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CO_2 UPTAKE BY 'SAMANTHA' ROSES

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'Samantha' roses grown in CO_2 enriched greenhouses, in rockwool, had maximum average photosynthetic rates greater than previously reported in the literature (1.41 mg CO_2 per sq.m.-sec) at an average radiation level of 285 W/sq.m., a CO_2 concentration of 86 Pascal (1016 ppm), and 86°F respectively. Leaf temperature became increasingly more important at high radiation levels. Stomate resistance did not appear to vary significantly, and calculations suggested that resistance to CO_2 uptake in the bulk air would be the determining factor at wind speeds less than 0.08 m/sec (16 fpm).

Introduction

Few research articles have dealt with the environmental physiology of greenhouse roses in environments similar to commercial ranges. With the loan of a LI-COR 6000 photosynthesis system[2], and the climate control system available (CGGA Bulletins 420, 430), 16 variables dealing with the environment and rose leaf were measured within two minutes with little disturbance to the plant's environment. This state-of-the-art technology provided a good picture of rose behavior in the greenhouse as compared to what might be obtainable in a growth chamber. The purpose of this study, a portion of which was reported in CGGA Bulletin 455, was to examine the CO_2 uptake of well watered roses.

The work deals with the period from Nov. 13, 1986, to Dec. 13, 1986, on the same 'Samantha' roses described in CGGA Bulletin 455. Briefly, CO_2 was injected into the rose canopy of each greenhouse based on inside solar radiation levels. A minimum 35 Pascal (413 ppm at Ft. Collins) was maintained at inside radiation levels below 100 W/sq.m., and increased automatically 0.2 Pascal per W-sq.m. above 100. CO_2 injection was cut-off at 2nd stage cooling with a ten minute delay before injection could re-occur.

Stems on 'Samantha', grown in wettable rockwool and irrigated automatically, with flower bud diameters of 0.28 to 0.47 inches, were measured for internal water stress, and CO_2 uptake on one 5-leaflet leaf. Stems were randomly selected with the restriction that each plant was sampled only once during any day. Individual leaves were visually graded on a scale of one to five to estimate relative leaf age the day before measurements were taken. The leaf age was the relative degree of red and green colors exhibited by the top surface of the 5-leaflet leaf. At the time of grading, any leaflets beyond a total of 5 were removed.

Measurements were obtained under clear sky conditions with the HP computer recording the four environments at one minute intervals, and the photosynthesis system (LI-COR 6000) recording gas exchange of individual leaves. The average air velocity over the sampled leaf was estimated with a thermistor anemometer clamped to a stand before and after the leaf was placed into the four liter photosynthetic chamber. Data were collected between early morning and mid-afternoon. The LI-COR instrument recorded ten measurements at three second intervals with the averages used as individual leaf values for data anlysis. Means were calculated from two to seven replicates per greenhouse at any one given time-of-day. These were weighted according to the number of replicates for each mean, i.e., a mean with seven observations was given more weight than a mean with only two observations. The weighted means for all four houses were combined in the data analysis.

An estimated aerodynamic resistance was calculated from the measured air velocity, based upon an equation presented by Grace (1981). Air velocities were compared to both aerodynamic and stomatal resistances.

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[2] *Thanks to David Nielsen, Akron, CO, Research Station, for the loan of equipment during the winter season.*

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Results and discussion

Measurements were collected from statistically similar rose stems. The average time-of-day was 1130 hours MST. The mean relative leaf age was three — half red, half green, upper leaf surface. The average bud and stem diameters were 0.37 and 0.19 inches respectively.

The highest average net photosynthetic rate obtained during this study was 1.41 mg CO_2 per sq.m.-sec, with an average radiation level of 285 W/sq.m. (657 μmol m^{-2} s^{-1} PAR), CO_2 level of 86 Pascal (1013 ppm) and leaf temperature of 86°F. This rate was higher than previously published maximum rates (Bozarth et al., 1982) with value of 0.57 mg CO_2 per sq.m.-sec at 207 W/sq.m. (475 μmol m^{-2} s^{-1} PAR), and a normal (350 ppm) CO_2 concentration. Butt (1986), in Canada, observed that the photosynthetic rate of an entire rose plant increased 51% with elevated CO_2. A review by Porter and Grodzinski (1985), indicated increased photosynthesis with higher CO_2 concentrations if the diffusion process of CO_2 into the leaf was not limited by stomate closure.

