AUTOMATIC COLLECTION, RADIO TRANSMISSION, AND USE OF SOIL WATER DATA[1]

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Abstract

Precise scheduling of drip irrigation has become very important to help assure optimum crop yield and quality. Soil moisture sensors have often been adopted to assure irrigation management. Integrated systems that use soil moisture data for irrigation management could enhance widespread applicability of soil moisture-based irrigation management. An ideal system would include the equipment to monitor field conditions, radios to transmit the information from the field, interpretation of soil water status, and the equipment to automatically control irrigation systems. Radio transmission of data would be advantageous because wires impede cultivation and complicate cultural practices.

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). However, 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 performance to the research system based on Campbell Scientific (Logan, UT) components currently used (Shock et al. 2002).

Materials and Methods

The onions were grown at the Malheur Experiment Station (MES), Ontario, Oregon, 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

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to center of double row) on 44-inch beds on March 16, 2005. The 2 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-inch depth between the 2 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/min/100 ft.

Onion emergence started on April 17. 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 that 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 3 zones that were 8 rows wide by 50 ft long. There were four automated irrigation systems tested. Each integrated system contained several distinctive parts, some completely automated and some requiring manual input: soil moisture monitoring, data transmission from the field, collection of the data, interpretation of the data, decisions to irrigate, and control of the irrigation. All data were downloaded for evaluation of the system.

Campbell Scientific

The system currently used for research at MES 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 (SWP) (Shock 2003). The GMS from all three zones were connected to an 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 SWP calibrations (Shock et al. 1998a). 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 8 hours if the SWP threshold was exceeded. The Campbell Scientific datalogger used an average SWP at 8-inch depth of -20 kPa or less as the irrigation threshold (Shock et al. 1998b, 2000). The datalogger controlled the irrigations using an SDM16 controller (Campbell Scientific) to which the solenoid valves at each zone were connected. The datalogger was powered by a solar panel and the controller was powered by 24 V AC. Data were downloaded from the datalogger with a laptop computer or with an SM192 Storage Module (Campbell Scientific) and a CR10KD keyboard display (Campbell Scientific).

Automata

Each one of the three zones in the Automata system (Automata, Inc., Nevada City, CA) 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 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, which was 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 8 hours if the SWP threshold was exceeded. The irrigation threshold was the average SWP 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.

Watermark Monitor

Irrometer manufactures the Watermark Monitor datalogger that can record data from seven GMS and one temperature probe. The soil temperature is used to correct the SWP calibrations. Each of the three Watermark Monitor zones had seven GMS connected to a Watermark Monitor. Data were downloaded from the Watermark Monitor both by radio and with a laptop computer. The Watermark Monitors were powered by solar panels. Irrigation decisions were made daily by reading the GMS data from each Watermark Monitor. When the SWP reached -20 kPa the zone was irrigated manually for 8 hours.

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 were downloaded from the controller using a laptop computer. For comparison and calibration, the GMS were connected to the Campbell Scientific datalogger, which monitored the SWP as described above. The CS3500 controller was programmed to irrigate the zone when the volumetric soil water content was equal to or lower than a preset value. The SWP data were 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 at -20 kPa (Fig. 1).

All Systems

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. 1998a). The Campbell Scientific, Acclima, and Automata controllers were programmed to make irrigation decisions every 12 hours. Zones were irrigated for 8 hours if the soil moisture threshold in that zone was exceeded. The Campbell Scientific and Automata dataloggers used an average SWP 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 MES by an AgriMet weather station (U.S. Bureau of Reclamation, Boise, ID). Onion ET_c was estimated and recorded from crop emergence until the onions were lifted on September 12.

On September 12 the onions were lifted to field cure. On September 19, onions in the central 40 ft of the middle 4 double rows in each zone were topped and bagged. On October 3 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 (2¼-3 inch), jumbo (3-4 inch), colossal (4-4¼ 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 (Hintze 2000).

Results and Discussion

All systems maintained the SWP close to the target of -20 kPa (Figures 2 and 4). The Campbell Scientific system had the smallest amplitude of oscillation of SWP around -20 kPa compared to the other systems. The Automata system had wide oscillations in SWP compared to the Campbell Scientific system. The Automata system had impaired communication between the office computer and the field datalogger, hindering the irrigation automation. The impaired communication of the Automata system may have been caused by interference from other automated communication systems being tested concurrently.

