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SIMULATED DRIP IRRIGATION WITH DIFFERENT SOIL TYPES

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Abstract. **Irrigation is essential for intensive agricultural production. As water resources become more scarce, microirrigation (microsprinkler and drip irrigation) is gaining popularity because of its efficiency compared to flood irrigation. Growers prefer drip irrigation given the low initial cost compared to microsprinkler irrigation. However, drip irrigation system performance is influenced by many factors, such as the soil physical properties, which are often ignored by many irrigators. The objective of this paper was to use a water flow and solute transport numerical model, HYDRUS-2D, to demonstrate the performance of drip irrigation with three different soil types. Results of this work showed that with sandy soil, the water front moves vertically; with loam and clay soils, water front movement is a multidirectional process. Compared to sands, the same drip system can cover twice and 1.5 times as much horizontal area in clay and loamy soils, respectively. Drip irrigation systems work better with loamy and clay soils than sandy soils. For citrus, in order to get the same surface coverage, more than one dripper per tree needs to be used on sandy soils. It is essential to consider the soil type when choosing any irrigation system. More field work will be conducted to confirm the findings of these simulation results.**

As water resources become more scarce, growers are pressured to look for efficient irrigation methods. Many citrus growers use under-tree microsprinkler systems; however, a small number of them choose drip systems. Florida citrus growing regions have extremely sandy soils in which the percentage of sand is over 95% of the total mineral content. In such coarse sand soils, the effectiveness of drip irrigation is questioned by many hydrologists, irrigators, and growers.

Microirrigation includes drip, trickle or microsprinkler irrigation systems. It is a growing technology that has the potential to maximize crop productivity and conserve soil, water, and fertilizer resources while also protecting the environment. Drip irrigation systems usually use only a few drippers per tree. This irrigation method has the advantage of precisely applying irrigation water in both location and amount. This offers the potential of increased profit due to reduced water, fertilizer, and cultural costs and increased revenue due to increased yield. Application rates are typically in the range of 0.25-4 gallons per hour (gph) per emitter or 0.3-2.0 gallons per minute (gpm) per 100 ft of lateral length.

Drip irrigation is able to localize the amount of water needed for a specific soil. As clay has a higher water-holding capacity, it needs less frequent wetting than low capacity sand. Rate of infiltration is dependent on soil type (Bresler, 1977). Inconsistent infiltration will cause runoff and erosion in different soil types. Drip irrigation is effective in many soils. The exceptions appear to be in extremely coarse and fine-grained texture soils (Troth, 1980). For typical Florida sandy soils, the soil surface wetted is only that within a lateral distance of 1-2 ft of the water source (Smajstrla et al., 1991).

The crop and soil type dictate drip system capacity, drip line spacing, and emitter spacing. The drip system capacity must be able to satisfy the peak water requirement of the crop through the combination of the applied irrigation amount, precipitation, and stored soil water. The system capacity will influence the selection of the drip line flow rate and the zone size (area served by each submain). Improper selection of these items can result in more expensive systems to install and operate. Drip line spacing is an important factor in system cost. However, wide spacing will not uniformly supply crop water needs and will likely result in excess deep percolation on sandy soils. The drip line spacing is dictated by the lateral extent of the crop root zone, lateral soil water redistribution, and in-season precipitation. Careful attention to drip line and emitter spacing is a key factor in achieving water conservation and water quality protection.

Based on extensive literature review, no published scientific information was found evaluating the spread of the water front from drip systems under Florida sandy soil conditions. Thus, the objectives of this study were to 1) introduce a numerical model, HYDRUS-2D, and 2) to evaluate the effect of soil type on the performance of a drip irrigation system.

Materials and Methods

This is a simulation project that uses a well-tested numerical model, HYDRUS-2D, a Microsoft Windows-based modeling environment for analysis of water flow and solute transport in variably saturated porous media. The software package includes the two-dimensional finite element model HYDRUS2 for simulating the movement of water, heat, and multiple solutes in variably saturated media. HYDRUS-2D is a two-dimensional numerical model that was developed by Šimůnek et al. (1999) at the U.S. Salinity laboratory, USDA-ARS, Riverside California. More information can obtained about this model by visiting the website (http://www.ussl.ars.usda.gov/models/hydrus2d.HTM).

The HYDRUS-2D program is a finite element model that numerically solves the Richards' equation for saturated/unsaturated water flow and the Fickian-based advection/dispersion equations for heat and solute transport. The flow equation incorporates a sink term to account for water uptake by plant roots. The heat transport equation considers conduction as well as convection with flowing water. The solute transport equations consider advective-dispersive transport in the liquid phase, and diffusion in the gaseous phase. The trans-

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port equations also include provisions for nonlinear and/or non-equilibrium reactions between the solid and liquid phases, and linear equilibrium reactions between the liquid and gaseous phases. The program may be used to analyze water and solute movement in unsaturated, partially saturated, or fully saturated porous media.

