selecting the appropriate glazing material for the structure and reglazing when needed will aid in managing the light environment. Reducing overhead equipment and removing externally applied shade cloth or shading compounds will increase light transmission, especially during winter months. Attaching shade cloth or applying liquid shading compounds will reduce light transmission and heat in growing environments during summer months (FIGURE 9A–B). All practices will have an influence on crop quality.

FIGURE 5. In greenhouses, thermostats are often used to manage heating and cooling of the growing environment.

FIGURE 6. Within greenhouses, production systems vary and include (A) container production or (B) hydroponics.

Lighting Systems

Artificial lighting technologies are best deployed in greenhouses and there are various technologies that can be used. High-pressure sodium (HPS) lamps, light-emitting diodes (LEDs), metal halides (MH) lamps, and incandescent and compact fluorescent bulbs are common lighting technologies; (FIGURE 10A–E) however, not all of these are energy efficient or applicable to all growers. The most advantageous lighting technology will depend on the lighting strategy required to manipulate the growing environment, including supplemental and photoperiodic lighting

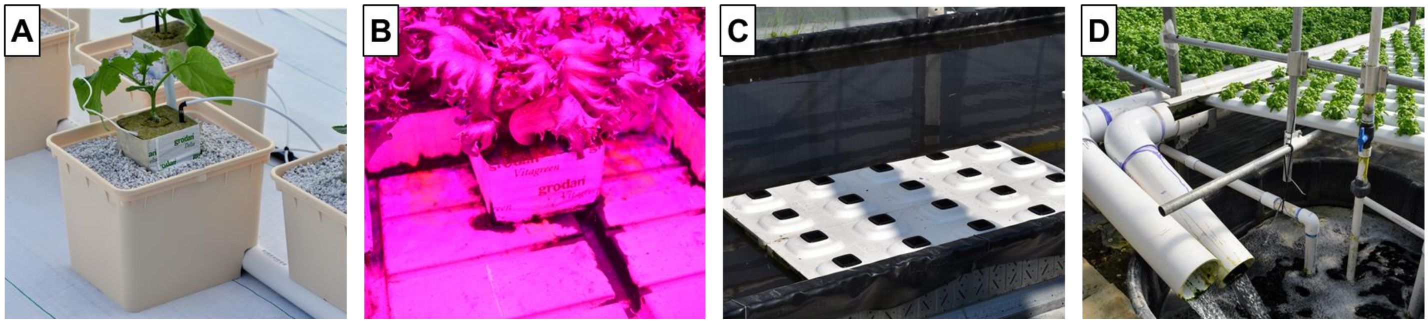

FIGURE 7. Hydroponic systems can deliver nutrient solutions to plants through (A) drip, (B) ebb-and-flood, (C) flood, or (D) continuous recirculation.

