Research Using Automated Irrigation Systems

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Abstract. Starting in 1995, we initiated the use of automatic drip irrigation, based on soil moisture feedback, to address research problems. Soil moisture data to be used for feedback control of drip irrigation has been measured as soil water tension or soil water content. A datalogger checks plots several times a day for soil moisture and irrigates them according to pre-established soil moisture criteria. Using this system, the optimal soil water tension for initiating irrigation for onion and potato were determined. This automation strategy has also been successfully used to determine ideal N fertilizer requirements for drip irrigated onion, to evaluate irrigation intensity and frequency for drip irrigated onion, and to study the effect of the timing of short water stress on onion quality. Starting in 2004, radio telemetry systems were also used to automate irrigations.

Introduction. Soil moisture measurement can provide timely and accurate information to schedule irrigations. Soil moisture can be measured as soil water tension or volumetric soil water content. In the late 1980's the Malheur Experiment Station chose soil water tension as the preferred unit of measurement. Soil water tension can be more closely related to crop productivity than volumetric soil water content, because soil water tension is a direct measurement of the force that plant roots need to exert to exctract water from the soil. Also, soil water tension varies less with minor soil type changes and specific field soil conditions than volumetric soil water content.

Granular matrix sensors (GMS, Watermark Soil Moisture Sensor, Irrometer Co., Riverside, CA) are used in our studies to measure soil water tension. Data from a calibration study was used to modify the equation that converts the electrical resistance reading of the GMS to soil water tension (Shock et al., 1998a). In this study, the GMS electrical resistance was compared to soil water tension readings from tensiometers and to gravimetric soil moisture data in a weighing lysimeter with silt loam soil.

Optimum soil water tension for onion irrigation. Prior to the automation of irrigation systems the optimum soil water tension for furrow irrigated onion was determined testing a range of soil water tensions as setpoints for manually initiating irrigations. The results showed that onion requires frequent irrigations at a soil water tension of 25 cb for maximizing yield and grade (Shock et al., 1998b). Furrow irrigation at 25 cb results in the soil water tension reaching values close to 0 cb (extremely wet, Figure 1).

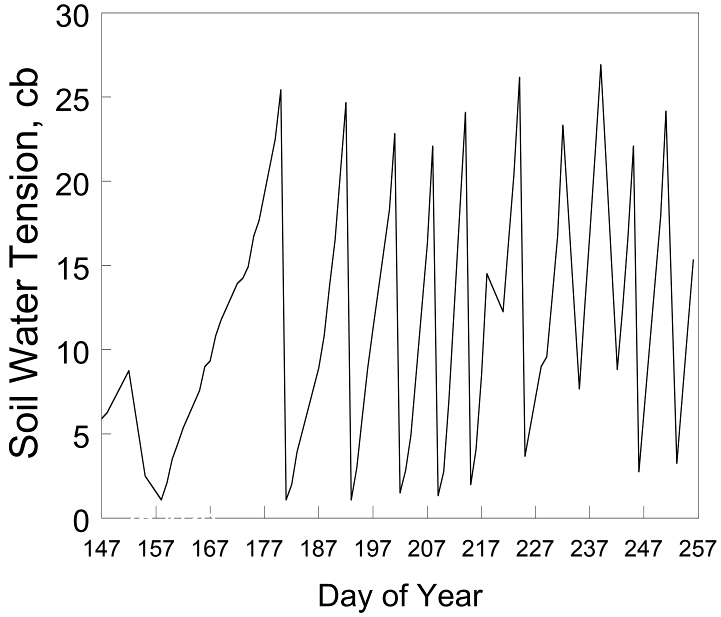

Figure 1. Soil water tension over time for onion furrow irrigated manually at 25 cb.

Frequent furrow irrigations result in nitrate leaching and soil erosion. Drip irrigation can reduce the negative environmental consequences of frequent furrow irrigation and thus has increased in usage. With drip irrigation, the application of small quantities of water at a higher frequency is feasible, thus making irrigation automation feasible and necessary.

