Measuring water use and root distribution of drip irrigated watermelon in a humid climate using multi-sensor capacitance probes.

Ian McCann
University of Delaware Research and Education Center
Georgetown, DE 19947

Abstract.

Water for use by drip irrigated crops in a humid climate can come from both irrigation and rainfall. Scheduling irrigation using daily reference ET (ET_0) requires the use of rainfall data along with estimates of how much of the rain the crop can actually use. In mulched drip irrigation the contribution of rainfall to crop water uptake depends upon how much rainfall infiltrates into the volume of soil accessed by the roots. Multi-sensor capacitance probes (MCPs) measure near-continuous soil water content simultaneously at discrete depths. Replicated field studies on drip irrigated watermelon were conducted in Delaware using MCPs to measure water uptake under different irrigation amounts from different vertical and horizontal locations relative to the drip tape and the plastic mulch. Results indicate that the watermelon root system allows the crop to use significant amounts of rainfall, resulting in lower irrigation requirements than growers commonly apply.

Introduction

Drip irrigation in humid areas is difficult to manage because, unlike in arid areas, there are two potential sources of water. The first is irrigation, over which the grower has full control over timing and amount. The second water source is rainfall over which the grower has no control. In arid areas the rootzone of the crop is primarily limited to the volume of soil that is wetted by the irrigation, while in humid areas rainfall can wet the soil outside the volume wetted by irrigation. Rainfall can infiltrate the soil directly, but also runs off the plastic mulch to the edge where it is concentrated before it infiltrates. This infiltrated rainfall can contribute to crop water use if roots are present to use it. Rain can also enter the soil under the mulch through the planting holes (perhaps also channeled by stem flow) and through cuts and tears that may develop in the mulch. The lateral and vertical root distribution relative to the drip tape may therefore be affected by both irrigation management and rainfall patterns.

