De La Salle University - Dasmarinas

SMART CONTROLLABLE PLANT GROWTH SIMULATION SYSTEM

A Research Study Presented to the Faculty of Computer Engineering

College of Engineering, Architecture and Technology

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APPROVAL SHEET

This thesis entitled

"Smart Controllable Plant Growth Simulation System"

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ABSTRACT

The "Smart Controllable Plant Growth Simulation System" is an innovative web-based application designed to facilitate optimal plant growth through real-time monitoring and adjustment of environmental parameters. This thesis aimed to develop a system that enables users to remotely measure and control humidity and temperature levels, providing an interactive and customizable plant growth simulation experience.

The system made use of sensor technologies to precisely detect environmental conditions, and it has a user-friendly web application interface. Users can customize the growth simulation through the web application by changing humidity and temperature factors according to the needs of their plants.

Test results showed that the "Smart Controllable Plant Growth Simulation System" accurately measured and regulated temperature and humidity levels, delivering a customized and interactive plant development simulation experience. An improved user experience was a result of the system's user-friendly interface and responsive performance. The system's functionality and potential for usage in various plant growth applications were highlighted by the simulated plant development patterns' close agreement with anticipated results.

The outcomes of this research contributed to the advancement of smart plant growth systems and offered potential applications in agriculture, horticulture, and indoor gardening. The "Smart Controllable Plant Growth Simulation System" provided a user-friendly platform for individuals to monitor and optimize plant growth conditions remotely, facilitating sustainable and efficient plant cultivation practices.

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CHAPTER 1

INTRODUCTION

Background of the Study

Increases in plant volume and/or mass may occur with or without the development of new structures like organs, tissues, cells, or cell organelles. Growth is typically linked to development (the specialization of cells and tissues) and reproduction (the creation of new individuals). There are four stages of plant growth. One is the sprout stage where the seeds contain all the nutrients they need to germinate and grow their first pair of leaves. At the seedling stage where roots begin to appear and develop to spread, plants need a quick boost of absorbing of well-balanced nutrients. As the vegetative stages begin nitrogen is the most important for plants when their energy is directed into growing stems and foliage. As adult plants begin, this is where the budding, flowering, ripening began, where full grown plants need extra phosphorus during the transition to the blooming stages. The importance of plant growth is that plants take in carbon dioxide from the atmosphere and produce oxygen. In addition, plants make up the base of the food web by producing their own food using light, water, carbon dioxide, and other chemicals. Plants need five things to grow. These are sunlight, proper temperature, moisture, air, and nutrients. These five things are provided by the natural or artificial environments where the plants live.

Plants can grow in different weather but there are only certain types of plants that can grow under these circumstances. In colder climates, other plants can reduce plant enzyme activity. As a result, plants' ability to absorb nutrients is hampered since they produce enzymes to break down their environment for soil. As a result, this may slow growth or, in more extreme cases, result in death. However, some things can grow, like spinach and carrots. Furthermore, most plants thrive in a temperature range of 59°F to 86°F. Plant growth is hindered, and certain plants start to exhibit signs of stress when temperatures exceeding 90°F are maintained for extended periods of time. With a few exceptions, the answer is somewhere around 90 degrees F.

The study aimed to develop a system that simulated a certain environment in which a cold- or hot-growing plant flourished. The users entered their preferred temperature, humidity, and type of cold or hot plant into this system. This suggested that the system be automated, in which case it recorded the plant's growth over a predetermined period and produced the desired results based on the data acquired by the researchers.

Statement of The Problem

This research has a chief concern regarding the primary factors affecting performance and availability. To obtain all essential knowledge, data, and information, the research sought to answer the following questions:

1. What made you sure that the system was automated properly?;
2. Was it efficient to grow a cold type of plant in hot weather?; and,
3. Did the system become a way of improvement to the process of growing plants?

Objectives

The study aimed to develop a system that monitored the growth of the plant in certain weather conditions and identified if it was an improvement to the way of growing plants.

1. Develop an automated plant growth simulation system tester that sets the temperature and the humidity based on what the user wants;
2. Develop a program that sends a notification if the humidity and temperature is too low or high inside the system;
3. Develop a website application that allows users to select any given plant and helps to monitor if that plant inside the system is growing or not; and,
4. Monitor and gather data of the width and length of the root and stem of the plant in plant growth simulation system by a ruler and differentiate the growth of the plant.

Conceptual Framework

Input

1. Moisture
2. Temperature
3. Plant
4. Heat

Process

a) Observation through the process of plant growth inside the simulation system.
b) Tabulation of Data gathered in the experiment.
c) Statistical Analysis and Interpretation

Output

- Better quality of Plant
- Improved quality of life of the process of Plant Growth.

Significance of the Study

The study may be significant to the following:

The Researchers

The researchers are unfamiliar with this type of subject that causes challenges. In order to uncover significant, verifiable, and credible components of the laws guiding plant growth, this technique may act as a navigational tool. It may also be a way to understand the features of different plants in varied climates.

Future Researchers

Future researchers may improve this system by adding more features, improving the reading, and making it more versatile.

Scope and Delimitation of the Study

The system only tested a tiny amount of data because it was too small to handle many data collections. Future studies may add the notion of expanding the system or adding additional automated devices to measure plant development more precisely.

CHAPTER 2

REVIEW OF RELATED LITERATURE

In this chapter, the researchers discuss plant growth as well as its problems and benefits. There are various related plant growth theories on how they benefit in the crop yield, quality of plants etc. This study benchmarks on both its benefits and problems. This also gives way to understand how plant growth works.

Foreign Literature

Molecular Mechanisms of Plant Growth

A greater comprehension of the molecular traits of seed and germination is necessary to learn more in order to improve agricultural output and quality. The regulation of seed dormancy and germination has advanced significantly because of the elucidation of the molecular mechanisms underlying the functions of plants and hormones, particularly ABA and GA. The impact of additional regulatory mechanisms, like post-transcriptional and epigenetic regulation of gene expression on seed germination and dormancy was also still unknown.

Plant Physiology and Development

In addition to seeds, pollen and spores are also referred to as germination. Pollen germination is the process by which a pollen particle transforms into a pollen tube. Germination is the process by which hyphae (filamentous structures) emerge from fungus spores. When a seed is said to have germinated, it means that a new plant has emerged. However, seed germination can refer to several stages of an occurrence. The phrase, seed germination describes the appearance of green seedlings with one (mono) or two (di) cotyledons through the soil surface; however, germination also refers to the process of a seed's radicle tip poking through the soil surface.

The Influence of Light Intensity on Plant Growth

This study aimed to assess the impact of light intensity on plant growth. The researchers hypothesized that varying levels of light intensity have significant effects on plant growth parameters. To test this hypothesis, the researchers conducted a controlled experiment with different light intensity treatments. The results indicated that light intensity significantly influenced plant growth, with higher light intensities leading to increased growth rates, larger leaf areas, and higher biomass production.

The Influence of Temperature and Moisture on Germination and Plant Growth

Temperature and moisture are crucial environmental factors that affect the germination and growth of plants. Previous research individually examined the effects of these parameters on plant development. However, a comparative analysis was essential to determine if temperature and moisture elicited similar responses in terms of germination and plant growth. Understanding these relationships contributed to better management practices and the development of strategies for optimal crop growth.

Comparative Analysis of Plant Growth Process and Germination Process

Plant growth and germination are two fundamental stages in the life cycle of plants. While germination represented the process by which a seed developed into a young seedling, plant growth encompassed the subsequent growth and development of the plant. Previous studies explored each process independently, but a comprehensive analysis comparing the two proved that the parameters affecting the two cycles were almost the same. Understanding more of the similarities between germination and plant growth provided valuable insights in the underlying physiological mechanisms governing these processes.

Local Literature

Soil Temperature

The temperature of the soil, not the air around it, determined how quickly seed germination occurred. Between 21 and 29°C (between 70- and 85-°F), seeds typically started to grow. For each type of seed, there was a precise temperature range where germination rates were highest. Gardeners were also aware of the temperature ranges (minimum and maximum) outside of which a specific type of seed did not even start to germinate (see "Grow Great Vegetables" for a more detailed chart). This information was printed on the labels of certain seed packets by seed companies. Because local seed suppliers in the Philippines rarely disclosed these facts, they frequently needed to do some online research.

Moisture Triggers Seed Germination Essential to Plant Growth

Throughout the germination phase, the soil was maintained continually moist. If seeds were allowed to dry after germination has begun, they were easily killed. Spraying or sprinkling the seed trays with water once or twice daily was done to moisten the soil. One method they discovered involved covering the seed tray with clear plastic to create a greenhouse effect that keeps the soil moist. Utilizing a damp paper towel was another method.

Foreign Studies

Molecular Mechanisms in Plant Growth Promote Bacteria (PGPR) to Resist Environmental Stress in Plants

The first stage of a plant's life cycle was seed germination. The amount of soluble substance in the soil decreased its water potential because salt adversely affected seed germination. Water flowed from an area of higher potential to one with lesser potential. As a result of hormonal imbalance, acid metabolism reduced protein metabolism, and reluctance to take in water from the soil, seeds that have already been planted did not use up their seed reserves. Salinity has a significant impact on seed germination in a variety of plants, according to more studies. Additionally, the rate of seed germination in Brassica napus declined when salt content rose.

African Underused Leafy Vegetables and Edible Weeds: The Role of Fire and Fire Cues in Seed Germination, Seedling Vigor, and Establishment of Species from Fire-Prone Vegetation

Plant production vital for human survival in terms of medicinal herbs, safety, and for animal grazing was determined by seed germination. Some plants were only multiplied through seed, and only if they were difficult to germinate. This has put their expanding existence in danger.

Some seeds waited for the right weather conditions to encourage germination before emerging from the soil. Due to weak seedling vigor and weak seed dormancy, other seeds did not germinate. By starting the physiological and physical processes required to break seed dormancy and promote seed germination, fire encouraged the germination of seeds. Its evaluation was extremely important for bush fire and fire cues in promoting the germination of seeds that were both fire-prone and non-fire-prone. Potentials of fire and fire cues induced the seed germination and were effective for flower production was also highlighted.

A Complete Review of Rice Responses and Salt Stress Tolerance

A complicated process comprising various physiological and biochemical changes that activate the embryo, is a key element in the development of total biomass and yield. Usually, there is a considerable inverse relationship between the salinity level, the proportion of seeds that germinate, and the time it takes for seeds to germinate. Various illnesses and metabolic alterations, such as solute leakage, K+ efflux, and -amylase activity, are brought on by salinity during seed germination. Salinity first resulted in osmotic stress, which reduced the moisture availability. Ionic toxicity and nutritional imbalance are the following effects. Cell membranes are key players in controlling both active and passive solute transport as well as plant nutrient uptake. The ability of the lipid bilayer membrane to control the selective transport of ions and solutes inwards is generally affected by an imbalance of mineral nutrients under salinity stress. As a result, the membrane became leaky to the solutes it contained. By subjecting six rice cultivars with varying levels of salt tolerance to 0, 50, 75, 100, and 200 mM NaCl solutions, tests were conducted to examine the effects of salinity on seed germination.

Research on Rice that Harnesses Cold Tolerance: Scope and Progress

Plant growth is the most crucial stage in the life cycle of a plant. Starting with imbibition, activation, and subsequent manifestation, the germination of seeds depends on water, air, temperature, and light. Rice seed germination is significantly influenced by temperature. Temperatures below the optimal range (18-33°C) hinder the germination process. Cold temperatures slow down the diffusion process, which interferes with imbibition and lets solutes escape from the seeds. Cold stress is particularly apparent during the drinking phase, which is regarded to be the most delicate period. Rice seeds are exposed to cold stress during this phase, which causes more solute to escape from the seeds.

