COLORADO FLOWER GROWERS ASSOCIATION, INC.

IN COOPERATION WITH COLORADO STATE UNIVERSITY

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# Water Loss and Stress in Carnations Grown Under Glass

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Several short articles in previous CFGA Bulletins have dealt with various aspects of water loss and possible influences on carnation growth. Analysis of the data for 1967-68, from carnations grown in inert media show a doubling of water consumption over that found in Hanan and Jasper (CFGA Bul. 204) for carnations in soil, and a direct relationship between internal plant stress and water loss. The exact effect of varying degrees of stress has not been shown although general observations indicate a range that should not be exceeded.

Several factors operate to determine internal plant water stress. The primary factor, however, is the balance between flow of water into the root system, and the evaporative demand imposed by the environment about the leaves. As the sun rises in the morning, an increasing part of the energy goes to evaporate water, causing a suction to be exerted within the plant to draw water from the soil. This is opposed by ability of the cells to imbibe water. If stress exceeds the ability to take up water, water is removed, the cell walls become flaccid because there is no internal pressure, and the carnation wilts. But, if the internal pressure within the cells approaches a maximum, the practical result may be stem brittleness. An intermediate stress may act to harden the carnation without actually causing it to wilt. The stomatal pores and epidermal cells become smaller, leaves are narrower and internodes are shorter. As a result, there may be increased resistance to $CO_2$ uptake with slower growth, and the stem, because of hardened cell walls, may not elongate as far so that short grade flowers are cut instead of standard or fancy grade.

## General Observations

There are several methods to determine plant stress. The quickest is to remove a stem, place it upside down in a chamber so the cut stem is exposed to the air, and apply an increasing pressure to the leaves. An external pressure sufficient to cause water to be forced out of the cut stem is a measure of the difference between water uptake and water loss, and indicates the internal stress to which the carnation is being subjected. In preliminary observations on unwilted carnations grown in soil under glass, external pressures as high as 300 psi were sometimes required to force water from the stem. This implies a negative suction, or stress, within the stem equal to the applied pressure. As experimentation continued on carnations grown in inert media, using a nutrient solution with an osmotic concentration of about 10 psi, such pressures were never seen. Instead, when stress reached a range around 250 psi the carnation stem was likely to be flagging. Similarly, initial measurements on carnation cv Coquette, grown in inert media in 1967, showed the existence of zero stress in the stems under certain conditions. Usually lowest stress followed a cloudy day. This low stress was associated with extreme stem brittleness. This phenomenon has never been observed with cvs White Pikes Peak and CSU Red—although an observable increase in tendency toward brittleness has been noted whenever stress dropped much below 40 psi.

## Water Loss

During 1967-68, the CSU weighable lysimeters were used to determine short term water loss from White Pikes Peak grown in an inert medium in a glass house and irrigated a minimum of once daily. Fig. 1 shows typical rates of water loss for four different days. As can be seen, remarkable quantities of water may pass through the carnation, depending upon environmental demand and supply. Water loss measurements were not continuous, but restricted to two or three days for each month between October, 1967, and April, 1968.

The total water loss for each of the days was determined and compared with the total solar radiation outside the greenhouse — since the latter is usually the easiest to determine. A regression analysis was

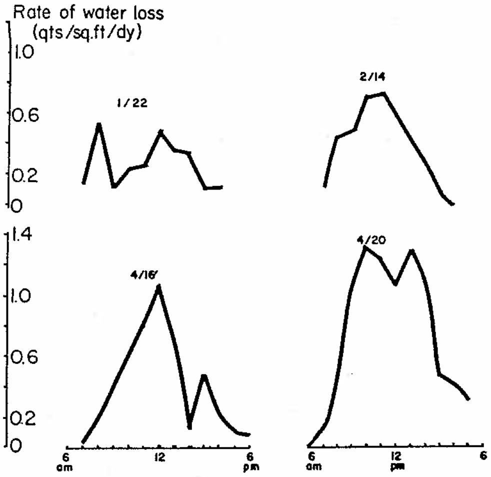


Fig. 1. Examples of water loss during four days from carnations grown in an inert medium in a glass greenhouse.

