ARDUINO BASED AUTOMATION IN THE SOILLESS AGRICULTURE

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Abstract—In this study, greenhouse automation was performed in a hydroponic environment using Arduino. The temperature of water, EC (electrical conductivity) value of the nutrient solution in the hydroponic environment, which are the parameters that affect the development process of plants from their planting into the stand in the created greenhouse environment up to the time of collecting the products, were kept under control. Regarding these parameters, while the temperature of the water was changed by the aquarium heater, the EC (electrical conductivity) value in the hydroponic environment was set by means of automation by proportioning the nutrient kits. In this application performed, it was aimed to change farmer's perspective on modern agriculture and accelerate the economic and agricultural development by contributing to the spread of modern agriculture.

Index Terms—Arduino, soilless agriculture, greenhouse automation, EC.

I. INTRODUCTION

According to the data of the Turkish Statistical Institute (TSI), the total population of our country reached 78741053 people in 2015 and this number is still increasing [1]. Due to the increase in the need for food along with the country's population, agricultural production should be higher in parallel to it.

The developments that have occurred in the agricultural sector along with the technological progress increase the quality and quantity of the product in greenhouses where greenhouse growing is performed, and also, they provide many benefits for producers by decreasing the workload and harvesting time. Different factors (weeds, insects, harmful wastes, etc.) that may damage the product are encountered since the products are in soil in the traditional agriculture. In this case, product losses are inevitable and agricultural producers have to use chemical drugs to get rid of these problems. In the modern agriculture, they will get rid of the harmful formations from the soil as the plant is in a place which is completely independent of the soil environment. Furthermore, the ecological balance will not be deteriorated due to the products which are not exposed to chemical disinfection. The increasing population's food needs are met more easily and the country's economy is also improving by means of the modern agricultural practices. In these new applications, agriculture has been accelerated by the electronic control system and automation. Automation is widely used in soilless agriculture.

In this study, an Arduino microcontroller was chosen as the control element. The temperature of the running water in the hydroponic environment, pH value, circulation of the running water and EC (electrical conductivity) variable of the system were automatically controlled, and the suitable environment required for the development of the product was provided due to Arduino.

II. GREENHOUSE

The closed areas where suitable environments for crop growing are created along with the monitoring of climatic environmental conditions are called a greenhouse [2]. Greenhouses used in greenhouse cultivation, also known as greenhouse growing, vary by the materials used in their structure. Since our country is located in the mild temperate zone, greenhouse cultivation has developed depending on natural conditions, and it is mostly performed in the Mediterranean region. Greenhouses are considered as more favorable areas for air conditioning since they are the areas independent of the external factors.

A. Greenhouse Automation

Greenhouse automation consists of two parts as hardware and software. The hardware part is composed of a computer, a system with PLC (programmable logic control) or a system with a microcontroller (Arduino, PIC, etc.) or a control system consisting of the combination of them, and output units (relay, contactor, etc.) controlled by them. The sensors used to perceive the physical changes controlled in the environment act like the sense organ of the system. The software part performs the decision-making function by fulfilling the tasks of controlling the existing hardware and receiving data [3].

B. Soilless Agriculture

Soilless agriculture is the technique of growing products in another area without using the soil. In other words, the difference of agriculture in the water from the greenhouse system in the soil is that growth of the plant can also be controlled. The braking system of the plant can be removed by this method used. Abnormal growth can occur in the plant as this process is not performed in the greenhouse with soil. Another advantage compared to the production in the field is the fact that plants are made free from other environmental conditions, atmospheric effects. The commercial spread of the technique dates back to the 1970s [4]. It is possible to grow many different...
products using this technique. The developments in soilless agriculture indicate that its popularity will further increase in the future. An example of a soilless agriculture application is seen in Figure 2.1.

![Figure 2.1. Soilless Agriculture Application [5].](image)

Some of the advantages of soilless agriculture are as follows:
- The labor force required to grow crops decreases in soilless agriculture.
- Plants can be grown by performing soilless agriculture even in areas with unfavorable soils.
- The amount of expenditures spent on growing crops is not high.
- Soilless agriculture is more suitable for automation system compared to normal agriculture.
- Products are systematically fed by means of automation in soilless agriculture.
- Water saving is provided by minimizing the water loss in greenhouse systems.
- There is not any danger of insects and weed problem in the products.
- With this modern agriculture, the quality of the crop increases and more harvest opportunities are provided.
- Products are cleaner than the crops in the traditional agriculture during the harvest season.
- The fallowing method is not used as it is not necessary to be dependent on the soil to grow the crop. In addition, crop planting can be performed again after harvesting [6].

