DETERMINATION OF SENSOR LOCATIONS FOR MONITORING OF SOIL WATER CONTENT IN GREENHOUSE

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ABSTRCT

Monitoring and control of environmental condition is highly important for optimum control of the conditions, especially in greenhouse and plant factor, and the condition is not uniform within the facility. Objectives of the study were to investigate variability in soil water content and to determine optimum sensor locations for better irrigation control. Experiments were conducted in a strawberry-growing greenhouse (greenhouse 1) and a cherry tomato-growing greenhouse (greenhouse 2). Soil water content, electrical conductivity (EC), and temperature were collected over the entire area, different distances from an irrigation pump, and ridge and furrow. Soil water content was highest near the starting point of irrigation, and overall difference was about 3%. Different between water contents at ridge and furrow was in a range of 10.2~18.4%. EC was lower at ridge than at furrow, but temperature was not different.

Keywords: Greenhouse, Soil water content, Monitoring, Variability, Sensor location

INTRODUCTION

Protected crop production facilities have been increased in many countries due to reliable production regardless of weather condition. For example in Korea, agricultural area was decreased from 1,889,000 ha in 2000 to 1,737,000 ha in 2009, but protected production area was increased from 94,508 ha in 2007 to 97,300 ha in 2009. Major crops produced in greenhouses were high-value crops such as leaf vegetables, fruit vegetables, and flowers (KAMICO and KSAM, 2010).

Environmental conditions including soil water content affect significantly crop growth and quality. In protected crop production, drip irrigation is the most widely used method to make water distribution uniform and constant (Jerzy, 1998; Nam and Kim, 2007). Gulshan and Singh (2006) reported that tomato production in a facility with fertigation equipment was improved by 59.5% compared with the case of no fertigation and by 116.2% compared with the case of open field. Irrigation scheduling could save about 50% of water (Maisiri et al., 2005). Especially drip irrigation could improve plant yield such as plant height, leaf area index, fruit weight and quality by 10~15% (Kahlon et al., 2008).

Paz et al. (1998) related root depth, hydraulic conductivity and water content of soil in 3-year research, and reported that soil water content influenced on soybean yield considerably (about 69%). Soil water solve nutrients and is absorbed through active transportation, water potential, and capillary movement (Scott, 2000), and also affects indirectly through evapotranspiration, heat capacity, surface temperature, and vegetation coverage (Dirmeyer, 1995). In study on effects of salts contained in the soil and irrigation method, drip irrigation resulted in a higher water use efficiency of 77.29 kg/m^3, compared with 19.71 kg/m^3 of furrow irrigation, at salinity level of 2.0 dS/m, and improved yield by about 33% (Malash et al., 2008).

Conventional irrigation scheduling using timer that irrigates at a planned time based on past experience is vulnerable to unexpected weather such as heavy rainfall. Water shortage may result in prevention of leaf and stem growth, evapotranspiration and photosynthesis, and transportation of produced materials, while over supply would reduce root growth, oxygen concentration, and nutrient utilization efficiency (Ryu and Eom, 1986). Therefore continuous and accurate monitoring of soil water content is critical for precise water management and efficient utilization of soil water (Kim et al., 2003).

Objective of this research was to determine the optimal location of soil water content sensor. Soil water content obtained from a sensor was examined and analyzed in order to identify the variability.

MATERIALS AND METHODS

Experimental sites and equipment

Experiments were conducted at two greenhouses with drip irrigation systems, strawberry-growing three-layer facility (greenhouse 1; Figure 1) and cherry tomato-growing two-layer facility (greenhouse 2; Figure 2), in December 2011 and January 2012, respectively.

Soil water content was measured using a FDR (Frequency Domain Reflectometry) sensor (Model: WT1000N, Mirae Sensor, Seoul, Republic of Korea). The sensor provided measurements in a range of 0~99.9% with errors about 1%, and also soil electrical conductivity and temperature values. Probe length was 11.5 cm, diameter of sensing area was 48 mm, and the response time was 1 second (Table 1).

