DRIP AND EVAPORATION

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ABSTRACT

Loss of water from the soil profile through evaporation from the soil surface is an important contributor to inefficiency in irrigated crop production. Residue management systems may reduce this evaporative loss, but cannot be used in all cropping systems. Choice of the irrigation system and its management also can reduce evaporative loss. In particular, subsurface drip irrigation limits soil surface wetting and can lead to an overall reduction in evapotranspiration (crop water use) of as much as 10%. The example presented shows that most of the water savings occur early in the season when crop cover is not yet complete. Because evaporation from the soil surface has a cooling effect on the soil in the root zone, irrigation methods that limit evaporation will result in smaller fluctuations in soil temperature and warmer soil temperatures overall. For some crops such as cotton, this has beneficial effects that include earlier root growth, better plant development and larger yields.

PREVIOUS STUDIES

Crops grown under subsurface drip irrigation may out yield those grown under surface drip (Phene et al., 1987) or use less water for the same yield (Camp et al., 1989). Yield differences may be related to differences in plant available water due to greater evaporation from the soil surface with surface irrigation. However for corn (Zea mays) grown in 1993 on the Pullman clay loam at Bushland, TX, there was no significant yield difference for well-watered treatments (Howell, et al., 1997).

Tarantino et al. (1982) compared microclimate and evapotranspiration (ET) of tomatoes under surface drip and furrow irrigation on weighing lysimeters and found no difference in seasonal ET when canopy development was similar. Drip irrigation was daily in their study while furrow irrigation frequency was about 10 d. The higher ET from furrow irrigation for the 3 d after irrigation was offset by the generally higher ET from drip irrigation on other days due to the continuously wetted soil surface under drip. Even though the loam soil surface was only partially wetted, advection from dry, hot inter-row areas contributed to the energy available to drive evaporation from the wet surface. If soil surface wetting could have been reduced by using subsurface drip, the ET from drip irrigation might well have been lower than that under furrow irrigation. When drip and sprinkler irrigations were both daily on a sandy soil, net radiation and ET were larger for sprinkler irrigation compared to drip irrigation of tomatoes (Ben-Asher et al., 1978).

Bordovsky et al. (1998) compared LEPA and SDI irrigation of cotton at application rates of 0.1, 0.2, and 0.3 inches per day. Lint yields of 1145, 1225, and 1259 lb/acre for SDI were all larger than the yields of 980, 1142, and 1187 lb/acre under LEPA. The yield decrease with LEPA was attributed to larger evaporative losses. Spacing of LEPA drops and SDI laterals was identical; but SDI laterals were buried at 12-inch depth. Emitter spacing was 24 inches and flow rate was 0.336 gal/hr.

Computer Modeling Efforts

Drip irrigation using buried emitters has the potential to save irrigation water by reducing soil surface wetting and thus reducing evaporation (E). However, measurement of evapotranspiration (ET) for different combinations of emitter depth and cropping systems is very difficult and time consuming, in part because of non-uniform soil surface wetting (Matthias et al., 1986). Thus, computer simulations are important tools for looking at ET differences for different irrigation practices. Water flow during microirrigation has been variously simulated as essentially one-dimensional (Van Bavel et al., 1973), two-dimensional axisymmetric (Brandt et al., 1971; Nassehzadeh-Tabrizi et al., 1977), and two-dimensional rectilinear (Ghali and Svehlik, 1988; Oron, 1981). Lafolie et al. (1989) introduced both axisymmetric and rectilinear finite difference solutions. Although some of these studies included root uptake, none of them attempted to model the energy and water balances of the crop canopy and soil surface.

Recognizing the inability of existing models to simulate the differences in crop ET due to dripline depth, Evett et al. (1995) modified a mechanistic ET model, ENWATBAL, to simulate irrigation with drip emitters at any depth. They used the model to simulate energy and water balance components for corn (Zea mays L., cv. PIO 3245) grown on the Pullman clay loam soil at Bushland, TX using emitters at the surface and at 0.15- and 0.30-m depths (6 and 12 inches). Data were from an actual corn crop grown with drip irrigation. Irrigation was daily and was scheduled to replace crop water use as measured in the field by neutron scattering (Fig. 1).