In 1997 and 1998, irrigation automation was used to determine the optimum soil water tension for drip-irrigated onion (Shock et al., 2000). Onions were submitted to 5 soil water tension thresholds for automatically initiating drip irrigations (10, 20, 30, 50, and 70 cb). Soil water tension was measured at 8-inch depth below the onion row using GMS. The drip tape was buried at 4-inch depth between the onion rows. The soil water tension was checked by a datalogger reading GMS and the onions were irrigated automatically up to eight times per day if the soil water tension was equal to or exceeded the respective treatment threshold. At each irrigation 0.06 inch of water was applied. The GMS were connected to a datalogger (CR 10 datalogger, Campbell Scientific, Logan, Utah) via multiplexers (AM 416 multiplexer, Campbell Scientific). The irrigations to each plot were controlled by the datalogger through a controller (SDM16 controller, Campbell Scientific) using a solenoid valve. Data was downloaded from the datalogger with a laptop computer or with a SM192 Storage Module (Campbell Scientific) and a CR10KD keyboard display (Campbell Scientific). The datalogger was powered by a solar panel and the controller was powered by 24 V AC. With high frequency automated drip irrigation at 20 cb, the soil water tension remains more constant and does not reach the extremely wet values as with furrow irrigation (Figure 2). With high frequency automated drip irrigation, the amount of water applied over time tracked ET_c (Figure 3). In 1997, the highest marketable yield was achieved at a soil water tension of 21 cb. Marketable yield was lower with higher soil water tension due to increased storage decomposition. In 1998, onion marketable yield was highest with a soil water tension of 10 cb. Storage decomposition was not significant in 1998. Based on this research, a soil water tension threshold of 20 cb is recomended for drip irrigated onion.

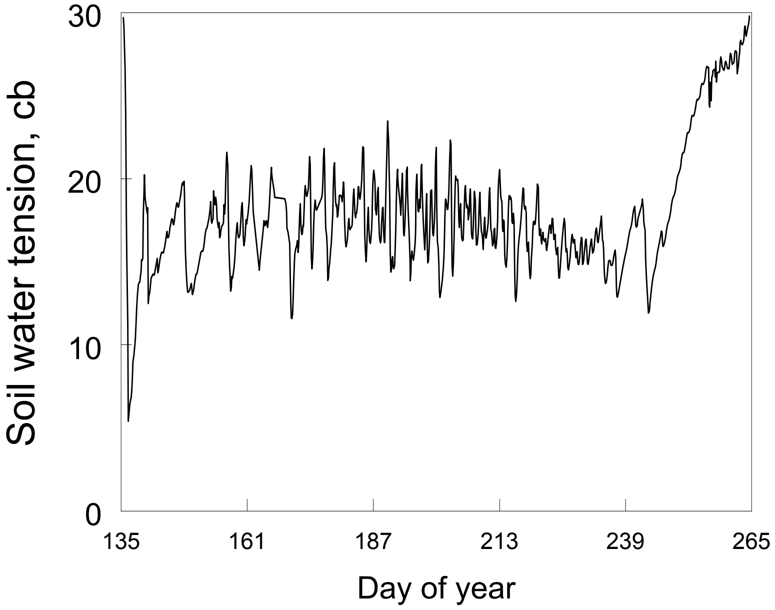

Figure 2. Soil water tension over time for onion drip irrigated automatically at 20 cb.