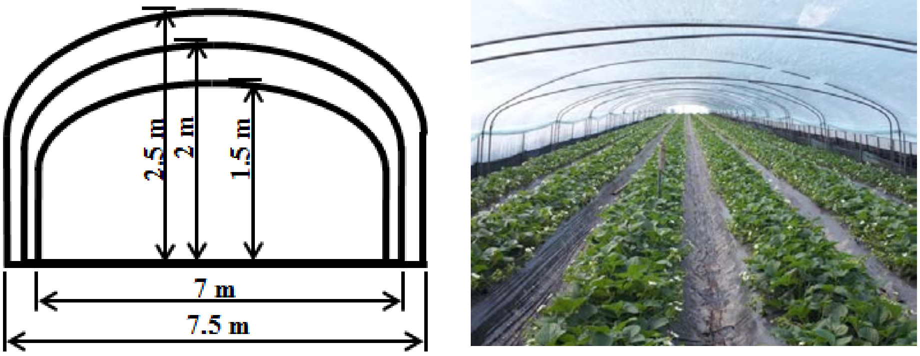

Figure 1. Dimensions (left) and view (right) of the strawberry-growing greenhouse.

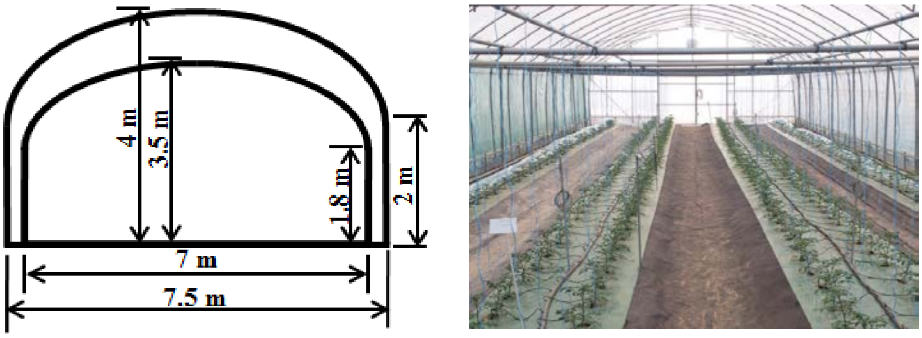

Figure 2. Dimensions (left) and view (right) of the cherry tomato-growing greenhouse.

Table 1. Specifications of the soil water content sensor.

Signal output	Analog	Voltage : 0 to 5 V, 1 to 5 V, 0 to 1 V, 0 to 2.5 V (linear output) Current : 4 to 20 mA (linera output)
	Digital	serial TTL level 9600, N, 8, 1 (RS-232c)
Range & accuracy	Moisture	0 to 99%, ± 1%
	EC	0 to 6.0 dS/m, ± 0.1 dS/m
	Temperature	0 to 60°C, ± 0.5°C
Sensor type		FDR (Frequency Domain Reflectometry)

Experimental procedures

Strawberry was planted in six rows in greenhouse 1. Water pump was located outside of the greenhouse, and irrigation was conducted during nights from 21:00 to 5:00 at 1.5~2 ton/day. Figure 3 shows measurement locations for the experiments. First, data were obtained at 9 locations across the greenhouse 6 hours and 10 hours after irrigation (Figure 3, top). Then, measurements were taken at 10 locations in 10-m intervals along one of the irrigation pipes to investigate linear distribution of soil water content by distance from the pump (Figure 3, middle). Finally, difference in soil water content on ridge and furrow was tested (Figure 3, bottom).

