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Smart greenhouses using internet of things: case study on tomatoes

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Abstract

Many practices are available to apply to smart agricultural methods, defended as allowing monitoring and controlling the environment necessary for the growth of many crops. Due to the random conditions affecting crop growing and cultivation, the idea of greenhouse use is emerging, as a way of managing all variables affecting growth and production of crops. Photosynthesis is the most important process for plants, with three main inputs: water, light, and carbon dioxide. Atmospheric temperature and humidity, soil richness, and plant nutrition are also vital for crop production. This research is concerned with controlling the environment of plants and plant nutrition. The Internet of Things (IoT) is proposed in this research as a solution to control and to manage all of these variables. Most important was to find a method that provides perfect analysis and control of a suitable environment for crops in greenhouses. Smart management of variables to manage crops is becoming a necessity. With IoT we can keep an eye on and manage all variables to grow crops in the best conditions for crop production. This article will discuss the kinds of variables that play important roles in growing a good crop. The next issue is how to retrieve these variables as big data, using sensors; how to save them to the cloud for processing; and then how to create actions according to readings of variables and predefined interdependent relations, with the main aim of better production in smart greenhouses.

Keywords

Smart greenhouse, event-trigger, photosynthesis, NPK, sensors, Arduino

Introduction

Greenhouse structures adapted to new possibilities in the 1960s, when wide sheets of polyethylene film became widely available. Water-related greenhouses became more prevalent in the 1980s and 1990s. Greenhouses connected to gutters are usually covered with a polycarbonate structural material [1, 2] or a double layer of polyethylene film with air blown between the layers to provide increased heating efficiency. Heating inputs have been reduced as the ratio of floor area to exterior wall area has been greatly increased. Water-connected greenhouses are now commonly used both in production and in situations where plants are grown and are also sold to the public [3, 4].

This article is concerned with monitoring the nutrition available for the plant to grow in the best conditions, and with enriching the soil with the most

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appropriate amounts of these nutrients, most importantly nitrogen, phosphorus, potassium (NPK). The aim is to reach the optimum production level. Other variables have their influence on production, such as improving the surrounding conditions of the crops in greenhouses, also to increase production and reduce cost. These surrounding variables will be adjusted to reach the best conditions for growth and production [5–7]. Conditions will be read using sensors and transmitted to IoT big data management to read for optimal conditions to plant and cultivate crops. The variables to be considered are breathing (ventilation), atmosphere temperature (heating and cooling), lighting (photosynthesis) and others.

Photosynthesis formula

In plants, photosynthesis occurs mainly within the leaves. Since photosynthesis requires carbon dioxide, water, and sunlight, all of these substances must be obtained by or transported to the leaves. Carbon dioxide is obtained through tiny pores in plant leaves called stomata. Oxygen is also released through the stomata [8]. Water and nutrition are obtained by the plant through the roots and delivered to the leaves through vascular plant tissue systems. Sunlight is absorbed by chlorophyll, a green pigment located in plant cell structures called chloroplasts.

$$6CO_2 + 6H_2O + \text{Chlorophyll} + \text{light} \rightarrow C_6H_{12}O_6 + 6O_2 + 6H_2O$$

(Carbon dioxide) (Water) (leaves) (Glucose) (Oxygen)

If we took this equation as basic to growth in the chosen plants, then we must study each input of this equation and determine what the variables are that affect each input.

CO_2 breathing and ventilation

Ventilation is one of the most important components of a successful greenhouse. If there is no proper ventilation, the [9, 10] greenhouse and its growing plants can become exposed to severe problems. The main purposes of ventilation are to regulate *temperature and humidity* to an optimum level, ensuring air movement and thus preventing the buildup of plant pathogens (e.g., Botrytis cinerea) that favor still air conditions. Aeration also ensures that fresh air is provided for photosynthesis and plant respiration, and may enable important pollinators to gain access to the greenhouse crop.

H_2O water

The volume of water needed by tomato plants for optimal growth and production varies with the season and size of the plants. Soil moisture can determine how much water should be added, and soil moisture sensors can measure the appropriate amount of water needed. Young seedlings usually need about two fluid ounces (50 ml) per plant per day, while mature plants need two to three quarts (2 L) per day. On average, 90% of the water taken up by [11] the plant is used for transpiration (cooling), and the remaining 10% is used for growth. Inadequate amounts of water lead to wilted plants, and wilted plants are not productive. Prolonged water deficits can lead to permanent wilting, which can result in the death of the growing tips of the plant.

The water should be provided in six to twelve (or more) applications per day, depending on the type of growth medium used. Well-drained media, such as rice hulls, may need more than twelve applications per day. The timing of [12] applications should be determined by the water demand of the plants, with most of the applications occurring during the day. Some nighttime watering may be needed during periods of low humidity. More applications may be needed on sunny days to accommodate the increased rates of transpiration by the plants. Enough water should be applied that some drainage occurs from the growth medium bags (10%–20% of the water applied), and this additional amount of water needs to be added to the total amount of water required.

Light

Light is an essential factor in maintaining plants. The rate of growth and the length of time the plant remains active depends on the amount of light it receives. Light energy is used in photosynthesis, which is the basic metabolic process of a plant. When determining the effect of light on plant growth, there are three areas to consider: intensity, duration, and quality. Light conditions and duration are not included in this research study, as we will make our test in optimum light duration and exclude light variables from this study. The concentration will be on plant nutrition [13, 14].

