A laboratory evaluation of Watermark electrical resistance and Campbell Scientific 229 heat dissipation matric potential sensors

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Abstract

There is much interest in continuous recording of soil matric potential with porous matrix sensors for irrigation scheduling purposes. Watermark electrical resistance and Campbell Scientific 229 heat dissipation matric potential sensors were simultaneously tested in a modified pressure chamber. Both sensors are suitable for automatic recording of changes in soil water content or matric potential. Initial indications are that individual sensor calibration will be unnecessary for irrigation scheduling purposes. The electrical resistance measurement was shown *to be* affected by soil salinity and temperature and to be dependent on wetting history. Moderate hysteresis of heat dissipation sensors was recorded. Both the electrical resistance and the heat dissipation measurement provided reliable estimates of soil matric potential in the range from -100 to 0 J-kg-' at various salinity levels. A minimum reading interval of 3 min is recommended for the heat dissipation sensor to allow the block temperature to re-equilibrate.

Introduction

The measurement of soil matric potential ¥$_m$, is of cardinal importance for irrigation monitoring and research on soil-plant-water relationships. Irrigation amounts can also be determined from matric potential measurements if a soil water retention curve is available.

Several techniques for measuring water potential components of a medium in equilibrium with soil water are described in the literature: tensiometry (Cassel and Klute, 1986); thermocouple psychrometry (Rawlins and Campbell, 1986); and electrical resistance and heat dissipation (Campbell and Gee, 1986). Tensiometers require frequent maintenance and have a limited range of measurement (approximately -70 to 0 J-kg')- Thermocouple psychrometry is a highly specialised measurement and requires instruments of extreme accuracy. Electrical resistance sensors estimate matric potential through the measurement of the electrical resistance of the solution in a porous block in matric potential equilibrium with the surrounding soil. Heat dissipation sensors rely on the effect of the water content on thermal conductivity and heat capacity. As the electrical resistance and heat dissipation sensors do not directly measure soil matric potential, empirical calibration is required. The interest in monitoring soil water potential with such soil water sensors is rapidly increasing due to the simplicity of management and particularly since data acquisition and control systems have become accessible to crop producers.

A variety of porous materials have been used to construct electrical resistance sensors: gypsum (Perrier and Marsh, 1958); fibreglass (Colman and Hendrix, 1949); and nylon (Bouyoucos, 1949). Gypsum blocks slowly dissolve providing a saturated solution of Ca^{2+} and SO_4^{2}~ ions in the porous block. They are therefore less sensitive to salts than fibreglass and nylon blocks as the saturated solution buffers the effects of changes in soil salinity on measured electrical resistance (Taylor, 1955). The blocks, however, gradually deteriorate due to dissolution of gypsum, changing the pore geometry and thereby alter the calibration and make the measurement of matric potential unreliable. Fibreglass and nylon sensors are longer lasting, but the electrical resistance output includes both matric and osmotic effects. Individual field calibration of fibreglass units was recommended by Seyfried (1993) due to the high variability among calibration statistics of individual sensors. Scholl (1978) built a two-element ceramic sensor for measuring both matric and osmotic potential. The matric potential element is used to determine electrical resistance response during pore drainage, while the salinity block is made of a high-porosity ceramic with a fine pore distribution. The salinity sensor therefore remains saturated over the measured matric potential range, measuring electrical resistance changes due only to salt movement. The Watermark soil water sensor (Irrometer Co., Riverside, CA) is made of a fine sand material held in place by a synthetic porous membrane. [Mention of manufacturers is for the convenience of the reader only and implies no endorsement on the part of the authors, their sponsors or the University of Pretoria]. The membrane prevents penetration of fine soil material which could change the physical properties of the block (England, 1965). An internal gypsum tablet buffers against the salinity levels found in irrigated soils. The sensor consists of two concentric electrodes embedded in the reference matrix material. Thomson and Armstrong (1987) found the variability between the sensors not to differ significantly in the -100 to -10 J-kg^1 potential range. According to Eldredge et al. (1993), the resistance response of the sensor to drying in air in an oven and in the field is similar.

Transient heat-pulse theory is discussed by Jackson and Taylor (1986) and Campbell et al. (1991). In practice, heat dissipation is determined by applying a heat pulse to a heater within the soil sensor and monitoring the temperature at the centre of the block before and during heating. The temperature rise is a function of the thermal diffusivity, and therefore of the water content of the block. The choice of the block material is critical as its pore size distribution determines the useful range of measurement. Construction procedures and the choice of porous material for a heat dissipation block were discussed by Phene et al. (1971). The reference matrix must be large enough, and the amount of heating small enough, to avoid emission of the heat

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