AUTOMATIC COLLECTION, RADIO TRANSMISSION, AND USE OF SOIL WATER DATA

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Abstract

Precise scheduling of drip irrigation has become very important to help assure optimum drip-irrigated crop yield and quality. Soil moisture sensors have often been adopted to assure irrigation management. Integrated systems for using soil moisture data could enhance widespread applicability. An ideal system would include the equipment to monitor field conditions, radios to transmit the information from the field because wires impede cultivation and can complicate cultural practices, interpretation of soil water status, and the equipment to automatically control irrigation systems.
Key words**:** automation, irrigation scheduling, onion, *Allium cepa*

Introduction

Onions (*Allium cepa*) require frequent irrigations to maintain high soil moisture. Drip irrigation has become popular for onion production because a higher soil moisture can be maintained without the negative effects associated with furrow irrigation. Drip irrigation can also be automated. Automated drip irrigation of onions has been used for irrigation management research at the Malheur Experiment Station since 1995 (Feibert et al., 1996; Shock et al., 1996, 2002). In addition the extensive wiring impedes cultivation and can complicate cultural practices. Several companies manufacture automated irrigation systems designed for commercial use that use radio telemetry, reducing the need for wiring. This trial tested three commercial soil moisture monitoring systems and compared their irrigation on onion performance to the research system based on Campbell Scientific (Logan, UT) components currently used (Shock et al., 2002).

Material and Methods

The onions were grown at the Malheur Experiment Station, Ontario, OR on an Owyhee silt loam previously planted to wheat. Onion (cv. Vaquero, Nunhems, Parma, ID) was planted in 2 double rows, spaced 22 inches apart (center of double row to center of double row) on 44-in beds on March 17, 2004. The two rows in the double row were spaced 3 inches apart. Onion was planted at 150,000 seeds/acre. Drip tape (T-tape, T-systems international, San Diego, CA) was laid at 4-in depth between the two double onion rows at the same time as planting. The distance between the tape and the center of the double row was 11 inches. The drip tape had emitters spaced 12 inches apart and a flow rate of 0.22 gal. per min. per 100 feet.

Onion emergence started on April 2. The trial was irrigated with a minisprinkler system (R10 Turbo Rotator, Nelson Irrigation Corp., Walla Walla, WA) for even stand establishment. Risers were spaced 25 ft apart along the flexible polyethylene hose laterals which were spaced 30 ft apart.

Weed and insect control practices were similar to typical crop production standards and fertilizer applications were similar to common practices and followed the recommendations of Sullivan et al. (2001).

The experimental design was a randomized complete block with three replicates. Each irrigation system was tested in three zones that were 16 rows by 50 feet long. There were four automated irrigation systems tested. Each integrated system contained several distinctive parts, some automated and some requiring human input: soil moisture monitoring, data transmission from the field, collection of the data, interpretation of the date, decisions to irrigate, and control of the irrigation. Additionally, all data was downloaded for evaluation of the system.

Campbell Scientific. The system currently used for research at the Malheur Experiment Station uses a Campbell Scientific Inc. (Logan UT) datalogger (CR10X). Each zone had four granular matrix sensors (GMS, Watermark Soil Moisture Sensor Model 200SS, Irrometer Co. Inc., Riverside, CA) used to measure soil water potential (Shock, 2003). The GMS from all three zones were connected to a AM416 multiplexer (Campbell Scientific) which in turn was connected to the datalogger at the field edge. The soil temperature was also monitored and was used to correct the soil water potential calibrations (Shock et al., 1998). The datalogger was programmed to monitor the soil moisture and controlled the irrigations for each zone individually. The Campbell Scientific datalogger was programmed to make irrigation decisions every 12 hours: zones were irrigated for eight hours if the soil water potential threshold was exceeded. The Campbell Scientific datalogger used an average soil water potential at 8-inch depth of -20 kPa or less as the irrigation threshold. The datalogger controlled the irrigations using a SDM16 controller (Campbell Scientific) to which the solenoid valves at each zone were connected. 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. The Campbell Scientific system was started on May 15.

