A HUMIDITY- AND TEMPERATURE-CONTROL CABINET FOR GROWING PLANTS [1]

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INTRODUCTION

The demand for experimental evidence on many problems requiring an accurate control of temperature and humidity prompted the construction of an apparatus in which growing plants could be placed under as nearly natural light as could be obtained under controlled conditions. In view of the fact that only the visible region of the solar spectrum and the near ultraviolet rays are used in the process of photosynthesis, as reported by Arthur (*1*) [2] and substantiated in the review by Popp and Brown (*5*), it seemed desirable to use glass in the construction, since the use of natural light would make a more nearly normal condition for plant development. Window glass transmits 90 to 95 percent of the total visible radiation of sunlight and absorbs only the extreme infrared and the ultraviolet beyond about 320 mμ. Neither of the regions absorbed appears to be of any appreciable significance as far as plant growth is concerned.

Cabinets to control humidity and temperature have been designed for use in laboratory experiments, but most of them are elaborate and expensive. Chace (*3*) and Carson (*2*) described methods of controlling humidity in small spaces by means of aqueous solutions of sulphuric acid. A feature of the cabinet designed by the present writers that was not used in those described in the literature is the utilization of sunlight instead of artificial light. This, however, made it more difficult to control the temperature, because of heat accumulation from the rays of the sun that penetrated the glass. Wilson (*7*) showed, however, that the relative humidity over any concentration of sulphuric acid is practically independent of the temperature. As pointed out in a previous paper by the present writers (*8*) the use of sulphuric acid is a very satisfactory means of controlling the relative humidity under similar conditions.

DESCRIPTION OF THE CABINET

A view of the cabinet designed by the writers is shown in figure 1. It is a double chamber constructed entirely of window glass except the floor and framework. The glass is sealed to the frame and floor, making it practically airtight. The mechanical equipment is enclosed below the chamber and fastened to the top of the refrigerator, on which the cabinet is constructed and from which cold air is used to aid in the temperature control. While the cabinet is a separate unit

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[2] Reference is made by number (italic) to Literature Cited, p. 507.

it was mounted above a low-temperature chamber (*6*) in order to have a supply of cold air for temperature control and dehumidification. Details of the construction and arrangement of the controls and mechanical equipment are shown in figure 2.

RELATIVE HUMIDITY CONTROL

Control of relative humidity is brought about by using an aqueous solution of sulphuric acid in the inside chamber. As shown in figure 2, the acid container, which is a lead trough, is built around the temperature controls, instrument stand, and the openings in the floor through which the plants are introduced into the chamber. The air-circulating fan is located in such a position that a current of air blows over

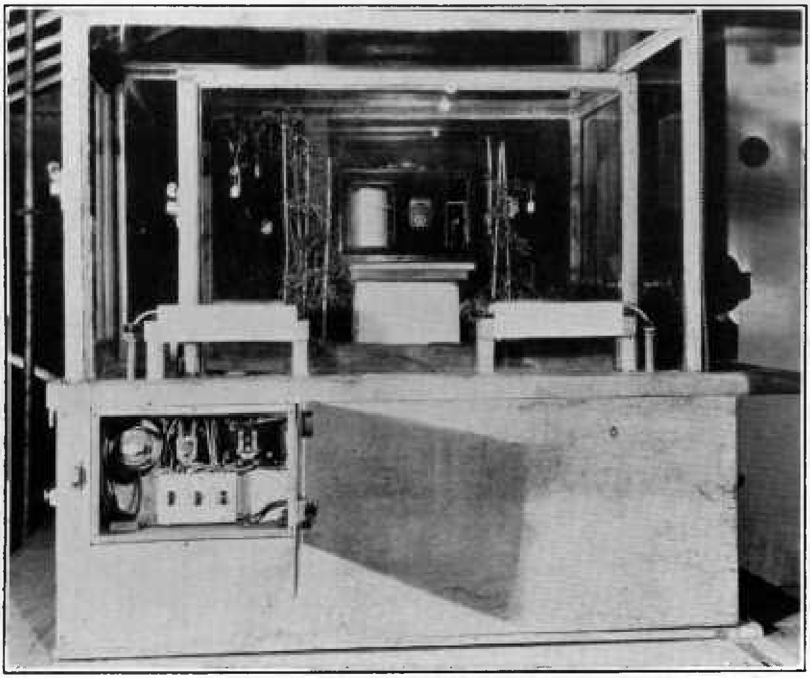

FIGURE 1.—Humidity- and temperature-control cabinet.

the acid on one side, agitates the surface, and causes a continuous flow of acid through the trough. This fan runs continuously, as it is used only for circulating air.