Increasing the time (duration) that plants are exposed to light can be used to compensate for lower light intensity, as long as the plant's flowering cycle is not sensitive to day length. The increased light duration allows the plant to produce enough food to

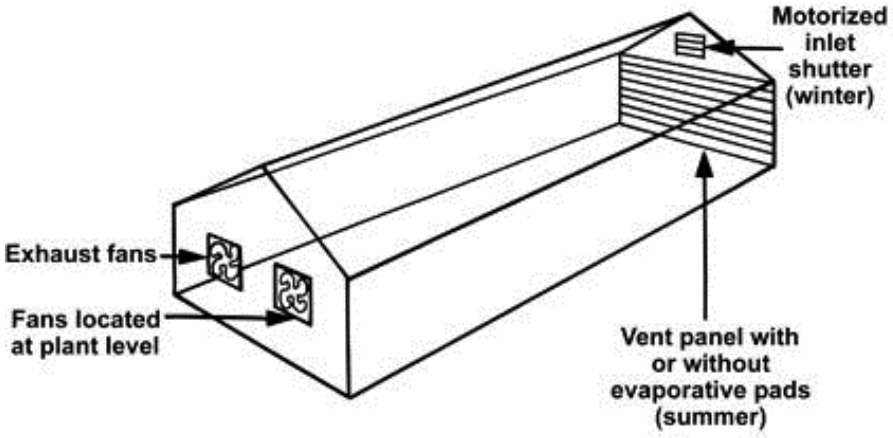


Figure 1: Smart Greenhouse with ventilation and automated cooling and heating system.

survive and grow. However, plants require a period of darkness to develop properly and must be exposed to light for no more than 16 hours a day. Too much light is as harmful as too little. When a plant gets too much direct light, the leaves become pallid, sometimes burn, turn brownish, and then die. Therefore, we need to protect the plants from excessive exposure to direct sunlight during the summer months [15, 16, 17].

Chemical nutrient contents (NPK, Chlorophyll)

The most important factor in planting crops is the nutrition of plants. In the next section we will discuss the effect of nutrients on building up chlorophyll [19], the vital input element in photosynthesis. It must be mentioned that there are many chemical subsidizers: most important are the NPK supplements. There are some other chemical elements (e.g., magnesium [Mg], sulfur [S], and calcium [Ca]) that have their effects on plant growth in all growth stages, from *nursery phase* to *fruit formation* [19] to *maturity* phase, which represents the final production of a plant (see Figure 3). This article is primarily concerned with collecting data readings of NPK concentrations in soil and determining the best NPK concentration in planting soil for optimum production.

Surrounding environment

This section is mostly concerned with the environment [20, 21] (physical surroundings). These elements are important in the process of cultivating tomatoes in greenhouses. As shown in Figure 1, physical conditions can be automated and controlled according to threshold readings of data for each condition. If a threshold is reached, an action will be activated to reduce or increase readings to that most appropriate to the plants. These conditions are:

1. **Air humidity:** Humidity is important to photosynthesis. In the case of anthurium, good humidity around the plant is even more important than for most other crops, because the plant can only absorb a reduced amount of humidity and hence has less water evaporation than most plants. If the plant loses too much water, the stomata will close with the result that photosynthesis stops [22]. If this happens, no further CO_2 can be absorbed, and CO_2 is required to keep the photosynthesis going. Improper humidity levels affect plant functions and can cause irreparable damage to roots, stem, foliage, flower, and fruit.
2. **Temperature:** Air temperature affects many aspects of tomato development, including growth, photosynthesis, respiration, and physiological development. Temperature also affects relative humidity as warm air can hold more water than [23] cold air, and relative humidity is expressed as a percentage of the maximum amount of water the air can hold. Understanding the effects of temperature is essential to improving tomato production in protected systems. In general, the optimum temperature during the day for tomato production is 70 to 82°F (21 to 27°C), [24, 25, 26, 27] and optimum temperatures at night between 17°C and 18°C. However, optimum temperatures vary somewhat with the stage of plant

growth. Symptoms of nutrient deficiencies, primarily from a lack of phosphorous intake, begin to appear in temperatures below 16°C. At temperatures above 30°C, lycopene, the red pigment in tomatoes, does not form, and the fruit does not color properly. Temperatures must be at 25°C for seed germination and [28] the first few days after emergence. Then, the temperature should be lowered gradually over two days (19–20°C) during the day and night. Maintain this temperature until it is time to transplant the seedlings into blocks of mineral wool. When transplanting, set the temperature to 24°C. Maintain this temperature for 1 to 2 days after transplanting and then gradually reduce it by 2°F daily (1°C per day) until the temperature reaches 66°F (19°C) during the day and night.

3. **Soil moisture:** [29, 30, 31] in this research we will not go through soil kinds and characteristics. We will look at soil as a container to hold the root of plants. The roots can absorb water and other nutrients. This research will not go through various irrigation systems and their characteristics; we are mainly interested in giving plants adequate amounts of water by using moisture sensors to read the water concentration in the soil, preventing overwatering or drought.
4. **Heating, cooling, and ventilation** can be monitored by sensor readings (trigger, event) and the system will react depending on the needs to keep the greenhouse in its optimum condition. Normally the reaction to triggers might be mechanical or electronic action – for example, opening the sides of the greenhouse for ventilation, turning the fan on or off given high temperatures, spraying water in low humidity [32, 33], starting heaters when too cold (less than 10°C) and so on. We need to maintain the inside temperature for best conditions, and balance temperature and humidity. This balance would be defined according to the Table 1.

