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SO SPEAKS THE ROSE

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Wherein "listening" to a rose provides some intriguing information on water loss and the effect of a heating system.

In November, 1986, we were visited by Dr. M.L. Tyree, University of Vermont, with regard to a cooperative project on "cavitation" in plants. Dr. Tyree is well known in scientific circles for his work on acoustic emissions in plants and has been a forerunner in this area. At his suggestion, we were able to borrow equipment and undertake preliminary measurements on greenhouse roses.

The movement of water through a plant in the xylem tissue requires a pressure gradient from root to leaf, which is usually negative. As water stress increases, there is greater tension within the vessels, increasing the tendency for the water columns to cavitate with the formation of a vapor bubble, similar to the cavitation around a boat propeller. The formation of the embolism results in noise. Much of the early work in this area was carried out in sound-proof chambers since background sound in the waveband to which our ears are sensitive would necessarily interfere. Research in the last few years has found that cavitations can be detected in the waveband around 350 to 700 kilohertz. These wavelengths are much less susceptible to ordinary background noise.

The equipment (Fig. 1), consisting of a suitable transducer (microphone), was attached to the rose stem, and the electronic equipment set to count the number of cavitations (events) occurring with time. In our case, the microphone was attached to a grafted 'Samantha' flowering stem grown in rockwool and irrigated by computer control. The system was generally set to accumulate cavitations over a 24 hour period. During our initial trials, we set the gain too high so that considerable electrical noise interfered with the actual acoustic emissions. In particular, we found we had to shut off the Morestan heating pans as the count rate increased drastically during pan heating. By reducing the amplifier gain and increasing the threshold sensitivity (to 3

Fig. 1a: Attachment of microphone to rose cane.

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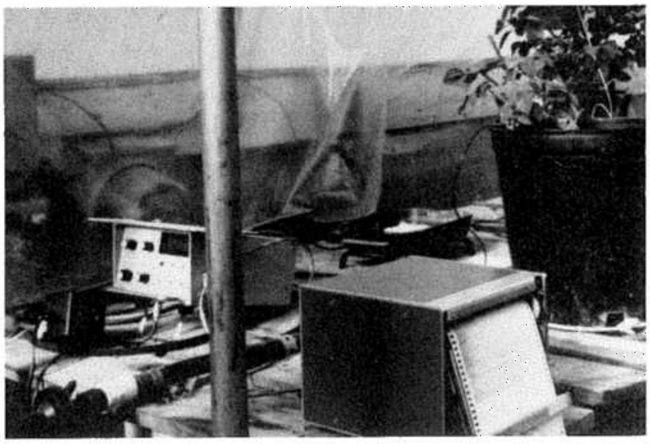

Fig. 1b: Acoustic emission equipment for counting and recording cavitations from the rose cane shown in Fig. 1a.

volts), we were able to reduce background counts (microphone hanging free) to zero, with considerable confidence that we were actually "hearing" water cavitating within the rose stem.

These measurements were carried out in a fiberglass-covered house, controlled by the Colorado State University computer control system. During each measurement, we set the system to record all instantaneous environmental variables every 15 minutes for 24 hours. It became immediately apparent that the fan jet-natural gas heating system in the house could have a drastic effect on humidity in the house at night when the mist system was automatically turned off. An example is shown for November 9, 1986 (Fig. 2), when the outside temperature was below 0°F (−18°C), and the relative humidity dropped below 20% during the early morning hours. Heavy heating, combined with

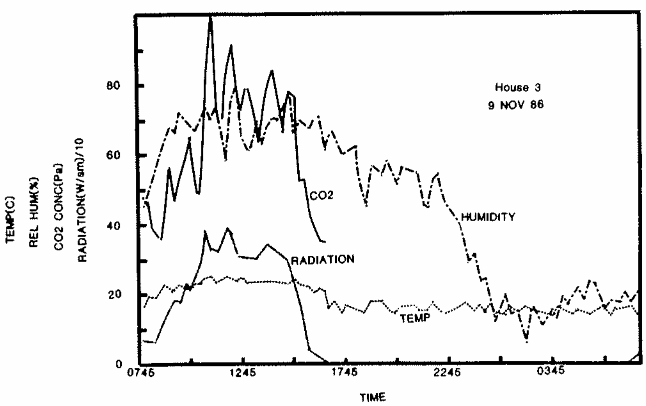

Fig. 2: Relative humidity in a fiberglass covered greenhouse over a 24 hour period when: 1) the fogging system was turned off at night, 2) the outside temperature dropped below −18°C, and 3) the heating system was a fan jet blower with natural gas, unit heaters. The figure shows that humidity inside a greenhouse is a function of heating system and outside temperature which can rapidly dry out a greenhouse.

high infiltration, resulted in excessive drying, and acoustic emissions for the rose *increased* at night — even though we would suppose that the stomates should be closed.

