COLORADO FLOWER GROWERS ASSOCIATION, INC.

IN COOPERATION WITH COLORADO STATE UNIVERSITY
Dorothy Conroy, Executive Secretary
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Observations on Carnation Stomata

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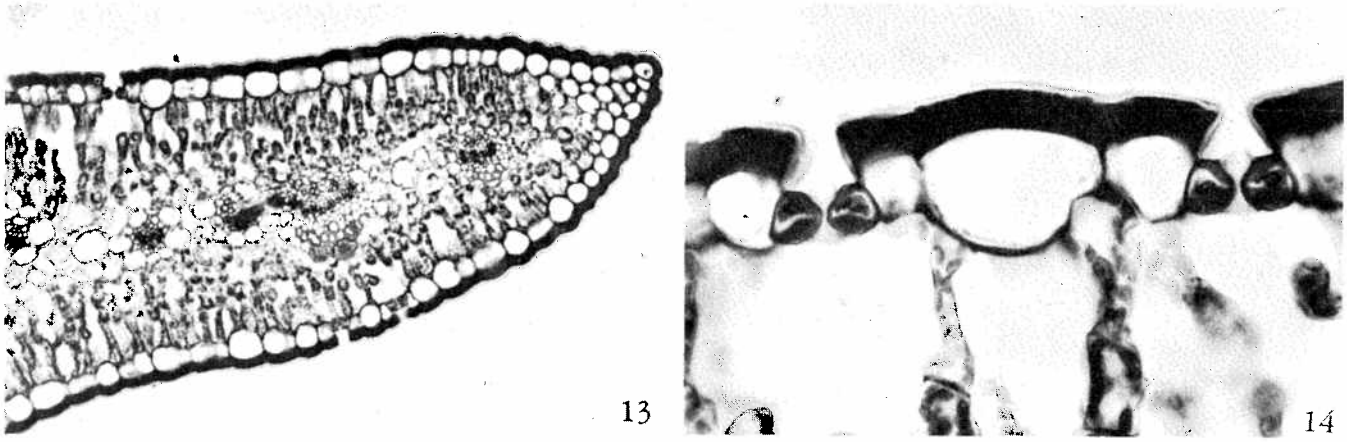

Fig. 1. Cross section of carnation stomata from plants grown in soil. Note that the leaf is covered with a thick cutin layer, and the stomatal openings are sunken.

More than 80% of the water taken up by plants is lost through the stomatal pores of the leaf. Fig. 1 shows a cross section of a typical carnation leaf with its sunken stomata. Knowledge of stomatal behavior would permit a better understanding of those factors affecting internal plant water stress.

In CFGA Bull. No. 213, response of carnations grown in different soils, and under different greenhouse covers was presented. In addition, preliminary studies were also undertaken to evaluate water loss from individual carnation leaves and the variation of stomatal numbers as the result of treatment.

[1] Graduate Assistant. This report presents a part of the thesis for the M.S. degree. Supported by Grant No. WP-00780, Federal Water Pollution Control Administration.

Methods and Materials

The north beds in each compartment of the CSU Temperature House were divided into 6 plots, 4 plots in each compartment containing two growers' soils, A and B, with one plot of the two 4 inches deep. All other plots, including a Fort Collins Loam (CSU New) and a productive greenhouse soil (CSU Old) were 8 inches deep. All soil plots in a compartment were irrigated simultaneously when plants in one of the 4 inch plots showed signs of wilting. Included in this report are results of measurements made on "Coquette", grown in a 50-50 Scoria-Idealite mixture in a south bed of each compartment, and watered daily regardless of season. Plants in the soil plots were "White Pikes Peak", all plants benched on June 26 1966. Greenhouse covers were frosted fiberglass,

clear fiberglass, clear polyvinylchloride and glass.