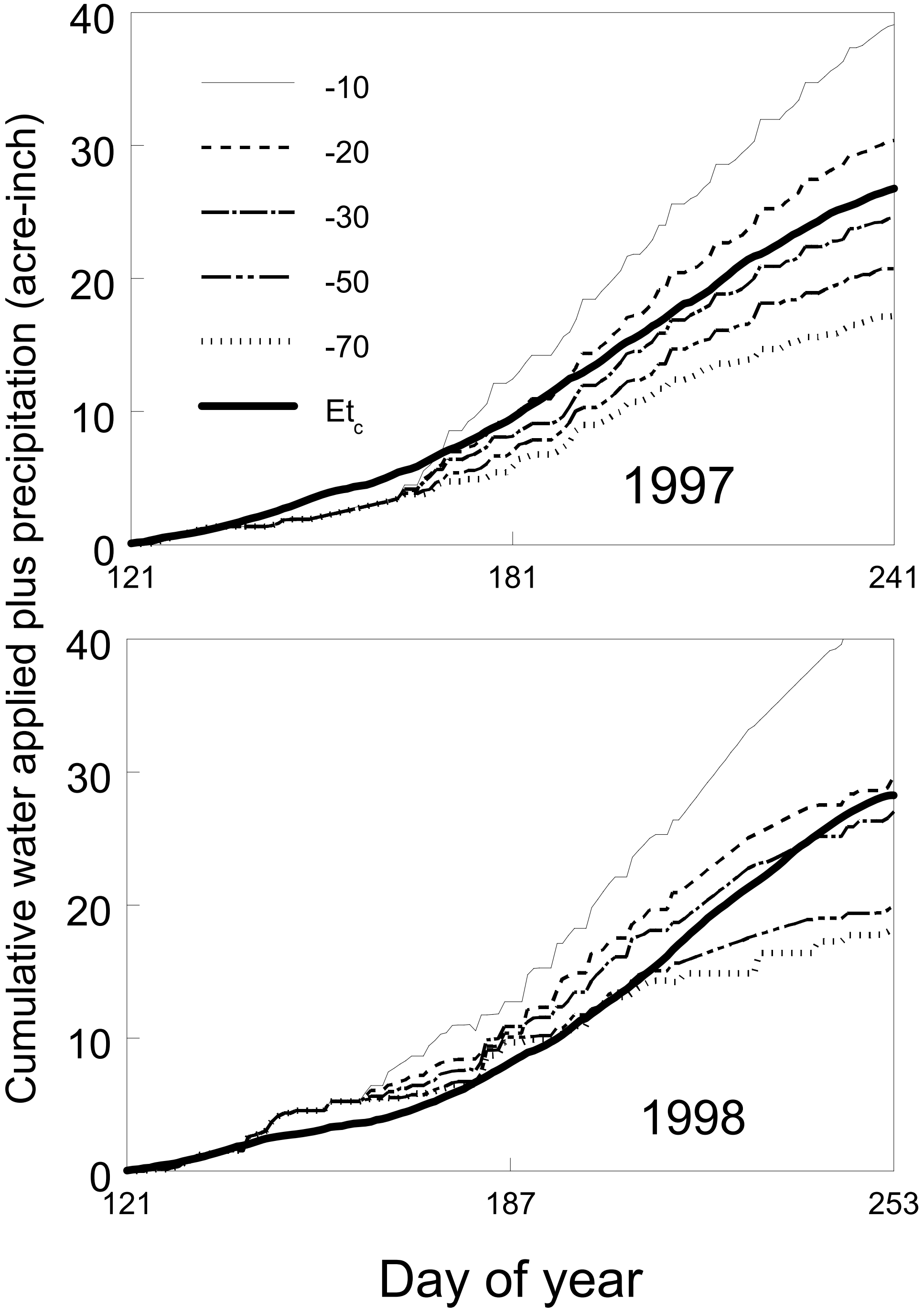

Figure 3. Water applied plus precipitation and ET$_c$ for onion drip irrigated at 5 soil water tensions.

Other research using automated irrigation. The previously described automated drip irrigation system was used to investigate the optimum plant population and N fertilization needs of drip irrigated onion in 1999, 2000, and 2001 (Shock et al., 2004). Each N rate plot had plant populations as subplots. All plots were irrigated automatically, as previously described, at a soil water tension treshold of 20 cb. This research showed that with a carefully managed automated drip irrigation system, onion N fertilizer requirements were very low. With drip irrigation, leaching tension was low and the crop could utilize the substantial amounts of N derived from N mineralization. Onion bulb size distribution was sensitively affected by plant population.

The low intensity, high frequency drip irrigation as used in our earlier drip-irrigated onion research. If applied on a farm scale, low intensity, high frequency drip irrigation might result in large water application disuniformity and inefficiencies, because of water losses from the frequent charging and drainage of the drip irrigation system. In addition, growers might not be able to allocate water nearly continuously to each field, which low intensity irrigation requires. In 2002 and 2003, the same automated drip irrigation system used in 1997 and 1998 was used to determine the influence of irrigation intensities higher than 0.06 inch per irrigation on onion yield and grade (Shock et al., 2005). Onions were submitted to 8 treatments as a combination of 4 irrigation intensities (0.06, 0.12, 0.24, and 0.48 inch per irrigation) and two emitter flow rates. The datalogger was programmed to irrigate each plot automatically and separately according to the 4 irrigation intensities. Irrigation intensities of 0.5 inch per irrigation slighthly increased onion yield and grade above the irrigation intensity of 0.06 inch per irrigation. An irrigation intensity of 0.5 inch did not result in an increase in water applied (Figure 4) nor in any significant difference in average soil water tension (Figure 5). Lowering the emitter flow rate from the currently used of 0.132 gal/hour to 0.066 gal/h resulted in slightly lower onion yield and grade.

