UNIT II: THE GROWING STRUCTURE

Lesson 1: Greenhouse Parts, Structures, and Coverings

This lesson addresses site selection, types of greenhouse structures, basic construction of a growing structure, and interior components of a greenhouse. Additional information concerns other structures and areas that are part of most commercial greenhouse operations as well as the exterior layout of buildings and work areas.

Site Selection

One of a greenhouse owner's primary considerations is selecting a suitable site for the growing structure. The greenhouse, even as an indoor structure, is still affected by outdoor elements, such as the direction and intensity of wind, sun, snow, and frost. A region's climate that typically has winter blizzards, spring tornadoes, or summer and fall hurricanes may adversely impact the success of a greenhouse operation.
By studying historical weather patterns, the owner can assess the amount of precipitation, sunlight, and temperature variability in the proposed site.

An optimal location has high, natural light levels and moderate temperatures. Some sites, however, could increase energy and maintenance costs, making them not suitable for a greenhouse. A growing structure in a cold location requires additional heating to sustain plant growth. Sites with extremely high temperatures and humidity increase the costs of ventilation and fans. If a structure is located in high elevations, it is subject to windchill and must compensate by increasing heat. A greenhouse located in a valley protected from harsh winds may be exposed to frost, which also necessitates additional heating.

The topography of the site affects where a growing structure is built. (Topography refers to the shape of the land, e.g., hilly, steep, rocky, flat.) The surface of the ground should be level. A 0-5% slope is recommended. Placing a growing structure on a flat surface is efficient because it facilitates easy adjustments to various mechanical controls in the greenhouse, which is economical. A level surface provides good drainage and reduces the cost of grading the land. Selecting where to place the greenhouse depends on location. The optimal site is where the greenhouse receives the most morning sunlight, thereby promoting the plant food production process (photosynthesis). For example, in Maryland, the optimal direction for a growing structure is toward the south or southeast. The next best option is placing the structure to the southwest, which provides sunlight later in the day. In Missouri, the ridge of the greenhouse should run north and south to permit the light to enter from a sidewall, not an endwall. Winter light is maximized and shadows are reduced. For states whose latitude is 40^{o} north or above, an east-west direction is best.

It is also important to shelter the structure from winter wind. A windbreak, composed of trees, shrubs, or annual or perennial crops, provides a protective barrier that lessens and redirects the force of winter wind. It is usually placed to the north of the greenhouse. To prevent shading the greenhouse, the distance between the windbreak and greenhouse should be two and a half times the maximum tree height. All major obstacles - trees and large buildings - must clear the growing structure.

Another critical factor in site selection is the availability of resources. The site must have an ample supply of water either from the city or a well. During peak use, the greenhouse requires approximately 2 quarts per day per square foot. To ensure water quality, a laboratory or county Extension agent can test for correct pH, alkalinity, and level of soluble salts. Electricity, natural gas, and sewer services have to be hooked up, which may involve connection fees. Greenhouses also need convenient access to materials for growing plants (growing media, fertilizers, pesticides, etc.). The greenhouse owner must determine if labor is available to perform both routine and harvest-time duties. Basic services such as waste removal are required. To maintain a competitive edge, the greenhouse owner needs access to sources of information, such as local university Extensions or a nearby testing/advising service.

Land is a major factor in site selection. A greenhouse owner's fundamental concern usually is the cost of the property (purchase price and taxes). Another consideration is selecting land that is close to the main roads so that delivery trucks and customers can easily drive to the greenhouse. For example, a parking area may be necessary. The land should also be near utilities. The ideal site has potential for expansion.

Land selection directly impacts marketing. A retail operation that is visible from the road encourages customers to stop by whenever they wish. For wholesale operations, proximity to markets and suppliers is important. In order to succeed competitively, the greenhouse owner must have easy access to suppliers, raw goods, and customers.

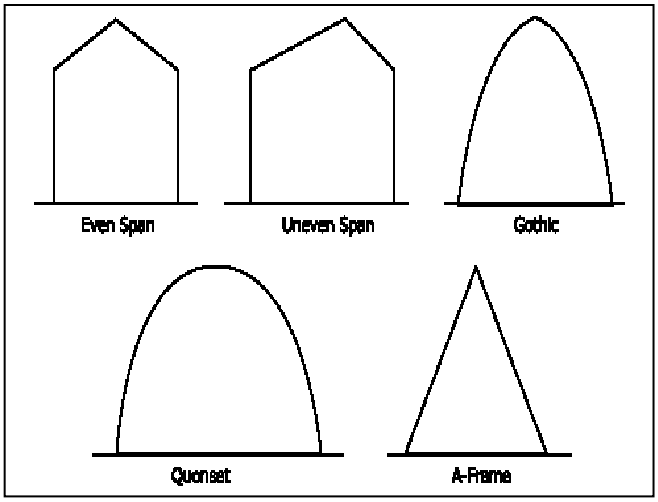
Finally, site selection involves various legal considerations. Permits, licenses, and zoning regulations govern where a greenhouse may be built and often even dictate what type of building materials may be used. Retail greenhouses should be zoned for business. Selecting an appropriate site also involves how the greenhouse operation affects its neighbors. If the proposed site is near a school, hospital, or residential community, the greenhouse must cooperate with the zoning rules of these entities. If water from the site drains into parks, farms, or ecological areas, the land may be subject to various state and federal regulations. Some states require the owner to obtain certification to purchase restricted-use pesticides. (See Unit VI, Lesson 3, for details.) In addition, the greenhouse owner must also be aware of relevant mandates from the Occupational Safety and Health Administration that ensure employee safety.

