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Development and Testing of an Automated Computer-Controlled System for Plant production by Cutting

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Abstract

Propagation by cuttings is very important for fruit trees production. High quality and high rooting ratio are of primary importance on rooting from cutting. This depends on temperature and humidity of the rooting media as well as other factors; such as, type of cutting, time of cutting collecting, and age of mother plant. Moisture and temperature of rooting media has to be controlled at desired level needed by rooting. In this study, a computer-controlled system for rooting based on hot water piping was developed and tested. The system included a main desktop computer, a PLC unit, a soil moisture sensor, a temperature sensor, a solenoid valve, a sprinkle irrigation line, and nozzle. A software program was developed using SIMATIC WinCC Flexible to coordinate and monitor the operation. The sensors tips were inserted and located approximately in rooting zone of cuttings. Sensor measurements are recorded with the datalogger. The computer-controlled system was able to continuously monitor temperature and soil moisture levels, start heating and irrigation in time when required, and stop the operation when reached the desired levels. Automated rooting system was able to perform all the functions required and was successful keeping the temperature and humidity at set-up levels.

Keyword: Rooting, Propagation by Cutting, Instrumentation, Sensor, Agricultural Automation.

INTRODUCTION

Many types of fruit are grown in Turkey. It is known that there are two propagation techniques in fruit tree reproducing: Generative and vegetative production. Generative propagation may not show the features of mother fruit species. Propagation by cutting method is used to produce of rootstock with outstanding features. However, some types of fruit has low percentage of propagation by cutting. Therefore, many studies have been done on propagation by cutting.

High quality and high rooting ratio are of primary importance on rooting from cutting. This depends on temperature and humidity of the rooting media as well as other factors; such as type of cutting, time of cutting collecting, and age of mother plant. Moisture and temperature of rooting media has to be controlled at desired level needed by rooting. This requires automation.

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 levels for cutting to remain alive during the rooting of cutting and to achieve the maximum regeneration [11].

Soil temperature is one of the factors that has important effects on physical, chemical and biological processes in the soil. Soil temperature also affects the yield and the quality of propagation. Root growth of most plants stops at below 5 degrees Celsius [3]. Generally, the activity is accelerated with increasing temperature. Proper temperature is to accelerate the development of rooting. Also, there are important effects of temperature on root development in plants, plant nutrient solubility and suggestibility.

Floor heating system in the rooting benches are made in two different ways in propagation. They are electrical and hot water piping systems constructed on upper surface of the rooting bench. Heating cable and the heat pipes are positioned below the rooting medium in both electric and water heating systems. Heat pipes are placed in two ways in water heating system. They are spiral and hairpin type. The average temperature is approximately the same all over the floor in the spiral type. Water inlet temperature decreases logarithmically in the hairpin type [2].

Researchers working on propagation by cutting reported different rooting ratios. Rooting percentage of the wood cuttings varied between 60% and 19% depending on the type and concentration of hormones without any heating system. On the other hand, rooting percentage is up to 89% in floor heating system. [7], [8], [9], [10], [12]. These different results depend on type of cutting, time of cutting collecting, age of mother plant and the environmental factors [12]. There are significant differences in the percentage of rooting even between the same dose and the same hormones types. These may have been caused by the difference of rooting conditions [4].

The temperature of daytime 21-27 ° C and night 16-21 ° C is usually adequate in the cutting pads medium. More favorable results were obtained in rooting by using the thermostat controlled heating systems that hold temperature around 21 ° C in the bottom part of cuttings [5].

Temperature and moisture conditions of the environment are among the most important factors affecting rooting success during adventitious root formation [1], [6], [12]. The more precise control of the temperature and humidity of the rooting medium is performed, the higher rooting ratio and rooting quality are likely to be achieved [13].

MATERIALS AND METHODS

This study was carried out by employing a computer controlled rooting system which was developed by Yıldırım et al. [14]. The experiments were performed in 2014 in Aydın, Turkey.