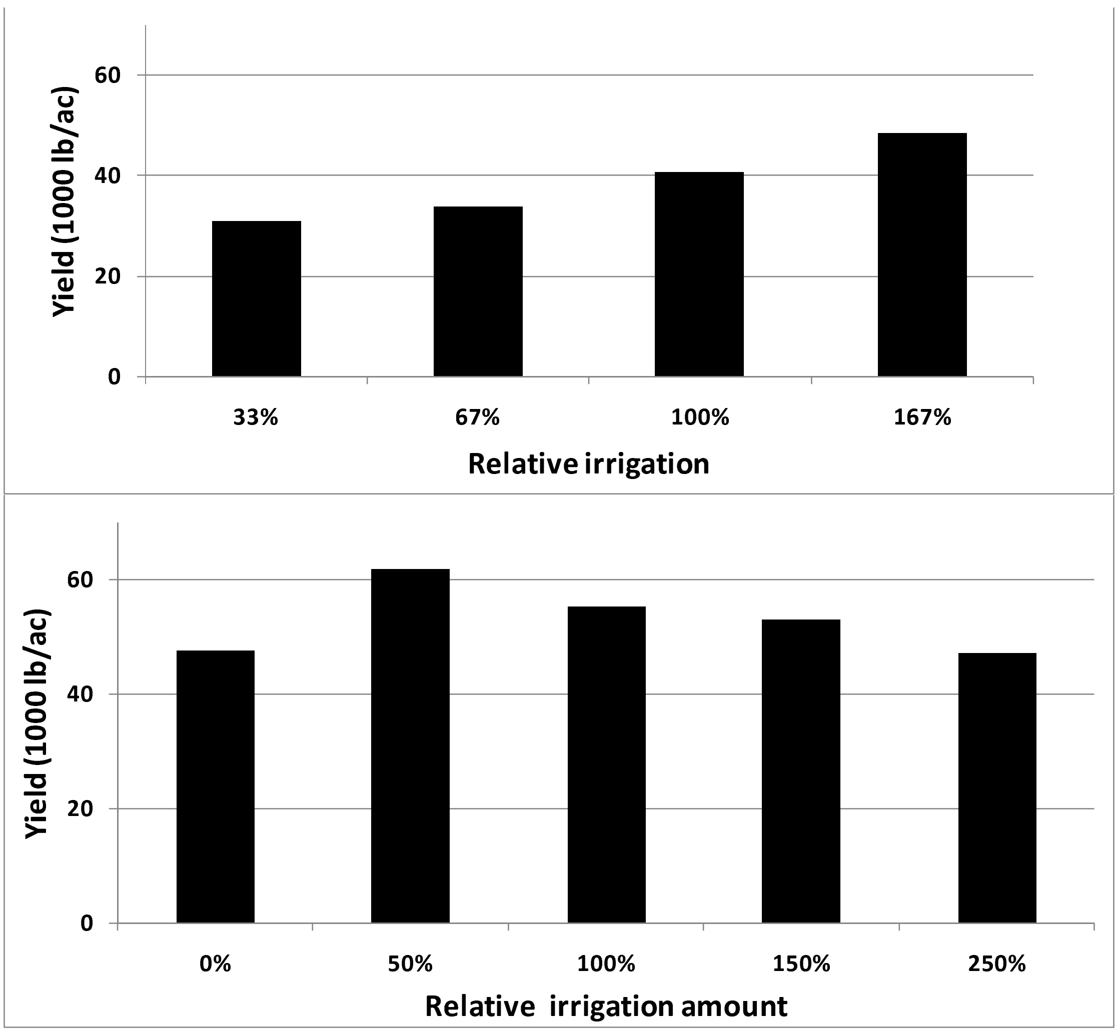

Figure 1. Yield of seedless watermelon as a function of relative irrigation amount in 2007 (top) and 2006 (bottom).

Figure 1 shows yield of seedless watermelon in 2006 and 2007 in experiments at the University of Delaware Research and Education Center in Georgetown, Delaware. Different relative irrigation amounts were used to try and determine the response of watermelon to irrigation. In both years the irrigation amount varied from deficient to excess. The 100% relative rate was determined using reference ET from a nearby weather station, and by continuous measurements of soil water content (SWC) to determine trends over time, with the purpose of maintaining soil water content within an optimal range. The other relative rates received irrigation amounts in proportion. In 2006 the deficient irrigation treatments included relative rates of 0% (no irrigation) and 50%, while in 2007 the deficient rates were 33% and 67%. The difference between 2006 and 2007 was in the rainfall during the season. In June 2006 rainfall totaled 13.4 inches, while in June 2007 the total was 2.6 inches. In July 2006 the total was 4.4 inches while in July 2007 there was 1.7 inches of rainfall. Thus, 2007 was much drier than 2006.

In 2006 the 50% irrigation rate had the highest yield (although the yields under all except 0% were not statistically different). The yield under 0% irrigation was still good, at 77% of the highest irrigated yield, and this yield was due entirely to rainfall. In 2007, the highest irrigation rate (167%) had the highest yield. There was no 0% treatment, but the lowest rate (33%) had the lowest yield (64% of the yield at the highest rate). Yields in 2007 were generally lower than in 2006.

Obtaining significant yield with reduced or no irrigation prompted this study. The relative yields as a function of relative irrigation indicate that rainfall can make a substantial contribution to crop water requirements, and this has implications for the development of improved irrigation management guidelines.

Methods

To attempt to quantify SWC and root distribution of mulched drip irrigated watermelon, we used multi-sensor capacitance probes (MCPs) located at three positions relative to the drip tape. The probes were located in the "center", "fringe" and "edge" positions, as shown in figure 2. The fringe position was halfway from the center to the edge of the mulch, while the edge position was outside the mulch. The sensors were located at depth of 4, 8, 12, 20 and 28 inches relative to the surface, and automatically read every 10 minutes in 2006 and every 30 minutes in 2007. In 2006 we measured SWC under the 50%, 100% and 150% irrigation rates in three replications, while in 2007 we made measurements under the 33%, 67%, 100% and 167% treatments in two replications. Further details of the experimental setup can be found in McCann and Starr, 2006.

MCPs can be used to show daily water uptake patterns (eg. McCann and Starr, 2007; Townsend, 2007; and Thompson et al, 2007). On days when the only change in soil water content is from crop water uptake, there is a characteristic "stair stepping" pattern in which SWC decreases during the daytime and levels off during the nighttime.