Automata. Automata, Inc. (Nevada City, CA) manufactures dataloggers, controllers, and software for data acquisition and process control. Each one of the three zones had four GMS connected to a datalogger (Mini Field Station, Automata). 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 every 12 hours: zones were irrigated for eight hours if the soil water potential threshold was exceeded. The irrigation threshold was the average soil water potential at 8-inch depth of -20 kPa or less. The Mini Field stations were powered by solar panels and the Mini-P Field station was powered by 120 V AC. The Automata system was started on June 24.

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 correct the soil water potential calibrations. Each of the three Watermark Monitor zones each 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 potential reached -20 kPa the zone was irrigated manually for eight hours. The Watermark Monitors were started on May 15.

Acclima. Acclima (Meridian, ID) manufactures a Digital TDT™ that measures volumetric soil moisture content. Each zone had one TDT sensor and four GMS. The TDT sensors were connected to a model CS3500 controller (Acclima) at the field edge. The controller monitored the soil moisture and controlled the irrigations for each zone separately using solenoid valves. The controller was powered by 120 V AC. 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 potential as described above. The Acclima system was started on May 16. 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 potential 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. Due to excessive soil moisture, on June 11 the lower threshold at which irrigations were started was changed from 27% to 19%, and 21% for Acclima zones one and two, respectively, to correspond to -20 kPa soil water potential. When installed, due to a software constraints, the controller could only water a maximum of four hours at each irrigation. On July 21 the software was upgraded allowing irrigation durations to be increased to 8 hours. Given the flow rate of the drip tape, 8 hour irrigations applied 0.48 inches of water. Previous research indicates that the ideal amount of water to apply at each irrigation is 0.5 inches (Shock et al., 2004).

All soil moisture sensors in every zone of the four systems were installed at 8-inch depth in the center of the double onion row. The GMS were calibrated to SWP (Shock et al. 1998). The Campbell Scientific, Acclima, and Automata controllers were programmed to make irrigation decisions every 12 hours: zones were irrigated for eight hours if the soil moisture threshold was exceeded. The Campbell Scientific and Automata dataloggers used an average soil water potential at 8-inch depth of -20 kPa or less as the irrigation threshold. The Irrometer zones also had a threshold of -20 kPa. The amount of water applied to each plot was recorded daily at 8:00 a.m. from a water meter installed downstream of the solenoid valve. The total amount of water applied included sprinkler irrigations applied after emergence and water applied with the drip irrigation system from emergence through the final irrigation.

Onion evapotranspiration (ET_c) was calculated with a modified Penman equation (Wright 1982) using data collected at the Malheur Experiment Station by an AgriMet weather station (U.S. Bureau of Reclamation, Boise, Idaho). Onion Et_c was estimated and recorded from crop emergence until the final irrigation on September 2.

On September 24 the onions were lifted to field cure. On September 27, onions in the central 40 ft of the middle four double rows in each zone were topped and bagged. On September 28 the onions were graded. Bulbs were separated according to quality: bulbs without blemishes (No. 1s), double bulbs (No. 2s), neck rot (bulbs infected with the fungus *Botrytis allii* in the neck or side), plate rot (bulbs infected with the fungus *Fusarium oxysporum*), and black mold (bulbs infected with the fungus *Aspergillus niger*). The No. 1 bulbs were graded according to diameter: small (< 2¼ inch), medium (2¼ to 3 inch), jumbo (3 to 4 inch), colossal (4 to 4¼ inch), and supercolossal (>4¼ inch). Bulb counts per 50 lb of supercolossal onions were determined for each zone of every variety by weighing and counting all supercolossal bulbs during grading.

Differences in onion performance and water application among irrigation systems were determined by protected least significant differences at the 95 percent confidence level using analysis of variance (NCSS 97, Statistical System for Windows, Hintze, 2000).