Types of Greenhouse Structures

The two basic types of greenhouse structures are freestanding (detached) and connected (attached). Freestanding structures can be constructed in several frame styles. The *even span (gabled)* frame is commonly used. The angle and width of its roof are equal. This frame type can be lengthened. It has more usable space than other types and promotes good air circulation and maintains even temperatures in the greenhouse. The *uneven span* frame, with one roof side longer than the other, is used if the land's slope is not too steep. This structure is placed on hillsides with southern exposure. It captures more of the low light during winter than the even span greenhouses.

The high *gothic arch* frame provides ample headroom and is used primarily to grow potted crops and spring flowering annuals. The *Quonset* frame, developed during World War II, is extremely simple to build and efficiently designed, but its circular frame lowers the sidewall height, which limits headroom and storage space. The design of the *A-frame* provides more space along the sidewalls, which promotes good air circulation. Figure 2.1 illustrates each of these frame types.

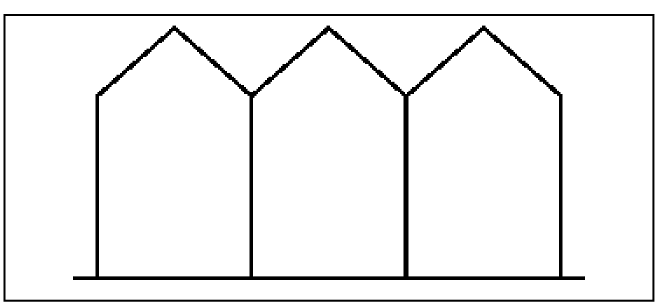
Figure 2.1 - Frame Types



Freestanding structures are easy to maintain. Because there is space between these buildings, shoveling snow from the rooftops can be done with minimal difficulty. Regulating the temperature and ventilating the air are also easier to perform. As a result, plants are not exposed to erratic temperature fluctuations or harsh blasts of cold air. Another advantage of freestanding structures is uniform light with minimal shadows. However, this type of structure costs more to construct because it requires additional sidewalls and occupies more space than a single connected structure. It is also less energy efficient because more surfaces are exposed to the outdoor elements.

The framing styles of <u>connected structures</u> are similar to those listed above, but they are joined by a common roof, typically a *ridge and furrow* construction. The furrows form gutters. (See Figure 2.2.) The interior walls create separate zones for crops.

Figure 2.2 - Ridge and Furrow Construction

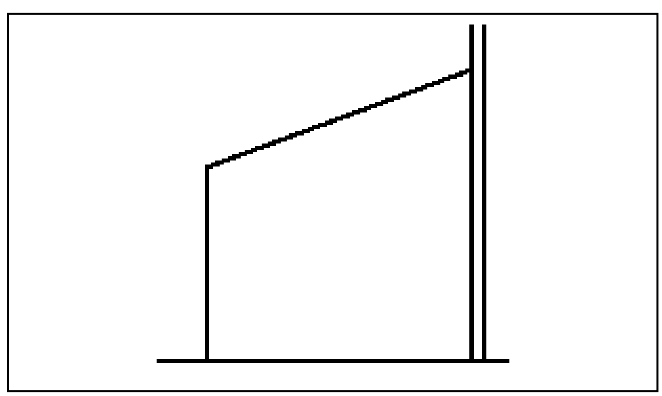


Connected structures occupy less land and have no sidewalls; therefore, fewer materials are needed for construction. Because there are no walls where the gutters are, more interior space is available than in several freestanding structures. Less energy is required to heat and cool the greenhouse because the exposed wall surface area is reduced.

But being connected to another building makes it harder to apply insecticides that produce vapors, gas, smoke, or fumes and to zone heat to specific plants. Another drawback is that the gutters collect snow, making removal very difficult. To avoid excessive accumulation that can collapse the greenhouse, the owner may have to add expensive heat lines to induce melting. Gutters also create shadows, thereby diminishing light intensity. As a result, plants may ripen later than expected. This delay in harvest time can affect the grower's market opportunities.

The *lean-to* is a common example of the connected structure. It is attached to an existing building that generally faces east or south. Confined to a width of about 7-12 feet, this is the least expensive growing structure. Heat, water, and electricity come from the adjacent building. It is often used for forcing bulbs and starting seeds. However, lean-to greenhouses have limited space and less roof support. Figure 2.3 illustrates a lean-to greenhouse.