Different percentages of relative humidity are obtained by using different concentrations of sulphuric acid, since the amount of water evaporated varies with the concentration of the solution. Wilson (*7*) pointed out the advantages of this method for obtaining any desired relative humidity and worked out the physical-chemical theory of the calculations.

The cabinet is also equipped with a humidostat used for dehumidifying. Dehumidification is brought about by pumping dry air out of the low-temperature chamber into the cabinet. This was found necessary because of the moisture transpired by the plants. A rotary air pump with a capacity of 4.7 cubic feet per minute, driven by a motor, is used for this purpose.

TEMPERATURE CONTROL

The temperature is controlled entirely by radiation through the glass into the inner chamber. Two thermoregulators, one for the cold air and one for the heaters, are located in the inner chamber. No conditioned air for temperature control is introduced into the inner chamber, but as the temperature changes in this chamber, switches are thrown automatically to turn on or off either cold or hot air that is introduced between the chambers. This will raise or lower the temperature in the inside chamber, as the case may be, by radiation through the glass of the inside chamber. The thermoregulators are sensitive to 1-degree change in either direction and are

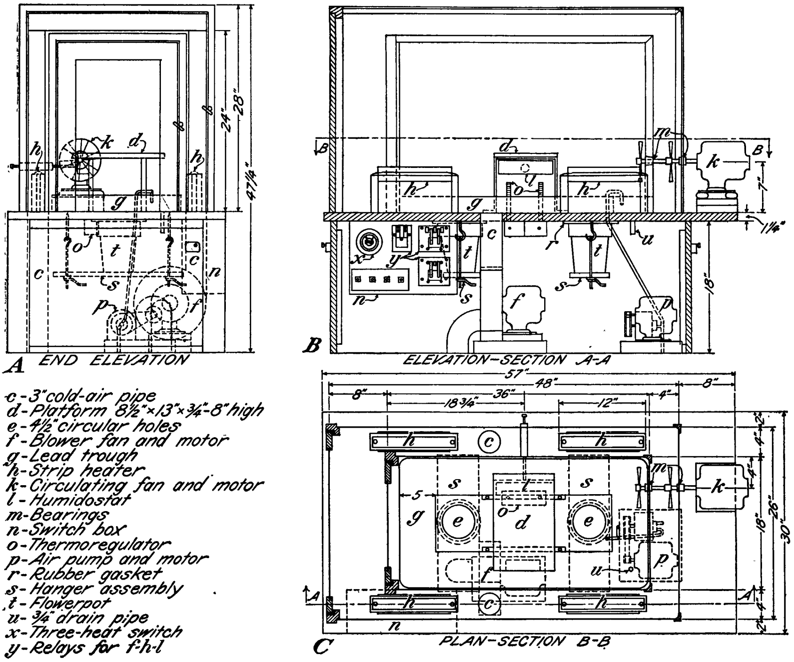

FIGURE 2.—Details of construction of the humidity- and temperature-control cabinet.

regulated to turn on the cold-air fan or the heaters as the temperature of the inner chamber fluctuates. The outer chamber is constructed around the inner chamber, with a 4-inch space allowed around three sides and the top and an 8-inch space in the end containing the door. Mounted on the floor of this intervening space are four 250-watt strip heaters hooked to a 3-way switch to supply 250, 500, or 1,000 watts. A blower-type fan mounted on a ¼-horsepower electric motor draws the cold air out of the refrigerator and blows it up into the intervening space. The air is brought in on one side and back to the refrigerator on the other. The connections are of 3-inch galvanized-tin pipes. In order to obtain a rapid distribution of the heat, as well as of the cold air, between the cabinets, and also to have a good circulation of air in the inner chamber, a ⅛-horsepower motor is mounted on the floor at one end outside of the cabinet and connected to a shaft on which are two fans, one in the inner chamber and one in the space between the chambers. The shaft is mounted 7 inches above the floor through 1-inch holes in the glass. Bearings placed in rubber stoppers hold the shaft in place.

DISCUSSION

The specific gravity of the acid used in a closed chamber is probably as accurate a measure of the relative humidity of the circulated air as any instrument devised for that purpose. In the operation of this cabinet the acid solution is placed in the cabinet and a few hours are allowed for the relative humidity to become stabilized. The recording hygrothermograph then is adjusted according to the graph worked out by Wilson (*7*) from the density of the acid. This may be checked at intervals by a hygrometer and psychrometric tables (*4*).

