Potato diseases detection system

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Table of Contents

Introduction

Egypt faces a lot of obstacles on its road to development, which are represented by 11 grand challenges. Through this project, we are working on three of them, which are increasing agriculture and industrial bases of Egypt, Work to eradicate public health issues, and improve the scientific and technological environment for all. These challenges are related to some problems: climatic changes, which increase the frequency and strength of extreme events (such as moisture, floods, droughts, and storms) that threaten agriculture and industrial bases, public health, in addition to safety. Our 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. An example of a prior solution is Plant Village 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 (Algorithmic Agricultural Advice) that works to increase the yield and profitability for millions of farmers. It is our goal to reach hundreds of millions in partnership with an ecosystem of farmer facing organizations and the farmers themselves. Our algorithms come from our integration of AI, satellite technology and our unique field force (the Dream 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, SMS, TV or real-world social networks. By researching and studying the prior solutions, our team came up with the solution, 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 stress or disease presence before visible symptoms appear. Second, DHT-11sensor which is responsible for measuring 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 preventive measures, such as applying fungicides or adjusting irrigation practices. Our design requirement is Raising crop yields. We succeeded in achieving this by predicting the early appearance of the disease and thus applying the suitable pesticides and modifying irrigation methods, which led to a higher rate of plant recovery from the disease and thus preserving the largest possible yield of the crop.

Present and Justify a Problem and Solution Requirements

- Egypt Grand Challenge

- Improve the use of alternative energies.
- Recycle garbage and waste for economic and environmental purposes.
- Deal with urban congestion and its consequences.
- Work to eradicate public health issues/disease.
- Increase the industrial and agricultural bases of Egypt.
- Address and reduce pollution fouling our air, water and soil.
- Improve uses of arid areas.
- Manage and increase the sources of clean water.
- Deal with population growth and its consequences.
- Improve the scientific and technological environment for all.
- Reduce and adapt to the effect of climate change

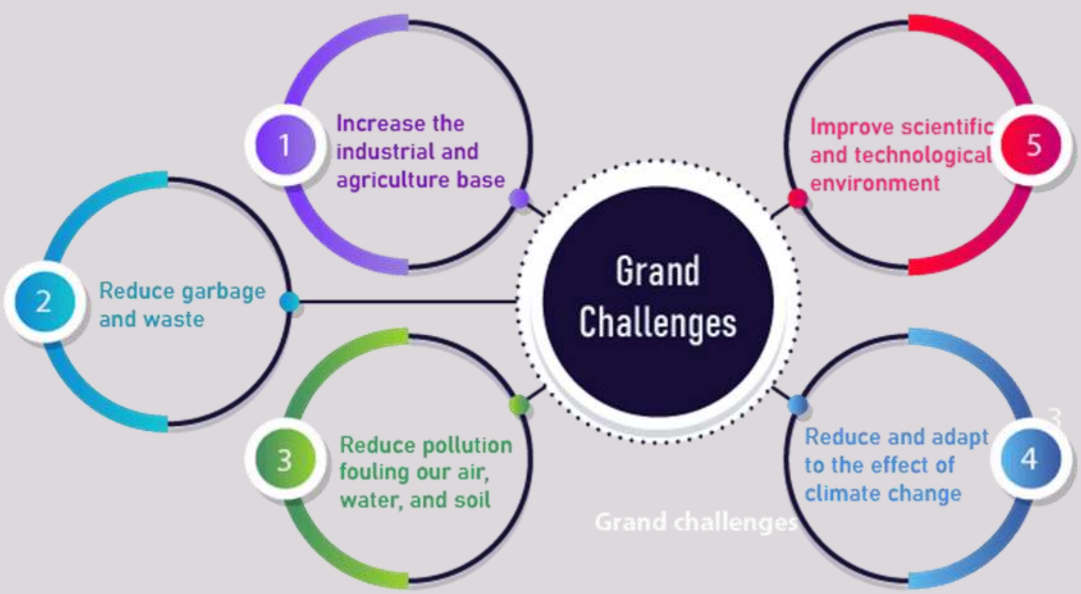


Fig1: Egypt's Grand Challenges.

1) Increase the industrial and agricultural bases of Egypt

Well, the answer for that is the industrial base of a country that consists of all the infrastructure, facilities and systems in place for manufacturing, producing and distributing goods and services. It includes different industries including, but not limited to, manufacturing, mining, construction, energy generation, transportation and utilities. A country's economic growth and the development of its competitive edge in the international market, are dependent on the strength and efficiency of its industrial base.

- **The development of industry in Egypt**

The industrial movement in Egypt has been influenced by various factors—political, economic, and demographic—and has significantly progressed over the last 20 years. Among these, the demographic aspect is particularly crucial, as population pressure has intensified during this period. With the Egyptian population now exceeding 19 million and growing at nearly 2 percent annually, the agricultural land is severely limited due to the vast deserts surrounding the Nile Valley and Delta, which make up all but 3.5 percent of the country. The area suitable for cultivation is roughly the size of New Hampshire, leading to a population density approaching 4 people per acre of arable land. Recently, as the threat of overpopulation has become more pronounced, the industrial movement has gained momentum. Economists have highlighted the urgent need to shift the occupational structure of the population. Developing mechanized manufacturing industries that produce more output per person and exploring new resources could alleviate the pressure on land while simultaneously improving living standards and benefiting the Egyptian nation as a whole. It is essential to accurately assess the current state of Egypt's industry, as despite notable advancements in recent years, the country remains predominantly agricultural. The exact number of individuals engaged in industrial activities is difficult to determine due to differing criteria in various censuses and the delayed release of the latest census data from 1947. However, it is estimated that around 750,000 people were involved in all types of industrial work, including construction and mining but excluding transportation, in 1939. This number is likely closer to 900,000 today, which still represents less than 5 percent of the total population. At least 70 percent of Egyptians are engaged in agriculture.