The main idea is to protect plants from extreme cold and frost. But heat can also be deadly; for tomatoes, therefore, it's important to properly manage the temperature and humidity inside the greenhouse [34, 35].

The ideal temperature for a greenhouse is between 80°F to 85°F (26.5°C–29.5°C). You want humidity, but you do not want your humidity to be too high, as high humidity can foster viruses, fungi, and mold.

At 80°F (26.5°C), humidity should be 40%–85%, depending on what plants you are growing. We can

Table 1: Recommended temperature of tomato greenhouse based on light levels

Minimum Temperature	Low Light (Cloudy Days)	High Light (Sunny Days)
Night	63°F (17°C)	64°F (18°C)
Day	66°F (19°C)	70°F (21°C)

Table 2: Relative humidity ranges related to temperature in greenhouses

Temperature °F (°C)	Relative humidity range
60 (16)	60%–75%
65 (18)	65%–80%
70 (21)	70%–80%
75 (24)	75%–85%
80 (27)	80%–85%
85 (29)	85%–90%

determine and control temperature and humidity in [36] a greenhouse using thermometers and humidity sensors. These can be linked to automated systems that adjust the temperature and humidity via fans, windows, humidifiers (and other means which are not our main focus in this article).

Figure 2 defines the best environmental values of temperature and humidity for growing tomato plants. The equation that satisfies this condition is

$$\text{TH Max} = \sum \Delta(RH\ Min + RH\ Max) - |Temp\ \alpha|$$
$$\text{TH Min} = \sum \Delta(RH\ Min - RH\ Max) - |Temp\ \alpha|$$

The environmental aspects of plant growing conditions are dealt with by the threshold method with this state.

For example, an event can be reaching a minimum or maximum threshold that will trigger a ventilation fan or opening of the greenhouse walls; other triggers can switch a heater or cooler on or off to raise or reduce temperature.

Methodology: technical issues, smart greenhouse

The main aim of this research to obtain the best harvest of tomatoes [37, 38], which is the most consumed vegetable among the earth's populations. This main goal can be achieved by supervising and

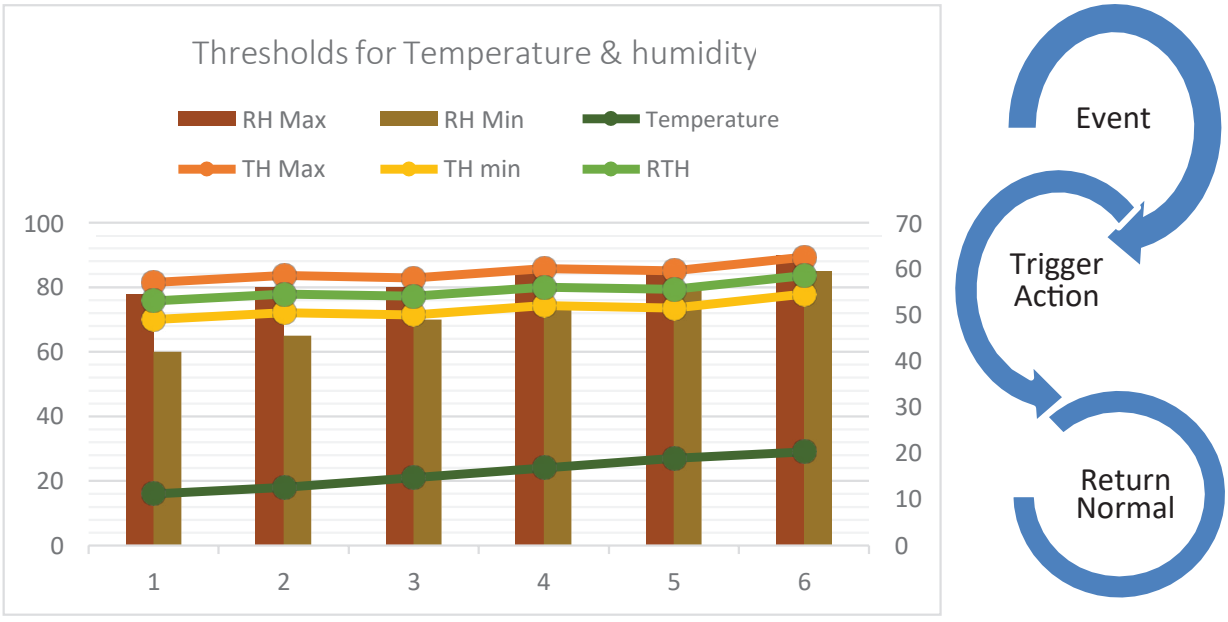


Figure 2: Relation between temperature and humidity. RH Max, Maximum Relative Humidity; RH Min, Minimum Relative Humidity; Temperature, Absolute temperature degree; RTH, Normal Relative Temperature to Humidity level; TH Max, The Maximum Value of Threshold to Action.

controlling conditions around tomato plants and nutrients supplementing tomato plants in greenhouses. We have identified at least six variables that are the main affects for this seedling plant. Half of them are concerned with the surrounding environment and can be controlled as actions responding to threshold triggers; the second half concerns nutrition of the crop. We are mostly interested in NPK nutrition because these nutrients are the most needed [39, 40, 41]. The seventh variable is the *light*. Light is separated from these main variables, as light and carbon dioxide are naturally existing (light) and cast off by plants (carbon dioxide). Nevertheless, light has variable intervals that affect the crop lifetime, and these intervals are beyond this research. On the other hand, CO_2 is normally constant in theatmosphere environment.