Beginning December 17, we let the high pressure mist pump operate continuously and set the controls to maintain a vapor pressure deficit of 5, 10, 15, and 20 millibars over four successive 24 hour periods. Examples of actual counts are shown in Fig. 3, and some of the environmental parameters are presented in Fig. 4. Although all days were clear, the outside temperature seldom reached −10°C, which would tend to limit the minimum humidity obtainable at the 20 mb VPD level. The relative humidity at each of the four VPDs corresponded roughly to 85, 70, 60, and 40%. Rose plants controlled at 5 mb VPD were continuously wet throughout the night. At 10 mb VPD, there was some moisture, and at the other two levels, the rose bushes in the house remained dry.

Of particular interest was the fact that average hourly count rates *decreased* during the day, and *increased* at night (Fig. 5). We feel the following explanation is the most logical. During the day, with solar heating, the fan jets operated for shorter and fewer periods, resulting in very low wind velocities, as shown by Karen Panter in her examination of wind velocities at the Bay Farm, using the fan jet system. As the sun went down, the fan jets began to operate more-or-less continuously with heavy heating, which would tend to dry out the greenhouse interior to the limits set by the system. Also, during the day, CO_2 was injected (Fig. 4), which would tend to close the stomates, reducing water loss. No water was applied at night to the rockwool. Although this situation undoubtedly influenced the count rate, the average hourly count rate for each 24 hour period increased as VPD was increased (Fig. 6), and the average difference between 5 and 20 mb was significant.

The importance of wind velocity in affecting plant growth in greenhouses has been worked on by Jay Koths, University of Connecticut, wherein he has proposed horizontal air flow (HAF) as a means to improve growth and environmental control. The problem was also approached by Karen Panter at Colorado State University and was a subject presented by her at horticultural meetings in Davis last year. Her measurements at the Bay Farm showed that, with no forced air circulation in a greenhouse, natural convection would generally result in wind speeds less than 4 feet per minute. By borrowing a formula from agronomists working in the field, she was able to estimate the aerodynamic resistance to water vapor movement from leaf to air under a variety of wind speeds (Fig. 7). Based upon her work, and early data from the Dutch worker Gaastra, the effect of the aerodynamic resistance on CO_2 uptake was calculated (Fig. 8), showing that any time air velocity in the greenhouse drops to values much less than 24 fpm, photosynthetic rates can be markedly reduced, and a similar effect would be expected on water loss. Koths recommends HAF at speeds above 50 fpm, but these calculations suggest otherwise. Nevertheless, the use of acoustic emissions technology has opened our eyes to some rather interesting phenomena in greenhouse climate control, which need to be investigated. We are continuing our cavitation measurements on other commercially important greenhouse species with a view, ultimately, of incorporating this method into climate control of greenhouses.