Input parameters for the model were determined in the field (Fares et al., 2000) and laboratory (Sodek et al., 1990). The main input parameters include: soil water release curves, hydraulic conductivity as a function of water content, bulk density, and initial and boundary conditions of the simulated system. Three soil types were used: sand, clay, and loam. A 0.5 m width by 1.5 m depth two-dimensional homogeneous profile was simulated for each soil type. A dripper with a rate of 1 L h^{-1} in the top edge of the system was simulated. The duration of the simulation was 24 h with continuous water delivery from the drip. Except for the location of the drip, it was assumed that there was no water flux into or out of the system. In the lower boundary of the system, we assumed that water will continue to move downward to a deep groundwater table. Seven observation points (N1 . . . N7) were chosen, 25 cm below the soil surface, vertically, and 0, 16, 19, 22, 25, 30 and 35 cm, horizontally to evaluate horizontal spreading of the water front (Fig. 1).

Results and Discussion

Results of the 24-h simulations were analyzed. Figure 2 shows the water content at the seven observation points. These points were used to monitor the progress of the water front through the soil profile of the three soil types (sand, loam, and clay). The shape and progress of the water front influences the water content at these different points throughout the simulation. Five of the seven monitoring points showed an increase of the water content for sandy soil indicating that the water front was not able to reach the other two points. The water content at 16 cm took slightly over 5 h to go from its initial to its maximum level under these simulation conditions. Moving laterally away from underneath the dripper, the maximum water content level decreased substantially. It was only possible for the 19-cm point (N2) to reach 0.14 cm^3 cm^{-3}. The 25-cm point (N5) showed a slight, almost insignificant, increase in its water content compared with the other points. Practically, it was not possible to significantly increase the water content beyond 22 cm (N4).

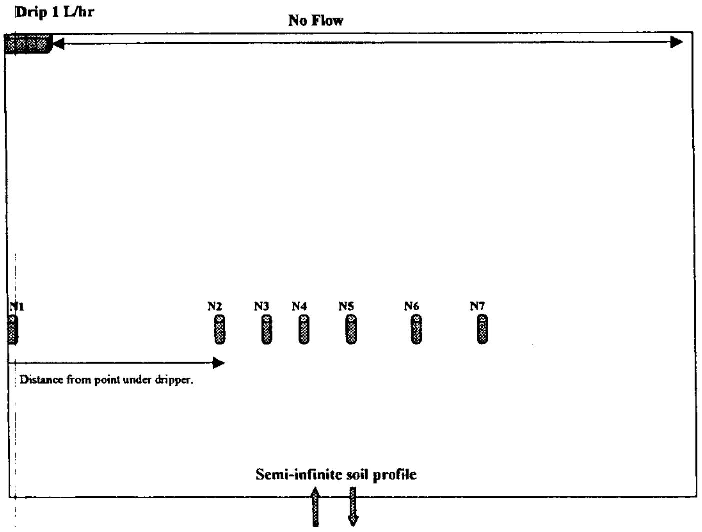

Figure 1. Schematic of the simulated drip irrigation system with boundary conditions and monitoring point locations. Monitoring points N1 . . . N7 represent 0, 16, 19, 22, 25, 30, and 35 cm horizontal distance from the dripper at a depth of 25 cm below the soil surface.