Crop Enhancement Strategies for Drought Adaption

Lack of soil moisture has a significant impact on seed germination and seedling establishment. Even though management techniques lessen this stress, it would be wise to create varieties with innate stress tolerance through high imbibition rates. Under ideal moisture conditions, finger millet seed germination took 2–3 days for both laboratory germination and field emergence. Since quick imbibition was required for seed germination in rainfed monsoon conditions, where the average soil evaporation was close to 3–4 mm per day and the seed was sown 2 cm deep. Within 2 days after sowing, the soil moisture in the top layer was depleted. In rainfed soil, seed germination was impeded, and the rate of imbibition was low. Although transplanting was used to manage sowing in dry conditions, when it rained, the shock of transplanting was high and practically challenging when large areas needed to be planted. Therefore, direct sowing under ideal conditions was appropriate for rainfed situations. As a result, both in vitro and field circumstances were used to identify genotypes that were suited for rainfed environments. Utilizing polyethylene glycol, which inhibited water from entering the seed coat's cell wall, it was possible to replicate drought conditions. Furthermore, rather than simulating field conditions, a gravimetric technique using pot cultures was more suited. Identification of a specific feature of fast seed germination was through increased seed solute absorption rates.

Current Crop Protection Transformation Concerns in France are Addressed through the Eco Phyto Plan's Priorities for Research and Innovation

The seed germination and seedling emergence phases of a crop cycle are the most critical and vulnerable. Because poor seed quality and sowing techniques have an impact on seed germination and seedling emergence, they have both direct and indirect implications on crop health. For instance, poor seed germination necessitates more costs for resowing or causes a decrease in plant density and, as a result, a decrease in production. Therefore, it is essential to use any kind of seed treatments or cropping practices to reduce young radicle and seedling exposure to biotic (pests that are transmitted by the soil) and abiotic (drought, heat, and mechanical) stresses during such a sensitive time.

Current Status and Future Prospects of Engineered Zinc and Copper Oxide Nanoparticles in Promoting Plant Growth and Yield

Its indexes and elongation are the primary determinants of crop growth with metal and metal oxide NPs. Seed germination and plant growth have improved because of NPs' impacts on plants. The genes responsible for water channel protein, better cell growth protein, and better cell growth through regulating cell cycle are activated when plants are exposed to NPs. the examination of A. When hypogea were grown with various dosages of ZnO NPs treatment, the maximum germination percentages were discovered in group A. Hypogea seedlings grew in the 300-ppm treatment as opposed to the control (Rajiv & Vanathi, 2018). These tests showed that NPs improved seed germination by penetrating the seed and increasing water absorption. According to reports, the ZnO NS-based nano fertilizer system boosted the maximum rate of plant development, which is a sign of the cellular enzymes controlled by nanoparticles working at their peak efficiency. Additionally, zinc improves the ability of the roots to exchange cations, which in turn improves the digestion of critical nutrients, particularly nitrogen, which stimulates the production of protein and regulates the concentration of plant growth hormones.

Application of a Plant Biostimulant's Effects on Seed Germination

When a dry, dormant seed consumes water, the process known as seed germination begins, and it is completed when the radicle protrudes from the seed coat. Multiple signals are involved in the intricate process of seed germination, which is controlled by both internal and external factors. Examples of intrinsic aspects include seed dormancy and readily available food sources, whereas extrinsic elements include things like water, temperature, oxygen, light, relative humidity, substances in the seed environment, and substrate type. Since irregular seed germination can result in poor stand formation, which affects the crop's overall performance. Germination is essential to the domestication of crops.

Local Studies

Effects of Static Electric Field Stimulation and Exposure Time on Philippine Zea Mays Hybrid Genotypes' Germination and Stem Tissue

The Philippines' tropical and maritime climate makes it impossible for the agricultural areas to produce consistently. Industrial crops are electrotropism-sensitive; thus, activating them can break germination hibernation and increase growth and quality. However, the strength of the effective electric field depends on the genotype. In an electroculture setup with 0.4 V/cm electric fields, three replicates of each of the three hybrid Philippine maize genotypes NSIC CN 282, IPB VAR6, and PSB CN 97-97 were cultivated. Treatments included five minutes per day (T5), ten minutes per day (T10), fifteen minutes per day (T15), and control. Modeling of each genotype's germination rate was done using 5-gene genetic programming. In order to confirm the impact of the electric field on plant tissue, morpho-anatomical microscopy was performed. Plants subjected to static electric fields for a longer time (T10-T15) produced more basal roots, longer and heavier root and shoot systems. In seedlings treated with T15, the thickness of the stem and parenchymal tissue multiplied more quickly. Furthermore, it was discovered that seedlings treated with T15 had bigger and more noticeable xylem and phloem vessels, which biologically made it simpler to carry water and sugar from the leaves to other parts of the plant system and speed up growth.

Banana Wild Relatives' Seed Germination Ecology Using Synthetic and Seminatural Settings

The extent of ecologically significant seed germination research was constrained by the availability of seeds and suitable testing environments. This was especially true when a species being studied was far from its home habitat. In these artificially created natural and semi-natural environments, seeds grew in response to exposure to sunlight. The influence of seed burial depth was only tangentially significant even when seeds were buried 7 cm beneath the surface of the ground. The difference in temperature between the areas that were shaded and those that were exposed to the light was only a few degrees. The highest temperature experienced in the days preceding germination had the greatest impact on germination responses. Above a 23°C threshold and up to the soil's maximum temperature of 35°C, germination rose linearly.

Clitoria Ternatea L.'s Blue Ternate (Pod Maturation and Seed Germination)

It is essential to harvest seeds at the proper stage of development for better seed quality. Excellent seed performance can be described in terms of the seeds' vigor, viability, and field performance. This study evaluated the seed viability of several blue ternate plants, or Clitoria ternatea, cultivars. These cultivars had five different pod maturities: cultivar 1 had 100% green pods; cultivar 2 had 50% green + 50% brown pods; cultivar 3 had 100% light brown pods; cultivar 4 had 100% brown pods; and, cultivar 5 had 100% over-mature, twisted brown pods. The experiment was carried out using four replications of a Split Plot Design with a Randomized Complete Block Design. It was significantly influenced by the visual hue of the pods, which reflected pod maturity. Both light to brown pods were uniform in color, which suggested a higher germination rate. Seeds from over-mature pods with shriveled and twisted conditions nevertheless germinated; albeit, having a lower chance of doing so. Additionally, the results indicated that while blue ternate pods were still green in color, their seeds still germinated even if they were currently black; albeit, more slowly than seeds in brown pods.

Using Seminatural and Simulated Habitats for Seed Germination Ecology

Access to seeds and appropriate testing settings at the same time limited the scope of ecologically significant seed germination research. This was especially true when a species being investigated was studied distant from its native habitat. To expand the ecological interpretation of germination studies, present an alternative; thus, the use of glass houses in botanic gardens as simulated-natural habitats. The Musa acuminata subsp. burmannica, M. acuminata subsp. siamea, and M. balbisiana, native to tropical and subtropical Southeast Asia, were the foci taxa. In Belgium, experiments were conducted to determine how seed germination responded to sunlight and foliage shade, the depth at which seeds were buried in various heated glass house compartments, and the extent to which seeds survived and released dormancy from the earth.

Seed Morphology, Storage Behavior and Germination Pattern of *Atuna Racemose*

Despite *Atuna racemosa's* potential for economic gain, nothing was known about its morphological measures, seed storage habits, or the specific growth and development of seedlings. The seed shape, storage behavior, and germination pattern of A were all described in this work seeds of *racemosa*. Characterization was done on 300 mature fruits from three accessions of the Institute of Crop Science's germplasm collection at the University of the Philippines, Los Banos. The viability of the seeds was assessed morphologically, evaluated at fresh (65%) and dry (12%) moisture contents, planted, and regularly monitored for growth and development. A. *Racemosa* seeds measured 48.88 x 1.56, 37.56 x 0.85, and 33.75 x 0.92 mm in length, width, and thickness, respectively. They ranged in shape from obovate to orbicular.

Effects on the Germination of Falcata of Various Hot Water Pre-Germination Treatments and Germination Media

The most common pre-treatment for falcata seeds before germination is hot water. The ideal soaking time in hot water (100°C) to break dormancy in falcata seeds was examined, as well as the most effective germination media that boosted germination. Comparative studies were done on the germination of seeds that were submerged for 5, 15, and 30 seconds. Pure sand, pure soil, cloth, tissue paper, and direct potting (70 percent soil, 20 percent sand, and 10 percent vermicast) were the germination media used in this study. All hot water-treated seeds were steeped in tap water for an entire night prior to being transferred to the various germination substrates. In 30 seconds of soaking in hot water, a higher germination percentage (66 percent) was seen.

Malayan Box Turtles (Cuora amboinensis) from Laguna Province, Philippines, Endozoochory and Germination of Selected Ingested Seeds

The ecological niche occupied by Malayan box turtles is crucial to the ecosystem. They are frequently forgotten in relation to this. To find out how it affected seed germination and dissemination, this investigation looked at the germination of a few specific seeds that have already been ingested by the subject. This study showed how crucial the Malayan box turtle was to the ecosystem because of its contribution to plant seed germination and dispersal.

CHAPTER 3

METHODOLOGY

This chapter presents the type of research used and the design of the study. Also, this includes the materials utilized whether the said system was successful in simulating the plant growth. The steps of every procedure in this part determined how the researchers managed to come up with the results.

Methodological Framework

The construction of a system to simulate plant growth was the main goal of this study, which also examined how user-selected plants fared in terms of growth and survival under various climatic circumstances. To examine how various climatic conditions affected plant growth in the simulation environment, the researchers used a combination of experimental and observational methods. This study also addressed current difficulties with plant growth, like variations in temperature and humidity.

Figure 1.1

Schematic Diagram

Gathering of Materials

The plant, the hardware component needed software to use for the coding.

Making of database and web application to help with the simulation system

Putting the plant on the rack with the said system

(These plants were under the influenced of the simulation system.)

A non-participant, structured, controlled, and uncontrolled observation of the results were for few weeks.

Tabulation of Data

Gathering of Data

The researchers made a plant growth simulation system for the plant growth of the selected plants. The procedure of data gathering was to observe, and the study was then conducted for 5-7 days depending on the plant in the application. The plant was in the said simulation system. Each plant was observed and assessed by each subject from small plant to adult plant.

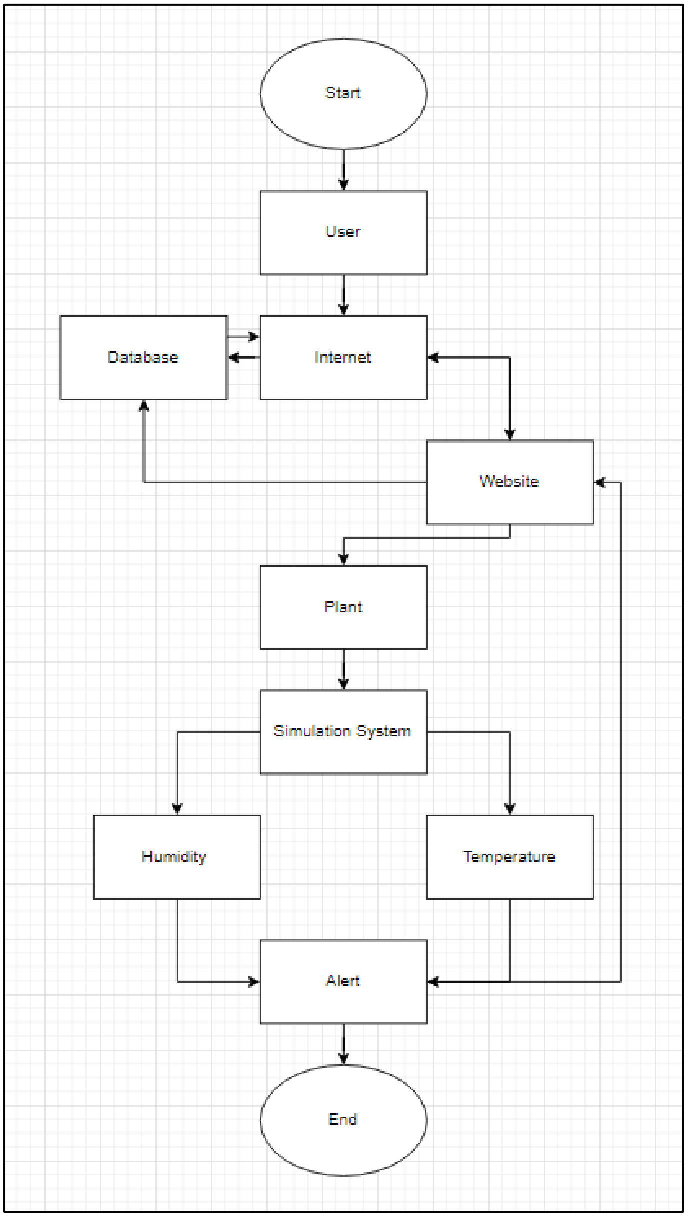
After collecting all data, the researchers, with the help of the thesis adviser, tabulated and tallied the data for observation. The results were hopefully the basis for an alternative way for growing plants with different specifications of needed temperature and humidity.

