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# $CO_2$ TRANSPORT THROUGH CELL WALLS INTO THE CHLOROPLASTS OF BEAN LEAVES

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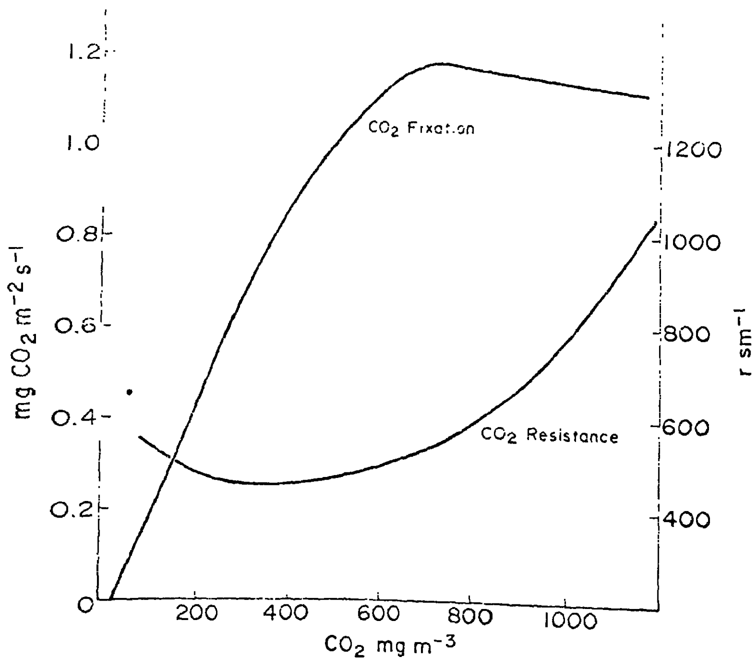
To achieve maximum growth, $CO_2$ must be present in non-limiting quantities at the carboxylating sites in the chloroplasts. Stomatal resistance may limit $CO_2$ entry and reduce photosynthesis, as may the resistance to $CO_2$ transport through the cell walls and membranes surrounding the chloroplasts. The cell wall and membrane resistance has never been directly measured but estimated values in the literature range from near zero to more than 600 s $m^{-1}$. By comparison stomatal resistance of bean leaves is often in the neighborhood of 100 s $m^{-1}$. In 1981 von Caemmerer and Farquhar showed that increasing $CO_2$ levels in the gas phase of the mesophyll tissue of bean leaves can cause $CO_2$ fixation to decrease, Fig. 1. The cause of this $CO_2$ response curve's peak and subsequent decrease is unknown, but we believe it may be due to an increasing resistance to the transfer of $CO_2$ through the cell walls and membranes.

Figure 1. The effects of increasing $CO_2$ concentration in the air surrounding mesophyll cells on the net rate of $CO_2$ fixation and on cell wall and membrane transport resistance, r, in a bean leaf at 1% $O_2$.




Using an approach similar to that of Jones and Slayter (1972) we derived, from recent kinetic models, an equation that shows how the cell wall and membrane resistance may change in response to the $CO_2$ concentration in the gas phase surrounding the mesophyll cells, i. e.,

$$r = C_a P^{-1} - r_s - [B+(B^2 + D)^{1/2}]D^{-1} \qquad (1)$$

where $B = P\ (0.35K + 1)$ and $D = 1.4KP(P_m - P)$. $C_a$ is the $CO_2$ concentration in the air around the leaf, P is the rate of $CO_2$ fixation, $r_s$ is the stomatal resistance, $P_m$ is the maximum $CO_2$ fixation rate, and K is the Michaelis-Menten constant as used by Jones and Slayter (1972). Details concerning the derivation of eq. 1 are available upon request.

Values of r may be found from eq. (1) using measurements of $CO_2$ fixation and stomatal resistance made at various $CO_2$ levels in a 1% $O_2$ gas mixture. We used the data given by von Caemmerer and Farquhar (1981) to calculate the values of r shown in Figure 1. The result shows that an increasing cell wall and membrane transport resistance, associated with increasing $CO_2$ concentration, can cause the fixation curve to peak and then decrease as the $CO_2$ level continues to rise, even though the stomata do not close. Other plants also show this phenomenon (Woo and Wong, 1983).

Inherent in our analysis is the definition of a carboxylating resistance, $r_c$. It is inversely proportional to the concentration of ribulose-1, 5-biphosphate molecules that are attached to activated carboxylating enzyme sites in the chloroplasts. Examples of some results of our measurements on bean leaves are shown in Table 1. The resistance to $CO_2$ transport across the mesophyll cell wall and membranes increases as light intensity decreases and as $CO_2$ levels rise. The concentration of RuBP attached to active carboxylating sites rises as light increases and as $CO_2$ decreases.

Table 1. Values, P, of net $CO_2$ fixed, r and $1/r_c$ at various levels of light and leaf gas phase $CO_2$ concentrations, $C_i$.

| | Light | $C_i$ | P | r | $1/r_c$ |
|---|---|---|---|---|---|
| | $Em^{-2}s^{-1}$ | $mg\ m^{-3}$ | $mg\ s^{-1}m^{-2}$ | $s\ m^{-1}$ | $mm\ s^{-1}$ |
| Leaf #1 | 1250 | 660 | 0.50 | 954 | 3 |
| | | 289 | 0.30 | 885 | 13 |
| | 240 | 694 | 0.32 | 1816 | 3 |
| | | 330 | 0.18 | 1748 | 12 |
| Leaf #2 | 1250 | 665 | 0.57 | 766 | 3 |
| | | 281 | 0.37 | 689 | 14 |
| | 240 | 737 | 0.32 | 1053 | 1 |
| | | 305 | 0.27 | 767 | 3 |

Literature Cited

von Caemmerer, S. and G. D. Farquhar, 1981. Planta 13:376.
Jones, H. G. and R. D. Slayter, 1972. Plant Physiol. 50:283.
Woo, K. C. and S. C. Wong, 1983. Aust. J. Plant Physiol. 10:75.