MISR JOURNAL OF AGRICULTURAL ENGINEERING
https://mjae.journals.ekb.eg/

ISSN-Print: 1687-384X
ISSN-Online: 2636-3062

Misr J. Ag. Eng., 39 (4): 493 - 508

DOI: 10.21608/mjae.2022.148880.1080

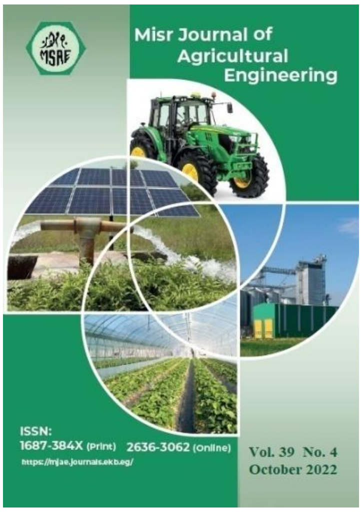
SCHEDULING A SMART HYDROPONIC SYSTEM TO RAISE WATER USE EFFICIENCY

Ahmed Ibrahim Abd-elhakim[1&*] and Helal Samy Helal[2]

[1] Researcher, Irrigation and Drainage Eng. Dept., Ag. Eng. Res. Inst., (ARC), Giza, Egypt.

[2] Researcher, Ag. Mechanization Operations Systems Dept., Ag. Eng. Res. Inst., (ARC), Giza, Egypt.

* E-mail: elhakem19777@gmil.com



Keywords:
Smart hydroponics scheduling; Wi-Fi technique; Composite and Perlite; Water use efficiency; Greenhouse cucumber

ABSTRACT

The presented study aims to create smart hydroponics scheduling to raise water use efficiency of the cucumber crop in a greenhouse by setting up and building a smart Wi-Fi controller unit based on the limited moisture sensing level in the growth media (sand). The water retention materials was added to the growth media (sand) like, composite and perlite compared to sand only as a control. The experimental study was carried out at Tractors and Farm Machinery Research and Test Station, Alexandria Governorate. The results showed that using composite and perlite materials led to increase the moisture content for growth media compared with sand only. The lowest water consumption (Wt) was 115 L/m^2 by using composite treatment, while the highest Wt was 211 L/m^2 with sand-only treatment. The highest cucumber yield (Y) was 19.7 kg/m^2 by using the perlite, while the lowest Y was 12.7 kg/m^2 with sand only. The highest water use efficiency (WUE) was 167 kg/m^3 by using the treatment of composite, while the lowest WUE was 60 kg/m^3 with sand-only treatment. In contrast, WUE increased by (177, 158 %) by using composite and perlite materials with sand as growth media compared with sand only. According to the obtained results, applying a smart scheduling system recommend based on the Wi-Fi technique with composite to improve water retention in the sandy media. Thus, this led to save water in the hydroponics and raising yield and WUE.

INTRODUCTION

Global climate changes and warming cause severe threats to water use and food security. Consequently, smart hydroponic systems are a promising direction to save water consumption in agricultural irrigation and developing sustainable agriculture. This necessitates an increased focus on improving the efficiency of water usage in irrigation agriculture through smart and automated control methods such as Wi-Fi, the Internet of things (IoT), and advanced control strategies being leveraged in managing irrigation systems. This achieves improved monitoring and control of irrigation farming (**Abioye, et al., 2020**).

Crop productivity can be increased by considering environmental conditions. Crop Quality depends on the factor of temperature, humidity, and substrate moisture (**Seethalakshmi, et**

al., 2021). The cucumber crop from vegetable crops which are required a warm climate for seed germination and growth of plants, where the best temperature for plant growth rate is from 18 to 20 °C at night and 21 to 24 °C during the day. The growth of the cucumber plant growth rate decreases with the low temperature. It causes the exposure of seeds to the fixed temperature of 12 °C to affect the composition of fatty substances which is a falling in the installation of the cell membrane. It has been mentioned that the cucumber crop in the warmed greenhouses under the Egyptian conditions reached five times the crop in non-warmed greenhouses (**Zaki, et al., 2010; Hassan, 2012; and Chemicals, 2014**). The optimum daily average air temperature is 15-24°C (65-75°F). Optimum temperatures for growth are at night, about 18°C, and during the day, about 28°C accompanied by high light intensity (**Chemicals, 2014**). High relative humidity (RH) generally favors growth. However, reasonable growth can be achieved at medium or low relative humidity. The crop can adjust to and withstand relative humidity from low to very high but reacts very sensitively to drastic and frequent variations in relative humidity. Other disadvantages of cropping under conditions of high relative humidity include the increased risk of water condensing on the plants and the development of serious diseases. The resultant low transpiration rates are blamed for inadequate absorption and transport of certain nutrients, especially calcium to the leaf margins and fruit. At low relative humidity, irrigation becomes critical, because large quantities of water must be added to the growth medium without constantly flooding the roots and depriving them of oxygen. Furthermore, low relative humidity favors the growth of powdery mildew and spider mites, which alone can justify installing and operating misting devices (**Hassan, 2012; Chemicals, 2014**).

Excessive moisture in the growth medium weakens the cucumber plant and increases its susceptibility to diseases that affects plants through the roots and through the base of the stem. Also, wetting the surface layer of the growth medium for long periods leads to an increase in surface evaporation and thus an increase in relative humidity, which leads to an increase in disease aerial growth. Therefore, irrigation must be done according to the plants' needs, which requires the use of a smart hydroponics scheduling system for uniformity irrigation (**Khalil, 1998; Ismail, 2002; Hassan, 2012**).

Traditional farming results in a reduction of yield under the changing climatic conditions and to tackle this problem water usage in irrigation must use the smart irrigation system using a controller that processes not only the field data from soil moisture sensor but also analyzes the condition of the future weather data from an open API " application programming interface", with these parameters the occurrence of rainfall is predicted and based on which irrigation is carried out. It results in water conservation and a reduction in energy consumption. This technique can also be carried out in a hydroponic system, which is a method of growing crops without soil (**Seethalakshmi, et al., 2021**).

Hydroponic lives rely on nutrients from the water. Hydroponics is very important to save water, the timing of when the water should be added and replaced nutrients, and it would be very inconvenient if the plant owner has Hydroponics plants with a lot. The recycling of the drainage water resulted in a 33% reduction in potable water used for irrigation in cucumber production (**Grewal, et al., 2011**). Therefore, it found hydroponics plants have various types of planting media such as Rockwell, sponge, coconut, and other coconut powder. Growth media and soilless growing systems have a significant effect on the microbiological characteristics in the area surrounding the root. There are the physical properties of reused perlite grow-bags remained quite steady over five cropping years and perlite reuse had no negative effect on the fertigation, growth, and productivity of sweet pepper and melon crops (**Acuña, et al., 2013**). Hydroponic irrigation scheduling based on soil moisture sensors is one of the used approaches to assist with the determination of the timing and volumes of irrigation of vegetable crops. The use of soil moisture sensors for irrigation scheduling of vegetable crops was reviewed by (**Thompson and Gallardo, 2003; Gallardo et al., 2013; and Pascale et al., 2017**). The various classes of soil/substrate moisture sensors that have been used in greenhouse crops are reviewed, regarding their general suitability and practical use with vegetable crops under greenhouse conditions are reviewed (**Incrocci, et al., 2020**). Field capacity can be determined in the field or using soil cores (**Cassel and Nielsen, 1986**), and the Refill Point can then be defined by an allowable depletion of soil moisture. Depending on the sensor configuration, continuously monitored volumetric soil moisture data can be used to assess the depth of infiltration, rate of crop uptake of soil water in different soil depths, and horizontal movement of applied water (**Thompson and Gallardo, 2003**). The use of volumetric soil water content for irrigation scheduling can be applied to a particular location to define Full and Refill Points. Various types of sensors can measure volumetric soil water content, the most commonly used for irrigation scheduling and research applications are dielectric sensors. Previously, the neutron moisture meter was commonly used, but its use has been largely discontinued on account of the radiation hazard. The maximum limit of soil moisture is referred to as the full point or upper limit (field capacity), and the minimum limit of soil moisture is referred to as the refill point or lower limit permanent wilting point (PWP) (**Cassel and Nielsen, 1986**).