Marketable onion yield in 2005 was lower than in 2004 for all systems, averaging 751 cwt/acre over the 4 drip irrigation systems, compared to the average of 1,041 cwt/acre in 2004 (Table 1). Factors possibly causing the lower yield in 2005 were spring bedded ground, lack of fumigation, slower seed emergence, delayed weed control due to excessive rain in May, heavy thrips pressure, and the presence of iris yellow spot virus. Due to excessive rain in the fall of 2004, the field work was delayed until early March of 2005. Fall bedding results in better soil tilth than spring bedding. In addition, spring field work precluded soil fumigation, leaving the onions more vulnerable to soil borne diseases. Onions took 32 days to emerge in 2005 compared to the previous 8-year average of 17 days for drip-irrigated onions at the MES. Despite planting occurring a day earlier in 2005 than in 2004, emergence in 2005 started 15 days later than in 2004.

Excessive rain in late April and May delayed weed control, resulting in excessive weed competition during a period of intense onion vegetative growth.

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 system required adjustments after the start of operation.

The Irrometer system resulted in the lowest colossal bulb yield and the highest medium bulb yield in 2005, possibly due to human collection of the SWP data and human control of irrigation onset and duration. There was no significant difference in yield or grade between the other systems.

Water applications over time followed ET_c during the season (Fig. 5). Total amounts of water applied were substantially higher than ET_c for all systems except the Irrometer system. The higher amounts of water applied in 2005 than in 2004 could be related to the lower saturated hydraulic conductivity of the soil in 2005. A lower saturated hydraulic conductivity would result in more water being necessary to maintain the sensors wet. The total water applied plus precipitation from emergence to the end of irrigation on September 5 was 48.2, 32.6, 45.3, and 57.6 inches for the Campbell Scientific, Irrometer, Acclima, and Automata systems, respectively. Precipitation from onion emergence until irrigation ended on September 5 was 4.8 inches. Total Et_c for the season was 35.0 inches from emergence to lifting.

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Table 1. Onion yield and grade for a drip-irrigated onion field irrigated using four soil moisture monitoring and control systems, Oregon State University, Malheur Experiment Station, Ontario, OR, 2004 and 2005.

System	Total yield	Marketable yield by grade					Super-colossal counts	No. 2s	Small
		Total	>4¼ in	4-4¼ in	3-4 in	2¼-3 in			
	cwt/acre						#/50 lb	cwt/acre	
				2004					
Campbell Sci.	1,035.9	1,026.1	21.4	258.5	727.4	18.8	42.6	1.3	3.1
Acclima	1,008.4	997.9	15.7	215.2	746.4	20.6	47.9	3.7	4.2
Automata	1,072.4	1,064.0	18.2	306.0	724.6	15.2	41.8	1.5	2.2
Irrometer	1,081.4	1,076.1	36.2	337.2	685.6	17.1	39.5	0.0	3.4
Average	1,049.5	1,041.0	22.9	279.2	721.0	17.9	43.0	1.6	3.2
LSD (0.05)	51.2	52.0	NS	86.5	NS	NS	NS	NS	NS
				2005					
Campbell Sci.	782.1	777.7	0.7	100.1	654.9	22.0	11.1	0.5	4.0
Acclima	798.7	793.6	0.0	96.6	669.3	27.6	0.0	0.4	4.7
Automata	767.4	762.0	1.5	84.7	647.0	28.8	23.1	0.2	5.2
Irrometer	657.2	648.8	0.0	14.5	570.7	63.7	0.0	0.0	8.4
Average	751.4	745.5	0.6	74.0	635.5	35.5	8.6	0.3	5.6
LSD (0.05)	NS	NS	NS	47.7	NS	26.1	NS	NS	NS
				Average					
Campbell Sci.	909.0	901.9	11.1	179.3	691.1	20.4	26.9	0.9	3.5
Acclima	935.5	928.8	9.1	201.3	697.0	21.4	20.9	0.9	3.5
Automata	887.9	880.0	8.6	149.9	696.7	24.7	35.5	2.0	4.7
Irrometer	869.3	862.5	18.1	175.8	628.1	40.4	19.8	0.0	5.9

