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Smart Hydroponic Greenhouse (Sensing, Monitoring and Control) Prototype Based on Arduino and IOT

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Authors' contributions

This work was carried out in collaboration between all authors. Author MAA-S designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors MSAE and SMM managed the analyses of the study and the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: Sensing, monitoring and control the micro-climate measurements and environmental conditions of greenhouse prototype to create a smart hydroponic greenhouse for maximizing the food production as well as minimizing the ecological footprint under the climate change impacts, Coved 19 crisis, and natural resources shortages.
Study Design: Factorial with 3 replicates.
Place and Duration of Study: Central Laboratory for Agriculture Climate (CLAC), Agriculture Research Center, Egypt during 2020.
Methodology: Two systems of hydroponic culture, nutrient film technique (NFT) and deep flow technique (DFT) that cultivated by lettuce plants were established under greenhouse (polycarbonate) prototype (0.8 * 1.2 * 0.6 m) designed with artificial grown light and cooling system. Based on Arduino Mega 2560 that programmed via the Arduino IDE program, different sensors and actuators were used to establishing the smart greenhouse. Internet of things (IoT) via Node MCU ESP 8266 that programmed to transmitted the data every 30 min. to the internet web google platform (Firebase) for presenting the real-time records and hosting the data. Vegetative characteristics; yield parameters and N, P, and K contents of lettuce plants were measured.
Results: the smart greenhouse worked according to the programming of Arduino Mega and Node

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MCU with high efficiency. Google firebase platform displays the real-time records and hosts about 100 thousand different sensor records during the lettuce season. Decreasing the distance between the lettuce and artificial lightning source led to increasing the intensity of light that had a positive impact on lettuce growth but it wasn't sufficient to give a high quality of lettuce yield under the experiment. NFT system gave higher values of average No. of leaves and fresh weight of lettuce plants than DFT system that presented higher plant length.

Conclusion: Integrated monitoring and control system and IOT provide a wireless sensors network that offered a high capability of accessing huge data anywhere and anytime. Smart management of nutrient solution (TDS, pH, temperature, and level), without smart control, were not useful enough regarding the rapid solution changes and the need for a high response.

Keywords: Smart agriculture; monitoring; control; NFT; DFT; arduino mega; IOT; WiFi; sensors and goggle firebase.

1. INTRODUCTION

Developing the agricultural production process by using modern digital systems and smart agriculture has become extremely vital to preserve natural resources and increase agricultural food production to face the high population increase under those circumstances.

Hydroponic culture as a flexible modern technology is a sustainable and environmental food production method for reducing the use of agricultural chemicals (fertilizers and pesticides) while maximizing the water, soil and power use efficiencies [1-5] reported that nutrient film technique (NFT) where the plants are grown in plastic tubes, PVC pipes, plastic channel (gullies) which nutrient solution is continuously circulated while the plants are floating in pool in deep flow technique (DFT) which the plants in net pots, holes are perforated in a foam board which rest on the surface of the water. Both systems are the most popular systems of hydroponic on the commercial scale for producing leafy vegetables and herbs. Hydroponics is a highly exacting and demanding system that requires a huge production knowledge, experience, technical skill and financial investment than many other greenhouse systems. A grower must be supervised and managed the daily demands of production to be successful [6]. Hydroponic lettuce is commercially produced using NFT or DFT as closed systems that require precision monitoring and adjusting for micro-climate and environmental conditions especially the solution (pumping, EC, pH, temperature sterilized, dissolved oxygen index (DOI) and etc.) [6-8].

Monitoring of micro-climate and the environmental conditions plus smart automation control integrated with internet of things (IOT) gave the farmer the power and flexibility to make the right decision, to avoid the human mistakes and environmental stress impacts on food production. Automate the hydroponic culture take in consider of many researchers and makers to develop many systems for satisfying the farmer's needs. All micro-climate records (air temperature, relative humidity, light intensity, carbon dioxide, wind speed and etc..) and environmental measurements of the root zone (soil moisture, substrate and nutrient solution temperature, EC, DOI, water level and etc. should be sensing by different sensors to monitored for automation the hydroponic system via suitable actuators. Microcontroller boards i.e. Arduino (mini, nano, uno, miga and etc..) and microprocessor such as Raspberry pi in different types and version mainly used for artificial intellegence (AI) and computer vision projects.

Sensors such as DHT 11 and DHT 22 have been used for measuring air temperature and relative humidity;LDR module and TSL 2561 for estimating light intensity; waterproof temperature for recording the water temperature; TDS and pH kit sensors for measuring EC and pH of solution respectively. IoT allows for machine to machine interaction and controlling the hydroponic system autonomously and intelligently employing deep neural networks [9-21].

The smart hydroponic prototype pilot create an opportunity for learning, demonstrate the smart agriculture knowledge and to implement monitoring, control and automation practically.

This work through smart hydroponic greenhouse prototype pilot aims to investigate the effect of different hydroponic systems and artificial grown light on the lettuce production, the efficiency of Arduino Mega, different sensors and actuators for sensing the required measurements and control the different agriculture operations as well as the vital role of IoT via firebase platform of Google through smart hydroponic prototype pilot.

2. MATERIALS AND METHODS

The smart hydroponic greenhouse was designed, constructed, wired, programmed and investigated in Central Laboratory for Agricultural Climate (CLAC), Agriculture Research Center (ARC), Egypt, during August to October 2020. Lettuce plants were grown into two systems of hydroponic culture (nutrient film technique (NFT) and deep flow technique (DFT) under smart greenhouse prototype (sensing, monitoring, control and internet of things (IOT)).