To control in growth medium moisture in hydroponics plants, need to do an automatic system that can automatically hydrate the hydroponics if necessary such as an Arduino controller system. The improvement of automated fertigation systems has gained great importance for the efficient use of water and fertilizers and for environmental sustainability in recent decades. a new improved fertigation method using (proportional integral derivative, PID) controlled method, which leads to a better adjustment of the leaching fraction, substantially improves the fruit size of a tomato crop in soilless culture and consequently increases the economic benefits (**Rodríguez et al., 2014**). A control tool was developed for the flow of nutrients of hydroponic plants automatically using an Arduino microcontroller and controlled by a smartphone, where the microcontroller can also send data of fluid level (solution) and temperature around the plant to the smartphone android of the owner of the hydroponics plant. The height of the nutrient solution (water) is detected by the Ultrasonic sensor HC-SR04 and the temperature is detected by the temperature sensor LM35. Data from the sensor will forward into Arduino Uno and displayed in a liquid crystal display (LCD) then via wireless fidelity (WIFI) ESP8266 module will transmit the height of the nutrient solution and the temperature around the plants to the Android smartphone (**Sihombing et al., 2018**).

The use of composite material is considered as an effective way to solve the problems of water limitation using it in hydroponic and that consists of mixed materials in the rate of 5:1

from local "Aswan Clay and Hydrogel (super absorption polymer, SAP) (**Abd-elhakim, 2019**). Polymer material was able to increase soil moisture for longer periods, improve seed emergence, and reduce crust problems (**Maghchiche et al., 2010; Ali, 2011; and Zin El-Abedin, et al., 2015**). Some researchers, (**Andry, et al., 2009, Yang et al., 2014, and Al-Jabari, et al., 2019**) indicated that (super absorption polymer, SAP) featured good water retention properties and was very effective in enhancing water uptake and utilization of water for plants growth where hydrophilic polymers swell by absorbing huge volumes of water. This property has led to many practical applications in arid regions for improving water retention in sandy soils and the water supply to plants grown on them.

The objective of this study was to improve and raise water use efficiency through scheduling a smart hydroponic system for greenhouse cucumber crop by setting up and building a smart Wi-Fi controller unit based on the limited moisture level in the growth medium and which contains water storage materials composite as thus, reduces water and nutrients in drain solution.

MATERIAL AND METHODS

1. Building a Smart hydroponics system

1.1. Growth media moisture monitoring

Smart hydroponics irrigation system scheduling was based on use of volumetric soil water content for growth media (sand). Soil moisture is one of the most crucial parameters needed for plant growth. Monitoring of growth media moisture content for opened hydroponic systems is necessary towards ensuring optimal irrigation scheduling. In this study was monitoring of growth media moisture content depended on field capacity (FC) at stop-time, and permanent wilting point (PWP) at run-time. Therefore, the Running time of the pump is based on the moisture level of sandy soil. Field capacity can be determined in the field or using soil cores and the Refill Point can then be defined by an allowable depletion of soil moisture (**Thompson and Gallardo, 2003**). Where run-time was 20% of moisture level (FC), stop-time was 10% of moisture level (PWP) (**Ismail, 2009**). The growth medium was three cases based on the degree of irrigation water retention. These cases were sand plus composite materials (100 gm per bucket), sand plus perlite, and sand only as a control. Smart soil moisture monitoring system for hydroponics management was using Wi-Fi unit plus controller unit (Esp8266 module). This is interfaced with different sensors for real-time soil moisture fluxes for monitoring crop water use for irrigation decisions and scheduling in hydroponics.

1.2. The experimental setup

The management of the irrigation scheduling system in hydroponics depends on sensing moisture level in a growth medium that contains water preservative to save irrigation water and thus raise the efficiency of water use. When the moisture level in the growing medium reaches 10% or less, the sensor sends a signal to the control unit to operate the irrigation system. This is done when the control unit gives a signal to open the Solenoid valve and operate the pump, and when the moisture level in the growing medium reaches 20% or more, the sensor sends a signal to the control unit to stop the irrigation process by stopping the pump and then closing the valve. During the irrigation process, the irrigation time and flow rate by the flow rate sensor are recorded as shown every 15 min through the Wi-Fi network for the internet. This was illustrated in the flow diagram as shown in Fig. 1. The data that was recorded included moisture content of the growth medium, irrigation time, flow rate for each case, in addition to air temperature, and relative humidity every15 minutes inside greenhouse in Google Sheet through the Wi-Fi network for the internet as shown in Fig. 3. The retrieved data can be uploaded by the Wi-Fi technique to examine and process data. The users can view the data using a mobile phone. Thus farming is done effectively with automated irrigation system based on the weather and soil moisture.

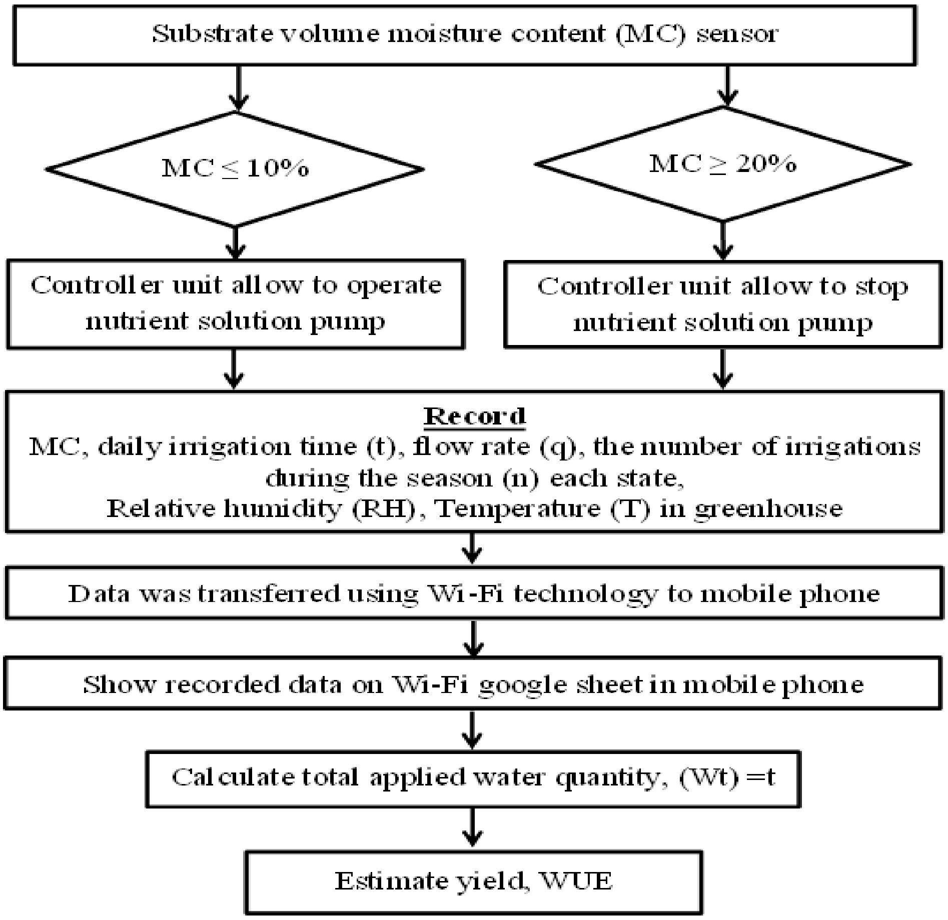


Fig. 1: Flow diagram of scheduling a smart hydroponic system.

