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THE EFFECT OF SHADING ON 'SAMANTHA' ROSES

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Shaded 'Samantha' roses produced fewer stems per plant than nonshaded plants over an 18 week period. Shaded plants produced average stems with 14% larger leaf area and 9% more dry weight of leaves compared to nonshaded plants. These responses were due to the lower percentage of outside solar radiation transmitted by the shade treatments. Internal water stress was fairly constant at -7.6 bars from 425 to 550 W/sq.m. (R^2 = 0.51). Stomatal resistances tended to decrease with increasing water stress, which ranged from -3 to -12 bars (R^2 = 0.64).

Introduction

Colorado's climate is excellent for greenhouse roses, but the high sunlight in this region also provides conditions for excessive water demand, which may result in high water stress and reduced growth. This experiment was conducted to test the hypothesis:

> If an automatic shade curtain was used inside a greenhouse to cover a rose crop only during periods of high sunlight, then water stress on shaded roses would be significantly reduced and increased yields could result.

A pressure chamber and steady state leaf null porometer were used in this experiment to determine the degree of water stress the rose plants experienced. A pressure chamber measures the stem's xylem water potential, which is always reported as a negative number. The pressure value obtained with a pressure chamber implies what the water potential in a plant's stem xylem is at the time of measurement. As water stress increases in a plant, its water potentials become more negative. A leaf null porometer measures the stomatal resistance or the degree of stomatal closure. Typically, high stomatal resistances indicate that a plant is stressed for water and stomata are closing.

Materials and Methods

This experiment was conducted at PERC in four separate quonset greenhouses, 20 × 50 ft, oriented north-south. The raised west bench in each greenhouse was utilized. The climate control system for these four greenhouses has been reported in previous Bulletins (430, 449).

Twenty 'Samantha' miniplant roses grafted on *R. odorata* were planted in each of the four identical greenhouses on April 19, 1986. The plants were placed in individual five gal-

Fig. 1: Senior author (right) and assistant Paul Zimmerman conducting photosynthetic measurements on 'Samantha' roses discussed in this article. The wide spacing and individual treatment of each plant was deliberate in this study in order to avoid shading and permit the type of work as shown.

[1]*Graduate research assistant and Professor respectively.*

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lon containers filled with rockwool **(Fig. 1)**, and automatically irrigated with the standard Colorado State University nutrient solution for six minutes at a time, by the computer system. Irrigation was set to come on when the total accumulated radiation exceeded 2300 KJ/sq.m. since the previous irrigation. During the summer, this value caused the plants to be irrigated six to eight times daily. Two greenhouses were covered with double, air-inflated polyvinyl fluoride (PVF), and two with single layer fiber reinforced plastic (FRP). One greenhouse of each cover type was equipped with an automatic shade curtain, which, according to the manufacturer, provided a 40% reduction in solar radiation when the shade was closed. The automatic shade curtains covered the rose crop when the inside radiation exceeded 700 W/sq.m., and opened when the outside radiation dropped below 600 W/sq.m.

After one week, each rose plant, consisting of one stem, was pruned to three five-, or seven-leaflet leaves. Stems, having bud diameters of 0.47 inches or greater, were cut