run to determine the relationship (Fig. 2). As has been noted before, water loss ($E_t$) exceeded total radiation ($R_o$). The reasons for this arise from additional energy supplied by the heating system to evaporate water, and dry air brought into the greenhouse during spring and fall when the cooling pads are not operating. However, the relationship probably overestimates water consumption during the summer when the cooling system is operating (Hanan, CFGA Bul. 207). Water loss may be reduced to less than the total outside radiation. Sufficient data were not obtained during the main cooling months. This curve (Fig. 2) represents the first empirically determined relationship between short-wave solar radiation and water

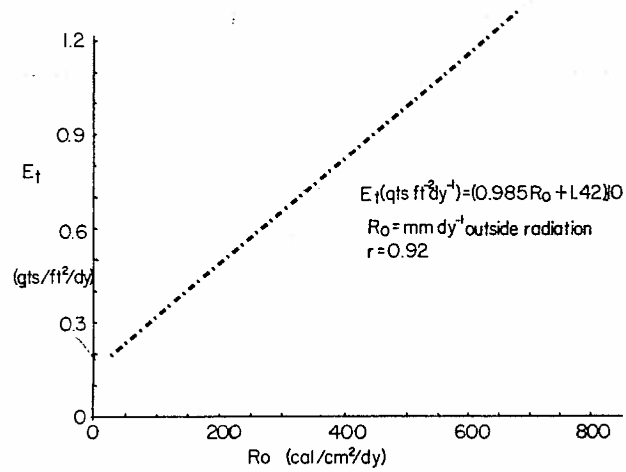


Fig. 2. Computed relationship between total outdoor, short wave radiation ($R_o$), and water loss from carnations ($E_t$). Radiation and water loss were originally in millimeters (mm) equivalent depth of water and the regression computed. The value 0.10186 is the factor for converting $E_t$ from mm/day to quarts per square foot per day.

loss to be obtained in the U.S. for a greenhouse crop.

Bulletin 210 presented a curve showing the mean daily solar radiation for the past 8 years at Fort Collins. Using the values from this curve, and the relationship shown in Fig. 2, the mean daily water loss ($E_t$) that might be expected from carnations past the first crop, in inert media, and in glass greenhouses, was plotted for an entire year in Fig. 3. The mean daily water loss may vary from less than 0.4

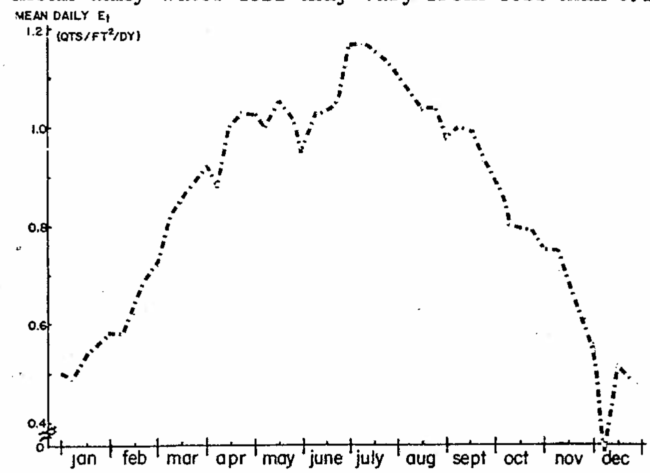


Fig. 3. Mean daily water loss ($E_t$) from carnations grown in inert media in a glass greenhouse for an entire year. Values for outside solar radiation obtained from CFGA Bulletin 210, representing average values obtained over a period of 8 years. The equation given in Fig. 2 was used to calculate $E_t$.

quarts per square foot to nearly 1.2 quarts per square foot. If the maximum and minimum values of solar radiation are included, then water loss may vary between 0.22 and 1.25 qts/ft$^2$/day, corresponding to 130 and 720 gm-cal/cm$^2$/day. As indicated before, the values may be overestimated for high light periods.

