Colorado Flower Growers Association Inc.

IN COOPERATION WITH COLORADO STATE UNIVERSITY
Dorothy Conroy, Executive Secretary
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Preliminary Measurements of Flower Temperature

By Joe J. Hanan

To obtain uniform plant temperature control, the air temperature rise across a fan-and-pad house should be reduced as much as possible. Secondly, direct admittance of uncooled air into the greenhouse (summer conditions) should be avoided. Thirdly, air movement across red flower heads should never be less than 10 fpm or more than 100 fpm. Lastly, direct solar radiation during bright periods should be reduced--even in the winter if air movement across the flower is near zero.

Plant temperature in the greenhouse is usually controlled indirectly by modifying the surrounding air temperature. Unfortunately, we know that plant temperature seldom is equal to air temperature. Several things influence plant temperature. Among these are thickness and color of the plant, the position of the leaf in respect to incoming light, the amount of light, the rate of air flow, and the rate of water loss from the plant. An approach to determining actual plant temperature could be attempted by measuring the effect of major factors, and on the basis of this information, modify the plant's environment sufficiently to eliminate major differences between plant and air.

As a result of the development of the Tiros weather satellite, there are available instruments that permit the surface temperatures of remotely located objects to be determined without handling them (Fig. 1). Technically, they are called "radiation pyrometers" or "radiometers." The instrument used at CSU is also called an "infrared thermometer."[1] The

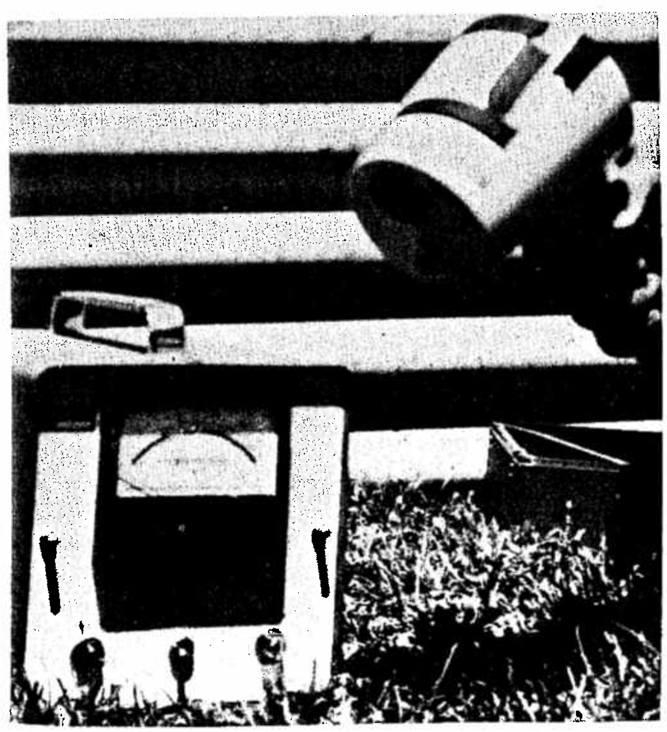

Figure 1: Infrared thermometer used in plant temperature studies. The part being held is the viewing head of the instrument, and is normally focused on the flower.

[1] A portion of the funds for purchase of this instrument and associated equipment was donated by the Kenneth Post Foundation.

thermometer measures radiation from an object in a selected wavelength in the infrared. Since intensity is a function of the temperature of the object being measured, the instrument can be calibrated to read directly in degrees.

For this initial study, open flowers were selected since they are relatively large and do not require support to hold them in position. The instrument is fitted with a 3° viewing head, which, when 18" away from the object being viewed, includes an area 3/4" in diameter. Where a flower was located in the bench, the instrument could be set on a tripod some distance away from the flower and only the flower would be in the field-of-view.

Beginning in December, 1964, surface temperatures of different colored flowers were measured over an 8-hour period during the day in a glass house. Figures 2 and 3 show information obtained for red and white carnations under comparable December light conditions. Air temperature was approximately 65 to 70F. Under these conditions, the surface temperatures of both red and white flowers markedly exceeded air temperature during the brightest part of the day. The differences between red and white were what might be expected since red would normally absorb more heat from the sun. On one or two days, red flower temperature occasionally exceeded 100F or 30° to 35° above air temperature. The effect of solar radiation can be noted by the sharp valleys where shadows from the roof bars passed over the flower.

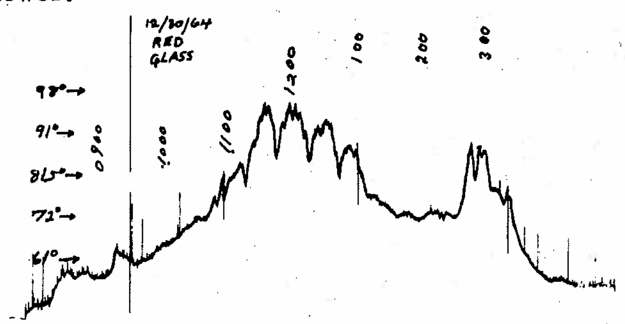

Figure 2: Constant record of red carnation flower temperature in a glass covered greenhouse on December 30, 1964. Note the sharp valleys caused by shading of roof bars.