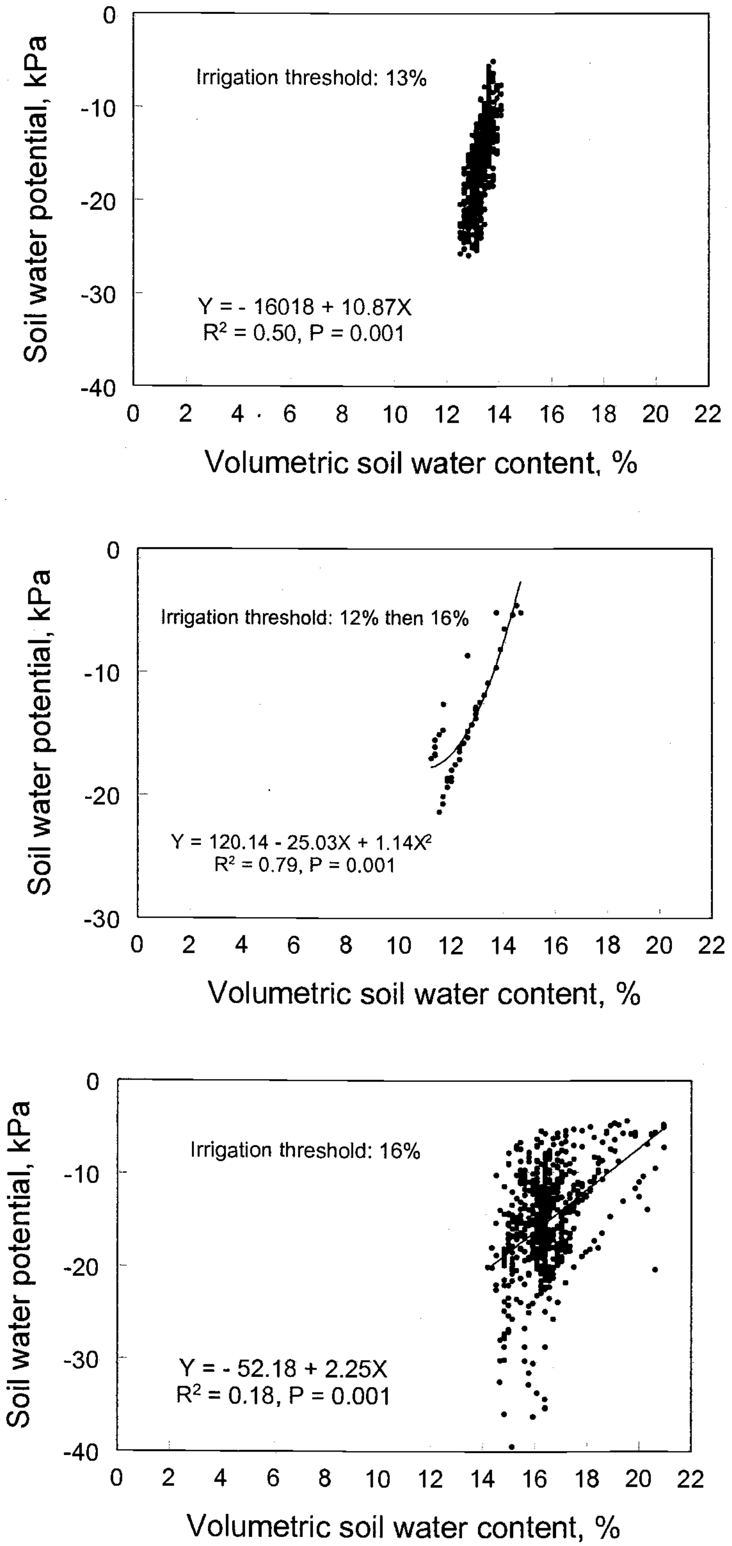

Figure 1. Regressions of volumetric soil water content from Acclima TDT sensors against soil water potential from Watermark soil moisture sensors for each Acclima plot. Malheur Experiment Station, Oregon State University, Ontario OR.