Computer-controlled system for rooting consisted of the parts below (Figure 1):

- A main desktop computer to monitor and coordinate all the operations,
- Control software for the automation of the entire process and data acquisition,
- Programmable Logic Controller (PLC) unit,
- Moisture sensors,
- Temperature sensors,
- Solenoid valves,
- A sprinkle irrigation line and nozzle.

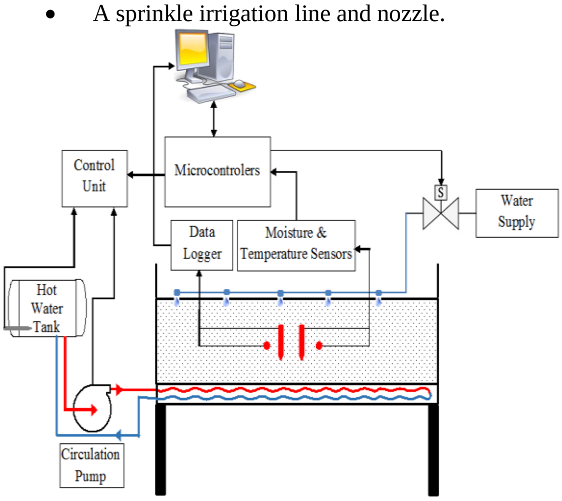

Figure 1. Water pipe heating system

The control unit controlled heating and irrigation in accordance with temperature and moisture sensors which were placed in rooting zone. It also provided the ability real-time monitoring and recording the data. The data from temperature and moisture sensors in rooting table was processed in a controller based on PID and ensure the operation of drip irrigation and heating systems. The moisture and temperature sensor measurements were recorded via the data acquisition unit and transferred to software program. In addition, real-time temperature and moisture conditions could be observed graphically. Solenoid valve and the circulation water pump were controlled by PLC digital output. The position of valves (open and closed) and operation of the recirculation water pump in the system could be monitored and controlled by the software program. Moisture and temperature data were transferred to an Excel file and stored in the computer.

Siemens S7-300 model PLC that has 40 digital inputs / outputs and 24 analog input unit was used as a control unit which communicated with the main computer.

The dimensions of rooting bench were 1000x1000x800 mm and the depth was 300 mm. Thermal insulation was applied on the base and the sides of the bench for preventing the loss of the heat. The perlite media in rooting bench was heated from the bottom of bench.

The automated drip irrigation system was used to keep the moisture of the rooting media at the desired levels. Drip irrigation system consisted of a solenoid valve, irrigation pipes and nozzles.

Water pipe heating system which was arranged spirally on upper surface of the rooting bench consisted of a hot water tank with the capacity of 180 liters, a resistance, a PT100 (Platinum Resistance Thermometers) temperature sensor, a circulation pump and heating pipes (Figure 2). Hot water was circulated in the heating pipe by the pump which was connected to hot water output of the tank.

Figure 2. Placement of the floor heating pipe on the bench surface

PT100 temperature and Waterscout SM100 moisture sensors, one for each rooting bench, are used to measure temperature and humidity values in the bench. These sensors were integrated directly into the control system to measure the moisture and temperature of the rooting media continuously and provided the data flow. Sensor readings were recorded with Hioki LR8400-20 model data logger.

Perlite substance was used as a rooting media, measurements were performed 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 (Table 1).

The water tank temperature was set at 10 °C which was over the temperature of rooting media.

Table 1. Temperature and moistures levels for the experiments.

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

RESULTS AND DISCUSSION

The control of the temperature and moisture at 18 °C and 40 % moisture level

Twelve hours data received from SM100 moisture sensor and PT100 temperature sensor at 18 °C and low (40%) moisture level (Figure 3).

