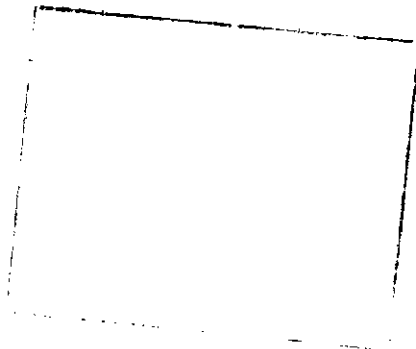# STOMATAL SENSITIVITY TO AIR HUMIDITY:

A HYPOTHESIS FOR ITS CONTROL THROUGH PERISTOMATAL EVAPORATION [1]

Mabrouk A. El-Sharkawy and James H. Cock [2]

Abstract

Analysis of previously published data shows that an extremely close correlation $(r^2 = 0.83)$ exists between stomatal sensitivity to changes in leaf to air vapor pressure deficit and the maximum leaf conductance at low VPD in a wide range of plant species. The hypothesis is presented that stomatal sensitivity to changes in VPD is related to the evaporative area of the stomatal apparatus coupled with a large hydraulic resistance between the epidermal cells and the bulk of the leaf.

Additional index words: Stomatal density, Maximum leaf conductance, Bulk leaf Water potential, Hydraulic resistance.

The sensitivity of stomata to atmospheric humidity has first been recognized by Leitgeb in the last quarter of the 19th Century (cited by Haberlandt, 1914) . Nevertheless, much of the recent work on stomatal closure has concentrated on demonstrating that the stomata close in response to the release of abscisic acid when bulk leaf water potential falls below a threshold value (see reviews by Hsiao, 1973; Raschke, 1975; Zeiger, 1983). Recently El-Sharkawy et al 1984, and El-Sharkawy and Cock 1984 have shown that in some species stomatal closure may occur at large leaf air Vapour Pressure Difference (VPD) with no change in bulk leaf water potential. Tyree and Yianoulis (1980) have developed a model to show how stomata might close at large VPD through peristomatal evaporation. They point out that for transpiration to decrease as VPD increases above a certain value peristomatal evaporation must occur from the external surface of the stomatal apparatus and not within the stomatal cavity. The response they describe has been found in cassava (El-Sharkawy et al 1984) and peanuts (ICRISAT 1983) and Maier - Maercker (1983) has shown that external peristomatal evaporation can be significant, thus indicating that external peristomatal evaporation is likely to be an important factor, if not the most important factor, in determining stomatal sensitivity to changes in VPD.

Stomata will close in response to large VPD with no change in bulk leaf water potential. There is however presumably a localized decrease in water potential at the stomatal site. Stomata of different species might be inherently more or less sensitive to changes in water potential, or have large differences in the resitance to evaporation from their external surface, however there is no evidence either to support or reject these hypotheses. It is however well known that large differences exist in stomatal density between species (Metcalfe and Chalk, 1950; Slavik, 1974; Körner et al, 1979).

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We suggest that the total evaporation from the external peristomatal surface will, other things being equal, increase with external stomatal area. Furthermore, if localized decreases in water potential of the stomatal apparatus is to occur with no change in bulk leaf water potential, then either the resistance to water flow between the bulk of the leaf and the stomata must be large or the evaporation from the stomatal surface must be large. The fact that transpiration decreases markedly to very low levels as VPD increases in such species as cassava and peanuts indicates that the evaporation from the external stomatal apparatus is small in comparison to maximal evaporation. This then suggests that the resistance between the stomata and the bulk of the leaf must be large (from the minor veins via mesophyll-epidermis pathway).

If the resistance between the stomatal apparatus (guard and subsidiary cells) and the adjacent epidermal cells is large and the resistance between the epidermal cells and the spongy mesophyll , palisade layers and veins is small then the drop in water potential of each stomatal apparatus would be relatively independent of other stomatal apparatus as all adjacent epidermal cells would have a water potential close to that of the bulk leaf water potential. If on the other hand the resistance between the epidermal cells and the bulk of the leaf were high, then an increased evaporation load would decrease epidermal leaf water potential substantially. This would then indicate that if the hydraulic resistance between the epidermis and the bulk of the leaf is large in comparison to that between the epidermal cells and the stomatal apparatus we would expect a close relationship between the sensitivity of stomata to changes in VPD and the total external area of stomatal apparatus. It is to be expected that maximum con-ductance of a leaf will be closely related to the total stomatal areas and the stomatal density.

The data of El-Sharkawy et al 1984 were taken and reanalysed. Maximum leaf conductance was taken from their regression equations of leaf conductance and VPD at 1 K Pa (the lower end of their range of measurements) and stomatal sensitivity from the slope of the same regression equations. The stomatal sensitivity of the eight species studied showed a highly significant correlation with maximum stomatal conductance (Fig. 1).

From these data we conclude that stomatal sensitivity to VPD is closely related to maximum leaf conductance and that the basis of this response is the large evaporative area of the stomatal apparatus related to a high stomatal density coupled with a large resistance between the epidermal cells and the bulk of the leaf.

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Legend for figure 1.

Stomatal sensitivity to leaf – air vapor pressure difference (VPD) as a function of maximum stomatal conductance. Data points are for the species: Cassava (Manihot esculenta), Siratro (Macroptilium atropurpureum), beans (Phaseolus vulgaris), eucalyptus (Eucalyptus deglupta) , amaranth weed (Amaranthus retroflexus), grain sorghum (Sorghum bicolor) , rice (Oryza sativa), and andropogon (Andropogon gayanus) .   (El-Sharkawy et al , 1984).

y = 0.32 x - 0.96

r^2 =

Stomatal Sensitivity $(mm\ s^{-1} / K\ Pa)$ vs Conductance at 1 KPa VPD $(mm\ s^{-1})$

$y = 0.32\ x - 0.96$

$r^2 = 0.83\ **$