

TRANSPIRATION OF CONTRASTING SUGARCANE CULTIVARS DURING SOIL DRYING IN THE FIELD

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INTRODUCTION

Identification of physiological mechanisms responsible for regulation of water use by crops is a vital need in the development of genotypes with improved water use efficiency and resistance to drought. During development of well-irrigated field- and greenhouse-grown sugarcane (*Saccharum* spp. hybrid), the rate of water vapor loss from the leaves is coordinated with changes in liquid phase transport properties (Meinzer & Grantz, 1990). Similarly, stomatal conductance and root hydraulic conductance declined in parallel during soil drying in greenhouse-grown plants of three commercial sugarcane hybrids (Saliendra & Meinzer 1989). In the present study, the stem heat balance (SHB) method (Sakuratani, 1984; Baker & Van Bavel, 1987) was used to measure the mass flow rate of sap in stems of four contrasting *Saccharum* genotypes during soil drying in the field. The objectives of the study were to contrast rates of water use and factors regulating transpiration in diverse *Saccharum* genotypes during soil drying in the field.

MATERIALS AND METHODS

The study was conducted near Waipahu (island of Oahu), Hawaii in an experimental field (Molokai silty clay loam; clayey, kaolinitic, isohyperthermic, Typic Torrox) under commercial plantation practices. Rows were spaced alternately at 0.9 and 2.1 m, with drip irrigation applied between the narrow rows for 24 h out of each 72 h. The crop was 6 months old when irrigation was withheld and measurements began.

Four *Saccharum* genotypes were used in the study. H69-8235 and H65-7052 are commercial hybrids derived mostly from *S. officinarum* and *S. spontaneum*. AP85-0068 is an *S. spontaneum* clone with a thin stem, narrow leaves and relatively short stature. Cavengerie is an *S. officinarum* clone with a thick stem, wide leaves and a dense canopy.

Photosynthetic photon flux density (PPFD), transpiration (E), midday leaf water potential (ψ_L) and volumetric soil water content (θ_V) were monitored between 0 and 23 days following suspension of drip irrigation. PPFD and E were monitored using a quantum sensor (LI-COR, Lincoln, NE, U.S.A.) and SHB gauges (Dynamax, Houston, TX, U.S.A.), respectively, linked to a data logger (21X with AM 32 multiplexer, Campbell Scientific Inc., Logan, UT, U.S.A.). Data were logged every 15 s and averaged every 5 min. Average E on a unit leaf area basis was calculated from sap flow rate monitored by 2 SHB gauges per genotype. Number of leaves per stem were counted weekly. At the end of the experiment, leaves were excised for individual leaf area measurements with an area meter (model 3100, LI-COR). E on a unit leaf area basis was calculated from area of expanded leaves on each date. ψ_L was determined with a pressure chamber (PMS Inc., Corvallis, OR, U.S.A.) from leaf segments (Saliendra *et al.*, 1990) excised at midday from 3 to 5 youngest fully expanded leaves. θ_V was measured by time-domain reflectometry (TDR) as described in detail by Grantz *et al.*, 1990.

Maximum E was obtained as the mean of 10 highest 5-min averages during the day, and the mean PPFD corresponding to maximum E was also obtained. E was adjusted for daily weather conditions (E_{adj}) by dividing maximum E by the corresponding PPFD (expressed as a dimensionless standardizing factor).

Total hydraulic conductance (G_{tot} , $\text{mmol m}^{-2} \text{s}^{-1} \text{MPa}^{-1}$) of the soil-plant continuum was calculated as the ratio of E_{adj} ($\text{mmol m}^{-2} \text{s}^{-1}$) to midday ψ_L (MPa). Midday ψ_L represented the total hydrostatic pressure difference between the soil and the uppermost leaves, because soil water potential estimated from tensiometer and predawn ψ_L measurements remained above -0.1 MPa throughout the drying cycle.