Figure 2.3 - Lean-To Greenhouse



Several innovations in energy-efficient growing structures have been developed in Europe. The Netherlands developed an energy-efficient growing structure called the "Venlo greenhouse." The galvanized steel superstructure supports a gable roof. It has a self-supporting glazing bar system. The bars are placed opposite each other, so less material is needed and more light is available. The structure is rust free, requires no maintenance, and lasts for years. The polycarbonate sides and endwalls provide thermal insulation and regulate the temperature inside the greenhouse. High-light glass glazing transmits light very well and promotes high-quality growing environments for the plants. The roof vents are controlled thermostatically or by computer. They cut energy costs by using natural ventilation to cool the greenhouse.

Also from the Netherlands is the "Rovero" greenhouse. It has a retractable roof that can be closed, half closed, or opened as needed. The roof covering is made of clear or diffused polyethylene. The sidewalls and endwalls are motorized and have 8-mm-polycarbonate roll-up curtains. The entire Rovero greenhouse environment is fully computer controlled.

Originally developed in France (as single span) and Spain (as multispan) are field-scale tunnels and conventional tunnel designs.

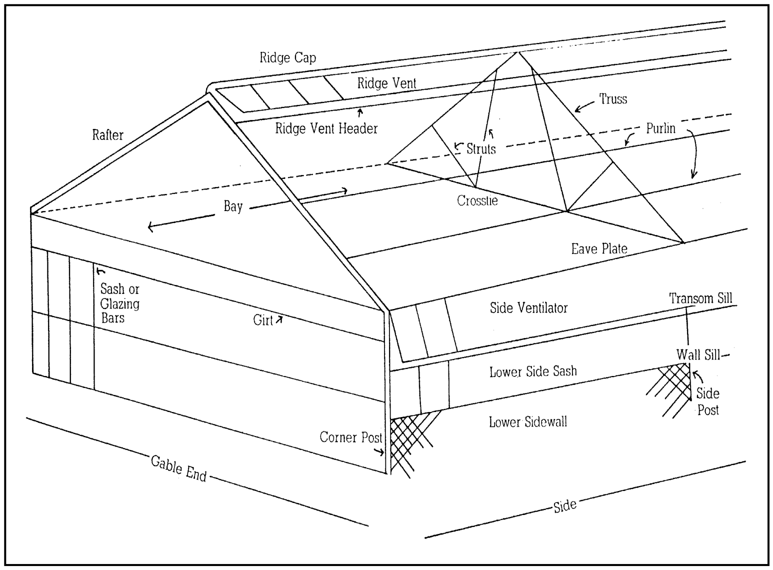
From "National Polytunnels" in Lancashire, England, cantilevered roof vent units are used. The vents are positioned on top of each roof span; the winch mechanisms can open five vents in a row.

Another innovation is a folding roof that can fold back into the gutter. One model, "Max Air," comes from National Polytunnels. An additional model is from Polybuild (Surrey, England) in cooperation with the Dutch company HCT.

Construction of a Growing Structure

The basic components of a greenhouse are illustrated in Figure 2.4.

Figure 2.4 - Parts of a Greenhouse



The owner has several decisions to make concerning how to frame the greenhouse: cost of construction and maintenance, strength of the structure, choice of covering materials, and amount of light blocked.

The framing materials may be used alone or in combination. If *wood* is used, it must resist decay. Some trees (e.g., ash, birch, cottonwood, hickory, and pine) are naturally resistant to decay even when untreated and have an average expected life of 15 years. Other trees such as redwood must be treated with either an oil-based or a waterborne, salt-type preservative that is safe for plants. The wood must NOT be treated with chemicals that emit toxic fumes to plants (e.g., creosote and pentachlorophenol, known as PENTA). Painting preservative-treated wood with light-reflecting, white, water-based paint provides further protection.

A better choice of framing material is *aluminum* alloy because it is flexible, durable, affordable, and long lasting. It is a versatile metal, able to conform to various shapes and thicknesses, and can be molded into the desired framing structures.

Steel or iron can also be used for the support structures. Wood and iron create a solid framework that provides strength and stability.

Selecting covering materials entails several factors: style of greenhouse; durability in withstanding snow, wind, and extreme temperatures; cost of construction and maintenance; type of framing that can support the cover; and availability of materials. Other considerations are how the covering affects the interior environment in terms of heat retention, light penetration, light diffusion, condensation potential, and static electricity charge.

Heavy, tempered *glass* is traditionally used because it is strong, inexpensive to maintain, offers excellent light transmission, and is long lasting. But it requires a heavier, more costly framing structure and is also breakable.

Polyethylene film is another type of covering. It is lightweight, flexible, easy to install, and can be supported by a lightweight frame. This film transmits light as well as glass and has the added advantage of using a lighter frame for support. However, plastic film is susceptible to weather damage, accumulates dust so repeated rinsing is needed, and requires frequent replacement.

Other options for covering greenhouses are *rigid plastic panels*, typically made from polycarbonate, fiber-reinforced polyester (FRP; fiberglass), and polymethyl methacrylate acrylic (PMMA). To prevent ultraviolet light from deteriorating the rigid covering, a stabilizer is required. Unfortunately, the stabilizer compromises the strength of polycarbonate. PMMA is tough, light, and durable in the weather. However, it turns yellow and loses its strength under extended exposure to the outdoors. Of all the plastic coverings, FRP lasts the shortest amount of time and requires frequent replacement. FRP transmits approximately 80-90% of the light that glass does.