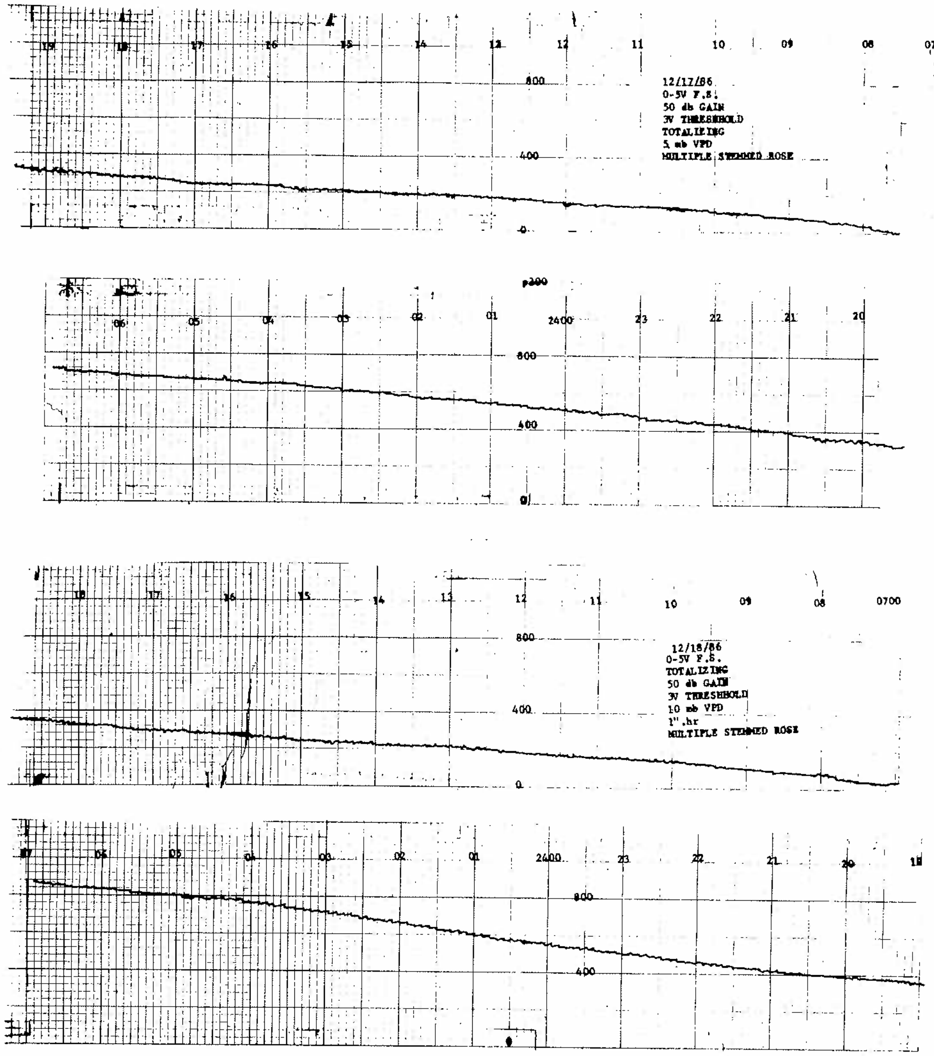

Fig. 3: Actual records of acoustic emissions from a rose cane. Recording system set to total events over a 24 hour period, beginning at 0700 to 0700 the following morning when the system was reset. The top figure shows cumulative counts when the environment was set to maintain a maximum 5 millibar vapor pressure deficit as contrasted to a 10 mb VPD in the bottom graph. The counts per hour were estimated from these records.

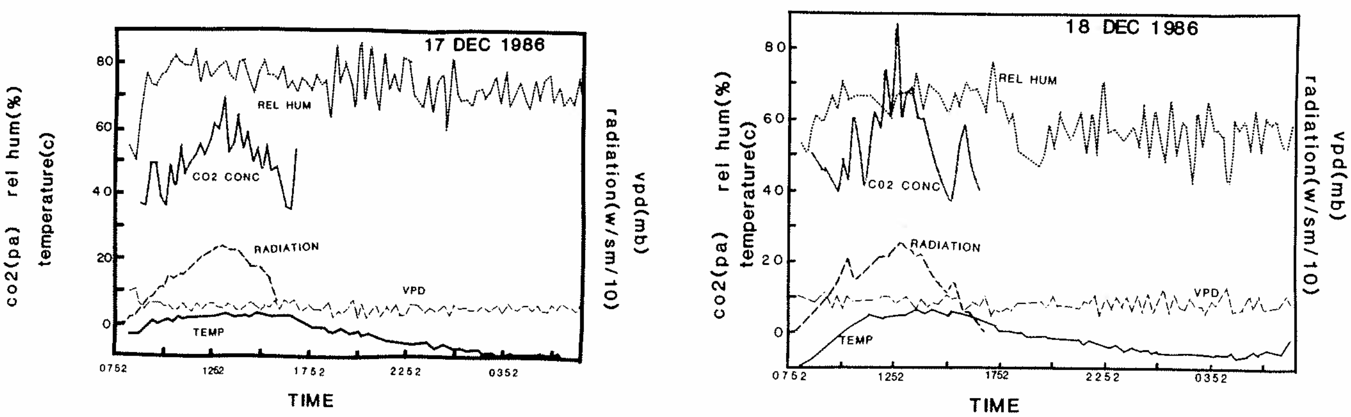

Fig. 4: Environmental conditions in the greenhouse in which the acoustic emissons were measured on a rose cane. The curves show instantaneous values of outside temperature (°C), relative humidity (%), vapor pressure deficit (millibars VPD), radiation (watts per sq.m.), and CO_2 concentrations (Pascals) at 15 minute intervals. These two graphs correspond with the acoustic emission counts shown in Figure 3 for 5 and 10 mb VPD.

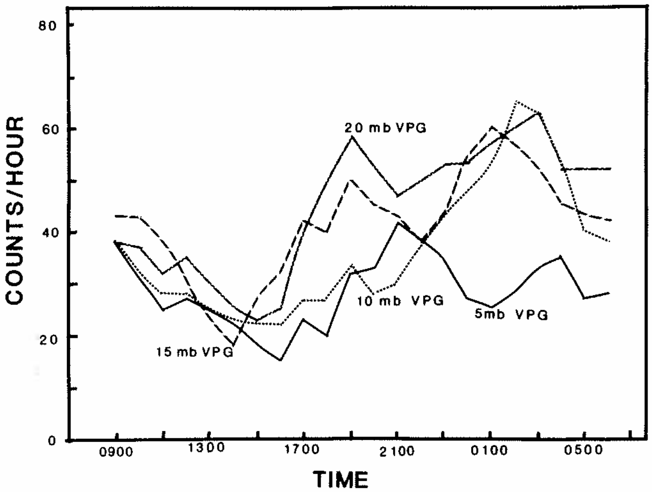

Fig. 5: Hourly cavitation rates on a rose cane, estimated from graphs, as shown in Fig. 3, when humidity in the house was controlled over successive 24 hour periods at 5, 10, 15, and 20 millibars vapor pressure deficit. Curves subjected to a 3 moving means smoothing process with the resultant loss of the first and last data points.