Preparation of Sample

The moisture and temperature of the plant growth simulation system were modified data or independent variables. The plant's growth was the dependent variable, and it was assessed based on how long and healthy it was. The chosen plant was the focus of the investigation. The user's input into the web application for the simulation system constituted the subject as a group. The plant was the source of data, and each plant that was planted in the system resulted in data that was recorded there. The plants that were given in the study were aloe vera, cactus, and snake plant. The three plants were chosen because of their not complicated growth conditions, meaning they grew in wetlands and drylands with the temperature of 24-29°C and a humidity of 70-80% with or without constant light, or they grew regardless of the humidity or temperature.

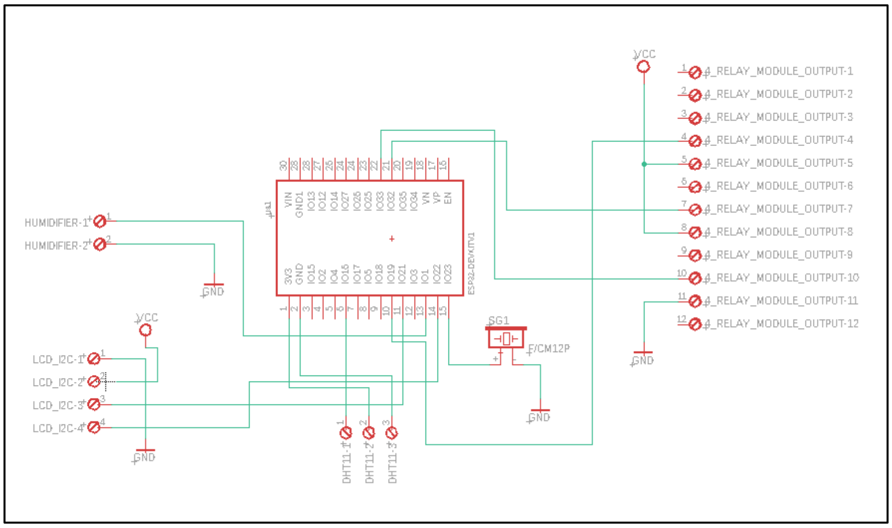
System Flowchart

The researchers proposed a system. The flowchart showed how the automated system for plant growth simulation worked and how it was connected to the internet and the user.



Schematic Diagram

The figure below shows the graphical representation of the researchers' model of the plant growth simulation system that was used for automation of the plants and was presented in a simple, accessible way. The application of EAGLE was used to create the figure diagram below and was the guide of the researchers to create the hardware part of the said study.



Procedure

The requirement of this study was to know what to do first. In addition, the main point was to build the plant simulation system with a minimum error regarding changing the temperature and making sure that humidity was right. The said temperature and humidity were inter-correlated to the plant growth for the data to be accurate and precise. The study underwent different phases that included the schematic diagram, namely: Planning: Implementing; and, Analysis. The plant that was used needed to be identified and the proper component of the system was required for the Planning Phase. Making the system simultaneously and placing the plant in the seedbed were needed in the Implementing Phase of the study. Gathering data in the Implementing Phase was the analysis of the study. In addition, testing procedures were implemented to find defects in the system and in the process of the plant growth. Since there was a possibility of fault in the said system, it needed to be fixed right away for it to satisfy and meet the objectives without affecting the accurate data gathered in different plants.

By implementing all these phases, the researchers were able to determine if the plant growth simulation system was used as an alternative way of plant growth or a process that led to an improvement of quality of life for those who did farm life in a chaotic weather.

Research Instrument

The research instrument used in the research study was observation schedule. This chosen instrument was used in the collection of data to test validity and reliability of the study being conducted.

Observation was used for data collection. A systematic description of the event, behavior, of a social setting was also done. The researchers made a different set of observations inside and outside of the system. Unstructured observation was used for the researchers to freely gather data or information from the plant unrestricted, for the researchers to have no rules to follow, and for the implementation of the plant growth to be quick and easy.

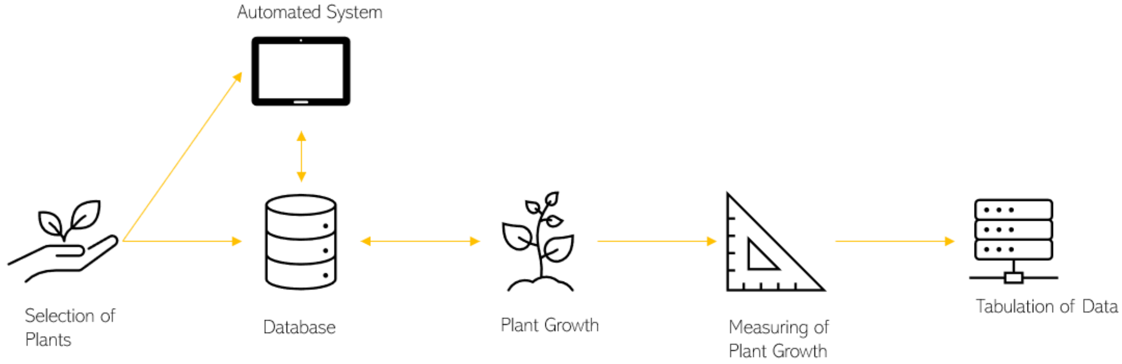
This instrument was the most applicable way to gather data because it was mostly observing the plant on how they grew inside or outside of the system. The researchers just recorded on what was going on in the process of plant growth in the said simulation system.

Statistical Analysis

The research methodology obtained primary data which was the plant growth through observation. The proposed sample size were 1-3 plants in the said system. In other words, the researchers' sample size was A = 1-3. The researchers used the analysis of variance to determine the relative effectiveness of the different ways of doing things to which randomized groups were respectively exposed to. These sample sizes informed the statistical analysis by verifying within the results of the simulation process (Variable A). Since the sample size was not very large, it was not as accurate results as if the research study was on a larger scale. But in addition, there was enough information gathered to at least determine trends of the simulation system options to make the most informed decisions on which process were most likely the most beneficial. Most of the observations were quantitative in nature since the primary data were predetermined and many were involved, Measurements were objective, quantitative and statistically valid.

System Architecture

The diagram showed how the plant growth simulation system process flowed throughout the research. It also showed the key steps to take to resolve the issue. In addition to the diagram, it was easy for the researchers to know what to do next or what part of the study they were in.



System Components

For the layout of the system, it was depicted as a close system. The base or the rectangular part of the system consisted of marine wood since the built system needed to be very thick to stop it from shattering. The specs were an ESP32 Controller (Figure 2.1), DHT11 (Figure 2.2) that measured the humidity and temperature, and humidifier (Figure 2.3), which gave a specific amount of water for the plant to grow and helped to control the humidity of the system. The fan (Figure 2.4) was automatically turned on to adjust the temperature around the system. The LCD (Figure 2.5) displayed the current humidity and temperature of the system. The buzzer (Figure 2.6) notified the user if the temperature inside the system was high and if the humidity inside the system was too low. Four (4) channel relay was used to control high voltage components.

Figure 2.1

ESP32

Figure 2.2

DHT11

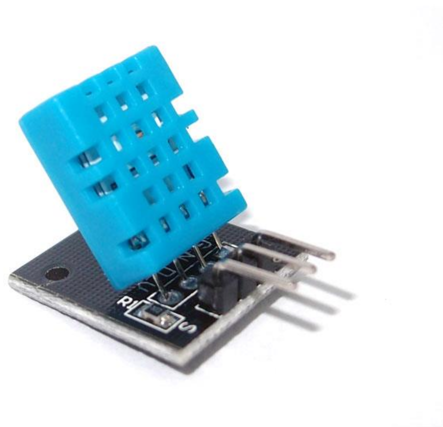


Figure 2.3

Mini Air Humidifier Mist

Figure 2.4

Mini Fan

Figure 2.5

LCD

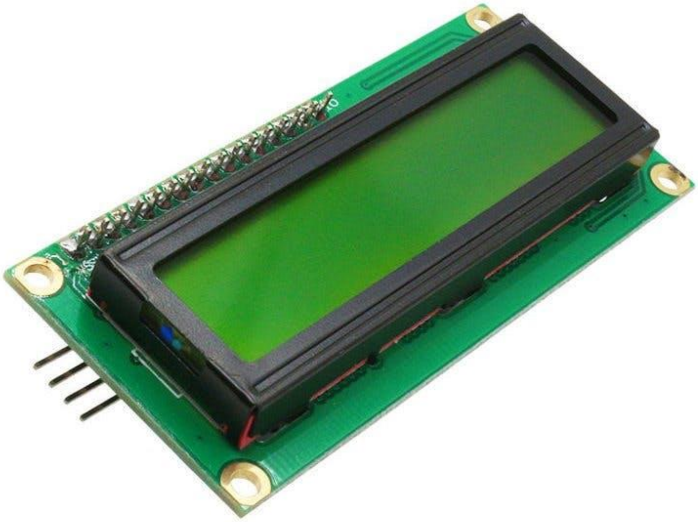


Figure 2.6

Buzzer

Figure 2.7

4 Channel Relay

Software Components

The researchers implemented the system with the help of Arduino IDE to connect the hardware components to upload programs to them and communicate with the said system. The researchers selected this type of software because it was beginner friendly since it has a minimalist interface making it simple to compile, write code etc. Also, it has versatile software that is compatible with windows, MAC, Linux. The researchers also selected the software Visual Studio Code or Atom for the development of the web application needed for the automated system. This type of software has the advantage of fast and feature-rich emulator which the researchers tested the web application before implementing it. In addition, the researchers also selected SSMS SQL Server for the database of the study which showed the temperature and humidity of the plants currently undergoing in the plant growth simulation system.

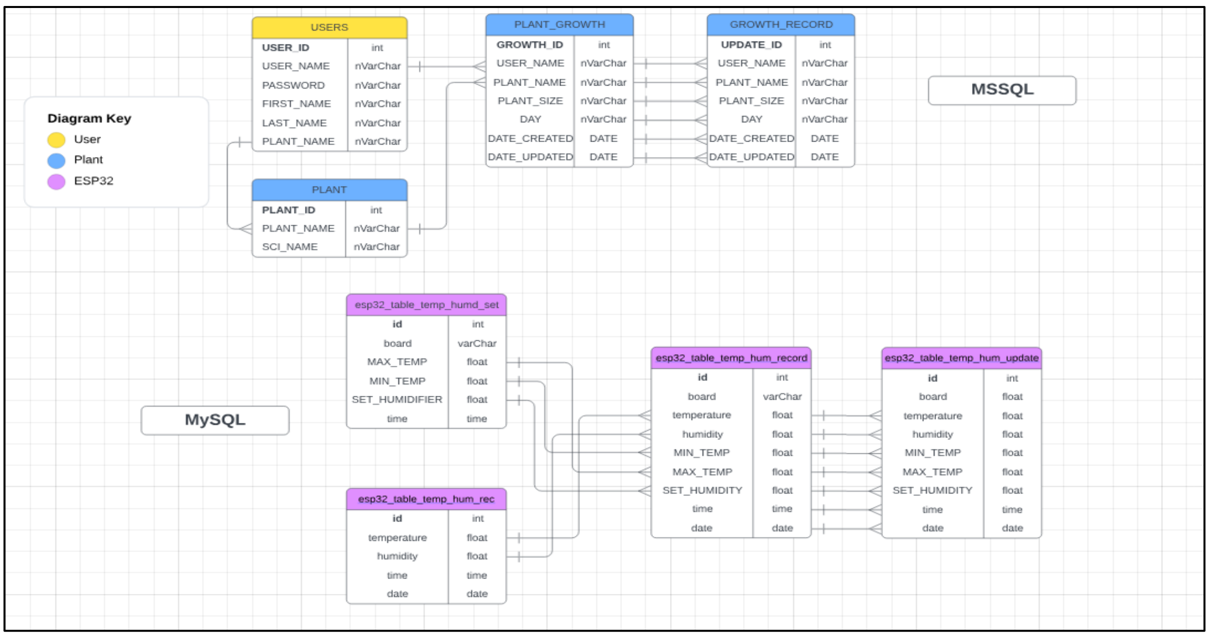
Database Design

The researchers designed SQL Server since it has a complete language for a database. It also gave the researchers different views of the structure and content of the database. This database showed the updated temperature and humidity of the plant undergoing the simulation on their plant growth.