1.3. <u>Components of Smart control system</u>

The control unit for smart hydroponics system was as shown in Fig. 2 consists of the following: **1) Capacitive Soil Moisture Sensor:** This is a new type of waterproof soil moisture sensor introduced by DF Robot. Compared with the other version of the soil moisture sensor, it has increased waterproof performance, optimized corrosion resistance, increased plate length, and optimized circuit performance. Compared with the resistive sensor, the capacitive soil moisture sensor solves the problem that the resistive sensor is easily corroded, and can be inserted into the soil for a long time without being corroded. The sensor has increased waterproof performance, and the sensor can still be used normally after being immersed in water; the length of the capacitive electrode plate is increased, and the soil moisture information can be measured more accurately. The sensor has a wide input voltage and can work in a wide voltage range of 3.3V-5.5V (Output Voltage: 0 ~ 2.9VDC).

Dimensions is 6.89 x 1.18 inches or 175 x 30 mm (L x W). **2) Esp8266 Wi-Fi controller:** The ESP8266 is a low-cost Wi-Fi microchip, with built-in (Transmission Control Protocol/Internet Protocol, TCP/IP) networking software, and microcontroller capability. This small module allows microcontrollers to connect to a Wi-Fi network and make simple TCP/IP connections. WiFi Controller is used to sending and receives messages to Arduino with ESP8266 WiFi module using TCP/IP Protocol. To connect with the device you have to add the IP and PORT of the device and select it. **3) Solenoid valve:** Plastic Solenoid Valve, it specifications 12v, 0.5 inches. **4) DC pump**: Specifications of the DC pump were 12 Volts, 15 Watt, flow 4.5 LPM and press 6.8 bars. **5) Water Flow Sensor YFS201**: This sensor measures the flow of water. The sensor has a 7mm coupling on both sides and is therefore easy to connect to a 6mm hose. The output of the sensor gives 98 pulses per second with a duty cycle of approximately 50% for each liter of fluid passing through per minute: Q [L/min] = pulse [Hz]/98. Specifications were as follows: Voltage range was 5-24V. Pulse frequency per L/min was 98Hz. Measuring range was 0.3-6L/min (with an accuracy of +-10%). Maximum water pressure was 0.8MPa. Working temperature was -25-80^{o}C. Duty cycle pulse: 50% +-10%.Voltage pulse (with 5V as input voltage) was 4.7V. **6) Temperature and Humidity sensor:** Temperature and Humidity sensor module (DHT11) to sense temperature (T) and relative humidity (RH) inside greenhouse **7) Router:** Access point router to provide wireless (Wi-Fi) internet network by Mobile. **8) Google sheet**: Use Google Sheets to create and edit online spreadsheets to save data for the possibility of analysis.

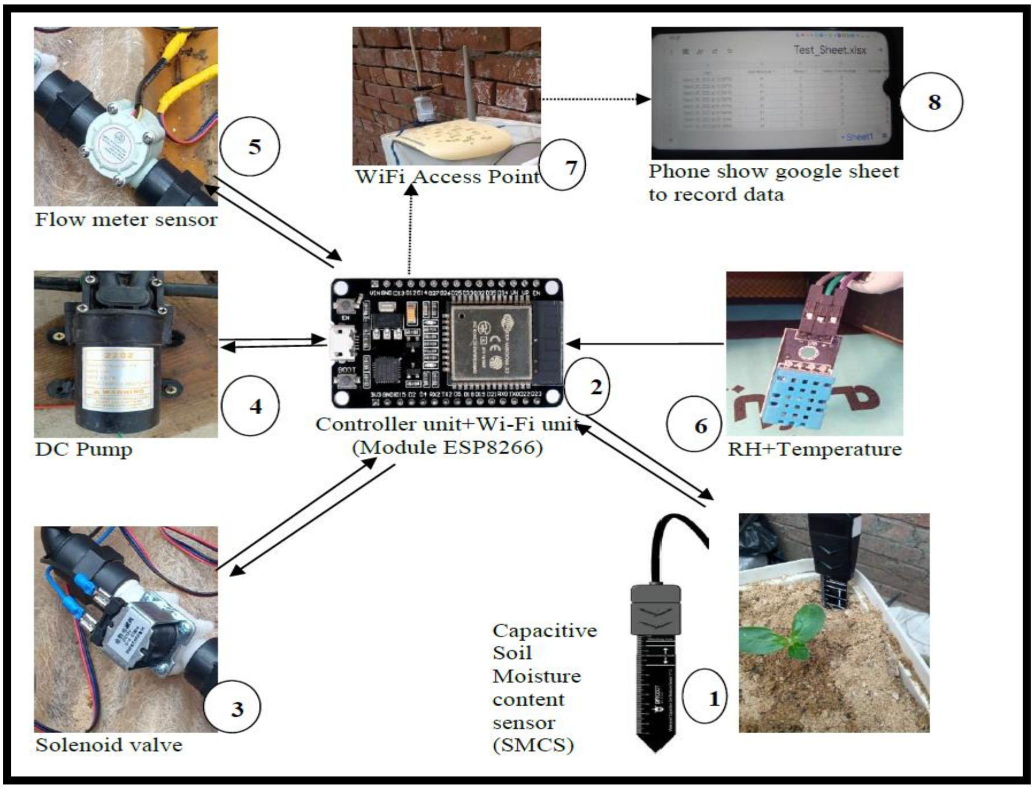


Fig. 2: Components of smart hydroponics management system.

2. Experimental site description

The field experiments were carried out in a plastic greenhouse (dimensions: length of 12 m, the width of 4m, and height in the range of 2-3m). The greenhouse is situated at Tractors and

Farm Machinery Research and Test Station, Alexandria Governorate (Latitude 31.24 N, and Longitude 29.98 E) for one season in 2022 from 10th March to the 18th of June. Weather data inside the greenhouse were recorded every 15 min based on a Wi-Fi controller unit using sensors for temperature (°C), and humidity (%). Weather data for the experimental site outside the greenhouse was taken from El-Nouzha airport station, Alexandria Governorate, Egypt which includes daily observations for temperature, and humidity.

3. Plant materials and growth conditions

The experiments were carried out for scheduling a smart drip hydroponic system on the Cucumber crop (Cucumis sativus) in dutch buckets inside a plastic greenhouse. The drip hydroponic system was opened. An irrigation system was dependent on a soil moisture sensor in the growth medium. The growth medium was three cases based on the degree of irrigation water retention. Each case was a comparison treatment. The first case was sand plus Composite which consists of mixed materials at the rate of 5:1 from local "Aswan Clay and Hydrogel (super absorption polymer, SAP) according to (**Abd-elhakim, 2019**) (100 gm per bucket). The second case was sand plus Perlite by 4:1. The third case was sand only as a control. The used nutrient solution in Hydroponics was Hoagland. The treatment was divided into 4 replicates. Each replicate was specified to contain a number of buckets were 10 buckets. The bucket scale was (0.3 m width x 0.3 m length x 0.25 m depth). Each bucket is planted with one seedling. The growth media was disinfected and sterilized before starting cultivation. Distances between buckets were 50 cm. The drip irrigation system used lateral lines containing online emitters of 4 L/hr discharge, where each bucket used one emitter. Specifications of the pump were 12 V, 15 W, flow 4.5 L/min and press 6.8 bars. The experimental description was shown in Fig. 3. The statistical analyses were carried out based on a completely randomized design (CRD). The obtained data were analyzed by (Minitab) software package (version16). The mean values of the three treatments were compared using L.S.D. test at a significance level of 0.05.