The principal factors that have hampered industrial development since the first World War are:

(a) The lack of tariff protection (until 1930).

(b) The small home market, due to the low purchasing power and depressed standard of living of the bulk of the population.

(c) The limited range of raw materials available to industry and the lack of cheap fuel.

(d) The shortage of technicians and skilled labor, and the poor quality of the available unskilled labor.

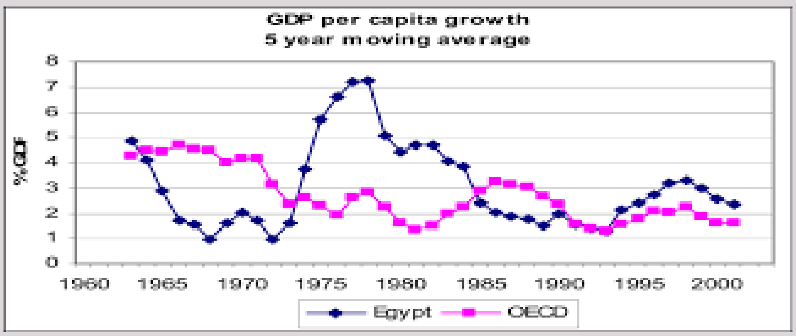


Fig 1: The development of industry in Egypt.

Types of Industries:

1) Primary industry

This part of a country's economy encompasses agriculture, forestry, fishing, mining, quarrying, and mineral extraction. It can be categorized into two main types: genetic industries, which involve the production of raw materials that can be enhanced through human intervention; and extractive industries, which focus on the production of finite raw materials that cannot be replenished through cultivation. Genetic industries include agriculture, forestry, livestock management, and fishing, all of which can benefit from scientific and technological advancements aimed at improving renewable resources. On the other hand, extractive industries involve the mining of mineral ores, quarrying of stone, and extraction of mineral fuels. In many undeveloped and developing countries, primary industry plays a significant role in the economy, but as secondary and tertiary industries grow, the contribution of primary industry to overall economic output tends to decline.

2) Secondary industry

This sector, often referred to as the manufacturing industry,
(1) takes raw materials from primary industries and transforms them into consumer goods, or
(2) further processes products that have already been modified by other secondary industries, or
(3) produces capital goods that are used to create both consumer and non-consumer goods. The secondary industry also encompasses energy-producing sectors (like hydroelectric power) and the construction industry.

Fig2: Example of primary industry

Secondary industry can be categorized into heavy, or large-scale, industry and light, or small-scale, industry. Large-scale industry typically requires significant capital investment in facilities and machinery, caters to a broad and varied market that includes other manufacturing sectors, has a complex organizational structure, often employs a skilled and specialized workforce, and produces a substantial volume of output.

Examples of large-scale industry include petroleum refining, steel and iron production, manufacturing of motor vehicles and heavy machinery, cement production, nonferrous metal refining, meat-packing, and hydroelectric power generation.

On the other hand, light, or small-scale, industry is characterized by the non-durability of its products and a lower capital investment in facilities and equipment. It may involve nonstandard products, such as customized or artisanal work. The workforce in this sector can range from low-skilled, as seen in textile and clothing manufacturing, food processing, and plastics production, to highly skilled, as in electronics and computer hardware manufacturing, precision instrument making, gemstone cutting, and craftwork.

3) Tertiary industry

This broad sector, often referred to as the service industry, encompasses various fields that, despite not producing physical goods, offer services or intangible benefits that contribute to wealth generation. It typically includes both private and public enterprises.

Fig3: Examples of Quaternary Industry.

Industries within this sector comprise, among others, banking, finance, insurance, investment, and real estate services; wholesale, retail, and resale trade; transportation; professional, consulting, legal, and personal services; tourism, hotels, restaurants, and entertainment; repair and maintenance services; as well as health, social welfare, administrative, police, security, and defense services.

4) Quaternary industry

An extension of the tertiary industry that is often seen as its own sector, the quaternary industry focuses on information-based or knowledge-oriented products and services. Like the tertiary sector, it includes a blend of private and government initiatives. This sector encompasses various industries and activities such as information systems and information technology (IT), research and development—which includes technological advancements and scientific research—financial and strategic analysis and consulting, media and communications technologies and services, as well as education, which covers teaching and educational technologies and services.

2) Work to eradicate public health issues/disease:

Public health issues and diseases present major challenges to both human well-being and agricultural sustainability. Addressing these problems demands a comprehensive approach that integrates scientific research, public policy, community involvement, and technological advancements. This essay examines strategies designed to eliminate diseases impacting humans and plants, emphasizing both achievements and persistent challenges.

Human Health Issues:

1. Infectious Diseases: The success of vaccination campaigns is exemplified by the eradication of smallpox. Global initiatives, spearheaded by organizations like the World Health Organization (WHO), have effectively eliminated smallpox through extensive immunization efforts. Presently, initiatives are directed towards diseases such as polio and measles, where continuous vaccination programs remain crucial. 2. Non-Communicable Diseases (NCDs): NCDs, which include heart disease and diabetes, are increasingly acknowledged as significant public health challenges. Approaches to tackle NCDs focus on encouraging healthy lifestyles through education, enhancing access to healthcare, and implementing policy changes to mitigate risk factors like tobacco use and poor dietary habits. 3. Vector-Borne Diseases: Diseases like malaria and dengue fever, spread by mosquitoes, necessitate comprehensive vector management strategies. This involves environmental management, the application of insecticides, and the development of vaccines. Innovative solutions, such as genetically modified mosquitoes, show potential in

curbing disease transmission.