The figures below are the entity relationship model and proposed table for plant list for the database design.

Figure 3.1

Entity Relationship Model Table



Hardware Design

Figure 4.1 is the researcher's visualization of the said system. The system has dimensions of 1ft in height, 1.5 ft in length, and 1.25 in width. It was a basket-like system which has a small humidifier on top that spread mist to moist the base of the plant. The fan opened automatically to adjust the temperature of the base of the plants. The LCD showed the current temperature and humidity of the system.

Figure 4.1

3D view

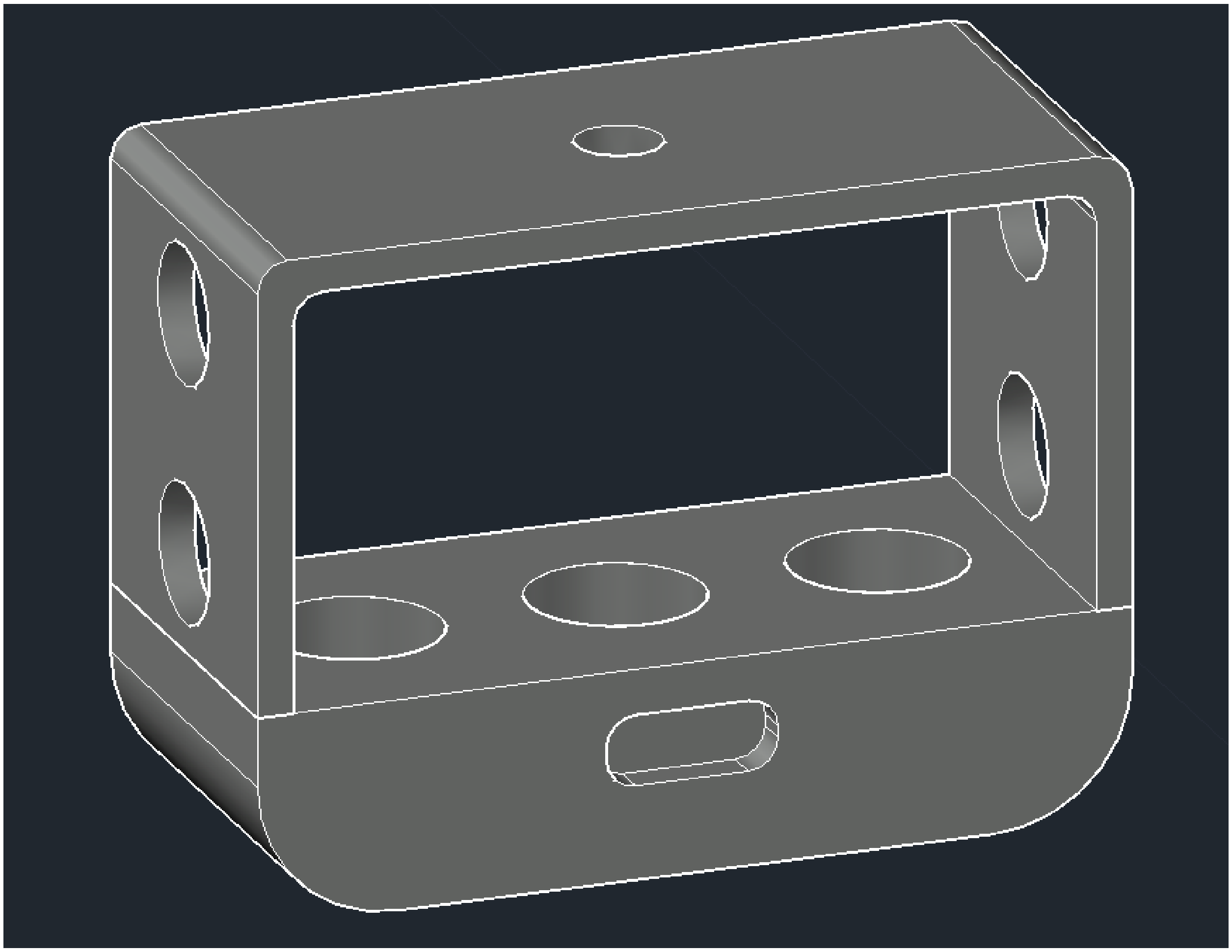
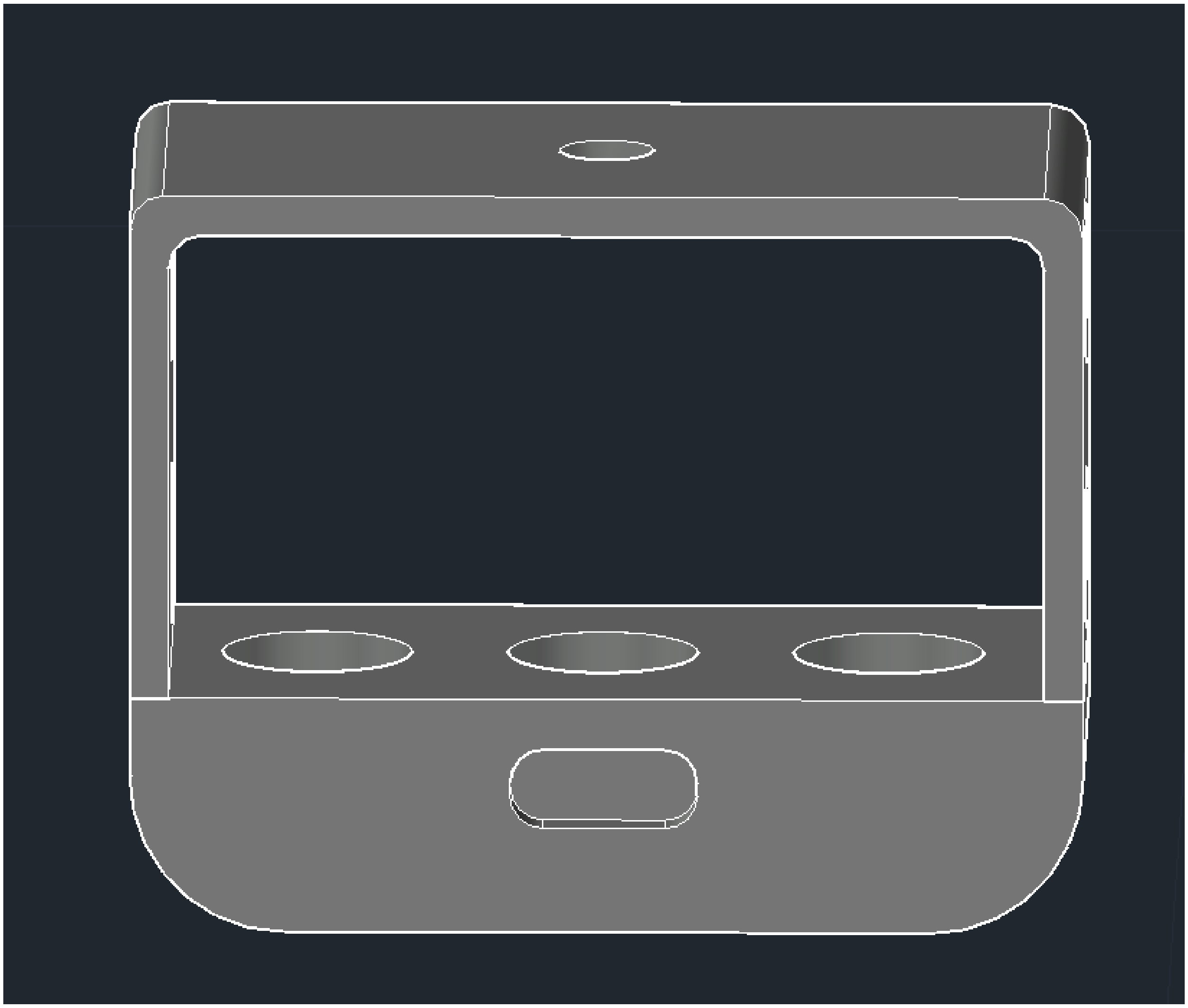


Figure 4.2

Front View



Software Design

The researchers created a website application which was the medium where the users input their selected plant processed by the simulation system. Creating an application was the simplest form for the users to navigate the use of the said system.

The figures below included the user interface that has a Home where users navigated all the functions of the system including the alerts. The users also saw what the app was about. The Plant Page enabled the users to see all the variables including temperature, humidity etc. around it.

