COLORADO FLOWER GROWERS ASSOCIATION, INC.

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Dorothy Conroy, Executive Secretary
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Temperatures in Carnation Flowers

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Preliminary results on red carnation flower temperature showed that about 69% of the variation in flower surface temperature could be accounted for by measuring: (1) radiation, (2) wind velocity, (3) air temperature and (4) fitting these values into a suitable equation (CFGA Bulletin 188). Measurements were continued during 1966 and 1967 with red and white flowers under a variety of greenhouse covers. The factors influencing flower temperature were found to be very complex, but permit explanation of many things that have been observed. In general, there were marked differences in flower temperatures between red and white flowers. Placing any type of greenhouse cover over the flower drastically changed its temperature. There were significant differences between covers. Due to problems with experimental control, insufficient measurements were made on many covers, and only comparisons between no cover, glass, clear fiberglass and PVC (polyvinyl chloride) are presented here.

Methods

Variously colored carnation flowers were placed in Cornell solution in a box in which air velocity over the flower could be controlled between zero and 500 fpm. The interior of the box was painted a flat black so that reflected radiation from the inside walls was ignored. The box and flower were then oriented to the sun so that when a cover was placed between the flower and the sun, the sun's rays were perpendicular to the surface of the cover and to the flower.

Solar radiation after it passed through the cover was measured with a silicon cell, calibrated in BTU per square foot (BTU/ft^2). Wind velocity was measured in feet per minute (fpm) and air temperature in degrees F. An infrared thermometer was focused on the top of the flower in order to measure the surface temperature. Temperature at the bottom of the calyx was determined by inserting a thermocouple at the junction of stem and calyx. The infrared thermometer was calibrated once monthly with a standard black body. Therefore, determinations of flower surface temperature required the assumption that differently colored flowers, under different covers, behaved as a black body. This has not been proven.

For any greenhouse cover tested, the radiation level on the flower surface was varied by placing layers of saran cloth over the cover. Wind velocity was then systematically varied from zero to maximum and back to zero, allowing one to five minutes between each step before recording data. Air temperatures were not controlled. At low wind velocities, radiant energy raised the temperature within the box above outside. As wind speed increased, air temperature decreased until it was equal to outside temperature. Thus, the range of air temperatures employed was limited, and there was considerable interaction between the three so-called independent variables of wind, radiation and air temperature.

In addition to the three variables mentioned above, color and type of greenhouse cover were two others. There were two dependent variables: (1) difference between flower surface temperature and air temperature and (2) difference between the flower surface temperature and temperature at the bottom of the calyx.

A relationship of each dependent variable with wind, radiation and air temperature was computed. Since the effect of wind was not linear, wind velocity was converted to logarithms. Depending upon flower color and other conditions, the amount of variation of each dependent variable that could be accounted for in the computer programs varied from 20 to 70%. White flowers were usually less affected than red flowers. If one or the other of the dependent variables (surface or differential temperature) was included in the multiple regression, over 85% of the variation in either surface temperature or temperature variation within the flower could be removed.

An increase in flower surface temperature would increase the flower temperature differential. Conversely, an increase in the differential would tend to lower the surface temperature. Therefore, no attempt was made to relate, by means of computer programs, the two dependent variables of flower surface temperature and flower temperature differential.

Results

Using the relationships determined by computer, Fig. 1 shows the effects of radiation on flower temperatures at wind speed of 10 fpm and an air temperature of 72 F: while Fig. 2 shows the effect of wind speed at a radiation level of 200 BTU/ft^2 and a 72 F air temperature. The effects of wind or radiation on white flower temperatures, compared to red flowers was relatively slight. Placing a cover over a red flower markedly increased flower surface temperature and increased the difference in temperature between top and bottom of the flower. These differences may be explained on the basis of balance between radiation absorbed and emitted by the flower. A red flower will absorb more incoming, short wave, visible radiation than a white flower. On this basis alone, the temperature of a red flower will be higher than a white flower. However, all objects at normal temperatures will re-radiate long wave, infrared energy. It so happens that both red and white flowers probably emit long wave radiation equally well. Thus, a white flower will lose heat by radiation at the same rate as a red flower. Glass, fiberglass and PVC do not readily transmit this infrared radiation. Therefore, the loss of heat by long wave radiation to space from a flower is reduced when such a cover is placed over the flower. This would account for the much higher temperatures of red flowers under any of the covers tested. If white flowers had been examined under no cover, the results would likely have been similar.