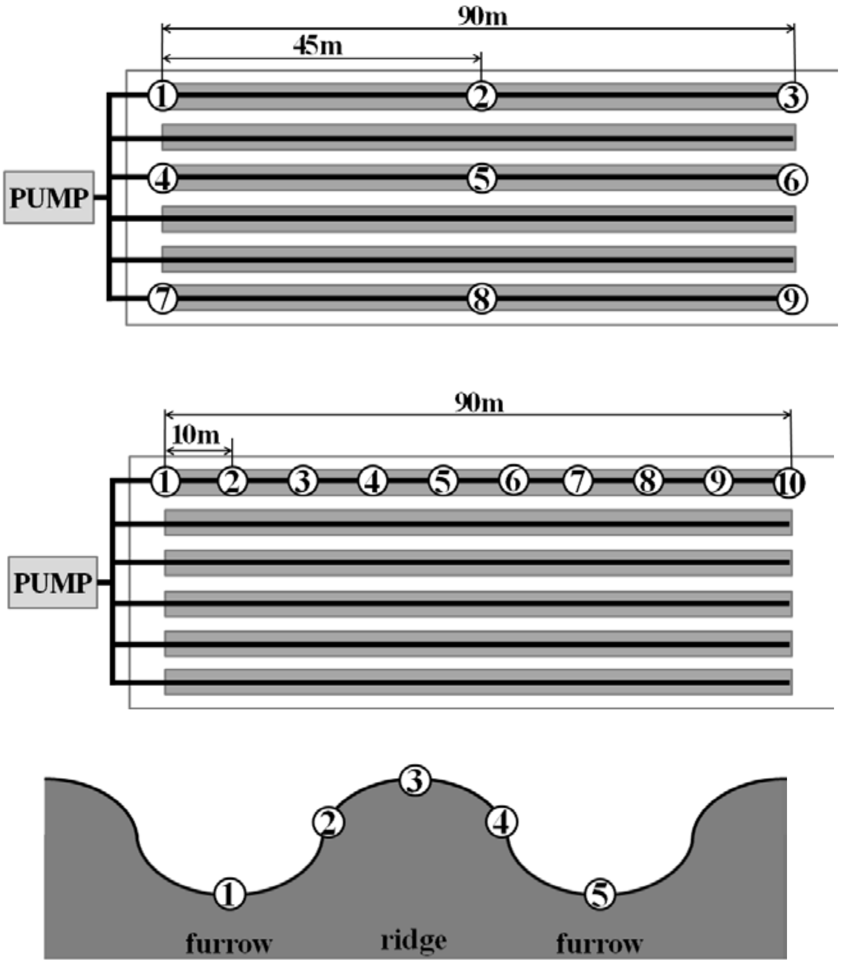

Figure 3. Diagrams explaining locations of soil water content measurements in greenhouse 1. Multiple locations across the entire area (top), along one of the irrigation pipe (middle), and on ridge and furrow (bottom).

Irrigation pump was also located out of the greenhouse 2. Fertigation was performed at 15:00 at rates of 600~800 ton/day. Soil water content was collected at 6 locations at 5-m intervals along the first and second crops rows from the side, at 20 hours and 25 hours after the irrigation. Temperature was maintained at 17°C using a heater with air tunnel around the interior perimeter of the greenhouse.

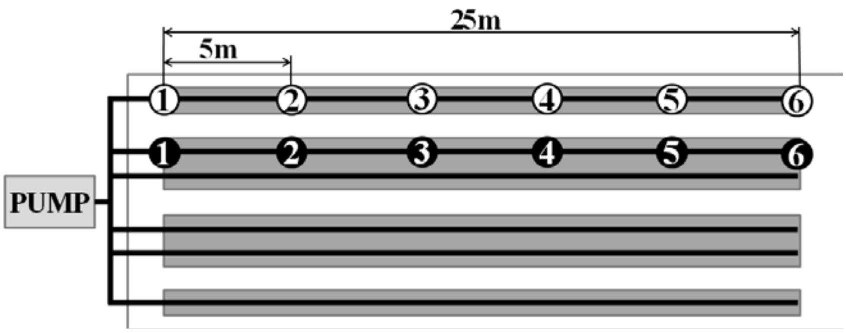

Figure 4. Diagrams explaining locations of soil water content measurements in greenhouse 2.

RESULTS AND DISCUSSION

Greenhouse 1: strawberry production

Table 2 shows results of measured soil water content, temperature, and electrical conductivity over the greenhouse area at different times. Overall, soil water content decreased, and temperature and electrical conductivity increased over time. Difference in averaged soil water content over time was about 3%. Water contents near the pump were higher than other locations. Soil temperature decreased over time by 1.4°C, and electrical conductivity values were not changed significantly over time.

Table 2. Averaged soil water content, temperature, and electrical conductivity in greenhouse 1 at different times.

Time	Location	Water content, %			Temperature, °C			EC, dS/m		
11:00	1-2-3	31.3	26.3	25.0	12.4	12.7	10.0	0.6	1.0	0.8
	4-5-6	38.4	25.7	28.8	12.7	13.1	11.7	0.8	0.8	0.8
	7-8-9	38.3	25.4	23.3	11.7	11.7	10.8	0.6	0.8	1.0
15:00	1-2-3	30.0	21.4	25.4	13.4	14.2	12.5	0.8	1.0	1.1
	4-5-6	27.2	26.3	26.6	13.8	14.8	13.5	1.0	1.2	1.0
	7-8-9	29.6	26.1	24.4	12.5	13.4	11.4	0.7	1.0	1.0

Figure 5 shows measured data along the irrigation line by distance. Water content decreased by distance up to 70 m and increased after that, and temperature showed an inverse pattern. Maximum water content was 33.1% at a 10-m distance and minimum water content was 24.5% at 60- to 70-m distance. Locations provided water contents close to the average value were 20, 30, and 90 m. Average, maximum, and minimum values were 0.84, 1.13, and 0.65 dS/m, respectively.

