Crop growth model parameters of 19 summer vegetable cultivars for use in mechanistic irrigation scheduling models

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Abstract

Mechanistic, generic crop, irrigation scheduling models require crop-specific growth parameters which are not readily available for many crops and conditions. The objective of this work was to determine growth parameters for 19 summer vegetable cultivars, and to calibrate the SWB (soil-water balance) model. These vegetable crops were grown in a field trial at Roodeplaat (Gauteng, South Africa) during the 1996/97 summer rainy season. Weather data were recorded with an automatic weather station, phenological stages monitored and growth analyses carried out weekly. Fractional interception of radiation was measured with a sunfleck ceptometer and soil water content was monitored with a neutron water meter. Field measurements were used to generate a database of crop water and radiation use efficiencies, specific leaf areas, stem-leaf partitioning parameters, canopy extinction coefficients, maximum rooting depths and crop heights, as well as thermal time requirements for crop development. These data are invaluable for generating the parameters required to accurately simulate the soil-water balance with mechanistic crop models.

Introduction

The interest in computer models for agriculture is rapidly increasing, particularly since PCs have become accessible to crop producers. Computer models operated from offices could facilitate irrigation water management by making frequent field visits and measurements less essential. Several crop growth and water balance models have been developed with different levels of complexity depending on specific requirements (Whisler et al., 1986; Bennie et al., 1988; Singels and De Jager, 1991a, b and c; Smith, 1992; Annandale et al., 1996; Crosby, 1996). Walker et al. (1995) published a comprehensive review of wheat models, and Mottram and De Jager (1994) an overview of soil-water balance and reference evapotranspiration models. Advantages and disadvantages of several models were also described by Hanks and Ritchie (1991).

The soil -water balance (SWB) model was developed as a real-time, user-friendly, irrigation scheduling tool (Benadé et al., 1997). It is based on the improved generic crop version of NEWSWB (Campbell and Diaz, 1988). A cascading soil-water balance is used once canopy interception and surface runoff have been accounted for. Each soil layer is assumed to be filled to field capacity and then pass on a fraction of the remaining water to the layer below. Any water which passes beyond the bottom layer is assumed lost as deep percolation. Potential evapotranspiration (PET) is calculated as a function of daily average air temperature, vapour pressure deficit, radiation and wind speed, adopting the internationally standardised FAO (Food and Agriculture Organisation of the United Nations, Rome, Italy) Penman-Monteith methodology (Allen et al., 1998). The two components of PET (potential evaporation and potential transpiration) are estimated using canopy cover (Ritchie, 1972). Water loss by evaporation is assumed to occur only from the top soil layer, which thickness is an input. Actual evaporation proceeds at the potential rate until the water content in the top soil layer reaches the permanent wilting percentage. Thereafter, it is equal to the product of potential evaporation and the square of the remaining evaporable water down to the air-dry soil-water content (Campbell and Diaz, 1988). Similarly, actual transpiration is determined on a daily basis as either being limited by soil water supply or evaporative demand (Campbell and Norman, 1998). Total soil-water potential is used to determine the amount of water available for crop transpiration from each soil layer. The daily dry matter increment is taken as the minimum of the transpiration-limited (Tanner and Sinclair, 1983) and radiation-limited (Monteith, 1977) dry matter production, with water stress affecting the partitioning of assimilates to the different plant organs. A detailed description of SWB can be found in Annandale et al. (1999).

The mechanistic approach used in SWB to estimate crop water use has several advantages over the more empirical methods often used. Using thermal time to describe crop development removes the need to use different crop factors for different planting dates and regions. Splitting evaporation and transpiration solves the problem of taking irrigation frequency into account. Deficit irrigation strategies, where water use is supply-limited, can also be more accurately described. The SWB model gives a detailed description of the soil-plant-atmosphere continuum, making use of weather, soil and crop databases. The crop database includes several crop-specific growth parameters: vapour pressure deficit-corrected dry matter/water ratio, radiation conversion efficiency, specific leaf area, stem-leaf dry matter partitioning parameter, canopy extinction coefficient for solar radiation, maximum root depth, maximum crop height, cardinal temperatures and growing day degrees for the completion of phenological stages.

Since SWB is a generic crop growth model, parameters specific for each crop have to be experimentally determined. In previous work, a database of crop-specific growth parameters was generated for annual crops and pasture species (Barnard et al., 1998), as well as for winter vegetables (Jovanovic et al., 1999). Very little literature is available on growth parameters for summer vegetables. The objective of this study was to collect field data to generate crop-specific growth parameters, and calibrate the SWB model for 19 summer vegetable cultivars. This study is, therefore, complementary to the paper published by Jovanovic et al. (1999).

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