Figure 5.1

Log-in Page

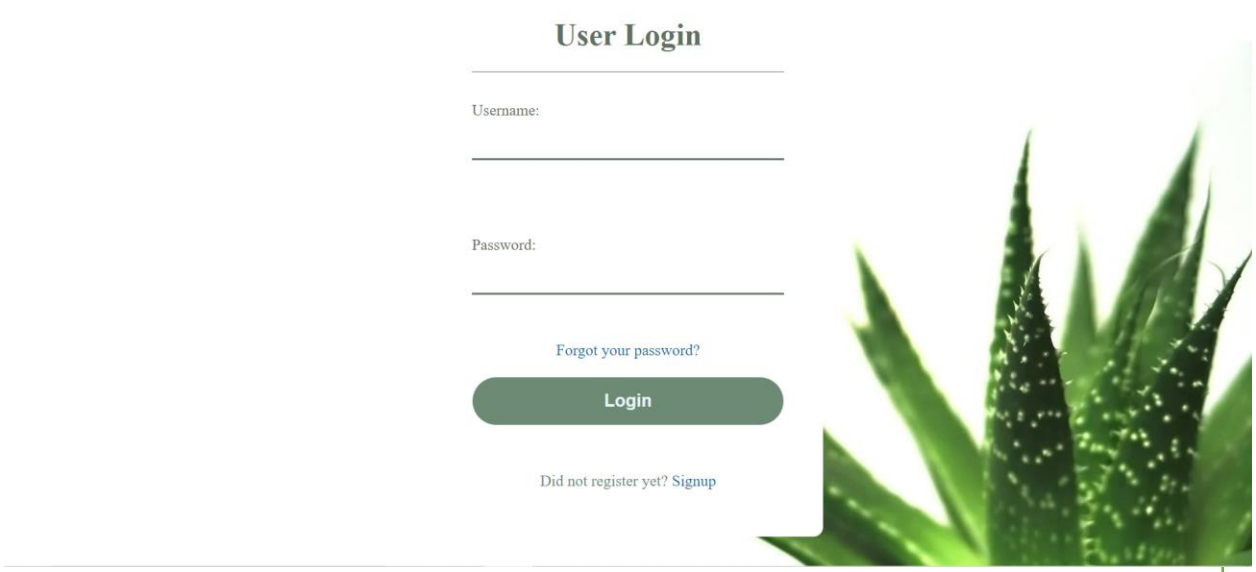


Figure 5.2

Reset Password Page

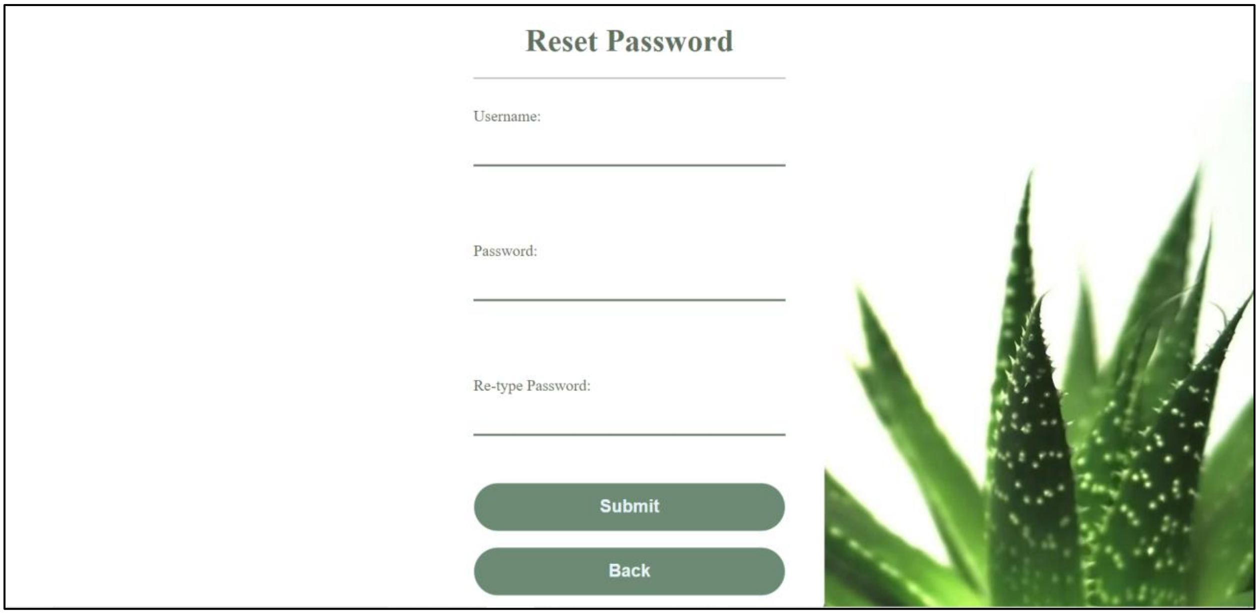
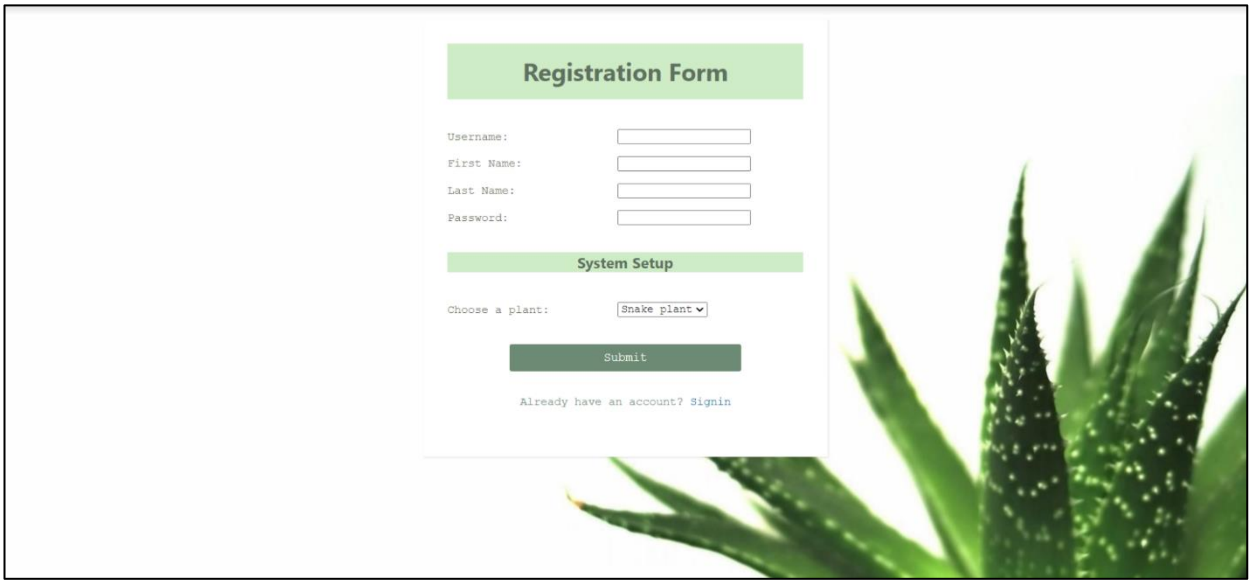


Figure 5.3

Registration Page



Figures 5.4

Home Page

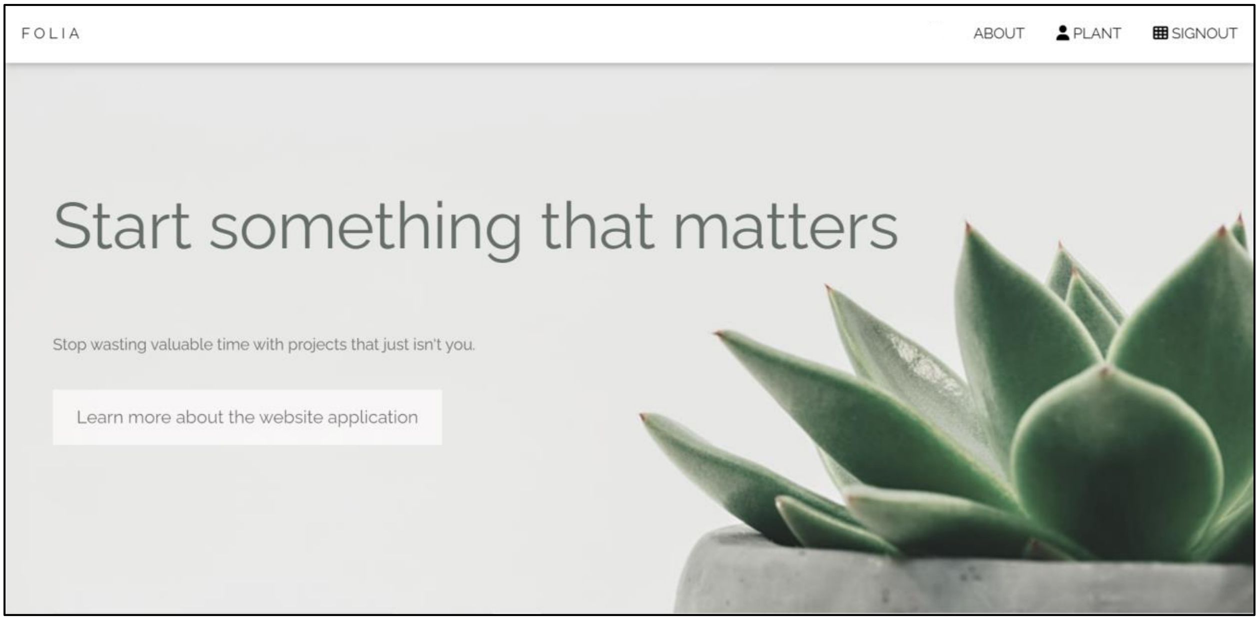


Figure 5.5

Home Page About Section

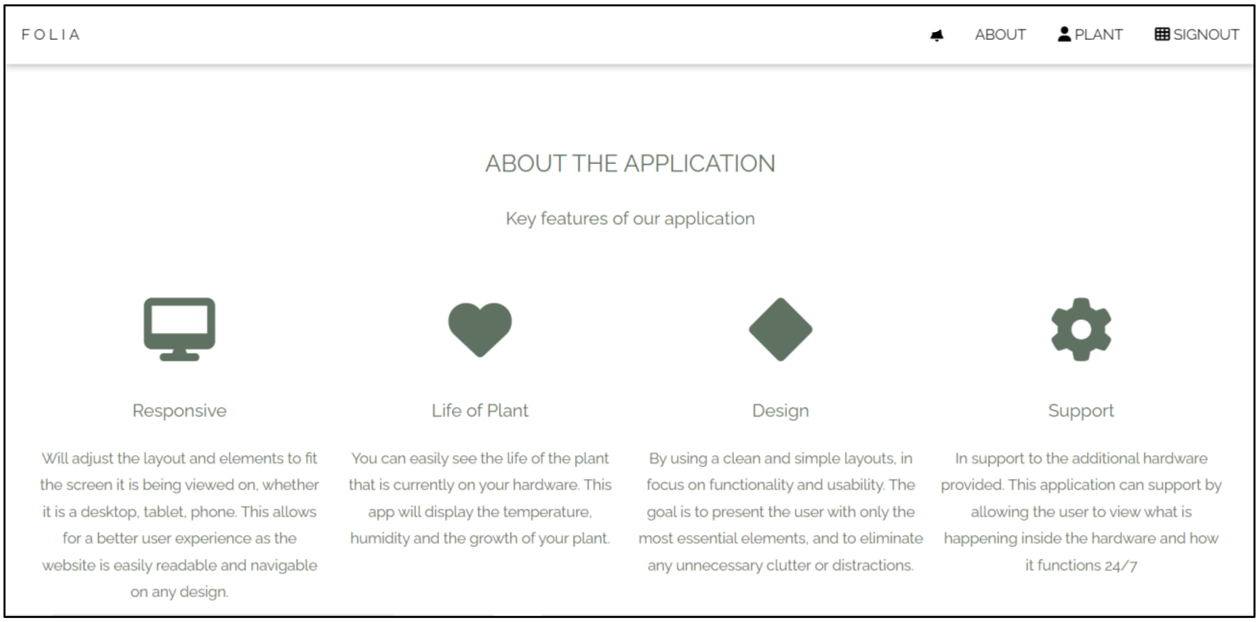


Figure 5.6

Home page Plant Section

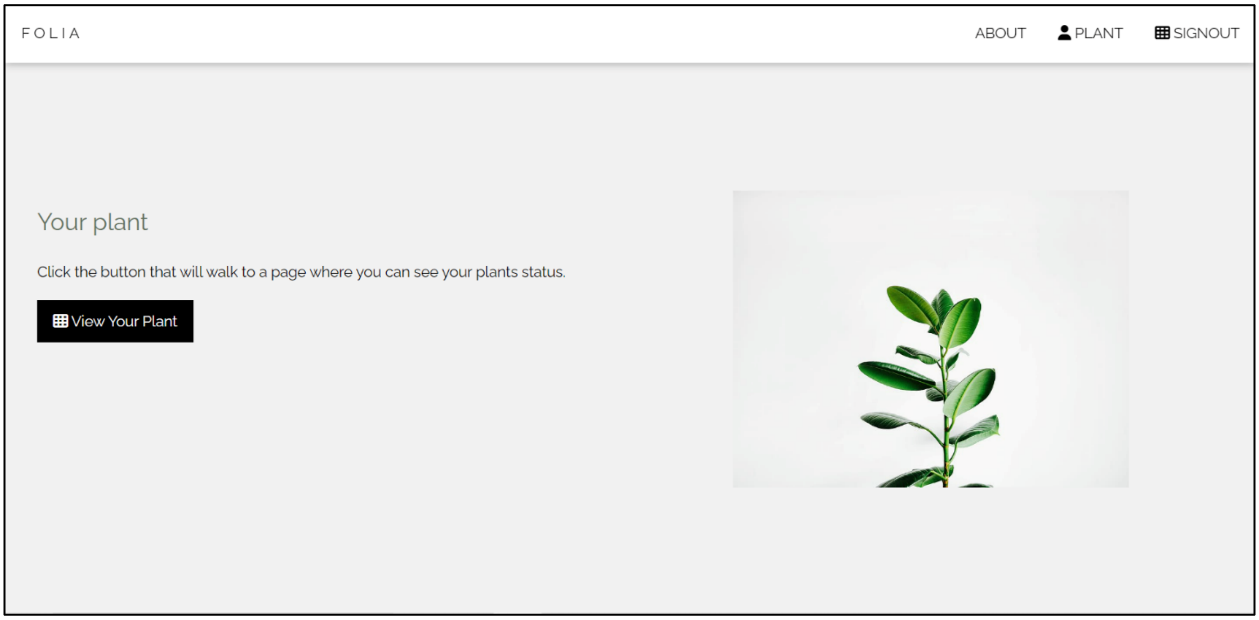
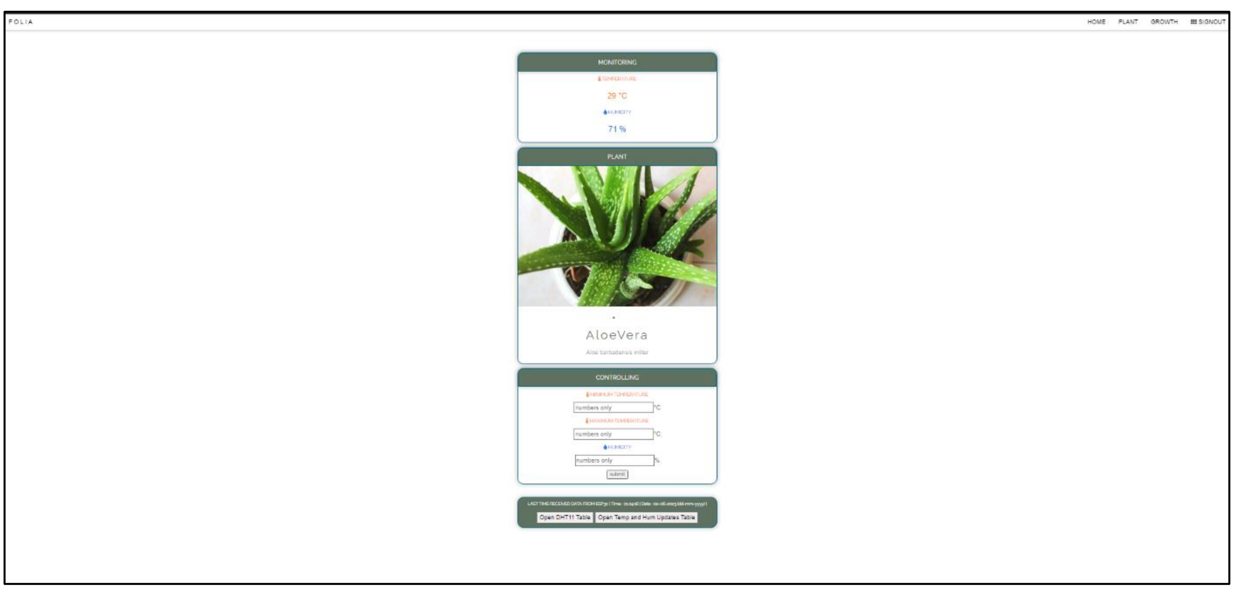