Plant Health Issues:

1. Crop Diseases: Plant diseases caused by pathogens like fungi, bacteria, and viruses pose a significant threat to food security. Integrated Pest Management (IPM) utilizes a combination of biological control, resistant crop varieties, and sustainable practices to lessen the dependence on chemical pesticides. 2. Biosecurity Measures: To curb the spread of invasive species and plant diseases, countries adopt biosecurity measures that include monitoring and regulating the import of plant materials. Early detection and rapid response systems play a vital role in managing outbreaks. 3. Genetic Engineering and Biotechnology: Recent advancements in genetic engineering, particularly CRISPR technology, present promising solutions for creating disease-resistant crops. These innovations are designed to boost resilience against pathogens while ensuring agricultural productivity remains high.

3) Improve the scientific and technological environment for all:

Fig4: Represents Smart Home.

In the past decade, Egypt has made remarkable progress in technology, highlighting its dedication to innovation and digital growth. The rapid expansion of its startup ecosystem and significant investments in renewable energy projects illustrate Egypt's potential as a technological hub in the region. Initiatives like launching communication satellites, developing smart cities, and advancing biotechnology and medical research reflect Egypt's ambition to harness technology for sustainable development and societal improvement through strategies such as investing in research and development, promoting STEM education, supporting startups and innovation hubs, enhancing infrastructure, and fostering international collaboration. Recently, Egypt has experienced significant advancements in technology across various sectors, indicating a strong commitment to innovation and digital transformation. Through initiatives like the National Strategy for Science, Technology, and Innovation, the country is cultivating an environment that encourages technological progress. Moreover, increasing partnerships between public and private sectors are becoming more prevalent, supporting research and development efforts aimed at addressing societal challenges and driving economic growth. The rise of smart home technology in Egypt can influence the country's technological landscape in several ways: 1) Infrastructure Development: Implementing smart home technology requires the enhancement of digital infrastructure. 2) Technological Innovation: The introduction of smart home devices and systems can stimulate technological innovation in Egypt. Local companies may emerge to create and produce smart home products that cater to the needs and preferences of Egyptian consumers, resulting in job creation and economic growth in the tech sector. 3) Digital Skills Development: As smart home technology gains traction, there will be an increasing demand for.

Fig5: Technological Innovation.

Problem to be solved:

Potato is an important global food security crop. Its production is, however, severely hindered by plant diseases, particularly late blight, powdery mildew and downy mildew. They not only minimize yield but also impact the quality of the potatoes. Conventional solutions for checking plant health typically rely upon manual inspections, which are time-intensive and ineffective to say the least. This essay presents the primary issue surrounding the diseases management in potato farming and presents an integrated multi-sensor system that can help to monitor, analyze crop better and yield its maximum. The Problem: Plant Diseases in Potato Cultivation Plant diseases pose a serious risk to potato cultivation practices with late blight infections caused by Phytophthora being the most destructive. One disease that can cause total crop loss if not controlled. Powdery mildew and downy mildew can also cause equally damaging impacts on leaf health, affecting photosynthesis, growth and ultimately yield. The economic consequences of these diseases can be substantial, with losses amounting to millions of dollars each year. To address these problems, this project proposes to develop an integrated multi-sensor-based system as a combination of RGB, temperature, and humidity sensors. This system is aimed at developing potato leaves and their environment to monitor them constantly for early disease detection and appropriate interventions in time.

1. RGB Sensor: To decompose leaf color and pigmentation, an RGB sensor will be used. They can change color in response to stress or disease before symptoms become visible. Monitoring these changes lets farmers put into action control measures like fungicide application or irrigation modification.

2. Temperature Sensor: The temperature influences the metabolic activities of the potato plants as well as the pathogens attacking them. Tracking temperature ranges may aid in understanding when conditions are ripe for disease development. For instance, temperatures may suggest greater risk for late blight.

3. Humidity sensor: Humidity is an essential parameter for spreading fungal diseases. Humidity levels will be monitored to assess the risk disease outbreaks. High humidity and warm temperatures provide an ideal environment for the pathogens to flourish.

Research:

We searched about grand challenges which are related to the challenge,

- Increase the industrial and agricultural bases of Egypt,
- Work to eradicate public health issues/disease and improve the scientific and technological environment.
- Improve the scientific and technological environment for all
- Potato diseases and how the environmental factors effect on developing them.
- We searched about types of sensors for system such as, DHT-22 and RGB sensors.

Other Solutions Already Tried:

1-SmartAgriHubs

This is a European initiative dedicated to driving the digital transformation of agriculture through a vast network of Digital Innovation Hubs (DIHs) and Competence Centers. The project integrates cutting-edge technologies such as IoT, AI, big data, and robotics into farming practices, enhancing productivity, sustainability, and efficiency across the agricultural value chain. By connecting technology providers, agricultural experts, and farmers, SmartAgriHubs aims to accelerate the development and adoption of digital tools that improve crop management, livestock monitoring, and resource efficiency.

A key focus of the initiative is to empower farmers by providing them with access to region-specific digital solutions that enhance precision agriculture and sustainable farming practices. Using IoT sensors, AI, and robotics, farmers can optimize tasks like irrigation, fertilization, and pest control, reducing costs and improving yields. The project also supports innovation experiments (IEs), where new technologies are tested and refined in real farming environments, ensuring practical and scalable solutions for the agricultural sector.

SmartAgriHubs offers a range of impactful applications, including precision agriculture, where real-time sensor data helps optimize planting and resource use, livestock monitoring systems that enhance animal welfare, and smart greenhouses that regulate environmental conditions using IoT and AI. These innovations not only increase productivity but also contribute to more sustainable agricultural practices by optimizing resource use and reducing environmental impact.

