Beyond burying the lateral: Current issues in and future opportunities for subsurface drip irrigation

Prepared for Netafim by

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Irrigation is an essential component of agricultural management where greater production of food and fiber is required under severe constraints of water resources protection and conservation. We are challenged to increase production using less water and are often required to do so with low-quality water sources. Drip irrigation, applied either on or below the soil surface, attempts to increase water use efficiency through; reduced runoff and evaporation losses, reduced leaching of water and contaminants below the root zone, and increased yields by providing optimum conditions for plant uptake of water and nutrients.

Drip irrigation has been shown to successfully increase efficiency of water application and to increase yield for many crops (Phene, 1995; Camp, 1998). The main advantage of drip over other irrigation methods is derived from its ability to provide small water quantities at elevated frequencies and hence to maintain relatively high water content and available nutrient concentrations within the root zone (Rawlins and Raats, 1975). In order to successfully develop and promote even more efficient water use management, current research includes investigations into ever higher irrigation frequencies including the study of the relevant changes in water, fertilizer and salt distribution patterns in soil and the response of root growth and uptake to these modified growing conditions. Results indicate that steady conditions, maintained as water and nutrients are supplied at very high frequencies or for much of the day through application at

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very low flow rates, lead to enhanced water and nutrient uptake (Glenn 1999, Clothier and Green 1994, Segal et al 2000, Ben-Gal and Dudley 2003).

Subsurface drip irrigation (SDI) is regularly used to provide water and nutrients to plants while maintaining a dry soil surface. Drip emitters in SDI systems are positioned within the soil in attempts to alternatively conserve water, control weeds, minimize runoff and evaporation, increase longevity of laterals and emitters, ease use of heavy equipment in the field, and prevent human contact with low-quality water (Camp, 1998; Lamm, 2002). Additional motivation for SDI comes as savings of the extensive labor involved with seasonal installation and collection of surface drip system laterals. Drippers are commonly buried 7 to 30 cm under the soil surface but are found as deep as 100 cm (in date palm orchards at Yotvata, Israel). Development of SDI started in the 1960s but held limited interest and realized limited success until the 1980s following successful Israeli development of surface drip irrigation (Camp, 1998). Today, subsurface techniques and systems for drip irrigation represent increasingly important components of agricultural and landscape irrigation.

Water, fertilizer and salt distribution in the soil around a buried dripper depend on soil hydraulic properties, dripper characteristics, inlet pressure, dripper outlet-soil interface geometry and size, and on root uptake. Desired wetting patterns can be obtained by manipulating dripper flow rate and spacing (Lubana and Narda, 2001), and by influencing the soil dripper interface (Shani and Ben-Gal, 1999; Meshkat et. al., 2000). Mathematical models can be used to increase the ability to predict water, fertilizer and salt movement and distribution in the soil accordingly (Mmolawa and Or, 2000). The importance of such models lies in the possibility for analysis and optimization of any relevant case with moderate investment in time and effort. Soil moisture distribution after 3 hours of irrigation at 2 L/h modelled for drippers in (a) clay and (b) sandy loam soils buried 25 cm below the surface using numerical solutions as implemented in Hydrus-2d (Simunek et. al., 1999; Lazarovitch and Shani, 2003 personal communication) are shown in Figure 1. This example of model use clearly shows the saturated and wetted areas and the differences between the soil types.