2.1 Plant Material

Lettuce (*Lactuca sativus*) cv. Othilie -RZ*F1 hybrid* (Batavia green lettuce) seeds were sown in plastic net cups (size 5 cm) filled with peat moss : perlite (1:1 *v/v*) in the middle of August 2020. After the fourth true leaf stage (17 days after sowing), seedlings were transplanted to both of NFT and DFT systems. Each one of lettuce seedling was transplanted into holed foam plate that cover the deep flow technique (DFT) surface or to the holed plastic tube directly of nutrient film technique (NFT). The final plant spacing was 20 cm in the row and among the plants to create plant density 9 plant/system.

All other agriculture practices of lettuce cultivations were in accordance with the standard recommendations for commercial growers by Agriculture Research center (ARC), Ministry of Agriculture (MOLAR), Egypt.

2.2 Hydroponic Culture Material

2.2.1 DFT system

Deep flow technique (DFT) constructed by a wooden frame with dimensions of 0.52 x 0.52 m and a depth of 0.15 m, covered with black polyethylene sheet (600 micron) to created DFT container with water volume about 35 L. Polystyrene Foam (high density) plates (0.5* 0.5 m) covered the water surface and holed in 3 rows with distances 20 cm among the rows and in-between to offer place for nine lettuce seedlings in the net cups (5 cm). Air supply was applied via air pump (2 watt) and submersible water pump (5 watt) (that used for pumping nutrient solution to NFT system) for offering sufficient O_2 and to prevent O_2 depletion. Arduino was programmed to operate air pump to work during the day 5 min. on / 10 min. off).

2.2.2 NFT system

Nutrient film technique (NFT) was established on horizontal scale through three white plastic tube (0.5 m length, 0.1 m width and 0.05 m height). NFT system used the DFT as a nutrient solution tank (35 L) and located in slope 1% by using wooden stand (17 cm length) for collecting the drainage by gravity to DFT system. The nutrient solution was pumped via submersible pump (5 watt) connected to polyethylene (16 mm as a main line and 4 mm as a sub-main) pipes to NFT tube. Arduino was programmed to manage the fertigation schedule to work during the day light period 5 min. on / 10 min. off while during the night darkness period 5 min. on / 20 min. off per day.

Chemical nutrient solution [4] was modified as [6] to be in range of TDS sensor range (0 – 1000 ppm), so it was applied as illustrated in Table (1). The electrical conductivity (EC) of nutrient solution for both hydroponic systems was adjusted by using digital EC meter to the range level (800 – 950 ppm).

2.3 Greenhouse Material

The greenhouse prototype pilot constructed mainly from wood by using the disassembly and installation method to create the base (to install the both of NFT and DFT systems) and the posts by dimensions 0.8 m width, 1.2 m length and 0.6 m height as well as a two frames for cooling pad system at both ends of the greenhouse. Polycarbonate sheets were used to cover the all sides of greenhouse.

Greenhouse prototype pilot designed and established to work under indoor conditions which controlled by air condition that timing to perform 26^{o}C during the day (06:00 to 20:00) and 18^{o}C during the night).

Table 1. The chemical composition of different sources of nutrient solutions

Nutrient solution	Macronutrients (ppm)					Micronutrients (ppm)					
	N	P	K	Ca	Mg	Fe	Mn	Zn	B	Cu	Mo
Ch. N.S.	125	30	200	115	40	2.0	0.6	0.3	0.4	0.20	0.02

Cooling pad system consists of two cooling fans (220 V, 120X120X38 mm) at one end of greenhouse and pad systems (a porous pad (0.1m width x 0.6 m length x 0.2 m height) was circularly watered through and over by submersible water pump (5 watt) using water tank (25 L) at the opposite end of the greenhouse as presented in Fig. (1). Arduino Mega was programmed to manage the cooling pad system according to sensing data (air temperature and relative humidity) of DHT 22 sensor.

To offer the lettuce demands of spectra and light intensity during the grown season under indoor condition, artificial grown light system was installed in inner roof. Light emitting diodes (LEDs) performed in three white, blue and red LED tube (18 watt, 220 V, beam angle 2400, 1710 lumen (lux), color temperature: 6500 Kelvin and 120 cm length) were used to offer the range of the visible spectrum (380-760nm). The artificial light operation was done through digital timer that programmed to operate the light On from 06:00 to 20:00 while from 20:00 to 06:00 is Off.

2.4 Smart System Material

The smart system builded based on microcontroller board Arduino Mega 2560. Arduino Mega 2560 was programmed by using Arduino web IDE 1.8.13 software [22]. Different sensors and actuators components were used to monitoring the micro climate conditions (air temperature, relative humidity and light intensity) and environmental conditions (EC, pH, water temperature and water level) beside alarm noise for water level as presented in Table (2). The electronic components (Arduino Mega, sensors and actuators) were selected based on the efficiency, accuracy and the system requirments to detect the micro climate and environmental conditions as well as the deires control.

The Arduino skitch starts by identify the different sensors and actuators. Sensing and collecting the required information data each 5 seconds (5000 mlSec). Sensing data of air temperature and relative humidity were done via DHT22 sensor. If temperature records over 24^{o}C, the cooling pad system (fans and celling pad) will be On while the colling pad is Off in case of air temperature is equal 16^{o}C. Humidity and air temperature less than 40% and 24^{o}C respectively, the celling pad only will be On. The fans only will be On when humidity was more than 70% and air temperature less than 24^{o}C. The control system was programmed to had the choice regarding to the DHT sensor detection to operate the fans only (to reduce RH less than 70 % to avoid fungi diseases and regularly to renew the air flow and conserve CO_2 level in optimum range), celling pad only (RH is equal or lower than 40% to avoid dry air stress) or both in case of the need to decrease the temperature to the optimum level. The temperature and relative humidity values justified regarding to [8]. The power use efficiency take in consider because of control more means electricity required more.

