GROUP 224

CONDITIONAL MINT

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Key Words: Mint plant - Greenhouse - Phonosynthesis process - Smart system - Feedback system

ABSTRACT

The grand challenges Egypt faces pose a threat to the country's plans to achieve self-reliance and prosperity. Two of those grand challenges are a lack of industrial and agricultural bases and a lack of a scientific and technological environment. Using old techniques in farming would get result in having low-quality crops and not yielding enough for the residents of Egypt. So, the problem the project attempts to solve is having the best conditions to have a better version of a plant. And through that approach, the design requirements, include a temperature range that mint needs to live and high light intensity. And to improve energy conservation efficiency as much as possible with zero-wastes, increase mint yield by a bigger percentage compared to a normal environmental yield, and increase essential oil. However, after obtaining a proper degree of knowledge, the project was constructed using the researched scientific concepts of building a greenhouse and the impact of the Peat moss and perlite soils and using many components of an embedded system in order to make it a smart system, and many other secondary scientific concepts, all of that to have the suitable environment to get the best mint plants ever. Though the first test results were hardly successful, the second one demonstrated a .more promising result that confirmed the success of the project

INTRODUCTION

Egypt faces many severe challenges, with different reasons, causing different negative impacts. From them, there're two lack points affecting us every day: a lack of industrial and agricultural bases, As the World Bank, Egypt is the second-highest level of unemployees ir the Middle East and North Africa with a rate of 7.2% of its inhabitants in 2022 **as shown in the graph (1)**. And a lack of a scientific and technological environment. When a farmer uses an old technique in his farming, this for sure, will not get the desired efficiency of the .crops

Graph 1: Unemployment rate in Egypt from 2020 to 2022

according to the Food and Agriculture Organization of the United Nations (FAO) in 2020, many smallholder farmers in developing countries still rely on traditional farming practices due to limited resources and a lack of access to modern technologies. These and other studies in this field gave us an idea for planting in specific conditions using a feedback system and sustainable energy source, which is the purpose of the study. Increasing the percentage of technology to recover agricultural production was .chosen as the problem we should focus on

Searching for some previous solutions to grasp the advantages and disadvantages to learn more about the idea The "CropX" and the " The Solar Chilling for Milk Preservation " were the two of them. Soil sensing and analytical studies were the main ideas of the mechanism for the CropX company to increase the production of the crops. On the other hand, you'd spend a lot of money to install and use the technology of it. Secondly, solar chilling for milk preservation, which depends on the process of solar cooling to use solar energy in the refrigeration system. This can be reached through the body of the process **as shown in Figure (1)**. But of its disadvantages is dependence on Sunlight, which has a deficiency on cloudy or rainy days

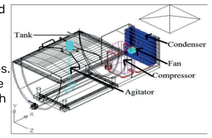


Figure 1: describing the process of the second project.

We created an outline for our idea using these and other prior solu- .tions

The success of a project requires design specifications, including a temperature range of 18°C–25 °C and high light intensity. The goal is to improve energy conservation efficiency by a certain percentage at least 20%, increase mint yield by a certain percentage not less than 50 %, and increase essential oil content by at least 40%. A greenhouse will be built with specific soil components like Bit moss and perlite with the garden soil, and sensors like DHT11 and LDR modules connected to the ESP32 microcontroller will monitor and control the heating, cooling systems, and LED light. Also, using the MFC and solar panels to get the desired amount of electricity. Materials needed for the prototype will be dis- .cussed in the next section

