

ESTIMATING ROOT WATER USE IN SUGARCANE

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The sugarcane growth model, CANEGRO (Inman-Bamber, 1991), is based on the CERES-Maize crop growth model (Jones and Kiniry, 1986). Many of the subroutines of the latter model have been modified to describe the growth of sugarcane. Despite recent modifications to the water balance subroutine, the model still predicts water stress too late and then reduces growth too rapidly. For this reason CANEGRO is unable to estimate yields accurately when conditions are dry for a prolonged period.

The fault appears to lie with the Ritchie equation which is used to calculate water supply by the soil-root continuum. This equation is found in all CERES crop models. In CANEGRO the Ritchie equation is:

$$RWU = (0.00132 \text{ EXP}((120-250LL)(SWC - LL)))/(6.67-\ln(Lv)) \quad (1)$$

where RWU is root water use, and lower limit (LL) is a constant for a specific soil layer and is subtracted from soil water content (SWC) to obtain plant available water. Root length density (Lv) is the only plant related parameter in the equation.

Philip (1966) has described the uptake of water through roots as a dynamic physical continuum which can be divided into a demand and supply component. The rate of non-limiting soil water depletion by plants is primarily controlled by atmospheric demand in combination with characteristic plant and soil properties. However, under limited water conditions, supply to the soil-plant-atmosphere continuum is controlled by the soil-root characteristic (Hillel, 1982; Botha *et al.*, 1983). The current version of CANEGRO can accurately estimate the diurnal atmospheric demand for water through a modified version of the Penman-Montieth equation (McGlinchey *et al.*, 1996). Thus, our problem was to find an electrical analog equation to estimate root water use when controlled by the soil-root continuum.

In this paper an equation derived from the BEWAB model (Bennie *et al.*, 1988) is evaluated:

$$RWU_i = LWSR_i / (Lv_i z_i) \quad (2)$$

$$LWSR_i = Fsr (Ln(\theta_i / \theta_{o_i}))((Lv_i \pi)^{1/2})(\psi_{s_i} - \psi_{l_c})z_i \quad (3)$$

where

LWSR = layer water supply rate (mm/day)

Fsr = soil-root conductivity coefficient (mm²/day/kPa)

θ = soil water content (v/v %)

θ_o = soil water content where $\psi_s = \psi_{l_c}$

ψ_s = soil matrix potential at θ (kPa)

ψ_{l_c} = critical plant water potential where stomata starts to close (kPa)

Lv = rooting density (mm/mm³)

z = depth of soil layer i (mm).

Rooting density and θ are determined in CANEGRO; θ_o and ψ_s are obtained from the water release characteristics that are known for many sugarcane soils. ψ_{l_c} was calculated from

the relationship between stomatal resistance and leaf water potential, determined experimentally from the trials described in this paper and was 1 080 and 1 183 kPa for the Swartland and Fernwood soils respectively. The determination of Fsr was the objective of the experiments reported here.

Two pot experiments were conducted in March and November 1995 at our rain-out shelter facility at Umhlanga Rocks (latitude 29° 43' 30", longitude 31° 04' 30" and altitude 76 m) to measure all components of the BEWAB equation except Fsr. The pots were filled either with 69 litres of Fernwood topsoil containing 5% clay or 65 litres of Swartland topsoil containing 36% clay. One pre-germinated single eyed set of variety NCo376 was planted in each pot. Half the pots were well watered for the duration of the experiments and half were denied water about three months after planting.

The ratio of evaporation from stressed plants to that of unstressed plants was regarded as an index of water stress (SI). The measurements required to solve for Fsr were: plant water use, leaf water potential, stomatal resistance and root length. The first three were measured at least four times per week and root length every fortnight. For the reasons mentioned above it was necessary to determine Fsr while plant water use was controlled by the soil-root continuum rather than by atmospheric demand. This work has shown that after the SI ratio has reached a value of 0,5 it quickly drops to SI values of 0,4 and lower (Figure 1). The SI value of 0,5 usually corresponded with the critical leaf water potential value for stomatal closure. This was interpreted as the onset of serious stress and was excluded in the period taken to calculate Fsr. In order to be certain that these conditions were met, measurements for Fsr determination were disregarded when SI was more than 0,9 or less than 0,5.

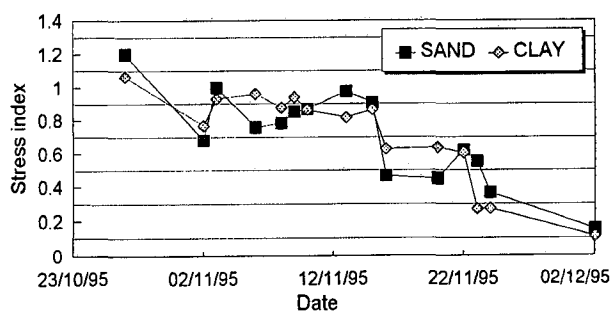


FIGURE 1: Mean stress index per soil type determined from cane growing in 80 litre bins over a 30 day period in November 1995. Denial of water commenced on 1 November.

Fsr values determined from the November experiment were $7,52 \times 10^{-5}$ and $72,05 \times 10^{-5}$ mm²/day/kPa for the sand and clay soils respectively. The validity of Fsr values determined from the November trial was tested through their use in the calculation of RWU for the independent March experiment. Figure 2 shows that the Ritchie equation initially overestimated RWU

of unstressed sugarcane, which suddenly dropped to very low values at the onset of stress. The BEWAB model overestimated RWU of unstressed cane only by a small margin and produced realistic estimates for stressed cane. Although the unstressed and seriously stressed phases were excluded from the calculation of Fsr, RWU was satisfactorily estimated for all three phases using only one Fsr value per soil form.

The BEWAB equation deals more realistically with RWU than the Ritchie equation in conditions where soil water is both unlimited and limited, and it should improve the performance of the CANEGRO crop model. Future work should include incorporating the BEWAB RWU equation into CANEGRO, evaluating Fsr values under field conditions and searching for a relationship between Fsr and an easily measurable soil property such as texture.

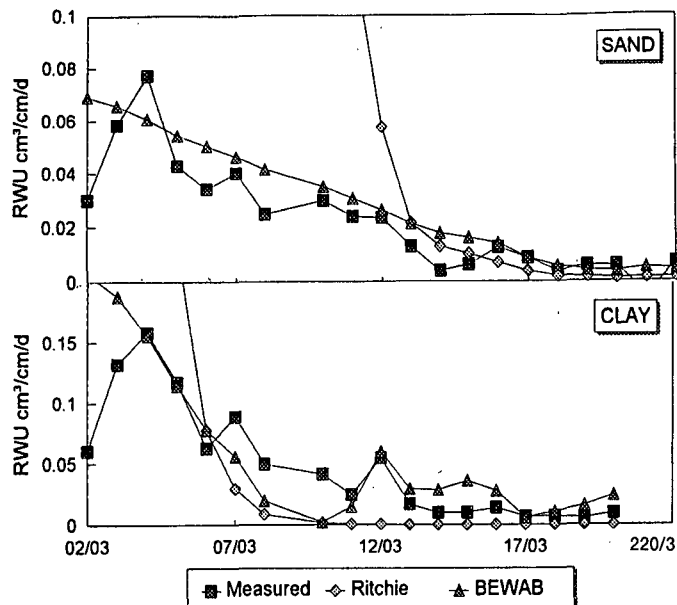


FIGURE 2: Comparison of root water use (RWU) from the BEWAB and Ritchie equations with the measured values for two soil types from the bin trial conducted in March 1995.

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