An Environment System for Plant Studies with Controlled Temperature, Humidity, and Light

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Need for reliable information concerning the effects of environment on the response of plants to herbicides motivated the construction of the controlled environment system described herein. A unit suitable for such studies should have these general specifications: 1. a useful range of control of light, temperature, and relative humidity; 2. no recirculation of air, to avoid overall contamination of the unit by volatile herbicides; 3. capability of maintaining several sets of conditions simultaneously; and 4. a design which may be modified easily. The system described was constructed with these points in mind.

A schematic diagram illustrates the major structural components of the environment system (Figure 1). Outside air enters the cooling compartment, which is maintained at a suitably low temperature by means of a refrigerator-type air conditioner. The cooling compartment serves as a continuous source of air at a selected tempera-

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ture and relative humidity for the growth room. Four growth cabinets located within the growth room utilize the conditioned air. Control systems incorporated in the growth cabinets condition the air to the temperature and humidity levels desired within each growth cabinet. Then the air is passed over the plant material and exhausted from the system.

**Cooling system.**

The cooling compartment consists of a 250-cu. ft. plywood box insulated with glass wool. A 22,000-B.T.U., refrigerator-type air conditioner mounted in one end cools and thoroughly mixes incoming air with that already present. An essential feature of the cooling process is the removal of moisture from the air. Recirculation of air within the cooling compartment greatly increases the effectiveness of dehumidification. When the temperature of incoming air is 80° F. or higher, a minimum of 50° F. can be maintained in the cooling compartment. At temperatures below 50°, moisture freezes on the cooling coil, which eventually blocks the flow of air through the coil. When outside temperatures are below 80°, lower temperatures can be attained in the cooling compartment because the cooling system operates intermittently and ice does not accumulate on the cooling coil.

**Connecting duct.**

An insulated metal duct carries air from the cooling compartment to the growth room. An 8-inch, 3-speed fan and a heating unit are mounted in the duct. The fan facilitates the flow of air through the system. The heating unit, controlled by a thermostat mounted in the growth room, maintains the air temperature at the level desired.

**Growth room.**

The growth room is an insulated, 8-foot by 8-foot plywood box having a height of 4 feet (Figure 2). The top is covered with 3/16-inch transparent plastic (Plexiglass). The front has openings for insertion of the growth cabinets. Conditioned air from the connecting duct enters the growth room through an opening at the rear. Two 10-inch fans circulate the air within to insure a uniform environment throughout the growth room.

The growth room serves three purposes: 1. It surrounds the growth cabinets with air of uniform temperature and humidity which insulates them from external fluctuations in temperature and humidity; 2. by means of the transparent top, it permits the use of an externally mounted illumination system which lessens considerably the amount of heat introduced into the air conditioned area, thus permitting the use of a small capacity, low cost air conditioner; and 3. it serves as a reservoir of conditioned air for the growth cabinets.

**Growth cabinets.**

Each of the four growth cabinets consists of a 3/4-inch plywood base with a 1/8-inch transparent plastic superstructure (Figure 3). Their dimensions are 7 feet long, 1 foot wide, and 21/2 feet high. The
Figure 2. Front view of the growth room. The four front panels of the growth cabinets support the fans, temperature-control breakers, switches, and pilot lights. Mounted above the panels are the live steam and electrical power sources. At lower left is the drain pipe which carries the steam condensate from the growth cabinets to a floor drain.

top is removable and plants are handled through this opening. The growth cabinets are mounted on casters, which facilitates insertion in and removal from the growth room when servicing is necessary. Each cabinet is equipped with temperature and humidity control systems with the necessary heating and humidification being accomplished within an insulated aluminum pipe, 5 inches in diameter. The pipe is mounted under the cabinet proper and also serves as an air intake. Air enters the rear of the growth cabinet from the aluminum pipe. It passes over the plant material and the recording and control instruments and is then expelled by a 6-inch exhaust fan mounted in the front of the cabinet. A complete air change within each of the growth cabinets is accomplished in slightly less than 15 seconds.