MATERIALS & METHODS

Item: Bitmoth (Vermiculite) **Quantity:** 2 liters **Description:** It has a high surface area. It can hold onto nutrients, water, and beneficial microorganisms.		**Item:** Battery shield **Quantity:** 1 board **Description:** it is a mobile power source that offers outputs of 5 volts at 2.2 amps and 3 volts at 1 amp		**Item:** Garden soil **Quantity:** 4 liters **Description:** It is a versatile soil amendment.		**Item:** Relay module **Quantity:** 1 module **Description:** Electromechanical relay module for 5V applications.	
Item: Perlite **Quantity:** 2 liters **Description:** It is a lightweight, porous material		**Item:** Heating pad **Quantity:** 1 pad **Description:** It's a 5v electric device that produces heat.		**Item:** Acrylic (greenhouse) **Quantity:** 0.5 meters (1/4 plate) **Description:** It is used as a greenhouse glazing material, which is lightweight, and durable.		**Item:** LED strip **Quantity:** 1 meter **Description:** It's a pink, 12-volt Led strip	
Item: Mini breadboard **Quantity:** board **Description:** it's allowing for up to 10 pins to be connected in a single row. So, it is used to connect the circuit easily		**Item:** Graphite plate (10 * 5 cm) **Quantity:** 2 plates **Description:** It is used as the anode in MFC for its high electrical conductivity		**Item:** Servo motor **Quantity:** 1 motor **Description:** It's a 180-degree motor.		**Item:** LDR module **Quantity:** 1 module **Description:** It's a sensor that measures the light intensity for the feedback system.	
Item: ESP32 devkit v1 **Quantity:** 1 board **Description:** It is a microcontroller that integrated Wi-Fi and Bluetooth connectivity.		**Item:** DHT11 sensor **Quantity:** 1 sensor **Description:** It's a temperature and humidity sensor for the feedback system.		**Item:** Solar panel **Quantity:** 2 panels **Description:** Two series-connected panels (5-volt), providing a clean and renewable source of power for sensor operation		**Item:** Jumpers **Quantity:** 30 **Description:** They're small wires to connect any device to the controller	
Item: Brushless fan (5v-DC) **Quantity:** 4 Fans **Description:** It is used for regulating airflow and temperature.		**Item** lithium-ion battery **Quantity:** 2 Batteries **Description:** It's an energy storage, rechargeable device.		**Item:** Epoxy AB adhesive **Quantity:** 2 pieces **Description:** It's an adhesive glue to connect plastic pieces together.		**Item:** Real-time clock **Quantity:** 1 piece **Description:** The clock module tracks time with high accuracy.	
Item: Stainless steel (10 * 5 cm) **Quantity:** 2 plates **Description:** It is used as the cathode in MFC for its high conductivity and long-term stability in corrosive environments.		**Item:** Relay module **Quantity:** 1 module **Description:** Electromechanical relay module for 12V applications.					

Methods:

1- A 3D module in SketchUp is created to visualize the needed prototype. The constructed prototype **is shown in Figure 2**.

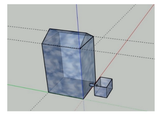


Figure 2: 3D model for the greenhouse

2- The total height of the prototype is about 0.45 m ± 0.001. In addition, the dimensions for the base of the greenhouse (acrylic) are 0.2 m ± 0.001 for length and 0.25 m ± 0.001 for width.

3- The prototype contains two containers with heights of 0.45 m ± 0.001, and 0.10 m ± 0.001, respectively, for the greenhouse (acrylic), and another container (plastic) for the MFC process.

4- For the first region, the greenhouse (acrylic) contains an 8-liter soil mixture of bit moth (vermiculite), perlite, and garden soil (composite) with a ratio of 1:1:2 and a height of 0.16 m ± 0.001. The mint is in the middle of the soil. There are four openings, two on each side for fans (5 v-DC).

5- There is a heating pad, DHT11 sensors, and LED lights inside the greenhouse with glue.

6- The second container for the first region will be connected to the greenhouse via PVC pipe, which will contain filter paper as a PEM and be installed using Epoxy AB Adhesive.

7- This container contains a solution of sodium bicarbonate (NaHCO3), which the stainless-steel plates will put to work as a cathode in MFC. Moreover, the graphite plates will be put in the soil mixture and work as an anode.

8- For the second region, the container contains the ESP32 devkit v1 connected with the mini-breadboard, the LDR sensor module, the RTC Ds1302 module, 2 relays (4 channels 12 v, 1 channel 5 v), 2 lithium-ion rechargeable batteries, a battery shield, and 2 solar panels (5 v).

9- The servo motor is used to trace the sunlight with the sensor of photoresistor for maximizing the power of the battery shield.

10- The connections in the greenhouse project include the battery shield connected to the ESP32 via micro-USB for power and recharging; the heat pad and fans powered by the battery and connected to the relay of 5 volts, which is connected to a mini breadboard; the LED light bulb powered by a separate adaptor and connected to the relay along with the battery; and the LDR and RTC modules directly connected to the mini breadboard.

