Potato Diseases Detection System

Dakahlia STEM school- Grade12-2024\2025

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Key words: Late Blight- Powdery Mildew- DHT22- Color Sensor- Potato - Real Time Monitoring

Abstract

Egypt loses around 25% and 50% of its annual potato crop due to the prevalence of numerous diseases, which affects the public health of those who consume it and reduces Egypt's agricultural foundation. **(Rabia, et al., 2022, P. 1)**. Therefore, our innovative solution focuses on maintaining potato yield by predicting potato diseases including powdery mildew, downy mildew, and late blight early on. Each disease manifests within specific ranges of temperature and humidity limits. Our system uses a DHT22 sensor to measure the temperature and humidity of the potato field to adjust to variations in these environmental factors. Additionally, the color of the leaf serves as an additional indicator of the disease that will affect the potato, so we use a color sensor to identify frequency variations of colors because the color of the potato leaf varies depending on the symptom of the disease. Incorporating hardware and software to allow the user to monitor the environmental conditions and the plant's general health. Our data will be visualized as a graph on REMOTE XY application, the data will be stored on excel sheet every 30 minutes and a push bullet notification will serve as our alarm. To validate the efficiency of our system, we conducted tests on three separate days at three distinct times of day: morning, midday, and evening. Based on a thorough measurement of temperature, humidity, and leaf color ranges, the results validate that our technology may provide an early identification of diseases and their progression.

Introduction

Egypt faces a lot of obstacles on its road to development, which are represented by 11 grand challenges. Through this project, it is working on three of them, which are increasing agricultural and industrial bases of Egypt, Work to eradicate public health issues, and improve the scientific and technological environment for all. The problem to be solved is helping in early detection of severe diseases which affect lots of plants specially potatoes such as, late blight, downy mildew and powdery mildew to In order to intervene at the appropriate time and prevent excessive loss of plant yield. One of the prior solutions is Plant Village which is a research and development unit of Penn State University that empowers smallholder farmers and seeks to lift them out of poverty using cheap, affordable technology. Due to excessive loss of plants yield, The Plant Village solution has developed a triple A model

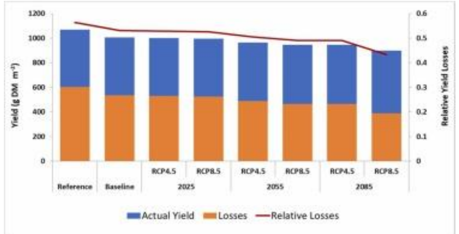
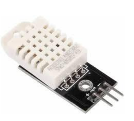


Fig1: Potato yield losses due to late blight.

(Algorithmic Agricultural Advice) that works to increase the yield and profitability for millions of farmers. The algorithms come from integration of AI, satellite technology and unique field force (the working team). Once a farmer inputs 3 critical details (crop type, location, planting date) the algorithms within the Plant Village engine can send out advice via smartphone, push bullet, or real-world social networks. By researching and studying the prior solutions, the focus of this project, which is development of an integrated multi-sensor system that combines RGB, temperature, and humidity sensors. This system aims to continuously monitor potato leaves and the surrounding environment, allowing for early detection of diseases and timely interventions. First, RGB Sensor: This sensor will analyze leaf color and pigmentation. Changes in leaf color can indicate disease presence before visible symptoms appear. Second, DHT-22, sensor which measures temperature and humidity. Temperature influences the metabolic processes of the potato plants and high levels of humidity or moisture cause rot in potato leaves. So, by monitoring these changes, farmers can take actions. The design requirement is detecting humidity and temperature using DHT22 and recognizing the plant color depending on color frequency using RGB color sensor.