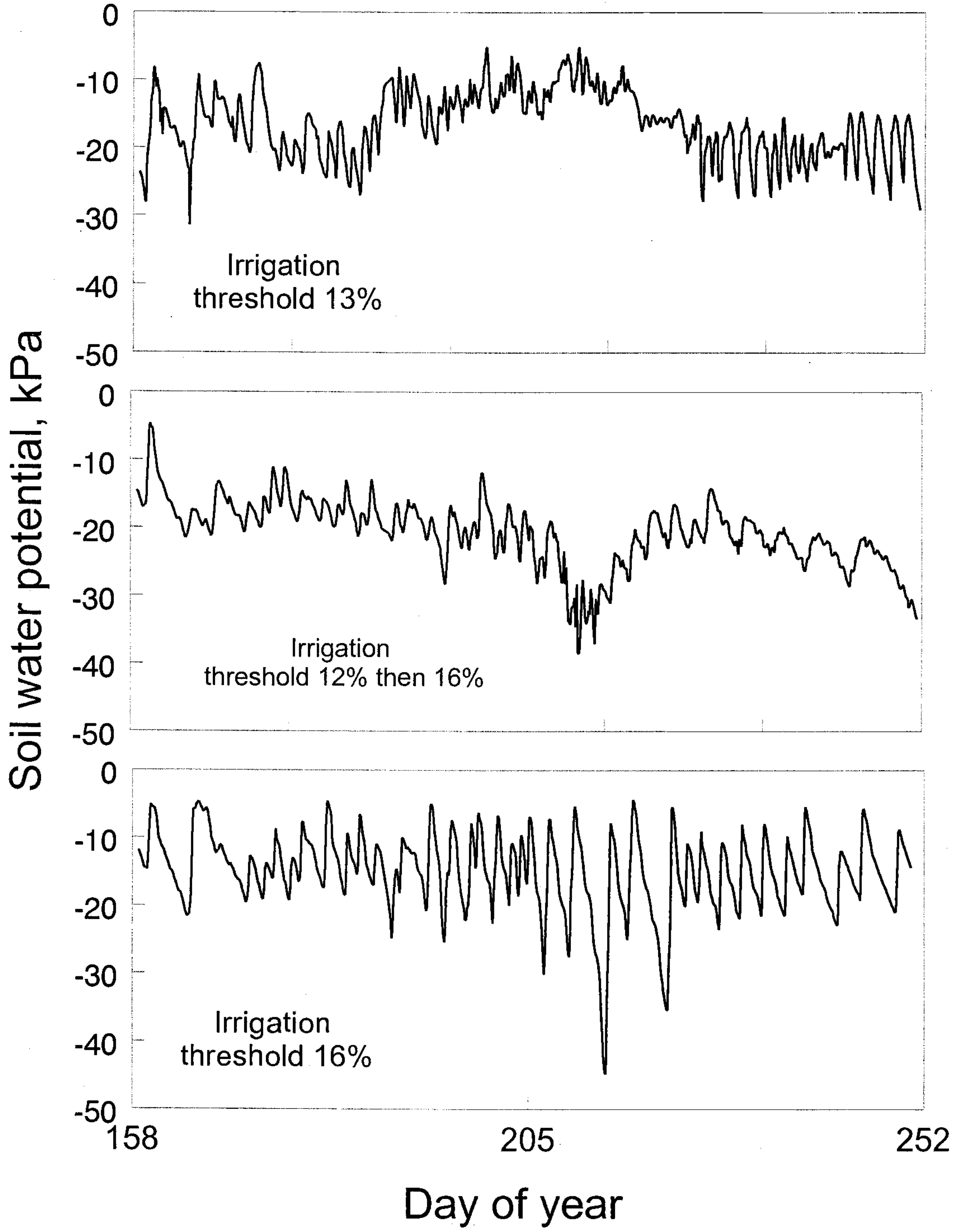

Figure 2. Soil water potential at 8-inch depth for a drip-irrigated onion field using the Acclima automated irrigation system with 3 volumetric soil water content irrigation thresholds, Oregon State University, Malheur Experiment Station, Ontario, OR 2005.

