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# CONTROLLING THE INTERNAL WATER STRESS OF ROSES PROGRESS REPORT

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**Results for 16 weeks (March 16 through June 29, 1986) with 'Royalty' roses are summarized on the effects of automatic shading under two cover types in the Colorado State University heat houses. Yield per plant has been very high with a trend toward longer stemmed roses in those houses using shade cloth.**

## Introduction

'Royalty' on *R. manetti,* 60 plants per treatment, were planted in gravel in Spring, 1985. The experimental installation was not complete until January, 1986, and the key experiment is now in progress through Summer, 1986. Records will be continued through the 1986-87 winter. During the 1985-86 winter, cutting procedure had to be drastically modified to prevent the bushes from getting out of hand. This meant a heavy under-cut when the break exceeded 24 inches above the soil line, cutting to the knuckle on ¼-inch diameter stems above 18 inches, and to the first 5 leaflet leaf on all other flowering stems. This has not appeared to have markedly reduced production. During the 16 week period (Mar. 16 through June 29, 1986), yield per plant has been 18 to 19 flowers, regardless of treatment. The data has been voluminous with probably the best documented greenhouse experiment ever published. An explanation of the control system has been published in the Colorado Greenhouse Growers' Research Bulletin, 430.

## Methods and Materials

The study consists of two parts: 1) examination of yield and quality of 'Royalty' under two different covers (fiberglass and double air-inflated PVF), with two of the four, separate, 960 sq.ft. greenhouses, fitted with automatic shade screens, making four treatments, and 2) detailed examination of internal water stress and stomatal resistance of 'Samantha' under the same conditions. To review the environmental conditions:

1. Air temperature is controlled according to the average reading of three sensors in each house, with the basic setting for night 62 F, and for day 72 F. The system executes every 60 seconds, and all data, including maximums-minimums, are stored separately for day or night periods. Ventilation begins a minimum of 2 degrees above the heating temperature, and both setpoints are automatically adjusted according to weather conditions. When the outside air temperature nears 30 degrees below the inside air temperature, no ventilation can occur. Fans are locked out at night when outside temperature is below the inside.

2. $CO_2$ concentration is determined by sampling inside the rose canopy every 10 minutes. $CO_2$ is injected through

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a trickle tube laid on the bench surface. $CO_2$ concentration is calculated in absolute pressure terminology, "Pascals," and, during the day, $CO_2$ is injected to maintain a minimum 35 Pascals up to 100 W/sq.m. intensity, and raised 0.2 Pascal for every W/sq.m. above 100 (28 Pascal = 350 ppm at Ft. Collins, 35 Pascal = 350 ppm at sea level). The time for $CO_2$ injection is monitored daily. Injection can occur during the first two stages of ventilation.

3. Shade curtains in two of the treatments are closed during the day when the inside radiation exceeds 700 and closed when outside radiation drops below 600 W/sq.m. A one hour delay is required in order to prevent excessive operation on cloudy days. The curtains are closed at night if the outside temperature is below the inside temperature. The system prints status of shade curtains (open or closed) with time and date noted, and counts the minutes curtains are closed during the day or night.

4. The system measures humidity in the center of each house and indicates percent relative humidity and absolute water vapor concentration in millibars pressure. High pressure mist is injected when the difference between actual concentration and concentration at 100% RH is greater than 10 millibars. This amounts to approximately 60 to 70% relative humidity. Data through the 1985-86 winter indicates that a de-humidification control is not vitally necessary.

5. The gravel medium is automatically watered through six rows of Chapin Twin Wall when the system switches to day control at 70 W/sq.m. Thereafter, the computer waters a bench for 6 minutes when the total accumulated radiation since the last watering reaches 2300 kiloJoules/sq.m. During the summer, this value causes the benches to be watered 6 to 8 times daily with automatic fertilizer injection, using the standard Colorado State University carnation nutrient solution with a basic water supply containing less than 100 micromhos/cm total salts. 'Samantha' roses are grown in individual pots filled with rockwool and watered at the same rate as gravel.