Figure 5.7

Plant Page



CHAPTER 4

RESULTS AND DISCUSSION

The Smart Controllable Plant Growth Simulation System's implementation strategy and specifics are covered in this chapter. The significance of simulating plant development, the drawbacks of traditional approaches, and the demand for a flexible and intelligent system to simulate and track plant growth are all thoroughly covered in the earlier chapters. This chapter's goal is to provide an overview of the strategies and methods used to create the Smart Controllable Plant Growth Simulation System. The researchers went into further detail about the system's architecture, the implementation process step-by-step, and the research technique. They also outlined the equipment, developments, and sources used in this study.

System Development

The system block diagram of the researcher's study, which is Smart Controllable Plant Growth Simulation System, provided an overview of the architecture and the interactions between its system components. Figure 1.1 shows the different hardware and software elements that were combined to simulate and monitor the plant growth in a controlled environment.

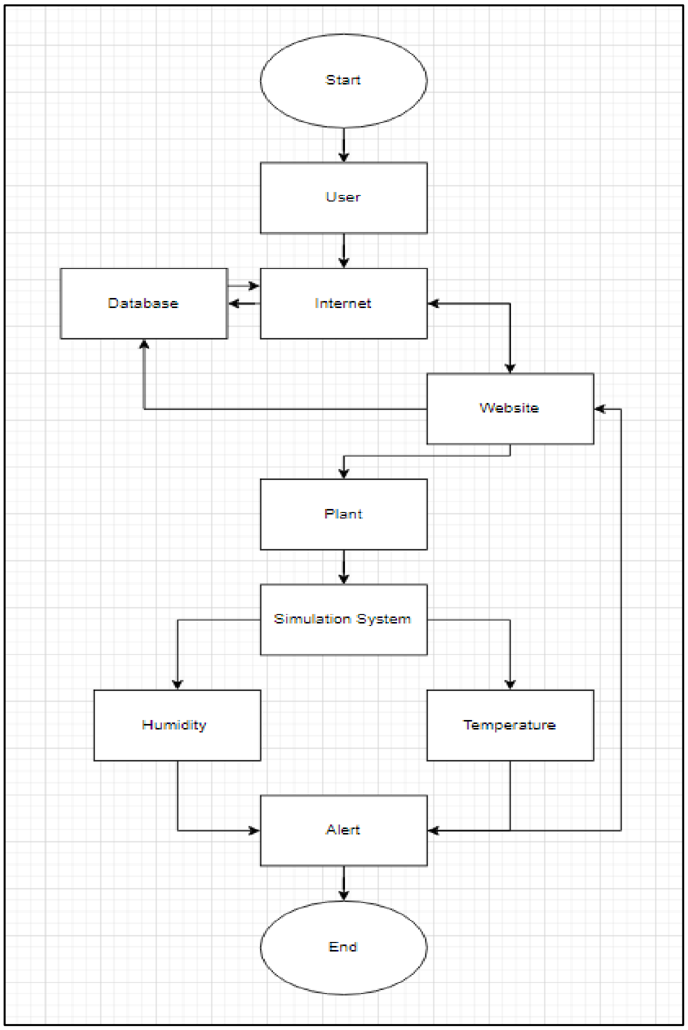
The web application (website) acted as the interface between all the users and the system. This application provided an interface that allowed users to input specifics parameters like temperature and humidity. This helped to establish the user's desired growth conditions and monitor the progress of the simulated plant.

Capturing the necessary environmental data for precise simulation, the system incorporated a sensor. These sensors continuously monitored the environmental conditions surrounding the casing of the system. The collected data were channeled into the researcher's database and displayed its data to the web application.

The figure below serves as a visual presentation of the connected components and various factors among the overall system. It also provided a comprehensive understanding of the system's architecture showing the flow of data and interactions between different components.

Figure 6.1

System Block Diagram



Software Description

The said study provided a user-friendly interface and intuitive web application as a component of its functionality. The web application acted as the primary interface for users to interact within the system. It provided access to its features and capabilities. The web application was designed with a clean and modern user interface with ease of navigation and excellent user experience. Users accessed the application within their personal PC, enabling convenient access.

Upon opening the application, users were greeted with a login page where they authenticated themselves. Once successful, users were presented with a dashboard that explained what the web application offered.

The web application also allowed users to input specific parameters and growth conditions for their simulations. Users input temperature and humidity to simulate a weather condition for growth scenarios of the plant. In addition, it supported the selection of three plant species, enabling users to study the growth of that different plant.

The application offered real-time monitoring of simulated plant growth and displayed a text visualization that showed the plants' growth and development. Key variables like growth were updated by the user. The age of the plant was automatically updated when the users updated their growth, enabling a thorough comprehension of the simulated plant progress.

A user-friendly and accessible interface for interacting with the system's features were provided by the web application built within the Smart Controllable Plant Growth Simulation System. Its user-friendly layout, real-time monitoring capabilities, customizability possibilities, and data analysis tools made it an indispensable tool for scientists and plant enthusiasts to precisely model, track, and conveniently assess plant growth.

Hardware Description

The Smart Controllable Plant Growth Simulation System's hardware setup consisted of several parts that operated simultaneously to create the ideal environment for simulating and monitoring plant growth. The system was contained in a square-shaped enclosure that covered all the hardware components as well as the plants.

The researchers used ESP32 Microcontroller as the processing unit for coordinating the different hardware components. It facilitated the sensors, and other components, enabling real-time data exchange and control.

Monitoring the environmental conditions, the system integrated the DHT11 sensor which measured the humidity and temperature inside the system. It provided accurate readings of the ambient conditions, allowing the hardware system to adjust the parameters according to the user input conditions.

The hardware incorporated mini fans and mini air conditioner to regulate the temperature within the casing of the system. The mini fans helped the air circulation while the mini air conditioner helped with the cooling inside the system. LED lights were also added into the setup to control the heat temperature. The lights emitted specific wavelengths to regulate the heat temperature within the casing.

For humidity levels, the system has a humidifier which releases moisture into the environment, maintaining a suitable humidity range for the plant and base of the user set conditions.

In addition, when specific predetermined circumstances were satisfied, a buzzer that was embedded into the hardware setup alerted the users. Users were instantly alerted of key events, thanks to the buzzer auditory alerts.

A square-shaped enclosure surrounded the complete hardware setup, protecting it from harm and providing the plants with a controlled atmosphere. To maintain the health of the plants, the casing was made to maximize space use and offered sufficient ventilation.

Prototype Design

Figure 7.1

3d View

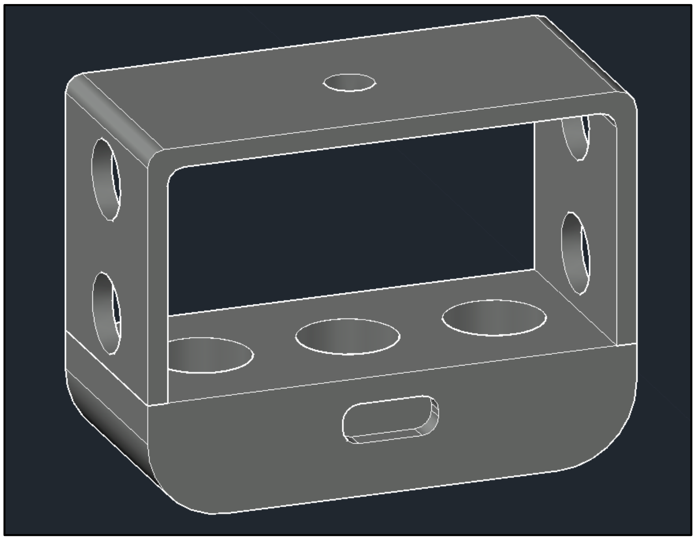


Figure 7.2

Front View

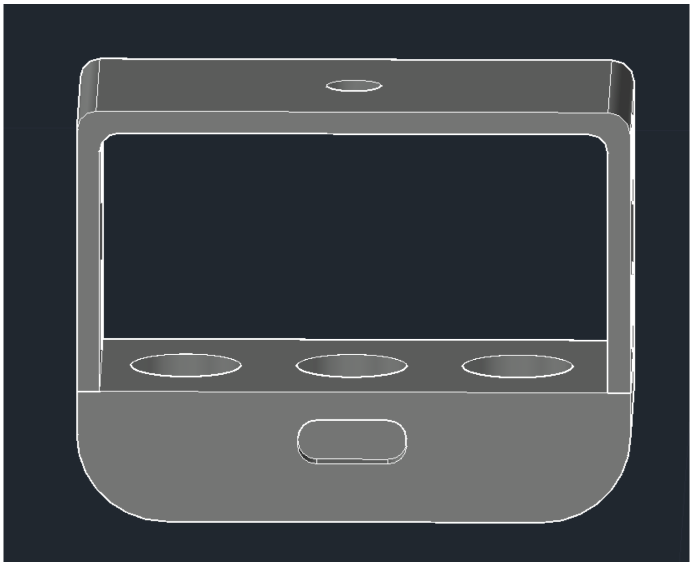


Figure 4.1 is the researcher's visualization of the said system. The system has dimensions of 1ft in height, 1.5 ft in length, and 1.25 in width. It is a basket-like system which has a small humidifier on top that spreads mist to moist the base of the plant. The fan opened automatically to adjust the temperature of the base of the plants. The LCD showed the current temperature and humidity of the system. For the water of the humidifier, the system has a container that held 650ML of water but the water was manually refilled by 24 hours.