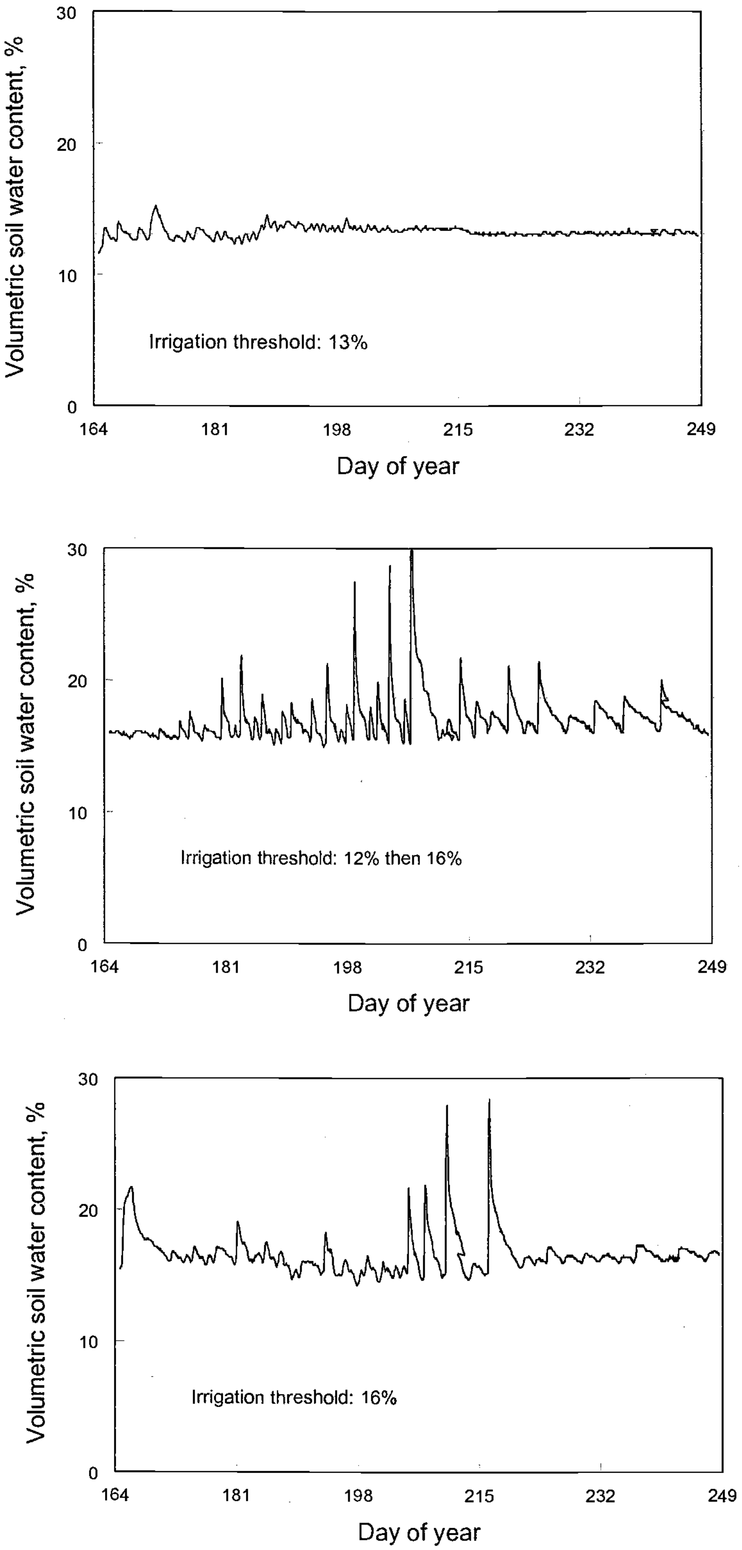

Figure 3. Volumetric soil water content at 8-inch depth for a drip-irrigated onion field using the Acclima irrigation system with 3 soil water content irrigation thresholds, Oregon State University, Malheur Experiment Station, Ontario, OR 2005.