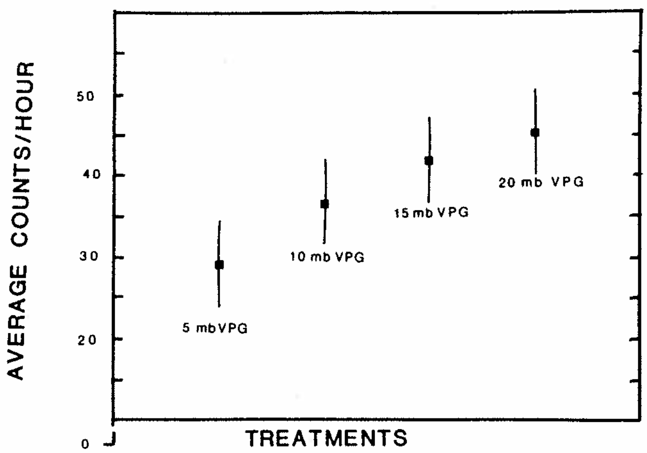

Fig. 6: Average hourly counts per hour of cavitations in a rose cane when the greenhouse environment was controlled at 5, 10, 15, and 20 millibars vapor pressure deficit over successive 24 hour periods. The vertical lines show the range over which the values can change before there is a statistically significant difference between the averages.

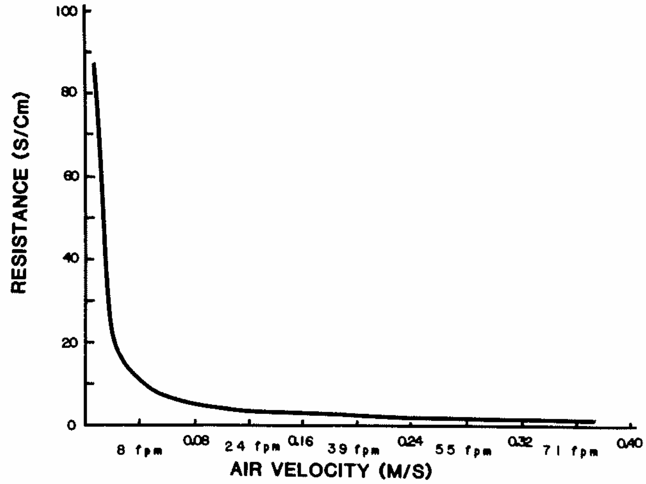

Fig. 7: Estimated aerodynamic resistance to water vapor movement from 60 cm above a crop canopy to the leaf as a function of wind velocity, using Hatfield et al.'s (1983) formula.

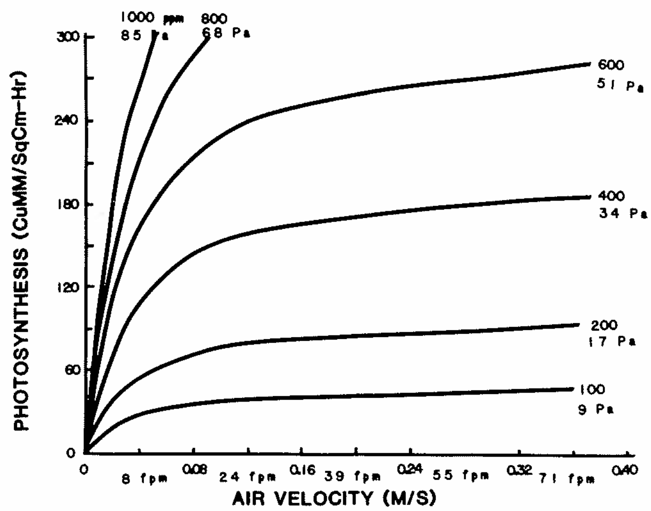

Fig. 8: The effect of bulk air CO_2 concentration at different air velocities on CO_2 uptake by a crop, assuming an internal leaf and stomatal resistance of 7 sec cm^{-1}, and conversion of the top curve for water vapor to CO_2, using diffusion constants of 0.14 cm^2 sec^{-1} for water and 0.24 cm^2 sec^{-1} for CO_2. Radiant energy assumed to be non-limiting (above 300 W m^{-2}) and internal water potential greater than −10 bar. The CO_2 concentrations in Pascals (Pa) have been corrected to Fort Collins' altitude.