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Real-Time Measurements of Moisture of Perlite-media of Rooting for Plant Production by Cutting

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Abstract

Moisture and temperature of the rooting medium where plant cuttings are located are two important environmental factors on fruit trees plant production by cuttings. In this study, measurements of moisture of the rooting medium which consisted of perlite was measured with different commonly used sensors; namely, RSU adapter tensiometer, Watermark 200SS, and Waterscout SM100 sensors. Measurements were made at three moistures levels; low (40%), moderate (60%) and high moisture (80%) levels and three temperature levels; low (18 °C), moderate (22 °C) and high temperature (26 °C) levels. Moisture readings of these sensors were compared in terms of precision and accuracy to determine the better sensor for use with computer controlled rooting system. Standard gravimetric method was used to determine moisture level of perlite media for comparison of sensor readings. As a result of the comparison, better readings were obtained from RSU tensiometer in terms of accuracy and precision. The results of the study suggested that the RSU adapter tensiometer can be used for continuous measurement along computer controlled rooting system to keep the moisture of perlite media at desired level needed for better rooting from cuttings for fruit trees reproduction in terms of yield and quality.

Keyword: Instrumentation, Tensiometer, Agricultural Automation, Plant Reproduction, Rooting.

INTRODUCTION

Temperature and moisture in the rooting medium are very important variables to be controlled for high rooting percentage and quality. Particularly, in propagation by means of semi hardwood or green cutting; some conditions such as water, temperature, light and rooting medium are required to be maintained at optimum level for cutting to remain alive during the rooting of cutting and to achieve the maximum regeneration. There are many types of rooting media such as peat moss, sand, vermiculite, perlite and their combinations. Perlite is a good rooting media and by far the most preferred one as it can be supplied easily and cheaply [19].

The measurement of soil moisture is required to determine the timing and amount of water applied. Gravimetric, tensiometric, electromagnetic, neutron radiation, plaster block and other methods are used for this measurements. These methods have both advantages and disadvantages [2]. There are various sensors used in these methods.

In gravimetric method, moisture in a soil sample is removed through evaporation, washing or chemical reaction and then the amount of the moisture removed from the soil is determined [5], [7]. The results obtained through this method cannot be evaluated in real-time. The most important feature of the gravimetric method is its being a standard method used for the calibration of indirect methods [18].

Tensiometers are used for measuring soil moisture tension. The tensiometers which were developed by Richard et al. [11], [12], [13], [14], are among the widely-used methods on measurement of soil water with in the range of a 0 to 85 kPa. In crop production, in order to determine the soil water potential, the use of solid-state transducers for measuring the pressure changes that occur in the tensiometer has become widespread in recent years [3], [4], [10].

Similar to tensiometer, Granular Matrix Sensor (GMS) which is made of a porous material run in balance with soil moisture. By using the calibration equation, soil moisture tension is measured in electrical resistance values between electrodes which are embedded in a porous material placed in the soil (Granular Matrix Block). These sensors are used in an automatic irrigation for cotton [8], onions and potatoes [15].

Many researchers have attempted to use automatic irrigation systems and soil moisture sensing devices, such as tensiometer. Tensiometers are used in various automatic controlled irrigation applications for tomato [16], citrus fruit [17], and Bermuda grass [1]. Shock et al. [15], described a system using GMX which started scheduled irrigation event and which was similar to many tensiometer controlled automatic irrigation systems.

Dukes et al. [6], reported 50% of water saving for the same types of yield and quality. The research's conducted by Muñoz and Dukes [9], reveal different results for different sensor types under the same conditions but emphasize the importance of saving water for the same product quality.

MATERIALS

This study was carried out by employing a computer controlled rooting system which was developed by Yıldırım et al. [20]. The system consisted of a main computer, an automatic controller and 10 rooting benches. The measurements obtained from Waterscout SM100 moisture sensor and Platinum Resistance Thermometer (PT100) temperature sensor in the rooting medium were processed in the controller based on Proportional-Integral-Derivative (PID) Siemens S7-300 Programmable Logic Controller (PLC) unit is used in automatic control panel for controlling the system. The control panel also has 40 digital inputs / outputs, 24 analog inputs, PLC power supply, irrigation and heating system control relays, power analyzer, a heating supply transformer and fuse elements.