The variables that will be considered are those which have a primary effect on the crop; however other variables also have their impacts on the crop:

1. **Nitrogen (N):** Nitrate (the form of nitrogen that plants use) helps foliage grow strong by affecting the plant's leaf development. It is also responsible for giving plants their green coloring by helping with chlorophyll production (gardensalive.com).
2. **Phosphorus (P):** Phosphorus is responsible for assisting with the growth of roots and flowers. Phosphorus also helps plants withstand environmental stress and harsh winters.
3. **Potassium (K):** This strengthens plants, contributes to early growth, and helps retain water. It also affects the plant's disease and insect suppression.
4. **Magnesium (Mg):** This contributes to the green coloring of plants. If Mg is deficient, the shortage of chlorophyll results in poor and stunted plant growth.
5. **Sulfur (S):** This mineral helps plants resist disease as well as contributing to plant growth and the formation of seeds. It also aids in the production of amino acids, proteins, enzymes, and vitamins (davesgarden.com).
6. **Calcium Ca:** This aids in the growth and development of cell walls. This is key because well-developed cell walls help the plant resist disease. It is also necessary for metabolism and the uptake of nitrogen by the plant.

Natural conditions on location (surrounding environment)

The geographic location plays a central role in managing the variables mentioned above [42, 43]. Temperature and humidity in our testing location, for

example, are very close to what we needed inside the greenhouse for some seasons of the year. The length of the light (day, night) is mainly responsible for photosynthesis.

Tomato fruits have several stages of growth, starting from seed until collecting ripe fruits. Figure 3 defines the growing stages.

This research project is based on data reading, supervising, and control of tomato plant growth. In our experiment we will plant one tomato plant in a container. In Figure 4 the dimensions are defined using an inch unit (“). This container will be filled with soil. The whole container filled with soil will be placed on a balance scale and the weight calibrated to zero. Tomato seed will be planted in the soil to start the process. Each day in the morning the weight sensor will send data on the weight of the growing plant: only the plant, with all its contents, such as seeds, leaves, stems, flowers, and fruits.

The testing area of this research is in Aroub, which located in a suburb of Hebron, a city in Palestine (see Figure 5 for location).

This is considered a rich agricultural area that produces all kinds of fruits, especially tomatoes and cucumber. The annual climate condition in this area is given is given in Figure 6.

As we declared in the introduction to this article [44, 45], there are two parts of supervising and controlling greenhouses. Firstly, the surrounding conditions, which can be managed using given data of sensors on the basis of events – that is, the trigger method. Secondly, management of data concerning nutrition: more precisely, NPK added substances. The surrounding conditions aspect is more simple and straightforward. After testing location climate, we will start planting at 20 April, as this time is ideal for planting tomatoes in that

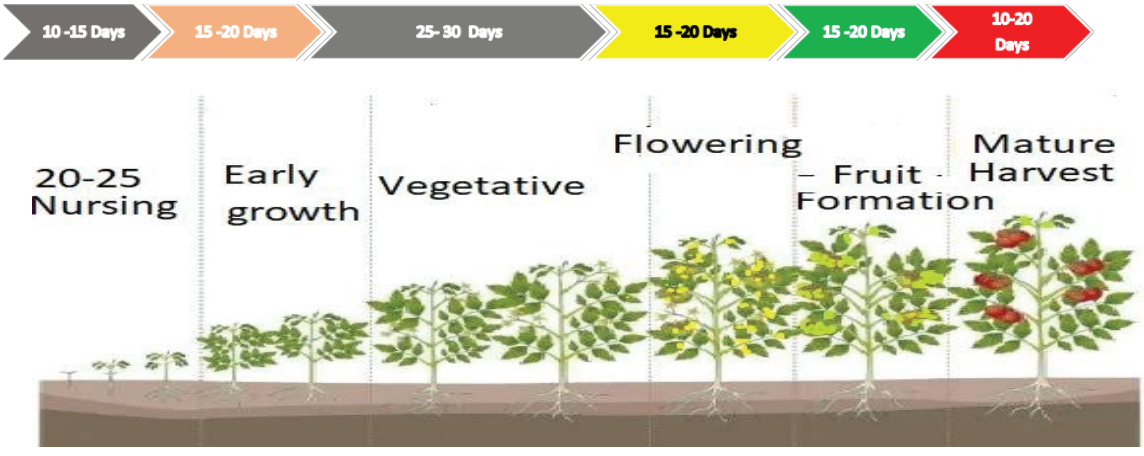


Figure 3: Growing stages of tomato plant last about 100 days.