Materials

Item	Source	Quantity	usage	cost	Pictures
Leaf of Potatoes	From the field	As needed	For conducting experiments	Free	
ESP-32S Development Board WIFI Bluetooth.	Electronics store	1 element	Used as a microcontroller.	450 L.E	
Color Sensor TCS3200	Electronics store	1 element	Used to monitor leaf color.	350 L.E	
Humidity Sensor Module (DHT-22).	Electronics store	1 element	Used to monitor the environmental factors that affect plant diseases.	285 L.E	
Jumper Wires	Electronics store	Enough for connecting sensors and battery	Used in connecting sensors to the microcontroller.	15 L.E	
3.7 V 2200 mAh lithium-ion battery.	Electronics store	2 elements	Used to provide power supply to the entire system.	2*120 L.E	

Total cost: 1340 L.E

Methods

Late blight, powdery mildew, and downy mildew are the three potato diseases that can be identified and differentiated using the selected prototype. Using an ESP-32 Development Board as a microcontroller, DHT-22 sensor was attached to the system by connecting it to a digital pin 13. The system measured humidity and temperature using a DHT-22 sensor. Each disease manifests within a certain range of these environmental factors. Furthermore, TCS3200 color sensor was attached to the system by also connecting it to a digital pin 14, based on the color of the potato's leaves, the system used a color sensor to identify frequency variations of colors. The color of the potato leaf varies depending on the disease's symptoms.

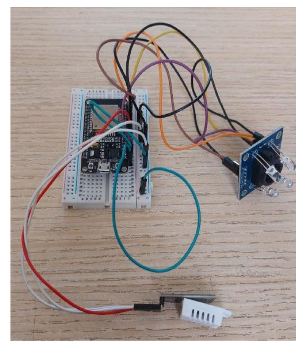


Fig2: Hardware system.

By integrating these sensors, the system can distinguish between these diseases based on their specific temperature, humidity, and distinct color. By connecting the hardware system to the software Arduino IDE, the user can monitor the plant's health. These readings are displayed in real-time on the REMOTE XY application, including parameters like temperature, humidity, and leaf color that indicate which disease will infect the plant. To facilitate early disease identification, the system sends instant alert notifications via SMS to inform users when environmental factors promote the development of disease. Analyzed data is stored and shown on an Excel document, and sensor values are shown on charts every 30 seconds. This is accomplished by employing algorithmic coding to link Arduino IDE to an Excel sheet so that the data will be stored for up to a year or more. To operate our system, two batteries with 3.7 V 2200 mAh lithium ion were used as a power supply. To determine the total voltage of the system, which includes components such as: ESP-32 Development Board which requires 5 Voltage, DHT-22 and TCS3200 color sensors also operate within a voltage range of 3.3V – 5V. By connecting these components in parallel, the total voltage required for operating this system is around 5V.

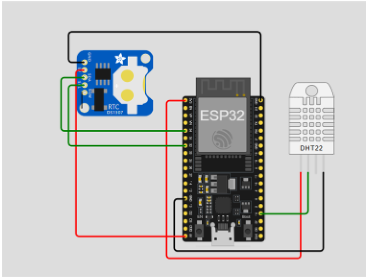


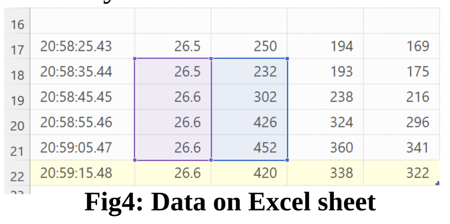
Fig3: Connections of hardware system.

Test plan

The study carried out three experiments. Potatoes were cultivated for the testing in a potato field around nine weeks ago. The tests were carried out at various intervals throughout 3 days. In three trials, 3 samples of potato leaves were used for testing, and one sample was used in the morning test for monitoring late blight disease, which develops under cooler humidity and higher temperatures. The second was used in the midday test which focused on tracking powdery mildew disease, which thrives with lower humidity and higher temperatures. Finally, the evening trial evaluated downy mildew, a disease associated with moderate temperatures and rising humidity.