The project continues to play a transformative role in shaping the future of European agriculture, fostering collaboration among more than 500 partners, including research institutions, agritech startups, and agricultural businesses. By integrating digital technologies into farming, SmartAgriHubs is driving innovation and ensuring the long-term sustainability of the sector.

Advantages

1. Enhanced Productivity: Digital technologies like IoT and AI optimize crop management, improving yields and reducing waste.

Sustainability: Optimizing resource use (water, energy, fertilizers) reduces the environmental impact of agriculture.

Real-Time Monitoring: Farmers benefit from real-time data on crop health, livestock, and environmental conditions, enabling swift interventions.

Disadvantages

High Initial Costs: Implementation of IoT, robotics, and AI may require significant upfront investment from farmers.

Technological Barriers: Smaller or less tech-savvy farms may struggle with adopting complex technologies.

Dependence on Connectivity: Many rural areas may lack the necessary digital infrastructure (e.g., reliable internet) for full system functionality.

2) AgroTech's Crop Disease Detection System

This is an innovative solution designed to help farmers monitor, detect, and manage crop diseases in real time. By integrating advanced sensor technology, imaging systems, and data analytics, the system provides early detection of diseases in high-value crops like potatoes, tomatoes, and wheat. Early intervention enables farmers to take swift action, preventing widespread damage and minimizing crop loss, which ultimately boosts yields.

The system leverages a combination of environmental sensors, RGB imaging, and machine learning to track key factors such as temperature, humidity, and leaf color changes. These technologies work together to monitor crops continuously, identifying patterns that indicate the onset of disease. The data is analyzed by AI algorithms, which offer predictive insights, allowing farmers to make informed decisions and apply resources like pesticides in a targeted, efficient manner.

Farmers benefit from real-time alerts and recommendations delivered through a mobile app or web platform, making disease management more efficient and accessible. AgroTech’s system is scalable, adaptable to both small farms and large operations, and provides detailed reports that help with long-term planning. Its user-friendly interface, precision agriculture features, and real-time monitoring allow farmers to act quickly and accurately, reducing operational costs and promoting sustainable practices.

By reducing crop loss, enhancing operational efficiency, and supporting sustainable farming methods, AgroTech’s Crop Disease Detection System is a valuable tool for modern agriculture. It allows farmers to protect their crops with timely, data-driven interventions, improving yield quality and profitability. Through ongoing collaborations with agricultural research institutions and technology providers, AgroTech continues to refine its system to meet the evolving needs of farmers and advance agricultural innovation.

Advantages	Disadvantages
Early Disease Detection: The system detects diseases at an early stage, helping farmers prevent widespread damage and minimize crop loss.	High Implementation Costs: Initial investment in sensors, imaging tools, and AI systems can be expensive, especially for small-scale farmers.
Scalability: The system is adaptable to both small farms and large-scale operations, making it versatile across different agricultural settings.	Technological Barriers: Smaller or less tech-savvy farms may struggle with adopting complex technologies.
Real-Time Monitoring: Farmers benefit from real-time data on crop health, livestock, and environmental conditions, enabling swift interventions.	Dependence on Connectivity: Many rural areas may lack the necessary digital infrastructure (e.g., reliable internet) for full system functionality.

3) **CropX is revolutionizing modern agriculture with its advanced soil and crop health monitoring platform.**

By integrating IoT sensors, cloud-based analytics, and machine learning, CropX helps farmers optimize water usage, improve crop health, and boost productivity through data-driven insights. The platform offers real-time monitoring of soil conditions and provides precise recommendations for irrigation, fertilization, and other critical farming activities. This technology empowers farmers to make informed decisions, enhancing both efficiency and sustainability in their operations.

One of the primary objectives of CropX is to promote **water efficiency** and conservation. The system's IoT soil sensors continuously measure moisture, temperature, and salinity at various depths across the field. This data is sent to a cloud-based platform, where it is processed and analyzed. Using machine learning algorithms, CropX delivers irrigation recommendations tailored to each field's specific needs, helping farmers conserve water while ensuring crops receive the right amount for optimal growth. This approach not only reduces water waste but also significantly improves crop productivity.

Real-time crop health monitoring is another key feature of the CropX platform. By continuously tracking soil and environmental conditions, the system alerts farmers to potential issues like water stress or excessive salinity. This early detection allows for timely interventions, preventing damage and minimizing crop loss. Farmers receive these insights through a user-friendly mobile app or web interface, where they can view detailed maps of their fields and monitor sensor data. The platform also factors in weather forecasts, making its recommendations even more precise.

The impact of CropX extends beyond just water savings. Farmers who adopt the system report increased yields and significant cost savings due to optimized use of water and fertilizers. The system's precision irrigation and nutrient management not only boost crop health but also prevent over-irrigation and nutrient leaching, reducing environmental harm. In regions facing water scarcity, CropX has helped reduce water use by up to **40%** without compromising yield, making it a vital tool for sustainable farming.

With widespread adoption across North America, Europe, and Australia, CropX continues to gain traction globally. The platform is used in a variety of farming environments, from large-scale field crops to high-value horticulture and controlled environments like greenhouses. Collaborations with agricultural research institutions and industry partners enable CropX to continuously improve its technology. By providing farmers with the tools to manage their resources more effectively, CropX is helping to transform agriculture into a more sustainable, data-driven industry.