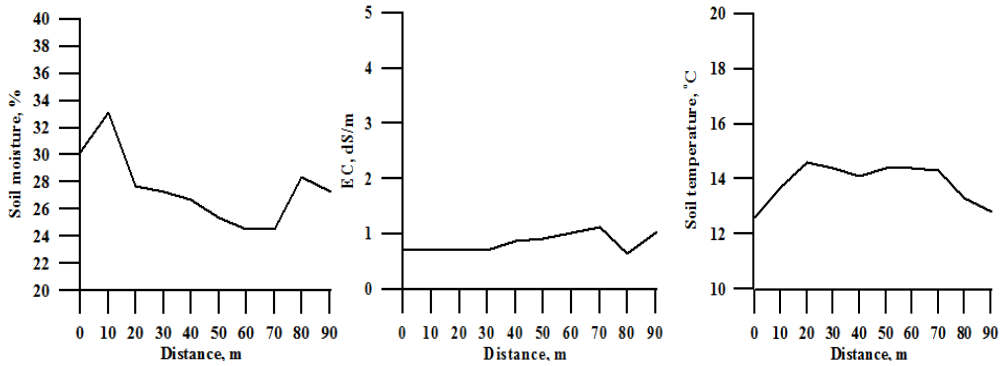

Figure 5. Variation of water content, electrical conductivity, and temperature by distance from the irrigation pump in greenhouse 1.

Figure 6 shows variation in the measured data between ridge and furrow. Soil water contents on the ridge were lower than those on the furrow, and the differences were 10.2~18.4%. The lowest EC were observed on the furrow, possibly due to absorption of nutrients by crop roots at those depths, and highest values were observed on the ridge. Temperature showed relatively uniform over the collection locations.

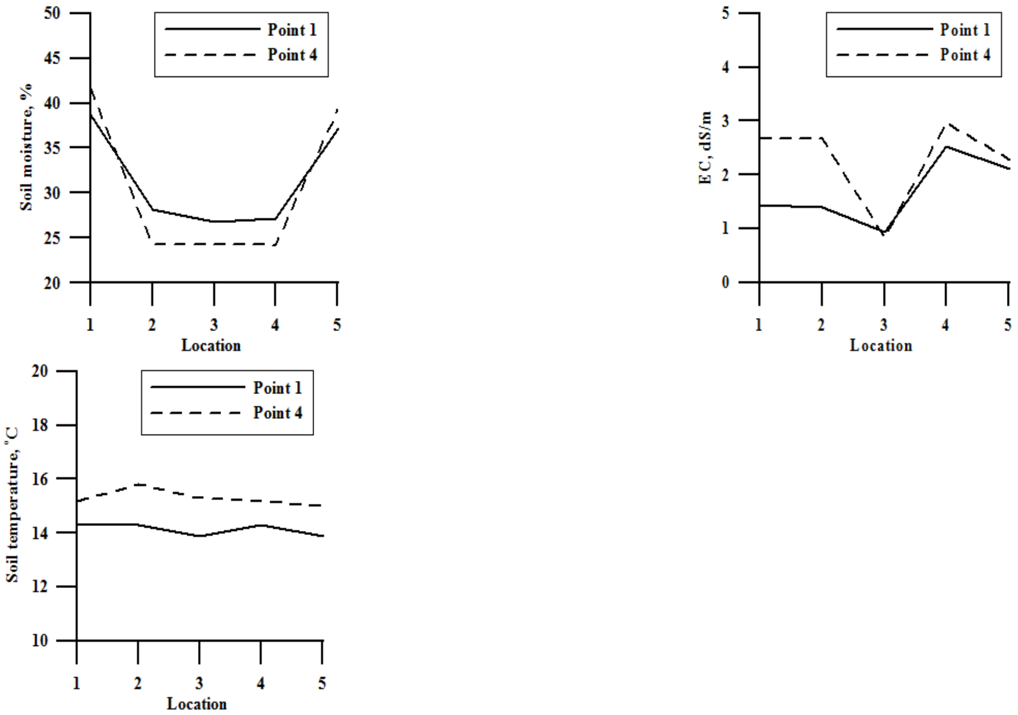

Figure 6. Variation of water content, electrical conductivity, and temperature on the ridge and furrow in greenhouse 1.