4. <u>Measurements and calculations</u>

a. Water consumption during season: W_t, total consumed water during the growth season was calculated to assist the relations based on data recorded by a designed smart control system for hydroponics,

$$\boldsymbol{W_t = q \times t \times n} \text{--} \quad (1)$$

Where W_t is total consumed water during the growth season, (L/m^2), q is flow rate (L/min), t is daily irrigation time, (min), and n is the number of irrigations during the season.

b. Cucumber yield: The harvest was in the growing season (2022) at the optimum stage of physiological maturity. Harvesting was done about 102 days after transplanting for one season, respectively. The cucumber yield was determined for each bucket and that represented treatment. The cucumber was hand harvested and weighted using a sensitive scale 0.01gm with a capacity of 2 kg and adjusted to cucumber yield in kg/m^2.

c. Water use efficiency (WUE): **WUE** was calculated according to **James (1988)** as follows:

$$\text{WUE} = \frac{\text{y}*1000}{\text{Wt}} \text{--} \quad (2)$$

Where WUE is Water use efficiency, g/L (kg/m^3), y is Total crop yield, kg/m^2, and W_t is Total applied water, L/m^2.

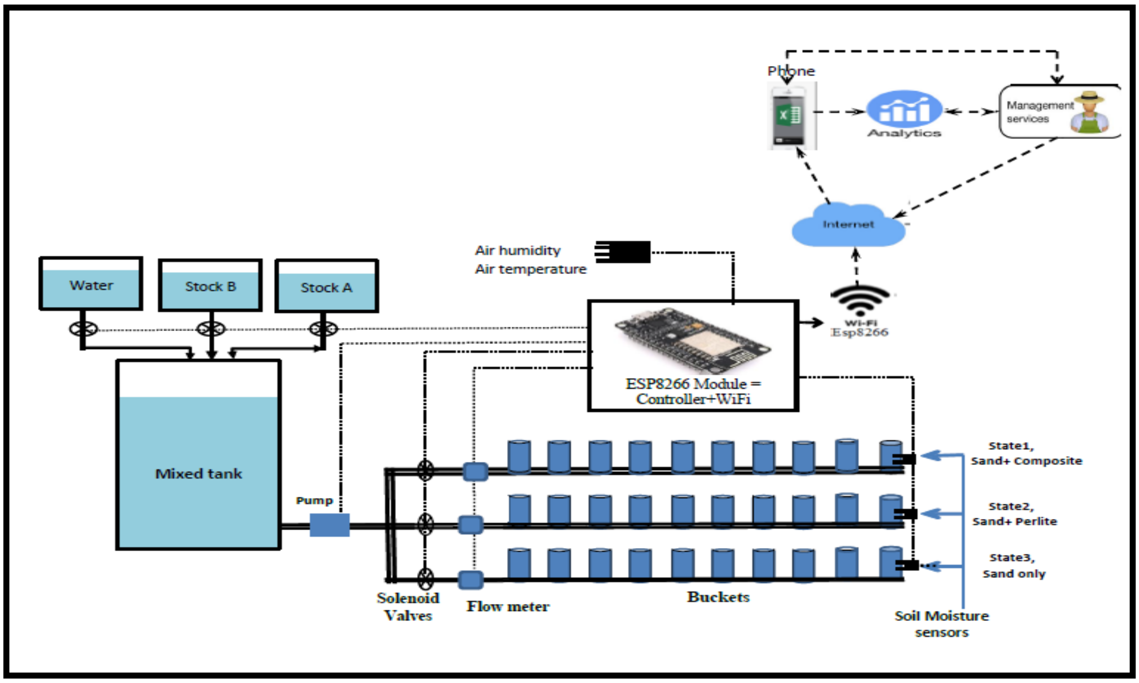


Fig. 3: The general architecture of smart hydroponics drip irrigation systems.

	Date	Soil Moisture 1	Relay 1	Water Flow Average 1	Average Work Time 1	Soil Moisture 2	Relay 2	Water Flow Average 2	Average Work Time 2	Soil Moisture 3	Relay 3	Water Flow Average 3	Average Work Time 3	Temp	Humidity
2	March 26, 2022 at 12:05PM	41	0	0	0	42	0	0	0	59	0	0	0	32	29
3	March 26, 2022 at 12:20PM	41	0	0	0	42	0	0	0	59	0	0	0	33	25
4	March 26, 2022 at 12:35PM	41	0	0	0	41	0	0	0	58	0	0	0	41	16
5	March 26, 2022 at 12:50PM	42	0	0	0	43	0	0	0	60	0	0	0	41	16
6	March 26, 2022 at 01:41PM	41	0	0	0	42	0	0	0	59	0	0	0	40	16
7	March 26, 2022 at 01:56PM	41	0	0	0	42	0	0	0	60	0	0	0	40	15
8	March 26, 2022 at 02:11PM	41	0	0	0	42	0	0	0	61	0	0	0	33	21
9	March 26, 2022 at 02:26PM	42	0	0	0	42	0	0	0	62	0	0	0	31	29
10	March 26, 2022 at 02:41PM	42	0	0	0	42	0	0	0	62	0	0	0	28	35
11	March 26, 2022 at 02:56PM	42	0	0	0	42	0	0	0	63	0	0	0	27	37
12	March 26, 2022 at 03:11PM	42	0	0	0	43	0	0	0	63	0	0	0	26	38
13	March 26, 2022 at 03:26PM	43	0	0	0	43	0	0	0	63	0	0	0	25	39
14	March 26, 2022 at 03:41PM	43	0	0	0	43	0	0	0	63	0	0	0	25	39
15	March 26, 2022 at 03:56PM	43	0	0	0	43	0	0	0	63	0	0	0	24	39
16	March 26, 2022 at 04:11PM	43	0	0	0	43	0	0	0	63	0	0	0	24	39
17	March 26, 2022 at 04:26PM	44	0	0	0	44	0	0	0	64	0	0	0	24	39
18	March 26, 2022 at 04:41PM	44	0	0	0	44	0	0	0	63	0	0	0	23	39
19	March 26, 2022 at 04:56PM	44	0	0	0	43	0	0	0	64	0	0	0	23	39

Fig. 4: The recorded data in Google Sheet of for smart hydroponics.

<u>RESULTS AND DISCUSSIONS</u>

1. Climate conditions

At the beginning of the growing season, the site exposed the low temperature outside of the greenhouse. The optimum temperature has been controlled inside the greenhouse in the range of 20 to 30 ^{o}C during the season by using the temperature sensor in the smart hydroponics system and according to the recommendations by researchers which conforms to (**Zaki, et al., 2010; Hassan, 2012**; **and Chemicals, 2014**) and as shown in Fig. 5. Where, the heater and fans were used to condition the air within the greenhouse. Also, fans were used for the ideal ventilation process to maintain a suitable climate in the greenhouse to maximize the productivity of the cucumber crop.

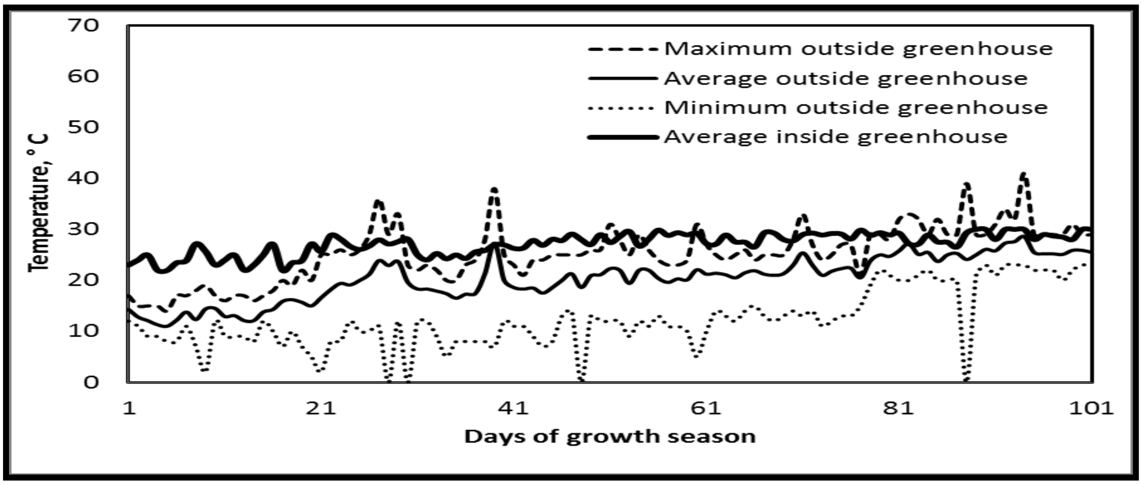


Fig. 5: Daily temperature (^oC) within and outside greenhouse during cucumber growth season from 10 March up to 18 June 2022.

