CHAPTER 12

GREENHOUSE CONTROL SYSTEMS

INTRODUCTION:

*Once a greenhouse structure is built various techniques, devices, etc. must be added in order to control the environment.

*Control systems include those for lighting, heating, cooling, relative humidity and carbon dioxide enrichment.

LIGHT:

***Importance:** Maximum light transmission, of the appropriate quantity and quality (photosynthetically active radiation, 400-700 nm), through the greenhouse structure to the plants is crucial for optimum photosynthesis, growth and yield.

***Structural considerations:**

- Large sections of glazing material (glass, polyethylene, polycarbonate, etc.), held in place by few supports, results in higher light levels and less shading.
- Minimize other opaque structures above the crop that would cause shading such as heaters, carbon dioxide generators, opaque vents, etc.

***Too much light:** Occurs in high light regions such as the desert southwest USA (including Arizona), Mexico, Spain, Israel, etc. during the summer months.

- **Shade paint/white wash**: A mixture sprayed on the outside of the greenhouse. This will either wear off by the end of the summer or it can be washed off.
- **External shade cloth**: Fabric cloth, placed on the outside of the greenhouse, made of varying degrees of mesh size to exclude specific amounts of light (ex.: 30%, 40%, 50% shade).
- **Internal shade cloth**: Fabric cloth, as above, hung inside the greenhouse.

***Too little light:** Occurs above/below 30^0 north/south latitudes during the "winter".

- **White reflective ground covers**: These are now in common use in commercial greenhouses in all locations and can significantly increase light levels to the plant canopy.
- **Artificial lights**:
  - Used above 30^0 north/south latitudes to extend the winter growing season.
  - Provide day length control (photoperiod) that can initiate plant processes.
  - Provide proper timing of light to control growth (photomorphogenesis).
  - Typical lamp types include incandescent, fluorescent, mercury vapor, high pressure sodium and low pressure sodium.
  - Artificial lighting COSTS MONEY! Therefore, choosing a location that minimizes the use of lights increases profits. Artificial lighting is most cost effective for "transplants" since they require less space.

HEATING:

***Importance:** Each plant species has an optimum temperature range. Heating devices will maintain the temperature within that range during periods of cold weather.

***Types of heat loss from a greenhouse**

Conduction = Heat transfer either through an object or between objects in contact. Conduction depends on area, path length, temperature differential and physical properties of the object(s).
Example: Heat loss through the glazing material on the greenhouse.

Convection = Heat transfer by the movement of warm gas or liquid to a colder location. Convection depends on temperature differential.
Example: Movement of warm air near the plants upward toward the roof.

Radiation = Heat transfer between separated objects. Radiation occurs from all objects and depends on the areas, temperatures and surface characteristics of the objects involved.
Example: Heat transfer from all objects in the greenhouse.

***Heat loss calculations**

It is important to be able to estimate the heat loss from the greenhouse in order to choose the correct size of heater to replace that heat.

Although radiation and convection transfer heat around the greenhouse, the main type of heat loss from a greenhouse is through conduction, i.e., the heat loss through the glazing material.

Conduction heat loss can be estimated:

Q = U A (Ti – To)

Where:
Q = conduction heat loss in Btu's (British thermal units) (also, the size of the heating unit needed)
U = heat transfer coefficient: Btu/hr*sq.ft.*deg F temp diff
A = surface area (sq. ft.) of greenhouse glazing not ground
Ti-To = temp req'd inside–lowest temp expected outside

Typical U coefficients for glazing materials:

1.14	Btu/hr*sq.ft.*deg F	Glass, single layer
0.65	"	Glass, double layer, ¼" space
1.15	"	Polyethylene or other film, single layer
0.7	"	Polyethylene or other film, double layer
1.0	"	Fiberglass reinforced panel
0.6	"	Acrylic or polycarbonate, double layer

Ex:

A gable greenhouse	2 Sq ends = 2x8x24 =	384
Double layer acrylic	2 Triangle ends = 24x6 =	144
15 F – lowest outside temp	2 Sides = 2x8x48 =	768
65 F – required inside temp	2 Sq roofs = 2x48x13.42=	<u>1288.32</u>
	Total square feet =	2584.32

Q = (0.6) (A) (65-15)
= (0.6) (2584.32) (50)
= 77,529.6 Btu's/hr

***The basic system:**

Consists of a **fuel burner**, **heat exchanger**, **distribution system** and **controls**.
Heat delivery to the crop is by **convection** and **radiation**.
The fuel = usually burn **natural gas**, but can also use oil, coal, wood, etc.