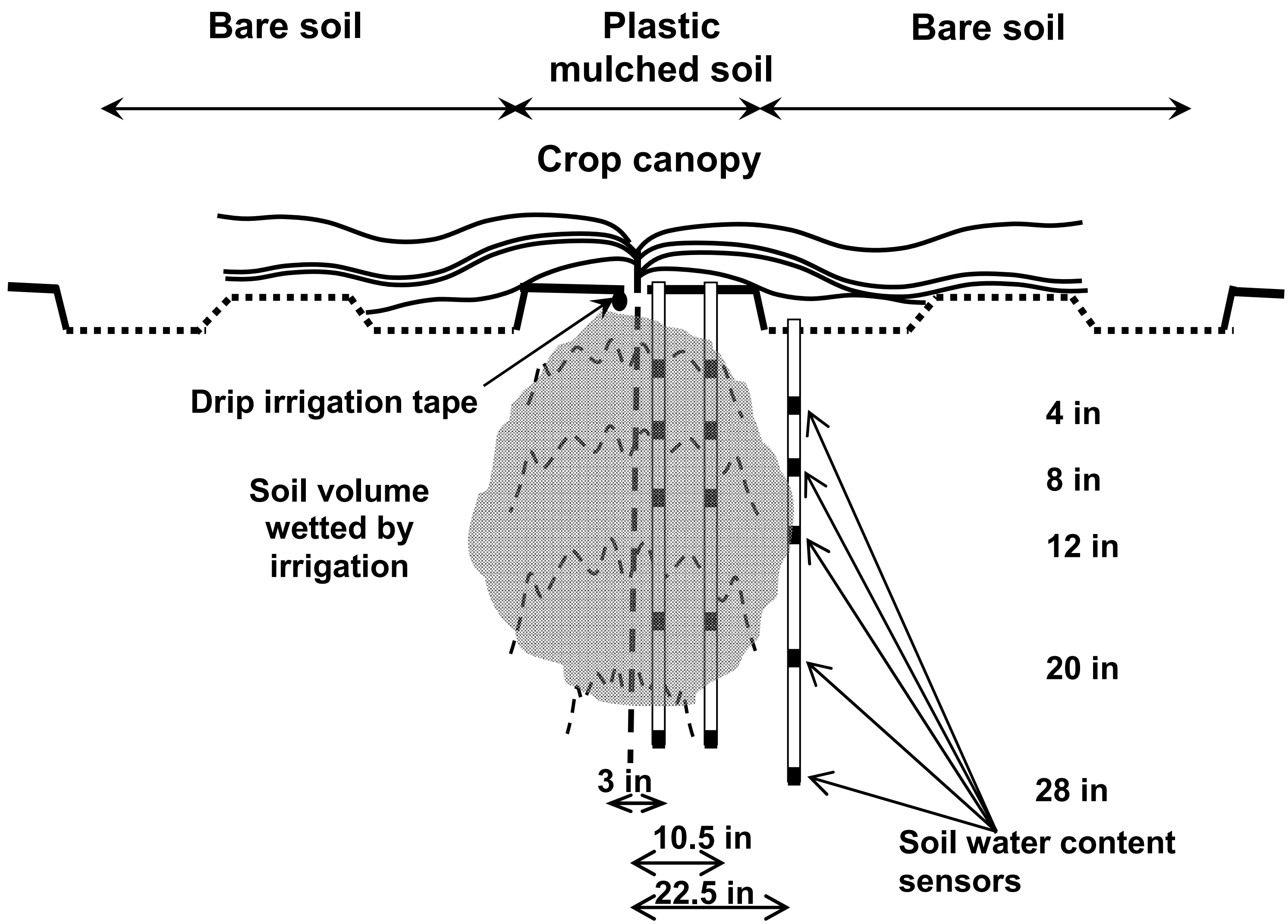

Figure 2. Plastic mulched drip irrigation of watermelon and layout of MCPs in 2006 and 2007. The center position and fringe position are in the mulched area, while the edge position is in the bare soil outside the mulch.

Results and discussion.

Figure 3 shows an example from 2006 that illustrates the "stair stepping" following an irrigation. The measured values of SWC are shown as a "stacked" graph in which the readings from the sensors are arranged from top (4 inches) to bottom (28 inches), each with a different scale so that they can be easily seen.

If stair stepping is evident, there must be active roots present. In figure 3, it can be seen that there are roots at the depth of the deepest sensor.