In general, rigid plastic covers are lightweight, sturdier than film, and durable. However, they can be damaged by the elements over time, which means they must be replaced every 10-20 years.

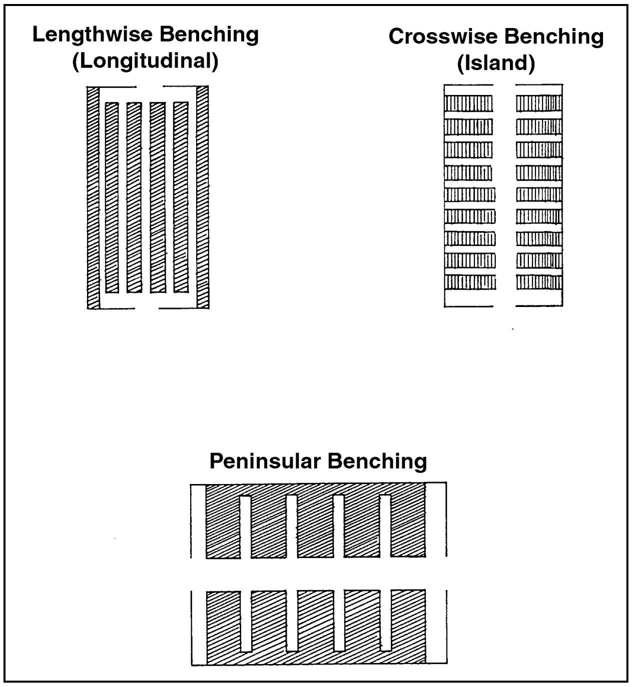
Interior Parts of a Greenhouse

The interior layout depends on two major factors: how the greenhouse is used (for wholesale or retail purposes) and what type of crop is grown. For a wholesale operation, the arrangement of equipment and buildings should facilitate the work flow so materials and labor can move smoothly through the production process. Maximizing all available space increases production and profit. By arranging plants close together, narrowing the width of the aisles, and placing the benches close together, the owner can use all available space. Hanging plants from the ceiling saves space and promotes a 1/3 increase in sales.

A retail operation also requires an efficient flow of materials but additionally focuses on whether customers can move easily throughout the greenhouse and have access to the merchandise. Important features include placing special displays and the cash register in a convenient location and creating an aesthetic shopping environment. Wide aisles and generously spaced plants invite browsing and promote sales.

The three common layout designs for benching are lengthwise, crosswise, and peninsular as seen in Figure 2.5.

Figure 2.5 - Interior Layout of a Greenhouse



Lengthwise benching is used for cut flowers grown in ground beds and potted plants. The long benches force workers to walk all the way to the end to get to the other side. This reduces efficiency. However, this type of benching supports water and heating lines without hindering walkways.

Crosswise benching uses space more efficiently because the center aisle allows access to each individual bench. This layout is useful for bedding plants and container-grown plants.

Peninsular benching is used for various container-grown plants, starter plants, flowering annuals, and other plants designed for home garden beds. This layout is best suited for retail operations because it provides easy access to plants and more area for growing plants.

The flooring must accommodate equipment and work flow and provide proper drainage. Bare ground is not acceptable because of the risk of pathogens and difficulty in providing drainage. Flooring can be constructed from concrete, including drain basins and slope toward drains, or it can be made from gravel. A weed mat covered with gravel is porous enough to allow the water to drain.

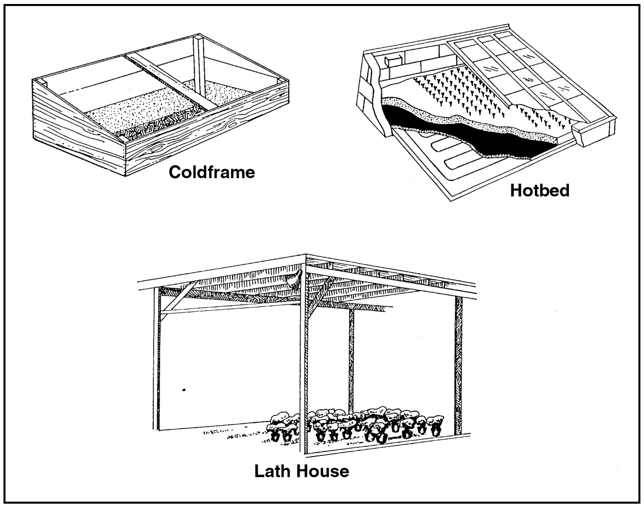
Benches must be sturdy enough to support the amount of plants. Raised benches should provide air movement between the plants, allow water drainage, and separate the plants to prevent spreading diseases and insects. The three types of benches are fixed, movable, and rolling. The movable benches can be put outdoors in favorable weather and used for double-crop production. (One crop is placed on the floor and second bench is moved outdoors.) Rolling benches maximize use of floor space, use less aisle space, and are intended for wholesale use only.

