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SOIL PHYSICS

A New Resistance Sensor for Monitoring Soil Matric Potential

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The electrical resistance sensor is an appropriate and inexpensive tool for measuring soil matric potential (ψ). These sensors are widely used in irrigation agriculture. One drawback of the resistance sensors, however, is that the measurements often are not accurate across a wide range of moisture conditions. The objective of this study was to design a resistance sensor that can measure accurately and precisely across a wide range of moisture conditions, thereby extending the measurement capabilities of currently available sensors. The sensor consists of two electrodes embedded in a sand–plaster matrix that is stabilized with polyacrylamide. The sensor was calibrated and tested to determine its sensitivity to soil texture, temperature, and electrical conductivity. Experimental results showed that the sensor was able to determine matric potentials in the range of −7.5 kPa to −10 MPa, and showed excellent precision, with a RMSE <5 kPa across the range of −5 to −80 kPa. A standard electrical resistance–water potential curve can be established in the laboratory on a soil, and can then be applied to different soil types.

Abbreviations: PAM, polyacrylamide; TDR, time domain reflectometry.

The matric potential of water in soil, ψ, is an important parameter for irrigation management and for quantifying unsaturated hydraulic properties of soil. The matric potential is often measured with water-filled hydraulic tensiometers; however, their measurement range is limited to ψ > −80 kPa (Young and Sisson, 2002), and they usually require regular maintenance, although recent developments have allowed automatic refilling of tensiometers (Morrison and Szecsody, 1987; Faybishenko, 2000).

Another method to measure soil water potential is thermocouple psychrometry. Although thermocouple psychrometry can be used for a relatively wide ψ range, the accuracy is better in drier conditions, and the upper measurement limit is about −30 to −200 kPa (Andraski and Scanlon, 2002). Furthermore, the measurements are very sensitive to temperature (Rawlins and Campbell, 1986), which limits the suitability of psychrometers for field applications.

Soil water potential can also be inferred by indirect methods, including heat dissipation, time-domain reflectometry (TDR), and electrical resistance measurements. The heat dissipation method is based on measuring the water-content-dependent heat dissipation in a porous matrix (Flint et al., 2002). Or and Wraith (1999) developed a sensor based on a coaxial cage embedded in a porous disk and measured electrical permittivity with TDR. Noborio et al. (1999) embedded a two-rod TDR waveguide in a gypsum block to determine soil water potentials. A similar design was used by Whalley et al. (2001), who embedded a three-rod waveguide in a ceramic matrix and measured the dielectric permittivity in the frequency domain. The soil water potential was then related to dielectric permittivity via a calibration equation.

Electrical resistance sensors operate with a similar principle as heat dissipation or electrical permittivity sensors by inferring the water potential from indirect mesurements. The water-content-dependent electrical resistance of a porous matrix embedded in soil is measured and related to matric potential (Scanlon et al., 2002). The porous matrix of the electrical resistance sensors is usually made of gypsum to control the salinity sensitivity of resistance measurements. The electrical resistance sensors are relatively inexpensive and have been widely used in irrigated agriculture (Thomson and Ross, 1996; Abraham et al., 2000; Miranda et al., 2005; Intrigliolo and Castel, 2006). The conventional gypsum electrical resistance block fails, however, when the water potential is greater than −30 kPa (Bourget et al., 1958). It was reported that the use of different porous materials allowed the measurement range to be expanded (Perrier and Marsh, 1958; Or and Wraith, 1999). For instance, the Watermark sensor (Campbell Scientific, Logan, UT) was optimized for use between −10 and −100 kPa (Spaans and Baker, 1992). Abraham et al. (2000) compared electrical resistance sensors made of different porous matrices, i.e., gypsum, soil, washed sand, sponge, and nylon. Based on reproducibility of measurements, they concluded that the washed sand provided the best matrix for the resistance measurements; However, they provided no details on how the sensors were constructed and how electrolyte concentrations in the sensor were controlled. Table 1 shows an overview of different water potential sensors and their measurement range.

It has been reported that certain water potential sensors have poor reproducibility. For instance, Spaans and Baker (1992) found that the Watermark sensor was not reproducible for a given soil. Whalley et al. (2001) concluded that poor

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