High relative humidity (RH) generally improves growth. The results showed that the relative humidity inside the greenhouse reached an ideal and appropriate range between (40-70 %), which is suitable for the cucumber plant and which conforms to (**Zaki, et al., 2010; Hassan, 2012; and Chemicals, 2014**) as shown in Fig. 6. Where it was found that by tracking the relative humidity readings outside the greenhouse on the experimental site, it was unstable during the season, and this exposes the plants to damage and fungal and insect diseases also, the increased risk of water condensing on the plants and the development of serious diseases under high relative humidity conditions as a result of unstable weather conditions and which conforms to (**Hassan, 2012; and Chemicals, 2014**). This leads to a reduction in productivity of the cucumber crop and as a result industrial heating and ventilation units were being installed in the greenhouse maintaining the appropriate range of relative humidity during the growing season inside the greenhouse, which leads to high productivity and economic returns and saving in irrigation water, which ultimately leads to raising water use efficiency under the smart management system for hydroponics.

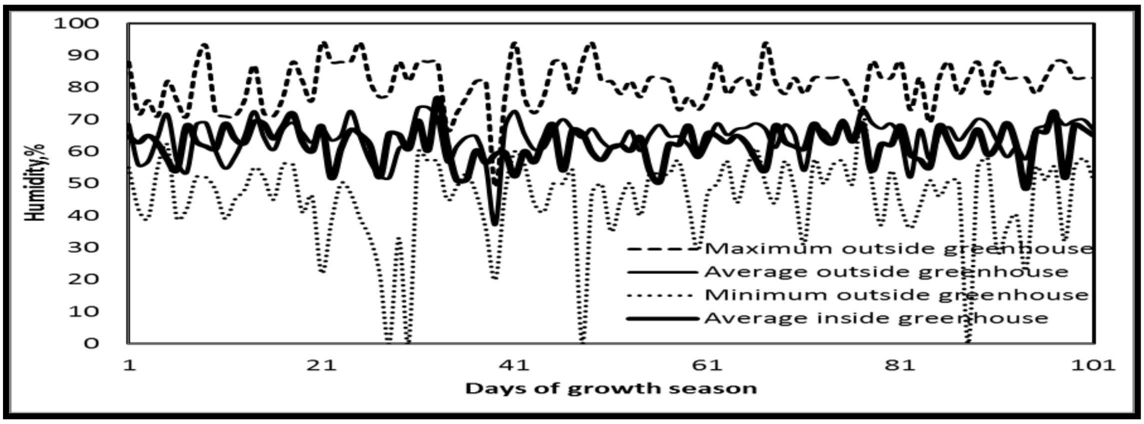


Fig. 6: Daily relative humidity (%) within and outside greenhouse during cucumber growth season from 10 March up to 18 June 2022.

2. The growth media moisture

The results showed that the use of composite then perlite materials with sand as growth media under a smart drip hydroponic system led to increasing the moisture content for long irrigation periods, while using sand only as the growth medium for cucumber growth media led to decreasing the moisture content for short irrigation periods as shown in Fig. 7. composite material property has led to improving water retention in sandy soils and the water supply to plants grown on them and which conforms to (**Andry, et al., 2009, Yang et al., 2014, and Al-Jabari, et al., 2019**). Where, the moisture content may be more or less than the specified range, as the system has been programmed on the basis that the irrigation is always in the early morning, so the moisture levels may vary outside or within the specified range for the beginning or end of irrigation.

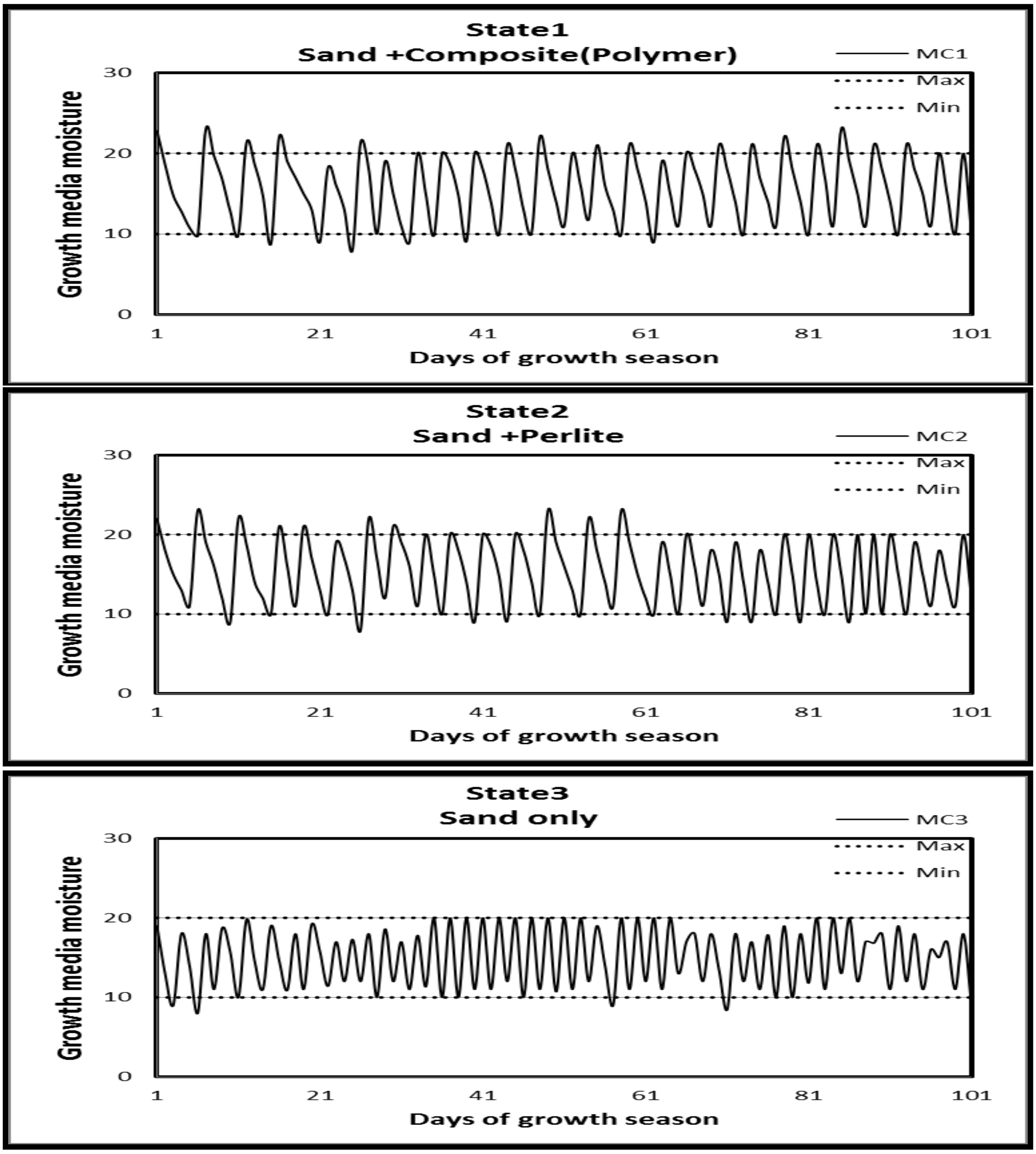


Fig. 7: Effect of using composite and perlite materials on the moisture content compared to sand only under a smart drip hydroponic system.