Through the software in PLC unit, moisture and temperature data were taken from the rooting medium and thus, the control of drip irrigation and heating systems was achieved. The data taken from the rooting medium was monitored instantly on the computer screen by the software of PLC unit. The software can set the moisture and temperature values on the rooting medium.

In the heating system, electric heating cables in 10 meters length which run by 50 volt alternative voltage. The system run by 200 watts power. Thermal insulation is done to prevent heat loss that may result from the rooting bench. The heating system is placed into the bottom of the rooting bench. 2 mm thick aluminum plate was placed on the heating cables to separate them from perlite media. PT100 temperature sensor was used to measure value of the rooting medium temperature.

Irrigation systems consisted of an irrigation pipe, a dripper and a solenoid valve. The moisture value of rooting medium was kept at pre set up values by the PLC unit using a solenoid valve.

Independent from the automatic control system, three moisture sensors were included to measure moisture in the rooting medium. They were Watermark 200SS (GMS type) sensor, Irrometer brand Remote Sensing Unit (RSU) adapter tensiometer and Waterscout SM100 (capacitance type) sensor. The data obtained from the sensors was recorded with a data logger.

METHODS

In this study, gravimetric method was used for the determination of the field capacity of perlite, for the detection of moisture of the samples which were taken at the end of experiments and for the calibration of the moisture sensors in line with the field capacity.

The samples which ranged from 0% to 100% were prepared according to the field capacity. And sensor measurements were obtained. Regression analysis was performed on data obtained from the sensors. The calibration equation of the second degree was achieved. Calibration curve was created for the sensor readings.

Three different temperatures levels; low (18 °C), moderate (22 °C) and high temperature (26 °C) levels and three different moisture levels; low (40%), moderate (60%) and high moisture (80%) levels were included in the experimental design (Table 1). Perlite substance was used for rooting media.

Table 1. Temperature and moistures levels for experiments.

Temperature (°C)			Moisture (Field capacity %)		
Low	Moderate	High	Low	Moderate	High
18	22	26	40	60	80

The experiments were conducted by using the computer controlled rooting system in a laboratory conditions. The moisture sensors were placed five centimeters away from each other and five centimeters above the rooting bench ground.

Temperature and moisture levels were set on the computer controlled rooting system according to the specified levels in the experimental design. The measurements of the three moisture sensors were recorded by the data logger for six hours since the system reached at stable state. Moisture sensor readings were compared with the moisture values of the samples determined by the gravimetric method.

RESULTS AND DISCUSSION

Field Capacity Determination of Perlite Media

Five replications treatments were performed for determining the field capacity of perlite media by gravimetric method. Perlite media field capacity was determined as 410,90% (standard deviation=0,19) on a weight basis average (Table 2).

Table 2. Field capacity determination by gravimetric method for perlite.

Experiments	Dry (g)	Wet (g)	Water Amount (g)	Dry (%)
1	85,20	432,70	347,50	407,86
2	88,30	474,80	386,50	437,71
3	82,40	408,50	326,10	395,75
4	85,00	417,80	332,80	391,53
5	86,90	453,30	366,40	421,63
Mean	85,56	437,42	351,86	410,90

The Moisture Sensor Calibration

11 different moisture levels of perlite media (0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100%) were prepared by gravimetric method. 300 grams of dry perlite was used for each moisture level. Measurements were taken from these samples for each moisture sensor. 10 minutes equilibrium data obtained by the sensors was used for calibration. Calibration curves were drawn based on the sensor readings and regression analysis was performed to obtain calibration equations.

Watermark 200SS Moisture Sensor Calibration

Watermark 200SS moisture sensor readings, due to its structure, remained at constant moisture level (100%) for all calibration experiments between 40% - 100% moisture levels (Figure 1). It was determined that the use of Watermark 200SS moisture sensor was not suitable to measure moisture of perlite media. Therefore, the data obtained by this sensor was not included in the present study.

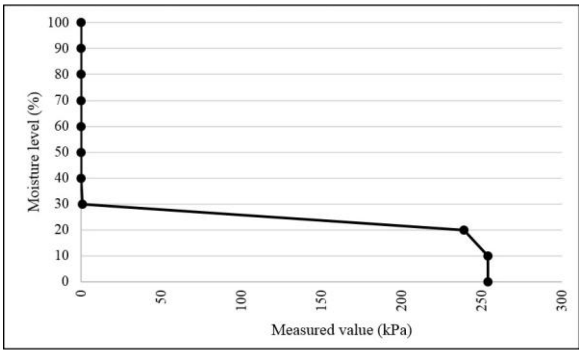

Figure 1. Watermark 200SS moisture sensor calibration curve

RSU Adapter Tensiometer Calibration

RSU adapter tensiometer calibration curve was obtained by using sensor readings (Figure 2). “$y = 147{,}82x^2 - 538{,}09x + 491{,}95$” ($R^2 = 0{,}97$) calibration equation was obtained with Microsoft Excel.