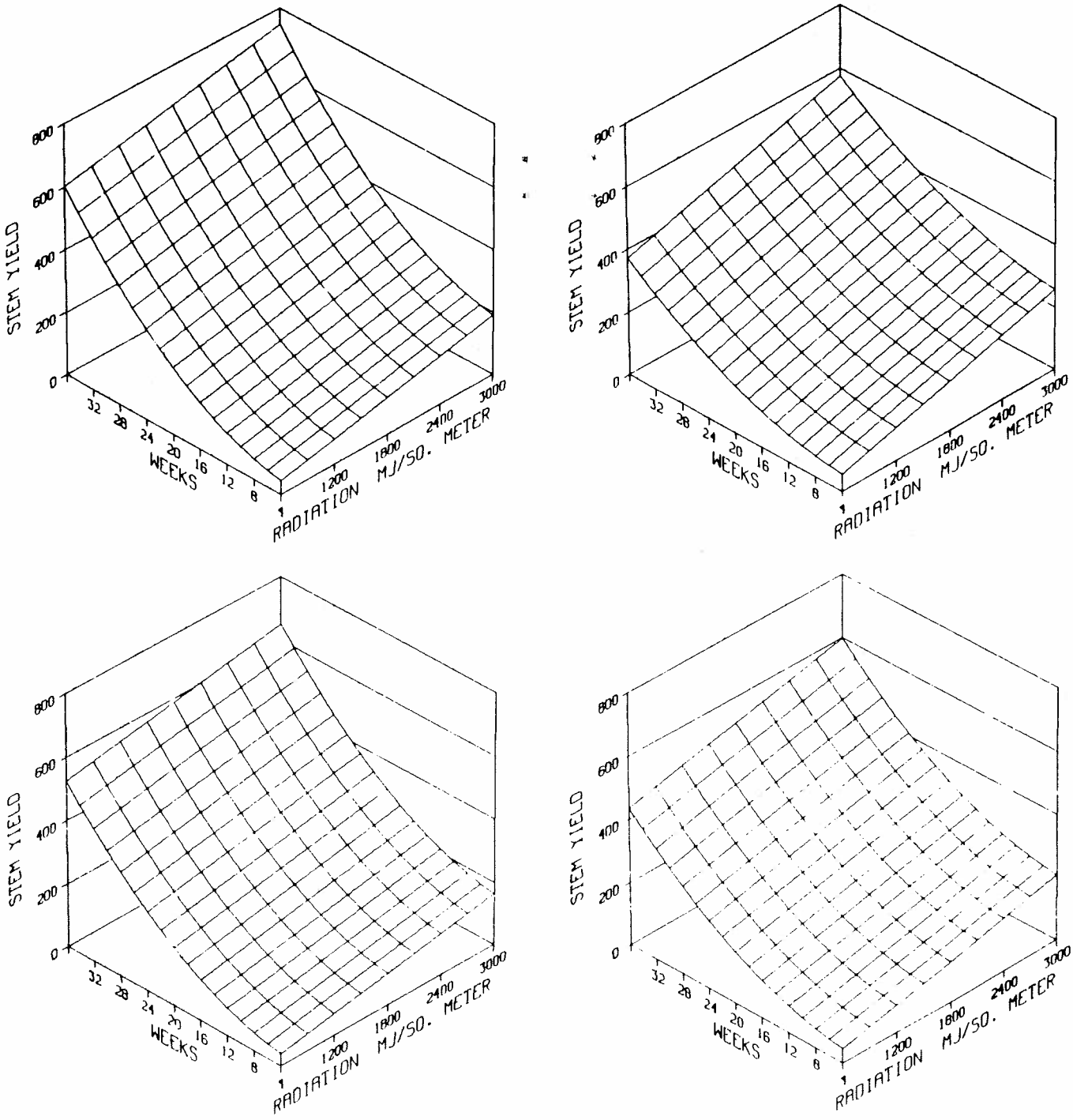

Fig. 2: Effect of cumulative solar radiation over 36 weeks on cumulative yield of 'Samantha' roses grown under two greenhouse covers, with and without shading. *Upper: Left:* Double air inflated PVF; *Right:* PVF with shade. *Lower: Left:* FRP; *Right:* FRP with shade.

weekly, leaving one to two five-, or seven-leaflet leaves, varying with the season. Any blind shoots were removed weekly. Any stems with basal diameters less than 0.18 inches were pruned weekly to their origin.

Two to four stems, with bud diameters of 0.28 to 0.47 inches, were used for water stress, stomatal resistance and stem growth measurements from each of the four treatments at any one given time. These stems were randomly selected with the restriction that each plant was sampled only once during any single period. Stress and resistance measurements were collected under completely overcast or clear days from May 24 to October 18, 1986, in the early morning to mid-afternoon. The computer recorded the instantaneous environment of all four greenhouses during the measurement process. Three leaves were randomly chosen on each stem for stomatal resistance of the center leaflet. After the leaf resistance measurements were noted, the stem was cut and placed in the pressure chamber for stem water potential determination.