'Royalty' is planted at one plant per sq.ft. with three rows per bench, each bench divided into six plots with 'Sonia' as buffers. Flowers are cut daily with records on yield and stem length kept on a weekly basis. The computer system also accumulates data on some 57 variables measured in the four greenhouses and provides a weekly average of each with maximums and minimums. Pinching and cutting studies are also being carried out on 'Sonia'. Several statistical analyses will be run on the data when the experiment terminates at the end of September. Data include inside and outside temperatures, inside and outside radiation, inside and outside humidity, plant temperature, inside and outside $CO_2$ concentration, irrigation frequency, natural gas consumption of each house, outside wind velocity and curtain closure time.

## Results

### March 16 through June 29, 1986

The report on system control (CGGA Bulletin 430) showed that average night temperatures have been maintained to within ±2°F, and to within ±4°F during the day — unless the system adjusted the ventilation temperatures upward. $CO_2$ concentration often dropped below 20 Pascal, especially within the crop canopy. This is in marked contrast to the calculated 350 ppm (28 Pascal) concentration often given for normal ambient $CO_2$. This confirms the need of enhanced $CO_2$ supply even during ventilation cycles as instituted by the British in summer vegetable production (CGGA Bulletin 434). The system is capable of increasing $CO_2$ above 1500 ppm under bright light and no ventilation. Injection within the canopy is certainly more efficient use of $CO_2$.

What has been surprising is the fact that shade curtains under double air-inflated PVF often to close longer (Fig. 1) than the shade curtain under fiberglass, even though the total accumulated radiation is lower in the double layer houses (Fig. 2). The presence of open shade curtains significantly reduced total light in houses in which curtains were installed. The amount of reduction of total accumulated energy increased through May and June, as would be expected as the sun intensity increased. Curtain closure prior to March was infrequent. Quite likely, the reduction in total light may adversely affect yield even though stress has been shown to be significantly reduced when the curtain closes on a bright day. Insufficient time has elapsed to show the possible benefits and losses even though there is a trend toward longer stems where shade curtains are employed (Table 1).

The cutting method prevents the usual timing procedure, and the initial heavy undercut in December and January reduced production with the unshaded double cover cycling ahead of the other three treatments. Total production gradually increased through the early summer months (Fig. 3). Weekly production for the single FRP and double layer, shaded, treatments was nearly identical through the data period, whereas the fiberglass, unshaded, house appeared to increase above the others during June. Plants in the two unshaded houses produced an average one flower more per plant than the plants in the two shaded structures. But, this difference was not statistically significant. Over the 16 week period, roses in shaded treatments produced two to three percent more flowers in the 21, 24, and 27 inch stem length classifications (Table 1) compared to the unshaded

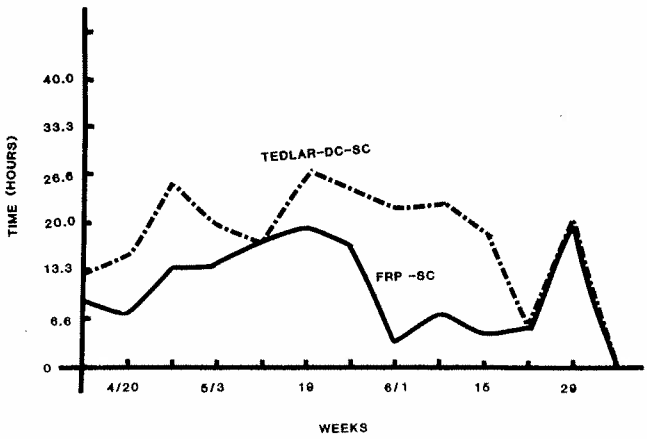


**Figure 1:** Smoothed curves of weekly closure times during the day of shade curtains under FRP and Tedlar©, double layer, air inflated between March 16 and June 29, 1986. Closure times were equal under both covers during the latter part of the measurement period which might have been due to the fact that we were modifying software for more reliable operation during that period.