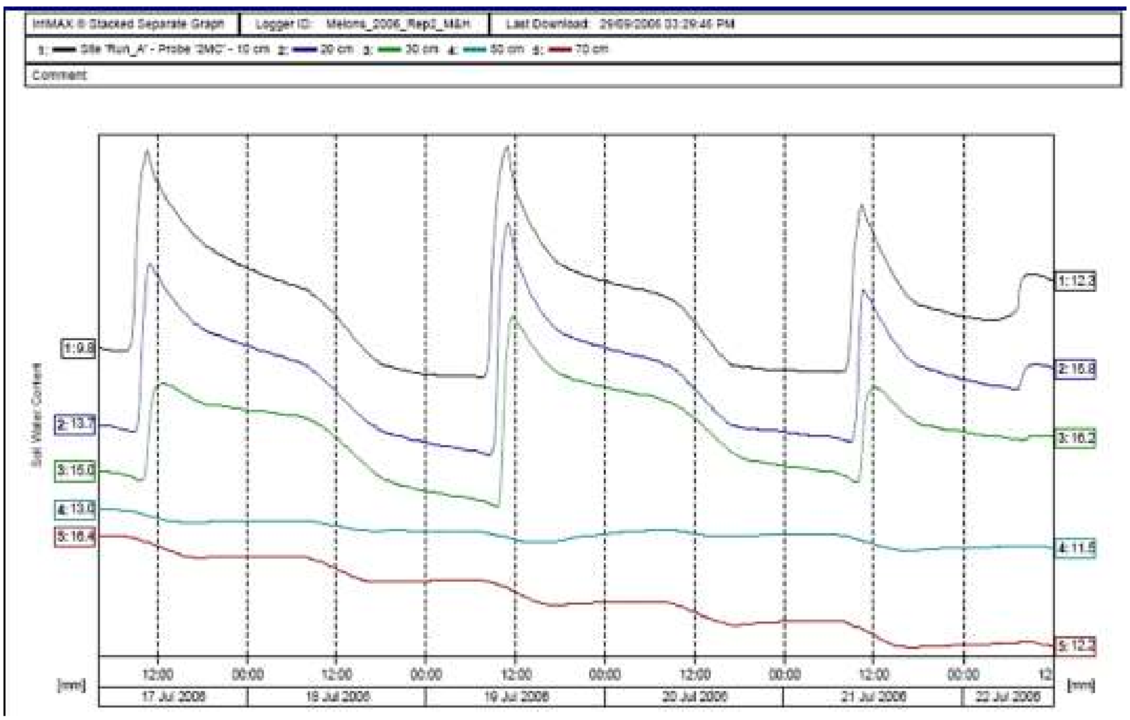

Figure 3. Example from 2006 of the "stair stepping" pattern of soil water depletion caused by crop water uptake during the daytime. The sensors are arranged from top (4 inches), through 8, 12 and 20 inches, to the bottom at 28 inches.

The magnitude of the decrease in SWC reflects the amount of water extracted from the soil surrounding the sensor. Each sensor represents a vertical cylinder of height from 5 cm below to 5 cm above the nominal depth of the measurement. Thus the 10 cm (4 inch) sensor represents a cylinder 10 cm in height extending from 5 to 15 cm depth. The sensors give measurements in units of % by volume, which corresponds to mm of water in the 10 cm cylinder.

If the decrease in SWC is summed in depth increments over the measured profile, (interpolating where necessary), the total decrease should be a function of the root density within the measured profile, and ET_0. Figure 4 shows such a sum for a probe at the center (top) and fringe position (bottom), for the 50%, 100% and 150% relative irrigation rates.