Figure 7.3

Wiring/Circuit

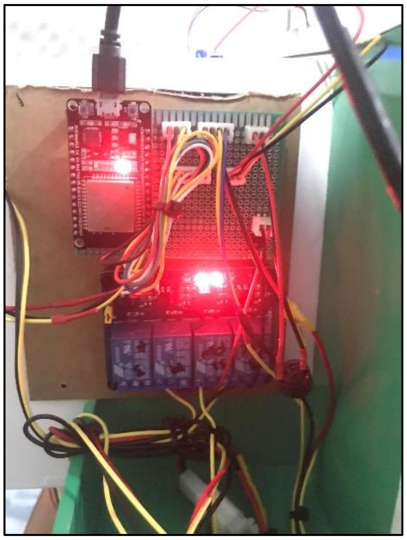


Figure 7.4

3D View Actual

Figure 7.5

Front View Actual

Figure 7.6

CAD Design for the Circuit"

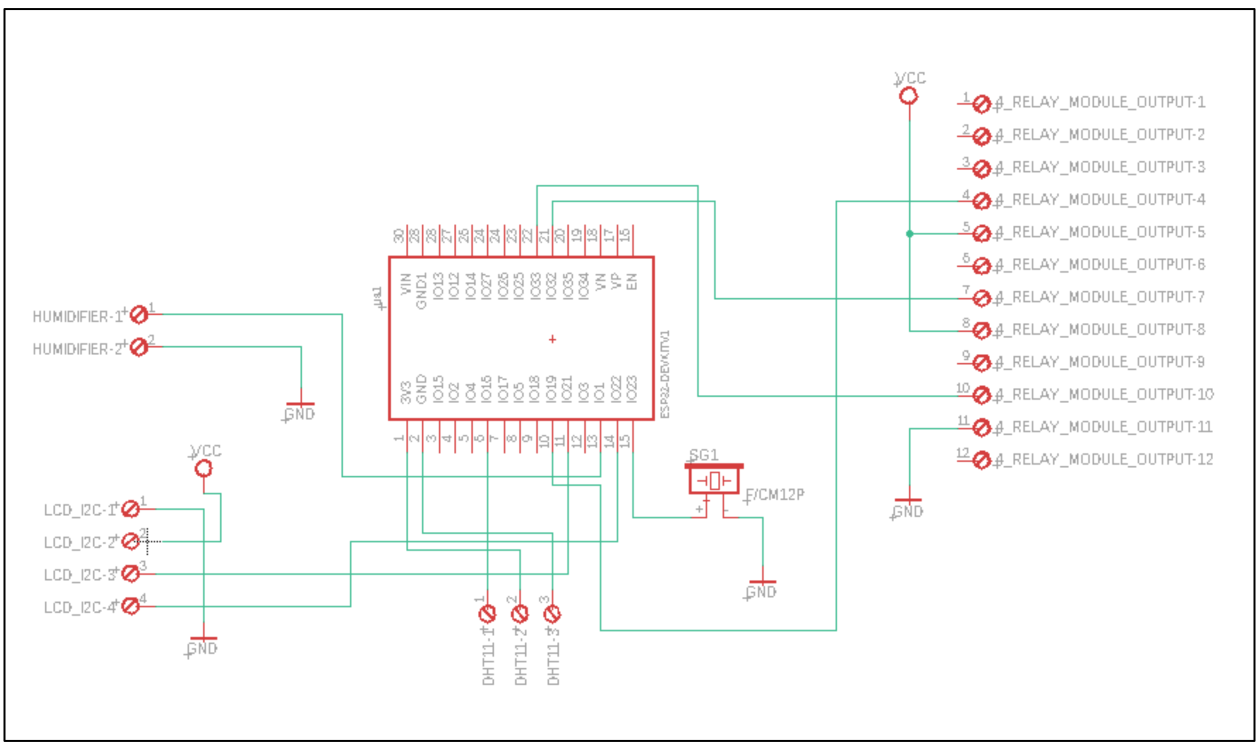


Figure 7.7

CAD Design for the Relays

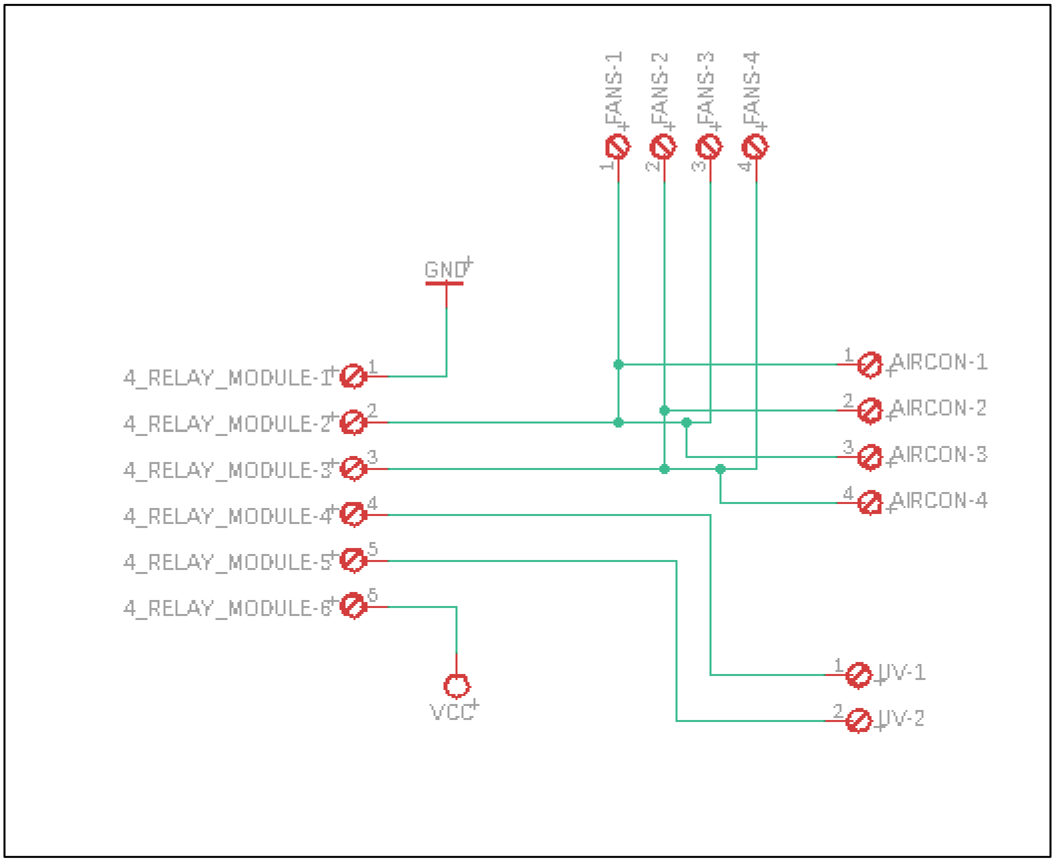


Figure 4.3, Figure 4.4, Figure 4.5 are the researcher's finished system. The wiring/circuit consisted of different components that were explained in the following section of the study. For the CAD designs, a PCB circuit layout diagram was not provided since the researchers used a universal PCB. The components that were included in Figure 4.6 were the ESP32, the buzzer, humidifier, LCD, DHT11 and the relays and other components because all of the researchers' components were connected to the microcontroller. In Figure 4.7, the connections were relayed into different components of the study system. The amount of energy to power the system was

only 5V and more than 2A. Failure to reach this condition resulted in the failure of the opening and closing of the components.

The time-to-prototype of the said study involved several steps. The design phase where the researchers analyzed the requirements, considering factors such as water efficiency etc. In addition, this stage included conceptualizing the system's architecture, creating detailed schematics, and selecting the appropriate materials and components. This took a few weeks for the researchers to finish. Once the design was finalized, it was in the construction phase where the researchers encountered several problems. Here, the researchers assembled and connected the necessary hardware, including the humidifier, fans etc. while ensuring the compatibility and reliability of different components. In addition, a software website application was also developed. The researchers conducted testing, experiments, collection of data and refined their design based on the test results. The time it took for this study was estimated to be approximately four months, including design construction and testing allowing to present a fully functional prototype that demonstrated the viability and potential of the plant growth simulation system.

For the layout of the system, it was depicted as a close system. The base or the rectangular part of the system consisted of marine wood since the built system was very thick to stop it from shattering. The specs were an ESP32 Controller (Figure 2.1), DHT11 (Figure 2.2) that measured the humidity and temperature, humidifier (Figure 2.3), which gave a specific amount of water for the plant to grow and help to control the humidity of the system. The fan (Figure 2.4) automatically turn on to adjusted the temperature around the system. The LCD (Figure 2.5) displayed the current humidity and temperature of the system. The buzzer (Figure 2.6) notified the user if the temperature inside the system was high and if the humidity inside the system was too low. The

L298n (Figure 2.7) helped the researchers to connect the fans and other components to the power supply.