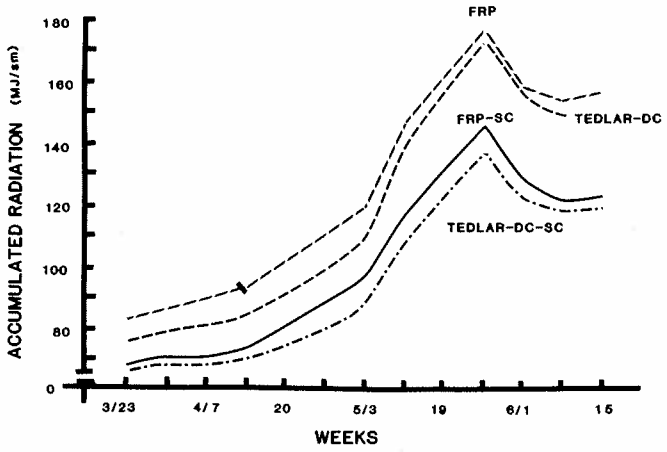


**Figure 2:** Smoothed curves of accumulated, weekly total solar radiation in four identically controlled greenhouses, two covered with single layer fiberglass (FRP) and two covered with double, air-inflated Tedlar© (Tedlar-DC). Automatically controlled shade curtains were installed in one house of each cover (SC), for the period from Mar. 16 through June 29, 1986 (MJ/sm = mega-Joules per square meter, one million Joules = 278 watt-hours per sq.m.).

**Table 1:** Percent stem length distribution of 'Royalty' grown in gravel and under two greenhouse covers, shaded and non-shaded between the periods March 16, 1986, to June 29, 1986.

| | Stem length (inches) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 9 | 12 | 15 | 18 | 21 | 24 | 27 |
| Double cover-unshaded[1] | 3 | 1 | 6 | 10 | 18 | 22 | 40 |
| Double cover-shaded | 2 | 1 | 4 | 10 | 17 | 21 | 45 |
| Single FRP-unshaded | 2 | 1 | 6 | 12 | 22 | 20 | 39 |
| Single FRP-shaded | 3 | 2 | 4 | 10 | 17 | 21 | 45 |

[1]*Forty percent shade closed when inside radiation level exceeded 700 Watts per sq.m., and opened when outside radiation dropped below 600 Watts per sq.m. Curtain operation subject to one hour delay before opening or closing to avoid rapid changes in cloudy weather.*

houses. In all treatments, 80 percent of all flowers cut had stem lengths greater than 21 inches. The low cutting method, which maintained the average height lower than would be found in commercial ground benches, tended to increase stem length. However, we like to think that environmental control, especially with good water supply and good nutrition, has shown that yield far exceeds anything we have seen in previous years.

Natural gas consumption on a warm rose crop steadily decreased as outside temperatures increased (Fig. 4). However, the shade curtains have closed every night this year. The effect of a thermal curtain on lowering gas consumption has not been as great as the effect of a double cover. Thus, a thermal screen in a single layer greenhouse does not equal a double cover, and adding a thermal screen to a double covered greenhouse does not have a proportionate effect in reducing energy consumption. As the outside temperature continued to rise in June, the effect of a thermal screen in a double covered greenhouse tended to disappear (Fig. 4).

For the first time, we have been able to monitor rose canopy temperature with equipment that has appeared to be reliable in maintaining calibration (Fig. 5). The average plant temperature in the double cover, shaded, treatment appears to have been consistently lower than plant temperature in any of the other treatments, with unshaded fiberglass having, consistently, the highest plant temperature. All temperatures have risen consistently from March through June. These are average weekly temperatures,

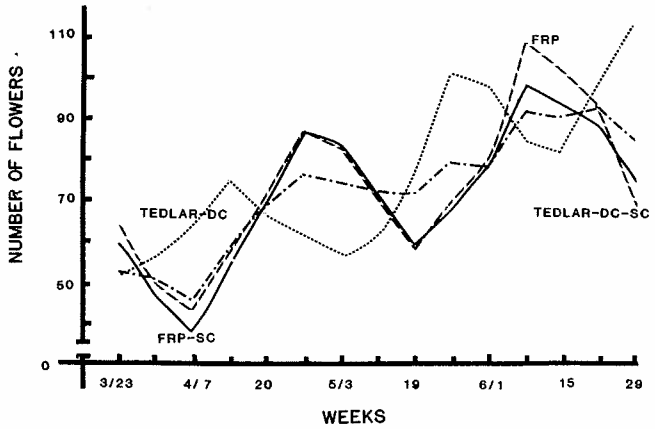


**Figure 3:** Smoothed curves of total weekly yield of 'Royalty' per treatment (60 plants) in four identically controlled greenhouses, two covered with single layer fiberglass (FRP) and two covered with double, air-inflated Tedlar© (Tedlar-DC), with one of each cover fitted with automatic shade curtains (SC), between March 16 through June 29, 1986. Roses grown in gravel, automatically irrigated and fertilized.

