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Soil moisture distribution under drip irrigation and seepage for potato production

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ABSTRACT

Keeping soil moisture content at field-capacity in the root zone tends to maximize crop yield. However, this is challenging in sandy soils with a shallow water table and low water holding capacity. Seepage irrigation (SEP) relies on capillarity water movement from a water table to irrigate the crop, creating uneven soil moisture distribution across the field, which could be improved with drip irrigation. The objectives of this study were to evaluate irrigation water use efficiency (IWUE) for potatoes and soil moisture distribution uniformity of two drip tape installation depths (surface at 0.05 m, SUR and subsurface at 0.15 m, SUB) as an alternative method to SEP. The design of the experiment was a randomized complete block with irrigation treatments as main plots, and potato varieties (Atlantic, Fabula, and Red LaSoda) as subplots. The volume of water applied, water table level, and soil volumetric water content were continuously measured for two seasons, 2011 and 2012. Drip irrigation significantly increased the moisture distribution uniformity in the potato ridge. The majority of the plant root system was concentrated in the upper soil layer (~0.3 m), regardless of irrigation treatment. Similar marketable yield between SUR and SEP were achieved for Fabula and Atlantic in the first season, while lower yields were reported for Red LaSoda under drip in both years. The SUB produced lower yield in both years attributed to limited water capillarity. Drip irrigation reduced water use 48% and 88% in 2011 and 2012, respectively. Higher IWUE was obtained with drip compared to SEP for all varieties in 2012. The SEP used more irrigation water to supply the crop than SUR resulting in a difference in IWUE of 5.7 kg m^{-3}. The SUR was capable of adequately irrigating the potato shallow root producing similar yield to SEP for Atlantic and Fabula varieties.

1. Introduction

Approximately 15,000 ha of land in Florida were cultivated with potatoes under seepage (SEP) in 2013 (USDA-NASS, 2014), which led to an estimated use of 62.7 million cubic meters of water in that year. These figures for 2013 clearly illustrate the need for efficient irrigation management for potatoes for environmental and economic sustainability. For potato, this is largely driven by high production costs and an inherently low tolerance to water stress when compared to other crops (Munoz-Arboleda et al., 2006; Patterson, 2010; Shock et al., 2007).

Seepage or subirrigation is a variation of subsurface irrigation or water table control that uses groundwater. The water table is artificially maintained by water furrows generally spaced every 18 m. (Dukes et al., 2010). It is a low-cost and effective way to irrigate crops in flat locations where a natural impermeable soil layer results in a shallow water table (Haman et al., 1989). However, seepage has relatively low water use efficiency (20–70%), low water distribution uniformity across the field, and high susceptibility to runoff, since the water table level is adjusted by either adding or subtracting water at subsurface layers (Smajstrla et al., 1984, 2000).

The groundwater for seepage irrigation has been both inexpensive and accessible. However in recent years, overpumping has caused the decline of the water levels and upconing of saline water from deeper zones to move into the fresh-water system. This increases chloride concentrations in wells, hence affecting water

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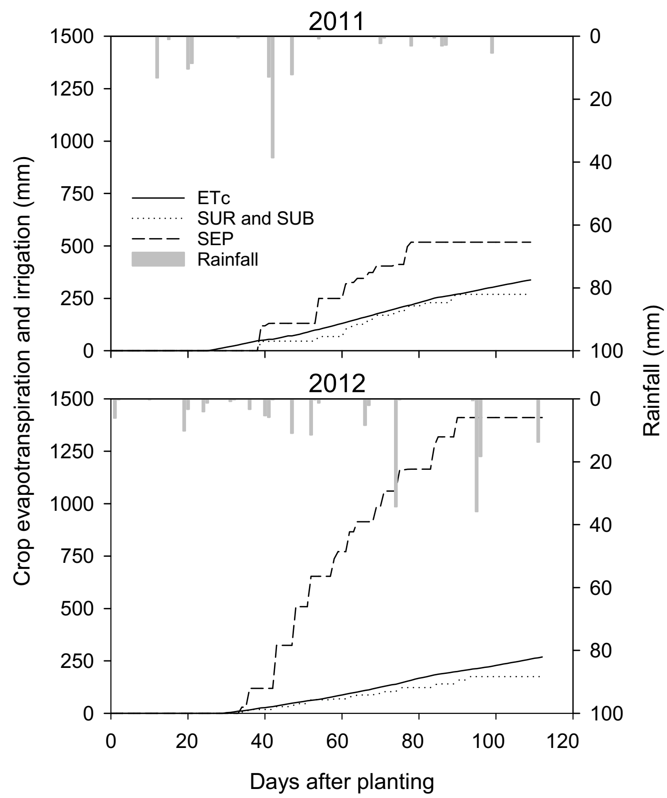