Light intensity (TSL sensor) data to be more sure the lettuce plants get sufficient light and there is no any missing or break in light LED source.

The TDS, pH, nutrient solution temperature and level measurements were sensing via different sensors as illustrated in Table (2). Float switch sensor was wiring on 7 cm depth to sensing the water level in the DFT container. In case of the water level is equal or less 7 cm depth (the hieght of sumersable pump is 6 cm + 1 cm for protection), the program sketch of smart control system was addressed as low level, the buzzer will be On to presented noise alarm as well as cloud the "Low level" to the firebase platform for monitoring. While the water level is higher than 7 cm, the buzzer will be Off and the the data will be cloud the "Full level" to the firebase platform. The Arduino was programmed to operate (On/Off) and timing both of water pump and air pump during the day and night as Fig. (2) presented the software flow chart of Arduino sketch.

The monitoring data will be displayed on LCD screen pluse Google platform firebase via Node MSU esp 32 and airbox to help acting the optimum decesion as Fig. (2) illustrated.

2.5 Internet of Things (IOT) Material

The measurements from all sensors collected via Arduino Mega and sent to NODE MCU Esp 8266 that via a wireless WiFi link send the data every 30 min. to Airbox (Orange Co.) that offer internet communication for sent the sensors measurments to smart hydroponic project that established on Google firebase platform for monitoring the micro-climate and environmental conditions as Fig. (2 and 3) presented. Depending on Google plateform firebase side, the measurements displayed the realtime records and stored the collected data. Users through mobile, tablet or desktop PC will be able to access the project through the internet and visualizing the measurements at real time.

Fig. 1. the design of hydroponic systems (NFT and DFT), greenhouse (Cooling pad system and artficial light) and project box of the smart system

2.6 The Investigated Treatments

Two hydroponic culture systems were investigated through smart hydroponic greenhouse prototype for producing littuce plants under full control indoor conditions as follows:

1. Nutrient film technique (NFT).
2. Deep flow technique (DFT).

The experimental design was factorial with 3 replicates. Each replicate contained 3 lettuce plants.

2.7 The Measurements

2.7.1 The vegetative and yield characteristics

After 45 days from the transplanting date, the vegatative growth characteristics were measured as follows: plant length (cm), No. of leaves and average fresh weight (g) at the end of cultivated seasons.

2.7.2 The sensors records

Air temperature (^{o}C), relative humidity (%), light intensity (Lux), TDS (ppm), pH, water tank level (Full or Empty), water temperature (^{o}F) measurments that sensing, collected, transmitted to Google firebase and stored were recorded.

2.7.3 The statistical analysis

Analysis of the data was done by computer, using SAS program for statistical analysis and the differences among means for all traits were tested for significance at 5 % level [23].

3. RESULTS

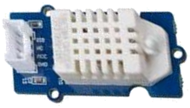
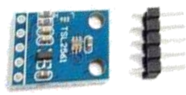
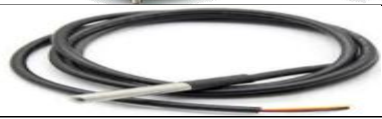
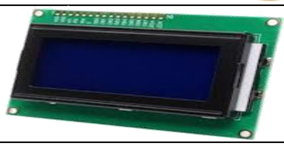
3.1 The Smart Hydroponic Greenhouse Prototype Performance

3.1.1 The monitoring of micro-climate and environmental conditions

The design and implementation of the smart hydroponics greenhouse prototype system automatically using arduino Mega microcontroller which connected to all installed sensores and LCD were tested before, during the experimental time to estimated the system performance in monitoring the Air temperature, relative humidity, light intensity, water level and temperature, TDS and pH. LCD screen was used to display the sensing measurments. LCD screen also presented the time and the date as Fig. (4) illustrated. All sensores presented an efficient performance in sensing the required measurments every 5 seconds (5000 mlsec.) but LCD screen didn't display the same efficient in monitoring the data. There was minor shifting among the lines of LCD screen that presented the different measurments as Fig (4) showd.

The monitoring system designed be able to maintain itself with no to minimal manual input. So, in case of any sensors stop working and there is no sensing data, the system made alarm and display the sensor problem on the LCD screen as Fig. (4) illustrated. Fig. (4) display the different seansing measurments as followd: line 0 of LCD screen show the day, time and date. The air temperature and relative humidity of the greenhouse measurments that measured by DHT 22 sensor presented in ^{o}C and % in line 1. While the level of light (%) that changed later to light intensity (Lux) and water tempertaure (changed also later from ^{o}C to ^{o}F) illustrated in line 2 were estimated by luminsoity sensor TSL 2561 and waterproff temperature sensors respectively. Line 3 introduced the water level (full or empty) that determined by float switch sensor. TDS and pH data of nutrient solution presented in second screen page in line 1.