Benches are made from wood, concrete, metal, or plastic. Wood promotes good air circulation but decays eventually. Concrete is very durable but is hard to move and usually expensive. Metal does not require maintenance but is expensive and has rough edges that must be smoothed. Plastic is very light and easy to clean but is expensive and may not be available in the desired size.

Other Structures and Areas in Commercial Greenhouse Operations

In addition to the greenhouse itself, the greenhouse owner can use three other types of outdoor growing structures: coldframes, hotbeds, and lath houses, as illustrated in Figure 2.6.

Figure 2.6 - Other Outdoor Growing Structures



The coldframe is covered with transparent glazing material. The sun is its only source of heat. The top is opened during the day and closed at night. Coldframes are used to harden and protect plants from frost and to store bulbs during winter.

The hotbed also has a transparent covering, but its heat source is steam, hot water, or electricity. Hotbeds are used to start seedlings and cuttings.

The lath house is covered with wooden slats (laths) or shade fabric and supported by vertical poles. The pieces of laths are spaced about 1 inch apart to reduce light intensity and provide shelter from the wind. The sun is the sole source of energy. This structure is used during the summer where the temperature is warm or year-round in warm climates to propagate tropical plants and plants needing shade.

Additional areas used in most commercial greenhouse operations include workspaces for soil mixing and propagation, storage areas, roadways, and loading and shipping areas. Retail operations typically have parking lots, display areas, rest rooms, offices, break room, and kitchen area.

Summary

Building a growing structure for a greenhouse operation presents the owner with several important decisions. Site selection involves climate, topography, available resources, land, marketing decisions, and legal issues. There are several different types of growing structures to choose from, depending upon the scope of the operation.

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UNIT II: THE GROWING STRUCTURE

Lesson 2: Environmental Control

Various environmental factors influence greenhouse operations. This lesson addresses types of environmental controls found in the greenhouse. It examines how temperature is monitored and controlled; how to keep a greenhouse warm, ventilated, and cool during appropriate times; and how to control the humidity. Equipment used in irrigation is also discussed as well as the effect of carbon dioxide and light levels.

Types of Environmental Controls

Several natural elements must be controlled in a greenhouse: temperature, humidity, water, light, carbon dioxide, pests, and diseases. These factors can be manipulated through one of three basic methods: manual, automated, or an integrated control system. If a greenhouse owner manually controls a thermostat, he or she has to physically move the setting. If that thermostat is automatically controlled, the setting is triggered mechanically; the greenhouse owner would not touch it at all.

The integrated control system provides analog and computer systems and multiple sensors throughout the greenhouse. It senses and controls air and soil temperature, light intensity, relative humidity, and carbon dioxide levels. It also records data for evaluating and troubleshooting and provides data for planning future crops.

Monitoring and Controlling Temperature

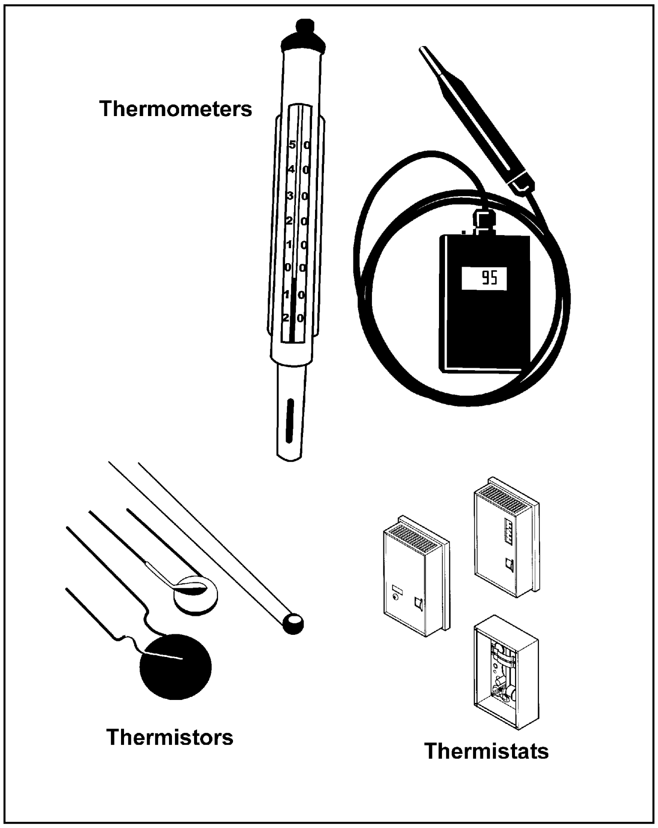
Before selecting a temperature control system, a greenhouse owner has to consider the cost of equipment, which includes installation and maintenance. To enhance plant growth, the system must also provide uniform control throughout the greenhouse by minimizing hot and cold spots and providing horizontal airflow.

The temperature control system regulates temperature extremes to suit the needs of the entire operation. To be reliable, this system should have a backup emergency generator and an alarm that signals when a power failure occurs so that the owner will know when any outages threaten the operation.