Results and Discussion

Marketable onion yield was excellent, averaging 1041 cwt/acre (116.6 Mg/ha) over the four drip irrigation systems (Table 1). The average onion bulb yield in the Treasure Valley was 625 cwt/acre (70.0 Mg/ha) in 2000, 630 cwt/acre (70.6 Mg/ha) in 2001, and 645 cwt/acre (72.2 Mg/ha) in 2002 (USDA, 2003). The excellent onion performance with all the systems used was consistent with the maintenance of soil water potential within the narrow range required by onion (Shock et al., 1998, 2000).

A comparison of the systems in terms of onion yield and grade is not completely justified, because the systems were started at different times. In addition, the Acclima and Automata systems required adjustments and modifications after the start of operation.

The Acclima system resulted in among the lowest marketable yield and yield of colossal bulbs. The Acclima system maintained the soil very wet at the beginning of the season due to our lack of knowledge of the appropriate volumetric soil water content that corresponded to ideal soil water potential (Figures 1 and 2). After changes were made to the irrigation threshold for each Acclima zone separately, the soil volumetric water content (Figure 2) was very stable with some seasonal deviations from the target soil water potential of -20 kPa (Figure 1). Due to initial software limitations the Acclima system had irrigation durations of 4 hours until July 21. After July 21 the software was upgraded and the irrigation durations were increased to 8 hours. Irrigation durations of less than 8 hours have been shown to reduce onion yield (Shock et al., 2004). Also early heavy irrigation could have leached nitrate needed for optimal onion growth.

The Campbell Scientific and Automata maintained the soil water potential relatively constant and close to the target of -20 kPa (Figures 3 and 4). The Irrometer Watermark Monitors maintained the soil water potential on target, but with larger oscillations than the other systems, due to the human collection of the SWP and human control of irrigation onset and duration (Figure 5).

Water applications over time followed ET_c during the season (Figure 6). The total water applied plus precipitation from emergence to the end of irrigation on September 2 was 31.5, 40.0, 43.9, and 36.2 inches (800, 1016, 1115, and 919 mm) for the Campbell Scientific, Irrometer, Automata, and Acclima systems, respectively. Precipitation from onion emergence until irrigation ended on September 2 was 3.88 inches (99 mm). Onion evapotranspiration for the season totaled 30.9 inches (785 mm) from emergence to the last irrigation. The Automata system used a new version of their software that had initial bugs to work out. The Acclima system over applied water when first installed until the irrigation thresholds were adjusted downwards.

Conclusions

All the systems tested performed well in this preliminary evaluation. Onion yield, grade, and quality were excellent. Any small shortcomings in precise irrigation may have been due to our unfamiliarity and inexperience using these systems.

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Table 1. Onion yield and grade for a drip irrigated onion field irrigated automatically by four systems. Oregon State University Malheur Experiment Station, Ontario, OR 2004.

System	Total yield	Marketable yield by grade: Total	>4¼ in	4-4¼ in	3-4 in	2¼-3 in	Super colossal counts	Nonmarketable yield: Total rot	No. 2s	Small
	------------------------- cwt/acre --------------------------						#/50 lb	% of total yield	-- cwt/acre --	
Campbell Sci.	1035.9	1026.1	21.4	258.5	727.4	18.8	42.6	0.5	1.3	3.1
Irrometer	1081.4	1076.1	36.2	337.2	685.6	17.1	39.5	0.2	0.0	3.4
Automata	1072.4	1064.0	18.2	306.0	724.6	15.2	41.8	0.4	1.5	2.2
Acclima	1008.4	997.9	15.7	215.2	746.4	20.6	47.9	0.3	3.7	4.2
Average	1049.5	1041.0	22.9	279.2	721.0	17.9	43.0	0.3	1.6	3.2
LSD (0.05)	51.2	52.0	NS	86.5	NS	NS	NS	NS	NS	NS
	------------------------- Mg/ha --------------------------						#/50 lb	% of total yield	-- Mg/ha --	
Campbell Sci.	116.0	114.9	2.4	29.0	81.5	2.1	42.6	0.5	0.2	0.4
Irrometer	121.1	120.5	4.1	37.8	76.8	1.9	39.5	0.2	0.0	0.4
Automata	120.1	119.2	2.0	34.3	81.2	1.7	41.8	0.4	0.2	0.3
Acclima	112.9	111.8	1.8	24.1	83.6	2.3	47.9	0.3	0.4	0.5
Average	117.5	116.6	2.6	31.3	80.8	2.0	43.0	0.3	0.2	0.4
LSD (0.05)	5.7	5.8	NS	9.7	NS	NS	NS	NS	NS	NS

