*Proceedings of the 7th Hungarian Congress on Plant Physiology, 2002*
*S5-04*

**Volume 46(3-4):181-183, 2002**
**Acta Biologica Szegediensis**
http://www.sci.u-szeged.hu/ABS

# Stomatal resistance investigations in maize

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**ABSTRACT** Field experiment was carried out at Agrometeorological Research Station of Keszthely, in maize, during the season of 2001. Estimation of the site of average stomatal resistance for leaf was determined by mapping the distribution of the resistance values within the blade. Vertical distribution of resistance in different leaf levels was also registered. To validate the estimation, the simulation model of Goudriaan (1977) was applied. A satisfactory agreement, less than 10% alteration was found between the measured and simulated stomatal resistance values. The exact value of the stomatal resistance of plants might play important role in simulation modelling, as an unique input parameter regarding the plant-water relation.
**Acta Biol Szeged 46(3-4):181-183 (2002)**

**KEY WORDS**

maize
plant-water relation
stomatal resistance

All the transpired water, as well as $CO_2$ absorbed in photosynthesis is under the control of the stomata, even though these pores occupy less than 5% of the whole leaf surface. The extreme environmental and physiological sensitivities of the stomata enable them to harmonise the balance between water loss and $CO_2$ uptake. There are several methods to study the stomata. One of the most meaningful methods in measuring the pore activity is the porometer use. The up to date method in stomatal activity investigations is the modelling.

The aim of the study was to find those blade section within maize, where the measured stomatal resistance is the closest to the mean of the whole plant. This information has of primary importance in modelling, because the average stomatal resistance is the input parameter of the most models. To validate the average resistance estimation, the CMSM model of Goudriaan (1977) was applied.

## Materials and Methods

Investigations were carried out at the Agrometeorological Research Station of Keszthely, during the 2001 season, in maize.

A part of the plants was grown in lysimeter growing chambers, at "Ad libitum" water supply. Surface area of the chambers of Thornthwaite type compensation evapotranspirometers were 4 $m^2$, and the depth of them 1m. We filled the chambers with Ramann type brown forest soil, characteristic soil type in the surroundings. Daily sum of evapotranspiration was given by the change in the volume of soil water in the chamber, by additional water supply through the compensation pot and by precipitation amounts. The rainfed plants served as control treatment.

In stomatal resistance determination we applied a diffusion porometer (Delta T Manufacturers, AP4 type transient porometer.), that provides all the leaf resistance to water vapour, including any cuticular part and boundary layer resistance in the porometer chamber. The instrument measures the humidity increase in a closed chamber arising from the water loss of the leaf section. The time taken for humidity increase over a fixed interval may be converted into a resistance value by using of a previously obtained calibration curve.

We constructed daily change in stomatal resistance by presenting hourly values randomly sampled on days with undisturbed radiation. The number of repetitions was 3 to 5. In spite of that the maize is an amphystomatous plant, at the beginning of the seasons (May-June) both abaxial and adaxial leaf sides were sampled. Later on only the lower blade side was applied for resistance determinations.

To find the place where to measure the "average" stomatal resistance several leaf sections on both sides of the main rib were sampled. Vertical distribution of resistances was drawn by measuring the resistance values in different leaf levels of plant height.

Meteorological data were measured on the local automatic station (QLC-50). Model input parameters were also collected locally.

## Results and Discussion

### Theory of modelling approach after Goudriaan (1977)

To test our field stomatal resistance observations the modified version of Crop Simulation Model of Goudriaan (1977) was applied. The original model was modified by Chen (1984) and Anda et al. (2001).

The basic of simulation of the stomatal resistance is the mass transport - both water vapour and $CO_2$ – that occur via stomata, so the ratio between their resistances is equal to the ratio between their diffusivities. In maize a linear relationship exists between net $CO_2$ assimilation and inverse leaf resistance (leaf conductance) at constant $CO_2$ concentration in the sub-stomatal cavity. This connection provided the basic for simulation of leaf resistance, since the net $CO_2$ assimilation can be deducted precisely from the absorbed visible radiation. Exceeding the saturation point of $CO_2$ assimilation (200 J $m^{-2}$ $s^{-1}$ for sunny maize leaves) the leaf

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resistance approaches the minimum value. Rate of net $CO_2$ assimilation was considered empirically by van Laar and Penning de Vries (1972) as follows:

$$F = (F_m - F_d)[1/\exp{*}/R_v\, \varepsilon / F_m)] + F_d \qquad (1)$$

where $F_m$ maximum rate of net assimilation,

$F_d$ dark respiration,

$R_v$ absorbed visible radiation (per LAI),

ε slope of the curve of $F$-$R_v$ at low light intensities, *or* efficiency ($17{,}2*10^{-9}$ kg/J light in maize).