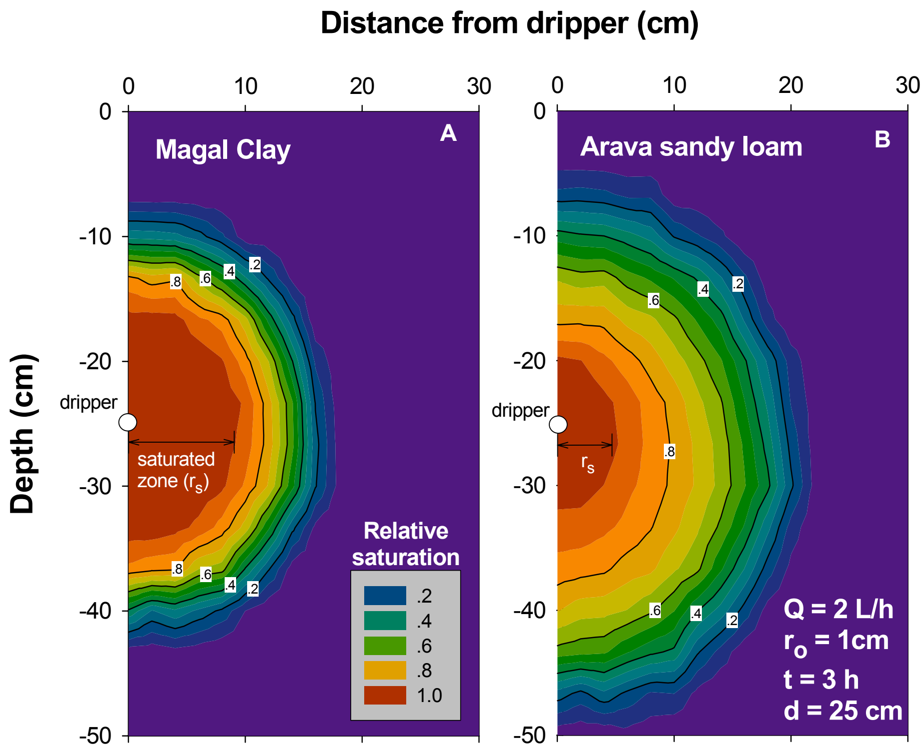

Figure 1. Soil moisture (as relative saturation) distribution modelled for two soils under SDI by HYDRUS-2d. Q = dripper flow rate, r_0 = cavity radius, t = time, d= depth, r_s = saturated radius.

Successful use of SDI is dependent on technological solutions to a number of obstacles. A subsurface drip emitter usually has a limited cavity around it into which water can freely flow. As the pore space at the dripper outlet fills with water, positive pressure develops since infiltration of applied water is limited by hydraulic properties of the soil (Shani and Or, 1995). Attempts to bury and use non pressure-compensated drippers result in conditions of backpressure formation at the dripper outlet leading to decreased flow rates and non-uniform water application in the field (Warrick and Shani 1996). Use of compensated drippers, low flow rates and higher operating pressures has successfully reduced problems of back pressure and non-uniformity for SDI. Growing plants have been found to eliminate and even reverse the phenomenon of backpressure. Root uptake causes soil drying and subsequent increased soil water tension (negative water head) (Clothier and Green, 1994, 1997). When nominal dripper discharge is sufficiently low, root uptake rate can be greater than dripper flow rate and hence, no backpressure evolves (Lazarovitch, Master dissertation 2001).

When positive head is generated in the saturated zone surrounding emitters, paths of least resistance to water flow and ensuing pressure alleviation can lead to surfacing (chimneying) and ponding of water, defeating the aims and purpose of SDI. Attempts to avoid surfacing include fastidious attention to design criteria where flow rates and depth of laterals take soil hydraulic properties into full consideration so that the saturated zone around the emitter remains under the surface and that pressure build-up is minimized. Further approaches to prevent surfacing include use of short duration irrigation events and provision of relatively high porous media replacing the soil in the immediate vicinity of the drippers (Meshkat et. al., 2000; Shani and Ben-Gal, 1999).

Buried emitters are hazard to clogging not only by water-born particles and chemical precipitates as with surface emitters (Capra and Scicilone, 1998), but also by solid particles or roots entering the emitter from the soil (Lamm, 2002). Due to the inherent clogging risk, and because repair and replacement of SDI systems are expensive and demanding, appropriate design and regular maintenance are fundamental to success. Filtration and regular flushing of lines to prevent clogging by particles in the water supply, air entry ports to prevent vacuuming of soil particles into the drippers, and chemical treatment to prevent scaling and accumulation of precipitates are necessary to prolong life and prevent system failure. Root infiltration can be avoided by applying the herbicide trifluralin (Treflan®, Dow AgroSciences, EPA Reg No 67219-250), by maintaining consistent conditions of relatively high water content through frequent irrigation events and by engineering of the drippers such that root penetration is unlikely.