The mean for each month was determined and the total water consumption for one year, per acre (assuming 60% in production area) calculated as approximately 2 million gallons. Data from Hanan and Jasper (CFGA Bul. 204) showed that 25 to 30% of the water applied was lost through drainage. Adding 25% to water loss resulted in about 2.7 million gallons or 8.3 acre-feet per year. This is nearly double the amount found by Hanan and Jasper for carnations grown in soil. Even if overestimated by 20%, it still represents a tremendous quantity of water. At 60¢ per 1000 gallons, it is a yearly cost of $1,600.00 and does not include additional wastage due to excessively long watering periods, leaching, or water evaporated from the cooling system. Inert media, while apparently reducing stress in the carnation through a better water supply, causes a significant increase in water consumption. As long as this water is freely available, and of reasonable quality, it remains the cheapest raw material in carnation production.

## Stress

Simultaneously with short-term water loss, stems were removed from selected plots on hourly intervals and stress determined in the pressure chamber. Fig. 4 shows typical values obtained for the same days as in

Fig. 1. As a general rule, as water loss increased, stress increased. The relationship between rate of water loss and stress is shown in Fig. 5 - lower. While this shows a high linear correlation, it is doubtful that it is linear over the entire range between 0 and maximum at wilting. The curve probably levels off as low pressures are reached, and again at high stresses when water loss is reduced as stomates close.

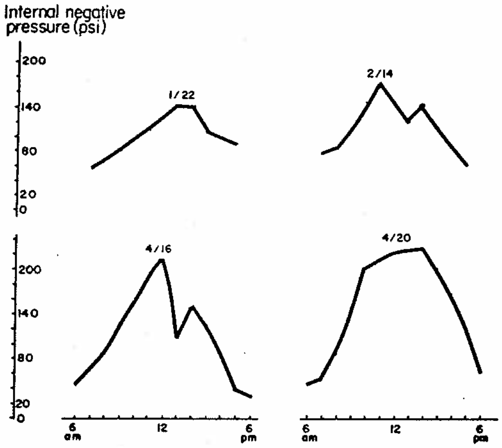


Fig. 4. Stress in carnations for selected days, expressed as pounds per square inch (psi) internal negative pressure.

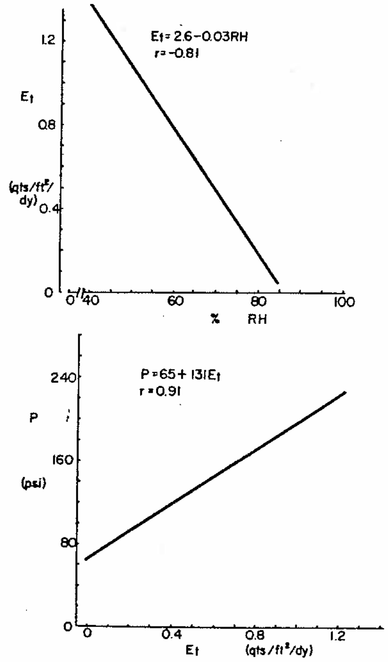


Fig. 5. Lower: Relationship between water loss ($E_t$) and stress in carnations in inert media in a glass house. Upper: Relationship between water loss ($E_t$) and % relative humidity (RH).

For any given environmental condition we think we may eventually find a pressure that represents the best compromise between stress and food production. Above this point, even though photosynthesis may increase, higher stress reduces growth. Below the compromise, handling qualities may be reduced, or it is an indication of insufficient light for photosynthesis.

What can be done to the environment to manipulate stress is indicated by Fig. 5 - upper. Wet and dry bulb temperatures in the greenhouse were measured in five locations, the relative humidity calculated and related to the rate of water loss. The range of relative humidity between zero water loss and maximum was narrow. At humidities much below 40%, water loss became excessive. There is no need to attempt humidification above 90%. An additional advantage to this high limit is that it reduces complications with disease. There was in effect, a 50% range in relative humidity over which water loss, hence stress was directly affected. Extending the use of pads as far as possible into the winter would go far to alleviating undesirable conditions due to low humidity.

It is understandable that these relationships shown here will vary, depending upon the nutrition of the carnation, its previous history, how it is watered, temperatures, methods of heating and air circulation, and type of greenhouse. As a practical recommendation, however, the range of humidities between 40 and 80% represent reasonable values that should not be exceeded in greenhouses. As light increases, the humidity should probably be maintained as nearly as possible between 70 and 80%. Under low light periods, the relative humidity may be permitted to drop lower.