SEEDLING-SIZE FUMIGATION CHAMBERS

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ABSTRACT

The design of fumigation chambers is described. Each chamber has individual temperature, humidity, light, and pollutant control. Temperature is variable from 15 to 35°C and controlled within ±1°C. Humidity is variable from 25 to 95 percent and controlled within ±3 percent. Seedlings have been successfully grown in these chambers for up to 3 months.

SINCE THE DISCOVERY that air pollution is a stress factor, many plants have been fumigated within enclosures of various designs, ranging from large outdoor chambers or greenhouses to small leaf chambers (Adams 1961; Berry 1970; Heagle, Body, and Pounds 1972; Heagle, Body, and Heck 1973; Heck, Dunning, and Johnson 1968; Hill 1967, Mandl and others 1973; Wood and others 1973). Each of the chambers was designed to meet a specific need that depended on the objectives of the researcher using it.

For our research we required a system of chambers both for fumigating forest tree seedlings for long periods of time at low concentrations and for fumigating large seedlings for short periods of time. The chambers needed to be environmentally controlled and equipped to regulate the concentrations of more than one pollutant.

The chambers described here meet these requirements and control temperature within ±1°C and relative humidity within 3 percent over a wide range of temperature and humidity. Light intensities range up to 2,800 foot candles and two pollutant concentrations can be controlled simultaneously from ambient to injury-causing levels.

APPARATUS

Chambers

The system consists of four plywood chambers, each 48 inches high, 48 inches deep, and 42 inches wide (fig. 1). The sides and bottom are made from 1/2-inch plywood. The front and back are framed with 1- x 6-inch boards set vertically to the bottom and sides. The openings in the front and back are closed by doors, each made of 1/2-inch plywood and held in place by eight horizontal-handle clamps. The seal between each door and the chamber is a gasket made from 1/4-inch i.d. Tygon[1] tubing glued to the chamber. The top of the chamber is covered with 5-mil Teflon[1] film held in place with furnace duct tape and wood cleats. The false floor in the chamber is 1/8-inch sheet aluminum supported 5-5/8-inches above the bottom of the chamber and has 1/4-inch holes in a 2- by 2-inch lattice. The inside of the chamber is painted with white epoxy paint to increase light intensity and prevent pollutants from reacting with the wood surface of the chamber. Each chamber sits on a wooden frame with the false floor of the chamber 36 inches above floor level.

Airflow system

The airflow system is a negative-pressure, single-pass system. The air mover is a high-pressure, belt-driven blower capable of drawing a static water pressure of more than 5 inches.

The blower is attached to a reinforced 8-inch furnace duct which is attached to each chamber by a 4-inch aluminum pipe that enters the chamber through the side but under the false floor. This section of pipe contains a butterfly valve to control airflow and an orifice plate with pressure-measuring taps on either side (Hinners, Burkart, and Punte 1968).

Air enters the chamber through two 4-inch aluminum pipes at the top of the chamber. The other end of these pipes are fastened to a sheet-metal plenum under the chamber. Each pipe has two pollutant inlets. The plenum contains a heater for warming the air, a steam inlet, and two 12- x 12- x 2-inch charcoal filters to clean the air. This plenum connects into another duct, common to all the chambers, and is attached to the outlet side of the air conditioning system. A particle filter is mounted on top of the air conditioning system to remove dust particles.