RESULTS AND DISCUSSION

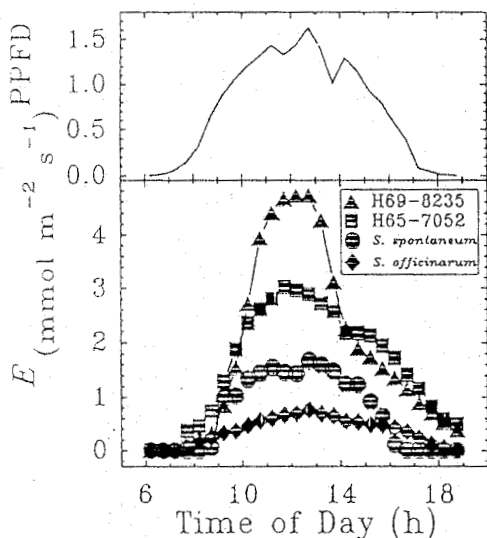
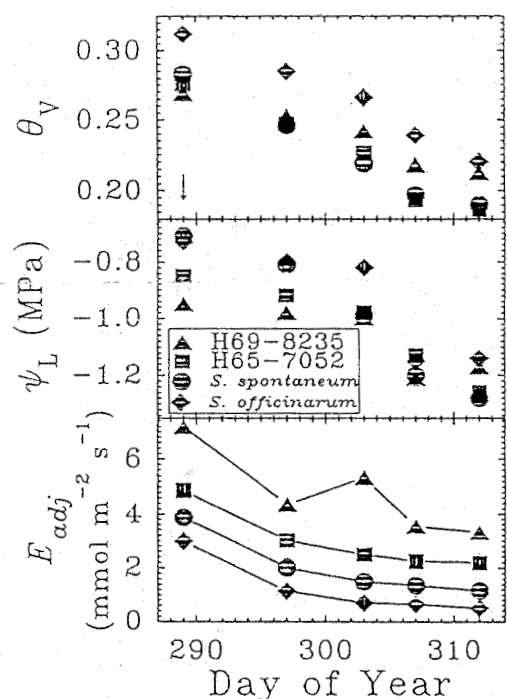
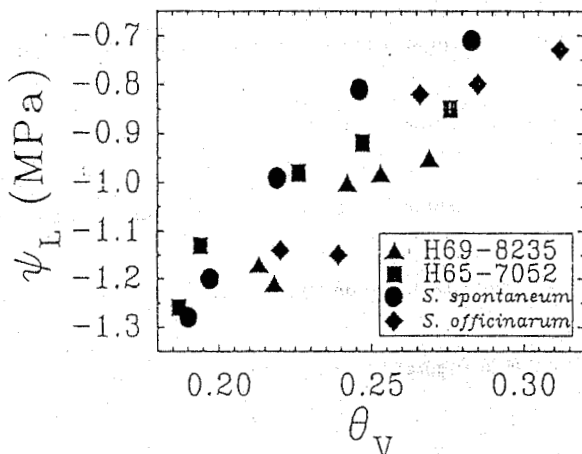


Fig. 1. A representative diurnal course of PPFD and of E on a unit leaf area basis for each genotype at 23 days after withholding irrigation. There were large genotypic differences, with E on a unit leaf area basis highest in the commercial clone H69-8235 and lowest in *S. officinarum*. Although individual plant size and stomatal conductance were similar in these two genotypes, wider leaves and greater stalk density in *S. officinarum* may have reduced E by decreasing canopy boundary layer conductance (Meinzer & Grantz, 1989). The ranking of E for the hybrids H69-8235 and H65-7052 observed in this field study is consistent with their ranking in E and stomatal conductance observed previously in a greenhouse study (Saliendra & Meinzer, 1989).

Fig. 2. θ_V , midday ψ_L and E_{adj} declined after drip irrigation was withheld (shown by an arrow). The genotypic ranking in E_{adj} was maintained throughout the period of measurement, though θ_V and ψ_L were less consistent. This suggested that factors other than θ_V and ψ_L may have been associated with regulation of E . The decline in θ_V during drought was restricted to the upper 0.36 m of soil.