Design requirements:

Main design requirements include a temperature range of 18°C–25°C and high light intensity. The goal is to achieve energy conservation efficiency by a certain percentage at least 20%, increase mint yield by a certain percentage not less than 50 %, and increase essential oil content by at least 40%.

Test plan:

To get the result and ensure that the prototype is going well, there must be a test plan and follow the design requirements as discussed before, which are having a temperature range in between 18°C–25°C, and high light intensity. Also, to have an energy conservation efficiency of not less than 20%. This project's prototype also lasted for 5 hours in the daylight to see the results. The two parameters we chose were measured using the sensors of DHT11, an LDR module connected to the microcontroller of ESP32, getting the readings every 1 hour for about 5 hours. The readings of the sensors make the microcontroller take the decisions depending on the "If" conditions. The database shown in the next section was built using the data that was gathered.

Calculating the yield to know the increase in the quantity. For testing the essential oil increasing percentage, the mint yield was harvested and chopped by a sharp knife into small pieces to increase the surface area exposed to the ethanol, which was used to separate the essential oils of the mint. Then, the separation flask was used to separate the essential oils from the ethanol, comparing it with the traditional conditions in planting.

RESULTS

Negative results:

At first, the ESP microcontroller board had code on it that used delay for a long time, which caused the board to burn. So, to prevent that from happening again, the RTC (real-time clock) is to be used for calculating the time. Secondly, the conductivity circuit was used as an alternative for the NPK sensor, but it didn't work. So, research has been done about the average time needed for the plant to deliver NPK to the plant.

Positive results:

The results after the test plan were promising and succeeded in achieving the design requirements effectively.

Parameters:

LDR sensor success to achieve 14 hours of photosynthesis process for the mint plant, which measures high light intensity, and the other 10 hours with low light intensity.

DHT11 sensor success in maintaining the ideal range for the mint, which is between 18°C and 25°C.**as shown in the table.**

Temperature (°C)	Light intensity
23°C ± 2°C	Low
24°C ± 2°C	High
24.5°C ± 2°C	High

Energy conservation efficiency:

The energy conservation measures reduction in the energy consumption of the system. The amount of energy consumed by the system is measured before applying energy conservation measures, including measuring the energy consumption of the sensors, and after **as shown in the table (accepted results).**

The power input will represent the power needed for the system. On the other hand, power output will be the power provided to the system.

Power input (watt)	Power output (watt)	Efficiency (%)	Time (hours)
13.2	2.5±7.5%	18.93%±7.5%	1
13.2	2.7±7.5%	20.45%±7.5%	2
13.2	2.9±7.5%	21.96%±7.5%	3
13.2	3±7.5%	22.72%±7.5%	4
13.2	3.05 ± 7.5%	23.10%±7.5%	5

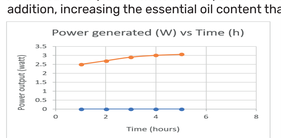
Yield and essential oil: $Eff = \frac{p\ output}{p\ input} \times 100 = \frac{3.05}{13.2} \times 100 = 23.10\%$

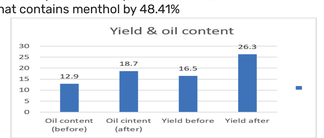
The yield efficiency is measured by the mass of the yield in the traditional one and another one after applying the optimal growing conditions for the mint and the same measurements for essential oil with different units of measurement by the following equations.

$$Yield\ efficiency = \frac{yield\ after}{yield\ before} \times 100 = \frac{0.0263\ kg \pm 0.00001}{0.0165\ kg \pm 0.00001} \times 100 = 159.39\%$$

$$Essential\ oil\ efficiency = \frac{oil\ content\ after}{oil\ content\ before} \times 100 = \frac{0.0187\ L \pm 0.0001}{0.0129\ L \pm 0.1} \times 100 = 148.41\%$$

As a result, the yield of mint in the system increased by 59.39% compared to the traditional one. In addition, increasing the essential oil content that contains menthol by 48.41%





ANALYSIS

Plant's processes:

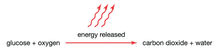
The plant is an independent living organism, which makes its own food by itself through the photosynthesis process. There are also transpiration and cellular respiration or fermentation processes. Every process differs from the other by its function and its purpose.