First trial: First day:

This experiment was conducted at three distinct times throughout the day: morning, midday and evening. Every experiment was intended to determine the changes in the environmental factors, and how different diseases can be identified and distinguished.



16					
17	20:58:25.43	26.5	250	194	169
18	20:58:35.44	26.5	232	193	175
19	20:58:45.45	26.6	302	238	216
20	20:58:55.46	26.6	426	324	296
21	20:59:05.47	26.6	452	360	341
22	20:59:15.48	26.6	420	338	322

Fig4: Data on Excel sheet

Second trial: Second day:

Also on the second day, testing was carried out in the morning, afternoon, and evening and even in this case, the times of testing varied from the first day. The aim was to increase the range of results and capture further changes in the environment to improve the system's capability to identify diseases that are developed in different periods of a day.

Third trial: Third day:

the testing times were modified again as compared to the previous days. This helped in gathering more diverse data as well as ensured that the performance to detect diseases at different times of the day was comprehensively measured.

Fig5: test the system in the potato field.

Results

First trial: First day: Table 1: Potato disease monitoring results: Day 1"

Time	Temperature (°C)	Humidity (%)	Leaf Color Sensor Reading	Disease Indicator
6:15 (AM)	17.5 (±0.5)	94 (±2)	(55, 95, 49)	**Late blight, initial symptoms.**
12:05 (PM)	23 (±0.5)	78 (±2)	(25, 170, 66)	**Normal healthy leaves.**
5:20 (PM)	25 (±0.5)	84 (±2)	(29, 169, 61)	**Normal healthy leaves.**

Second trial: Second day: Table 2: "Potato disease monitoring results: Day 2"

Time	Temperature (°C)	Humidity (%)	Leaf Color Sensor Reading	Disease Indicator
6: 57 (AM)	18 (±0.5)	92 (±2)	(30, 55, 25)	**Late blight-moderate symptoms.**
12:45 (PM)	25.5 (±0.5)	70 (±2)	(30, 169,70)	**Normal healthy leaves.**
6:00 (PM)	24.5 (±0.5)	85 (±2)	(32, 195,74)	**Normal healthy leaves.**

Third trial: Third day: Table 3: "Potato disease monitoring results: Day 3"

Time	Temperature (°C)	Humidity (%)	Leaf Color Sensor Reading	Disease Indicator
7:35 (AM)	20 (±0.5)	89 (±2)	(25, 184, 65)	**Late blight-advanced symptoms.**
1:40 (PM)	27 (±0.5)	65 (±2)	(150, 160, 170)	**Powdery mildew-initial symptoms.**
6:45 (PM)	22 (±0.5)	88 (±2)	(190, 174, 100)	**Downy mildew-initial symptoms.**

Analysis

Egypt loses most of its agricultural bases due to environmental and climate changes, which led to deforestation and diseases spreading to plants. In addition to plant diseases, people suffer from health issues because of eating infected plants. Rising environmental changes and disturbances in weather conditions require technological interventions for ecosystem protection and human health. However, gaps in technology adoption hinder progress in disease detection. **(Pokhrel, 2021, P. 1,2)**. The main challenge to be solved is the detection of three potato plant diseases: powdery mildew, late blight, and downy mildew, depending on differences in temperature, humidity, and intensity of leaf color. The required solution is to imply the DHT-22 sensor to measure humidity and temperature and RGB color to detect change in environmental factors and leaf color so it can determine if it's downy mildew, powdery mildew, or late blight similar to the transducer in communication systems which convert physical signals into electrical signals and send data to an esp32 which is similar to transmitter's role to encode and modulate the data from analog to digital after that it appears in REMOTE XY as analog physical signals which is similar in receiver when data decoded and demodulated to the original signals, as studied **in PH.3.0**. The selected solution fulfilled the design requirements for multi-sensor integration and demonstrated the recommended precision as studied **in CH.3.01**; the standard accuracy for the DHT-22 sensor is ±0.5 for temperature and 2% for humidity. The system was tested on 3 samples of potato plants, The system's data is gathered every 30 seconds in an **Excel sheet** during three different days in three different periods: the morning, midday, and evening, and visualizes the readings of the sensor in graphs that appear on REMOTE XY.