Table 2. The different sensors and actuators materials used in smart system

Smart material	Job	Image
Arduino Mega 2560	Designed for complex electronic projects with more sketch memory and 54 digital input /output pins (of which 15 can be used as PWM outputs), 16 analog inputs connected to a pc with a USB cable.	
DHT 22 sensor	Sensening air temperature (^{o}C and ^{o}F) and relative humidity (%) 5 volt power sensor	
luminsoity sensor TSL 2561	Light intensity (Lux) 5 volt power sensor	
TDS sensor	Sensing Total Dissolved Solids (TDS) measure range from 0 to 1000 ppm. 5 volt power sensor (Need to calibration).	
PH sensor kit	Water Acidity Measrments The pH scale ranges from 0 to 14. 5 volt power sensor (Need to calibration).	
Waterproof temperature Sensor	Water and nutrient solution temperature (^{o}C and ^{o}F). 5 volt power sensor	
Float switch sensor	Water level sensing 5 volt power sensor	
LCD screen (4*16)	Display the required inormation and data. 5 volt power screen	

Smart material	Job	Image
Relay module	Opertated On/Off from 5 V provided by Arduino to 220 V for actuating different controls. 5 volt power actuator	
Breadboard (830 pin holes)	a solderless construction base used for developing an electronic circuit and wiring for projects	
Buzzer	Create a buz voice for alarming. 5 volt power actuator	
Jumbers (male/male) (male/female)	Wiring the different sensors with Arduino, LCD, bread board and relay module	

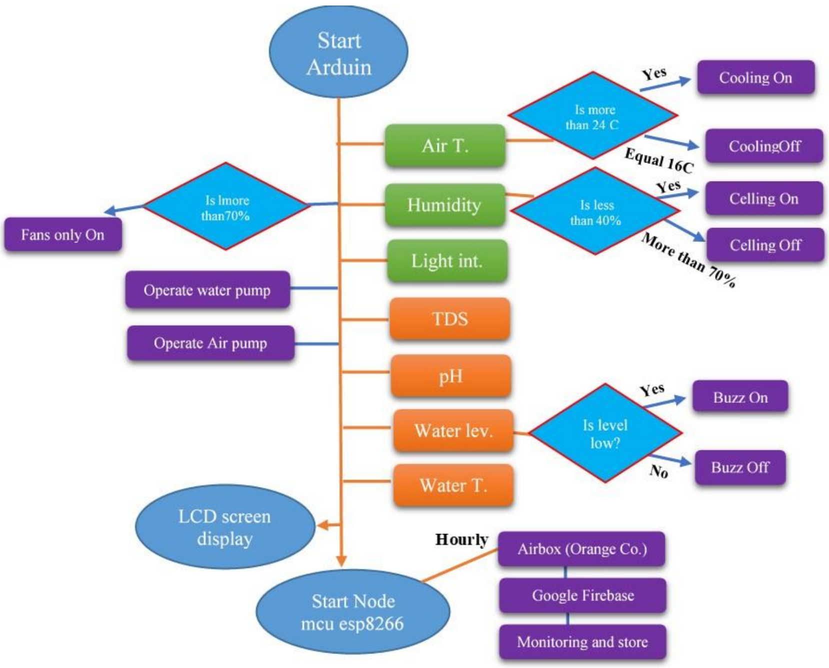


Fig. 2. Software flowchart of Arduino Mega and Node MCU Esp 32 skitches

Also, all sensing measurments could be display on the laptop or computer screen by connected to arduino maga board via mini USB cable that would presented later in this study.

3.1.2The control of micro-climate and environmental conditions

The control functions concerned on air temperature and relative humidity as a micro-climate conditions through cooling pad system while the nutrient solution pumping into NFT plastic tubes and air supply to DFT system were done by using submearsable pump and air pump respectively. All systems were actuated via relay module 4 channels. Arduino mega was programmed to actuated the different function regarding the air temperature and realtive humidity sensing measurments of the greenhouse while programmed to timing the operation functional of pumping both of water and air pumps during the day and night (the lightening and darkness periods).