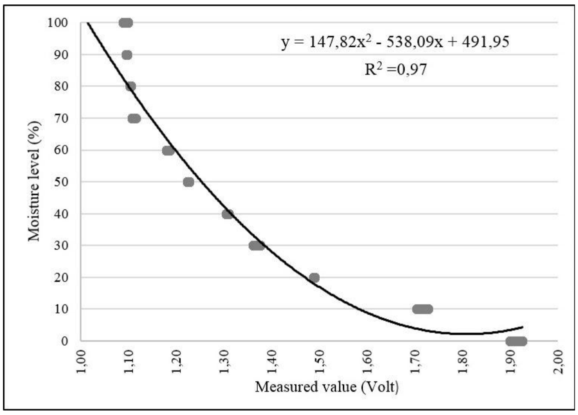

Figure 2. RSU adapter tensiometer calibration curve

Waterscout SM100 Moisture Sensor Calibration

Waterscout SM100 moisture sensor calibration curve was obtained by using sensor readings (Figure 3). “$y = 786{,}88x^2 – 579{,}49x + 46{,}32$” ($R^2 = 0{,}97$) calibration equation was obtained with Microsoft Excel.

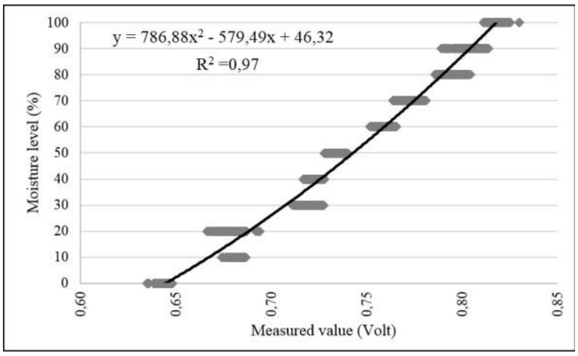

Figure 3. Waterscout SM100 moisture sensor calibration curve

Gravimetric Method Tests

After recording the data throughout the experiments, measurements with gravimetric method were applied on samples taken from the rooting medium. Total water amount and moisture in 100 gram sample of dry perlite were determined (Table 3). Rooting media moisture was observed close to set up value of the control system.

Table 3. Total water amount and moisture in 100 gram sample of dry perlite

Temperature (°C)	Moisture level					
	c		60%		80%	
	Water amount (g)	Moisture (%)	Water amount (g)	Moisture (%)	Water amount (g)	Moisture (%)
18	159,6	38,84	250,4	60,94	318,5	77,51
22	175,2	42,64	255,8	62,25	315,2	76,71
26	172,4	41,96	238,7	58,09	326,7	79,51

The Low Moisture Level Tests

Tests were conducted to measure moisture of perlite at low (40%) moisture level with SM100 and RSU adapter tensiometer at 3 different temperature (18, 22 and 26 °C). Six hours data (360 reading) received from SM100 and RSU adapter tensiometer and moisture curves were created (Figure 4).