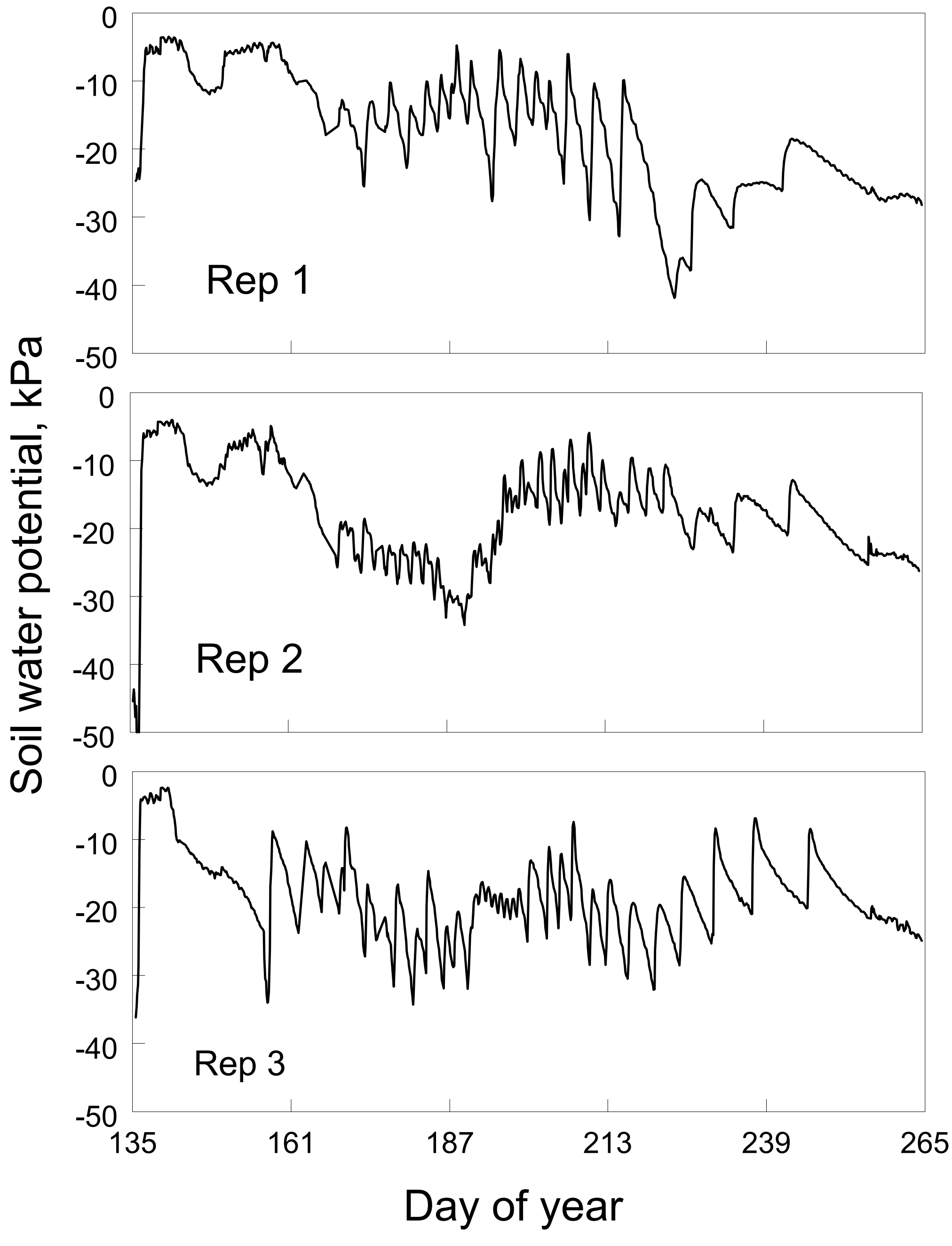

Figure 1. Soil water potential at 8-inch depth for a drip-irrigated onion field using the Acclima automated irrigation system with three irrigation thresholds. Oregon State University Malheur Experiment Station, Ontario, OR 2004.