The tendency to landless agricultural is expected to increase because of these advantages.

### III. ARDUINO

Arduino is a flexible, easy-to-use hardware and software-based physical programming platform which was developed by Italian electronics engineers from the development environment, that contains an input-output card and an application of processing / wiring language, as open source software, and in which everybody who wants can print their circuits by downloading printed circuits and can take the ready-printed and components with a stylish look as embedded [7]. While Arduino can be used to develop interactive systems that can run on their own, it can also run together with the software running on the computer by establishing contact[8]. Ready-made cards can be purchased or information about hardware design is available for those who wish to produce them. The microprocessor (AtmegaXX) on the Arduino development card is programmed using Arduino programming language (wiring based) and the program is installed to the card by using the Processing based Arduino Software Development Environment (IDE) [7].

![Figure 3.1. Arduino Leonardo [9].](image)

There are many different Arduino platforms on the market to be appropriate to the status of the system to be controlled and to be able to meet different needs [10].

With Arduino, many different operations can be performed as follows [11];
- New projects can be designed easily by interacting with the environment.
- It can be developed as required by users since it is an open source code development device.
- It is a device with the capacity to process analog and digital input signals as data.
- Since the sensors can be connected to this platform, the data from these sensors can be used.
- The programming of Arduino’s libraries and microcontrollers is very easy.
- Outputs (sound, light, motion, etc.) can be produced to the external world.

The programming interface is used in its connection to the computer to program the Arduino card. Some cards contain embedded USB jacks, so all you need to do is connect the USB cable to the computer. Some cards have headers. Therefore, the only thing to do is to connect the FTDI Basic breakout or FTDI cable. Cards like Arduino Mini are available for serial pin programming but are not compatible with FTDI headers. Each Arduino with embedded USB jack has some different hardware for USB conversions. In addition, some cards do not need additional hardware because microprocessors have embedded USB support [12].
Arduino Nano was used for the control of the system in this study. Arduino Nano is a small, useful breadboard-friendly Arduino card containing ATmega328 microcontroller (Arduino Nano version 3.x) or Atmega168 (Arduino Nano version 2.x) microcontroller. Arduino has almost the same features with Duemilanove. Arduino Nano has been designed and used by Gravitech [13]. The front and back sides of Arduino Nano V3 are presented in Figure 3.1.

Figure 3.1. Front and back sides of Arduino Nano [13].

IV. APPLICATION

The flow chart regarding the measurement and control for the automation of soilless agriculture in the greenhouse with Arduino is given in Figure 4.1.

Figure 4.1. Flow Chart of the System

A. DS18B20 Temperature Sensor

This sensor is a water-proof type of DS18B20 sensor which is used to measure the temperature of the environment, and it was used to measure the temperature of the main tank in the project. Since the sensor is digital, the temperature can be measured at deep distances by its cable. There is also no corruption in the data transfer. It can be configured via a single cable (1-wire), and 9 or 12-bit reading can be performed. The temperature measurement of the equipment, machines, and liquid pools in various places can be performed sensitively with this sensor [14].

Figure 4.2. DS18B20 temperature sensor

B. DS1302 RTC Module

DS1302 is the real time clock and battery-backed RAM (Random Access Memory) module produced by Maxim integrated company. The DS1302 module contains a real-time clock/calendar and 31-byte static RAM. It contains real-time information. DS1302 integrated RTC sensitively provides the required timings by externally connected 32,768 kHz crystal. In addition, since DS1302 is powered externally, it continues to run within itself even if the energy of the system in which it is used is disconnected, and it keeps time/date and RAM information in its memory. The DS1302 integration uses simple synchronic communication to communicate [15].

Figure 4.3. DS1302 RTC Module

C. Power Supply

The basic task of the DC power source is to convert 220V 50Hz alternating voltage or current in the grid into constant DC voltage and current. Power sources are a unit used in almost all electronic devices. A basic power source generally consists of a rectifier, filter, and regulator [16]-[17].