Selecting the type of fuel to run the temperature control system depends on cost, availability, storage requirements, and means of transporting the fuel to the greenhouse.

Several kinds of devices are used to monitor and control air temperature: thermometer, high/low thermometer that measures during the day and night, or thermostats that provide on-off control and step control (stages). Aspirated thermostats (drawing air by suction) read the temperature of air blown across the thermostat and are a more accurate control than standard thermostats. Thermistors are electronic semiconductors that sense even subtle temperature changes and signal the controller. Figure 2.7 illustrates these monitoring devices.

Figure 2.7 - Devices to Monitor Temperature



The monitoring devices should be level with the plants throughout the greenhouse, shaded from direct sunlight, and away from cooling fans.

Keeping a Greenhouse Warm During Cold Weather

Heat loss occurs in three ways. Through conduction, energy is lost through the materials that cover the greenhouse. Air infiltration permits heat to escape through leaks in the greenhouse's coverings, doors, and windows. Radiation occurs when warm objects emit energy that passes through the air to colder objects but does not warm the surrounding air to any degree. To protect plants in the greenhouse, all lost heat must be replenished. Heat should be energy efficient, reliable, and safe.

Heat is measured in Btu - British thermal units; 1 Btu raises 1 lb of water 1^oF. A typical boiler needs 33,475 Btu. This guideline may affect the owner's selection of fuel in terms of cost and availability.

Solar energy provides only some heat. The greenhouse collects and stores the energy from the sun that passes through the covering during the day. This heat warms the plants and other objects inside the greenhouse. The heat that is radiated back does not have enough energy to pass back through the covering (causing the "greenhouse effect"). Heat is retained at night (the amount retained varies with the type of covering). Solar heat alone is not sufficient for greenhouses in most northern climates. An additional source of heat must be provided.

Heating equipment includes unit heaters, central heaters, and radiant (infrared) heat. Infrared light warms surfaces (plants, soil, benches, etc.), not the air. Air is warmed only by heat radiated from surfaces. Emergency generators also provide heat. Generators, fueled by gas or fuel, provide supplemental power if an outage cuts off the electric fans that are essential to most heating and cooling systems.

There are three basic types of heat distribution. In forced hot air, the heat comes from burning several types of fuel, such as natural gas. The heat is distributed throughout the greenhouse and ventilated outside to prevent buildup of air pollutants. Mounted on the ground or overhead are horizontal discharge unit heaters that push the air through perforated polyethylene tubing that hangs above plants. In addition, vertical discharge unit heaters fans are mounted overhead and they move the air downward. The unit heaters use horizontal airflow (HAF) fans that help distribute the heat evenly.

Hot water is piped through the greenhouse by metal piping that is placed along walls and under benches. The temperature is variable. A circulating pump moves the water.

Steam heat distributes steam through the greenhouse by metal pipes, but the temperature is not as variable as with hot water. Steam heat carries more heat and moves farther than hot water heating.

Coal, kerosene oil, propane/natural gas, wood, and electricity are examples of fuel sources that can heat a greenhouse. Price and availability are determining factors. Electricity is generally not an efficient fuel for most commercial greenhouse operations.

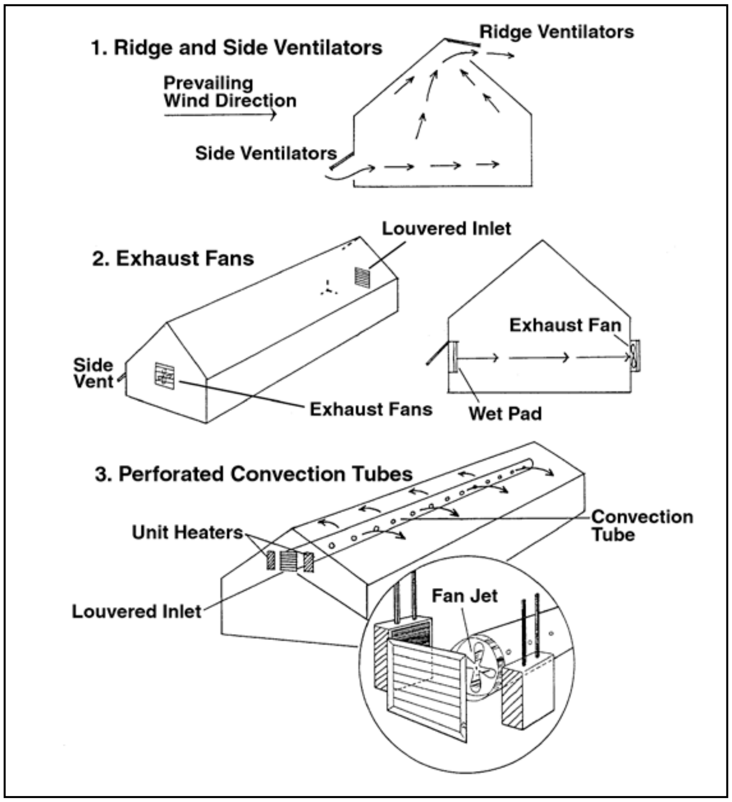
Ventilating a Greenhouse

Venting is important. Any heating system that burns fuel can be lethal to humans. When oxygen is deleted from the air, this shortage creates carbon monoxide - a gas that is fatal to humans. Impurities in fuel (e.g., ethylene gas and sulfur dioxide gas) and incomplete combustion can create other toxic fumes. To ensure safety, fuel-burning heat sources must be vented to the outdoors through a chimney. A ventilation system must be installed to bring fresh air into the greenhouse. Air circulation is essential to the heating process. Air-mixing fans push the rising hot air back down to the plants.

