Relationships Between Stomatal Resistance and CO₂ Level Around and Inside Leaves of Greenhouse Tomatoes

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An important subroutine in any physiological model of the effect of the ambient CO₂ concentration (Ca) on plant growth, yield, and water use expresses the effect of Ca on stomatal resistance (Rs). Raschke (1975) postulated that the relevant mechanism is a negative feedback of the internal, intercellular CO₂ level (Ci), the increase of which tends to throttle the stomata. Sinclair et al. (1984) proposed that, in effect, this mechanism would maintain a constant ratio of Ci : Ca, equal to ≈0.7 in C3 plants. Earlier, Goudriaan and van Laar (1978) obtained data that suggested the constant ratio hypothesis, as did Wong et al. (1980). Later work by Jones et al. (1985) with soybeans in controlled environment chambers gave ratios between 0.74 and 0.78.

In 1984, we did a long-term experiment with greenhouse tomatoes at College Station, Texas, to quantify the effect of CO₂ level on growth, water use, and yield (Shaer and van Bavel, 1987). In this experiment, 120 tomato plants (*Lycopersicon esculentum*, Mill. cv. Tropic) were planted on 25 July 1984 in each of three clear polyethylene chambers, 10 × 2 × 2 m (length/width/height), that were ventilated at 15 air changes per hour, or 0.0083 m·s⁻¹. The chambers were located inside a polyethylene greenhouse.

During the daytime, the level of CO₂ was controlled with a CO₂ injection system in two chambers, one at 700 and the other at 100 vppm (volume parts of CO₂ per million parts of air), with the third one left at ambient level (340 vppm). The plants were grown in 5-liter pots containing 3.5 kg of fritted (calcined) clay, and were kept well-watered.

On 1, 2, and 3 Oct. 1984, simultaneous

measurements were made around noon of the canopy CO₂ exchange rate/m² leaf area, CER (10⁻⁶ vppm m³·m⁻²·s⁻¹), and of the stomatal resistance, Rs (s·m⁻¹). During these tests, the CO₂ level was maintained at a range of values, rather than at the two levels specified above. The intercellular level of CO₂ (Ci) was calculated from:

$$\text{CER} = 10^{-6} \cdot (\text{Ce} - \text{Ca}) \cdot \text{V/LAI} \quad [1]$$

$$\text{RaC} = \text{Ra} \cdot 1.4 \quad [2]$$

$$\text{RsC} = \text{Rs} \cdot 1.6 \quad [3]$$

$$\text{Ci} = \text{Ca} - 10^{-6} \cdot \text{CER} \cdot (\text{RsC} + \text{RaC}) \quad [4]$$

where Ce and Ca are, respectively, the CO₂ level in the air entering and leaving the chambers in vppm, as measured with an infrared gas analyzer (Series 225, ADC Corp., Hoddesdon, Herts., U.K.). V is the ventilation rate in m·s⁻¹, LAI is the leaf area index, Ra is the aerodynamic resistance of the foliage for water vapor transfer, RaC is the corresponding value for CO₂, and RsC is the stomatal resistance for CO₂ diffusion, the latter three in s·m⁻¹. Other parameters are defined above. The value of Ra that corresponds to the ventilation rate used was 200 s·m⁻¹ (Shaer and van Bavel, 1987). The sto-

matal resistance Rs was measured with a steady-state porometer (LICOR 1600, LICOR, Lincoln, Neb.).

In Table 1 we show the measured stomatal resistance at different levels of Ca and the corresponding calculated values of Ci (Eq. [4]). There was a strong correlation between Rs and Ci, the linear regression equation being:

$$\text{Rs} = 24 + 0.11 \text{ Ci} \quad (R^2 = 0.82) \quad [5]$$

Equation [5] applies only to tomato plants in the light and not short of water. Table 1 also shows the average value of Ci : Ca as 0.77 ± 0.07, in agreement with the values reported by others. Hence, we can substitute that value in Eq. [5] to obtain:

$$\text{Rs} = 24 + 0.085 \text{ Ca} \quad [6]$$

Equation [6] could have direct usefulness in predicting both water use and CO₂ assimilation by well-watered greenhouse tomatoes as a function of the ambient CO₂ level.

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Table 1. Measured ambient CO₂ level (Ca, vppm), calculated intercellular CO₂ level (Ci, vppm), and measured stomatal resistance (Rs, s·m⁻¹) of leaves of greenhouse tomatoes around noon during 1, 2, and 3 Oct. 1984.

Date (Oct.)	Ca (vppm)	Ci (vppm)	Ratio (Ci : Ca)	(s·m ⁻¹)
1	730	597	0.82	110 ± 24
1	920	698	0.76	123 ± 43
1	340	266	0.78	47 ± 11
1'	340	253	0.74	57 ± 12
1'	760	663	0.87	114 ± 37
2	340	264	0.78	52 ± 4
2	480	294	0.61	46 ± 4
2	1100	850	0.77	93 ± 18
3	340	242	0.71	42 ± 10
3	880	709	0.81	95 ± 26
?	1200	1034	0.86	132 ± 32

Average ratio Ci : Ca = 0.70 ± 0.07

Linear regression (Rs on Ci): Slope = 0.11 ± 0.02; Intercept = 24 ± 10; R² = 0.82

¹Measured around 1400 HR CST. Average air temperature 27°C. 60% RH, and solar radiation 380 W·m⁻², all inside greenhouse.

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