Photosynthesis is a process by which green plants and certain organisms convert light energy into chemical energy during the day. The process involves the plant taking in carbon dioxide (C02) through the leaf and water (H20) from the soil through the roots. The presence of sunlight enables the oxidation of water and reduction of carbon dioxide, which leads to the formation of oxygen (02) and glucose by chlorophyll, **as shown in equation (1).**

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

Equation 1 photosynthesis equation

Cellular respiration is the process in which a plant combines oxygen with glucose to utilize the chemical energy from these substances for life-sustaining activities. The byproducts of this process are carbon dioxide and water, **as shown in equation (2).**



$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O$$

Equation 2 cellular respiration process equation

Humans have used plants to satisfy their requirements for food, materials, and energy. The human population is rapidly growing and that is creating a gap of needs that can be solved by increasing both the amount of photosynthesis and the efficiency of converting the photosynthetic output into products useful to humanity. One solution to those needs that achieved enormous improvements in agricultural yield using chemical fertilizers. One of the most important fertilizers is the NPK which consists of nitrogen (N2), phosphorus (P), and potassium (K).

Soil structure:

The soil consists of a mixture between peat moss (vermiculite), perlite, and garden soil (composite) with a percentage of 1:1:2. peat moss is a clay mineral that occurs as small particles in soils. It is added to aerate the soil while retaining water and allowing nutrient exchange. It is mica, a kind of magnesium, iron, and aluminum trioctahedral sheet silicate that is hydrated. Two tetrahedral silicate sheets are interlayered with an aluminum and iron-containing octahedral sheet that is the main structural component. On both the upper and lower surfaces of each tripartite layer are holes that are uniformly spaced apart from equivalent locations on other levels. The chemical components of an ideal sample of vermiculite **are summarized in Table 2.** Perlite is an amorphous volcanic glass with a high water content that is often created when obsidian is hydrated. It arises naturally and possesses the unusual property of greatly expanding when heated suitably. Perlite is a material that is not renewable. The mining and processing of perlite have a negligible impact on the environment, and it is a versatile and sustainable material. Perlite has captured water molecules and is primarily composed of silica. The chemical composition of perlite **is summarized in Table 3**. Garden soil is topsoil that has additional organic matter, such as compost, peat, and fertilizer, mixed all over it. Compost is a crumbly mass of rotten organic material formed from decaying plant waste. It is regarded by gardeners as "black gold" because of its various advantages. Compost improves soil structure, offers a variety of nutrients to plants, and increases the number of helpful bacteria in the soil. These improvements include aggregation, pore spacing, water storage, and crop output. Composite usually has a nitrogen content of 2%, a phosphorus content of 0.5–1%, and a potassium content of 2%.

Compound	Weight percent
SiO_2	38 to 46
Al_2O_3	10 to 16
MgO	16 to 35
CaO	1 to 5
K_2O	1 to 6
Fe_2O_3	6 to 13
TiO_2	1 to 3
H_2O	8 to 16
Other[a]	0.2 to 1.2

Table 2: chemical components of vermiculite.

	Oxides	Mass %
d	SiO_2	72.48
	Al_2O_3	13.15
y	Fe_2O_3	1.23
	TiO_2	0.15
	CaO	1.13
	MgO	0.35
e	K_2O	4.21
	Na_2O	3.56
	LOI	3.54
	Total	99.80

Table 3: chemical composition of perlite.

Microbial fuel cell:

As learned in (CH2.08), a microbial fuel cell (MFC) is an electrochemical cell that converts chemical energy in organic matter into electrical energy using microorganisms as catalysts. The MFC relies on redox reactions between electrodes to generate electricity and can power devices. The redox reaction involves two half-reactions and the transfer of electrons through an external circuit produces an electrical current **as shown in figure 3**.