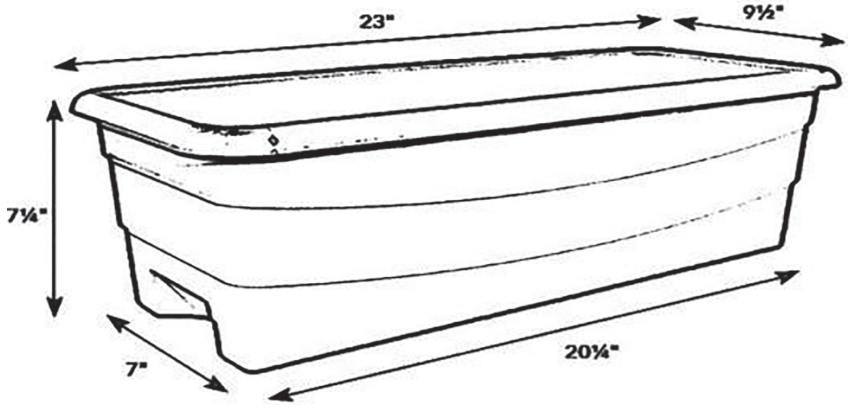


Figure 4: Testing container dimensions.



Figure 5: Geographic location where experiment is conducted, Palestine, Hebron district.

location, as all variable conditions (light, humidity, temperature) are ideal for planting. We will do the planting process in the best light duration for planting tomatoes: at least 8 hours and 9 hours for the fruit formation and mature fruit stages, and no more than 9 hours in vegetative and flowering stages. Daytime ideal humidity levels in a green house range from highs of 90% down to 80%.

The nighttime moisture levels, however, range slightly lower, between 65% and 75%. The least humidity is needed at the fruit formation and mature fruit stages, and the most humidity is required during vegetative and flowering stages. The best temperatures for tomatoes at various stages is as follows: in-earth growing (12–17°C), vegetative (14–17°C), flowering (16–20°C), fruit formation (18–22°C), and mature fruiting (26–30°C). In any case, temperatures should not go above 28°C or below 5°C. The plant will die if temperatures soar above 30°C or drop to less than 0°C. In any case, if the RTH curve hits the upper or lower threshold, it will be a trigger to correct the issue, as mentioned above in the section on surrounding conditions.

Soil nutrition, NPK

Adding nutrition is very important for the plant in all stages mentioned above, from the nursery stage until mature fruiting stage. Basically the nutrients that we will consider in this research are nitrogen, phosphorate, and potassium (NPK), normally, [46, 47, 48], as we have discussed above. We will add to our

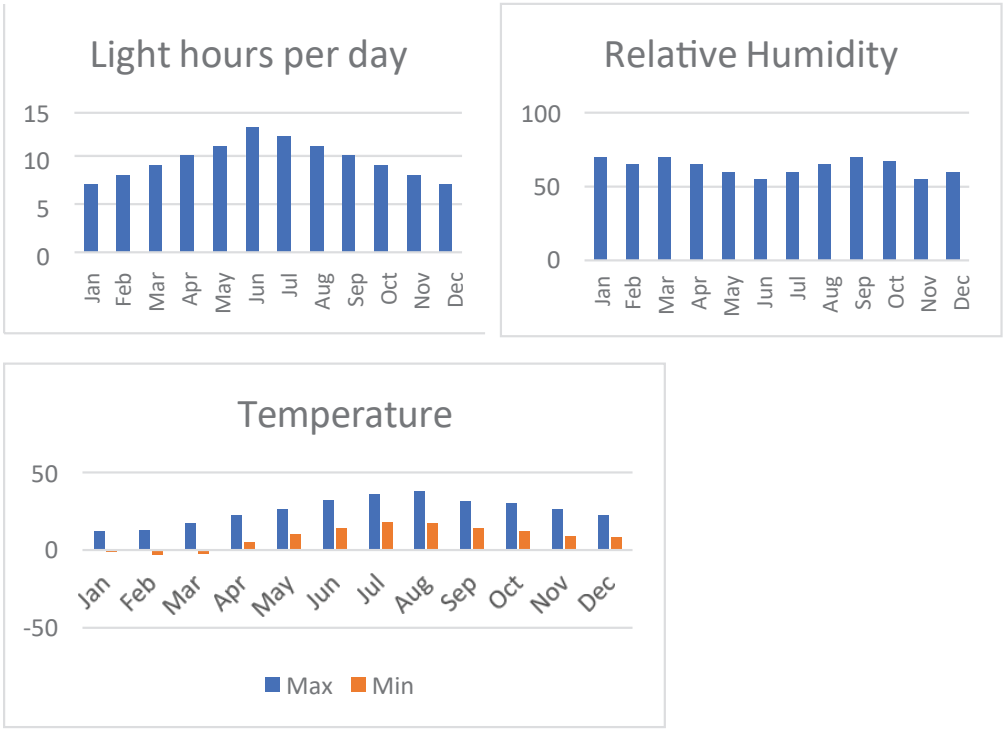


Figure 6: Annual climate condition of testing area.

container the following concentration values to reach better production: N (100–250 mg/kg), P (60–140 mg/kg), and K (60–120 mg/kg). We can control the concentration of these nutrition elements using soil sensors.

The soil nutrient content can be measured using an NPK soil sensor and Arduino of ammonium content. It is necessary to determine how much additional nutrient content should be added to the soil to increase crop production. The soil fertility can be measured using the NPK sensor. The major elements of soil fertilizers are nitrogen, phosphorus, and potassium. By reading values of soil nutrient concentration, we can learn about the nutritional deficiency or sufficiency in soil for plant growing stages. There are many methods for measuring soil nutrient elements, such as optical sensors or spectrometers. But the spectral analytical method of determining the nutrients is only 60% to 70% accurate. While comparing the spectral analysis method with traditional wet chemistry methods, accuracy of the product is yet to be fully resolved. So here we will use an optical sensor to detect nitrogen, phosphorus and potassium in the soil, as shown in Figure 7.