These results showed that leaf temperature was highly important in determining response to solar radiation at elevated CO_2 concentrations (**Fig. 1**). Previous reports, such as Gaastra's (1959), indicated that at high CO_2 levels, photosynthetic rates are strongly affected by leaf temperature. In fact, leaf temperature could be a limiting factor under high sunlight and elevated CO_2 — a situation that is quite common in Colorado. At low solar radiation, leaf temperature could vary from 59 to 86°F with little effect on CO_2 uptake.

Stomatal resistances varied from 0.32 to 1.32 sec per cm over the range of 48 to 296 W/sq.m. (110 to 681 μmol m^{-2} s^{-1} PAR), with an average of 0.59 sec/cm. There was a low correlation between stomatal conductance (reciprocal of resistance) and photosynthetically active radiation (PAR) and total radiation. The degree of opening of stomates on roses (stomatal resistance) was not affected by increasing CO_2 concentration inside the leaf (**Fig. 2**). The CO_2 concentration inside the leaf was a direct function of the external CO_2 level (**Fig. 3**). In other words, CO_2 concentration had no effect on stomate opening, and neither did radiation have a remarkable effect on stomates in this study.

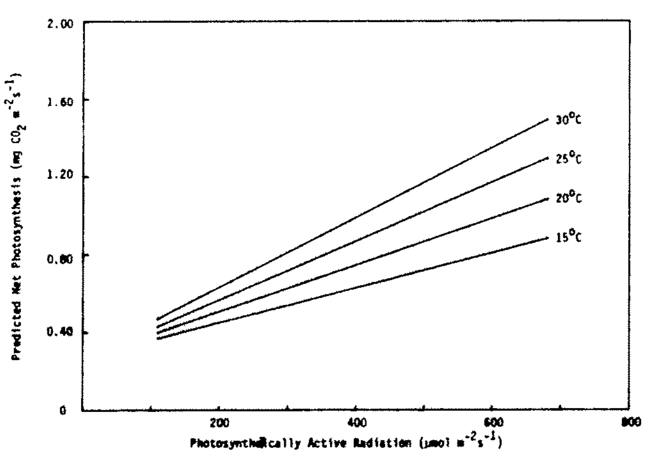

Fig. 1: Effect of Photosynthetically Active Radiation (PAR) at four different chamber leaf temperatures on the predicted net photosynthesis of 'Samantha' roses. Measurements collected on clear days between Nov. 13 and Dec. 13, 1986, with a portable, LI-COR photosynthesis system. Each line derived from the best all possible subset regression model, adjusted R^2 = 0.88.

Stomata of well-watered 'Samantha' did not appear to respond to their environment. If so, then these types of plants are well suited for CO_2 enriched greenhouses. A drawback is that low humidities could cause high water stress even when the plant is provided with adequate water. This might explain some of the results obtained in CGGA Bulletin 442 with acoustic emission studies.

With non-responsive stomata, resistance outside the leaf would be highly important in supplying CO_2 to a rose leaf. We refer to this as aerodynamic resistance which was brief-

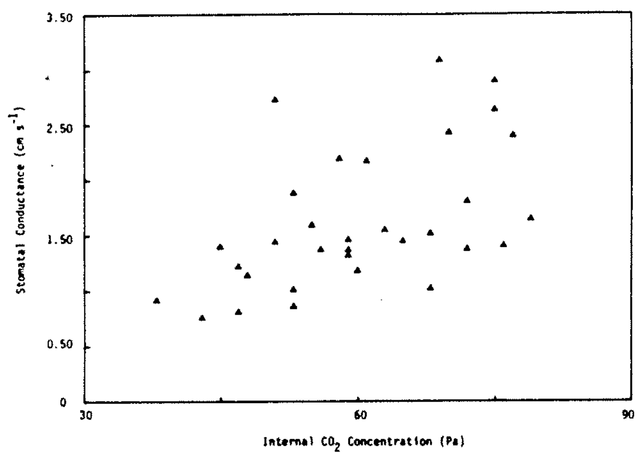

Fig. 2: Effect of initial internal CO_2 concentration on stomatal conductance (reciprocal of resistance) of 'Samantha' roses. Measurements collected on clear days between Nov. 13 and Dec. 13, 1986, with a portable LI-COR photosynthesis system. Each point represents a mean of two to seven leaf replicates from separate plants. Correlation between stomatal conductance and internal CO_2 concentration was r=0.60. The CO_2 concentrations were the absolute concentrations at this altitude and temperature (average station pressure = 84.66 KPa (846.6 mb) and 25°C.