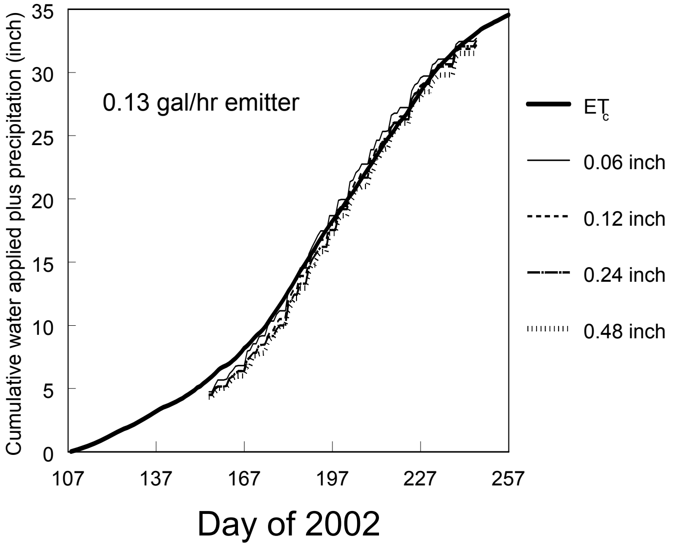

Figure 4. Onion evapotranspiration and total water applied plus precipitation over time for two drip emitter flow rates and four drip irrigation intensities in 2002.

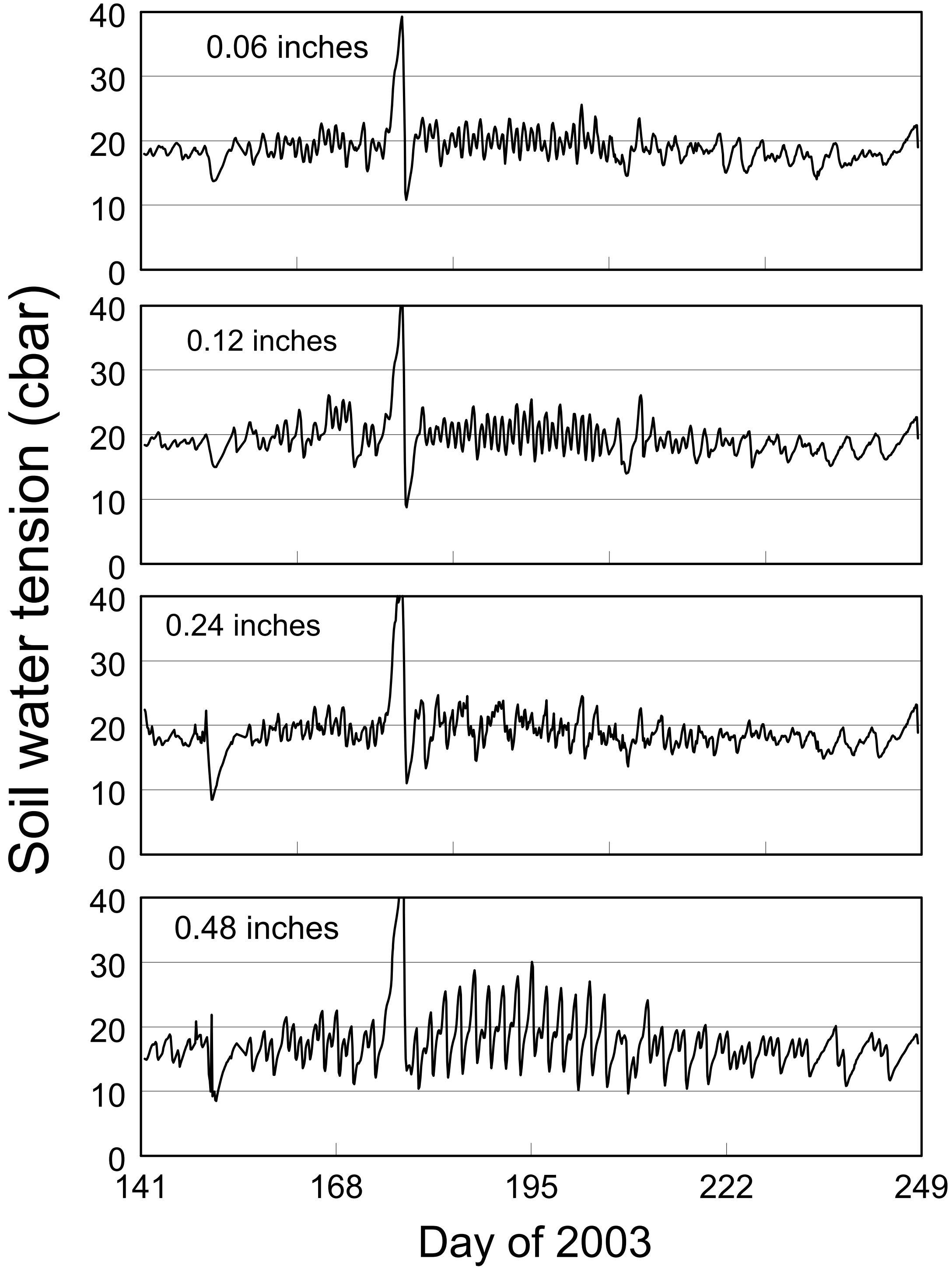

Figure 5. Soil water tension at 8-inch depth over time in 2003 for onions drip irrigated at four intensities with an emitter flow rate of 0.13 gal/h.