At $F_m$ calculation the influence of leaf age and ambient $CO_2$ concentration were simplified and their average values were applied. Dependence of leaf temperature was considered to a dependence on ambient air temperature. Dark respiration was at about –0.1 of $F_m$. To calculate maize leaf resistance, the Equation (1) can be re-written as follows:

$$F = \frac{1.83*10^{-6}\,(C_e - C_r)}{1.66\, r_{leaf} + 1.32\, r_{b,h}} \Rightarrow r_{leaf} = \frac{1.83*10^{-6}\,(C_e - C_r) - 0.783\, r_{b,h}}{1.66\, F} \qquad (2)$$

where $r_{b,h}$ boundary layer resistance for heat,

1.66 is the ratio between diffusivities (for $CO_2$ and $H_2O$),

$1.83*10^{-6}$ converts $CO_2$ concentration into kg $CO_2$ /m$^2$ at 20ºC,

$C_e$ external $CO_2$ concentration,

$C_r$ assumed as „regulatory" $CO_2$ concentration,

1.32 originates from calculation of boundary layer resistance for $CO_2$.

The $r_{leaf}$ was assumed to be equal to the mean resistance measured by the porometer.

## Stomatal resistance of the two leaf epidermis during the growing season

Sensitivity of pores to environmental and internal factors causes high variability in stomatal resistance in space and time. In field trials, in spite of newly developed sophisticated instruments, uncertainty is still exits at average resistance estimation.

In most investigations for maize, the same value of stomatal resistance is registered on both sides of the leaf epidermis, proving the earlier information that the maize is an amphystomatous plant and having almost the same number of pores in the upper (52 pieces mm$^{-2}$) and lower (68 pieces mm$^{-2}$) epidermis.

In May and June, we found at about 25-30% increase in stomatal resistance of the upper epidermis. Difference in resistance values between the two leaf sides manifested mainly at low solar angles. It might be attributed to the special radiation environment in spring, in the time of the open canopy structure, that lets a better radiation penetration into the stand decreasing the stomatal resistance of lower leaf epidermis. In fully developed canopy, from July, the difference in resistance values between the two leaf sides ceased. After canopy closure when stomatal resistance samples are taken, one leaf side seems to be enough, as a linear relation exists between the two blade sides (Fig.1).

In spite of daily inconstancy of measured stomatal resistances, the distribution of the values within the blade and also in plant height was similar. In the middle of leaf blades we found the lowest resistances (decrease was at about 40-45%). Moderate, always less, than 20% increase in stomatal resistance of leaf section closest to the stem was also registered. The site of highest resistances was the top of blade, where the increase in resistance was 30-35%. The site of the average resistance can be determined at the border of second third, close to the top of leaf.

After measuring the average stomatal resistance of blades in different leaf levels of plant height, the actual mean of the whole plant can also be estimated. Finally the site of the mean stomatal resistance for the whole plant was registered one or two leaf levels just above the cob.

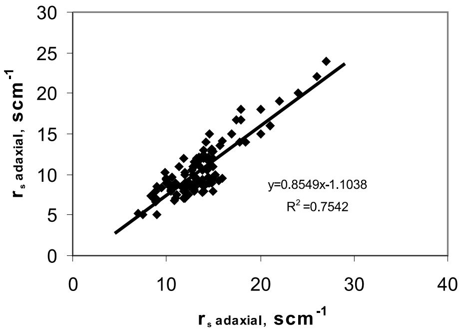


**Figure 1.** Relationship in stomatal resistance between the upper and lower epidermis in the early stage of vegetation period.

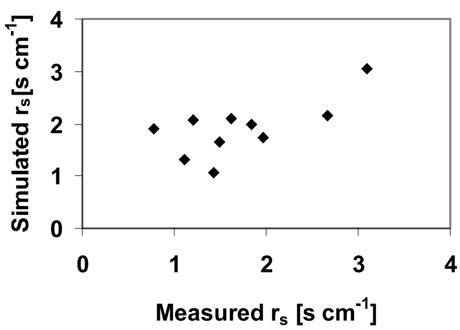


**Figure 2.** Results in simulation of hourly stomatal resistance values in irrigated treatment during July 2001.

## Validation of the approach

To test or average stomatal resistance estimation, the simulation model of Goudriaan (1977) was used. In first step daily change in stomatal resistance for ten soil water potentials from –0.1 to –14 bar were calculated. Later on two of these simulations were separated for comparison, where the *"in situ"* measured water potentials were the closest to the simulated ones (-1.16 and –5.82 bars). The measured and simulated stomatal resistance in daily average agreed well in both water treatment. Results are presented by a sample day in July, for irrigated treatment. The differences between the resistance values determined by two different methods were below 10%. Larger part on measured resistances were above the 1:1 line, with the meaning that the simulation produced higher stomatal resistance than that of the measured ones, mainly in the afternoon hours.

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