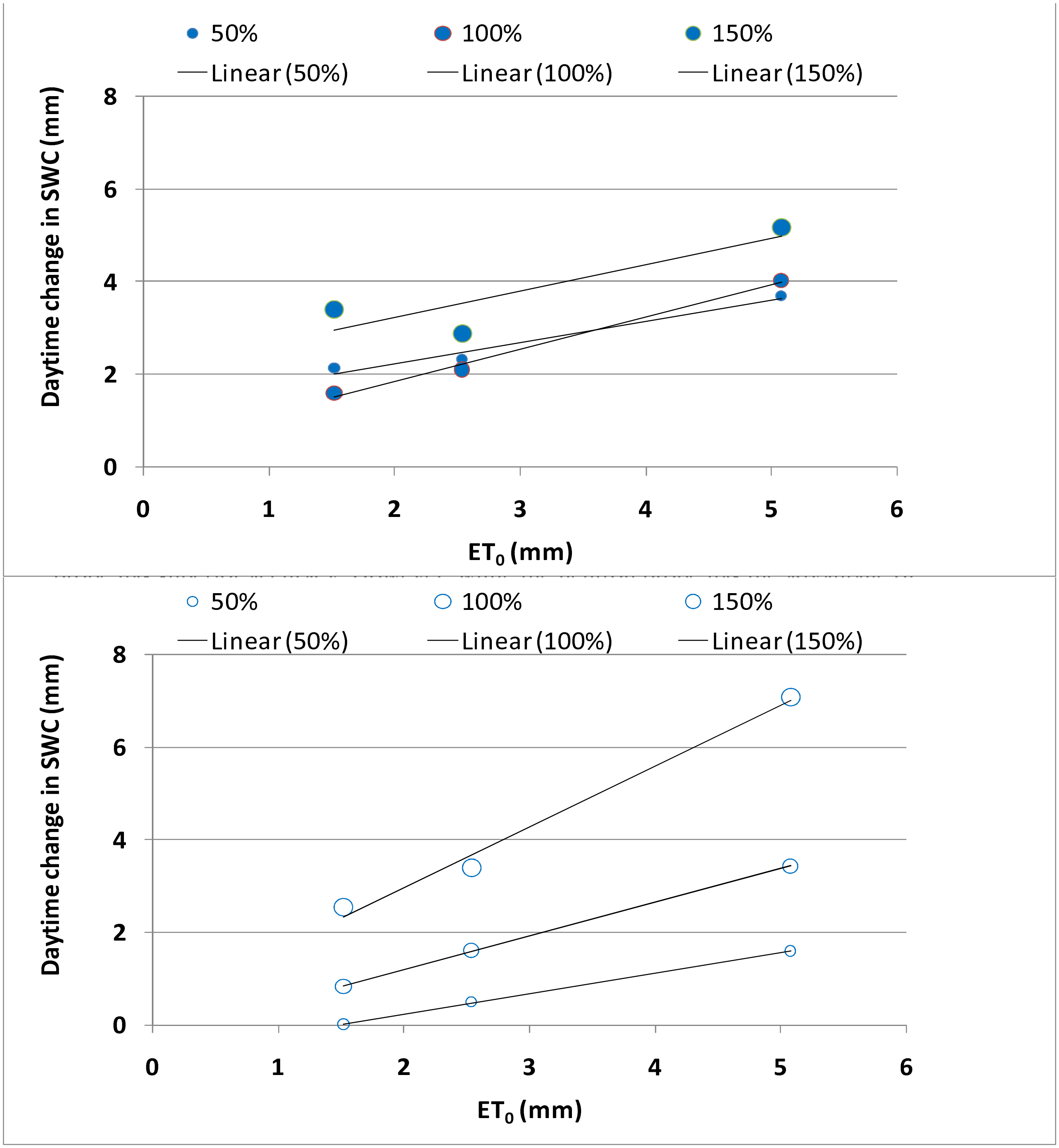

Figure 4. Change in SWC summed over the measured profile for the center position (top) and fringe position (bottom), for relative irrigation rates of 50%, 100% and 150%. The data are for 3 consecutive days following an irrigation and are plotted as a function of ET_0 on those days as estimated from weather data.

In this example, the decrease in SWC was greater at the center position under the 50% irrigation rate than at the fringe position. At the 100% rate the decrease in SWC was about the same at the center and fringe positions, whereas at the 150% rate the SWC decrease was greatest at the fringe position. There is an approximately linear relationship between ET_0 and the decrease in SWC under all irrigation rates and at both positions.