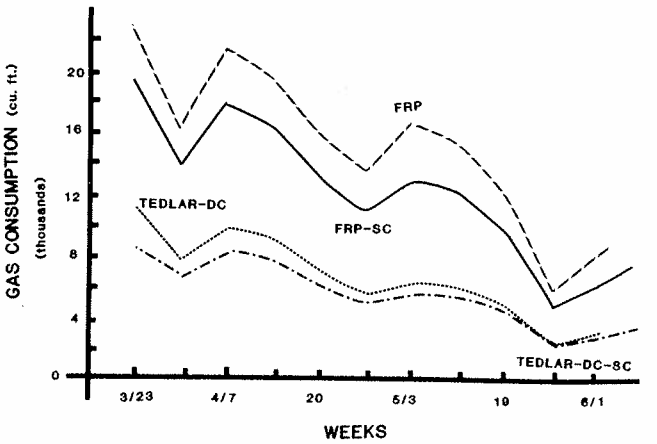


**Figure 4:** Smoothed curves of weekly total natural gas consumption in four identically controlled greenhouses covered with single layer fiberglass (FRP) and double, air-inflated Tedlar© (Tedlar-DC) with shade curtains installed in one of each cover (SC) between Mar. 16 through June 29, 1986. (Each house covers 960 sq.ft.)

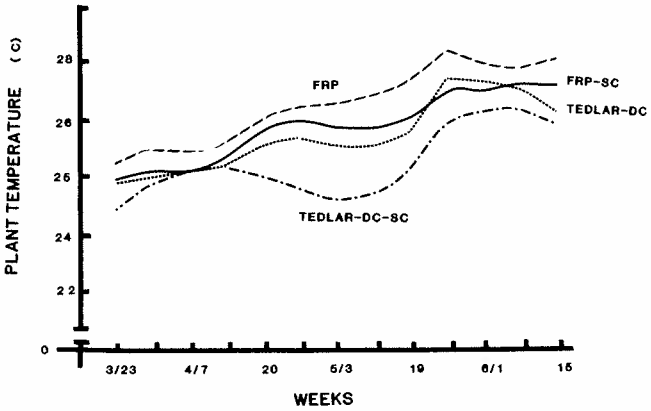


**Figure 5:** Smoothed curves of average weekly rose plant temperature during the day in four identically controlled, 960 sq.ft. greenhouses with two covered by single layer fiberglass (FRP), and two covered with double, air-inflated PVF (Tedlar-DC). One house of each cover has installed an automatic shade curtain, specified at a 40% reduction which are closed when inside radiation exceeds 700 W/sq.m. and open when outside radiation drops below 600 W/sq.m.

whereas observation of the digital display seems to indicate rapid variations with short periods, depending upon the rate of air movement, especially with full ventilation. During this measurement period, ventilation would occur within four degrees F of the setpoint (72 F) with maximum ventilation at 78 to 80. This corresponds to a setpoint of 22 on the Celsius scale (Fig. 5) with 80 F equal to 27 C. There appear to be consistently different plant temperatures in each of the treatments which seem to vary with season and local weather.

### Some Conclusions

The 16 week period has been too short to determine the benefits of shading on roses. Secondly, the amount of data available is phenomenal, and it will take considerable time to shift through it and assess its usefulness. We are likely to see very significant data that will have an immediate financial impact on growers if they decide to use it. We will also be able to apply some very sophisticated statistical analyses to this information for prediction purposes in timing. By this time next year, we will have the best data available for greenhouse growers on gas consumption as functions of weather conditions with two major means of conserving energy. We are noting several new things about rose behavior in these environments.