Advantages	**Disadvantages**
Water Efficiency: CropX helps farmers conserve water by providing precise, real-time irrigation recommendations based on actual soil moisture levels.	Initial Investment: The installation of IoT sensors and cloud-based systems can be expensive, particularly for small farmers.
Real-Time Monitoring: Continuous tracking of soil moisture, temperature, and salinity enables farmers to make informed, immediate decisions, preventing crop stress.	Reliance on Connectivity: The system depends on stable internet and cloud connectivity, which may be unavailable in remote areas.
Increased Yields: By optimizing irrigation and nutrient management, CropX improves crop health and productivity, often leading to higher yields.	Technical Skill Requirement: Farmers need to be comfortable using digital tools and interpreting data, which may require training or technical support.

4) The **Smart Vineyard Project**

This is a groundbreaking technology solution designed to enhance vineyard management through precision agriculture. By utilizing IoT sensors, data analytics, and predictive modeling, the system provides vineyard owners with real-time insights into grapevine health and environmental conditions. This innovative platform helps tackle key challenges such as disease outbreaks, unpredictable weather, and inefficient resource use, offering a smart, data-driven approach to optimize grape production and improve wine quality. Through continuous monitoring, SmartVineyard delivers the tools needed to predict potential problems and enhance overall vineyard performance.

A central feature of the SmartVineyard system is its ability to **predict and prevent grapevine diseases** like downy mildew and powdery mildew. These diseases can have a devastating impact on vineyards if not addressed promptly. By collecting and analyzing real-time data on factors such as temperature, humidity, and leaf wetness, the system provides early warnings when conditions become favorable for disease development. This predictive capability allows vineyard managers to take proactive measures, significantly reducing crop losses and reliance on reactive treatments like fungicides.

In addition to disease prevention, the project focuses on **resource optimization** by providing detailed insights into soil and environmental conditions. The IoT sensors track key parameters like soil moisture and temperature, enabling more precise irrigation and fertilizer application. This level of control helps vineyard owners minimize water waste and reduce the overuse of pesticides, promoting more sustainable farming practices. The system's data-driven recommendations ensure that resources are used only when necessary, resulting in both cost savings and reduced environmental impact.

The SmartVineyard system is accessible through a **mobile app or web platform**, offering vineyard managers a user-friendly interface to monitor real-time conditions, receive alerts, and implement recommendations. With the ability to view detailed maps and reports on various sections of the vineyard, users can make informed decisions quickly. This level of connectivity ensures that vineyard owners can react promptly to potential issues, even when they are away from their fields, helping them maintain control over vineyard health and productivity at all times.

Overall, the **SmartVineyard Project** is revolutionizing the way vineyards are managed by integrating advanced technology to improve grape quality and farming efficiency. Its predictive analytics not only enhance disease management but also promote sustainable and cost-effective practices. By partnering with research institutions and technology providers, SmartVineyard continues to refine its models and expand its applications across different wine-producing regions. As vineyards worldwide adopt this system, they benefit from more precise farming techniques that lead to better wine production and improved profitability.

Advantages	Disadvantages
Early Disease Detection: The system detects diseases at an early stage, helping farmers prevent widespread damage and minimize crop loss.	High Implementation Costs: Initial investment in sensors, imaging tools, and AI systems can be expensive, especially for small-scale farmers.
Scalability: The system is adaptable to both small farms and large-scale operations, making it versatile across different agricultural settings.	Technological Barriers: Smaller or less tech-savvy farms may struggle with adopting complex technologies.
Real-Time Monitoring: Farmers benefit from real-time data on crop health, livestock, and environmental conditions, enabling swift interventions.	Dependence on Connectivity: Many rural areas may lack the necessary digital infrastructure (e.g., reliable internet) for full system functionality.

5) Plant village:

Plant Village is research and development units of Penn State University that empowers smallholder farmers and seeks to lift them out of poverty using cheap, affordable technology and democratizing the access to knowledge that can help them grow more food. The rich countries of the world were once populated by smallholder farmers who practiced subsistence agriculture and suffered massive yield losses due to diseases and pests. An iconic example is the Irish of 1847. But in 2017 Ireland was recognized as the most food secure nation in the world. Today, 171 years later the situation for many farmers in Africa is no different to that of the

Irish of 1847. But today the world has amazing technology from AI to drones to mobile phones. The world also has a lot more knowledge of growing more food. At Plant Village we aim make this available to smallholder farmers. The Plant Village Solution Plant Village has developed a triple A model (Algorithmic Agricultural Advice) that works to increase the yield and profitability for millions of farmers. It is our goal to reach hundreds of millions in partnership with an ecosystem of farmer facing organizations and the farmers themselves. Our algorithms come from our integration of AI, satellite technology and our unique field force (the Dream 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, SMS, TV or real-world social networks.

Advantages	**Disadvantages**
1. Versatile & Accessible Technology: Plant Village draws on cheap and widely accessible tools- from smartphones, SMS, and AI - making it feasible even for low-resource farmers with limited number of devices to reach sophisticated agrometeorological advice	1-Limited Accessibility in Remote Areas: Farmers in areas with no or poor internet connectivity or no access to smartphones, face challenges to leverage potential of the platform.
2-Triple A: Which Provides Personalized Support to Farmer (With crop type, planting date and region-specific recommendation in terms of CROP maximum yield and minimum risk).	2-Dependence on Accurate Inputs: Farmers provide the input data on which the advice is based, such as planting date and location. Mistakes may result in less-than-optimal recommendations.

3-Scalability: Working in partnership with organizations that engage directly with farmers and in leveraging digital platforms, Plant Village has the capacity to reach millions of farmers globally.

3-Implementation Challenges: High-level tech like AI & satellite networks take lots of infrastructure, training, and adoption time in areas of lower income.