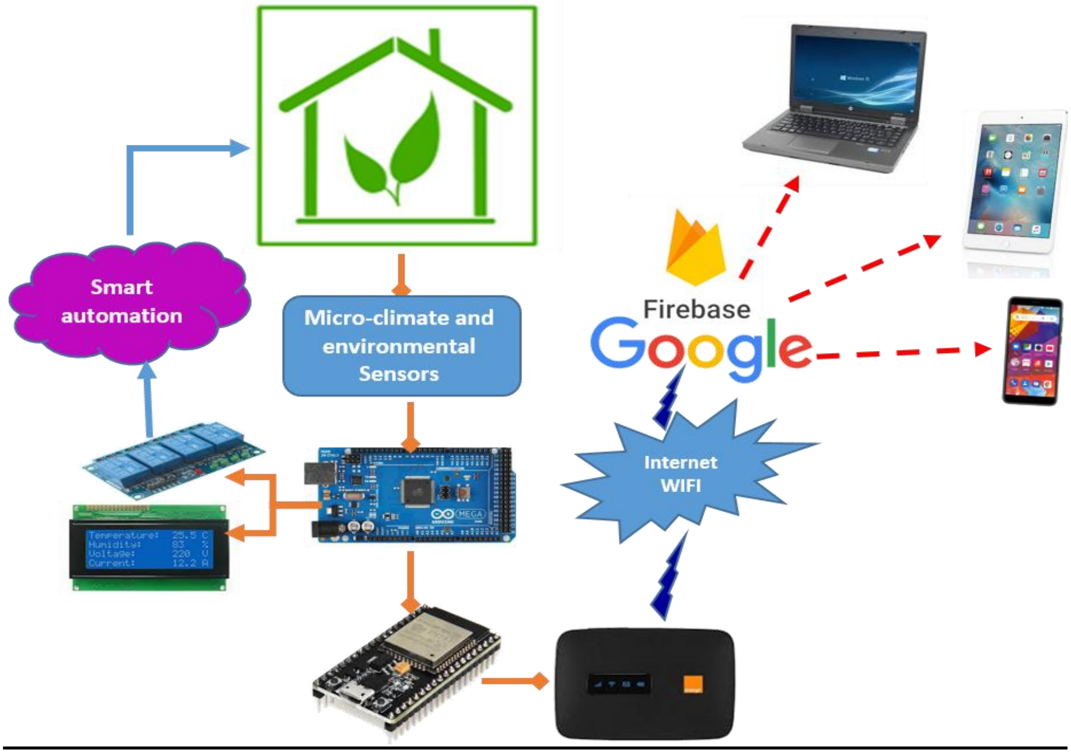


Fig. 3. Schematic of smart hydroponic greenhouse based on Arduino and IOT

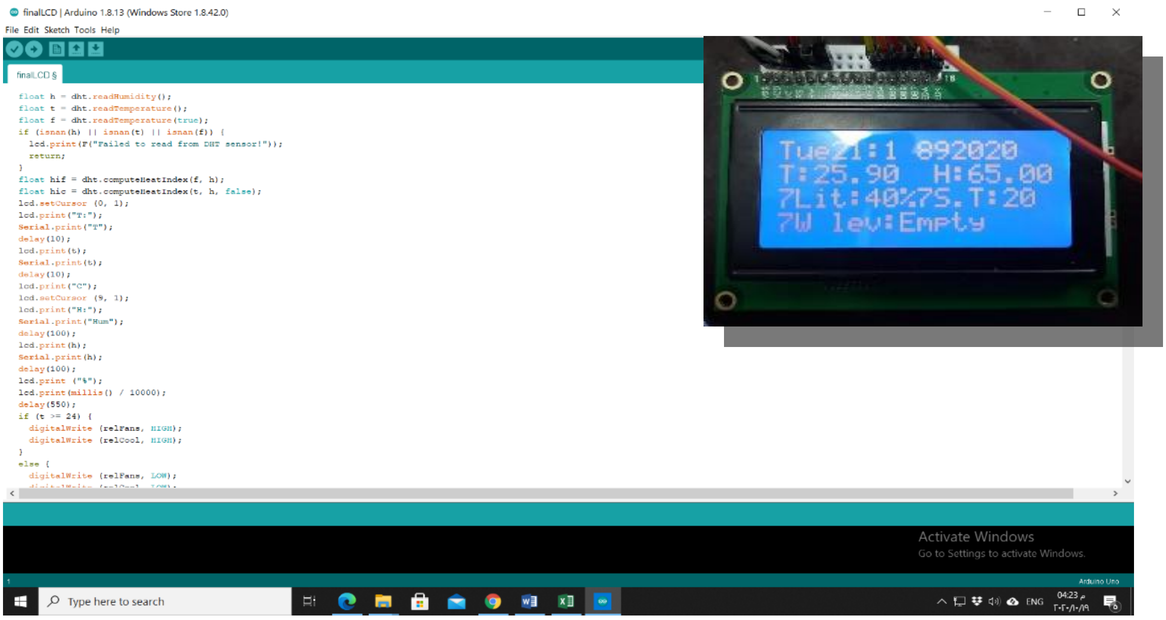


Fig. 4. A part of monitoring program skitch and LCD display

The control of air temperature and relative humidity respond efficiently every 5 seconds as measurments data flowd according to the programing but the efficiency of cooling bad system spent more time to maintained the required responce. The macro-climate of the indoor room was controlled by air condition to provide 26°C during the day and 18°C during the night. The two temperature degrees between indoor temperature and the required greenhouse temperature introduced the efficiency on the control system while relative humidity values were most of days recorded more than 75% that performed a real problem in control it equal or less than 70% regarding to indoor room conditions.

Relative humidity measurments during the experimental period showed in Fig. (5) as monitoring real-time records of Firebase platform on Google web indicated that acceptable control results. However, the function of automated control of air temperature of greenhouse provided a good response and performance as Fig. (6) illustrated. The average air temperature of greenhouse during the day and night demonstrated adherence to the specified program.

Artificial light controled by using digital timer to create the day period (lightening) from 06:00 to 20:00 and the rest was dark (night). The light intensity differed strongly during the lettuce growth. Increased the plant hieght as a resulting of lettuce growth led to decreased the distance bwteen the letuce plants and artificiail light by LED tubes resulting increasing the light intensity as Fig. (7) presented.

TDS and pH of the nutrient solution was modify daily to kepp them in range of 900 to 950 ppm and 6.5 to 6.8 respectievely, so there were no needs present their seansors data.

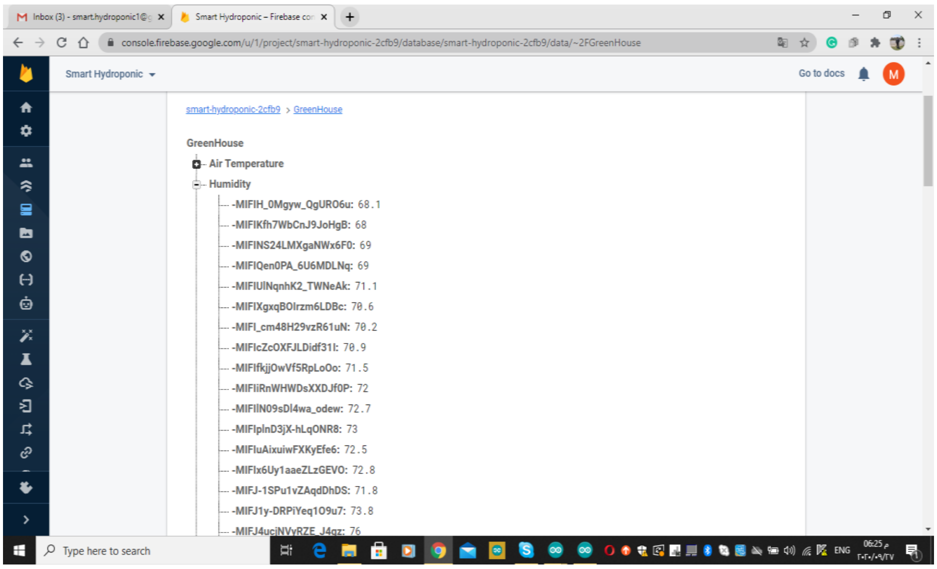


Fig. 5. The control effect on relative humidity measurments that presented on firebase

