GREENHOUSE STRUCTURES

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Floriculture crop production differs from other types of horticultural crop production in that it utilizes a structure called a greenhouse. A greenhouse is nothing more than a building that is covered with a material that allows light to reach the plants inside. It also serves as a barrier to the outside environment so that the inside environment can be controlled. This is a very simple view of the structures we call greenhouses. What you will find out though, is that greenhouse structures have come to be very sophisticated. This sophistication allows growers of floriculture crops to produce many types of crops, of high quality, on a very timely schedule.

TYPES OF STRUCTURES

Styles of greenhouses vary widely. How they are built and what they are built with is often the result of factors such as budget, material availability, area of the country, crops to be grown and long term use. There are three basic styles of greenhouse: lean-to, even span and ridge and furrow.

Lean-To Greenhouse

Lean-to greenhouses have one side attached to a building. The building supports the roof at the ridge. One might look at this style of greenhouse as half of an even span greenhouse. Such greenhouses are best located on the south side of a building for maximum exposure to the sun.

Even Span Greenhouse

These are single houses that have roofs with an even pitch and an even width. They have pitched roofs like a house with straight sides and two gable ends. This type of structure is what one usually envisions when the word greenhouse is mentioned. The framework is usually made from wood, aluminum or steel. The covering tends to be permanent or semi-permanent material like glass or structured sheets.

Hoop houses have evolved from the even span greenhouse style. Hoop houses are constructed from bent tubular pipe for the framework, which is then covered with some type of plastic. Hoop houses are low cost alternatives to even span structures. Hoop houses are often used as temporary holding houses or long term growing structures. Many growers utilize hoop house structures as a way of economizing on structures while still being able to grow an excellent product. Hoop houses would require recovering with plastic every 3-4 years.

Ridge and Furrow Greenhouse

This type of structure consists of a number of even span greenhouses connected along the length of the house. All shared walls are eliminated giving you more growing space. These houses are sometimes called *gutter connected* because gutters are installed where the houses are joined to help move water. It is best to site ridge and furrow greenhouses in a north-south direction to help reduce the amount of shadows cast by the gutters.

Another greenhouse style that is a modification of the ridge and furrow house is a style called *Venlo*. Venlo houses are ridge and furrow hoses where the gable ends are very narrow. This narrow gable end allows for the use of narrower bars and wider, single pains of glass to be used on the roof. This type of construction allows for a very high percentage of winter light to reach the crop. Venlo structures are a product of Dutch horticulture where they are used widely in Holland. Many northern U.S. growers are now using this type of structure where reduced winter sunlight tends to be a limiting factor in growing some crops.

GREENHOUSE FRAMEWORK

Frameworks provide the support for the covering material. This framework needs to be strong yet narrow enough to permit maximum light with the fewest shadows. Wood such as

redwood or cypress was the material of choice for many early structures. Wood requires costly maintenance in the form of painting, however. Today's greenhouses are made from aluminum, aluminum/steel combination or galvanized steel. All of these are long lasting and maintenance free.

GREENHOUSE COVERINGS

The covering on a greenhouse is also called *glazing*. The factors that go into selecting a glazing material are cost, durability, light transmission and heat loss. When glazing a greenhouse, three types of materials are available: Polyethylene, structured sheets and glass.

Polyethylene (Poly)

Polyethylene is the number one covering and is used on the majority of all new greenhouses built today. It is nearly always a double sheet that is blown 3-6 inches apart by a small "squirrel cage" blower fan. The air space that is created provides for great insulation. A good, tight fitting inflated poly house will use about 1/3 less fuel than a single glass roof structure. This tight fit can have its drawbacks though. Poly houses can't "breath" and this results in very high humidity levels. The high humidity encourages fungal diseases, especially *Botrytis*. Also, double poly-covered greenhouses reduce the light levels to 75%-80%. In the winter, this can be a factor in crop production.

Much of the poly being used has a useful life of 3-4 years. The greenhouse is then recovered because the poly starts to break down due to the effects of UV light.

Polyethylene coverings are constantly improving. Manufactures are now able to address issues such as excessive dripping inside poly houses, breakdown by UV radiation and heat retention. In the case of heat retention, infrared (IR) poly is able to diffuse sunlight, giving the house more available light and keep the heat (infrared energy) in. Plants use visible light for photosynthesis, so this diffusion helps plant growth.