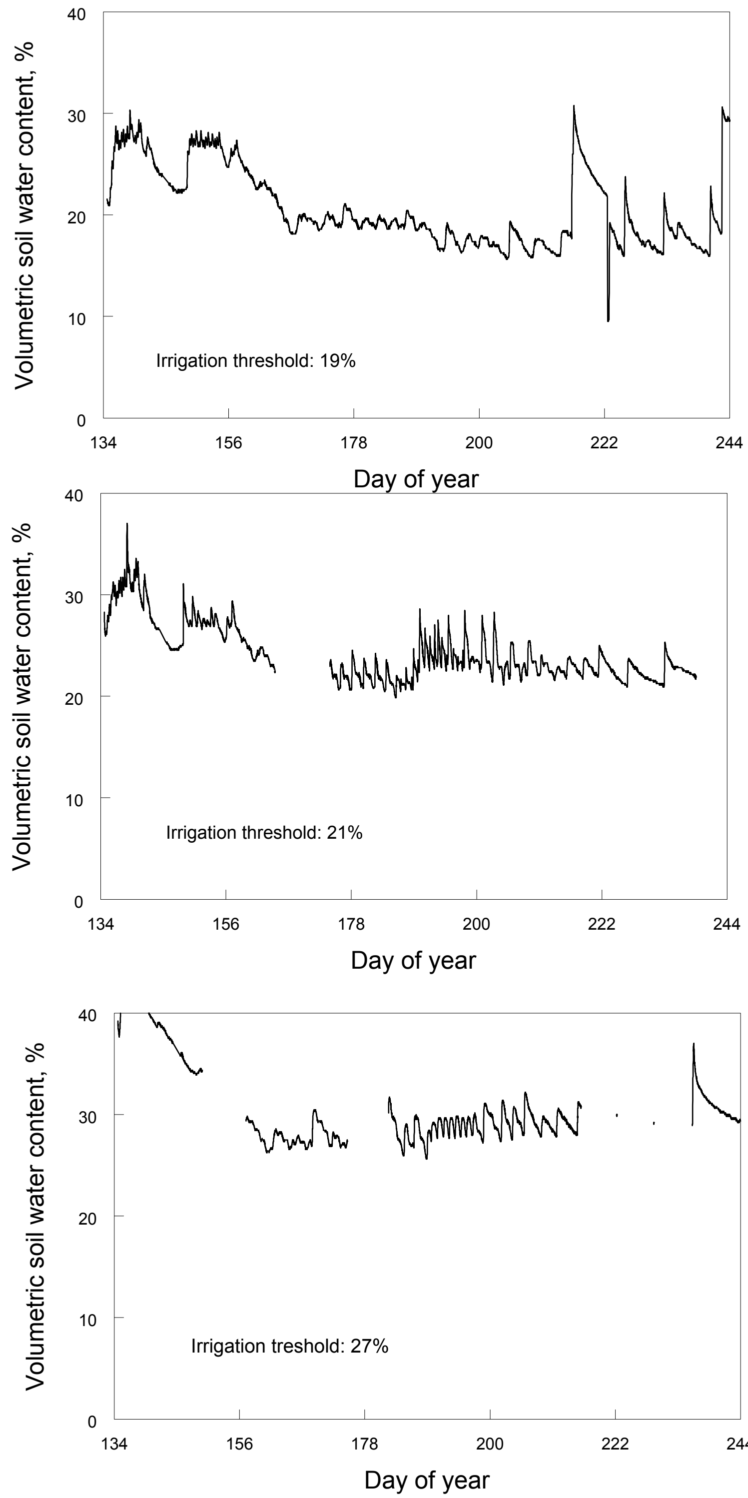

Figure 2. Volumetric soil water content at 8-inch depth for a drip-irrigated onion field using the Acclima irrigation system with three soil water content irrigation thresholds (19, 21, and 27%). Oregon State Univ., Malheur Experiment Station, Ontario, OR 2004.