The various growth measurements included leaf area, dry weight and potential yield (note stems were cut before flowering). All stems having bud diameters between 0.20 to 0.47 were counted weekly throughout the experiment to obtain a potential yield, duration and number of flower cycles within each of the four treatments. The potential yield was defined as the number of stems that would have been harvested for market within two weeks of being cut. The growth measurements of the last flower cycle were collected on January 24, 1987.

Results and Discussion

'Samantha' rose plants grown under automatic shade curtains produced fewer stems than rose plants grown without automatic shade curtains **(Fig. 2)**. Shaded plants received 17% less total transmitted solar radiation, and produced 22% fewer stems than nonshaded plans from April 26, 1986, to January 24, 1987. The shade curtains never closed during the day from November through January. During this time period, the roses produced six flowering cycles. Each cycle had a period of six weeks including one peak. Statistical analysis of three of these flowering cycles reflected the overall yields.

Shaded plants produced nearly three less flowers per plant than nonshaded plants over an 18 week period **(Table 1)**. These stems had the same average bud diameters, which indicated that they were the same relative age. Stem quality was statistically the same, as reflected by the mean bud dry weight, and the mean total stem dry weight, regardless of shade treatment. If these potential yields for nonshaded and shaded plants are calculated on a yearly basis, then the yield per plant would have corresponded to 49 and 40 flowers per plant respectively.

These results for 'Samantha' yields in this experiment were lower than was previously reported for 'Royalty' roses under the same climate control system (Bul. 449). Nonshaded and shaded 'Royalty' rose plants produced 60 and 54 stems per plant from February 2, 1986 to January 25, 1987, respectively.

There were differences in leaf measurements between shaded and nonshaded 'Samantha' rose plants, which appeared to be an effect of solar radiation. The average percentage of outside solar radiation transmitted by each of the four greenhouse covers was: 1) FRP (no shade), 77%; 2) PVF (no shade), 71%; 3) FRP (shade), 63%; and 4) PVF (shade), 60%. With the lower amount of solar radiation received, shaded plants produced average stems with 14% larger leaf area and 9% more leaf dry weight compared to nonshaded plants **(Table 2)**. Another indicator of the leaf's

Table 2. Effect of automatic shading on 'Samantha' rose leaf growth. The automatic shade curtain closed when the inside radiation was greater than 700 W/sq.m., and opened when the outside radiation was below 600 W/sq.m. Leaves, which had five to seven leaflets, were counted for the number of leaves. Specific leaf weight was the leaf dry weight per unit leaf area. The numbers in parentheses are standard deviations.

	Stem measurements[y]			
Treatment[z]	Number of leaves	Dry weight of leaves (g)	Specific leaf weight (mg cm^{-2})	Leaf area (cm^2)
No shade	8.9 (1.6)a	2.7 (0.8)a	4.7 (0.9)b	590 (168)a
Shade	9.1 (1.7)a	3.0 (0.8)b	4.4 (0.6)a	672 (167)b

[y] Stems with bud diameters between 7 to 12 mm
Stems per treatment = 105 and 117 respectively.
[z] Means within columns, which have different letters were significantly different at the 5% level.

Table 1. Effect of automatic shading on 'Samantha' rose growth. The automatic shade curtain closed when the inside radiation was greater than 700 W/sq.m., and opened when the outside radiation was below 600 W/sq.m. Yield was stems with bud diameter between 7 to 12 mm, and which would have been harvested for market within two weeks. The numbers in parentheses are standard deviations.

	Shoot measurements[x]			Yield[y]	
Treatment[z]	Bud dry weight (g)	Bud diameter (mm)	Total shoot dry weight (g)	Stems per plant	Mean weekly accumulated solar radiation (MJ m^{-2})
No shade	0.13 (0.06)a	9.4 (1.68)a	4.7 (1.6)a	17.2 (4.7)b	68.8 (30.8)b
Shade	0.13 (0.06)a	9.4 (1.58)a	5.1 (1.5)a	13.8 (3.5)a	58.5 (25.0)a

[x] Stems with bud diameters between 7 to 12 mm
Shoots per treatment = 105 and 117 respectively.
[y] Means of 40 plants for three flowering cycles.
[z] Means within columns, which have different letters, were significantly different at the 5% level.

previous light environment was specific leaf weight. Specific leaf weight is defined as the leaf weight per unit leaf area, with the lower specific leaf weight indicating a lower light environment. The lower specific leaf weight for shaded plants was probably the result of the lower solar radiation **(Table 2)**. Thus, shaded plants tended to compensate for lower solar radiation by increasing leaf area with lower specific leaf weight.