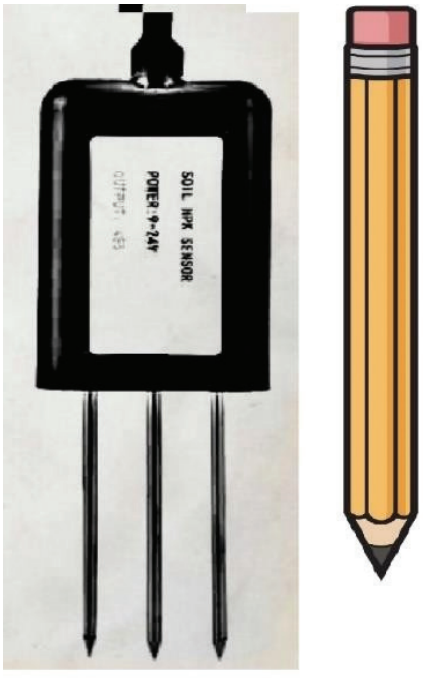


Figure 7: Nitrogen Phosphorus Potassium sensor actual size.

This kind of sensor is low-cost, quick, responsive, high precision, and portable, and it works with network and data transitions module Rs 485, with an output signal which can wirelessly transmit data up to 1200 meters [49]. The advantage of the optical sensor over a traditional detection method is that it gives instant measurements and highly accurate data. All we need is to insert its probes in soil and get the reading using Arduino. Thus, we can easily make our own instrument soil check NPK meter. In our test case we can read the details about the interfacing of soil nutrient sensor or NPK sensor with Arduino and display the NPK data in an OLED display. This soil sensor is suitable for detecting the contents of nitrogen, phosphorus, and potassium in the soil. It helps in determining the fertility of the soil and the sensor can be submerged in soil for a long time. It has a high-quality probe rust resistance, electrolytic resistance, and salt and alkali cover resistance. Therefore, this sensor is most appropriate for all kinds of soil. The sensor has high measurement accuracy, fast response speed, and good interchangeability, and it can be used with any microcontroller [50, 51, 52]. The sensor operates on 9 to 24 volts, and power consumption is very low. The sensor's accuracy is within 2%. The measuring range is from (0–1999) mg/kg. The operating temperature is between 5 to 40°C. The output signal can be read using a mode for Rs 465 transmitter. The sensor has a predictive layer made using IP Success rating [53]. The sensor we need to make a NPK meter has four wires and works using mode unit 20 Amber converter along with twelve-volt supply.

The system that is shown in Figure 8 has two objectives. The first is to get an instant reading of nutrition concentration in units of mg/kg. This reading will be displayed on an OLED display. The second is to send data, transmitted wirelessly, to a server in a data center, for advanced control and data management to get the best NPK percentages [54, 55] and the most accurate percentage of NPK needed, depending on the growing phases defined in Figure 3. The main objective of big data collected is to control NPK added amounts to increase production of tomato fruits, for more than 90 days, which represents the life cycle. Each day we need to take the measurements of NPK concentration in soil and the weight of the whole plant. We can change the amount of NPK nutrition and see the resulting production, so we will then find the best conditions (values for amount of variables N, P, and K). Then the interface module needs to be connected to the NPK sensor to get the NPK reading. Then we assembled the circuit of the entire system, which can be applied on a breadboard. Apart from the breadboard, we will need any Arduino board, which can be programmable. Similarly, we used an OLED display square where we can display the NPK readings.

This system works to retrieve the data from the RS 485 mode bus from the NPK sensor, which has 3 lines: one line is for getting the nitrogen value in soil.