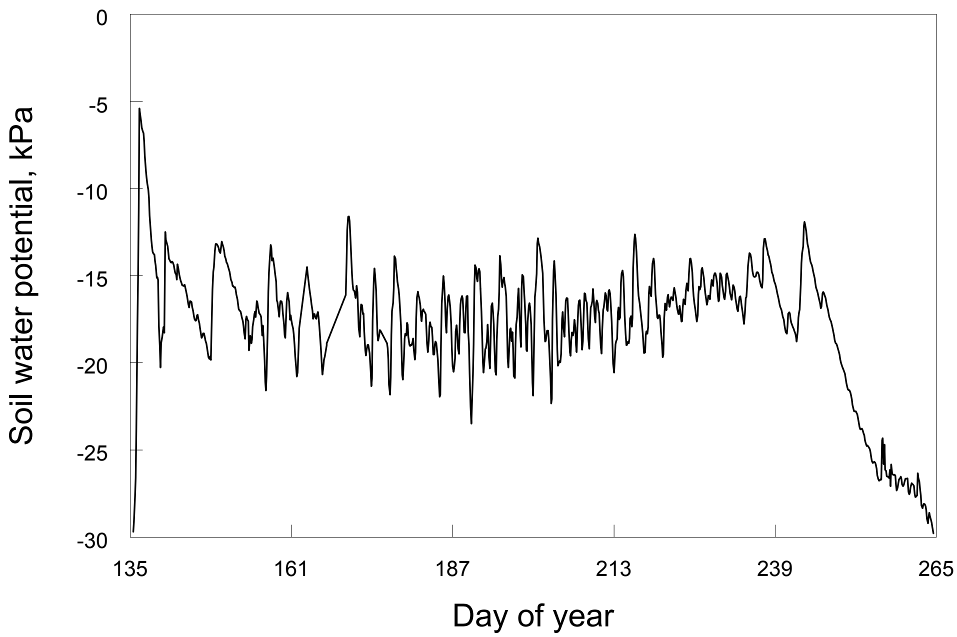

Figure 3. Soil water potential at 8-inch depth for a drip-irrigated onion field using the Campbell Scientific automated irrigation system. Oregon State University Malheur Experiment Station, Ontario, OR 2004.