***Heating by hot water or steam:**

Hot water or steam can be produced using boilers fired by natural gas, etc.
The hot water or steam is then transported throughout the greenhouse in pipes.
The pipes can end in a heat exchanger where a fan distributes heated air.
The pipes can run along the floor and also be used as cart rails between aisles.
  Heat will then rise upward through the crop by convection.
Heat pipes can also be positioned within the crop to steer plant growth (Ch. 3).
Heated tubes can create "bottom heat" for propagation or growing.

***Heating by hot air:**

Fuel is burned to heat air that is then distributed by fans around the greenhouse.
  Horizontal air flow (HAF) fans circulate warm air above the crop.
  Fan jet systems, with unit heaters or heat exchangers and perforated polyethylene tubes, distribute warm air and improve air movement and ventilation throughout the greenhouse.

***Moveable nighttime insulation:** Insulating material (cloth or film curtains) can be positioned above the crop or near the roof to retain heat near the crop. The insulating material used during the night can be the same material used for shading during the day.

COOLING:

***Importance:**

High temperatures can be detrimental to plant growth.
High temperatures can cause such problems as
  Thin, weak stems or, as in tomatoes, stick trusses (thin, weak truss stems)
  Reduced flower size or, as in tomatoes, flower fusion and boat formation
  Delayed flowering and/or poor pollination/fertilization and fruit set
  Flower and bud/fruit abortion

***Cooling requirements and calculations:**

The National Greenhouse Manufacturer's Association 1993 standards =
  8 cubic feet per minute/square feet of greenhouse floor area OR…
  1 full greenhouse volume exchanged per minute in warm climates.
    CFM = height x width x length (i.e., volume)

Example: Using the greenhouse dimensions in the heat calculation example:

CFM = volume lower section + volume triangular top
 = (8 x 24 x 48) + (6/2 x 24 x 48)
 = 9216 + 3456
 = 12,672 cubic feet per minute => size fans/pads accordingly

***Passive ventilation systems:**

Shading: Shade cloth or shade paint/white wash, besides regulating the light intensity, can also help cool the greenhouse.

Ridge Vents: Vents in the roof of a greenhouse that allow hot, interior air to escape. The area of the vents should be 25% of the floor area.

Roll-up Side Walls: Can be used in flexible glazing (polyethelene film) single bay greenhouses where the side walls can be rolled up several feet allowing a natural horizontal flow of air over the plants. As with ridge vents, the area of the side wall vents should be 25% of the floor area.

Cooling Towers: Water cooled pads at the top part of tall towers cool the surrounding air which then drops displacing warmer air below.

Removable Roof: Recent greenhouse designs can include a roof that retracts completely for natural ventilation. This would allow for adaptation of greenhouse grown plants to outside conditions prior to movement outside.

***Active cooling systems:**

Fan and Pad: "Evaporative cooling" where air from the outside is pulled through porous, wet pads (usually cellulose paper). Heat from the incoming air evaporates water from the pads, thereby cooling the air. Evaporative cooling will also help to increase the relative humidity in the greenhouse.

Fogging Systems: Uses evaporative cooling like the fan and pad but incorporates a dispersion of water droplets that evaporate and extract heat from the air. This system gives better uniformity since the fogging is distributed throughout the greenhouse and not just near one a pad end as with the fan and pad system. The smaller the droplet size, the faster each droplet evaporates and therefore the faster the cooling.

Mist droplets = 1000 microns in diameter.

Air Conditioning: Too expensive for most greenhouses.

RELATIVE HUMIDITY: $\frac{\text{Amount of water in the air}}{\text{Amt. of water poss. at a given temp.}} \times 100$

***Importance:**

High or low relative humidity can be detrimental to plant growth.