Greenhouse 2: cherry tomato production

Figure 7 shows variation of soil water content (top), temperature (middle), and electrical conductivity (bottom) by distance along the irrigation line at 18 hours (left) and 23 hours (right) after the irrigation in greenhouse 2. Except that a little decrease (2%) on the first line close to the window side, soil water content were not significantly different between the lines and measurement times. Pattern of water content along the irrigation pipe was different from that of greenhouse 1, possibly due to shorter distance of the line in greenhouse 2. Soil water content was greater at the middle locations than at the starting and ending locations. Temperature did not show significant differences by location and time, but somewhat higher values on the first line due to the heating tunnel. EC pattern was similar with the water content pattern.

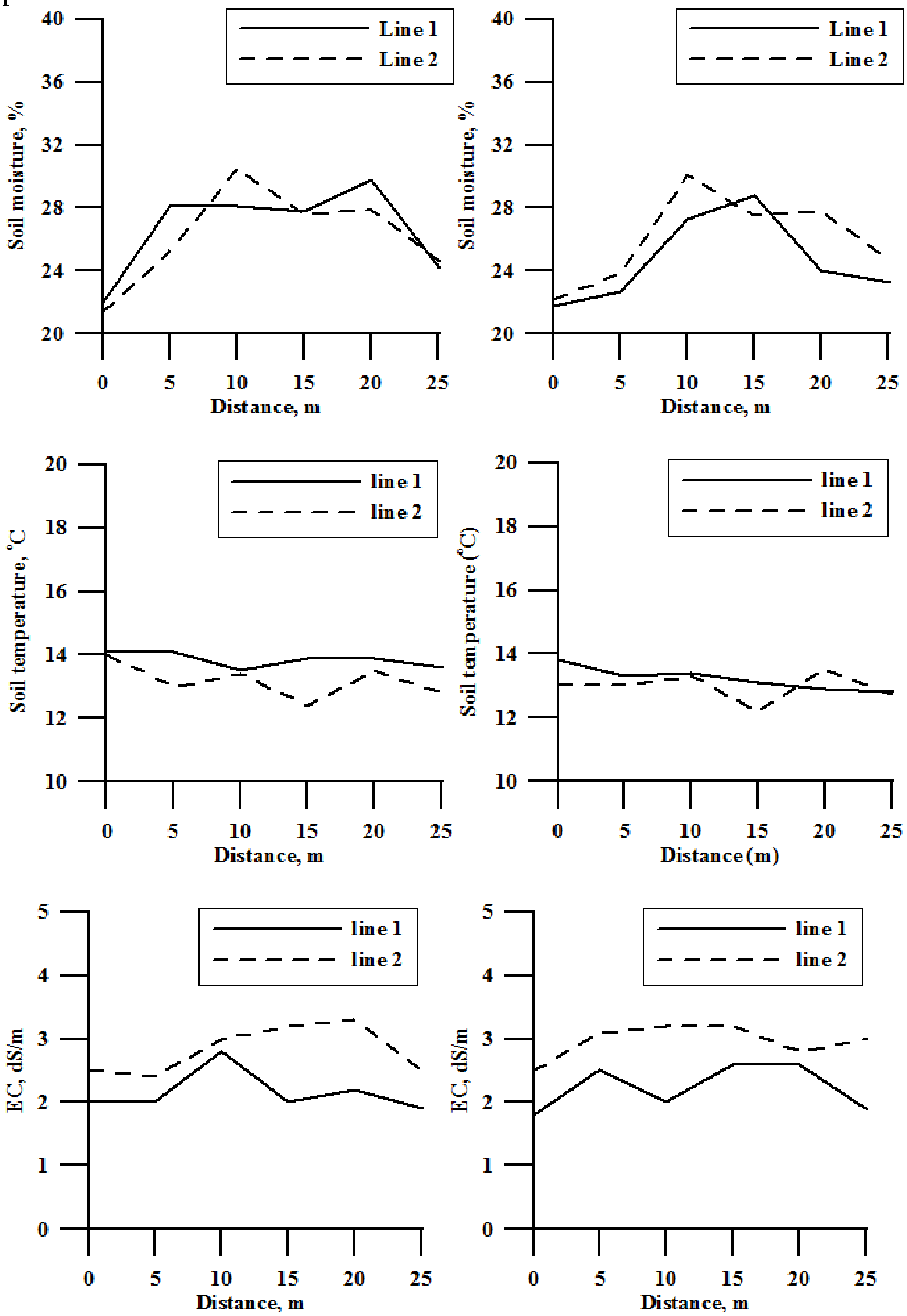

Figure 7. Variation of soil water content (top), temperature (middle), and electrical conductivity (bottom) by distance along the irrigation line at 18 hours (left) and 23 hours (right) after the irrigation in greenhouse 2.

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