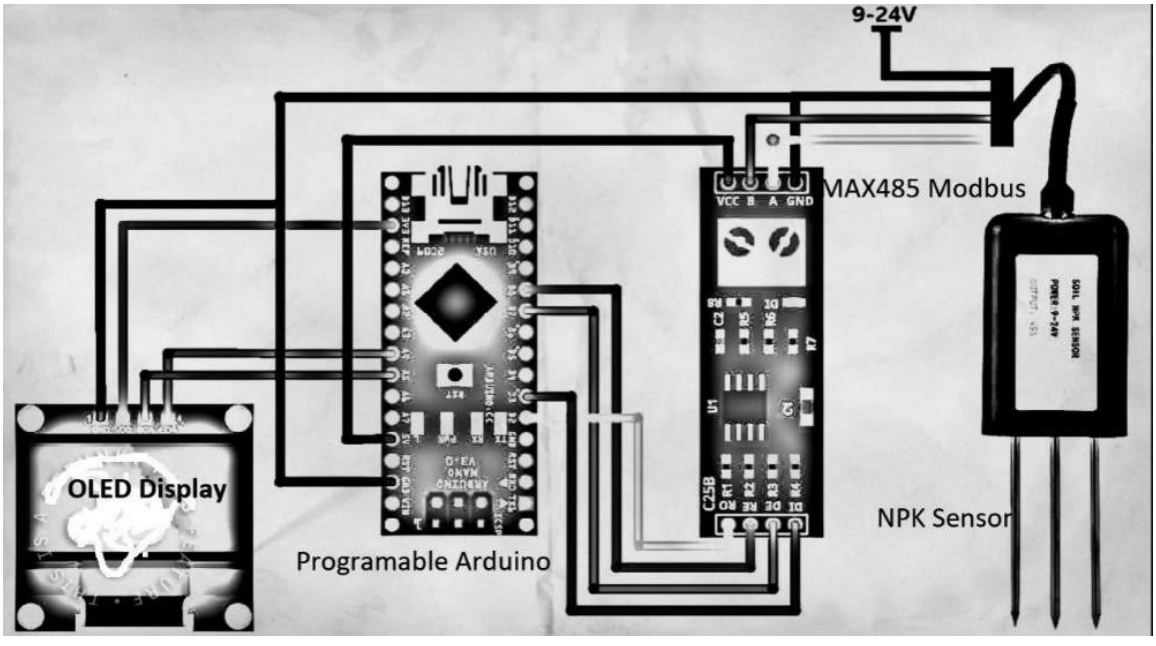


Figure 8: IoT system to check and calibrate substants NPK in soil.

[56] Similarly, the second line is for phosphorus, and the third is for getting the value for potassium. The instruction frame of data consists of the following data sets:

- Address code: the address code of instruction frame
- Function code: the code of function in the instruction
- Register start address: the address of data reading
- Register length: the reading of NPK
- CRC_L, CRC_H: Cyclic Redundancy Check network protocol

The general form of the instruction frame is:

Address Code	Function Code	Register Start address	Register Length	CRC_L	CRC_H
0x01	0x03	0x00 0x1e	0x00 0x01	0XE4	0x0C

An example of response to inquiry in the case of nitrogen is:

We can calculate the soil nitrogen from the

Address Code	Function Code	Effective Number of bytes	Nitrogen Value	CRC_L	CRC_H
0x01	0x03	0x02	0x00 0x20	0Xb9	0x9C

Response received. For example, if we get 0030 as a response then soil nitrogen value will be:

0020 H(hexadecimal) = 32 (Decimal) => Nitrogen = 32mg/kg

The NPK Sensor has 3 different inquiry frames for reading the value of nitrogen (N), phosphorous (P), and potassium (K). The inquiry frame is provided laterally with the instruction manual. For the NPK data the following individual inquiry frameworks:

1. *Nitrogen: {0x01,0x03, 0x00, 0x1e, 0x00, 0x01, 0xe4, 0x0c}*
2. *Phosphorus: {0x01,0x03, 0x00, 0x1f, 0x00, 0x01, 0xb5, 0xcc}*
3. *Potassium: {0x01,0x03, 0x00, 0x20, 0x00, 0x01, 0x85, 0xc0}*

Now, we are ready to read data and transmit the data frame to the big data repository. Using Arduino we can read data instantly from OLED and save it into the data center for future management and control.

We have seen in the previous section how to install the control system hooked with the NPK sensor. Programmable Arduino is connected for enabling an instant read of NPK amounts on a daily basis. Two main jobs are needed from the Arduino program: the first is to display the instant reading of NPK concentration in the soil; the second is to send signals to the cloud data center of all readings of given variables [57, 58]. Data transmission can be programmed on daily or hourly (or any specified) time intervals; in our case the data transmission can be on daily basis and no less. A per-day interval is chosen because, as we discussed before, real growth in plants normally occurs at night, which comes as an output of the photosynthesis process.

The interfacing software of the soil NPK sensor is connected to Arduino. It can retrieve soil nutrient values from the sensor via instruction command. The instruction command can be sent, and the value obtained in hexadecimal code. Then the HEX code needs to be converted into number values in decimal to get the value of soil nutrient contents in shape of big data [59, 60, 61].

Here we are using the OLED display to see the soil nutrient values (nitrogen, phosphorus, and potassium) in mg/kg. Also, we need to download the OLED Library. And added to this, the Arduino IDE commands can instruct a set of devices to do the following:

1. Change the value in one of its registers on/off, which is written to one bit register *coil* and read the value of holding register (16 bit) in Arduino
2. Get the reading of an I/O port, and get data (8 bits) from holding register and reading from one bit register (*Coil*) ports,
3. Command generating to the device (Arduino) to send and transmit values of iterations of Coil Registers and Holding Registers.

A Modbus instruction command contains the Modbus address of the device it is intended for (**1 to 247**). The Modbus instruction address is also called an inquiry frame. Only the addressed device will respond and act on the command, even though other devices might receive it, and it is transmitted to the big data repository. We applied the NPK data management on two experiments with ideal surrounding conditions, as mentioned in previous sections (geographic location at Aroub, Figure 5; start planting at April 25; and using the container mentioned in Figure 4 with same weight and soil; but in the first case it added NPK using soil mixing the traditional way of planting, which mixes soil