3. Water consumption during season

Water consumption during the season (W_t) with a smart drip hydroponic system was (115, 127, and 211 L/m^2) for composite, perlite, and sand only treatments, respectively as shown in

Fig. 8. The results showed that the use of composite and perlite materials with sand as growth media led to saving the consumed water by (45.5, 39.8 %) compared to using the growth medium containing sand only. Therefore, found that the highest applied water was achieved with the sand-only treatment, while the lowest applied water was for composite material because of that hydrophilic polymers swell by absorbing huge volumes of water. Thus, this led to a reduction in the number of irrigations during the season and an increase in the period between irrigation and the other, ultimately saving water in the hydroponics and raising water use efficiency which conforms to (**Abd-elhakim, 2019**). This property has led to saving water in sandy soils and the water supply to plants grown on them and which conforms to (**Andry, et al., 2009, Yang et al., 2014, and Al-Jabari, et al., 2019**).

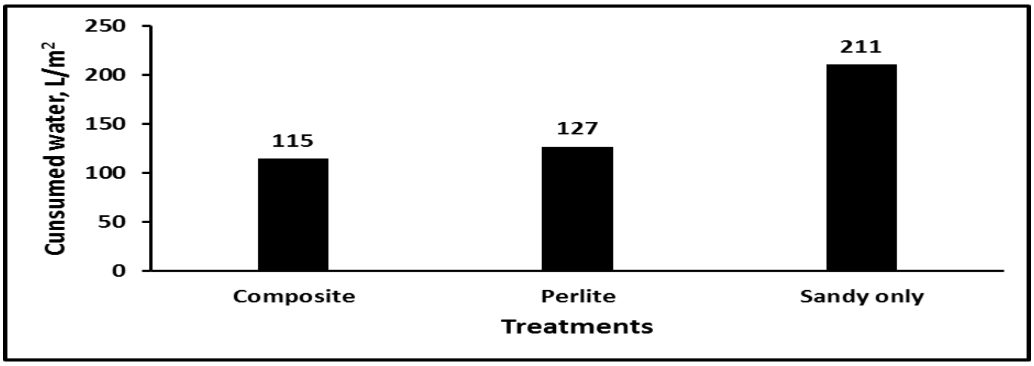


Fig. 8: Effect of using composite and perlite materials on consumed water quantity during the growth season compared to sand only under a smart drip hydroponic system.

Showed polynomial relationships were inferred for two orders to describe consuming water per plant during the growing season in a smart drip hydroponic system using composite, perlite materials, and sand only as shown in Fig. 9. Results demonstrated that using composite led to an increase in the period between irrigation and the other, ultimately decreasing the number of irrigations and saving water in the hydroponics and raising water use efficiency which conforms to (**Andry, et al., 2009, Yang et al., 2014, Abd-elhakim, 2019, and Al-Jabari, et al., 2019**).

4. Cucumber yield

Under use of a smart drip hydroponic system, cucumber yield (Y) was (19.1, 19.7, and 12.7 kg/m^2) for composite, perlite, and sand only treatments, respectively as shown in Fig. 10. The results showed that the use of composite and perlite materials with sand as growth media under a smart drip hydroponic system led to increase cucumber yield by (50, 55 %) compared to using the growth medium contains sand only. A significant effect ($p<0.05$) was observed on cucumber crop productivity for use of composite and perlite materials with sand compared to sand only under a smart drip hydroponic system.

5. Water use efficiency

Under a smart hydroponic system management, the results showed that the use of composite and perlite materials with sand as growth media led to increase water use efficiency by (177, 158 %) compared to using the growth medium contains sand only. This is a result of increased water retention for long periods with use of composite and perlite materials, which led to reduce the amount of the consumed water in hydroponics irrigation and this is what led to save and raise water use efficiency. The statistical analysis under a smart drip hydroponic system with use of composite and perlite materials with sand compared to sand only showed that there was a highly significant effect at the 0.01 probability level on WUE.

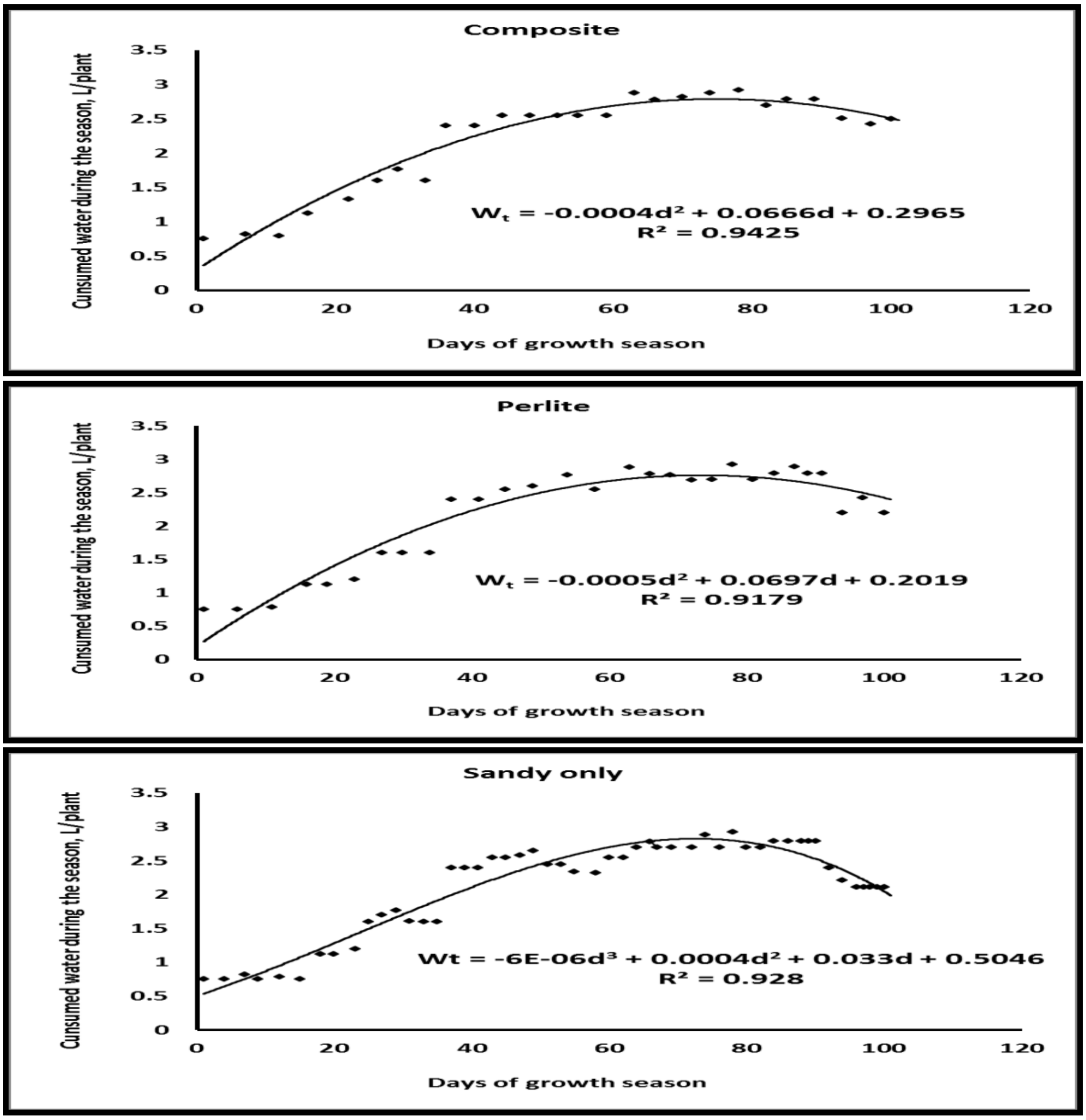


Fig. 9: Consumed water per plant during the growth season in a smart drip hydroponic system using composite, perlite materials and sand only.