Glass

Glass is probably the third choice of glazing material. Glass is the top of the line glazing material because of its light transmission capabilities and long life. When glass is used, several types can be selected. Most glass for greenhouses is double strength B (DSB) glass. Also available are *triple strength, tempered triple strength and low-iron glass*. The last type permits more and better light transmission

Structured Sheets

Structured sheets can be made from three materials*: polycarbonate, acrylics* and *fiberglass*.

Polycarbonates are the most widely used structured sheets. They are manufactured as twin walls held together by ribs and looking almost like corrugated cardboard. The hollow tubes that hold the sheets together offer an effective dead air space that provides insulation and helps reduce heating costs. Polycarbonates offer good light penetration, up to 80%. Polycarbonate sheets are treated with UV inhibitors, which gives them a useful life of about 10 years. They are also very flexible being able to be bent around hoop houses. Polycarbonate coverings also have good hail damage resistance and fire resistance. Polycarbonates can be expensive, costing about 0.75 - $1.00 per sq. ft. as compared to glass which costs about 0.60-0.65 per sq. ft.

Acrylic structured sheets are made the same way polycarbonate sheets are made. Thus, they offer similar insulation value. Acrylics offer better light transmission, up to 86%. Acrylics last about 8-10 years. Acrylics are less flexible than polycarbonates and are more prone to damage by hail. They also tend to burn easier.

Fiberglass was widely used in the 1960's and 1970's. Its use has declined significantly due to newer materials such as the polycarbonates and acrylics being made available. Fiberglass has a tendency to discolor after about 8-10 years reducing light transmission greatly. It also burns very easily and has no great insulation value.

RETRACTABLE ROOF GREENHOUSES

Retractable roof greenhouses are becoming more popular with commercial growers. These structures have entire roofs that can be opened and closed. Retractable roof greenhouses are designed for crops such as bedding plants, perennials and field grown cup flowers that would prefer to be outdoors but can't take the rain and cold early in the season. In this case, the entire roof can be open when weather conditions are favorable for growing and closed when the weather starts to get inclement. When needed, parts of the roof can be pulled back and folded up by electric motors. Entire roofs can be opened or closed in minutes. Woven poly-ethylene is used to cover retractable roof greenhouses. This type of poly is 6 times stronger than regular poly.

GREENHOUSE BENCHES

Benches are structures that hold the crop off the floor. In a production greenhouse, crops can be grown on benches, on the floor, or in beds. Benches provide several advantages:

- The crop is at a convenient height
- Allowance for good water drainage
- Good air movement around the crop

Benches can be made out of a variety of materials ranging from expanded aluminum, steel, plastic or wood. Bench construction can be very elaborate or simply the positioning of wood pallets on top of concrete block "legs".

In the early 1990's, many greenhouses converted to a style of bench called *rolling benches* which have now become the standard in many new greenhouse ranges. Rolling benches may be rolled several feet sideways either left or right. A typical greenhouse may have 4 benches and 4 walks. With rolling benches, they now have only 1 walk, which can be, positioned anywhere a grower wants simply by rolling the bench sideways. Large sections of rolling benches are designed to be easily moved, even when full, by one person.

The advantage to rolling benches is that growers can now use approximately 86%-88% of the space available compared to 62%-66% with standard fixed benches. This allows growers to produce about one-third more crop per year in their greenhouse.

CONTROLLING THE GREENHOUSE ENVIRONMENT

Greenhouses are becoming more and more complex. Managing the interior environment calls for controlling not only temperature but also irrigation, shade curtains, supplemental light, CO2 levels, mist and many other inputs. In order to accomplish the monitoring and control of systems, greenhouses rely on several types of controls. They include *thermostats, analog controls, computer controls and computerized environmental management.*

Thermostats are of two types: *on-off* and *proportioning*. Both are inexpensive and easy to install. On-off thermostats control fans, heaters and vents with a change in temperature. Proportioning devices provide continuous control of systems with temperature changes.

Analog controls utilize electronic sensors so that the operations of heating and cooling can be integrated giving better performance than with thermostats alone.

Computerized controls utilize micro-processors, which can make complex judgements based on information from sensors placed throughout the greenhouse.

Computerized environmental management offers the greatest flexibility. This system allows you to tie al of your equipment together giving you unlimited environmental options. These systems are based on using zones within the greenhouse. Each zone has sensors, which gathers and sends information to the computer to adjust the environment based upon certain parameters. Many growers now use some type of computer assisted environmental management. This allows the grower to do a better job of providing the optimum environment without the added worry of having to do it manually.