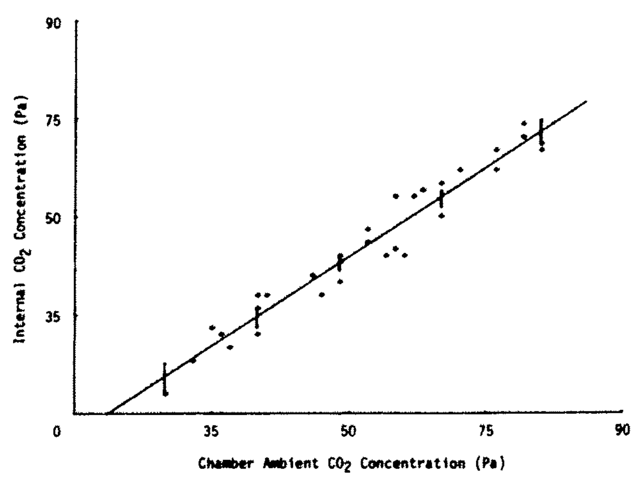

Fig. 3: The effect of ambient CO_2 concentration in the photosynthesis chamber on the internal CO_2 concentration of 'Samantha' rose leaves. The adjusted R^2 = 0.99.

ly discussed in Bulletin 442. Aerodynamic resistance is controlled chiefly by air speed and leaf size and shape. A high resistance would slow CO_2 diffusion, reducing the supply to an actively photsynthesizing leaf regardless of CO_2 concentration. Shaer and van Bavel (1987) calculated an aerodynamic resistance that was two to three times higher than stomatal resistance of tomatoes in a greenhouse, and concluded aerodynamic resistance to be the dominating factor. Jarvis (1985) also suggested that stomata of greenhouse crops probably play a much smaller role in control of water loss than in field crops because of the low air velocities often encountered in the greenhouse.

Using Grace's formula (1981), we estimated the aerodynamic resistance in the greenhouse as a function of windspeed and compared that with the stomate resistance over similar windspeeds (**Fig. 4**). The plot of aerodynamic resistance was not remarkably different from that obtained with Hatfield et al's formula (1983) (CGGA Bul. 442). It would appear that, at windspeeds much less than 16 fpm, aerodynamic resistance would be a limiting factor; whereas, above 25 to 30 fpm, stomatal resistance could be limiting.

With the exception of Dutch work, we do not know of any good data on aerodynamic resistance of a rose crop in

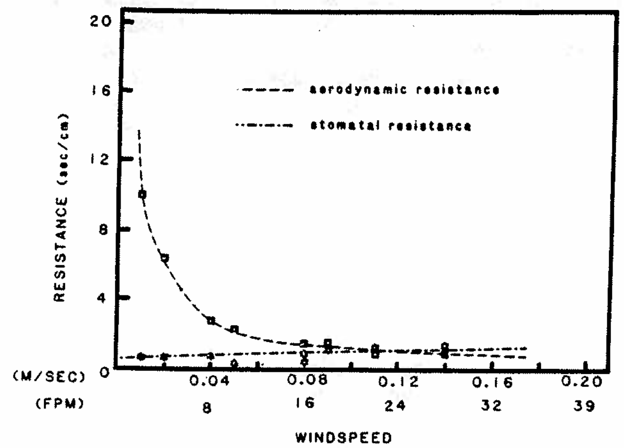

Fig. 4: The effect of air velocity on aerodynamic and stomatal resistances of 'Samantha' roses. Air velocity estimated with a thermistor anemometer before and after the leaf was placed into the photosynthesis chamber for measurement of CO_2 uptake. The two observations averaged for each sample. Aerodynamic resistance calculated from a formula presented by Grace (1981). Each point represents the mean of two to seven replicates. Statistical analyses run on conductances. Curves in this graph drawn by inspection.

American greenhouses. Nevertheless, this information is highly important in maximizing rose yield, making best use of expensive computer systems, and reducing fuel consumption. We believe there should be investigations on rose stomatal responsiveness to the environment, how well does HAF (Horizontal Air Flow) mix through rose canopies, what are the best wind speeds for achieving good mixing, and the trade-off between air movement, gas consumption and humidity control.

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Acknowledgements

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