When the percentage of total potential stem yield and total solar radiation of the FRP cover treatment was considered as a standard, and the other three cover treatments were compared to this standard, differences were evident. The PVF cover, with no shade, transmitted 8% less radiation and resulted in a 16% increase in yield. This observation implied that a slightly lower radiation transmission by a single layer FRP cover might be needed for increased stem yields of 'Samantha' rose plants grown in Colorado greenhouses (or, a very light shade, i.e. 10% versus 40%?) This is supported by previously reported 'Royalty' rose yield data (Bul 449). Without a shade curtain, 'Royalty' rose yield grown under a PVF cover produced nearly three more stems per plant than roses grown under a FRP cover over a 12-month period.

The automatic shade curtains used in this experiment reduced the percent outside solar radiation transmitted by either FRP or PVF cover type too much for maximum 'Samantha' yields. For example, with the FRP cover considered as a standard, the FRP cover, with shade, caused an 11% reduction in yield with an 18% reduction in radiation. The PVF cover, with shade, reduced radiation by 22%, which resulted in a 21% reduction in yield.

Radiation level did not adequately explain the measured stem water potential response **(Fig. 3)**. Stem water potentials, the degree of water stress, appeared to be fairly constant at -7.6 bars from 425 to 550 W/sq.m. In general, other reports determined stem water potentials for well-watered roses to be fairly constant at -9.0 bars for an irradiance of 600 W/sq.m. Between 600 and 800 W/sq.m., stem water potentials dropped to -10.0 bars. Although data were not collected in this experiment beyond 600 W/sq.m. to confirm at what irradiance well-watered roses displayed signs of water stress, these results tended to be in agreement with previous reports.

The stomatal response to decreasing stem water potential was not expected **(Fig. 4)**. The typical effect of decreasing water potential is to increase stomatal resistance. 'Samantha' rose stomata may not respond significantly to stem water potential until extreme leaf dehydration takes place.

The stomata resistances measured in this experiment **(Fig. 4)** were very low compared to values reported in the literature. One possible explanation for these lower values was the fact that the roses were grown in rockwool. The rockwool was frequently irrigated, which resulted in a very moist root environment. This type of root environment possibly contributed to conditions in which rockwool allowed a lowered resistance compared to other media utilized for roses. In actuality, the range of resistances shown in **Fig. 3** was very small, and, for all practical purposes, the aerodynamic resistance would be more important than any of the leaf resistances recorded (0.2 to 1.4 s cm^{-1}).

Conclusions

The results of these measurements indicated that shaded plants might have experienced high water potentials (less water stress) once the automatic shade curtains covered the rose crop at irradiance above 700 W/sq.m. Unfortunately, not enough data were obtained at these high irradiances to confirm this hypothesis.

The automatic shade curtain in this experiment was instrumental in reducing rose yield. Shaded 'Samantha' roses exhibited a reduction in yield, and compensatory leaf growth in response to the reduced solar radiation. With all other factors being equal, a maximum level for the percentage of outside solar radiation transmitted by a cover for maximum yield of Colorado greenhouse roses appeared to within 63% to 77%. A less dense (40%) shade curtain under FRP might be a better solution.