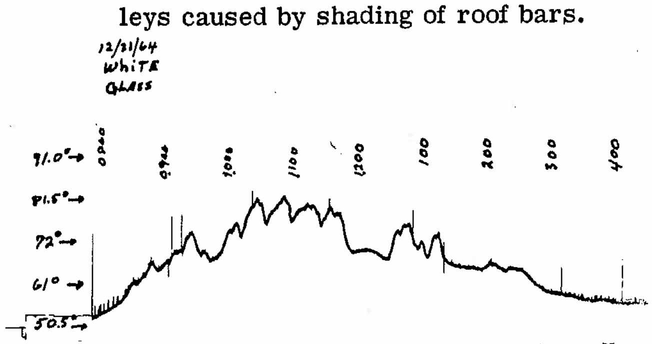

Figure 3: Constant record of white carnation flower temperature in a glass covered greenhouse on December 31, 1964. Valleys caused by roof bar shading not quite so apparent as in Figure 2. Clear day, greenhouse temperature about 65F.

These initial data indicated a requirement to control the major factors that influence flower temperature in order to obtain meaningful information. The box shown in Figure 4 was constructed. This set-up permitted air velocity to be controlled and measured. The interior was painted black so that only radiation coming directly on the flower would be measured and complicating effects of reflected light could be ignored. The flower was cut and placed in CS preservative solution in the box and the infrared thermometer focused on it. The entire box was then tilted until the direction of the sun's rays was perpendicular to the silicon cell light measuring device and flower. Light intensity was controlled by using various thicknesses of screening, fiberglass, and glass panels. Thermocouples were inserted into the flower at the top of the calyx and at the junction of the stem and calyx. A third thermocouple was used to measure air temperature.

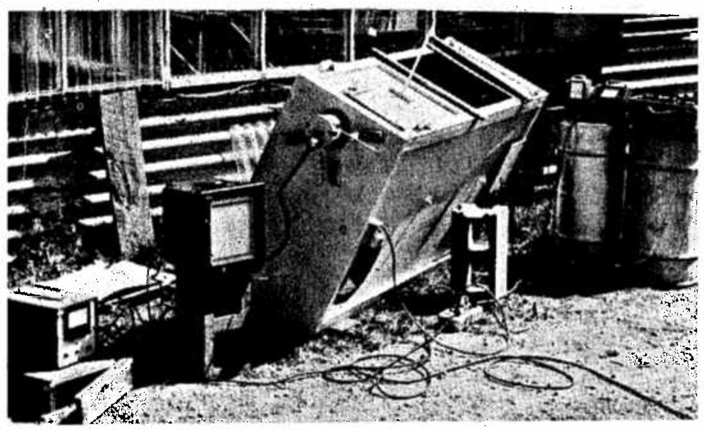

Figure 4: "Black box" constructed for the purpose of measuring plant temperature under controlled conditions. TOP: Carnation in position for measurement. On the lower right is an air speed meter. BOTTOM: Exterior of the box with infrared thermometer and recorder on left, supplementary equipment on the right.

By means of a computer program, the relationships between flower temperature differential (differences between flower and air) and air temperature, light intensity and air velocity were compared. Figures 5, 6, and 7 show the mathematically computed curves that best fit the data for fully opened, red carnation flowers. Figure 5 compares flower differential with light intensity at two different air temperatures and four air velocities. Under relatively high light levels and low wind speeds (less than 10 feet per minute), red flower temperature may be close to 90F or above when the air temperature in 70°. Figure 6 emphasizes the importance of maintaining air speeds above 10 fpm. A situation as this may prevail when the greenhouse is closed, with little air movement, and the day is clear. Figure 7 indicates that the warmer the air temperature, the less cooling

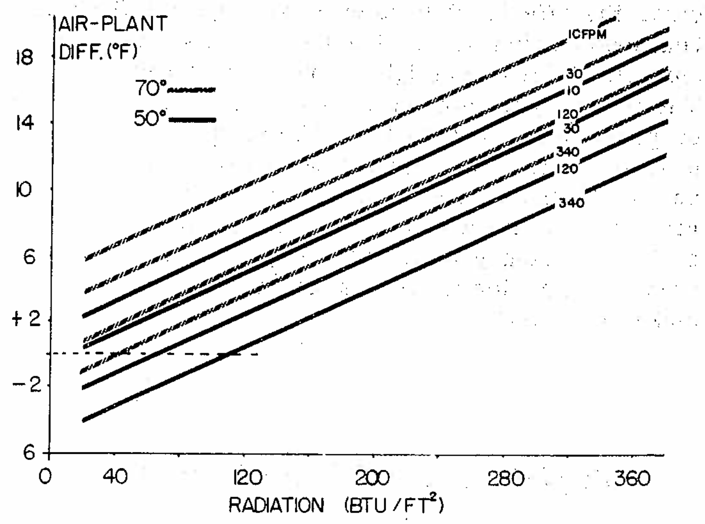

Figure 5: Calculated relationship between red carnation flower temperature and light intensity (radiation) at 2 air temperatures and 4 wind speeds. Air-plant diff. refers to the number of degrees the surface flower temperature is above or below the surrounding air temperature.