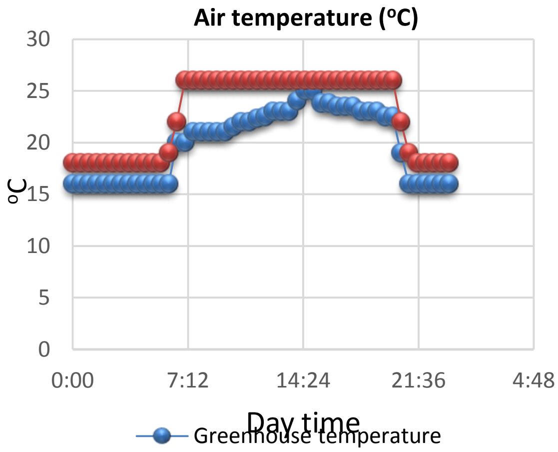


Fig. 6. The control impact on air temperature under greenhouse comapared to indoor condition

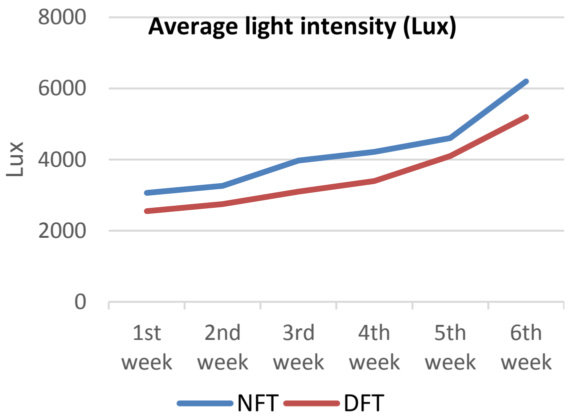


Fig. 7. The real light intensity on NFT and DFT systems

3.1.3 The use of IOT in transmitt micro-climate and environmental measurments

All sensores data transfered from arduino mega to node mcu 8266 via wiring tx pin (transfer) of arduino to rx pin (receive) of node and then via WiFi to airbox of Orange tele. Co. that transmitted the sensores data to the firebase plateform of Google web. Node mcu was programmed to transmitted the seansors data every 5 seconds at the first 5 days as it received from arduino but later regarding to the huge data, the program changed to transmitte the sensores data every 30 minutes. A progect entitle "smart hydroponic 'greenhouse' " was established on the firebase to receive and monitoring the all seansors data. The sensores data presented according to their classification on the Realtime database of firebase plateform as Figs. (5, 8, 9 and 10) that demonstrated the receiving of the all sensores data, relative humidity, water temperature and water level respectively. The authors prefered to introduce sensors data as they presented on firebase plateform to give an evidance on the efficiency of smart hydroponic greenhouse prototype that integrated with IOT instead of presenting the seansors data in scientific graphics. Fig. (8) displayed comparison between the two screens of realtime database and arduino program screen, this Fig. illustrated the difference between received the data every 5 seconds as in arduino or every 30 min. as on firebase plateform. The yellow marker on the reatime database function of firebase means the receving proccess of the sensores data worked well as Fig. (5) presented.

Needless to maintion that more than 86 thousands of sensores data were received and hosted on firebase platform in 5 dayes only before changed the transmittion programming to be about 13 thousands in 40 dayes. IOT introduced a great ability to display a huge amount of information that can be mointored, processed and used in making the right decision. The sensors data presented and stored in that experiment reached about a 100 thousands records.

3.2 The Effect of Hydroponic Culture Systems on Lettuce Plant

Figs. (11, 12 and 13) introduced the effect of hydroponic system vegetative characteristics and yield of lettuce plants such as the average plant length, average No. of leaves/ plant and average fresh weight/ plant respectively. The obtained results indicated that the use of NFT system recorded the higher average No. of leaves and average fresh weight per lettuce plants while gave the lower plant length compared to the DFT system.

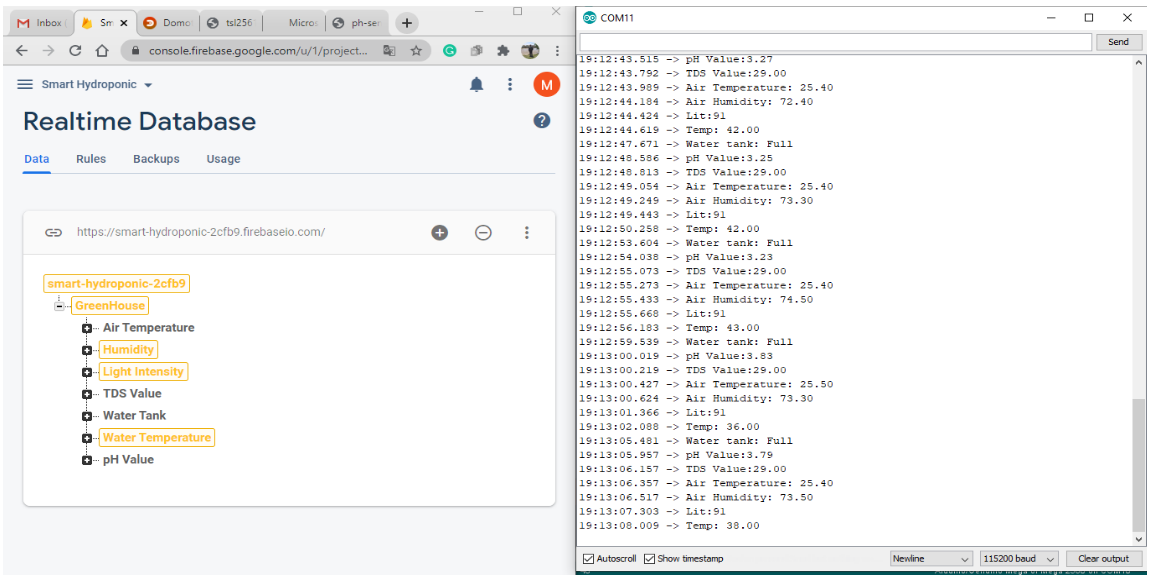


Fig. 8. The transmattion of measurments from arduino mage via node mcu and airbox to monitored on Firebase platform of google