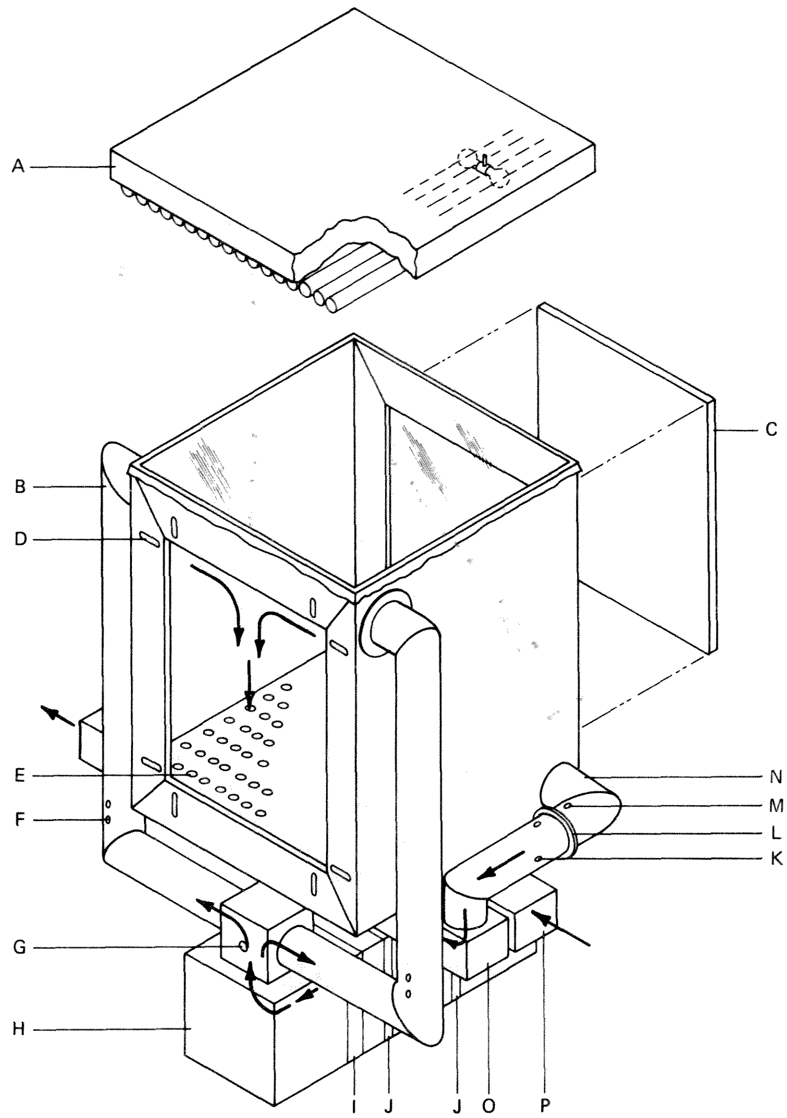
Air conditioning system

The air conditioning contains three individual compressor and evaporator coil units. The first is a 5-ton precooling system that lowers the temperature of the incoming air to about 5°C. The second and third units are 7.5-ton systems connected in parallel below the first unit. The air coming out of the second and third units at about -5°C causes them to ice up. They are alternately defrosted by passing hot gas through the evaporator coils. Each of the second and third units is large enough to supply cooled

[1] The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that may be suitable.

Figure 1. View of chamber:
A, Light bank
B, 4-inch inlet duct
C, Door
D, Horizontal handle clamp
E, False bottom
F, Pollutant addition port
G, Steam addition port
H, 12-inch inlet duct
I, Heater
J, Charcoal filter
K, Butterfly valve
L, Orifice plate
M, Pressure tap
N, 4-inch aluminum outlet pipe
O, Exhaust duct to blower
P, Inlet duct from air conditioner.

Arrows show direction of air movement.



air to the entire system, so defrosting one unit does not influence the temperature or humidity in the chambers.

Light system

Over each chamber is a bank of twenty-four 48-inch VHO cool white fluorescent bulbs and eight 150-watt incandescent bulbs. Each bank is controlled by a 24-hour timer.

Six different light intensities can be provided by turning out the fluorescent bulbs in groups of four and by dimming the incandescent bulbs with a rheostat. The fluorescent bulbs are switched off systematically so that as the light intensity is reduced it falls uniformly throughout the chamber.

Temperature control system

Temperature is controlled with set-point controllers connected to shaded thermocouples in the chambers. The controller electronically compares the chamber temperature with the set-point temperature and regulates the heat accordingly.

The temperature in each chamber is independent of the others. Temperatures are recorded continuously on a multipoint recorder. Each chamber also has a programer that can vary the temperature over a 24-hour period. Six 12-inch bar heaters with radiating fins are used to heat each chamber.

Humidity control system

Humidity is controlled in the same manner as temperature. Lithium chloride humidity sensors, mounted in the chambers, are connected to set-point controllers. The controller electronically compares the humidity in the chamber with the set-point humidity and opens or closes a motorized needle valve to increase or decrease the amount of steam added to the air moving through the chamber. The humidity in the chambers is monitored continuously with a multipoint recorder.

Pollutant addition system

Two pollutants can be added individually or in combination to each chamber. The pollutants move under slight positive pressure through Teflon tubing to a stainless steel shut-off valve, then to a stainless steel micrometering valve. The gases then travel through more Teflon tubing to the two 4-inch aluminum pipes that enter the chambers. The pollutants are added to the air stream about 5 feet before it enters the chamber to allow ample mixing.

The pollutant concentration in each chamber is monitored by pulling an air sample from the chamber through Teflon tubing and a stainless steel solenoid into a manifold with a metal bellows pump. The pollutant monitors are attached to the manifold to sample the air stream and record the pollutant concentration on a strip chart recorder. The monitors are changed from one chamber to another by a static stepper that opens and closes the solenoid valves on the sample lines from the chambers. The desired pollutant concentration is obtained by observing the strip chart recorder and adjusting the appropriate micrometering valves.

PERFORMANCE

The chamber system has performed very satisfactorily. The airflow system allows as many as two complete air changes per minute. The airflow rate was determined by measuring the airflow through the 4-inch exhaust line with a hot-wire anemometer. The rates are calibrated against the pressure drop across the orifice plate in the exhaust line and the desired flow maintained by measuring the pressure drop and adjusting the butterfly valve in the air outlet line. The system is usually operated at one change of air every 2 minutes.

The light intensity in the chamber at 12 inches above the floor ranges from 2,800 foot candles at full light to 800 foot candles at 1/6 of full light with new bulbs. The light intensity decreases approxiately 20 percent from the center to the corners of the chamber. Consequently in selecting an experimental design, plants must either be placed in a replicated block design or moved periodically to reduce the effect of the nonuniform light intensity.

Temperature control is within acceptable limits. The temperatures in the center of the chamber and in each corner at 6 and 18 inches above the floor were within a range of ±1°C. The temperature can be held constant at any temperature between 15 and 35°C. with the set-point controllers, or varies over a 24-hour period with programmers.

Relative humidity can be controlled at any value between 25 and 95 percent with a variation of ±3 percent at 23°C. This variation was found when the humidity was measured in each corner 12 inches above the floor. At low temperatures, a relative humidity of 25 percent cannot be maintained because air cooled to 5°C. and reheated to 15°C. has a relative humidity of 45 percent even without the addition of any steam.

Air pollutants can be added in a wide range of concentrations ranging up to levels that cause acute injury. The concentrations can be maintained with slight adjustments for long periods.

Seedlings have been grown in the chambers for 3 months. Leaf color was good and height growth was comparable to that of seedlings in growth chambers.

The chambers have functioned both as growth chambers and fumigation chambers. They could easily be modified by putting windows and glove-box gloves in the doors so that closure of stomata, photosynthesis, or other physiological processes could be measured during fumigation.

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