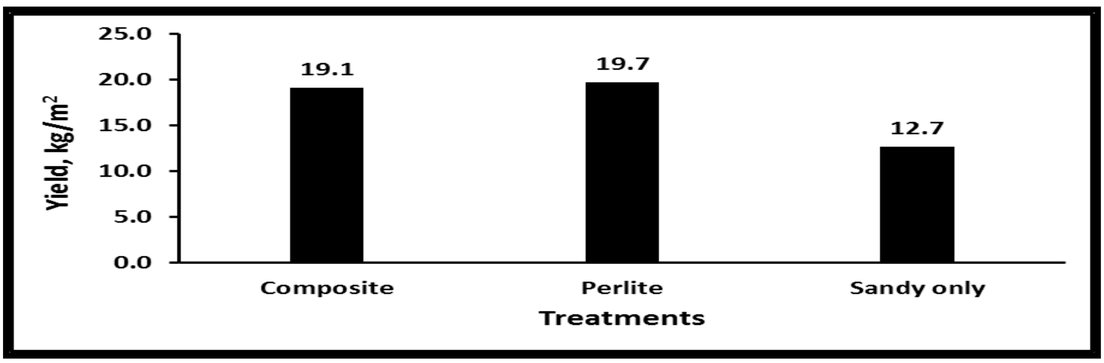


Fig. 10: Effect of using composite and perlite materials on cucumber yield compared to sand only under a smart drip hydroponic system.

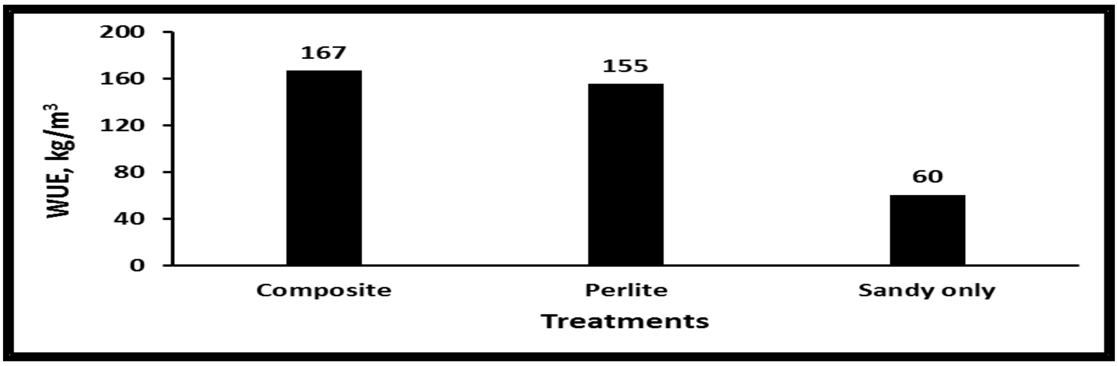


Fig. 11: Effect of using composite and perlite materials on water use efficiency compared to sand only under a smart drip hydroponic system.

CONCLUSIONS

The experiments were carried out to create an intelligent scheduling system of the opened hydroponics to raise the water use efficiency of the cucumber crop in a greenhouse by setting up and building an intelligent Wi-Fi controller unit based on the limited moisture sensing level in the growth media (sand). The water retention materials have been added to the growth media (sand) like, composite and Perlite compared to sand only in addition to controlling greenhouse climate like temperature and relative humidity. It was found that, the smart control system in the greenhouse climate has saved suitable limits for temperature and relative humidity where, the optimum temperature has been controlled in the range of 20 to 30 ^{o}C while, the relative humidity inside the greenhouse reached an ideal and appropriate range between (40-70 %), which is suitable for the cucumber plant during the season. Results showed that the use of composite then perlite materials with sand as growth media under a smart drip hydroponic system led to increasing the moisture content and longer irrigation periods, while using sand only as the growth medium for cucumber growth media led to decreasing the moisture content and shorter irrigation periods. Composite material property has led to improving water retention in sandy soils and the water supply to plants grown on them. Water consumption during the season (W_t) with a smart drip hydroponic system was (115, 127, and 211 L/m^2) for composite, perlite, and sand only treatments, respectively. The highest applied water was achieved with the sand-only treatment, while the lowest applied water was for composite material because of that hydrophilic polymers swell by absorbing huge volumes of water. Thus, this led to a reduction in the number of irrigations during the season and an increase in the period between irrigation and the other, ultimately saving water in the hydroponics and raising water use efficiency. The highest cucumber yield was 19.7 kg/m^2 when using the perlite, while the lowest yield was 12.7 kg/m^2 for sand only. The highest water use efficiency (WUE) was 167 kg/m^3 when using the composite. While the lowest WUE was 60 kg/m^3 for sand only where, WUE increased by (177, 158 %) for composite and perlite materials with sand as growth media compared to sand only. It can be noted that, the statistical analysis of a smart drip hydroponic system with use of composite and perlite materials with sand compared to sand only showed that there was a highly significant effect at the 0.01 probability level on cucumber yield and WUE. Therefore, a smart scheduling system is recommended to apply it based on the Wi-Fi technique with composite to improve water retention in the sandy media, thus this led to saving water in the hydroponics and raising yield and WUE.

REFERENCES

Abd-elhakim, A. I. (2019). Soil conditioner effect on soil wetting patterns under pulsed drip irrigation system. Misr Journal of Agricultural Engineering, 36(2): 473-492.

Abioye, E. A.; Abidin, M. S. Z., Mahmud, M. S. A., Buyamin, S., Ishak, M. H. I., Abd Rahman, M. K. I., and Ramli, M. S. A. (2020). A review on monitoring and advanced control strategies for precision irrigation. Computers and Electronics in Agriculture, 173, 105441.

Acuña, R. A.; Bonachela, S., Magán, J. J., Marfà, O., Hernández, J. H., and Cáceres, R. (2013). Reuse of rockwool slabs and perlite grow-bags in a low-cost greenhouse: Substrates physical properties and crop production. Scientia Horticulturae, 160, 139-147.

Ali, A. F. A. (2011). Study of Conditioning Effect of Hydrogels on Some Physical and Chemical Properties of Sandy Soil and Some Physiological Aspects in Cultivated Plants. A Thesis PhD, Bottany department, Facullty of Science, Sohag University.

Al-Jabari, M.; Ghyadah, R. A., and Alokely, R. (2019). Recovery of hydrogel from baby diaper wastes and its application for enhancing soil irrigation management. Journal of environmental management, 239, 255-261.

Andry, H.; Yamamoto, T., Irie, T., Moritani, S., Inoue, M., and Fujiyama, H. (2009). Water retention, hydraulic conductivity of hydrophilic polymers in sandy soil as affected by temperature and water quality. Journal of Hydrology, 373(1-2): 177-183.

Cassel, D. K.; and Nielsen, D. R. (1986). Field capacity and available water capacity. Methods of soil analysis: Part 1 Physical and mineralogical methods, 5, 901-926.

Chemicals, H. (2014). Nutritional recommendations for cucumber in open field's tunnels and greenhouses. Haifa Chemicals ltd.