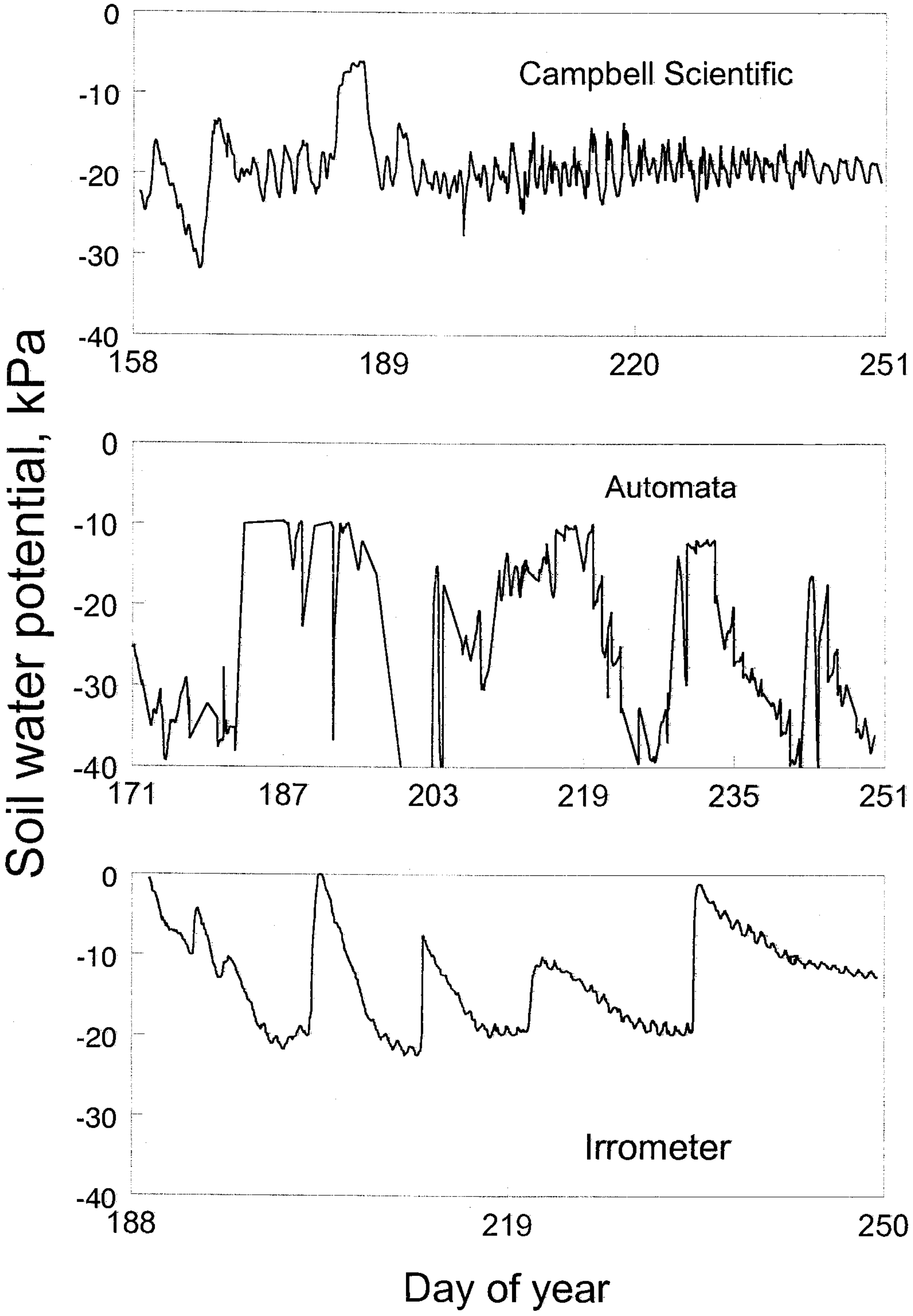

Figure 4. Soil water potential at 8-inch depth for a drip-irrigated onion field using 3 soil moisture monitoring and control systems, Oregon State University, Malheur Experiment Station, Ontario, OR 2005.