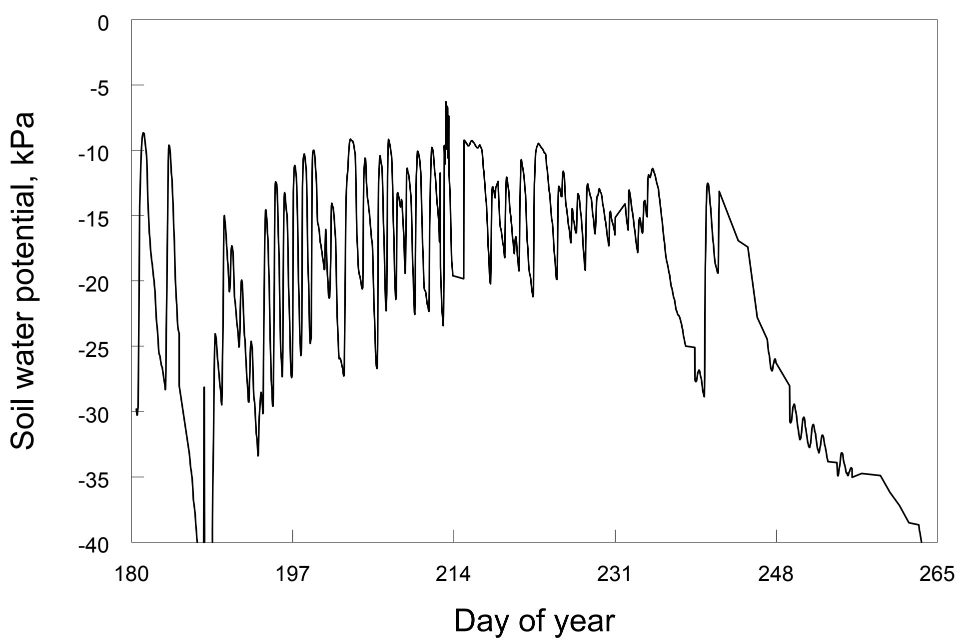

Figure 4. Soil water potential at 8-inch depth for a drip-irrigated onion field using the Automata automated irrigation system. Oregon State University Malheur Experiment Station, Ontario, OR 2004.

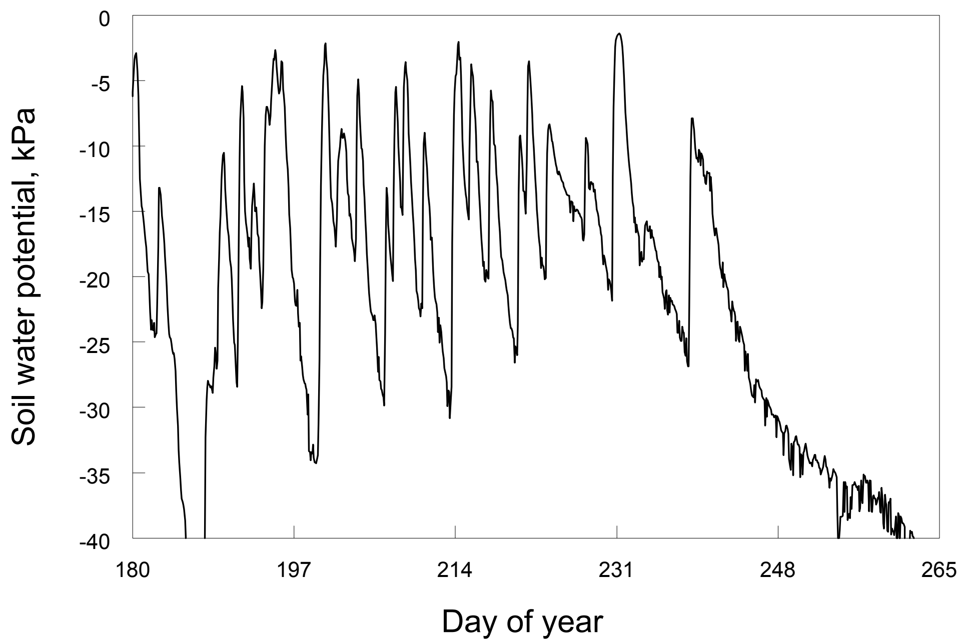

Figure 5. Soil water potential at 8-inch depth for a drip-irrigated onion field using the Irrometer Monitor. Oregon State University Malheur Experiment Station, Ontario, OR 2004.