Gallardo, M.; Thompson, R. B., and Fernández, M. D. (2013). Water requirements and irrigation management in Mediterranean greenhouses: the case of the southeast coast of Spain. Good Agricultural Practices for Greenhouse Vegetable Crops; Plant Production and Protection Paper, 217, 109-136.

Grewal, H. S.; Maheshwari, B., and Parks, S. E. (2011). Water and nutrient use efficiency of a low-cost hydroponic greenhouse for a cucumber crop: An Australian case study. Agricultural Water Management, 98(5): 841-846.

Hassan, A. A. (2012). The Origins of Protected Agriculture. 1st Ed, Arab House for Publishing and Distribution. Cairo, Egypt.

Incrocci, L.; Thompson, R. B., Fernandez-Fernandez, M. D., De Pascale, S., Pardossi, A., Stanghellini, C., and Gallardo, M. (2020). Irrigation management of European greenhouse vegetable crops. Agricultural Water Management, 242, 106393.

Ismail, S. M. (2002). Design and management of field irrigation systems. 1st Ed. Munshat elmaearif. Alex., Egypt. (In Arabic).

Ismail, S. M. (2009). Planning and Design of Irrigation Systems. Bostan elmarafa library, Alex., Egypt. (In Arabic).

James, L. G. (1988). Principles of farm irrigation systems design. John Wiley and Sons Limited.

Khalil, M. A. I. (1998). Water relations and irrigation systems. Munshat elmaearif. Alex., Egypt. (In Arabic).

Maghchiche, A.; Haouam, A., and Immirzi, B. (2010). Use of polymers and biopolymers for water retaining and soil stabilization in arid and semiarid regions. Journal of Taibah University for science, 4, 9-16.

Pascale, S. D.; Rouphael, Y., Pardossi, A., Gallardo, M., & Thompson, R. B. (2017). Recent advances in water and nutrient management of soil-grown crops in Mediterranean greenhouses. *Acta Horticulturae*, (1170), 31-44.

Rodríguez, D.; Reca, J., Martínez, J., Lao, M. T., and Urrestarazu, M. (2014). Effect of controlling the leaching fraction on the fertigation and production of a tomato crop under soilless culture. Scientia Horticulturae, 179, 153-157.

Seethalakshmi, E.; Shunmugam, M., Pavaiyarkarasi, R., and Joseph, S. (2021). An automated irrigation system for optimized greenhouse using IoT. Materials Today: Proceedings.

Sihombing, P.; Karina, N. A., Tarigan, J. T., and Syarif, M. I. (2018). Automated hydroponics nutrition plants systems using arduino uno microcontroller based on android. In Journal of Physics: Conference Series (Vol. 978, No. 1, p. 012014). IOP Publishing.

Thompson, R. B.; and Gallardo, M. (2003). Use of soil sensors for irrigation scheduling. Improvement of water use efficiency in protected crops. Advanced specialization course. Direccion General de Investigacion y Formacion Agraria de la Junta de Andalucia, HortiMed, FIAPA, Cajamar, 375-402.

Yang, L.; Yang, Y., Chen, Z., Guo, C., and Li, S. (2014). Influence of super absorbent polymer on soil water retention, seed germination and plant survivals for rocky slopes eco-engineering. Ecological Engineering, 62, 27-32.

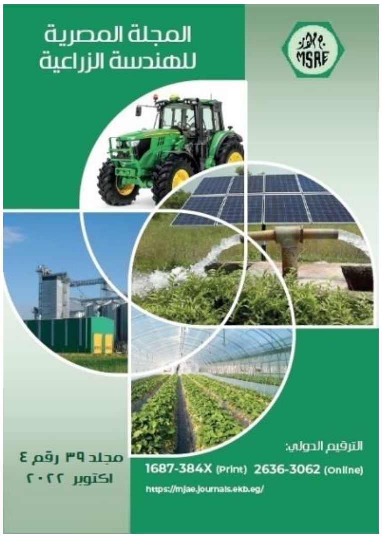
Zaki, H. Z.; A. M. Altony and Taha, A. M. (2010). Cultivation of tomatoes and beans under low plastic tunnels. Technical Bulletin No. 5, Agriculture Research Center, Ministry of Agriculture. Egypt. (In Arabic).

Zin El-Abedin, T. K.; Mattar, M. A., and Alazba, A. A. (2015). Soil wetting pattern from subsurface drip irrigation as affected by application of a polyacrylamide layer. Irrigation and Drainage, 64(5): 609-618.

جدولة نظام الزراعة المائية الذكي لرفع كفاءة استخدام المياه

د. أحمد إبراهيم عبد الحكيم[١] و د. هلال سامى هلال[٢]

[١] باحث بقسم بحوث هندسة الري والصرف الحقلي - معهد بحوث الهندسة الزراعية - مركز البحوث الزراعية - الجيزة - مصر.
[٢] باحث بقسم بحوث نظم ميكنة العمليات الزراعية - معهد بحوث الهندسة الزراعية - مركز البحوث الزراعية - الجيزة - مصر.



الملخص العربي

تهدف الدراسة المقدمة إلى إنشاء جدولة ذكية لنظم الزراعة المائية المفتوحة لرفع كفاءة استخدام المياه لمحصول الخيار في صوبة زراعية من خلال إنشاء وبناء وحدة تحكم ذكية اعتمادا علي Wi-Fi بناءً على استشعار مستوى محدد للرطوبة في وسط النمو (الرمل). تمت إضافة مواد تحتفظ بالماء لفترات طويلة إلى وسط النمو (الرمل) مثل مادة الكمبوزيت و التي تحتوي علي (٩٠ ٪ طين أسوانى و ١٠ ٪ هيدروجيل) والبيرلايت مقارنة بالرمل فقط. أجريت التجارب بمحطة اختبار وابحاث الجرارات والآلات الزراعية بمحافظة الإسكندرية لموسم زراعة عام ٢٠٢٢ من ١٠ مارس إلى ١٨ يونيو. أظهرت النتائج التالي: أن نظام التحكم الذكي في مناخ الصوب قد وفر نطاقًا مناسبًا لدرجة الحرارة (٢٠-٣٠ درجة مئوية) والرطوبة النسبية (٤٠-٧٠٪). أدى استخدام مواد الكمبوزيت والبيرلايت إلى زيادة المحتوى الرطوبي لوسط النمو مقارنة بالرمل فقط. كان أقل استهلاك للمياه ١١٥ لترًا/م٢ عند استخدام الكمبوزيت ، بينما كان أعلى استهلاك للمياه ٢١١ لترًا/م٢ عند استخدام الرمل فقط. كانت أعلى إنتاجية لمحصول خيار ١٩,٧ كجم/م٢ عند استخدام البيرلايت ، بينما كانت أقل إنتاجية هي ١٢,٧ كجم/م٢ عند استخدام الرمل فقط. كانت أعلى كفاءة في استخدام المياه ١٦٧ كجم/م٣ عند استخدام الكمبوزيت ، في حين أن أقل كفاءة استخدام المياه كانت ٦٠ كجم/م٣ عند استخدام الرمل فقط حيث زادت كفاءة استخدام المياه بنسبة (١٧٧ ، ١٥٨٪) للكمبوزيت والبيرلايت مع الرمل كوسيط للنمو مقارنة بالرمل فقط.

وفقًا لدراستنا ، نوصي بتطبيق نظام جدولة ذكي يعتمد على تقنية Wi-Fi مع استخدام الكمبوزيت لتحسين الإحتفاظ بالماء في أوساط النموالرملية. وبالتالي ، أدى ذلك إلى توفير المياه في الزراعة المائية وزيادة الإنتاجية و كفاءة استخدام المياه.

الكلمات المفتاحية:
جدولة الزراعة المائية الذكية؛ تقنية Wi-Fi؛ الكمبوزيت والبيرلايت؛ كفاءة استخدام المياه؛ خيار الصوب.