Fig. 3. ψ_L declined similarly during soil drying (decreasing θ_V) in all genotypes. The maximum value of θ_V observed was lowest for H69-8235 (highest E_{adj}) and highest for *S. officinarum* (lowest E_{adj}), suggesting that the irrigation was insufficient for the genotypes with the highest rates of transpiration (cf. Fig. 1). ψ_L was not a consistent function of θ_V for any genotype.



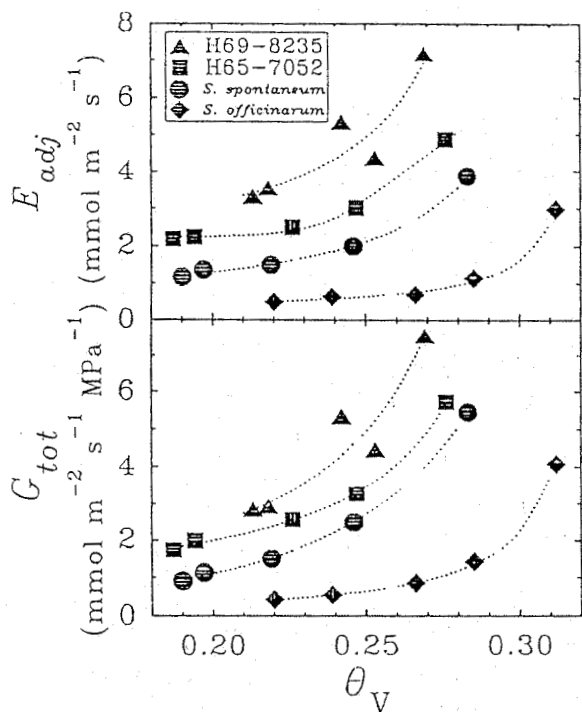


Fig. 5. When E_{adj} was plotted as a function of G_{tot} , a single, linear relationship was found for all *Saccharum* genotypes ($y=0.27+0.86x$, $r^2=0.93$). Thus, during soil drying, the stomatal loss of water in the vapor phase was coordinated with the changing efficiency of vascular transport of water in the liquid phase through the whole plant. This is consistent with results from our previous investigations, which showed a single, linear relationship between total stomatal conductance per plant and total plant hydraulic conductance in well-irrigated sugarcane, whether growing in the field or in the greenhouse (Meinzer & Grantz, 1990). This coordination of developmental changes in stomatal and root hydraulic conductances was associated with changes in the composition of the xylem sap (Meinzer *et al.*, 1991). The present results complement previous findings that stomatal conductance declined in parallel with root hydraulic conductance during soil drying in the greenhouse (Saliendra & Meinzer, 1989). G_{tot} seems to be an integrating physiological parameter.

CONCLUSIONS

- There were large differences in transpiration among *Saccharum* genotypes at all stages of soil drying.
- A single, linear relationship between transpiration and total plant hydraulic conductance was found for all genotypes, suggesting that loss of water vapor is regulated by the efficiency of transport of liquid water.
- Hydraulically-based measures of the ability of the root system to supply the shoot with water were better predictors of stomatal conductance and transpiration of several genotypes than were variables such as leaf and soil water status.
- These patterns are consistent with a role for root-to-shoot communication in the regulation of transpiration in sugarcane.

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Fig. 4. E_{adj} also declined with θ_v during soil drying. There was a unique relationship between E_{adj} and θ_v for each genotype. These results are consistent with those from previous studies using different species, which reported a close relationship between soil water status and stomatal conductance during soil drying (Gollan *et al.*, 1986; Henson *et al.*, 1989). In these past studies, maximum stomatal conductance and threshold soil water status for stomatal closure were species-dependent, similar to the differences observed within the genus *Saccharum*.

Total hydraulic conductance of the soil-root-leaf pathway (G_{tot}) declined with θ_v during soil drying. A unique relationship between G_{tot} and θ_v was observed for each genotype. It was not possible to partition G_{tot} into soil and plant components. Previous determinations of water movement (Sharma & Uehara, 1968) in this soil demonstrated that within the range of θ_v observed here, the soil capillary conductivity remained constant. Thus, G_{tot} should largely represent the total hydraulic conductance of the plant.