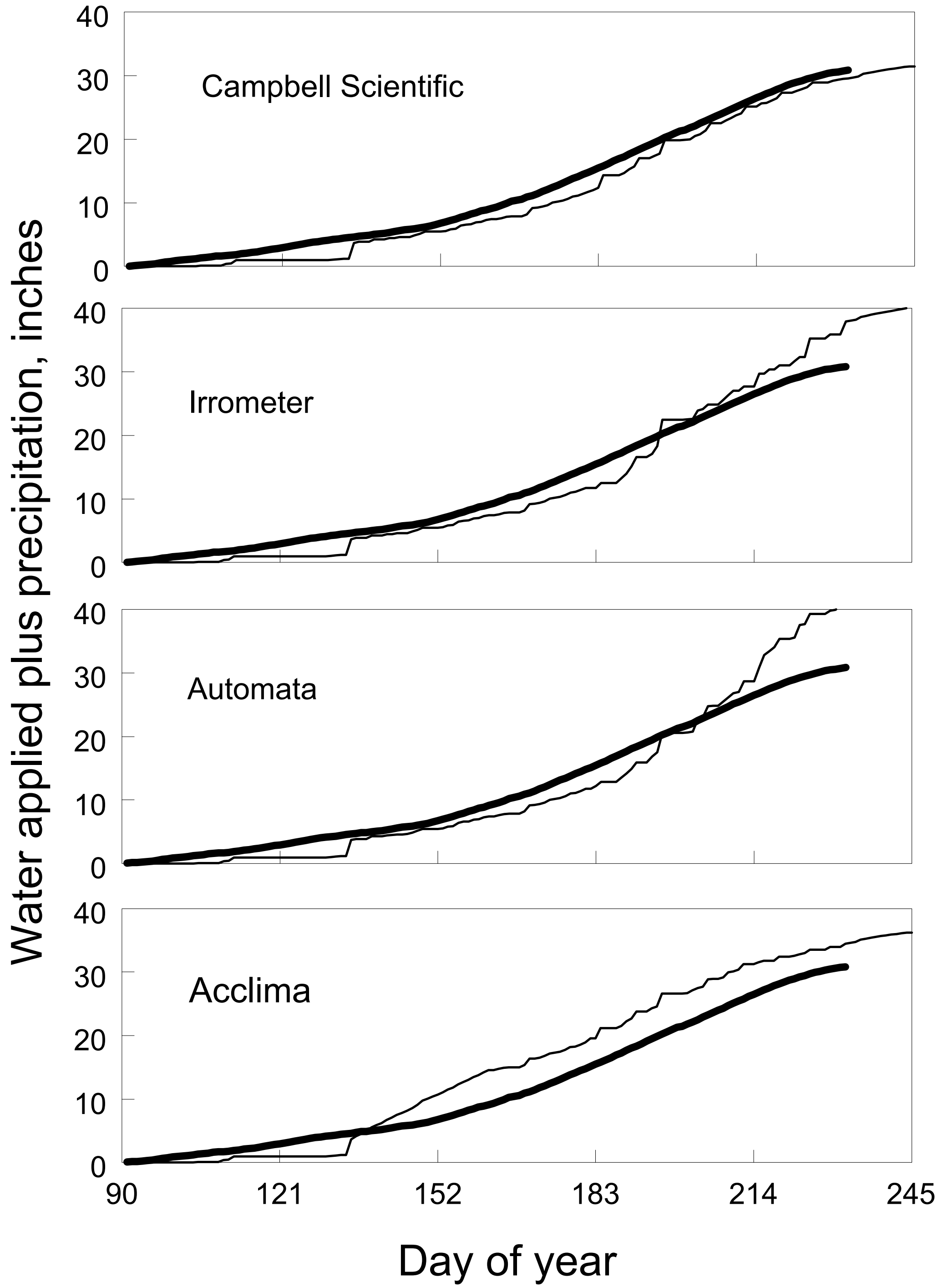

Figure 6. Water applied plus precipitation over time for drip-irrigated onions with four automated irrigation systems. Thin line is water applied and thick line is ET_c. Oregon State University Malheur Experiment Station, Ontario, OR 2004.