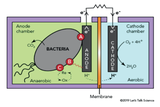


Figure 3 MFC diagram

The anode half-reaction in microbial fuel cells involves the oxidation of organic matter by bacteria, resulting in electricity. This can be expressed as follows:

$$Organic\ matter + H2O \rightarrow CO2 + e- + H+$$

The cathode half-reaction in microbial fuel cells involves the reaction of electrons and protons (H+) from the anode with oxygen or another electron acceptor to create water or another product. This can be expressed as follows:

$$O2 + 4e- + 4H+ \rightarrow 2H2O$$

The MFC in the project employs microorganisms in the soil to produce electricity, with carbon-based electrodes and graphite as the anode and stainless steel as the cathode. The anode is buried directly in the soil, while the cathode is in a sodium bicarbonate solution, connected by a PVC pipe that contains a proton exchange membrane (PEM) to transfer protons without the passage of electrons.

Embedded System:

The embedded system utilized an integrated feedback mechanism to optimize the growth of mint plants within predetermined environmental parameters, specifically regulating temperature and light intensity.

Integrated components were incorporated to automatically modulate the environmental conditions as needed, including an evaporative cooling system and heating pad to control temperature and humidity levels, LED strip lighting to adjust light intensity, and supporting power modules including a battery shield, relay boards, solar panels, breadboard, and jumper wires to supplement the feedback system **as depicted in figure (4)**, and all of these were connected together using the ESP32 devkit v1 as the microcontroller of the system.

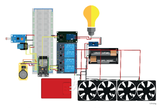


Figure 4: connections of the electronics

ESP32 devkit v1 (microcontroller):

The ESP32 DEVKIT V1 is a microcontroller platform with Wi-Fi and Bluetooth capabilities, a 32-bit dual-core processor, and 448 KB of ROM memory. It has 38 pins in total, including 18 GPIO pins for digital, 10 analog input pins, a 3.3-volt power supply pin, and 2 GND pins. It is compatible with Arduino **as shown in Figure (5)**. And it is used as a microcontroller for the feedback system.

Figure 5: the diagram of the ESP32

DHT 11 module (Temperature and Humidity sensor):

The DHT11 module is a temperature and humidity sensor that uses a thermistor and a capacitive humidity sensor. Measure temperatures from 0 to 50°C ± 2°C and humidity from 20 to 90% RH ±5%. It uses a digital communication protocol to send data to the microcontroller. It has a 3-pin VCC, DATA, and GND pins connected with the esp32, **as shown in Figure (6).**

Figure 6 : connection of the sensor with the ESP

LDR module (light intensity sensor):

The Light Dependent Resistor (LDR) module is a light intensity sensor. It measures the intensity of light by outputting a voltage signal on its analog output pin to automate turning lights on and off. The module has 4 pins, but we don't use the digital pin, the analog output, VCC, and GND connected with the esp32, **as shown in figure (7)**.

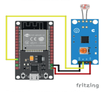


Figure 7 : connection of the sensor with the ESP

Relay module:

Relays are employed to control a circuit using a low-power signal or where multiple circuits need to be controlled by a single signal, **as shown in Figure (8)**. The isolation allows for the use of a low-amperage sensor to turn a much higher-capacity load on and off in circuits, thereby reducing the current flowing through the primary control switch, and relays have two types or modes: normally open and normally closed.

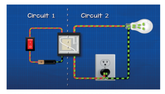


Figure 8 : shows the usage of the Relay.

Lighting system (LED with relay and RTC):

The lighting system adopts an automated, programmable approach to controlling LED strip lighting based on the intensity from LDR and real-time clock, and all of that is connected to the esp32 **as described in figure (9).** Specifically, LED strip is turned off from 7 p.m. to 5 a.m., according to RTC module readings. During the remaining hours, the status of the LED strip depends on the LDR readings. If the light intensity is low, the LED strip is turned on to provide additional lighting. Otherwise, the LED strip remains closed.

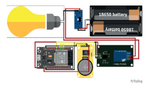


Figure 9 : shows the lightning system and connections

Mobile power expansion board module (battery shield):

The battery shield is an electronic circuit board. It houses two rechargeable lithium batteries. The module offers outputs of 5 volts at 2.2 amps and 3 volts at 1 amp, enabling it to power most USB-powered devices like microcontrollers. It incorporates overcharge and over-discharge protection, **as shown in figure (10)**. And we use it to store electricity from solar panels and the MFC as the power source for the system.