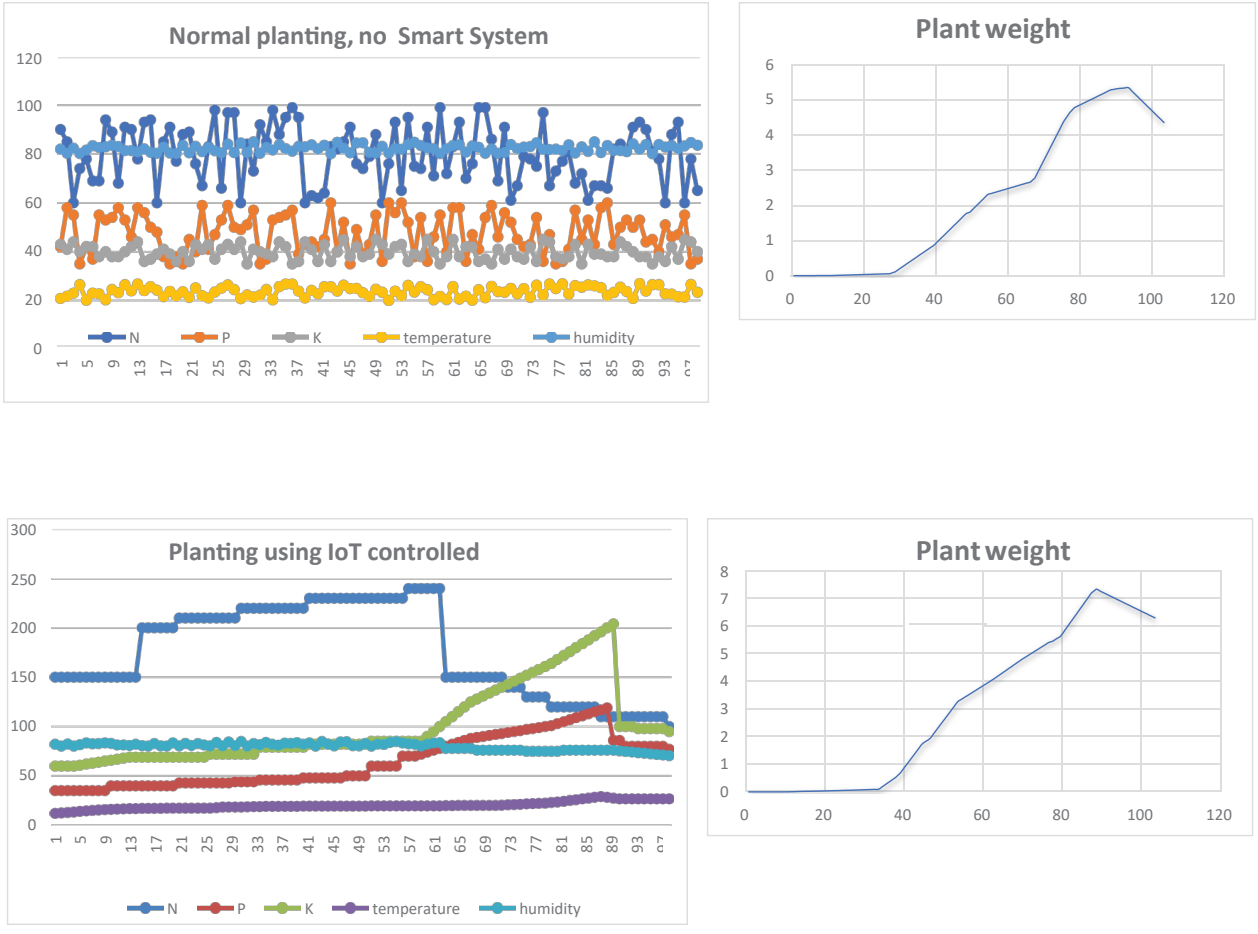


Figure 9: A) Concentrations of NPK and

with NPK; the second case in the experiment is to irrigate a solvent of NPK as a solution on the plants in containers, and check the amount of each nutrient on a daily basis. The experiment ran for 100 days [63].

Figure 9 shows two experimental plantings of tomatoes in two different containers in the same greenhouse conditions. In the first experiment we planted tomatoes using a traditional planting method: this method adds nutrients according to best-practice manual experience, which is adding nutrition as needed. The result – production of green and fruits – is up to 5.6 kg. The second part of Figure 9 shows planting tomatoes using controlled addition of nutrition based on each stage of growth. We found that with IoT controlled NPK addition, production will reach 7.4 kg, which exceeds the first, traditional, method by 2 kg. We can do more readings and experiments, playing with all variables, keeping records in our big data repository, until we define the very optimum production of greenhouse tomato cultivation.

Conclusion

This research is based on experimental big data applied to smart greenhouse cultivation to give better production for tomato fruits. This article shows that we can define two categories of variables (parameters) that actually affect tomato growth. First: the surrounding environment and conditions like temperature, humidity, and light: these variables can be controlled and kept at ideal levels using RTH (Relative Temperature to Humidity) levels. Also, we can manage this category of conditions for greenhouses using method of sensor readings of values, and actuators based on events and triggers for action. Second: the tomato plant percentage of nutrient concentration in

soil where the plant root is located can be known. These nutrients are dissolved in soil where plant roots absorb these nutrients. This article has defined more than five growing stages of the plant life time circle; each stage needs a certain amount of these nutrients added as a solution in the irrigation water (particularly nitrogen, phosphorus, and potassium [NPK]). Using special soil sensors, we can read data for the amount of each element and transmit the data readings to a data repository in a data center. Two experiments on tomato plants are conducted to determine the best amount of each nutrient to add to each plant growing stage. As we noticed, in the first stages of growth plants need the N element, and then we can play with the amounts of P and K to get the best production. The future work on this research is managing the data accumulated in the data center, to determine the best amount of each nutrient to give at each growth stage, and to use this big data to apply to other fruits' growing stages, to create the best production plan.

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