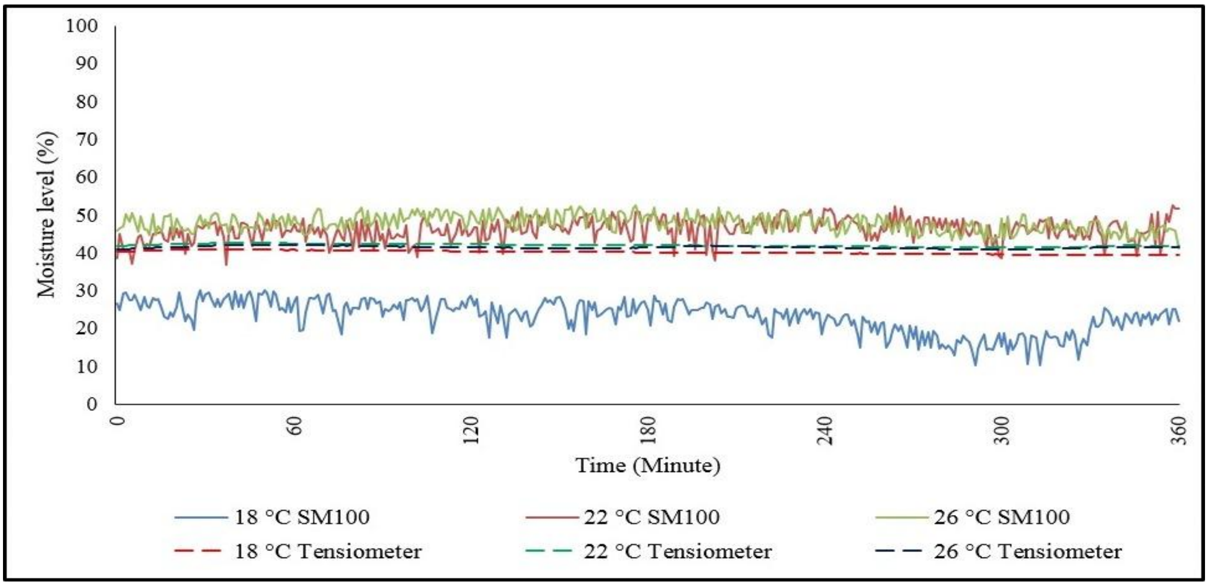

Figure 4. SM100 and tensiometer moisture curves at the low (40%) moisture level tests

Moisture values measured by SM100 sensor at 22 and 26 °C were similar. But it was lower at 18 °C. Measurements of RSU adapter tensiometer at all temperature levels were found to be closer to each other and there were less fluctuation. For SM100 sensor, mean moisture at 18 °C treatment was 23,16% with a 4,24 standard deviation; mean moisture at 22 °C treatment was 46,17% with a 2,97 standard deviation; mean moisture at 26 °C treatment was 47,78% with a 2,29 standard deviation. For tensiometer sensor, mean moisture at 18 °C treatment was 40,11% with a 0,44 standard deviation; mean moisture at 22 °C treatment was 41,97% with a 0,34 standard deviation; mean moisture at 26 °C treatment was 41,42% with a 0,34 standard deviation. Mean moisture and standard deviations for all temperatures were given in Table 4. Moisture determination at 22 °C with RSU adapter tensiometer was more precise (Mean moisture= 41,97% and standard deviation=0,34).

Table 4. SM100 and tensiometer values in low (40%) moisture level tests

Temperature (°C)	SM100		Tensiometer	
	Mean (%)	Standard Deviation	Mean (%)	Standard Deviation
18	23,16	4,24	40,11	0,44
22	46,17	2,97	41,97	0,34
26	47,78	2,29	41,42	0,34

The Moderate Moisture Level Tests

Tests were conducted to measure moisture of perlite at low (60%) moisture level with SM100 and RSU adapter tensiometer at 3 different temperature (18, 22 and 26 °C). Six hours data (360 reading) received from SM100 and RSU adapter tensiometer and moisture curves were created (Figure 5).

Moisture values measured by SM100 sensor at 18, 22 and 26 °C were not similar. Measurements of RSU adapter tensiometer at all temperature levels were found to be closer to each other and there were less fluctuation. For SM100 sensor, mean moisture at 18 °C treatment was 47,26% with a 5,51 standard deviation; mean moisture at 22 °C treatment was 69,57% with a 6,38 standard deviation; mean moisture at 26 °C treatment was 59,26% with a 6,20 standard deviation. For tensiometer sensor, mean moisture at 18 °C treatment was 60,57% with a 0,16 standard deviation; mean moisture at 22 °C treatment was 60,51% with a 0,19 standard deviation; mean moisture at 26 °C treatment was 59,92% with a 0,21 standard deviation. Mean moisture and standard deviations for all temperatures were given in Table 5. Moisture determination at 18 °C with RSU adapter tensiometer was more precise (Mean moisture=60,57% and standard deviation=0,16).

Table 5. SM100 and tensiometer values in moderate (60%) moisture level tests

Temperature (°C)	SM100		Tensiometer	
	Mean (%)	Standard Deviation	Mean (%)	Standard Deviation
18	47,26	5,51	60,57	0,16
22	69,57	6,38	60,51	0,19
26	59,26	6,20	59,92	0,21

The High Moisture Level Tests

Tests were conducted to measure moisture of perlite at low (80%) moisture level with SM100 and RSU adapter tensiometer at 3 different temperature (18, 22 and 26 °C). Six hours data (360 reading) received from SM100 and RSU adapter tensiometer and moisture curves were created (Figure 6).