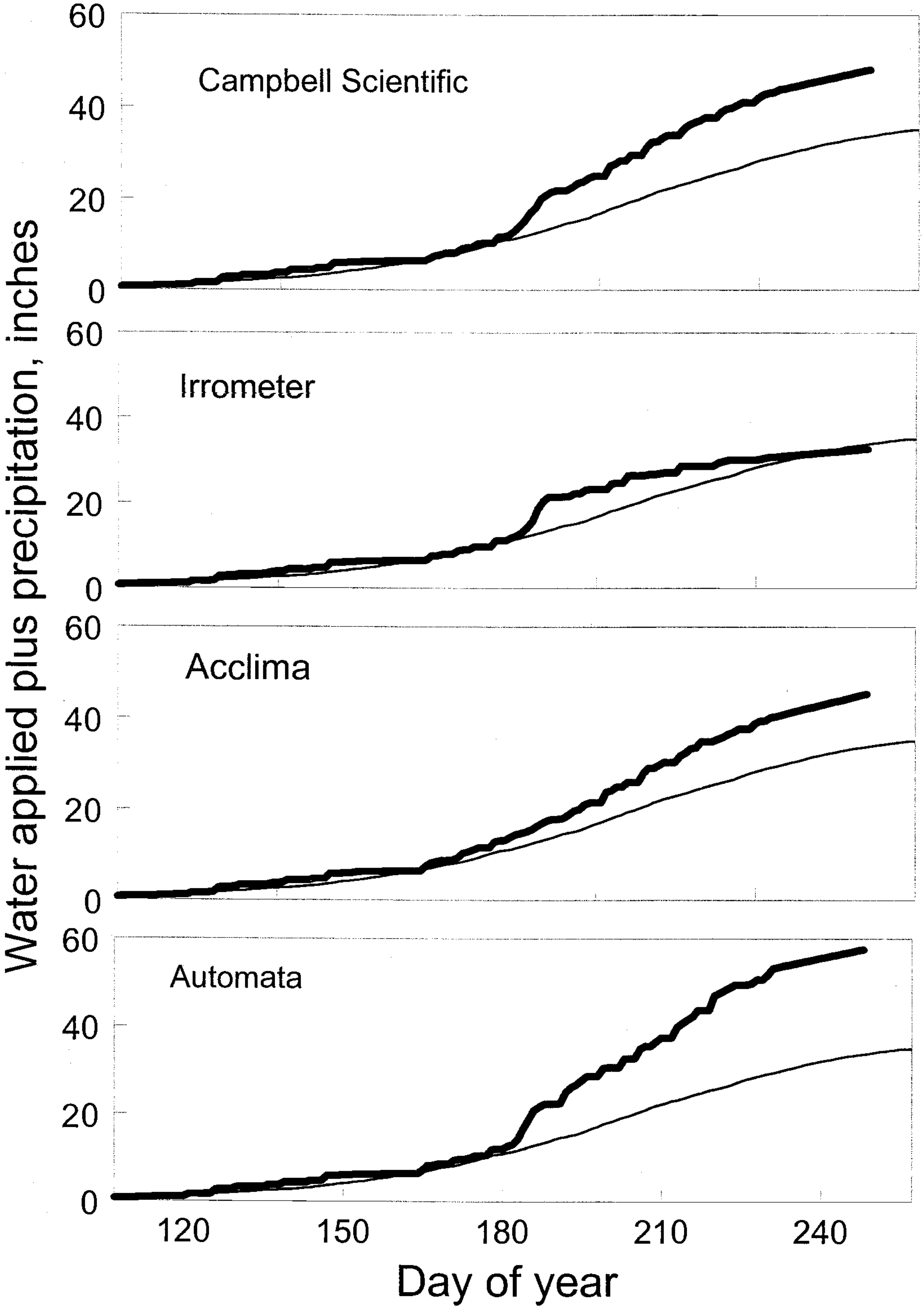

Figure 5. Water applied plus precipitation and ET_c over time for drip-irrigated onions with 4 soil moisture monitoring and control systems. Thick line is water applied and thin line is ET_c, Oregon State University, Malheur Experiment Station, Ontario, OR 2005.