ENERGY AND SHADE CURTAINS

Energy curtains are automated "window shades" which are installed gutter to gutter and can be automatically opened or closed based upon light levels or temperature. Many modern greenhouses are now making use of curtains, which serve two main functions. First, they can help reduce light levels during the day providing some needed light shade for crops and, by pulling the curtains closed at sunset and opening them at sunrise, major fuel economies, up to 25%-30% can be realized.

The same type of technology is applied to short day curtains. The purpose of short day curtains is to reduce day length to trigger flowering in short day crops like kalanchoe, poinsettia and chrysanthemums. It is the same as the black cloth idea.

GREENHOUSE HEATING SYSTEMS

Three types of heating systems are used in greenhouses: *hot water, steam* and *forced hot air.* New greenhouse construction as well as those being remodeled, tend to use *hot water* as the source of heat. Modern boilers are small and very efficient. A hot water system consists of a boiler that heats the water and pumps that move it through pipes placed in the greenhouse. Pipes are generally placed under the benches, along the walls or buried in a porous concrete floor. Hot water systems have relatively low maintenance. Heat is also delivered evenly and can be adjusted as needed into zones for growing crops with different heat requirements.

Steam heat has been the standard method of greenhouse heating for a long time. Boilers tend to be very large and require more maintenance. The boiler brings water to the boiling point providing steam. Steam flows through pipes, condenses and the water returned to the boiler. Steam heat does not tend to be as uniform as hot water nor is it easy to adjust temperatures. Steam heat can be an advantage though in that it can be used to sterilize soil for greenhouse use.

Many small growers as well as new growing operations rely on low cost *unit or forced hot air heaters.* These units are hung in the greenhouse and, depending on the size of the greenhouse may require several units positioned in the greenhouse space. Air is heated within the units and blown by fans throughout the greenhouse. In order for the heated air to be distributed most efficiently, growers use large perforated poly tubes and *fan jets* to collect the hot air and move it the entire length of the greenhouse. They may also use *horizontal airflow fans (HAF)* to move the heated air in the greenhouse. These fans are hung from the ceiling and are positioned to blow air in one direction down one side of the greenhouse and in the opposite direction down the other side of the greenhouse. This effectively sets up a circular air pattern moving heated air around the greenhouse. An advantage of the fan jet or HAF system is that they can be used without turning on the heaters. This can provide for air movement during warm days helping to cool the greenhouse as well as reducing conditions (warm, moist, still) that enhances disease.

Infrared heating is another system that is used in greenhouses and it is similar to how the sun heats the earth. Infrared systems are mounted in the peaks of the greenhouse. Energy is reflected directly down to the crops below. The plants, soil, benches and floor absorb the heat and transfer it to the plants and air space around them. The plants and soil are kept at the desired temperature but the air in the greenhouse peak is kept much cooler. Infrared is most cost effective in the taller greenhouse structures that are now being built.

GREENHOUSE COOLING AND VENTILATION

The main form of cooling and ventilation in greenhouse is done through the use of *vents.* Vents are located along the ridge of the greenhouse and along the sidewalls. When temperatures get too high, motorized vents are activated and open to allow hot air to escape. The design of newer greenhouses has lead to whole roof sections being able to be opened resulting in maximum ventilation.

Many greenhouses utilize cooling systems called *fan and pad systems*. These systems involve the use of a "wet wall" of cellulose pads installed along one side or in the end wall of the greenhouse. The pads are kept wet by a system of pumps and gutters that recirculate water. On the opposite end of the greenhouse is a series of fans. The fans are sized correctly so they pull air through the pads and across the greenhouse. As outside air passes through the pads, the water evaporates and as it does so it is cooled. This cool air is pulled across the greenhouse lowering the temperature inside. Air is the coolest closest to the pads, warming up as it exists. The amount of cooling possible with fan and pad cooling varies with the dryness of the air. This changes not only by location in the country but also the time of the year.

Some greenhouses combine both vents and fan and pad cooling. Initial cooling is done with vents open and when the temperature starts to rise, the vents shut and the fan and pad system is turned on.

AUTOMATION

There has been a revolution of sorts in the greenhouse business as many growers are utilizing technology to reduce the amount of human labor inputs when it comes to the most repetitive, labor intensive tasks. The labor required to fill pots, flats, seed, transplant, space, move plants, water, harvest and package is costly. Labor alone can account for about 30%-35% of production costs. Technological developments have allowed greenhouse growers to utilize computers and robotics to grow more and better crops with less human handling.