In 2000 and 2001, research with potato was conducted to determine the optimum soil water tension and drip tape placement for drip-irrigated potato (Shock et al., 2002). The previously described automated drip irrigation system (Shock et al., 2000) was used to submit potato to 4 soil water tension thresholds for initiating drip irrigations (15, 30, 45, and 60 cb) and two drip tape placements (one tape per row or one tape per two rows). The plots were irrigated automatically up to 4 times per day applying 0.1 inch of water per irrigation whenever the soil water tension reached the treatment level. The results showed that drip irrigated potato on silt loam should be irrigated at a soil water tension of 30 cb using one tape per row.

Test of commercial automatic irrigation systems. In 2004 and 2005, 3 commercial automatic irrigation systems were compared to the currently used Campbell Scientific system for onion. Each system was replicated three times. The datalogger for each system was programmed to make irrigation decisions every 12 hours: zones were irrigated for eight hours (0.5 inch of water) if the soil water tension exceeded 20 cb.

Campbell Scientific. This system was similar to that used above (Shock et al., 2000) using a soil water tension irrigation criterion of 20 cb.

Automata. Each one of the three zones had four GMS connected to a datalogger (Mini Field Station, Automata, Inc., Nevada City, CA). The dataloggers at each zone were connected to a controller (Mini-P Field Station, Automata) at the field edge by an internal radio. The controllers (Mini-P Field Station, Automata) at the field edge were connected to a base station (Mini-P Base Station, Automata) in the office by radio. The base station was connected to a desktop computer. Each zone was irrigated individually using a solenoid valve. The solenoid valves were connected to and controlled by the controller. The desktop computer ran the software that monitored the soil moisture in each zone and made the irrigation decisions. The Mini Field stations were powered by solar panels and the Mini-P Field station was powered by 120 V AC.

Watermark Monitor. Irrometer manufactures the Watermark Monitor datalogger which can record data from seven GMS and one temperature probe. The soil temperature is used to adjust the soil water tension calibrations. Each of the three Watermark Monitor zones had seven GMS connected to a Watermark Monitor. Data was downloaded from the Watermark Monitor with a laptop computer. The Watermark Monitors were powered by solar panels. Irrigation decisions were made daily by reading the GMS at each Watermark Monitor. When the soil water tension reached 20 cb the zone was irrigated manually for eight hours. This system only had an automatic recording system.

Acclima. Acclima (Meridian, ID) manufactures a Digital TDT™ that measures volumetric soil moisture content. Each zone had one TDT sensor and four GMS. The GMS were only used for comparison and were not used in irrigation automation. The TDT sensors were connected to a model CS3500 controller (Acclima) at the field edge. The controller monitored the soil water content and used the soil water content data to control the irrigations for each zone separately using solenoid valves. The controller was powered by 120 V AC. To monitor what the controller was doing, data was downloaded from the controller using a laptop computer. For comparison and calibration, the GMS were connected to the Campbell Scientific datalogger which monitored the soil water tension as described above. The CS3500 controller was programmed to irrigate the zone when the volumetric soil water content was equal to or lower than 27%. The soil water tension data was compared to the volumetric soil water content data to adjust the CS3500 controller to irrigate each zone in a manner equivalent to the irrigation scheduling using the GMS.

All of these systems produced high quality onions at yields considerably above normal commercial expectations.

Expansion of Drip Irrigation

Automated drip irrigation research has facilitated the reliable and reproduceable field results. Irrigation criteria, how to reduce N applications, ideal plant populations, and irrigation rates and frequencies have been carefully determined. These findings have encouraged the adoption of drip irrigation systems and helped growers understand how to manage their systems.

Conclusion

Automated irrigation of water sensitive crops such as potato and onion controlled by data loggers holds the promise of determining irrigation criteria that optimize yield or quality under the constraint of conserving water and minimizing off site contamination through irrigation runoff or nutrient leaching. Automated drip irrigation research has facilitated the development of efficient management guidelines that have aided the expansion of drip irrigation managemnet. Computer programs written for data loggers can be effective research tools in establishing and maintaining small differences in irrigation treatments and closely matching crop water needs to water applied.

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