Modeled transpiration (T) was essentially equal for all emitter depths [428 mm (16.9 inches) over 114 days from emergence to well past maximum leaf area index (LAI)]. But, loss of water to evaporation (E) was 2 inches (51 mm) and 3.2 inches (81 mm) less for 6- and 12-inch deep (0.15- and 0.30-m) deep emitters, respectively, compared with surface emitters (Fig. 2). This is about the same as the range of water savings predicted by Bonachela et al. (2001) when converting from surface irrigation to buried drip irrigation on a sandy loam soil in Spain.

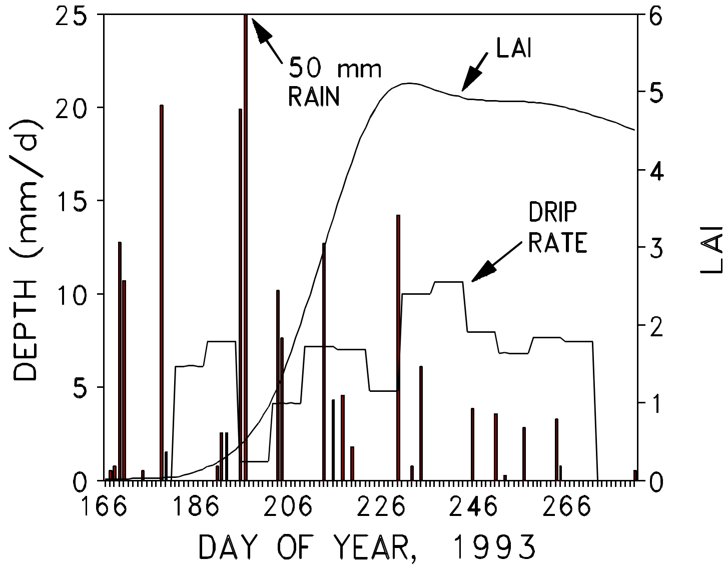

Figure 1. Depth of rainfall (25 mm is 1 inch) and drip irrigation for each day of the corn growing season. Also plotted is the crop leaf area index, which peaked in mid August. A 2-inch (50-mm) rain goes off the plot scale.

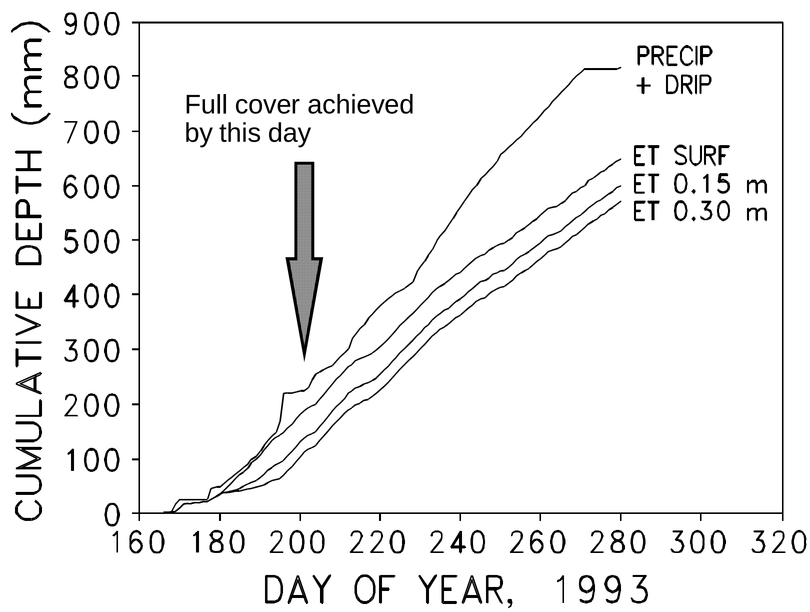

Figure 2. Cumulative depth of crop water use (ET) during the corn growing season for drip irrigation with dripline on the surface (SURF), dripline at 6-inch depth (ET 0.15 m), and dripline at 12-inch depth (ET 0.30 m). For comparison, the cumulative amount of precipitation plus drip irrigation since planting is also plotted. The difference between cumulative precipitation plus irrigation and the ET values is due to filling of the soil profile over the season, plus some drainage losses. One inch is 25.4 mm. Seasonal ET for drip irrigation with surface dripline was 25.6 inches.

For surface emitters, net radiation was much greater and sensible heat flux was smaller than for subsurface emitters until LAI increased past 4.2 mid-way through the season. Thus, almost all of the differences in ET occurred during the period of partial canopy cover (Fig. 2). Differences in energy balance components between treatments were minor after day of year 220 (early August). The study showed that water savings of up to 10% of seasonal precipitation plus irrigation could be achieved using 30-cm (12-inch) deep emitters under these soil and climatic conditions.