The technology found in today's greenhouses can be a marvel to watch. Large greenhouse ranges filled with hundreds of thousands of plants and only a few employees managing them to sale. Growers are now using automatic pot and flat fillers, automated precision seeders and transplanters, mechanized tray systems to move whole benches of plants at the push of a button. Robots that can space plants and also grade them for the most uniform product are being used in today's greenhouses.

All of this is not without cost. Automatic seeders can cost from $4000 - $30,000, transplanters $65,000 - $120,000, and pot fillers from $15,000 - $28,000. Growers have found that even though costs are high for such equipment, the savings in labor and increased production can justify such investments. Not every grower can afford to install such equipment. This does not mean they will not be successful in the greenhouse business. They may find a product, market or niche that allows them to be successful still using a conventional labor force.

GREENHOUSE GROWING MEDIA AND FERTILITY

The health and quality of floriculture crops rest largely with the growing media and how it is handled nutritionally. In outdoor gardening the growing medium is soil. In greenhouse production a variety of materials are used as growing media. Most medium used in greenhouse production today consists of a mixture of two or more materials. These materials are other things besides soil. Soil is being used less frequently now than ever before. Growers are using more media that has no soil at all. These media that lack any soil are often referred to as *soilless mixes*. Soilless mixes are the standard of the industry today. The one big advantage is that they are uniform and can be produced with a high degree of consistency. Growers either purchase prepared growing media in bulk or mix their own. Materials that are often components of soilless mixes include sand, sphagnum peat moss, coir, vermiculite, pine bark, perlite, plastic foam beads, and rock wool. When combined in the right proportions these materials are able to provide and excellent medium for growing plants. The decision as to which materials to use is often a matter of cost, availability and grower preference.

Peat moss is an organic material harvested from bogs in Canada, Michigan and Florida. Peat has good moisture retention, good air space qualities, and good capacity to hold on the nutrients.

Coir is made from waste products of the coconut industry. It has similar qualities as peat.

It has high water holding abilities and excellent drainage. It also encourages faster rooting of plants.

Vermiculite has its origins in the mineral mica. When heated, mica expands like an accordion. Vermiculite has good water holding capacity and good nutrient holding capacity.

Perlite is a volcanic rock that is also heated resulting in particles that look like tiny white beads. It is very light weight and is a good substitute for sand. It provides good water drainage and good aeration. It has very little ability to hold on to nutrients.

Bark is a by-product of the timber industry. Pine bark is most often used in growing medium. After being composted it is incorporated into mixes and provides moisture holding ability and aeration. It is the second most used component after peat moss.

Sand is the result of weathered rock. It is heavy and helps to improve drainage and aeration in mixes using soil. When used in peat or bark based media it can actually reduce aeration and drainage because it fills up all of the pore spaces.

Plastic foam is styrofoam beads. It does improve the drainage and aeration but it does little to improve water holding or nutrient holding capacity.

Rock wool is made from the rock called basalt. After heating it and causing it to liquefy, it is spun into fibers that look like cotton candy. Rock wool is often used in the propagation phase of growing where it is pressed into cubes and used for the rooting of cuttings.

FERTILIZERS IN THE GREENHOUSE

There are basically two ways fertilizer can be delivered to greenhouse crops. One is through the use of water-soluble fertilizers with an injection system where crops are fertilized each time they are watered (fertigation). The other method is through the use of slow release fertilizers.

Fertilizer injection systems are standard equipment in greenhouses. There are many types on the market but they all work basically the same. A concentrate fertilizer solution is mixed in a stock tank. The fertilizer injector has a pick up hose that is put into the stock solution and when the water is turned on, fertilizer is metered into the water line by the injector providing a very precise measured rate of fertilizer to be delivered. Nutrients in the fertilizer solution are measured in terms of parts per million (ppm). Growers can refer to tables, the injector of the fertilizer bad to determine how much fertilizer needs to be added per gallon of concentrate to deliver a certain ppm.

Slow release fertilizers consist of a water-soluble fertilizer held inside of a plastic resin or sulfur coating. The coating is designed to allow small amounts of nutrients to be released each time the crop is watered. Slow release can be used with a injected fertilizer program but usually one or the other is used. The trend is toward the use of fertilizer injectors in the growing of greenhouse crops.