Managing soil surface salinity with subsurface drip irrigation

Thomas L. Thompson[A], Trent Roberts[B], Naftali Lazarovitch[C]

[A]Texas Tech University, USA
[B]University of Arkansas, USA
[C]Ben-Gurion University, Israel

Abstract
The classical 'leaching requirement' approach for salinity management does not work well with subsurface drip irrigation (SDI), because irrigation with SDI results in no leaching above the depth of the drip tape, and salts will accumulate throughout the growing season. Irrigation with SDI can maintain suitable root-zone salinity, but surface salt accumulation will occur unless there is adequate leaching due to rainfall or supplemental surface irrigation. Facilitating crop establishment with SDI will help to improve the long-term economic sustainability of SDI. Our research has shown that, in arid-region soils irrigated with SDI, very high soil salinity can occur at the soil surface. This can inhibit germination of small seeded, salt-sensitive crops. Growers have several options for managing salinity with SDI: 1) supplemental leaching using sprinklers or flood irrigation, 2) transplanting, and 3) bed shaping to allow planting into soil of low salinity. The most appropriate method will depend on equipment, the crop to be planted, and other factors. In climates with >450 mm of annual rainfall, leaching from rainfall will probably be sufficient to maintain soil salinity below harmful concentrations with SDI.

Introduction
Drip irrigation is the application of water under low pressure through low-flow emitters embedded within the walls of plastic tubing. In the U.S.A., surface drip irrigation is reserved mostly for permanent (e.g. tree) crops, while subsurface drip irrigation (abbreviated herein as SDI) is used widely for annual crops. Modern SDI installations can last for 20 years or more with proper maintenance. When compared to surface irrigation (flood and furrow), SDI may reduce water loss to evaporation, deep percolation, and completely eliminate surface runoff (Phene 1990). The use of SDI may also increase crop marketable yield and quality (Ayers *et al* 1999). The use of SDI can result in high nutrient use efficiency (Thompson *et al* 2002). Saline irrigation water can be used with SDI, while maintaining yields and improving water use efficiency compared to surface irrigation (Cahn and Ajwa 2005, Siefert *et al* 1975, Tingwu *et al* 2003), because SDI can result in suitable root-zone salinity (Hanson *et al* 2009).

Accumulation of salts in concentrations detrimental to plant growth is a constant threat in irrigated crop production. With surface irrigation, leaching adequate amounts of water through the soil profile (e.g. the 'leaching requirement') is the desired method for maintaining suitable soil salinity. However, the classical 'leaching requirement' approach does not work well with SDI (Hanson *et al* 2009), because irrigation with SDI results in no leaching above the depth of the drip tape, and salts will continue to accumulate throughout the growing season (Dasberg and Or 1999; Hanson and Bendixen 1995; Oron *et al* 1999). The amount of salts that will accumulate above the drip tape is a function of several factors, including, but not limited to, water quality (Ayers *et al* 1993) and evapotranspiration (Burt *et al* 2003). Salt accumulation with SDI is of particular concern in arid and semi-arid regions, where high rates of evapotranspiration and low rainfall can result in large amounts of salt accumulation near the soil surface. This salt can hinder production of salt-sensitive crops.

Salts that accumulate near the soil surface become particularly important when SDI-irrigated fields are replanted. The most obvious way to avoid crop failure or yield reduction due to poor stand establishment is by leaching salts from the surface to a depth where they no longer pose a threat to seedlings (Hanson and Bendixen 1995; Hanson 2003). Sprinkler irrigation is the most commonly used method of leaching salts below the drip tape. Using sprinkler irrigation for germination in fields with SDI is effective but requires high capital inputs (Hillel 2000) above that required for installation and management of the permanent SDI system. The need for frequent use of sprinklers can threaten the long-term economic sustainability of SDI. Less than 10% of producers using SDI in California rely solely on SDI for crop establishment (Burt and Styles 1994). Farms in the arid southwest, USA may grow two crops per year. Reducing use of sprinklers could reduce costs of production and result in more acreage converted to SDI.

Researchers have investigated SDI tape depth and its resulting effect on yield following establishment (Charlesworth and Muirhead 2003; Lamm and Trooien 2005). This research focused on the availability and plant uptake of water and nutrients, but did not address effects of tape depth on salt accumulation and crop emergence. Oron *et al*. (1999) showed that salt accumulation near the soil surface depended on water quality and tape depth. They also showed that tape depth affects where salts accumulate by changing the location of the wetted perimeter. Cook *et al*. (2003) and Thorburn *et al*. (2003) showed that the wetted area with SDI (radius of wetted perimeter, wetted distance above the drip tape and wetted distance below the drip tape) is a function of texture and soil hydraulic properties. They showed that soil hydraulic properties control the wetted distance above the drip tape; however tape depth controls the amount of water that reaches the surface and the resulting salt accumulation.

Subsurface drip irrigation is a valuable irrigation method in arid and semi-arid regions. However, little research has been reported that evaluates effects of salinity on establishment of crops with SDI in successive seasons. Developing alternatives to reduce or eliminate the need for sprinklers during crop establishment will help to improve the long-term economic sustainability of SDI. Thus, we initiated a field experiment in Arizona to determine effects of tape depth, water quality, and germination method on salt accumulation and germination of successive crops.

We evaluated the effects of tape depth (18 and 25 cm), irrigation water salinity (ECw), (1.5 and 2.6 dS/m) and germination method (SDI vs. sprinkler) on end-of-season salt distribution with SDI during two growing seasons (Roberts *et al* 2008). We intensively sampled the planted area at the end of two growing seasons. Following season 1, in which we planted cantaloupe (*Cucumis melo cantalupensis*), salt accumulation was high enough to significantly reduce the germination and establishment of the next crop. Sprinklers were needed to achieve 100% establishment of direct-seeded broccoli (*Brassica olearacea* L. *Italica*) during season 2. Areas with exceptionally good water quality (<0.5 dS/m) may not require sprinkler pre-irrigation for several years, as shown by Burt *et al*. (2003). Where water cost is low and water quality is sufficiently high, the use of SDI for germination and establishment may be preferred. However, if water cost or salinity is high, use of sprinklers for pre-irrigation may be preferred, because less water is needed for germination. The cost and quality of water available to growers will influence which irrigation procedures are used during germination and establishment of small seeded, salt sensitive crops.

Conclusions

Methods for managing salt with SDI include using sprinklers, transplanting, and bed shaping. Using transplants would eliminate the need for sprinklers during establishment, because the root ball is usually placed a few cm below the zone of highest salt accumulation. However, sprinklers are often used with transplants to prevent desiccation, because several hours may be required for water to move from the drip tape to the root zone. Transplants may eliminate the need for sprinklers to manage salts, but require high capital inputs and may not improve the economic sustainability of SDI. Bed shaping has been use as a means to manage salt accumulation above the drip tape. This method involves forming the beds to a peak and pre-irrigating to move salts toward the peak. The tops of the bed are then removed into the furrow leaving behind soil of low ECe. Direct seeding of some large-seeded crops can then occur without concern of inhibited emergence. Small seeded crops that require precision planters cannot usually be direct-seeded into moist beds. Bed shaping procedures may prove effective in some crop rotations by eliminating the need for sprinklers, but the excess water needed to pre-irrigate beds may be less economically feasible, depending on water cost. In climates with >450 mm of annual rainfall, leaching from rainfall will probably be sufficient to maintain soil salinity below harmful concentrations, except when very saline irrigation water is used.

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