Predicted drainage was slight, ranging from 0.25 to 0.5 inch [6-, 8- and 12-mm for surface, and 6- and 12-inch (0.15- and 0.30-m) deep emitters, respectively], but comparisons of predicted and measured soil water profiles at season's end showed that deep drainage of more than 6 inches (150 mm) of water may have occurred. There were minor differences in soil heat flux between the treatments because soil heat flux was a relatively minor component of the energy balance.

The decrease in evaporative losses predicted by this computer model is supported by analytical solutions derived by Lomen and Warrick (1978) and Philip (1991). However, Philip (1991) pointed out that deep percolation losses potentially could increase as drip irrigation depth increases.

Evaporation and Soil Temperature

Rapid decreases in soil temperature, such as those often accompanying furrow or sprinkler irrigation, result in decreased plant transpiration (Ali et al., 1996). Since transpiration and yield are directly and positively related, this would translate into a decrease in yield. Comparative study has shown that subsurface drip irrigation at 10-inch depth (25 cm) resulted in warmer soil temperatures throughout the root zone when compared with furrow irrigation (Bell et al., 1998). Also, the daily range of temperature was smaller with SDI. These effects were associated with a decrease in lettuce disease (Bell et al., 1998). There is anecdotal evidence in the southern High Plains that drip irrigation of cotton results in improved yields due to warmer soil temperatures. Colaizzi et al. (2004b) found warmer soil temperatures with SDI than with LESA and LEPA sprinkler irrigation of cotton. This supports results of the modeling effort of Evett et al. (1995), which also predicted warmer soils with SDI compared with surface irrigation.

Cotton rooting is greatly decreased by cool soil temperatures. So there is a competitive advantage to managing for warmer soil temperatures earlier in the season. Some cropping systems employ plastic mulch to improve soil warming in the spring. This practice is common in the cooler regions of Uzbekistan, the cotton producing capitol of Central Asia. Comparative studies of SDI vs. furrow irrigation of cotton in Uzbekistan showed that cotton yield under drip irrigation was 22% greater than under furrow irrigation and that water use efficiency was 76 to 103% greater with drip (without plastic mulch) (Kamilov et al., 2003). There is some promise that SDI can provide similar advantages for cotton production on the southern Great Plains.

RECOMMENDATIONS

Subsurface drip irrigation will reduce losses to evaporation from the soil surface compared with furrow irrigation. The savings will increase as the wetted area on the soil surface decreases. Thus, wider dripline spacings and deeper burial will improve the water savings. With system designs that are commonly in use, the water savings may range from 1 to 3 inches per season. The economic impact of this savings will vary with the cost of water (primarily pumping costs) and the rate of return per inch of water. In a situation where water is plentiful and irrigation scheduling is managed for maximum yield, the increase in yield per inch of water may be non-existant. However, in the more common situation where the irrigation supply is less than the crop would use for maximum yield, we are in a deficit irrigation situation. In the deficit irrigation realm, the increase in yield per inch of water is usually near the maximum for a given crop. This is one reason why Colaizzi et al. (2004a,b) found greater sorghum and cotton yields under deficit irrigation regimes with SDI than with LEPA or spray sprinkler irrigation at Bushland, Texas. In the deficit irrigation regimes they studied, the increase of cotton yield was 86 pounds of lint per acre-inch of water, and the increase of sorghum yield was 232 pounds per acre-inch. At $0.40 per pound for cotton and $2.00 per bushel for sorghum, the 1 to 3 inch range of water savings represents marginal income increases ranging from $34 to $103 dollars per acre for cotton and from $7.70 to $23 for sorghum. Bhattarai et al. (2003) found similar trends for cotton grown under drip and furrow irrigation in Australia. Their dripline was buried at 16-inch depth and spaced at 40 inches. Yield for SDI at 75% of full ET was as large as that of furrow irrigation at 100% of full ET, and water use efficiency was larger for SDI.

Many other factors influence the decision to use SDI. For instance, deep percolation losses may increase with depth of dripline burial, depending on the soil layering and rooting pattern. Also, germination may be difficult in dry years, again depending on the soil, if dripline is buried too deeply and is spaced too far from the plant row. But, if water is short and the crop is sensitive to cool soil, then SDI can deliver with water savings and warmer soil temperatures.

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