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# Field evaluation and performance of capacitance probes for automated drip irrigation of watermelons

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ABSTRACT

Continuous, real-time monitoring of soil-moisture is essential to effective and efficient water management in an automated drip irrigation system. The primary objectives of this 3-year (2008–2010) field study were to demonstrate the utility of multi-sensor capacitance probes (MCP) to automate high frequency drip irrigation in watermelons [*Citrullus lanatus* (Thumb.) Matsum. & Nak.] production and to determine irrigation set points as percent soil water content depletion. Irrigation water treatments of 15% available water depletion (AWD), 50% AWD and No water application (fertigation only) were tested in sandy Coastal Plain soils in South Carolina. Multi-sensor capacitance probes (MCPs) monitored soil water status in the top 50 cm profile and automatically triggered short (30–60 min) duration irrigation water cycles whenever the average 0–30 cm profile soil water content reached the irrigation set points. During peak crop water use and on hot days, four to seven irrigation events per day were necessary to meet crop water needs and minimize leaching in the sandy fields. The tactical irrigation scheduling capability offered via MCPs in an automated mode was highly advantageous. The short but frequent irrigation water cycles reduced water movement below the root zone (0–30 cm). The 15% AWD irrigation water treatment showed a significant yield increase of 44% and 18.4% during 2008 and 45% and 40% during 2010 compared to No Water Application and 50% AWD irrigation water treatments respectively. The MCP factory calibration was as good as on-site calibration and was sufficiently accurate for irrigation scheduling.

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## 1. Introduction

The use of drip irrigation and fertigation, is essential to modern vegetable production systems. Although drip irrigation is used in the fruit and vegetable industry from arid California to the humid Carolinas, many challenges confront the efficient application of this technology. Vegetable growers must make decisions on how frequently to irrigate and how long to run their system each irrigation cycle. Typical on-farm irrigation cycles in the Southeast USA are longer than necessary and thus wasteful of water, energy used for pumping, and money paid for leached nutrients. Sandy Southeastern soils with low water holding capacities are especially vulnerable to water stress and to water and nutrient leaching below the root zone (Fares and Alva, 2000a). A survey of the South Carolina Watermelon Association (SCWA) membership indicates that nearly all of its members use drip irrigation and polyethylene mulch for their commercial production (Miller, 2008). Drip irrigation under plastic mulch is complicated because irrigation is applied from a line of point sources to only part of the field, while the plastic mulch not only suppresses evaporation but also sheds rainfall to the edge of the mulched row (McCann et al., 2007). Without monitoring of soil water content, it will be very difficult to estimate the contribution of rainfall to the root zone under the plastic mulch.

Depending on the soil type, stage of crop development, and climatic conditions, a well-managed drip-irrigated vegetable field generally requires multiple daily applications to avoid water stress and yield reduction. Intra-day irrigation triggering is most feasible with real-time knowledge of soil water content via advanced sensors and remote data access capability (Alva and Fares, 1998). Efficient irrigation water management also requires knowledge of the effective root zone (i.e., the vertical and lateral extent of root distribution) and the threshold soil water content depletion for

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stress-free growth. Neither of these is well established for drip-irrigated watermelon [*Citrullus lanatus* (Thunb.) Matsum & Nakai] in sandy soils.

Application of irrigation water should be limited to an amount that will penetrate only to the effective root zone (Ross and Hardy, 1997), i.e. the depth of soil from which the crop extracts the majority of its water (Allen et al., 1998; Evans et al., 1996; Ross and Hardy, 1997). There is little published information on the root characteristics of watermelon grown under drip irrigation with plastic-film mulch. A bare ground study with no water application (Weaver and Brunner, 1927), showed watermelon roots extending 4 feet (1.2 m) deep but little root development was found beneath the first foot of soil. Tomato (*Lycopersicon esculentum* Mill.) grown with drip irrigation has a relatively shallow root system concentrated in the top 30 cm or less of the soil profile (Oliveira and Calado, 1996; Bar-Yosef, 1977; Machado and Oliveira, 2005). Maintaining optimal soil moisture content in the limited root zone of vegetable crops while reducing deep percolation can be difficult, especially in sandy soils, without continuous monitoring of the soil moisture status (Alva and Fares, 1998).

Tensiometric sensors for measuring soil moisture status have been used to schedule irrigation for decades (Leib et al., 2003). Newer electronic sensors estimate *volumetric* soil water content by measuring the soil dielectric properties. One such sensor, the multi-sensor capacitance probe (MCP), has been widely used in irrigation water management since 1991 (Buss, 1993). Characteristics and functionality of capacitance probes have been extensively reviewed in the literature (e.g., Buss, 1993; Mead et al., 1995; Paltineanu and Starr, 1997; Starr and Paltineanu, 1998), including discussions on the need for on-site calibration versus the use of factory calibration. The general tendency in commercial operations is to use the factory calibration.

Automated irrigation scheduling relies on pre-determined trigger (or set) points based on a percent depletion of the available soil water content. Research is needed to quantify these depletion levels for watermelons grown in the sandy Coastal Plain soils that occupy many parts of the southeastern USA. The MCP's ability to quickly recognize changes in soil water content status lends itself to automation where frequent, short-duration irrigation water cycles are employed. The ability to automatically transmit real-time soil water content data (i.e., from capacitance probes) to a server for determination of mean root zone moisture content is of great value to a tactical scheduling strategy. Literature suggests that when such a system is fully operational, the demand for daily management time and system maintenance will be minimal (Dukes et al., 2003).