The purpose of greenhouse ventilation is to bring fresh air into the greenhouse and reduce temperature and relative humidity. Excessive humidity causes condensation. If condensation is left on plants, the risk of plant disease increases. Ventilation helps replenish carbon dioxide (CO_2), a necessary ingredient in plant growth that is consumed by plants during photosynthesis.

Types of ventilation include ridge and side vents that have a chimney effect and operate automatically or manually. Exhaust fans on sidewalls and endwalls draw in fresh air and are most beneficial in late spring, summer, and early autumn. Motorized louvers let in fresh air. Fans mix air with inside air then distribute air through a convection tube. The convection tube (running the length of the greenhouse overhead) distributes air through the perforated openings. See Figure 2.8.

Figure 2.8 - Methods of Ventilation



Cooling a Greenhouse During Warm Weather

The simplest way to cool a greenhouse during warm weather is to provide an even flow of cool air and reduce light intensity. The methods of providing cool air include ventilators/ vents, forced air ventilation, and fan and pad systems. In the fog system, water is forced through tiny nozzles to create a fine mist, and the evaporated water cools the air. Mechanical air conditioning systems are not efficient cooling methods for most commercial greenhouse operations

Shade fabric helps reduce light intensity. The fabric is available in a woven polyethylene cloth and also in a knitted polyaluminum cloth called “Aluminet”; both can be obtained from greenhouse suppliers. The weave densities determine how much light is shaded out. The densities range from 20 to 90%. The percentage approximates how much the light intensity is decreased. For example, a 55% shade fabric blocks or excludes approximately 55% of the ambient (surrounding) light. The owner selects the desired density for the operation. The fabric reduces heat best when the cloth is draped on the outside of greenhouse but it should be arranged so it does not interfere with ventilation.

Shade paint also helps diminish light. It is a diluted, weak-binding latex paint that is sprayed on the outside of the glazing, usually twice yearly. Typically, it wears off gradually during the summer and fall. But it can also be washed off easily with soap and water. The paint should be removed before winter to prevent light reduction during that time of year.

Another method for reducing light is to install wooden, plastic, or plastic-coated blinds and to mount them on the outside of the greenhouse, just like the shade fabric. Alternatively, adjustable blinds can be mounted inside. A final technique for reducing light intensity is to install thermal screens on ceilings and walls.

Controlling Greenhouse Humidity

Relative humidity (RH) measures how much water is dissolved in the air at a specific temperature. It is the ratio of how much moisture is actually in the air at a given temperature compared to the maximum amount possible without condensation. RH is expressed as a percentage. The ideal range of RH for most greenhouse plants is 45-85%. Greenhouse peppers thrive at 75%RH; African orchids prefer 40-60% RH. For roses, the ideal RH is 80%.

If the RH is above 85%, water may condense on plants and increase the risk of fungal pathogens and diseases. (However, cut tulips and cut daffodils should be stored at over 90% RH.) If the RH is below 45%, stunted plant growth or leaf burn may occur. More watering is required. (Yet succulents and cacti do best in 5-15% RH.)
To maintain proper RH, the greenhouse owner can use shading to reduce temperature and light as well as cooling pads (evaporative cooling). By keeping the greenhouse filled with plants, humidity is maintained because plants generate RH. Do not water plants late in the day and ensure that the greenhouse floor drains well.

To maintain the proper humidity level, install a fan in the greenhouse and set its timer to start operating at 9:00 p.m. or 10:00 p.m. for 30-60 minutes. This exchanges moist, warm, inside air with moist, cool, outside air. This enables the heating system to warm the air to its set point, which reduces the level of water in the greenhouse.

Open the roof ventilators to let the hot air escape. (Maximize the exchange of air by having wide roof ventilators and a double row of sidewall ventilators.) This prevents moisture from increasing and also prevents water vapor from condensing on plants, which can cause the spread of diseases.

Installing fans for ventilation during late spring, summer, or early fall introduces cooler outside air into the greenhouse. This helps sustain the proper humidity level. During late autumn, winter, and early spring, introduce air into the greenhouse through perforated polyethylene tubes. This prevents harsh, extremely cold outside air from harming plants. When cold air leaves the tubes, it mixes with warm greenhouse air, thereby preventing plants from suddenly getting chilled. Exhaust fans exchange greenhouse air with outside air.