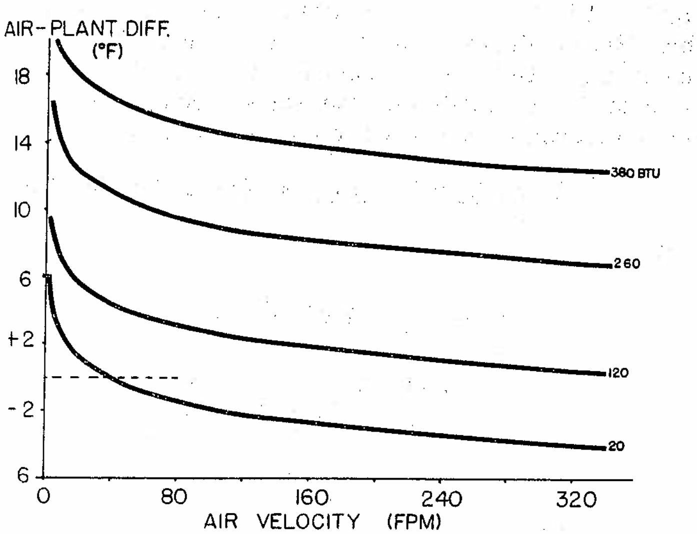

Figure 6: Calculated relationship between red carnation flower temperature and air velocity at 4 light intensity levels (BTU) at an air temperature of 70F.

is obtained at any given wind speed. The difference between plant and air temperature will increase as air temperature increases. The effect of increasing air temperature results partially from the decreased ability of air to absorb heat from the flower.

The relationship between air-plant differential and the three variables, radiation, air velocity, and air temperature, were not as high as expected. This indicated that there are other variables influencing flower temperature. The differences in temperature between the surface of the flower and the thermocouples inserted in the calyx indicated that heat was being conducted away from the flower to the lower

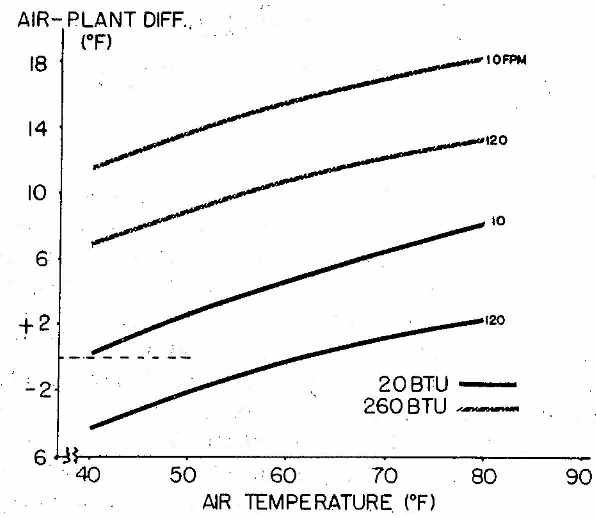

Figure 7: Calculated relationship between red carnation flower temperature and air temperature at 2 light intensity levels (BTU) and 2 wind speeds (FPM). At an air temperature of 40°, wind speed of 120 fpm and a radiation level of 260 BTU, the flower temperature is about 46°F. At 80° air temperature, radiation and wind speed the same, the flower temperature is 93°. At 40, the increase in flower temperature is 6°; at 80, the increase is 13°.

portion of the stems. Probably some of this heat was being used in evaporating water from the lower parts of the stem and calyx (transpiration), and other portions were being radiated to the walls of the box. It may be possible in future studies to account for this loss and to obtain better information on what happens to carnation plants in a greenhouse.

Summary

We may sum up the results by saying: 1) At zero or very low radiation levels, surface temperatures of red carnation flowers will be near or below air temperature provided air flow over the flower is in the neighborhood of 30 fpm. 2) As radiation level increases, red flower temperature will increase above air temperature, regardless of air velocity or air temperature. 3) At air speeds less than 10 fpm over the flower, flower temperature can be expected to increase drastically at all but the lowest light intensities. At velocities above 100 fpm, the decrease in flower temperature obtained is not sufficient to warrant the increased power consumption required to move the air. 4) As air temperature increases, the use of moving air to cool the flower becomes less efficient.