The objectives of the present research were threefold: (1) To evaluate the utility of the Sentek TriSCAN EasyAg 50 cm (Sentek Sensor Technologies, Stepney SA, Australia) soil moisture capacitance probe as a tool for drip irrigation automation; (2) to determine an appropriate set point in plasticulture drip irrigated watermelons in sandy Coastal Plains soils; and (3) to determine if the factory MCP calibration is suitable for southeastern Coastal Plains sandy soils.

## 2. Materials and methods

This study was conducted at the Clemson University Edisto Research and Education Center (EREC) near the town of Blackville, South Carolina in 2008, 2009, and 2010. The research project dealt with irrigation water management in drip-irrigated watermelon under plastic mulch and included extensive quantification of root distribution, shoot growth, yield and equipment functionality.

The Edisto research facility is in the southwestern part of South Carolina in Barnwell County and is considered part of the southeastern Coastal Plains of the United States. The field is located at 33°21′ N latitude and 81°19′ W longitude and 93 m above mean sea level. The soil in the test field in 2008 and 2009 was classified as Barnwell loamy sand with reported field capacity (FC) of 0.174 $cm^3\,cm^{-3}$, permanent wilting point (PWP) of 0.061 $cm^3\,cm^{-3}$ and available water capacity (AWC) of 0.113 $cm^3\,cm^{-3}$ for the top 30 cm of soil (USDA-NRCS, 2009). On-site soil texture analysis showed sand prevailing to a depth of 20 cm, loamy sand and sand at 30 cm, sandy loam at 40 cm and sandy clay at 50 cm.

The 2010 experiments were conducted in an adjacent field with soil classified as Wagram sand with reported FC of 0.10 $cm^3\,cm^{-3}$, PWP of 0.045 $cm^3\,cm^{-3}$, and AWC of 0.062 $cm^3\,cm^{-3}$ for the top 30 cm of soil (USDA-NRCS, 2009). Soil texture analysis showed sand to a depth of 50 cm. In situ available water capacity tests using the procedures described in Starr and Paltineanu (1998) yielded values similar to the above NRCS estimates.

### 2.1. Experimental design and measurements

The experimental design was a split plot with irrigation water as the main plot factor and plant type as the split plot factor (Table 1). The experimental area was divided into four replicates, each further divided into three main plots. The main plots were subdivided into three split plots (Fig. 1). The plant type treatments were randomly assigned to each split plot and replicated four times. The three plant types (Seminis Vegetable Seeds, Oxnard, CA) included in the research are listed in Table 1.

Experimental plots consisted of two raised bed rows spaced 2.44 m center-to-center and covered with black plastic mulch. The width of the raised bed covered by plastic mulch was approximately 0.76 m. The experimental plots were irrigated using Aqua-Traxx® drip tape (Toro Ag Irrigation, El Cajon, CA) with an emitter spacing of 0.30 m. The drip tape flow rate at 68.9 kPa (10 psi) was 1.14 lph/emitter (0.30 gph) or 1.89 lpm (0.50 gpm)/30.5 m length. Each split plot contained five plants for yield and fruit quality analysis (spaced 0.91 m apart, 2.23 $m^2$/plant). Also contained in the split

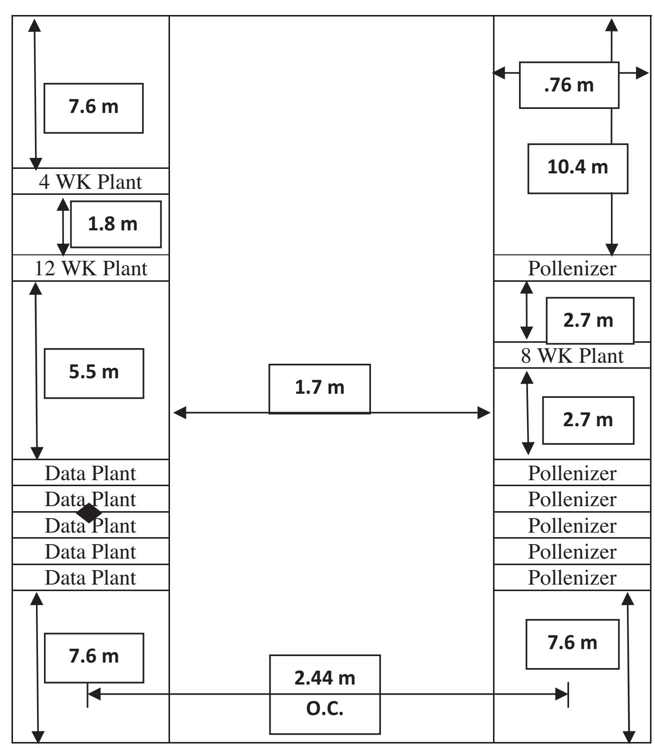


**Fig. 1.** Each of the thirty-six split plots was planted as demonstrated in this figure. ♦ Indicates MCP location adjacent to drip irrigation line between emitters.