12 Volt 5-Ampere Power source was used to feed the main circuit in the project.

Figure 4.4. Power supply

D. 8-Channel 5 Volt Relay Card

It is a relay card that can control contacts with 5 V and can be used with Arduino or other microcontrollers. It draws a current of 20mA during the triggering of the microcontroller. It is an electronic card circuit which is frequently used in various industrial and robotics projects. It can switch the current up to 10 Ampere at 30 V DC or 220 V AC voltage. There are control leds for each relay. The relays are active with logic 0 (0V) [18].

Figure 4.5. 8-Channel 5 Volt Relay Card
E. LCD Screen
6 legs are used under normal conditions for communication with 16x2 LCD Arduino kit. It was used with the one that converts 6 legs into 2 legs and uses the I2C module to provide savings from 6 legs used. This LCD Module is used to monitor the data obtained in the project from the external environment. The LCD screen connected to the I2C module is presented in Figure 4.6.

F. Water Pump and DC Motor
These motors fed with 12 Volt DC voltage were used to pump the nutrient solution to the main tank in the system. The water pump motor was placed in the main tank and used to provide the circulation of the water passing through the pipes where the products standing on the stand are located and the mixed nutrient solution. Both motors run at certain times of the day depending on the time.

G. Aquarium Resistance
In this study, aquarium resistance was used to bring the nutrient solution in the main tank to the desired optimum temperature actively according to the temperature parameter.

V. EXPERIMENTAL STUDIES
A. Temperature Control
The DS18B20 temperature sensor was selected in the temperature control, which is shown as one of the parameters required for the system to operate properly. The purpose of selecting this sensor is the fact that it has high data accuracy and it can reflect accurate results to the screen without being affected by the liquid medium consisting of water in the main tank and nutrient solution.

The average temperature value should be 15.5-18.3 °C in our system [19]. For this reason, if the temperature falls below the desired value at the temperature from the DS18B20 temperature sensor in Arduino software, the relevant output pin in Arduino will switch to the open position, activate the relevant contact on the relay card and run the aquarium resistance which is connected to the contact. The liquid mixture in the main tank will be heated to the desired temperature by means of the running aquarium resistance. When the mixture in the main tank reaches the desired temperature, Arduino will deactivate the relevant output pin when the temperature sensor detects it and exchange data with Arduino. As a result, the resistance will be disabled.

B. DS1302 Connection
Since the project is a time-driven study, a time module such as DS1302 was preferred and the time problem was resolved. The time study in the project is as follows; all data will be reflected on the screen at the beginning of the system. Then, the main motor will run. The main motor will run for 8 hours a day. Furthermore, it will run for a short time at the first system startup in our nutrient kits and it will continue to run by increasing the time in weekly periods. Thus, the system will continue to operate at a regular periodic time. As a result of these periodic time processes, the yield of our plants grown in the running water culture is also expected to be high.

C. EC Algorithm
EC is the name of Electrical Conductivity in English, namely the abbreviation composed of the initials of the words of electrical conductivity. Its unit is mS/cm [20]. The density of the fertilizer mixed with water circulating in the system can be adjusted by checking the level of electrical conductivity. The EC values of the plants are presented in Table 5.1.
In this study, the lettuce plant was preferred by the product selection. In our EC algorithm applied, 0.8 EC value was selected as the beginning, and our 1.1 EC value was selected as the last EC value. The system operates with an average of 40 liters of water. By means of the table given below, in what time the nutrient solution will be pumped into the water circulating in the main tank to bring our EC value to the desired level is seen.

