Feedback Control of Subsurface Drip Irrigation to Optimize Irrigation Research

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For competitive production of irrigated crops, growers need to optimize plant performance, often with reduced inputs to reduce off site effects of irrigation-induced erosion and irrigation-induced leaching. Yet irrigation research is often based on theoretical principles of crop evapotranspiration (Et_c), water use efficiency, etc. with little focus on the ideal range of plant stress and the limits of the soil to retain water. The OSU team envisioned optimizing plant performance by keeping the soil in the optimal range of soil water potential for a given species (hence optimizing plant performance) and limiting the amount of water at each irrigation to the small amount that the upper 0.3 to 0.4 m of the soil surface could hold without leaching (hence minimizing off-site environmental effects of irrigation and minimizing water and fertilizer requirements). The environmental goals were needed due to groundwater and surface water contamination. These twin economic and environmental goals were accomplished by using measurements of soil water status as a signal for automated feedback control of irrigation.

Starting in 1995, we initiated the use of automatic drip irrigation research based on soil moisture feedback. Soil water tension is measured by granular matrix sensors (GMS; Watermark Soil Moisture Sensors, Irrometer Co., Riverside, Calif., Fig. 1), installed as depicted in Fig. 2, and connected to a datalogger via multiplexers (Campbell Scientific, Logan, Utah, Fig.3). The datalogger is programmed to read the sensors in each zone several times a day and irrigate each zone as necessary according to pre-established soil water tension thresholds. Irrigations have a fixed duration. Irrigations are controlled by the datalogger signaling a controller connected to solenoid valves. The automated drip irrigation allowed for the maintenance of soil moisture within narrow ranges (Fig, 4) and resulted in the application of amounts of water that followed Et_c (Fig. 5).

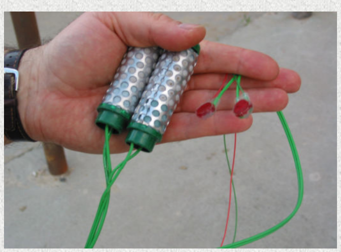

Fig. 1. Watermark soil moisture sensor (Irrometer Co., Riverside, Calif.) used to measure soil water tension.

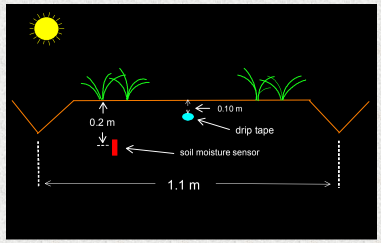

Fig. 2. Planting configuration for drip-irrigated onions.

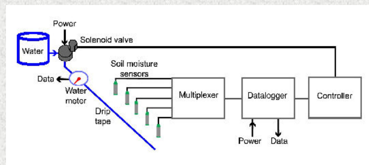

Fig. 3. Feed back control of subsurface drip irrigation.

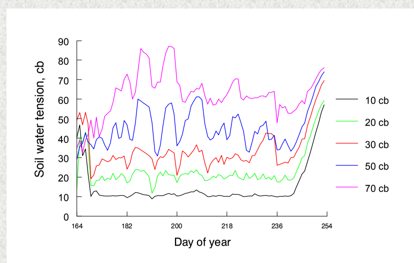

Fig. 4. Soil water tension over time for onions drip-irrigated at different soil water tensions.

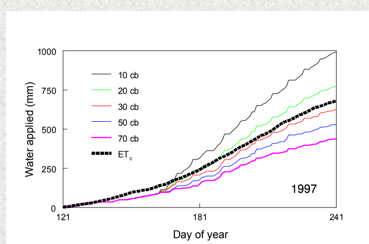

Fig. 5. Water applied over time and Et_c for onions drip irrigated automatically at different soil water tensions.

Research at the Malheur Experiment Station Using Automated Irrigation

An optimal irrigation threshold for drip irrigated onion was developed (Fig. 6). Using automated drip irrigation at the optimal threshold, onion response to different levels of N applied through the drip irrigation was tested. This research demonstrated lower N fertilizer requirements for drip-irrigated onion (Fig. 7). Onion response to different amounts of water applied at each irrigation was tested using automated drip irrigation with the optimal criterion. This research determined that high frequency irrigation did not improve onion performance. Irrigations every day or two resulted in larger bulbs than very frequent irrigations (Fig. 8). The automated system was also used to study onion response to water stress. Single episodes of short-term water stress were applied at different growth stages to onions drip irrigated automatically. Onion quality (single centers) was reduced when submitted to a single episode of short water stress early in the season (Figure 9).

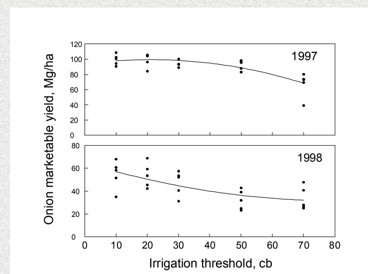

Figure 6. Marketable yield response to irrigation threshold for onions drip-irrigated at 5 thresholds. (Shock et al., 2000).

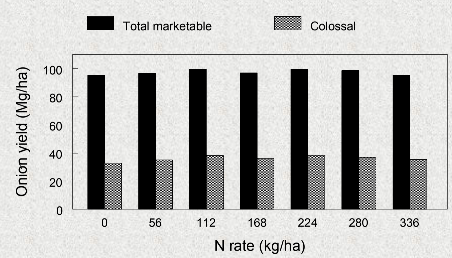

Figure 7. 3-year average Onion yield response to N fertilizer rate. (Shock et al., 2004).

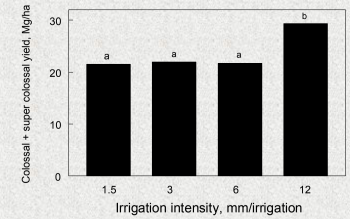

Figure 8. Onion yield response to irrigation intensity. (Shock et al., 2005).

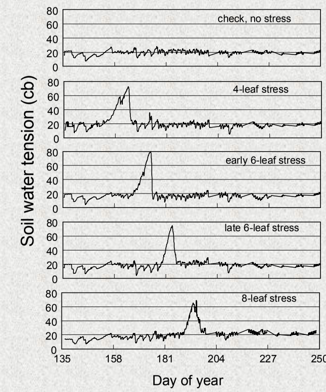

Figure 9. Soil water tension over time for onions submitted to short duration water stress at 5 growth stages. Water stress at the 4-leaf and 6-leaf stages resulted in reductions in bulb single centeredness. (Shock et al., 2007).

References

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