In first trial, the system's temperature and humidity were tested **as shown in figure 6** three times at different times of the day 6:15 (AM), 12:05 (PM) and 5:20 (PM). **In ST.3.02**, The correlation between humidity and temperature was measured:

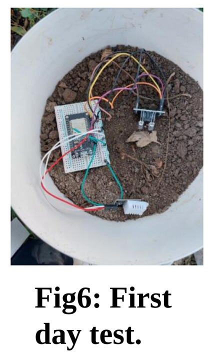


Fig6: First day test.

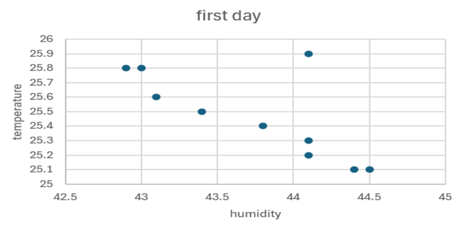


Fig7: First day (temperature and humidity).

$$\mathbf{r}=\frac{\sum(x-\sigma)(y-\mu)}{\sqrt[2]{\sum(x-\mu)^2\sum(y-\mu)^2}}$$

r=correlation coefficient

x=values of the x-variable in a sample , σ=mean of the values of the x-variable

y=values of the y-variable in a sample , μ=mean of the values of the y-variable

To measure the correlation, the nominator was -2.08 and dominator was 2.25 so the correlation was $\frac{-2.08}{2.25}$ = -0.924. it indicated strong negative correlation as temperature increased humidity decreased **as shown in figure 7.** Whereas correlation explains the strength of the relationship between an independent and a dependent variable, r^2 explains the extent to which the variance of one variable explains the variance of the second variable.

$$\boldsymbol{r^2 = -0.924^2 = 0.85 = 85\%},$$

so about 85% of the variation in temperature can be explained by the varation in humidity. Late blight disease was detected on the first sample, however, other two samples were healthy.

In Second trial, the system's temperature and humidity were tested **as in figure 8** three times at different times of the day 6: 57 (AM), 12:45 (PM) and 6:00 (PM). To measure the correlation, the nominator was -5.595 and dominator was 6.08 so the correlation was-$\frac{5.595}{6.08}$ = -0.92 which is strong negative correlation.

$$r^2 = -0.92^2 = 0.8 = 84\%$$

so about 84% of the variation in temperature can be explained by the varation in humidity as shown in **figure9.**

Late blight disease surged in the second trial, however, other two samples were healthy.

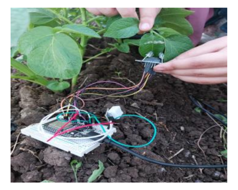


Fig8: second day test.

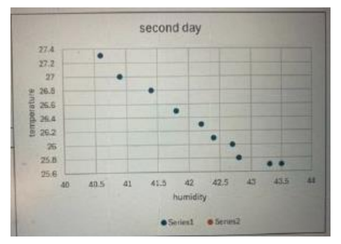


Fig9: second day data recorded

In third trial, the system's temperature and humidity were tested **as in figure 10** three times at different times of the day 7:35 (AM), 1:40 (PM), and 6:45(PM). The numerator= -1.78, and dominator= 1.99 so r = $\frac{-1.78}{1.99}$=-0.983 so there is indirect relation between humidity and temperature and approach to -1 (perfect indirect correlation), **As shown in figure 11**.

$$r = \boldsymbol{-0.983^2 = 0.96}$$

$= \boldsymbol{96\%}$, **so** about 96% of the variation in temperature can be explained by the variation in humidity.