The cabinet is designed so that only the plants themselves are in the controlled temperature and humidity chamber. The pots are placed

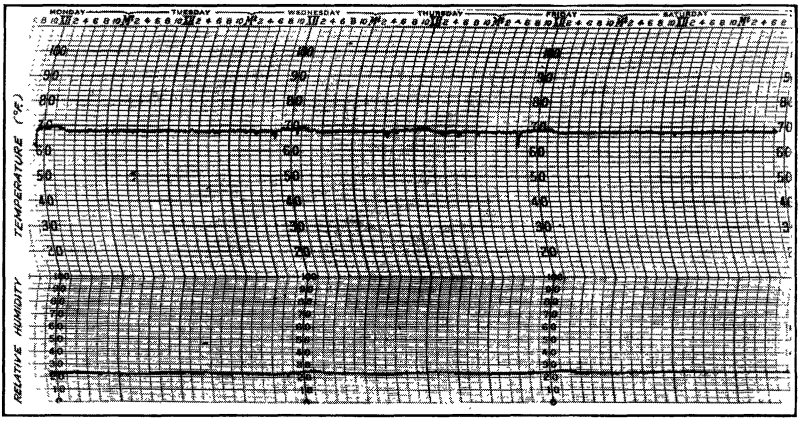

FIGURE 3.—Hygrothermographic record from the humidity- and temperature-control cabinet from Jan. 27 to Feb. 1, inclusive.

below, as shown in figure 2, *t*. There are two holes 4½ inches in diameter in the bottom of the chamber, through which the plants are introduced, and the pots are clamped tightly against the bottom and sealed by a rubber gasket. The clamps also hold a pan under the pot for watering. The trials have been confined to alfalfa plants, but by varying the method of sealing the pot almost any type of plant might be grown. Before a plant is placed in the chamber the soil in the pot is removed from around the crown and a rubber collar is tied tightly around the taproot and allowed to extend above the level of the soil. The soil is then replaced and the pot is sealed with paraffin. After the pot is sealed in this manner no moisture can get into the cabinet except that which the plant transpires.

After numerous trials it was found that during the day the moisture transpired by the plants was not absorbed by the acid as rapidly as the plants gave it off, and thereby the relative humidity was raised. Therefore, in order to maintain a constant humidity during night and day, dehumidification was necessary in the daytime, as previously mentioned. At night the humidity will reach the level determined by the specific gravity of the sulphuric acid.

Soil moisture is also a factor that may be controlled and used in conjunction with this chamber. With the proper set-up of plant containers and by the use of a balance the plants may be lowered onto the balance momentarily and brought back to weight by the addition of water through an opening in the paraffin seal. It has been noted that if the air-circulating fan is stopped very little change in temperature or humidity will occur when the holes through which the plants are placed are opened for a few minutes. The weighing and bringing up to weight can be done without entirely removing the plant from the chamber.

Figure 3 is a hygrothermographic record, covering a 6-day period, which shows the regulation of humidity and temperature obtained. The relative humidity as recorded on the chart indicates that the acid was diluted slightly by the water transpired by the plants. A check, made with acid hygrometers, showed this to be the case. However, such dilution may be balanced by adding daily a predetermined volume of concentrated acid. Other charts have been obtained at different temperatures ranging from 65° to 110° F. and with relative humidities ranging from 0 to 90 percent with just as good regulation in all cases except where the wet-bulb depressions are low. In that case the regulation is constant but the humidity shows a range of 2 percent owing to the condensation of some of the moisture on the glass, which is chilled as the cold air comes on. While the dehumidifier aids in keeping a constant humidity by quickly drying up the condensation on the glass, the lag of the instrument shows a somewhat wider fluctuation than actually occurs around the plants. Plants naturally transpire more rapidly in a dry atmosphere than in a wet one, so that the dehumidifier operates at longer intervals with the lower humidities than with the high humidities in use.

SUMMARY

A cabinet for the control of humidity and temperature, for use in agronomic experiments with plants growing under glass and exposed to natural light, is described.

Relative humidity is controlled by using an aqueous solution of sulphuric acid in the inner chamber of the cabinet.

Temperature is controlled entirely by radiation through the glass into the inner chamber.

The use of the cabinet may be extended to studies with soil-moisture control, thus providing equipment controlling three environmental factors that profoundly influence plant development. At the same time the plants are held under as nearly normal light conditions as it is possible to obtain under glass.

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