**Lighting system.**

The light source is composed of 52 cool white, Slimline fluorescent tubes, 8 feet in length, mounted on an 8-foot by 8-foot, 1/4-inch plywood panel. This panel is suspended over the transparent top of the growth room. The T-8 Slimline tubes are energized by T-12 lag lead ballasts mounted on a wall adjacent to the system. Six 150-watt,

*Lighting-system components suggested by M. W. Parker, Crops Research Division, A.R.S., U.S.D.A., Beltsville, Maryland.*
incandescent bulbs are mounted along the edges of the chamber to supplement the red portion of the light spectrum to assure light of a quality nearer to that of sunlight. Initially, the light intensity was 2200 foot-candles at plant level. After 1 year of operating time, the light intensity from the same tubes had fallen to 750 foot-candles. The necessity of systematic tube replacement is evident if the higher light intensity is desired. Differences in light intensity between the growth cabinets were less than 10 percent at both light intensities.

Temperature-control system.

Cone-type heaters are used throughout the system because of their low cost, ease of mounting, and the variety of sizes (15 to 660 watts) that are available. The large heating unit mounted in the connecting duct was built of a number of cone heaters mounted on a fireproof base. Some of the elements in this heating unit operate continuously, and the remaining ones are thermostatically controlled. This arrangement reduces the temperature fluctuations due to intermittent operation.

Inexpensive wafer-type thermostats designed for use in brooder stoves are used to control temperature.

Humidity-control system.

Relative humidity has proved to be the most difficult factor to control. Dehumidification is accomplished in the cooling compartment. The lowest humidity level is determined by the temperature of the cooling compartment and the temperature to which the air is heated in the growth cabinets. Live steam is utilized as a moisture
source in humidification. Steam is introduced continuously through the aluminum intake pipe at a rate just below that required for a given level of relative humidity. A final small part of the steam flow is controlled by a hygostat which operates a solenoid valve in the steam line. By the combination of continuous and intermittent steam flow fluctuations in relative humidity are minimized. Components of the apparatus used to control relative humidity are shown in Figures 2 and 3.

General operation.

In present operations, four growth cabinets are being used. However, a smaller number of larger cabinets or a larger number of smaller cabinets could be used with slight modifications of the openings into the growth room. Temperatures ranging from 65 to 100° F. can be maintained simultaneously provided polyethylene film dividers are used to partition the growth room. A relative humidity range of 20 to 100 percent is possible when the operating temperature of a growth cabinet approximates 85° F. The lighting system is operated manually; however, time switches could be installed. Variations in light intensity between individual growth cabinets may be effected by means of translucent or opaque covers. It is necessary to remove the tops of the growth cabinets to service the plants. The tops are secured by means of bolts and wing-nuts, which permit rapid removal and replacement.

For short-term experiments plants are grown in the greenhouse to the desired stage of development and then placed in the growth cabinets. For long-term experiments plants are placed in the growth cabinets immediately after germination and grown to the desired age or stage of development. Plants grown for two months in the growth cabinets produced normal growth.

Cost of materials for system.

Total cost of the system, excluding labor, was $2200. The costs of the materials, broken down according to the functions for which they were purchased, are as follows: Structural components of the system cost $600, of which $270 was needed to purchase the plastic used to cover the top of the growth room and construct the superstructures of the growth cabinets. The air conditioner cost $350. Lighting equipment cost $500. Fans for circulation of air and components of the heating system each cost $100. Humidification equipment cost $550.

Summary

An environment system is described which provides control of light, temperature, and relative humidity. Major features of the system include non-recirculation of air and capability of maintaining four sets of conditions simultaneously.

*The hygostat consists of a controller with remotely mounted electric sensing element.

* Mimeographed list of the source and cost of components will be supplied by authors on request.