II. Generating and Defending a Solution

Solution and Design Requirements:

This year's project themes are sensing and communication since the task is to measure three physical parameters using sensors and turn the results into data visualizations that can be utilized to make decisions. The selected solution must fulfill the design requirements for multi-sensor integration, which call for the use of at least three sensors to execute distinct functions with a standard precision of at least 2% for the temperature sensor. Signal processing: Using functions and the right methodology, the system must convert sensor data into useful measurements. Real-time monitoring: the system's data should be gathered every 30 seconds to establish a threshold, beyond which the system will sound an alarm. Data visualization: In order for technical users, like city planners or residents, to understand past trends and current situations, the raw data from the sensors must be analyzed and then visualized using charts and graphs. Power efficiency: The apparatus ought to possess energy efficiency. Batteries will be needed, and they shouldn't be changed for at least six months. Calculating the system’s batteries respective powers will demonstrate this. Data storage: For a minimum of a year of nonstop operation, the system must be able to manage the gathering and storing of data. It should also determine how much storage is required to complete this time frame. The project succeeds and the big concept question is answered as a result of these design specifications. Because it will depend on data analysis, IOT, and electricity efficiency, among other things. Regarding our proposal, it talks about how to identify powdery mildew, downy mildew, and late blight in potato plants. Numerous factors, including leaf color, temperature, and humidity, influence the growth of these diseases. Temperature: A DHT 11 sensor will be used to measure it. It is an important criterion for identifying these illnesses. Caused by Phytophthora infections, late blight thrives in damp, chilly weather. A temperature range of 10°C to 25°C (50°F to 77°F) is considered optimal. Caused by different species of Peronosporaceae, downy mildew like damp, colder climates. Best temperatures are between 15°C and 23°C (59°F and 73°F). pulverized mildew Lysiphe taurica and Erysiphe cichoracearum prefers, above the others, warmer and drier circumstances. Ideal temperature range: 68°F to 81°F, or 20°C to 27°C. Humidity: the growth and spread of many diseases in plants are influenced by humidity, which makes the DHT11 sensor ideal for detecting it. Depending on the needs of each disease, different humidity levels encourage the growth of late blight, downy mildew, and powdery mildew in potato plants. High humidity is ideal for late blight growth, with levels above 90% being optimum. This is especially true when coupled with extended leaf wetness, which fosters spore germination and infection. In a similar vein, downy mildew thrives in high humidity levels, usually around 85%. As the pathogen's growth and dissemination depend on the moisture present on the leaves. Conversely, powdery mildew favors settings that are a little bit drier and have moderate humidity levels of between 60% and 80%. It does not need as much moisture as the other two diseases, but it still needs some humidity to grow and spread. Given that each disease produces unique discolorations on the lead color, RGB color analysis is a helpful design requirement for identifying late blight, downy mildew, and powdery mildew in potato plants. A shift towards lower RGB values, especially in the green and red channels, will be seen in the affected areas of late blight, which usually appears as dark brown or black lesions. Due to the yellowish-brown patches caused by downy mildew, the RGB values will first increase in the red and green channels, indicating a shift towards the yellow color. In comparison to healthy, green leaves, the infected parts look lighter and more washed out due to the appearance of powdery mildew, which manifests as white or greyish patches and increases the blue and green channels. By using an RGB sensor to detect these color changes, early disease detection can be aided, allowing for prompt crop management measures.

Selection of Solution:

The integrated multi-sensor system project aims to address critical challenges facing Egypt, particularly those related to food security and agriculture. One of the most pressing issues is the growing vulnerability of crops, especially potatoes, to diseases such as late blight, powdery mildew, and downy mildew. These diseases can severely affect productivity and quality, jeopardizing both food security and the livelihoods of farmers. Furthermore, the agricultural sector in Egypt must advance its scientific and technological capabilities to foster innovation and enhance productivity.

This project seeks to create an integrated system using temperature, humidity, and RGB sensors to provide farmers with real-time insights into crop health and environmental conditions. By facilitating early disease detection through timely data, the system empowers farmers to make informed decisions, leading to improved crop management practices.

In addition to addressing urgent agricultural challenges, this initiative aligns with Egypt's broader goals of expanding its industrial and agricultural sectors. By integrating cutting-edge sensor technology with traditional farming methods, the project modernizes potato cultivation, resulting in greater efficiency and sustainability. This technological advancement not only supports a robust agricultural industry but also stimulates the local economy while enhancing overall yield and quality.

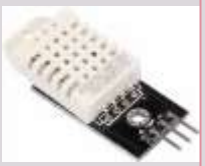
The system’s actionable insights will enable farmers to optimize resource utilization, including water, fertilizers, and pesticides, leading to cost savings and minimal environmental impact. As the benefits of this integrated multi-sensor system become evident, it can serve as a model for other agricultural sectors, encouraging the widespread adoption of similar technologies across Egypt. In doing so, the project contributes to a more innovative and resilient agricultural landscape, ultimately supporting the nation’s food security and economic development objectives.

Selection Prototype

The multi-sensor system uses RGB, temperature, and humidity sensors to monitor leaf color and environmental conditions to combat plant diseases like late blight, powdery mildew, and downy mildew which are influenced on variation on temperature and humidity measured by DHT 11 sensor, and each diseases has a specific color such as yellow for Downey mildew, white for powdery mildew and black for late blight which detected using RGB Color frequency, so they perfectly meet the design requirements. And using the most appropriate battery to give effective power source for the system. This data-driven approach enhances crop health and maximizes potato yield, reducing manual inspections and providing continuous monitoring, ultimately improving disease management effectiveness. The prototype can be tested by using plenty of sensors such as DHT11 Sensor and RGB color.