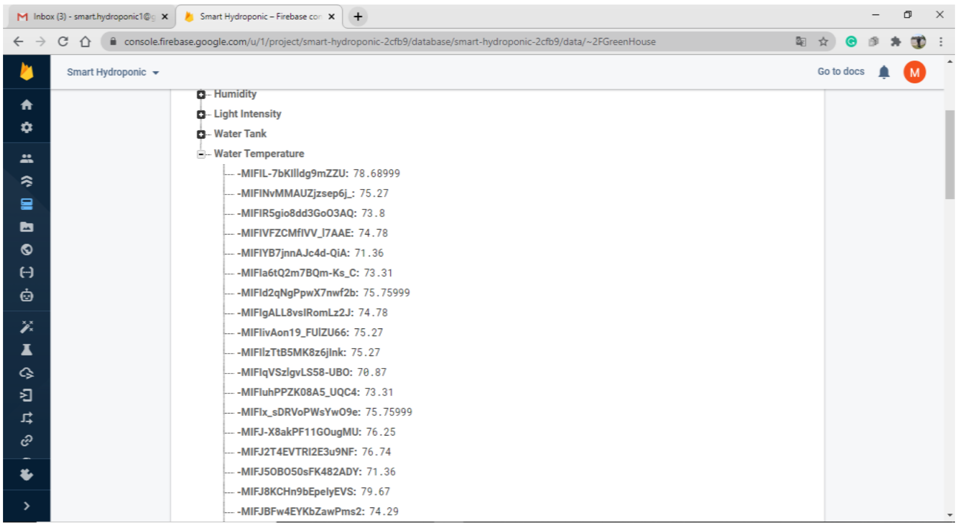


Fig. 9. the water temperature (°F) measurments that monitored on firebase platform

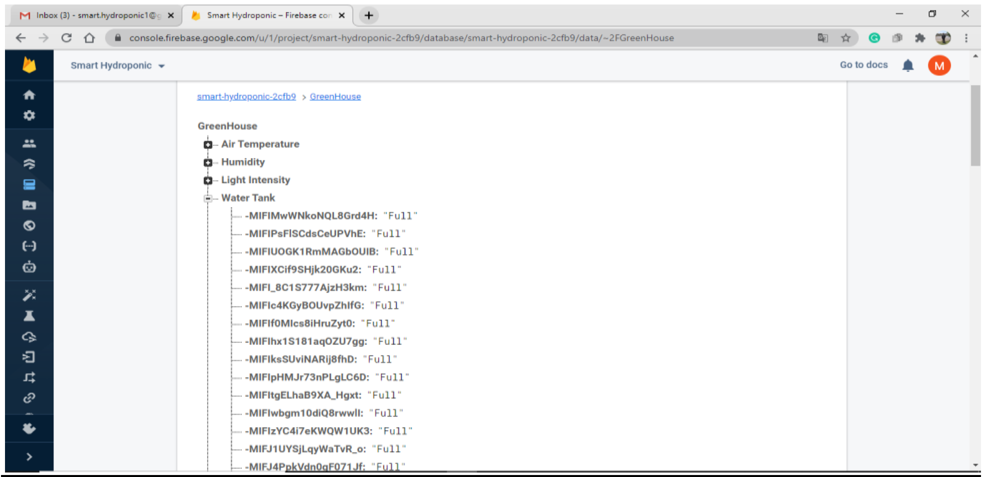


Fig. 10. the water level measurments that monitored on Firebase platform

The results of averages plant length and fresh weight of lettuce plants strongly indicated that the lettuce plants suffered from elongation symptoms regarding to insufficient light intensity (the light intensity requirements is more than 10000 lux). Moreover, there are more doubts about the impact of the hydroponic system level on the growth of the lettuce plants wherever the NFT system level was higher than DFT system by about 8 cm that resulted varied the light intensity during the growth period of lettuce as Fig. (7) Introduced and this difference was differed from 500 lux at the transplanting time up to 1000 lux at the end of experiment. The difference of average plant length between NFT and DFT systems about 4 cm was not enough to compensate the difference of both system levels.

4. DISCUSSION

Sensing and monitoring the required micro-climate and environmental measurments by real-time as well as automated the agricultural operation mainly aimed to provide a great help to hydroponic greenhouse farmer regarding to the high infrastructure cost of hydroponic greenhouse and to avoid the climate, environmental and human mistakes risks. Moreover, offering optimum conditions for lettuce growth and yield either micro-climate and environmental conditions in both hydroponic systems (NFT and DFT) under greenhouse to achieve a maximum profit yield face many technical challengers beside the cost of different inputs (fertilizers, water, energy and infrastructure).