Particular interest for utilization of SDI systems is found in wastewater disposal systems. Whether for simple soil-based waste disposal or for agricultural utilization, regulated flow and prevention of surfacing are extremely important when wastewater is regarded. SDI is a potential tool for alleviating problems of health hazards, odor, contamination of groundwater, and runoff into surface water (Trooien et al 2002). SDI particularly augments opportunity for reclaimed municipal wastewater in landscape and turf culture (Gushiken 1995) and in edible crops (Oron et al 1991). In Israel, SDI is officially recognized by the Ministry of Health as a separation technique allowing otherwise forbidden crop-water quality combinations to be permitted for irrigation.

Figure 2. Exposed roots in a washed soil profile in a vineyard after 8 years of (a) surface and (b) subsurface drip irrigation with municipal wastewater effluent. (Ben-Gal and Shani, work in progress)

SDI presents a unique opportunity to manipulate root distribution and soil conditions in order to better manage environmental variables including nutrients, salinity, oxygen and temperature. Root distribution can be influenced by irrigation regime (Ben-Gal and Shani, 2003) and by emitter placement (Shani et. al., 1995). Grapevine roots developed under both surface and subsurface drip irrigation are pictured in Figure 2 and are seen to concentrate in the wetted areas of the soil. Melon plants irrigated from drippers placed 0 to 45 cm below the surface concentrated their roots directly around and above the emitters such that increased depth of the drippers generated deepened root mass (Figure 3).

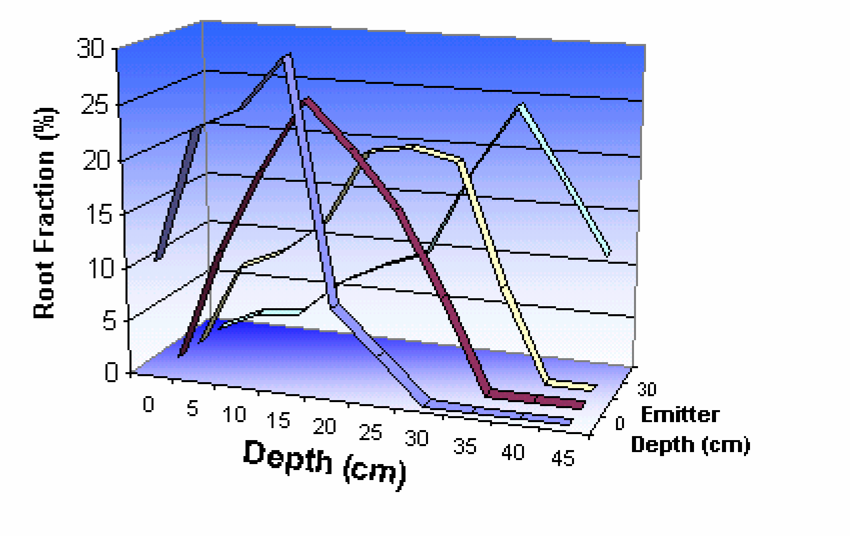

Figure 3. Root distribution (% of all roots in the profile) of melon plants irrigated with drippers at four depths (surface, 15, 30, and 45 cm). From Shani et. al. (1995).

Recent efforts attempt to come ever closer to matching of water and fertilizer application to actual plant consumption through very high frequency of pulsed irrigation events or by extended application over time at low flow rates. While beneficial to surface drip irrigation as well, high frequency applications are specifically relevant and appropriate for SDI. High frequency irrigation positively affects water use and yield. As the roots of a plant use the water adjacent to them the plant needs to either wait for the soil to replenish the water, shift to uptake in a different zone, or grow new roots into wetter soil. Conditions conducive to growth are created by maintaining relatively high water content where replenishment of drying soil easily occurs. Plants concentrating root growth and uptake in constant or slowly changing regions of the soil are faced with less temporal conditions of stress. The high water content of the soil maintains relatively high soil hydraulic conductivity and good replenishment of water taken up by roots (Segal et. al., 2000). Nutrient availability is augmented as well under very high frequency or continuous application. Greater biomass production and higher plant tissue phosphorus content are found when water and fertilizer are applied continuously as compared to a 2-day intermittent application regime (Ben-Gal and Dudley, 2003).

In a world where water resource conservation goes hand in hand with ever increasing demand for food and fiber, subsurface drip irrigation offers tools for maximizing water use efficiency. Further progress in SDI application is expected as advancements are made regarding understanding of water and solute flow and uptake and appropriate technological advances are developed to manipulate that knowledge.

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