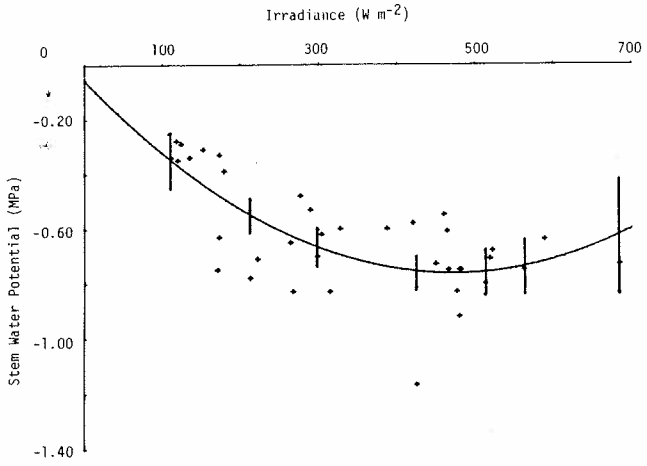

Fig. 3: Effect of solar radiation on stem water potential of 'Samantha' roses. Measurements were collected on completely overcast or clear days. Each point represents a mean of two to four replicates. Vertical bars are 95% confidence intervals. R^2 = 0.51. mPa = megapascals, 1 mPa = 10 bar.

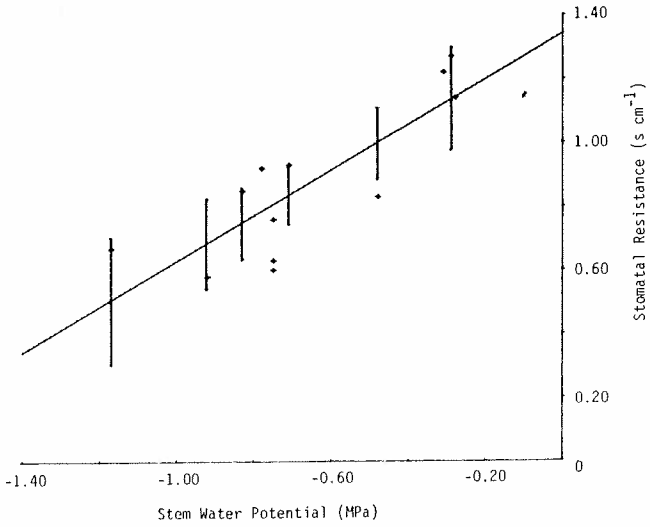

Fig. 4: Effect of stem water potential on stomatal resistance of 'Samantha' roses. Measurements were collected on completely overcast or clear days. Each point represents a mean of two to four replicates. Vertical bars are 95% confidence intervals. R^2 = 0.64. mPa = megapascals, 1 mPa = 10 bar.

Acknowledgements

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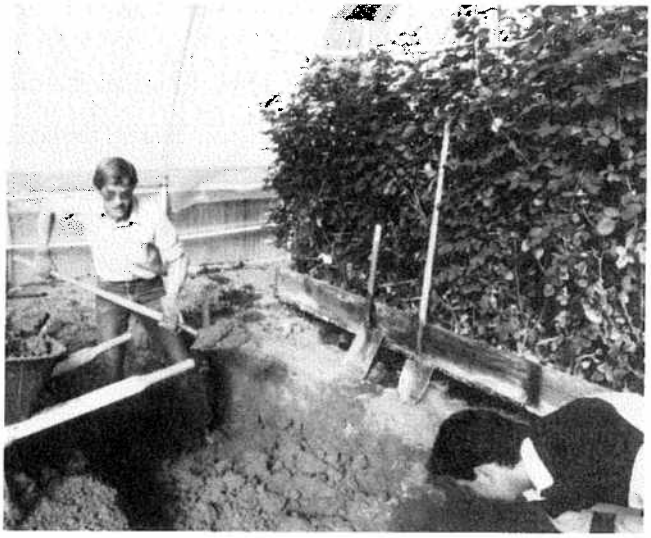
We understand that Colombia roses have a grade called "trees". We can do pretty well in Colorado. Richard Harkess holds a long stemmed 'Red Success' which we propose to call our "Redwood" grade. Actually we fudged. There is a three inch hook on the bottom end.



Rose growers get their soil benches. R.J. Schwartz, Richard Harkess, and several other leaders put their backs into the job. Four 12 ft benches were dug out to 18 inches, drain and gravel put in, the soil all mixed outside for all four houses, and replaced. Since this picture was taken, side boards have been added to bring the soil line three inches above the ground, steamed, and irrigation system installed. These are to be planted in March.