Stomatal apertures were measured by making silicon impressions of selected carnation leaves at periodic intervals as described by Green (CFGA Bul. 194). Stomatal and epidermal cells were counted. Water loss was measured by determining the time required for a specific change in humidity inside a small plastic cup attached to the leaf (Fig. 2). This is reported as "transit time" (Δt). It is a measure of the rate of water loss, and, when compared to other treatments under identical conditions, indicates relative magnitude of stomatal resistance to water flow. When suitably calibrated, and leaf and air temperatures are known, it becomes possible to calculate actual water loss and stomatal diffusion resistance.

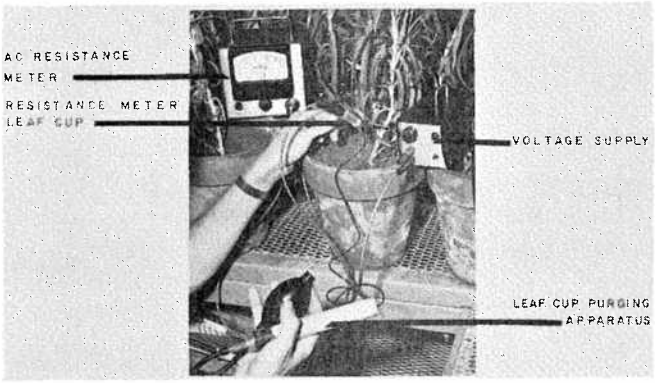

Fig. 2. Diffusion resistance equipment for determining water loss from carnation leaves.

Results and Discussion

Definite correlations between growth and stomatal variations in this phase of the study were not found. This would be expected, as discussed later, since many factors influence food production.

However, it was found that the number of stomata per unit area, their resistance to water vapor diffusion, and structural characteristics varied with season and with treatment. In Fig. 3, the number of stomata per unit area of leaf surface for each soil treatment is compared under two different light conditions. The pictorial differences were shown in Fig. 4. The higher the light conditions, or the higher the stress to which carnations were subjected, the greater the number of stomata per unit area. However, the transit time (Δt) did not decrease as might be expected, but increased - indicating higher resistance of individual stomata to water vapor movement. In Fig. 4, stomata of plants grown in soils appear to be smaller, less open, with a thicker surface layer around them. When the number of leaf surface cells per stoma was computed (stomatal index, Table 1), the values did not change markedly, except for plants grown in Scoria-Idealite. The latter could be attributed to varietal difference. In effect, the results suggest that individual cells and stomata were smaller, and the total number of cells per leaf was not radically changed. This is borne out in work by others, indicating that stress is most influential on enlargement of cells. The results also indicate that higher energy inputs (solar radiation) cause greater stress in the plant.

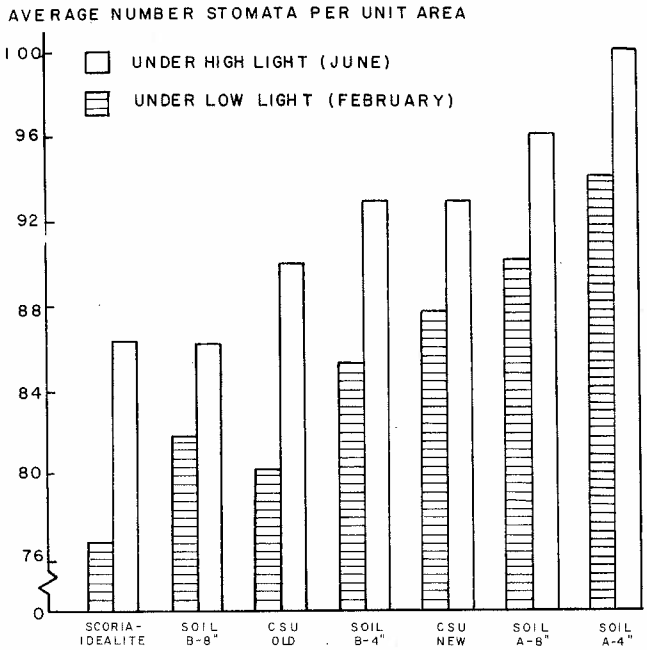

Fig. 3. Comparisons of number of stomata per square millimeter produced on carnation plants grown in differing water supply conditions and two radiation levels.