Effects on transpiration – When RH is too high, transpiration (the movement of water from inside the leaf to the outside) is reduced along with movement of mineral nutrients. When RH is too low, transpiration may be increased significantly resulting in plant wilt.

Effects on pollination – When RH is too high, the pollen can clump on the stigma causing cat facing or the pollen may not be released from the anthers at all. When RH is too low, the normally sticky stigma can dry out and the pollen may not stick to it's surface, decreasing pollination.

Note that many greenhouse crops are bred for higher humidity conditions. If those same crops are grown outside, in lower humidity environments, they usually perform poorly.

***Ways of controlling RH in the greenhouse:**

Relative humidity can be increased by running the cooling pads or by fogging.

Relative humidity can be decreased by running the heaters or simply venting.

CARBON DIOXIDE ENRICHMENT:

***Importance:**

The rate of photosynthesis is dependent upon the availability of carbon dioxide.

Carbon dioxide enrichment is most important during the winter months in the morning. The sun has risen and photosynthesis has begun. The plants can reduce the levels of carbon dioxide from the ambient level of about 330 ppm (higher in cities due to industry and vehicles) to around 220 ppm.

Lowered carbon dioxide levels will reduce growth and can cause flower and fruit drop reducing overall yields.

***Ways of controlling carbon dioxide levels in the greenhouse:**

Ventilating (bringing air in from the outside) may provide sufficient carbon dioxide during the Spring, Summer and Fall months.

Ventilating during the Winter months, or anytime in cold climates, will, however, result in cold outside air being brought into the greenhouse. Heating will then be needed to maintain the proper temperature which may become uneconomical.

Therefore, carbon dioxide generation is a typical and effective way to increase levels in the greenhouse during the Winter or in cold climates. Carbon dioxide generators can burn various types of fuel including natural gas (most economical)or propane. Carbon dioxide levels above 800 ppm, even as high as 1200 ppm, have been shown to be beneficial to plant growth.

AIR CIRCULATION:

***Importance:**

One reason for having a greenhouse is to create a “controlled environment” for all of the plants. And each plant within the greenhouse should receive the same conditions. However, especially during times when the heating and cooling systems are not in operation, pockets of high or low temperature, relative humidity or carbon dioxide may develop which can be less than optimal for plant growth or flower/fruit development.

***Ways of improving air circulation:**

Horizontal air flow (HAF) fans can be placed in the rafters of the greenhouse to circulate air above the crop. This helps to minimize pockets of warm or cold air and high or low humidity or carbon dioxide within the greenhouse.

HAF fans can be used in conjunction with hot air heating systems (see above) to circulate warm air throughout the greenhouse.

HAF fans can also be used at anytime to enhance air mixing in the greenhouse.

ENVIRONMENTAL CONTROL SYSTEMS:

***Control systems can be very simple or very complex. Examples include:**

The "original" environmental control systems were manual:
- Manually rolling up a side vent.
- Manually opening a roof vent or door.
- Manually turning on a heater or cooler.

Simple controllers operate from a thermostat in the greenhouse and:
- Automatically set day and night temperature ranges.
- Automatically open and close vents (side, roof, etc.).
- Automatically turn on or off heaters and coolers.

Step controllers operate from a thermostat in the greenhouse and:
- Automatically set day and night temperature ranges.
- Automatically control 1 or 2 heating stages (depends on # of heaters).
- Automatically control several cooling stages using cooling fans and pump(s) to wet the pads.

Sophisticated computers operate from a temperature sensor in the greenhouse and:
- Automatically set day and night temperature ranges.
- Automatically control heating equipment including boilers, root zone heating, heat retention curtains, etc.
- Automatically control other equipment including HAF fans, exhaust fans, vents, pad pumps, fogger systems, etc.
- Automatically control relative humidity.
- Automatically control shade curtains and artificial lighting depending on light requirements.

Sophisticated computers can also monitor an external weather station and use data from that station to control internal conditions in the greenhouse.
- Data monitored includes: outside light, temperature, RH, rain and wind.

Sophisticated computers can also operate the fertigator system (see Chapter 8)
- Automatically using light quantity (e.g., X ml of solution/Y amt. of light)
- Automatically controlling timing of watering, duration of watering, nutrient solution pH and EC, misting, watering booms, etc.

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