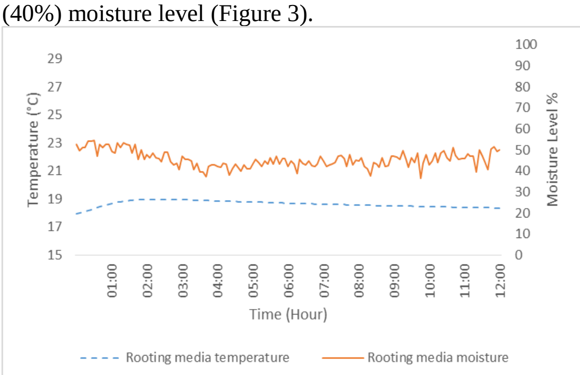

Figure 3. 18°C - 40% moisture level

Table 2. 18°C - 40% moisture level

	Laboratory temperature	Rooting media temperature	Rooting media moisture
Min	18.37	17.97	33.17
Max	18.80	18.98	57.04
Mean	18.61	18.65	45.53
SD	0.08	0.22	3.85
CV	0.46	1.17	8.46

In 12 hours of observation, the lowest and highest temperatures were 17.97 °C and 18.98 °C respectively. The mean temperature reading was 18.65 °C with a 0.22 standard deviation and 1.17 coefficient of variation (CV).

The lowest and highest rooting medium moisture were 33.17% and 57.04% respectively. The mean rooting media moisture was 45.53% with a 3.85 standard deviation and 8.46 coefficient of variation.

The settling time was reached after an hour. Then, stable and precious control occurred (Figure 3).

The control of the experiment on 18 °C and 60 % moisture

Twelve hours data was received from SM100 moisture sensor and PT100 temperature sensor at 18 °C and moderate (60%) moisture level. (Figure 4).

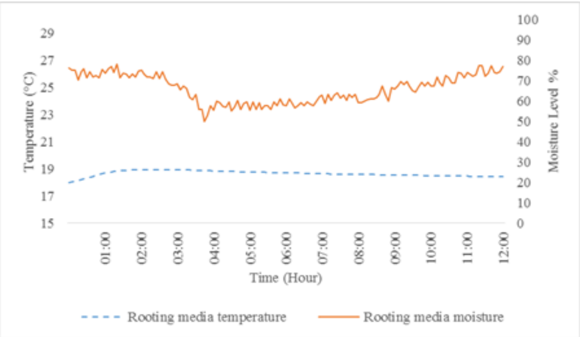

Figure 4. 18°C - 60% moisture level

Table 3. 18°C - 60% moisture level

	Laboratory temperature	Rooting media temperature	Rooting media moisture
Min	18.77	18.00	48.98
Max	19.20	18.97	81.28
Mean	19.01	18.67	66.31
SD	0.08	0.19	6.51
CV	0.45	1.06	9.81

In 12 hours of observation, the lowest and highest temperatures were 18.00 °C and 18.97 °C respectively. The mean temperature reading was 18.67 °C with a 0.19 standard deviation and 1.06 coefficient of variation.

The lowest and highest rooting media moisture were 48.98% and 81.28% respectively. The mean rooting media moisture was 66.31% with a 6.51 standard deviation and 9.81 coefficient of variation.

Stable and precious control was achieved at 18 °C and 60% moisture level (Figure 4).

The control of the experiment on 18 °C and 80 % moisture

Twelve hours data was received from SM100 moisture sensor and PT100 temperature sensor at 18 °C and high (80%) moisture level. (Figure 5).

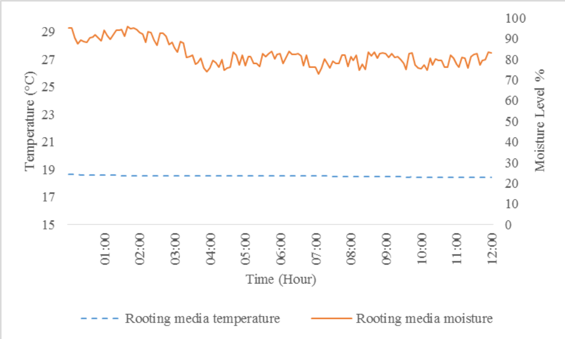

Figure 5. 18°C - 80% moisture level

Table 4. 18°C - 80% moisture level

	Laboratory temperature	Rooting media temperature	Rooting media moisture
Min	19.13	18.45	68.24
Max	19.79	18.63	97.41
Mean	19.42	18.51	82.47
SD	0.14	0.05	5.68
CV	0.72	0.25	6.89

In 12 hours of observation, the lowest and highest temperatures were 18.45 °C and 18.63 °C respectively. The mean temperature reading was 18.51 °C with a 0.05 standard deviation and 0.25 coefficient of variation.