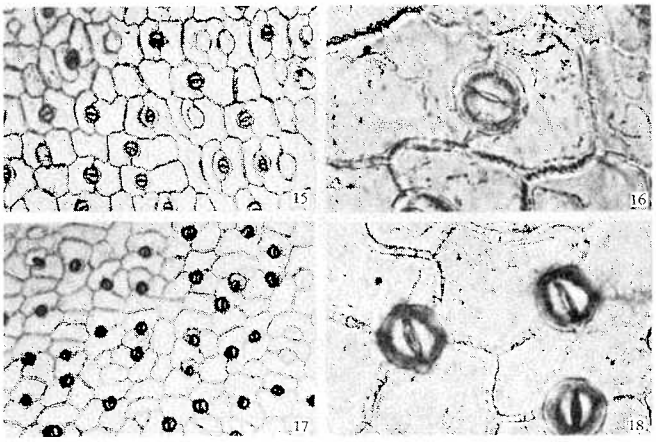

Fig. 4. Comparison of stomata between plants subjected to high water supply (top) and low water supply in soils (bottom).

As shown in Table 1, the number of stomata per unit area was highest for plants grown under glass. Water loss as indicated by Δt (Table 2) was highest for plants grown under glass. Holley et al. (CFGA 189) has shown that, for the covers employed in this experiment, higher direct radiation is received by plants under glass. Plants grown under glass were usually subjected to higher water stress. However, yield between covers was not significantly different - although yield of carnations under glass was highest for this period. It is possible to surmize that the

Table 1. Stomatal and epidermal cell frequency of carnations grown in different soils and under different covers.

Treatment	Number of stomata per mm^2	Stomatal index[1]
Soil Treatment[2]		
Scoria-Idealite	77.8	23.9
Soil B-8	82.0	26.3
CSU Old	82.4	25.8
CSU New	85.8	25.7
Soil A-4	87.1	25.6
Soil A-8	87.6	26.1
Soil B-4	87.7	25.7
LSD (0.05)	1.5	
Cover[3]		
Frosted	77.5	24.9
Clear	84.0	25.7
PVC	83.7	25.3
Glass	92.1	26.4
LSD (0.05)	2.1	

[1]Stomatal index - the number of stomata on the leaf surface per surface cell times 100.

[2]Type - Old: CSU old soil 8'' deep
New: CSU Fort Collins loam, 8'' deep, brought direct from field.
A-4: Grower's soil A, 4'' deep.
A-8: Grower's soil A, 8'' deep.
B-4: Grower's soil B, 4'' deep.
B-8: Grower's soil B, 8'' deep.
Scoria: Inert medium, 8'' deep, consisting of 50-50 Idealite and Scoria.

[3]Type - Glass: Conventional greenhouse construction with glass.
PVC: Clear polyvinylchloride, corrugated, rigid plastic.
Frosted: Rigid, corrugated fiberglass.
Clear: Rigid, corrugated, clear fiberglass.

increase in stress in plants under glass was not sufficiently high to offset greater food production brought about by higher light.

There appears to be a balance between water stress and the photosynthetic process. Low stress, by itself, will not result in high productivity unless accompanied by sufficient light. However, higher radiation means higher stress. It becomes possible to foresee that the other extreme of excessively high stress is reached, resulting in reduced production, when solar radiation is high. The relationship between light and water loss is presented in Table 2, and graphically in Fig. 5. At low light levels, Fig. 5 indicates that water loss was proportional to the available light. At around 0.6 cal cm^{-2}, however, this relationship seemed to be no longer true, and, in fact, there were indications that water diffusion began to decrease at higher light levels as the stomata began to close and the plant approached wilting. The data is incomplete, but we have good reason to believe that the situation as outlined above occurs with carnations in Colorado.