Moisture values measured by SM100 sensor at 22 and 26 °C were similar. But it was lower at 18 °C. Measurements of RSU adapter tensiometer at all temperature levels were found to be closer to each other and there were less fluctuation. For SM100 sensor, mean moisture at 18 °C treatment was 68,09% with a 5,64 standard deviation; mean moisture at 22 °C treatment was 89,65% with a 4,47 standard deviation; mean moisture at 26 °C treatment was 88,38% with a 5,94 standard deviation. For tensiometer

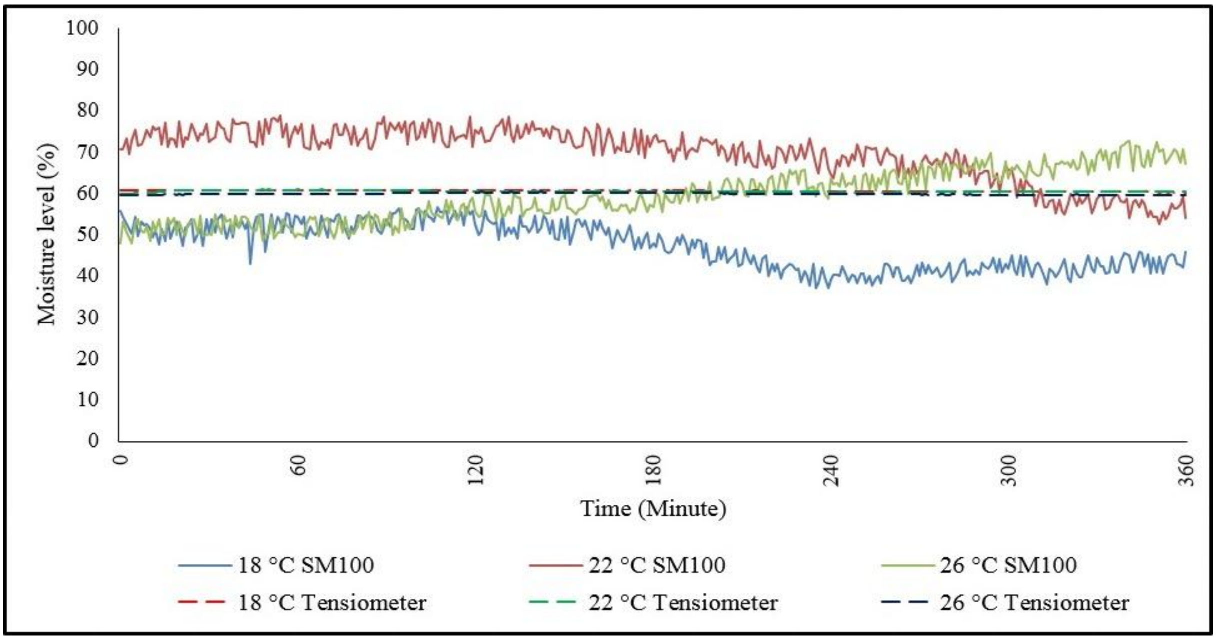

Figure 5. SM100 and tensiometer moisture curves at moderate (60%) the moisture level tests

