Field water balance and SWB parameter determination of six winter vegetable species

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Abstract

Mechanistic, user-friendly crop growth models are useful and accurate tools for irrigation scheduling. They require, however, specific crop growth input parameters which are not readily available for all crops and conditions. Six irrigated vegetable species (onions, cabbage, carrots, beetroot, lettuce and swisschard) were grown in a field trial at Roodeplaat (Gauteng, South Africa) during the 1996 dry winter season. The objective was to determine specific crop growth parameters required by the SWB (Soil-Water Balance) irrigation scheduling, generic crop growth model. Weather data were recorded with an automatic weather station, phenological stages monitored and growth analyses carried out fortnightly. Fractional interception of radiation was measured weekly with a sunfleck ceptometer as was soil water 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 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

In the absence of winter rainfall in the Gauteng Province, irrigation is required in order to achieve optimal yields of winter crops. Optimisation of irrigation water management is necessary for structural (irrigation system design), economic (saving of water and energy), and environmental reasons (risks of salinisation, fertiliser and nutrient leaching). The direct objectives of irrigation water management are to determine the amount of irrigation water to supply the crop and the timing of this irrigation. Several methods for irrigation scheduling are reviewed in the literature. They can be classified as soil-, plant- and atmosphere-based approaches. Examples are monitoring soil water by means of tensiometers (Cassel and Klute, 1986), electrical resistance and heat dissipation soil-water sensors (Campbell and Gee, 1986; Bristow et al., 1993), or neutron water meters (Gardner, 1986). Crop water requirements can also be determined by monitoring atmospheric conditions (Doorenbos and Pruitt, 1992), and plant water status is often used as an indicator of when to irrigate (Clark and Hiler, 1973; Bordovsky et al., 1974; Stegman et al., 1976; O'Toole et al., 1984).

The interest in scheduling irrigations with crop growth computer models is rapidly increasing, particularly since PCs have become accessible to crop producers (Bennie et al., 1988; Smith, 1992a; Campbell and Stockle, 1993; Annandale et al., 1996a). This provides a mechanistic description of the soil-plant-atmosphere continuum without the user requiring specialist knowledge to make the intricate calculations. It is, however, essential that the model interface be user-friendly.

Mechanistic crop growth models require specific crop input parameters which are not readily available for all crops and conditions. In particular, there is a lack of information on crop-specific parameters for vegetables. The objective of this study was to determine crop growth parameters of six vegetable species, and include them in the database of the SWB (Soil-Water Balance) irrigation scheduling model (Annandale et al., 1996b; Barnard et al., 1998). These specific crop growth parameters could also be used in other models, or the data could be used to calculate other parameters. Field measurements were used to determine the following parameters: vapour pressure deficit-corrected dry matter/water ratio (DWR), radiation conversion efficiency (E_c), specific leaf area (SLA), stem-leaf dry matter partitioning parameter (p), canopy extinction coefficient for solar radiation (K_s) and growing day degrees (GDD) for the completion of phenological stages.

Materials and methods

Experimental set-up

A field trial was established at Roodeplaat (Department of Agriculture - Directorate of Plant and Quality Control; 25°35' S, 28°21' E, altitude 1165 m), 30 km NE of Pretoria. The climate of the region is one of summer rainfall with an average of about 650 mm y^{-1} (October to March). January is the month with the highest average maximum temperature (30°C), whilst July is the month with the lowest average minimum temperature (1.5°C). Frequent occurrence of frost is experienced during winter months. The soil is a 1.2 m deep clay loam Red Valsrivier (Soil Classification Working Group, 1991), with a clay content between 27% and 31% and a water-holding capacity of about 300 mm·m^{-1}.

Six winter vegetable species were grown during the 1996 season: onions (*Allium cepa* cv. Mercedes), cabbage (*Brassica oleracea* cv. Grand Slam), carrots (*Daucus carota* cv. Kuroda), beetroot (*Beta vulgaris* cv. Crimson Globe), lettuce (*Lactuca sativa* cv. Great Lakes) and swisschard (*Beta vulgaris*). The experimental field was 30 m x 12 m in size. Each plot was 5 m x 12 m. Transplanting, seeding and harvest dates, as well as

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