Although flower temperatures were increased under all covers, there were significant differences between covers as to the effect of radiation or wind velocity. For example, the effect of radiation on red flower temperatures was less under fiberglass than under glass. That is, at a wind speed of 10 fpm and 72 F air temperature, increasing radiation from 80 to 320 BTU/ft^2 under glass increased the surface temperature of red flowers from 80 to about 96 F. The same change under fiberglass increased the surface temperature from 85 to 93°–a change of 16 and 8° respectively. There was a similar behaviour in the temperature difference between top and bottom of the flower (Fig. 1–*Lower*). The effect of radiation under a PVC cover was intermediate to fiberglass and glass covers.

The greater effect of wind velocity (Fig. 2) under a cover might have resulted from the fact that the higher temperatures naturally resulted in more heat being removed by conduction and convection than by infrared radiation. It should be emphasized that the wind velocity curves are plotted logarithmically. As shown in Bulletin 188, the lines are curved, and as wind velocity decreases, the flower surface temperatures and differences between top and bottom increase more and more rapidly. Beyond a wind speed of 100 fpm, the effect of increasing velocity was relatively slight. Below 10 fpm, the effect was very great. As with radiation (Fig. 1), changing air velocity (Fig. 2) had less of an effect on white flowers than on red flowers. For a white flower, under a cover, the temperature of the flower was usually close to that of the surrounding air, with the difference between flower top and bottom temperatures (Fig. 2–*Lower*) usually less than 5° at all wind speeds. But, with red flowers, under cover in bright sun, the difference between top and bottom of the flower was 18° at 10 fpm and about 11° at 100 fpm. Calculations showed that this differential could exceed 26° under bright sun and wind speeds less than 10 fpm.

Numerous statistical analyses were run on the data. The relationships were complex. In some instances, the experimental error prevented statistically significant differences (i. e. lack of air temperature control). A number of tentative conclusions might be made, however:

1. Wind velocity and air temperature are the primary methods of controlling flower temperature under a cover, since the cover eliminates the loss of heat by infrared thermal radiation. As the flower temperatures are higher under a cover, the effect of wind velocity is greatly enhanced.
2. The relationships between air temperature, flower temperature, color and greenhouse cover are better illustrated by means of a table comparing flower surface temperatures, assuming 200 BTU/ft^2 and 100 fpm:

	Air Temperatures			
	50 F		72 F	
		Diff.		Diff.
Glass cover				
Red flower	60	10	80	8
White flower	48	- 2	73	1
Fiberglass cover				
Red flower	64	14	82	10
White flower	61	11	77	5

   The table shows that lowering the air temperature will usually increase the difference between flower and air temperature, and this effect is greater under fiberglass than under glass. The results suggest that fiberglass is less transparent to infrared radiation than glass. Or, there exists the possibility that since fiberglass intercepts more of the sun's energy than glass, its temperature will be higher. Therefore, fiberglass will re-radiate more heat to the flower than will glass. The temperature of different covers, and its relationship to flower temperature, is a subject that apparently has never been fully studied. Flower temperatures under fiberglass will usually be higher than under glass if all other conditions are equal.
3. Increasing radiation did not increase white flower temperatures significantly under fiberglass, but it did under glass.
4. The influence of radiation, wind and air temperature on flowers under PVC is intermediate to fiberglass and glass. That is, there was no significant difference as to the effect of radiation and wind when fiberglass and PVC were compared, or when PVC and glass were compared.

5. Flower surface temperatures of red flowers will always be above air temperatures except at wind speeds above 100 fpm and radiation levels below 80 BTU/ft^2 (overcast, winter skies). Similarly, a differential between top and bottom in the flower will be found. It is not possible to completely compensate for increasing radiation under glass by increasing wind velocity. But, under fiberglass, plant temperatures can be maintained the same under increasing radiation if the air velocity is increased. For example, a flower surface temperature of 86° at 80 BTU/ft^2 and 10 fpm will remain at 86° at 300 BTU/ft^2 if air velocity over the flower is increased to 100 fpm.

In summary, some of these conclusions may appear mutually exclusive. But, it must be kept in mind that several factors influence flower temperature, and these statements are applicable only to the general situation that may occur in the greenhouse. Temperatures within carnation flowers will vary depending upon color and greenhouse cover. The ability to control quality is dependent upon flower color and greenhouse cover. The relationship between wind, radiation and air temperature varies in accordance with flower color and greenhouse cover.

It can be pointed out that: (1) Low air temperatures will have a proportionally greater effect on white flowers under glass than red flowers, increasing the chances of flushing in such varieties as White Pikes Peak. (2) However, unit heaters in fiberglass houses may be more prone to cause flushing than pipe coils since the air movement is higher with unit heaters, and the effect of wind movement is greater under fiberglass. (3) The lower temperatures in white and light colored flowers will enhance condensate formation, resulting in greater possibilities for botrytis flower blight. But, this possibility is reduced in fiberglass houses. (4) Wind velocity over red flowers under glass, during daylight hours, should never be less than 10 fpm. (5) The effect of wind velocity under PVC will be greater than under glass, and greater under fiberglass than under PVC.