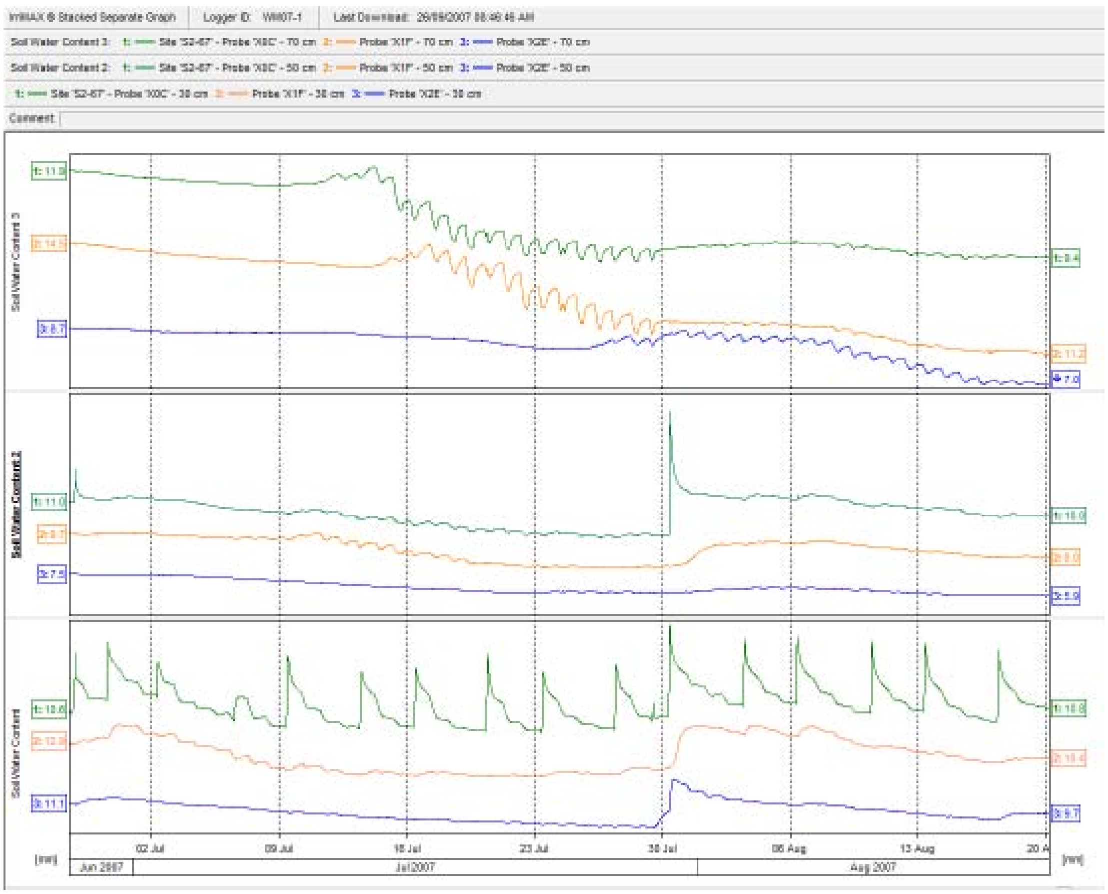

Figure 5. SWC measured at 70 cm (top), 50 cm (middle) and 30 cm (bottom) in 2007 under the 67% irrigation rate. Within each graph, the data are stacked with the center position at the top (green), the fringe position in the middle (red) and the edge position at the bottom (blue).

In figure 5, the fluctuations in SWC due to irrigations can be seen in the center position at 30 cm. A rainfall event at the end of July can also be seen that increased SWC at the edge position at 30 cm. There is some stair stepping at the edge position at all three depths, indicating that there is some root water uptake. At 70 cm, the stair stepping pattern begins first at the center position, but can be detected later at the fringe position and then at the edge position.

Figure 6 shows SWC at all five sensors at the edge position for the 33%, 67% and 100% irrigation rates in 2007. It can be seen that the rainfall event at the end of July penetrates