Irrigation Equipment

Irrigation methods use either manual or automatic equipment. Manual irrigation systems use handheld hoses and wands. Automated irrigation systems use the following equipment:

- Mist systems
- Spaghetti tubes controlled by timers
- Drip emitters
- Ooze tubes
- Water loop
- Capillary mat system
- Ebb and flood system
- Boom system
- Spray stake/nozzle system
- Fertigators

See Unit IV, Lesson 3, for a discussion of how equipment and systems are used to irrigate greenhouse crops.

Controlling Carbon Dioxide

Carbon dioxide is essential for plant survival. Plants consume CO_2 during photosynthesis, so the CO_2 levels drop during this process. If the greenhouse is tightly closed, it does not allow any exchange of air. Lost CO_2 must be replenished. Ventilation and light restore some carbon dioxide, but a CO_2 generator is especially effective in enriching the greenhouse.

Carbon dioxide generators provide a maximum amount of CO_2 with a minimum amount of heat as a by-product. The generator has a timer that regulates when to introduce CO_2 into the greenhouse. The recommended time to add CO_2 is at sunrise or when artificial lighting is turned on. The time to discontinue CO_2 enrichment is during dark hours. The amount of CO_2 that should be added into the greenhouse is quantified in units called “parts per million” (ppm). The average recommended level of CO_2 is 1,000-2,000 ppm.

The CO_2 generator operates by burning propane or natural gas. A thermocouple monitors the pilot light. If the pilot flame goes out, a safety valve closes to prevent unburned fuel from releasing into greenhouse. It is best to purchase a large generator rather than a small one. Large generators allow the greenhouse owner to set a shorter cycle time. A shorter cycle time adds CO_2 into the greenhouse more efficiently.

Controlling Light Levels

The amount of light intensity needed in a greenhouse depends on the plant. Intensity of available light is measured in foot-candles (f.c.), which range from 500 f.c. on an overcast winter day to 10,000 f.c. on a clear summer day. (Unit IV, Lesson 1, provides more details on foot-candles.) Environmental factors that affect light intensity are geographic location, season, time of day, pollution, and cloud cover.

Light intensity can be read by a light meter or a computerized photocell. Light intensity can be increased or decreased to meet the plant’s requirements.

Light intensity/day length can be increased with supplemental lights such as fluorescent lights or high-intensity discharge lights. Using black material to block plants from light decreases light intensity/day length. Putting plants under a bench reduces exposure to light. Spraying a shading compound on the growing structure and placing a shade cloth above plants or over the growing structure also decrease light intensity.

Summary

Temperature, heat, ventilation, relative humidity, irrigation, levels of carbon dioxide, and light intensity must be regulated within the greenhouse. Careful monitoring of these environmental controls helps promote crop yield and profit for the greenhouse operation.

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UNIT II: THE GROWING STRUCTURE

Lesson 3: Energy Conservation and Environmental Protection

This lesson describes several greenhouse modifications and procedures that the greenhouse owner can implement to conserve energy and protect the environment.

Greenhouse Modifications and Procedures Used to Conserve Energy

Optimizing natural light intensity minimizes the need for supplemental electric lighting. This can be accomplished by preventing large trees, buildings, etc., from shadowing growing structures. Painting interior surfaces (benches, frames, etc.) with white latex paint also brightens the greenhouse and intensifies the available light in the room. Do not use an oil-based paint. To maximize heating and cooling efficiency, it is wise to invest in high-quality heating, cooling, and ventilation systems. An energy-efficient system that uses economic, available fuel saves money and power.

Routine maintenance ensures optimal efficiency. It is important to get rid of debris in all parts of the system, calibrate the thermostat properly, and create energy-saving structures. The greenhouse owner should also check the growing structure for air leaks and ensure that vents and fan louvers seal tightly. Other preventative measures include sealing holes or cracks in the greenhouse covering and installing weather stripping around doors, windows, etc. Protecting the greenhouse from harsh weather is extremely important. During winter, the north-facing side needs insulation. Creating windbreaks helps protect plants from harsh weather. Whenever needed, high-intensity light bursts should be screened out. Also, installing thermal blankets inside the walls and roof helps conserve heat.

Greenhouse Modifications and Procedures Used to Protect the Environment

When constructing and operating a greenhouse, the owner should follow all government regulations. The structure's design or modifications should minimize the use of hazardous pesticides and other chemicals. Use the least toxic method of controlling pests. To ensure an optimal environment for plants, lower the humidity to reduce the risk of disease. Installing a humidity control system helps regulate the amount of moisture in the greenhouse. Providing adequate spacing for plants facilitates growth.

To prevent pests from entering the greenhouse, place screens over vents, construct screened entryways, and isolate and inspect all new material upon arrival

The owner can prevent the development of runoff pollution from water-fertilizer solutions by carefully designing or modifying the greenhouse site and its structures. A suitable location helps protect the integrity of the environment if it offers good drainage and an irrigation system that can be recycled.

Summary

The greenhouse owner should implement techniques that conserve energy and protect the environment. Various modifications, such as optimizing interior lighting and painting the interior with white latex, minimize the need for supplemental electricity. Installing a humidity system regulates the growing environment and enhances plant development.

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