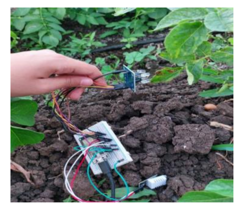


Fig10: third day test.

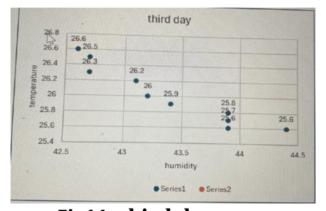


Fig11: third day data recorded

And established a threshold beyond which the system will send a notification when the temperature range is 10°C to 25°C (50°F to 77°F), humidity with levels above 80%, and leaf intensity is (25,184,65), which is the brown color, are considered optimal for late blight**. (Babli, et al., 2022, P. 3).**

If the temperature ranges between 15°C and 23°C (59°F and 73°F), humidity levels are usually around 85%, and leaf intensity is (150, 160, 170), which is close to yellow color, then it is downy mildew's best symptoms. However, if it is between 20°C and 27°C (68°F and 81°F), if humidity levels are moderate between 60% and 80%, and leaf intensity is (190, 174, 100), which is close to white color, it will be powdery mildew **(Colombo, et al., 2020, P. 1)**. In the **signal processing step**, the RGB color sensor was calibrated to measure the intensity of the color in a 0 to 255 range Using Map function, as the sensor was detecting the frequency of the observed color, so it could be easier to understand for non-technical users. **In CS 3.03,** The data is stored in excel sheet. The storage of the data for 1 minute is 24.9KB. so, The total **data storage in 1 year** = $\frac{24.9\times60\times24\times365}{10^6}$ = 13.08 GB.

In PH 3.05, To determine the power is consumed by the system for 6 months, the total time = $6\times 30 \times 16 = 2880\ hour$. When measuring the system at physics lab, the total current intensity= 62.075mA. the ESP32 voltage is **Power consumption**= $310.375mW$.

$The\ energy\ consumed = \frac{310.375\times2880}{1000} = 903.384Wh$. So the required battery to work six months should be not less than $903.384Wh$. As studied in ST.3.02, from the experiments of the system, it is predicted that there is a negative relation between color intensity and temperature; as temperature increased, color intensity decreased, and late blight disease increased from this equation: y= -9.28x+208.45, x in domain (10°C, 25°C). There is a positive relation between color intensity and temperature; as temperature increased, color intensity increased, and powdery mildew disease increased from this equation: y=28.2x- 643.01, x in domain (20°C, 27°C). **(Upton, Cook, 1996, P. 545)**. Finally, there is a negative relation between color intensity and temperature, as temperature increased, color intensity decreased, and late downy disease increased from this equation: y=-56.74x+1436, x in domain (15°C and 23°C).

Conclusion

The project's purpose is to develop and integrate a multi sensor system that can then be utilized to maintain and increase the quality of plant production. Based on the data obtained and previous research, our solution design was able to overcome the difficulty of plant loss by multiple diseases. To address this problem, we have decided to build a multi sensor system that consists of DHT-22 sensor that measures temperature and humidity, RGB sensor that measures leaf color, and ESP32 which is powered by a battery to ensure the maintenance of plants. They were chosen because they are the most significant factors in influencing plant quality. As an outcome of our test, we were able to make an early prediction to diseases. Finally, we met our design requirements, and our solution become more efficient and beneficial for early predictions, ensuring their safety and well-being.

Recommendations

Since has no limit therefor these are some recommendations, which we were not able to make, to improve this project:

1- Implement an image recognition system based on machine learning logarithms that includes a camera to take photos for other different potato diseases so the disease can be detected by the leaf image more accurately.

2. Use the same system for different plants that need to be in similar conditions such as tomatoes. 3. Construct a system to add a fertilizer automatically with the suitable amount according to plants need to save crops.

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