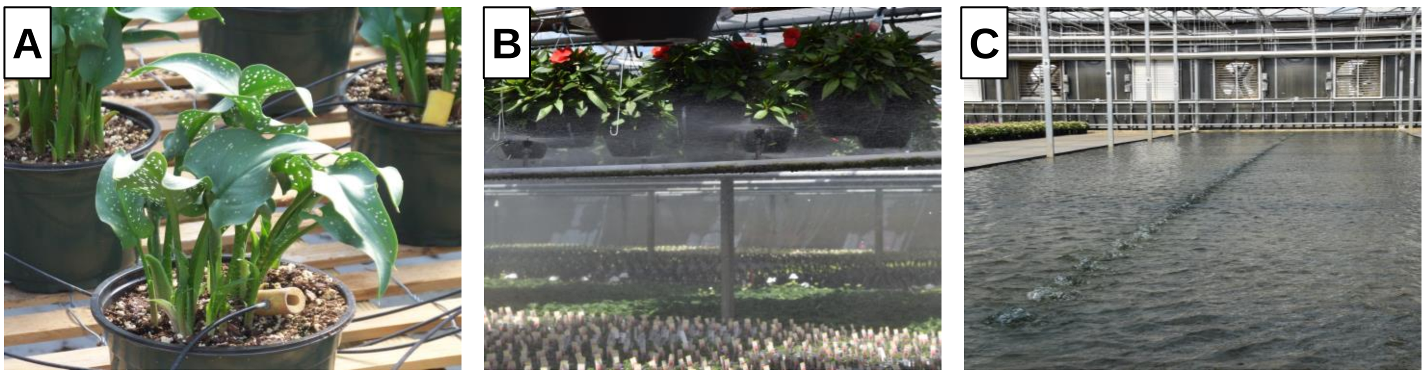

FIGURE 8. For container plant production, plants can be irrigated through (A) drip, (B) overhead, or (C) flood.

Supplemental lighting is the practice of adding light from artificial lighting sources to natural solar radiation (FIGURE 11). Photoperiodic lighting is the practice of manipulating the duration of the day length (also called day extension) with artificial lighting before sunrise and/or at sunset (FIGURE 12). In some instances, night interruption lighting can be deployed where plants are lit for 4 hours during the middle of the night. Overall, these lighting strategies will help manage crop vegetative or reproductive (flowering or fruiting) status and quality.

Heating Systems

Plant development depends on temperature. Under low and high temperatures, plant development can be slowed or ceased. Therefore, to maximize plant development, it is important to maintain optimal air, root-zone, water, and plant temperatures. The easiest temperature to measure and regulate in a greenhouse is air temperature. Multiple technologies are available to heat and cool greenhouses. To heat the growing environment, many growers utilize overhead unit heaters, while high-tech facilities may use perimeter, radiant floor, under- or bench-top heating systems (FIGURE 13A–D).

Horizontal air flow (HAF), vertical air flow fans, and convention tubes are low-cost technologies that can be installed to distribute heat throughout the greenhouse (FIGURE 14A–C). Cooling the growing environment can be achieved by using exhaust fans and louvers. In some instances, evaporative cooling systems and greenhouse ridge and eave vents are utilized (FIGURE 15A–C). This not only allows the growing environment to be cooled, but also increases gas exchange, especially oxygen and carbon dioxide (CO_2).

Other Systems

Other technologies that may be installed in greenhouses include CO_2 generators, energy curtains, blackout curtains, advanced water filtration, automation systems, and robots (FIGURE 16A–E). Many of these systems are not currently found in greenhouses in Kentucky; however, many cost-effective opportunities and technologies are emerging that will be available to advance the Kentucky CEH industry.

Overall, controlled-environment horticulture systems offer growers production methods to manipulate the growing environment in order to maximize plant growth. There are numerous combinations, from low tech to high tech, and from low cost to higher cost, that can be employed to achieve production success.

FIGURE 9. To reduce light transmission and heat, (A) shade cloth or (B) liquid shading compounds can be used.

FIGURE 10. Common horticultural lighting technologies include (A) high-pressure sodium (HPS) lamps, (B) light-emitting diodes (LEDs), (C) metal halides (MH) lamps, and (D) incandescent and (E) compact fluorescent bulbs.

FIGURE 11. Plants grown under natural solar radiation with the addition of supplemental light from a horticultural lighting source.

FIGURE 12. Plants receiving horticultural lighting after sunset to manipulate the photoperiod to extend the daylength.

FIGURE 13. In greenhouses, (A) overhead unit heaters, (B) perimeter, (C) radiant floor, (D) under-bench, and (E) bench-top systems can be used independently or together to manage the air temperature in the growing environment.

FIGURE 14. In greenhouses, (A) horizontal air flow (HAF), (B) vertical air flow fans, and (C) convention tubes are low-cost technologies to distribute heat throughout the growing environment.

FIGURE 15. To cool greenhouses, (A) evaporative cooling systems, (B) ridge, and (C) eave vents can be installed.

FIGURE 16. Examples of other technologies that may be installed in greenhouses including (A) energy curtains, (B) blackout curtains, (C) advanced water filtration, (D) automation systems, and (E) robots.

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