### Table 5.1. EC values of various plants

<table>
<thead>
<tr>
<th>PLANT</th>
<th>EC</th>
<th>PLANT</th>
<th>EC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banana</td>
<td>1.8 - 2.2</td>
<td>Lettuce</td>
<td>0.8 - 1.2</td>
</tr>
<tr>
<td>Melon</td>
<td>2.0 - 2.5</td>
<td>Spinach</td>
<td>1.8 - 2.3</td>
</tr>
<tr>
<td>Strawberry</td>
<td>1.8 - 2.2</td>
<td>Corn</td>
<td>1.6 - 2.4</td>
</tr>
<tr>
<td>Beans</td>
<td>2.0 - 4.0</td>
<td>Mint</td>
<td>2.0 - 4.4</td>
</tr>
<tr>
<td>Onion</td>
<td>1.4 - 1.8</td>
<td>Clove</td>
<td>2.0 - 3.5</td>
</tr>
<tr>
<td>Tomato</td>
<td>2.0 - 5.5</td>
<td>Rose</td>
<td>1.5 - 2.5</td>
</tr>
</tbody>
</table>

In the project, the lettuce plant with growth characteristics in all seasons was selected as the crop. The lettuces were placed in pre-drilled plastic cups at certain intervals. The pearlite substance, which is commonly used in soilless agriculture, was used to ensure that lettuces stood upright. Then, the plastic cups into which lettuce and pearlite were put were placed on the stand. The image of the crop planted on the stand is presented in Figure 5.2.

### Table 5.2. Amounts of the nutrient solution required for lettuce

<table>
<thead>
<tr>
<th>TAP WATER</th>
<th>0.25 EC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Addition from 15°C A pot and from 15°C B pot into 5 liters of water</td>
<td>0.40 EC</td>
</tr>
<tr>
<td>Addition from 25°C A pot and from 25°C B pot into 5 liters of water</td>
<td>0.60 EC</td>
</tr>
<tr>
<td>Addition from 35°C A pot and from 35°C B pot into 5 liters of water</td>
<td>0.75 EC</td>
</tr>
<tr>
<td>Addition from 45°C A pot and from 45°C B pot into 5 liters of water</td>
<td>0.95 EC</td>
</tr>
<tr>
<td>Addition from 55°C A pot and from 55°C B pot into 5 liters of water</td>
<td>1.05 EC</td>
</tr>
<tr>
<td>Addition from 70°C A pot and from 70°C B pot into 5 liters of water</td>
<td>1.25 EC</td>
</tr>
</tbody>
</table>

When the table is used, fluid fertilizers of 300 CC for 0.80 EC, 338 CC for 0.90 EC, 375 CC for 1.00 EC and 413 CC for 1.10 EC from A and B pots were mixed with the water circulating in the main tank by means of DC motors during the first planting for a 40-liter system. Thus, the nutrient density was adjusted by transferring the amounts of the nutrient solution mentioned above into the main tank to achieve these EC values over weekly periods. The optimization of the fertilizer density was ensured by running DC motors for 10, 12, 14, 16 seconds at weekly intervals to transfer the above CC amounts to the main tank.

### D. Project’s Stand and Crop Planting

In this study, the stand on which the plants will be placed generally consists of iron profiles and punch kit and various pipes drilled at 15 cm intervals. The stand is presented in Figure 5.1.

The development of the crop in the first, second and third weeks is presented in the following figures.
Arduino Based Automation in the Soilless Agriculture

CONCLUSION AND SUGGESTIONS

In this study, we aimed to proceed to the modern agriculture by combining the traditional sense of agriculture with technology. In line with this purpose, the plant growing in the hydroponic (running water culture) environment which is common abroad was applied in our system. This application was performed in two stages.

The first stage consists of stand construction, fertilizer selection, and plant selection. Lettuce which is a plant growing all seasons was selected during the plant selection. During the fertilizer selection were selected: Calcium Nitrate, Ammonium Nitrate, Potassium Nitrate, MKP, Potassium Sulphate. We used Magnesium Sulphate Boron, Zinc, Sodium Molybdate, Manganese, Copper, Molybdenum mixture. The stand consists of iron profiles and various PVC pipes.

The second stage is the automation part. In the system established, parameters such as temperature, EC variable and time dependent motor control were studied. The evaluated parameters were kept under control. As a result of our modern agricultural technique application, the harvest time of the planted crop was realized in a short time of 21 days. The quality of the crop also increased.

The change of the farmer’s viewpoint on modern agriculture is obvious along with the advantages we have mentioned above, thus, economic and agricultural development is predicted along with the farmer’s transition to the modern agricultural sector.

A PH sensor can be added to the system in subsequent studies. Thus, the control of the specific PH ratio can be achieved and more efficient and quality crops can be obtained.

REFERENCES

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