The lowest and highest rooting media moisture were 68.24% and 97.41% respectively. The mean rooting media moisture was 82.47% with a 5.68 standard deviation and 6.89 coefficient of variation.

Stable and precious control was also achieved at 18 °C and 80% moisture level (Figure 5).

The control of the experiment on 22 °C and 40 % moisture

Twelve hours data received from SM100 moisture sensor and PT100 temperature sensor at 22 °C and low (40%) moisture level (Figure 6).

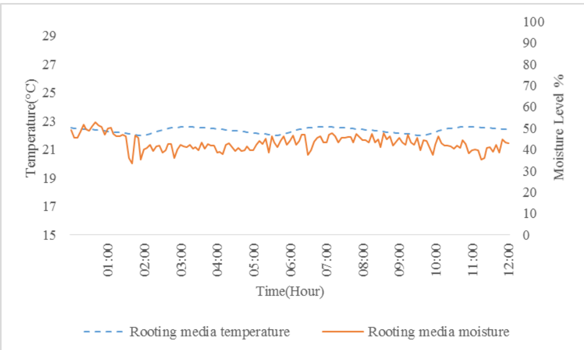

Figure 6. 22°C - 40% moisture level

Table 5. 22°C - 40% moisture level

	Laboratory Temperature	Rooting media temperature	Rooting media moisture
Min	20.16	21.98	29.15
Max	20.94	22.58	54.62
Mean	20.62	22.34	43.15
SD	0.18	0.19	3.49
CV	0.91	0.84	8.09

In 12 hours of observation, the lowest and highest temperatures were 21.98 °C and 22.58 °C respectively. The mean temperature reading was 22.34 °C with a 0.19 standard deviation and 0.84 coefficient of variation. The temperature values of the rooting medium was controlled at around 22 °C.

The lowest and highest rooting media moisture were 29.15% and 54.62% respectively. The mean rooting media moisture was 43.15% with a 3.49 standard deviation and 8.09 coefficient of variation.

Stable and precious control was achieved at 22 °C and 40% moisture level (Figure 6).

The control of the experiment on 22 °C and 60 % moisture

Twelve hours data was received from SM100 moisture sensor and PT100 temperature sensor at 22 °C and moderate (60%) moisture level (Figure 7).

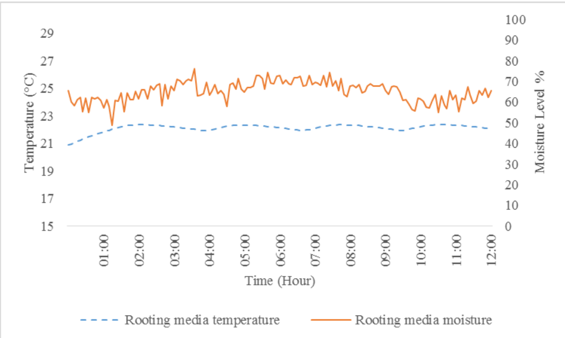

Figure 7. 22°C - 60% moisture level

Table 6. 22°C - 60% moisture level

	Laboratory Temperature	Rooting media temperature	Rooting media moisture
Min	19.90	20.88	19.09
Max	21.15	22.36	82.62
Mean	20.48	22.12	65.39
SD	0.27	0.27	4.63
CV	1.35	1.21	7.10

In 12 hours of observation, the lowest and highest temperatures were 20.88 °C and 22.36 °C respectively. The mean temperature reading was 22.12 °C with a 0.27 standard deviation and 1.21 coefficient of variation. The temperature values of the rooting medium was controlled at around 22 °C.

The lowest and highest rooting media moisture were 19.09% and 82.62% respectively. The mean rooting media moisture was 65.39% with a 4.63 standard deviation and 7.10 coefficient of variation.

Stable and precious control was achieved at 22 °C and 60% moisture level (Figure 7).

The control of the experiment on 22 °C and 80 % moisture

Twelve hours data was received from SM100 moisture sensor and PT100 temperature sensor at 22 °C and high (80%) moisture level (Figure 8).