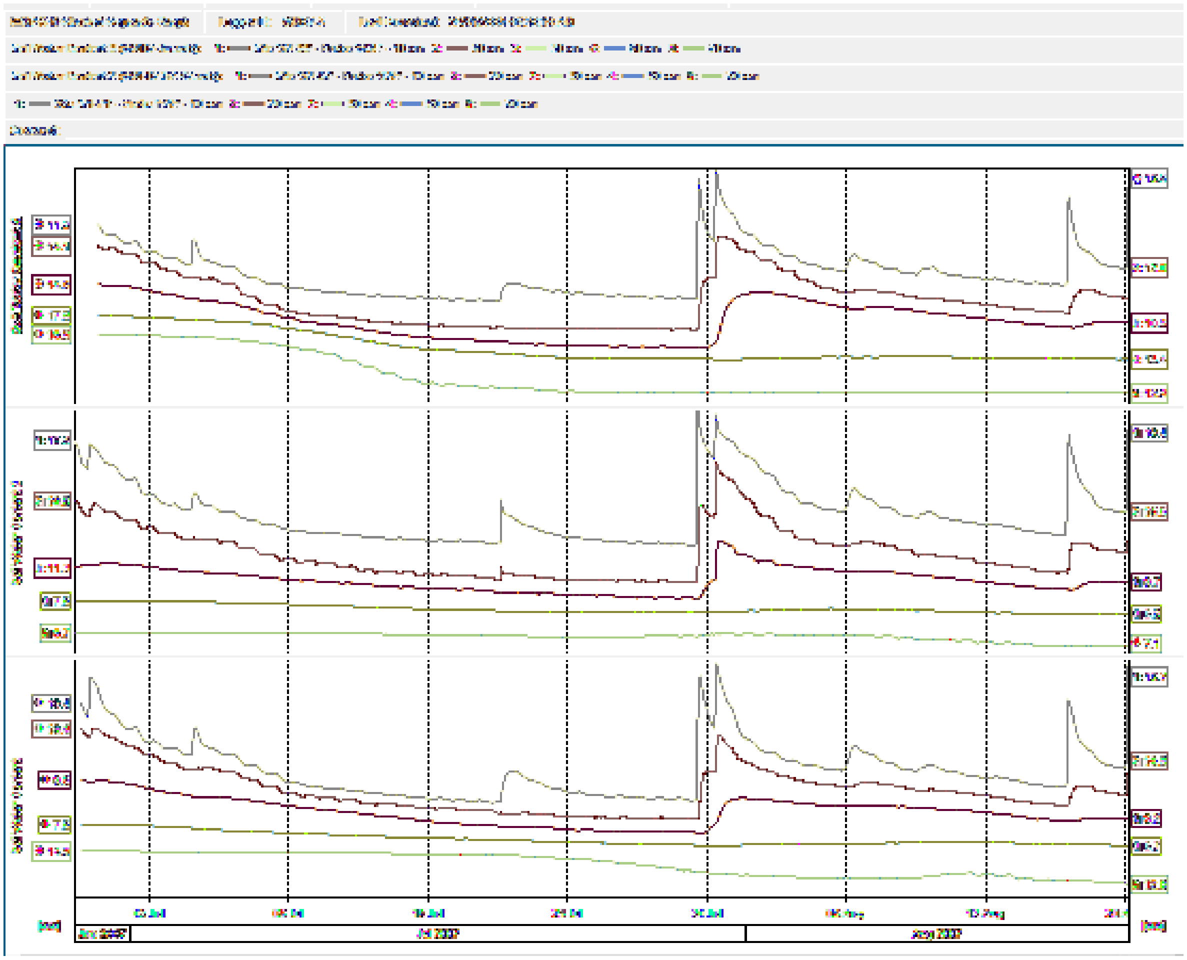

Figure 6. SWC measured at the edge position in 2007 for the 33% irrigation rate (top), the 67% rate (middle) and 100% rate (bottom). Within each graph, the data are stacked according to sensor depth with 10 cm at the top (blue), 20 cm (green), 30 cm (orange), 50 cm (purple) and 70 cm (red) at the bottom.the center position at the top (green), the fringe position in the middle (red) and the edge position at the bottom (blue).

to 30 cm in all cases. There is stair stepping evident at 10 cm, but this could be due to evaporation from the soil as well as root uptake. At deeper depths, evaporation would likely not be a significant cause of stair stepping. Under the 33% irrigation rate, root water uptake at 70 cm is more evident earlier in the season than it is under higher irrigation rates. Where there is some water stress, the crop may more actively develop a rooting system that is more extensive or deeper.

Conclusions

MCPs can detect root water uptake and may also be able to quantify crop water use, but further studies are necessary to investigate the complex dynamics of SWC under mulched drip irrigation.

References

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