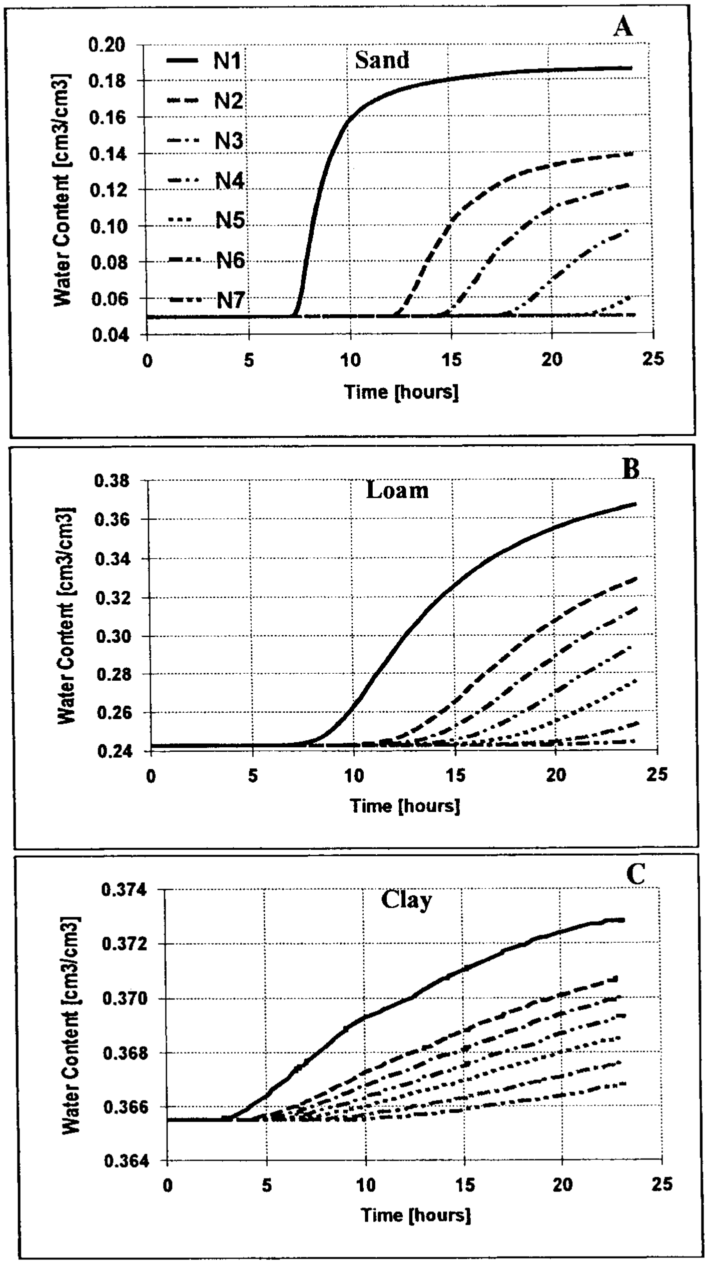

Figure 2. Water content as function of time in the seven monitoring points and for each soil type: a) sand, b) loam, and c) clay. Monitoring points as described for Fig. 1.

The shape of the water content curve increasing as a function of time for the loamy soil was different from that of the sandy soil (Fig. 2). Until the end of the simulation, the water content at 0 cm (N1) did not reach its maximum level. Six out of the seven points showed an increase in their water contents. Except for the 0-cm point (N1), differences in the increase of the water content among the different points were small compared with those differences among the observation points of the sandy soil. This is attributed to the movement of the water front, which was multidirectional for the loamy soil while it was vertically dominated for the sandy soil.

The water content increase in the clay soil was similar in many ways to that of the loamy soil. Water content increase was moderate compared to the two previous soil types. In addition, all points started to increase in water content at the same time with the exception of the 0-cm point. The slope of increase in the water content was much smaller than that of the sandy or even the loamy soils. This is clear evidence of the multidirectional spreading of the water front with clay soil. All monitoring points showed simultaneous increases in their water contents.

The spread of the water front illustrates the performance of drip irrigation for these distinct soils. With sandy soil conditions, water front movement is dominated by its vertical component. In other words, water has a tendency to move vertically rather than horizontally. Water moves in soils as a result of the matric potential (directly related to water content) and gravitational potential (tendency of the water to move downward as a result of gravity). In dry soils, matric potential is dominant compared with gravitational potential. As soils get wetter, gravitational potential dominates the matric potential. Sandy soils are dominated by large pores compared with fine texture soils such as clay and loamy soils. In order for water to move from a wet portion to a dry portion of a sandy soil, water uses large pores. Once the large pores of a sandy soil are filled, the driving force of water movement is dominated by the gravitational potential. Hence, the water content directly under the dripper (N1) increased from its initial level before irrigation to its maximum level in a short time. However, it took 4 to 5 times longer to reach the same point (N1) for the other two soil types (loam and clay). Consequently, to be able to wet horizontally a sandy soil compared to a clay soil, a drip system must run twice as long. By that time, water underneath the dripper would have moved beyond the root zone. This could increase production costs by causing excess water percolation and leaching of fertilizers and pesticides beyond their target zone of action.

The maximum radial extent of the water front during these 24-h simulations was 24, 38, and 47 cm for the sand, loam, and clay soils, respectively. Drip systems are expected to work better in clay soils than in loamy soils. Similarly, they will perform relatively better in loamy soils than in sandy soils. To have the same horizontal coverage in sandy soils as in clay soils, growers should use twice as many drippers per unit area. However, they only need 1.5 times as many emitters in loamy soils.

Drip irrigation can increase water use efficiency. This work shows that it is essential before choosing such an irrigation system to evaluate its suitability based on evaluation of the physical and water holding properties of the soil. More field work will be conducted to validate the findings of the simulations reported here.

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