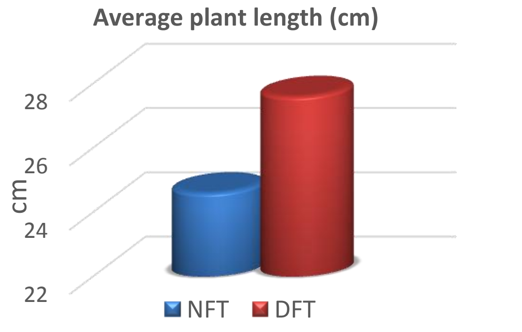


Fig. 11. the average plant height of lettuce in NFT and DFT under artificial light

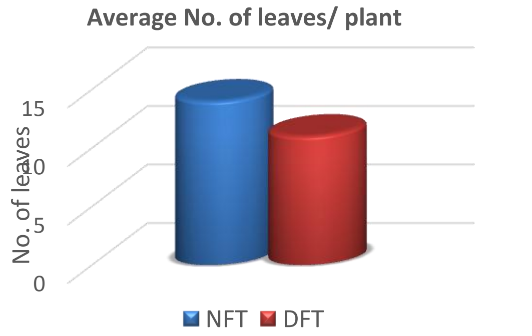


Fig. 12 the average No. of leaves of lettuce in NFT and DFT under artificial light

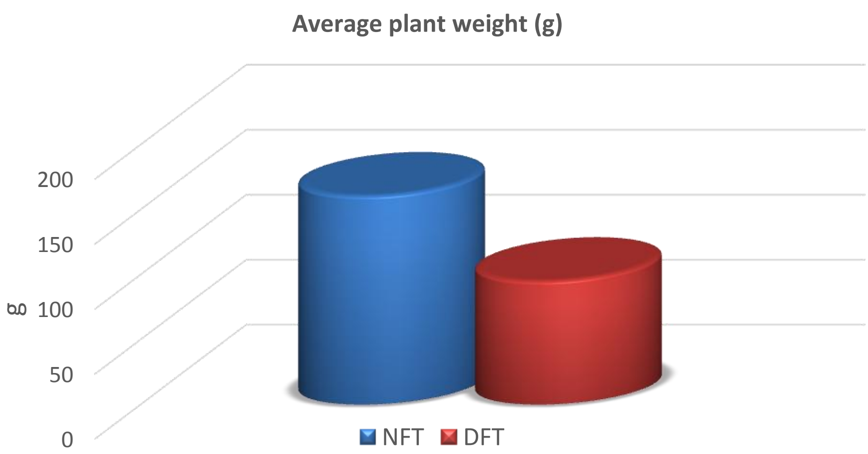


Fig. 13. the average plant weight of lettuce in NFT and DFT under artificial light

Monitoring and automated control of air temperature and relative humidty in optimum ranges (24^{o}C day, 16^{o}C night and 70% respectively) presented optimum condition of lettuce growth as results of high performance of automated control proccess. [8] demonstrated that the important parameters for a healthy and faster plant growth such as air temperature and relative humidity, lights, water temperature, etc. should be controlled or maintained. The automated control of micro-climate conditions were clashed with the light requirements (intensity and spectrum) affected the lettuce yield parameters and resulted elongation of lettuce head. The faried level between NFT system and DFT system may a play a role more than the effect of system itself on the lettuce yield parameters. The NFT system had a light intensity higher than DFT system. Increasing the light density led to increase the quality and quantitity of lettuce yield with satisfying the visiable light spectrum [8 and 24,25].

The automated TDS and pH monitoring for hydroponics greenhouse were calibrated, monitored and evaluated to determine its performance [20]. Real-time monitoring of the TDS, pH, temperature and level of the nutrient solution were recorded for 45 days and its performance was evaluated. The automated control of pumping the nutrient solution into NFT tubes and air supply for DFT system also illustrated a high performance with take in consider the monitoring and alarm system of nutrient solution level in DFT system that use as a tank for NFT system. This automation proccess performed a high efficiency in control the fertigation program and avoidance of pump damages, O_2 deplation and yield loss. The unique technique of installed node mcu with Arduino mega integrated with different sensors to transmit the sensors data via Wi-Fi led to create wireless sensors network that produced a high performance of monitoring the real-time records and provided huge data for processing. The monitoring of firebase platform showed proportion of non-fitting measurements less than 1%. These mistakes of measurements didn't notice on LCD screen that display the sensor measurements every 5 seconds.

Based on the sensing measurments from the monitoring system that transmitted via IOT to presented on firebase plateform, a validation and evaluation of data were done to create an full automated control system for hydroponic greenhouse in both NFT and DFT systems. [21,26,27] investigated the use of an electronic sensors, Internet-of-Tings (IoT), microcontroller boards implemented to monitor the micro-climate, automatic environmental control and cultivation process for hydroponic. The sensor reading is collected into a database to use later for training machine learning models and the development of intelligence automated indoor micro-climate horticulture. Furthermore, the adoption of the microcontroller and IOT in intelligent technique to sensing the different micr-climate and environmental conditions of soilless culture could decrease the hydroponic problems and human mistakes and increase the profit yield of hydroponic systems due to complicated manually monitoring and controlling process.

5. CONCLUSION

The smart hydroponic greenhouse that provides sensing and monitoring micro climate and environmental conditions, control and automation the different agricultural procedures beside – Internet of things (IOT) via clouding the sensors detection to the internet and host the data may play a vital role in assisst the farmers for presenting the required information to precise the agricultural management procedures for increasing sustainability and ecologically the production of agricultural. The smart automation technology integrated with IOT gave the farmers the power to face the climate change risks, global pandemics, food security demands, environmental and natural resources shortage. The need to develop and improve the use of microcontroller, sensors and actuators integrated with IOT to include all agricultural procedures espicially in developed country become more neccessry.

This work illustrated just some applications of using technology in agriculture to conserve the natural resources, efforts, time and cost beside increase the sustainability and production while observed the adventages of friendly, use, flexibility and efficiency.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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