Constructing and Testing a Prototype

Materials and Methods

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 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

Fig6: Hardware System

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. 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

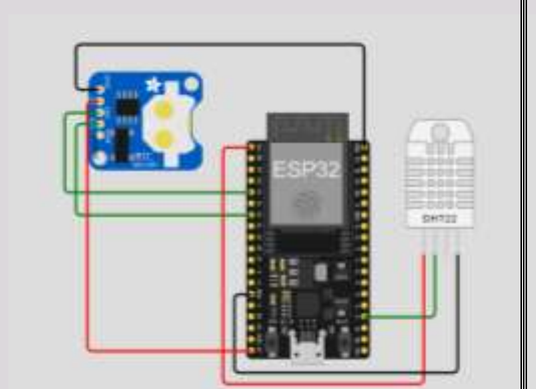


Fig7: Hardware System connection.

color that indicates 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 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.

Safety

We do all work in Fab lab under monitoring from our teachers. For safety Sketching the circuit online before connecting them in real to the effective use of the board and for long life of it. Turn off the board if we didn't use it to not burn.

Test plan:

The selected prototype is a potato disease detection system to detect and differentiate between late blight, downy mildew, and powdery mildew based on design requirements, temperature, humidity, and color frequency. The variation on temperature and humidity based on the range of each disease using the DHT-11 sensor and the color detected using RGB Color will help to detect the specific disease.

First, using the DHT11 sensor to measure humidity and temperature and RGB color to detect the color, the temperature range of 10°C to 25°C (50°F to 77°F) is considered optimal for late blight. If the temperature ranges between 15°C and 23°C (59°F and 73°F), then it is downy mildew's best temperature. However, if it is between 20°C and 27°C (68°F to 81°F), it will be powdery mildew.

As well as humidity, this is ideal for late blight growth, with levels above 90% being optimum. In a similar vein, if humidity levels are usually around 85%, it is downy mildew. Conversely, if humidity levels are moderate between 60% and 80%, it is powdery mildew.

After that, detecting the color of the leaf using an RGB color sensor, if it is black, it reflects the affected areas of late blight. If it is downy mildew, the RGB values will first increase in the red and green channels, indicating a shift towards the yellow color. If it is powdery mildew, it will manifest as white or grayish patches and increase the blue and green channels.

After getting the sensor readings every 30 seconds, it will appear on graphs on REMOTE XY applications. Furthermore, presenting the analyzed data of sensor reading on an Excel sheet. So, after detecting and analyzing the data, it facilitates the detection of the type of disease, so a notification will be created using a push bullet notify the farmers of the type of disease.

Testing prototype:

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

Fig8: 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.

Fig9: test the system in the potato field.

Data collection:

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 (±2)	89 (±5)	(25, 184, 65)	**Late blight-advanced symptoms.**
1:40 (PM)	27 (±2)	65 (±5)	(150, 160, 170)	**Powdery mildew-initial symptoms.**
6:45 (PM)	22 (±2)	88 (±5)	(190, 174, 100)	**Downy mildew-initial symptoms.**

Factors affecting results:

1) unexpected changes in environmental conditions, such as temperature and humidity caused by wind or rain, can impact the test results.

2) The presence of insects or pests in the soil might affect the health of the potatoes or change the color readings of the leaves.

3) The intensity of natural light could interfere with the accuracy of the RGB color sensor readings.

4) Mistakes in handling sensors or recording data may influence the outcomes.

5) Diseases might show subtle symptoms that the sensors cannot detect immediately.

Evaluation, Reflection, Recommendations:

Analysis and discussion:

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. 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 conditions and leaf color so it can determine if it's downy mildew, powdery mildew, or late blight similar to the transducer in

Fig10: First day test.

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.3.04**. 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 4 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:

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

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

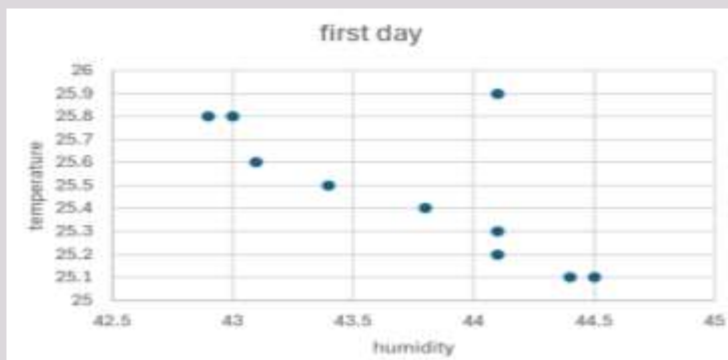


Fig11: First day (temperature and humidity).

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 5**.** 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**.**

$$\boldsymbol{r^2 = -0.924^2 = 0.85 = \ 85\%\ ,\ \ 85\%\ of\ the\ variation\ in\ temperature\ can\ be\ explained\ by\ the\ varation\ in\ humidity}.$$

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 three times at different times **as shown in figure 13** 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.