Fig. 1. Cumulative irrigation water volume applied for surface drip irrigation (SUR), subsurface drip irrigation (SUB) and seepage irrigation (SEP), calculated cumulative crop evapotranspiration (ETc), and daily rainfall during potato growing season of 2011 and 2012 in Hastings, FL.

suitability for agricultural purposes (Spechler, 1994; Lindsey et al., 2009). Excessive irrigation with saline water is particularly problematic for these soils with an impermeable soil layer because of the inability to use mitigation practices like leaching fraction (i.e. irrigation to remove excess salts from saline soils) without a tiling system. In addition, crop establishment and growth may be severely impacted when saline water is used because salt accumulates in the wetting front, impairing the plant's ability to take up nutrients (Hanson et al., 1997). High soil salinity severely reduces potato yield due to its restriction of root water uptake, reduced water infiltration rate, and negative effects on soil aeration (Ayers and Westcot, 1985; Levy and Veilleux, 2007).

It has been demonstrated that by developing irrigation practices that deliver appropriate water quantities that match crop demand, potato production can be optimized (Shock et al., 2003; Yuan et al., 2003). However, soil moisture uniformity at the upper soil layer is difficult to achieve with seepage due to drastic changes of the water table level, especially during rainfall events. Reducing off-site movement of fertilizer and keeping nutrients close to the active root zone is another challenge potato farmers could possibly overcome with more efficient irrigation practices (Alva, 2008). Precise irrigation methods, such as drip, provide the benefit of adequate soil moisture that can be readily extracted by plants. In case of heavy rain, there is also storage capacity in the soil profile for extra water (Onder et al., 2005). The use of drip irrigation can help reduce non-beneficial water consumption while increasing the yield potential of the crop (Howell, 2001).

Drip is an irrigation technology known to increase the control of water application and offers several advantages to growers. It reduces soil evaporation and weed population, increases plant transpiration, and when well-managed, excessive water drainage is unlikely to occur, thus allowing nutrients to be retained in the root zone for prolonged periods (Burt, 1998; Goldberg et al., 1976; Lamm et al., 2011). Moreover, drip offers an opportunity to inject soluble fertilizers combined with irrigation, a process known as fertigation.

Although drip irrigation has the potential to deliver water efficiently, it is necessary to thoroughly evaluate this technology in sandy soil conditions in order to better understand the soil water distribution in the root zone. The installation depth of drip tape is a very important factor to consider in sandy soils due to the high hydraulic conductivity, hence limited capillary rise. The optimal drip tape depth varies among cultural practices and soil physical properties (Burt, 1998). For instance, Patel and Rajput (2007) studied the effects of five different tape installation depths (0, 0.05, 0.10, 0.15, and 0.20 m) on potato yield grown in sandy loam soil and found that tape installation depth significantly affected yield, with maximum yields at 0.10 m installation depth. Deeper drip tape installation has a potential risk of not providing moisture to shallow rooted crops like potato, due to the limited wetting from a point source. Waddell et al. (2000) found that frequent application of a small volume of water using drip irrigation had positive results in maintaining nutrients accessible to plants within the crop root zone. Additionally, the use of drip irrigation for vegetable crop production has been reported to diminish NO_3 losses to water bodies, and increase water and nitrogen fertilizer use efficiency (Lamm et al., 2011; Thompson et al., 2003).

Agricultural water conservation practices are crucial for sustainable production, and drip irrigation may be an efficient strategy to optimize potato production in sandy soils (Ahmadi et al., 2011). Drip irrigation could reduce the volume of water used to grow potato and minimize the impact of agriculture on salt water intrusion in the Floridan aquifer. Therefore, the objectives of this study were to evaluate irrigation water use efficiency and soil moisture distribution uniformity of two drip tape installation depths as an alternative method to seepage in sandy soils. It was hypothesized that drip irrigation can maintain uniform soil moisture content