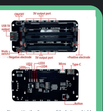


Figure 10: the diagram of the battery shield

Solar panel:

Solar panels convert photons from sunlight into electricity using the photovoltaic effect. Silicon solar cells have excited electrons that produce direct current when exposed to light. Multi-layered silicon wafers with doped semiconductors generate voltage through the photovoltaic effect, generating power from sunlight. a**s shown in Figure (11)**. It will be the main source of energy for the system beside the MFC, and it will be connected to the battery shield.

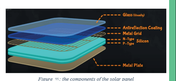


Figure 11: the components of the solar panel

Cooling and heating system (evaporative cooling and heating pad):

An evaporative cooling system using a moist sponge and fan efficiently cools greenhouses. Circulating air over the saturated sponge, evaporation lowers temperatures sustainably and affordably, regulating heat in small greenhouses. Keeping the sponge wet circulates a cooling breeze, providing an inexpensive solution for hot weather **as shown in Figure (12).**

The system will be connected to the microcontroller and controlled according to the DHT11 sensor, and the evaporative cooling and heating pad will be connected by relays **as shown in Figure (13)**.

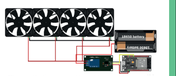


Figure 12: the connection of the cooling system

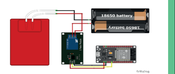


Figure 13: shows the connection of the heating system.

CONCLUSION

The project aimed to address the problem of recovering agriculture using a feedback system that optimizes the growth conditions of mint by monitoring and adjusting temperature, humidity, and light intensity parameters. The project successfully developed a system that improves the quantity and quality of the mint crop while promoting sustainable and efficient plant growth practices. The result is a significant change in the usage of technology in agriculture, providing opportunities for farmers to achieve better crop yields and quality while also reducing waste and promoting efficient resource use. The project met the design requirements of sustainability, efficiency, yield, and quality.

RECOMENDATION

Real-life scale:

To scale up the prototype, different components will be used to perform the same function on a larger scale. The power system will be upgraded from the solar panel and the battery, which will store the electric energy generated by solar panels. Secondly, the heater will also be replaced with a larger one, as it will need to cover a greater area. Similarly, the color that uses the fans to cool the plant will be swapped out for a cooling system that can handle the larger scale of the project.

Location:

The ideal location for the large-scale mint greenhouse would be in arid areas with high humidity and vast sunlight. The New Valley region achieves these requirements and would be a suitable location for the project.

Overall, the use of a battery-powered system, a larger heater, and a cooling system, in combination with the right environmental conditions, would enable the successful scaling up of the mint farm prototype.

NPK sensor:

As mentioned before, NPK is the main element that supports healthy and productive plant growth. Fertilizers act as a multivitamin or meal substitute for plants by supplying vital nutrients to grow flowers, trees, and vegetables.

The NPK sensor is used to add fertilizers at the optimal time, ensuring healthy plant growth. Giving too much or too little nutrition can be harmful to the plant, so it's essential to provide the right amount of nutrients. The data from the sensor can create a feedback system for determining when to add fertilizers, promoting healthy growth without the risk of over-fertilizing. By utilizing the NPK sensor data, farmers and gardeners can optimize their fertilizer usage and ensure plant health and vitality. The sensor **is shown in Figure (14)**

Figure 14: the NPK sensor

Carbon dioxide sensor:

Photosynthesis is vital for plants to produce food, and the right amount of carbon dioxide is necessary for the process and plant health. Increasing CO2 concentrations from 340 to 1,000 ppm can enhance net photosynthesis for most greenhouse crops by 50%. However, too much CO2 can be toxic, while too little will prevent photosynthesis from occurring. The economics of adding CO2 may not support it for low-light crops. In greenhouses, a carbon dioxide sensor **as shown in Figure (15)** is used to make sure the plant receives the right amount of carbon dioxide.

The sensor measures carbon dioxide levels and provides information to the control system, which adjusts the levels in the greenhouse. If the levels are too low, the greenhouse is opened to let in more carbon dioxide. If they are too high, the greenhouse is ventilated. This automated system helps maintain optimal carbon dioxide levels for healthy plant growth.

Figure 15: carbon dioxide sensor

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