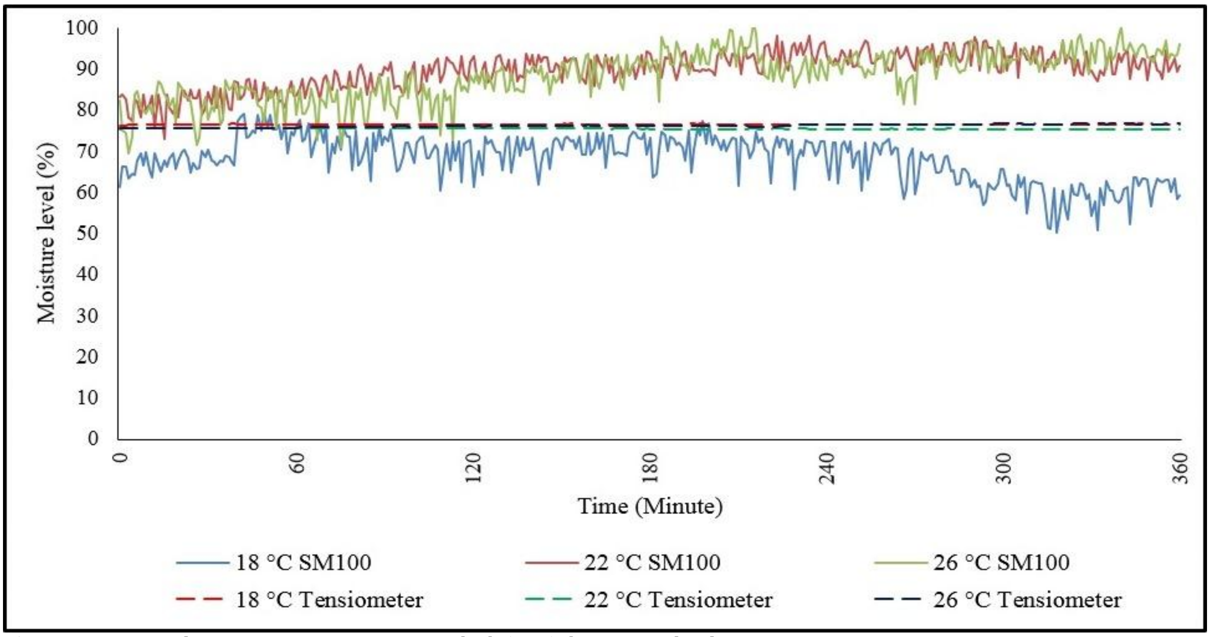

Figure 6. SM100 and tensiometer moisture curves at high (80%) the moisture level tests

sensor, mean moisture at 18 °C treatment was 76,50% with a 0,08 standard deviation; mean moisture at 22 °C treatment was 75,50% with a 0,10 standard deviation; mean moisture at 26 °C treatment was 76,18% with a 0,34 standard deviation. Mean moisture and standard deviations for all temperatures were given in Table 4. Moisture determination at 18 °C with RSU adapter tensiometer was more precise (Mean moisture= 76,50% and standard deviation=0,08).

Table 6. SM100 and tensiometer values in high (80%) moisture level tests

Temperature (°C)	SM100		Tensiometer	
	Mean (%)	**Standard Deviation**	**Mean (%)**	**Standard Deviation**
18	68,09	5,64	76,50	0,08
22	89,65	4,47	75,50	0,10
26	88,38	5,94	76,18	0,34

CONCLUSION

In this study, moisture of perlite media were measured with Watermark 200SS, Waterscout SM100 and RSU adapter tensiometer by the computer controlled rooting system. The tests were done for 9 different treatments included three moistures levels; low (40%), moderate (60%) and high moisture (80%) levels and three temperature levels; low (18 °C), moderate (22 °C) and high temperature (26 °C) levels. Moisture readings of these sensors were compared in terms of precision and accuracy to determine the better sensor in computer controlled rooting system.

Due to increase in perlite water-holding capacity, Watermark 200SS moisture sensor increased to 100% moisture level by holding moisture in all experiments. It maintains the moisture level during the measurement. Watermark 200SS moisture sensor was not appropriate for measuring moisture in perlite media.

In all experiments with Waterscout SM100 moisture sensor there found to be statistically significant differences between perlite temperature and moisture measurements. The difference between the measurements was found to be very high when you look at the standard deviation of the moisture measurements.

In this experiments, instant fluctuations were observed in sensor readings. The moisture measurements were affected by water infiltration due to increase in perlite water-holding capacity.

SM 100 sensor has advantages of low sensor weight and, easy and simple connection. İn addition, it doesn't require any setting before experiment and the response time of sensor was fast. However, it has low accuracy.

In all experiments with RSU adapter tensiometer there found to be statistically significant differences between moistures measurements obtained at different temperatures. The difference between the measurements was found to be minimal when you look at the standard deviation of the moisture measurements

Preparation for tensiometer use in the experiments lasts longer. After each preparation, calibration was required for measurement. An additional processing needed for setting sensor connection. These were disadvantages.

The time taken for the realization of the measurements which was made with RSU adapter tensiometer in very low moisture levels was very long. This was the disadvantage. But the time taken for realization of the measurements was short. However, the advantages were high accuracy and precision. As a result; RSU adapter tensiometer was recommended for real-time measurement of perlite media.

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