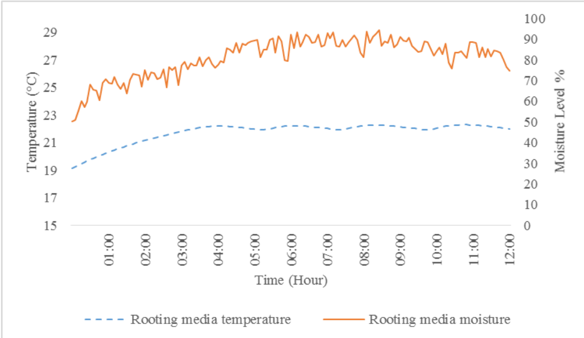

Figure 8. 22°C - 80% moisture level

Table 7. 22°C - 80% moisture level

	Laboratory Temperature	Rooting media temperature	Rooting media moisture
Min	18.95	19.15	47.23
Max	19.66	22.29	95.30
Mean	19.39	21.76	81.60
SD	0.14	0.74	8.92
CV	0.91	0.84	8.09

In 12 hours of observation, the lowest and highest temperatures were 19.15 °C and 22.29 °C respectively. The mean temperature reading was 21.76 °C with a 0.74 standard deviation and 0.84 coefficient of variation. The temperature values of the rooting medium was controlled at around 22 °C.

The lowest and highest rooting media moisture were 47.23% and 95.30% respectively. The mean rooting media moisture was 81.60% with a 8.92 standard deviation and 8.09 coefficient of variation.

Stable and precious control was achieved at 22 °C and 80% moisture level (Figure 8).

The control of the experiment on 26 °C and 40 % moisture

Twelve hours data was received from SM100 moisture sensor and PT100 temperature sensor at 26 °C and low (40%) moisture level (Figure 9).

In 12 hours of observation, the lowest and highest temperatures were 25.93 °C and 26.29 °C respectively. The mean temperature was 26.11 °C with a 0.102 standard deviation and 0.39 coefficient of variation. The temperature values of the rooting medium was controlled at around 26 °C.

The lowest and highest rooting media moisture were 31.28% and 57.04% respectively. The mean rooting media moisture was 46.12% with a 3.97 standard deviation and 8.61 coefficient of variation.

Stable and precious control was achieved at 26 °C and 40% moisture level (Figure 9).

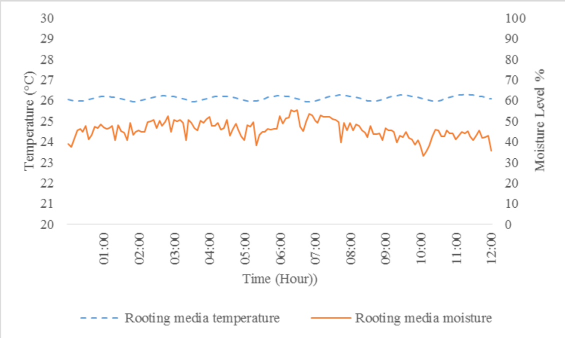

Figure 9. 26°C - 40% moisture level

Table 8. 26°C - 40% moisture level

	Laboratory Temperature	Rooting media temperature	Rooting media moisture
Min	20.20	25.93	31.28
Max	20.59	26.29	57.04
Mean	20.39	26.11	46.12
SD	0.09	0.10	3.97
CV	0.45	0.39	8.61

The control of the experiment on 26 °C and 60 % moisture

Twelve hours data was received from SM100 moisture sensor and PT100 temperature sensor at 26 °C and moderate (60%) moisture level (Figure 10).