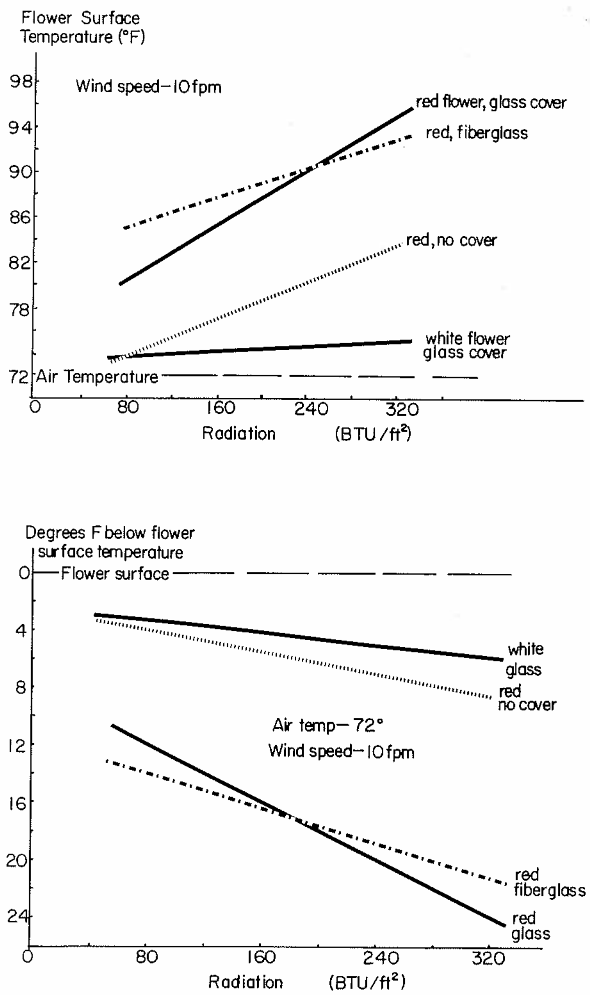

Fig. 1 (*Upper*)–Effect of radiation level on flower surface temperature at a wind speed of 10 fpm and an air temperature of 72 F. (*Lower*)–Effect of radiation level on the difference between flower surface temperature and bottom of the calyx temperature at a wind speed of 10 fpm and an air temperature of 72 F.

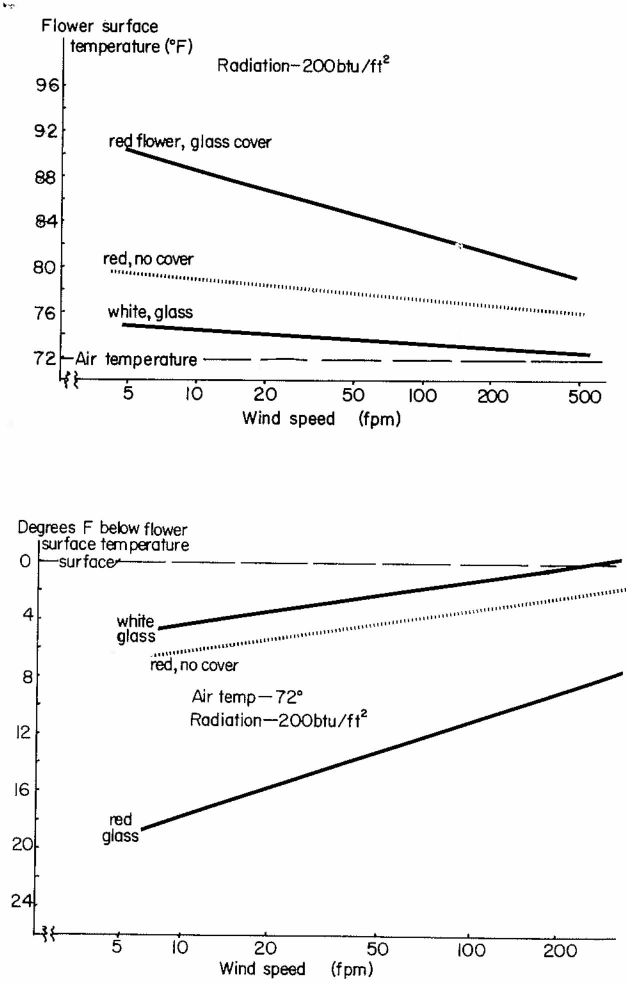

Fig. 2 (*Upper*)–Effect of wind velocity on flower surface temperature at a radiation level of 200 BTU/ft^2 and an air temperature of 72 F. (*Lower*)–Effect of wind velocity on the difference between flower surface temperature and bottom of the calyx.