Table 2. Effects of solar radiation, soil type and greenhouse cover on rate of water diffusion from carnation stomata.

Period of measurement	Radiation Cal cm^{-2}	Δt[1]	Cover Type	Δt	Soil Type	Δt
June 17	0.06	65.9	Glass	33.6	B-4	37.8
through	0.27	42.1	PVC	35.4	Old	35.6
June 23, 1967	0.97	29.8	Frosted	35.8	Scoria	34.8
	0.99	29.0	Clear	38.2	B-8	34.7
	1.01	28.9				
	1.03	26.1				
	1.05	28.4				
LSD (0.05)		1.6		1.2		1.2
March 21	0.20	42.2			A-8	31.9
through	0.60	25.3			B-4	31.8
March 26,	0.87	19.4			A-4	27.8
1967	0.91	23.2			B-8	27.3
	0.96	21.9			New	24.7
	1.00	25.9			Scoria	21.2
					Old	19.5
LSD (0.05)		2.7				2.9

[1]Δt - transit time in seconds, period required for resistance of lithium chloride cell in the leaf cup to increase from 3 to 6 microamps.

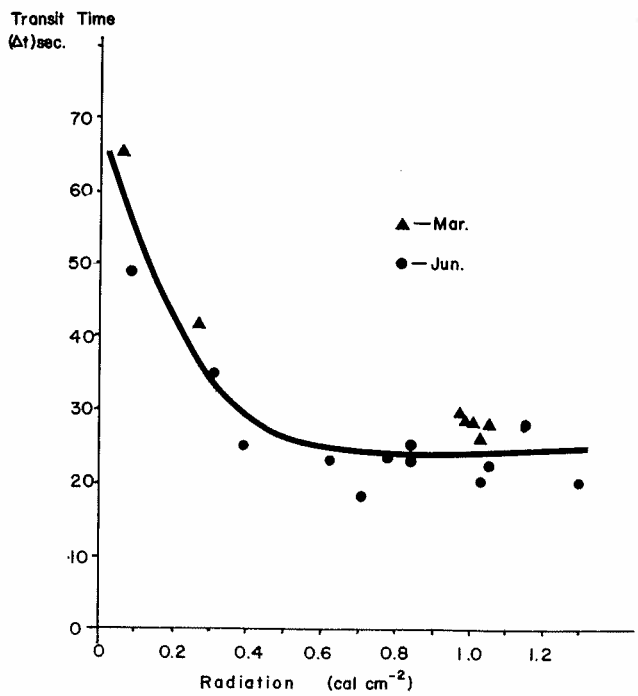

Fig. 5. Relationship between water diffusion rate from individual carnation leaves and solar radiation.

During high light conditions, therefore, stress must be reduced as much as possible through environmental manipulation while maintaining photosynthesis at a maximum rate. We can reduce stress by supplying more water to the roots (inert media), keeping soluble salts as low as possible, increasing humidity of the air, increasing CO_2 concentration, and reducing plant temperature. During low light conditions, when light is limiting, it may be necessary to induce stress to harden the cut flowers by withholding water, increasing soluble salts, decreasing humidity or raising the temperature of the plant above the air temperature. This study also points out a problem that may occur more often with carnations grown in inert media. From Figures 3 and 4, it is apparent that plants may be pre-conditioned to a degree where their response may be entirely different than expected. Plants conditioned to low stress will lose more water than plants conditioned to high stress. If these plants are then subjected to identical conditions, the low stress-conditioned plant will likely experience a greater initial reduction in growth. Response of plants grown in inert media to environmental changes are likely to be greater and more drastic. Efforts to reduce stress under increasing solar radiation during the spring should be given priority - such as increasing the irrigation frequency and making sure the pads are ready to operate.