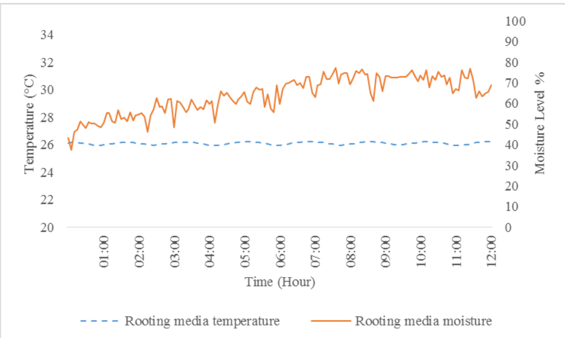

Figure 10. 26°C - 60% moisture level

12 hours of observation, the lowest and highest temperatures were 25.93 °C and 26.23 °C respectively. The mean temperature reading was 26.10 °C with a 0.08 standard deviation and 0.33 coefficient of variation. The temperature values of the rooting medium was controlled at around 26 °C.

The lowest and highest rooting media moisture were 33.99% and 79.62% respectively. The mean rooting media moisture was 64.24% with a 8.97 standard deviation and 13.96 coefficient of variation.

Stable and precious control was achieved at 26 °C and 60% moisture level (Figure 10).

Table 9. 26°C - 60% moisture level

	Laboratory Temperature	Rooting media temperature	Rooting media moisture
Min	20.04	25.93	33.99
Max	21.14	26.23	79.62
Mean	20.56	26.10	64.24
SD	0.24	0.08	8.97
CV	1.19	0.33	13.96

The control of the experiment on 26 °C and 80 % moisture

Twelve hours data was received from SM100 moisture sensor and PT100 temperature sensor at 26 °C and high (80%) moisture level (Figure 11).

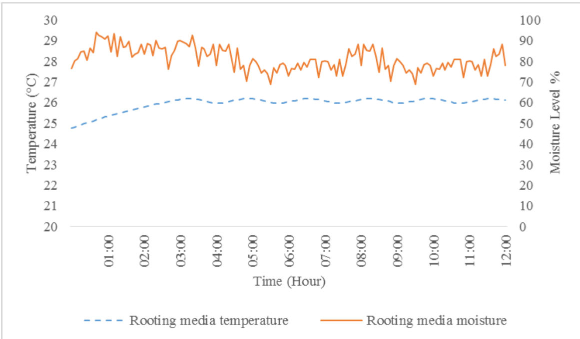

Figure 11. 26°C - 80% moisture level

Table 10. 26°C - 80% moisture level

	Laboratory Temperature	Rooting media temperature	Rooting media moisture
Min	20.06	24.75	63.51
Max	20.33	26.19	96.70
Mean	20.18	25.96	81.51
SD	0.04	0.32	6.29
CV	0.22	1.23	7.72

In 12 hours of observation, the lowest and highest temperatures were 24.75 °C and 26.19 °C respectively. The mean temperature reading was 25.96 °C with a 0.32 standard deviation and 1.23 coefficient of variation. The temperature values of the rooting medium was controlled at around 26 °C.

The lowest and highest rooting media moisture were 63.51% and 96.70% respectively. The mean rooting media moisture was 81.51% with a 6.29 standard deviation and 7.72 coefficient of variation.

Stable and precious control was achieved at 26 °C and 80% moisture level (Figure 11).

CONCLUSIONS

40%, 60%, 80% moisture reading were examined at 18 °C (Figure 3, 4, 5). The heating system was started when needed and stopped when the desired level was reached by the computer controlled system.

40%, 60%, 80% moisture level graphs were examined at 22 °C (Figure 6, 7, 8). The heating system started running when the rooting media temperature felt below the set temperature (22 °C).

40%, 60%, 80% moisture level graphs were examined at 26 °C (Figure 9, 10, 11). The heating system started running when the rooting media temperature felt below the set temperature (26 °C).

Good control of temperature of rooting medium was achieved at 40% moisture level.

Precise control of the temperature of perlite medium was achieved with a high accuracy. CV is less than 3.38 for all temperature levels (Table 2-10). The result showed that accuracy of the control for temperature variable decreased with increasing moisture level.

Similarly, precise control of the moisture of perlite medium was achieved with a high accuracy. Coefficient of variation is less than 13.96 for all moisture levels (Table 2-10).

Automated rooting system was able to perform all the functions required and was successful keeping the temperature and humidity at set-up levels.

The system could increase the rooting ratio and quality in propagation by cutting.

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