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

$\boldsymbol{so\ about\ 84\%\ of\ the\ variation\ in}$

$\boldsymbol{temperature\ can\ be\ explained\ by\ the}$

$\boldsymbol{varation\ in\ humidity}$ as shown in **figure12.**

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

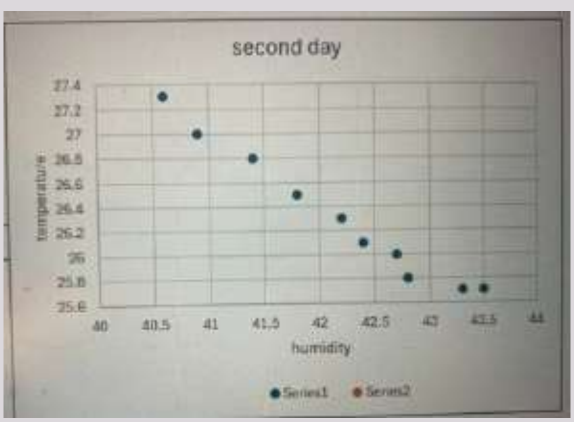


Fig12: second day data recorded

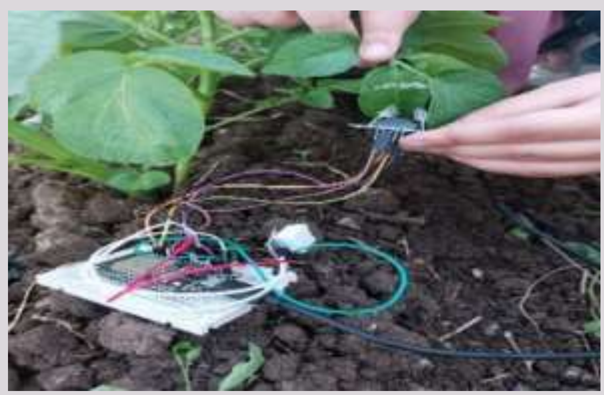


Fig13: second day test.

In third trial, the system's temperature and humidity were tested **as in figure 14** 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 15**.

r= $\boldsymbol{-0.983^2 = 0.96 = 96\%,}$ **so** about 96% of the variation in temperature can be explained by the variation in humidity.

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. 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.

Fig14: Third day test

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**

$$= \frac{24.9 \times 60 \times 24 \times 365}{10^6} = 13.08 \text{ GB.}$$

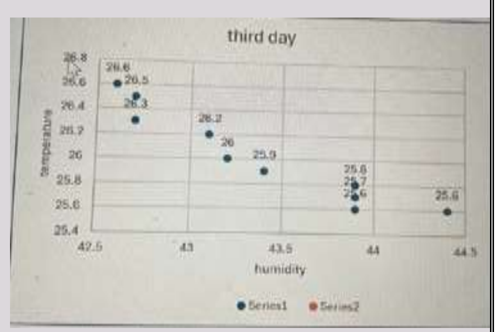


Fig15: third day data recorded

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= 36.075mA. the ESP32 voltage is 3.3V.

Power consumption= $119.05mW. \ The\ energy\ consumed = \frac{119.05 \times 2880}{1000} = 342.86Wh$. So the required battery to work six months should be not less than $342.86Wh$.

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). 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 that includes a camera to take photos for the potatoes leaves so, the disease can be detected by the leaf color.

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.

Learning Outcomes:

Learning outcome	Connection
PH.3.04	Our solution is a potato disease detection system, imply the DHT22 sensor to measure humidity and temperature and RGB color to detect change in environmental conditions and leaf color similar to the transducer in communication systems which convert physical signals into electrical signals and send data to esp32 which is similar to transmitter's role to encode and modulate the data from analog to digital after that it appears in REMPTE XY as analog physical signals which is similar in receiver when data decoded and demodulated to the original signals.
CH.3.01	The selected solution fulfilled the design requirements for multi-sensor integration and demonstrated the recommended precision, the standard accuracy for the DHT 22 sensor is ±0.5 for temperature and 2% for humidity.
ST.3.02	The correlation between humidity and temperature was measured by laws of correlation, and variation in humidity can be explained by the variation in humidity.

ES.3.01	This learning outcome covers GPS (Global positioning system) and its applications in locating a point on earth, its components of 24 satellites which rotate around the earth, processor and user interface which display the location in a form of: latitude, longitude and altitude. Similarly, in our system, DHT-22 measures temperature and humidity and RGB sensor determines the color of the leaf. Where these sensors receive signals. Furthermore, these signals where transmitted to ESP32 microcontroller where processing occurs. finally, the data will be visualized on an Excel sheet for storage.
MA.3.02	The leading outcomes explains first derivative and second derivative effect on the behavior of the functions and graphs. To determine the rate of change in the slope (first derivative of the function) of the relation of humidity and temperature. As humidity increasing temperature decreasing in a decreasing rate which calculated by the second derivative of the function. The function is concave upward when the second derivative greater than zero and downward when less than zero. The point of inflection is the point when the graph changes its sign from positive to negative.
BIO.3.01	This learning outcome explains the neuron and its structure including: the dendrite, a part of the neuron that receives signals from sensory neurons. Similarly to our system where DHT22 sensor receive signals to measure humidity and temperature and RGB color to detect the leaf color. Furthermore, the axon hillock is responsible for processing and transmitting signals which is similar to an ESP 32 microcontroller function. Ultimately, these signals go through the neurons by forming synapses. Following processing, the signals are then sent to the laptop for data visualization.

CS.3.03	This learning outcome was about the methods of computing the file size in bytes, megabytes, and gigabytes. Data storage estimation for around one year was calculated by multiplying the total number of records by the size of each record which was proven to be a more efficient method of determining storage requirements.
PH 3.05	The process of calculating the battery energy consumption within a certain system is associated with this leading outcome. Thus, we determined energy of battery is to be applied in the system to make sure the continuous operation for six months is by working out the power consumption of our system over that time.
ST.3.02	We used the regression line to predict the relation between the probability of infecting potato diseases (Late blight, powdery mildew and downy mildew) and the temperature of the surrounding atmosphere.
BIO.3.03	The learning outcome is an illustration of different types of receptors that receive signals from sensory organs, such as mechanoreceptors that detect touch and pressure, thermoreceptors that detect temperature, chemoreceptors that identify chemical changes, and pain receptors that are activated by harmful stimuli. Similarly, the DHT-22 sensor in our project also functions like a thermoreceptor, as both of them measure temperature. Just like thermoreceptors in biological systems detect temperature changes and transmit these changes to the brain, the DHT-22 sensor measures the temperature and transmit the data to the ESP32 microcontroller for further processing and visualization.

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