Figure 8.1

ESP 32

Figure 8.2

DHT11

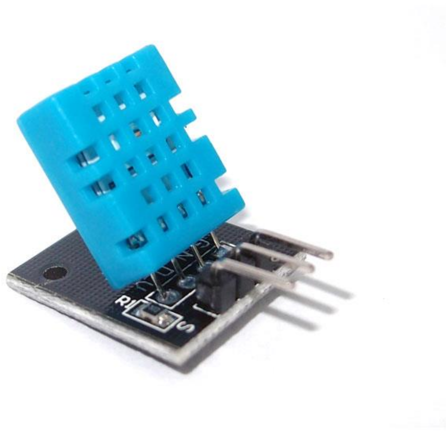


Figure 8.3

Mini Air Humidifier Mist

Figure 8.4

Mini Fan

Figure 8.5

LCD

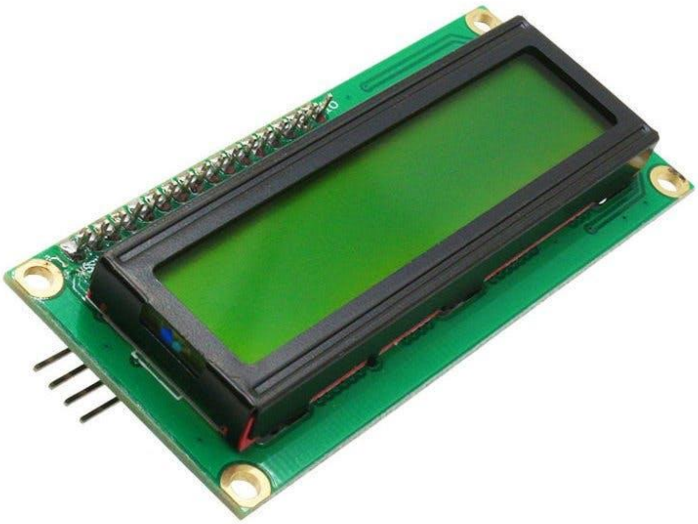


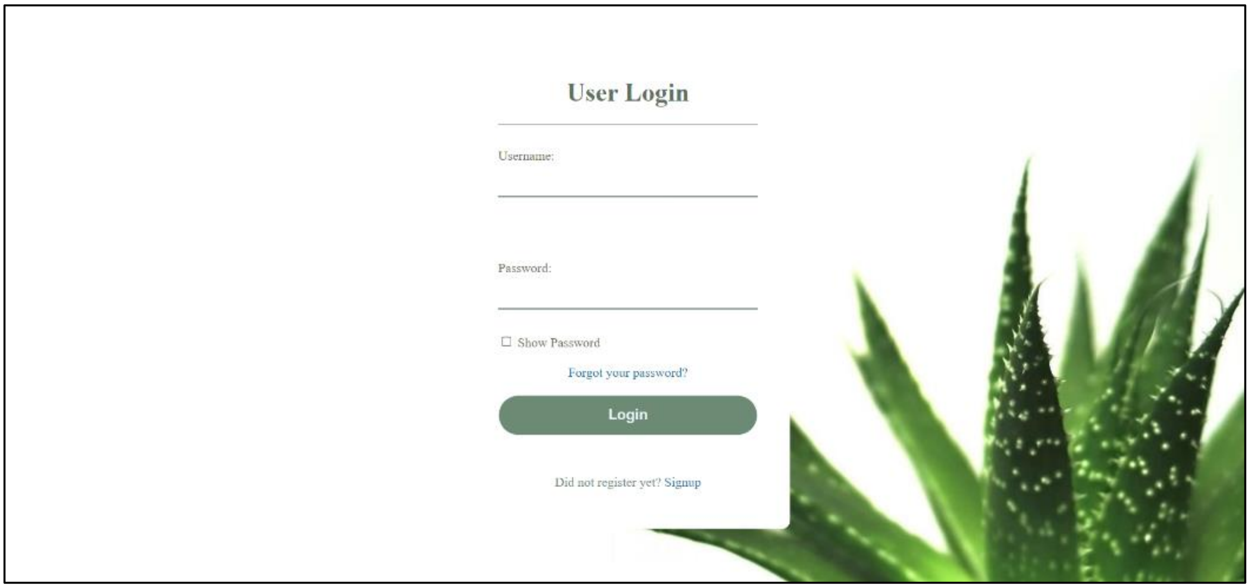
Figure 8.6

Buzzer

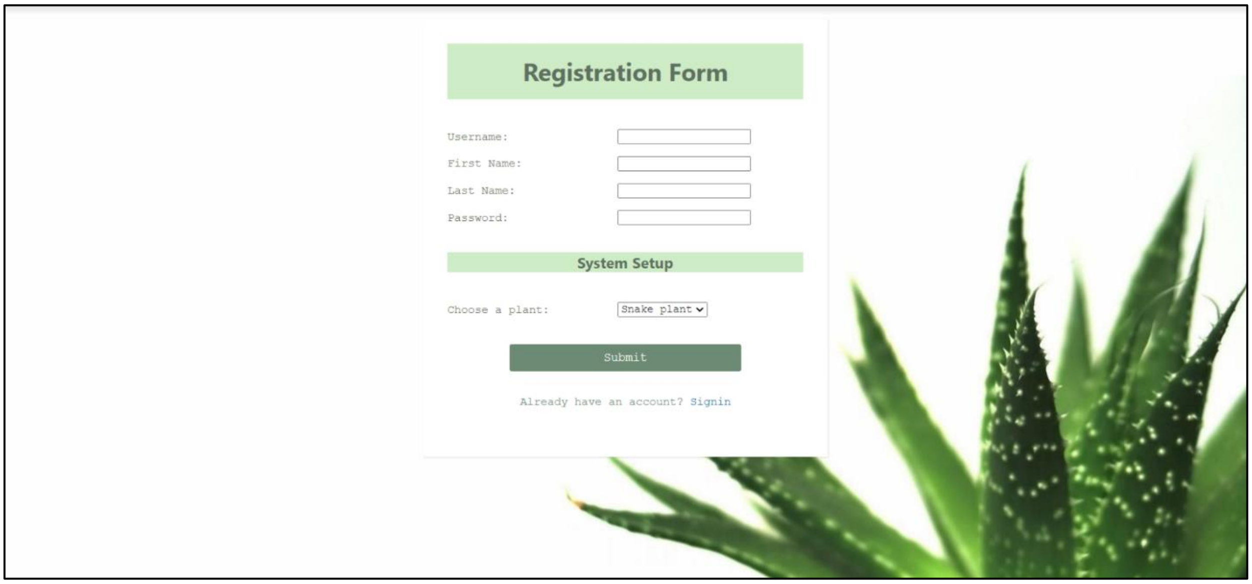
Figure 2.7

4 Channel Relay

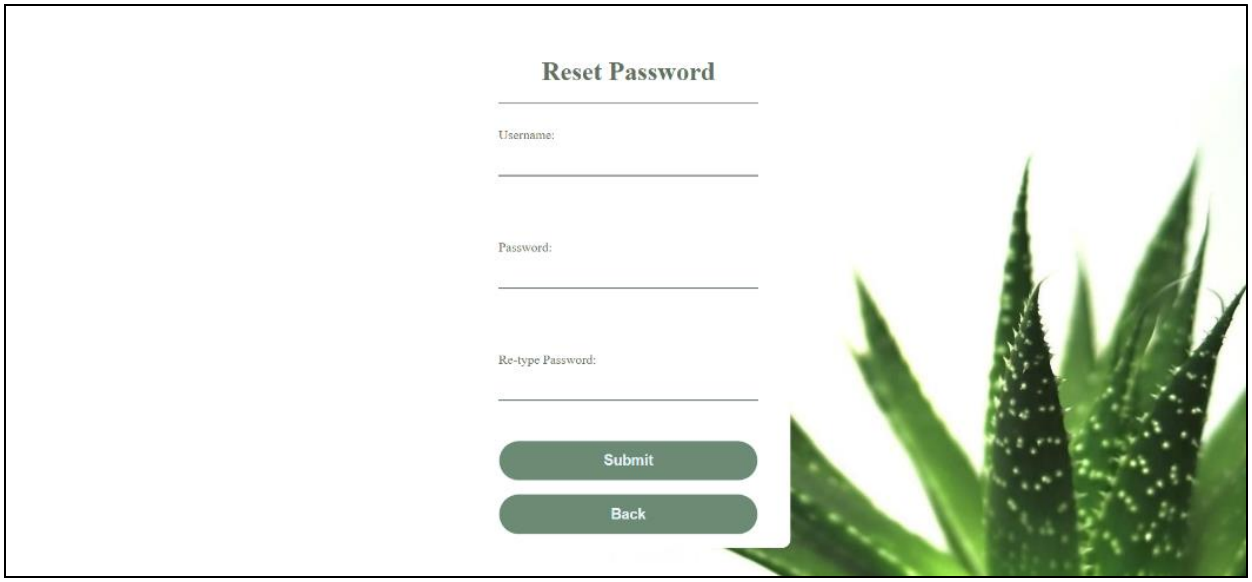
Software Development



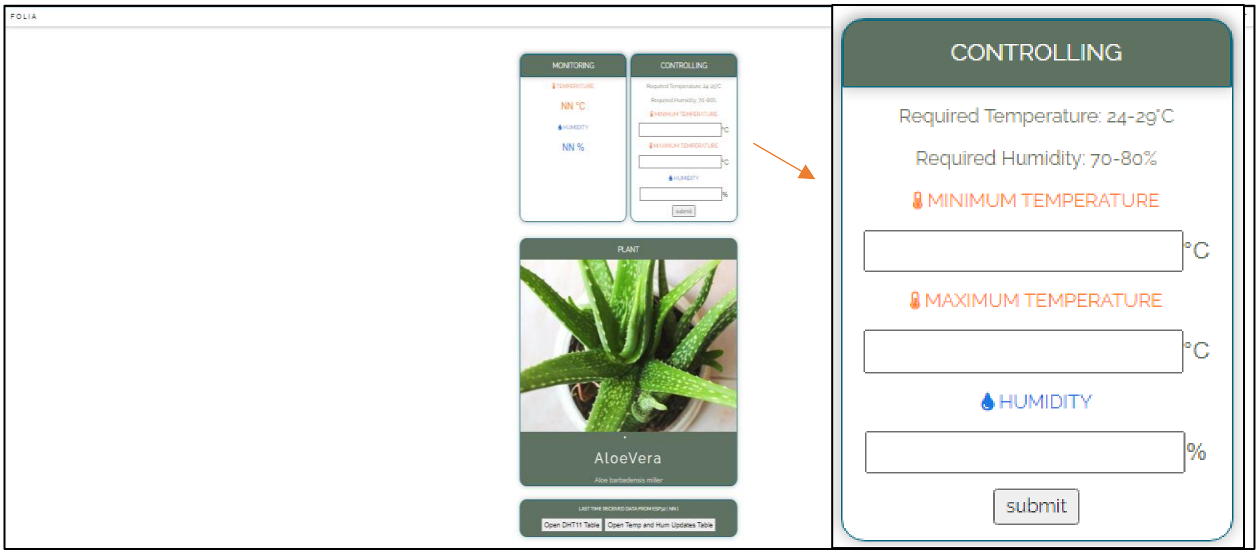
9.1 This was the beginning of the page. Users logged-in here with their registered information.



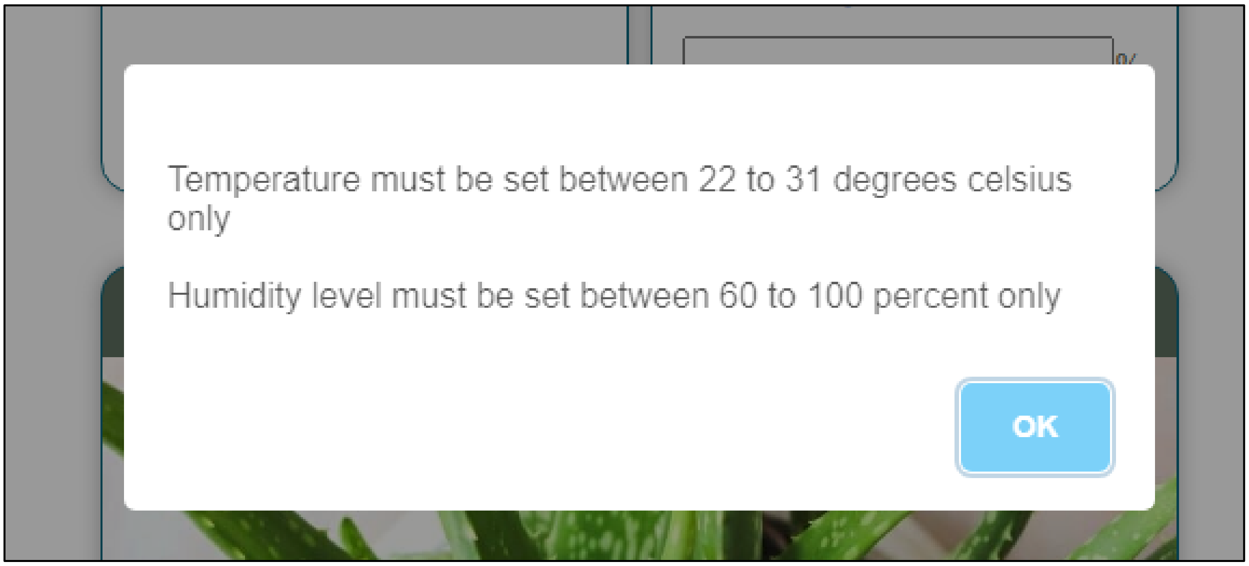
9.2 This was the registration form. This was accessed if the user clicked the Signup button on the log-in page. Users input their information in this page and the users wanted the system to do with their desired plant given by the system.



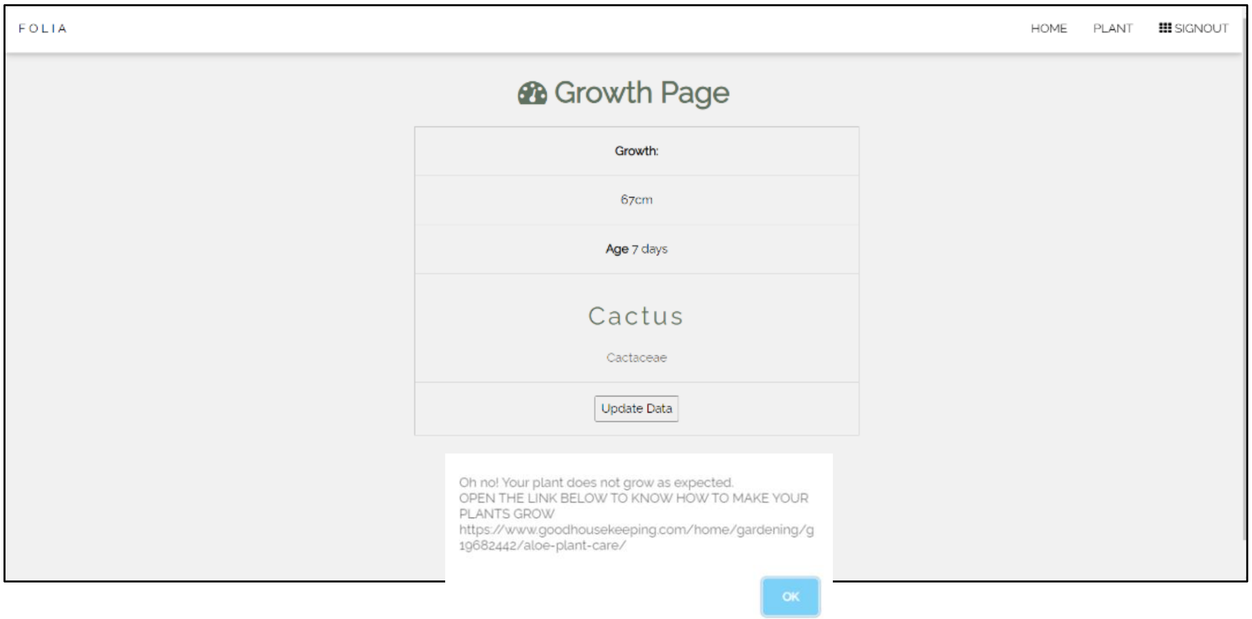
9.3 Reset Password page. This was accessed when the user clicks "Forget your password?" button. In this page users reset their password in case they did remember their previous password.



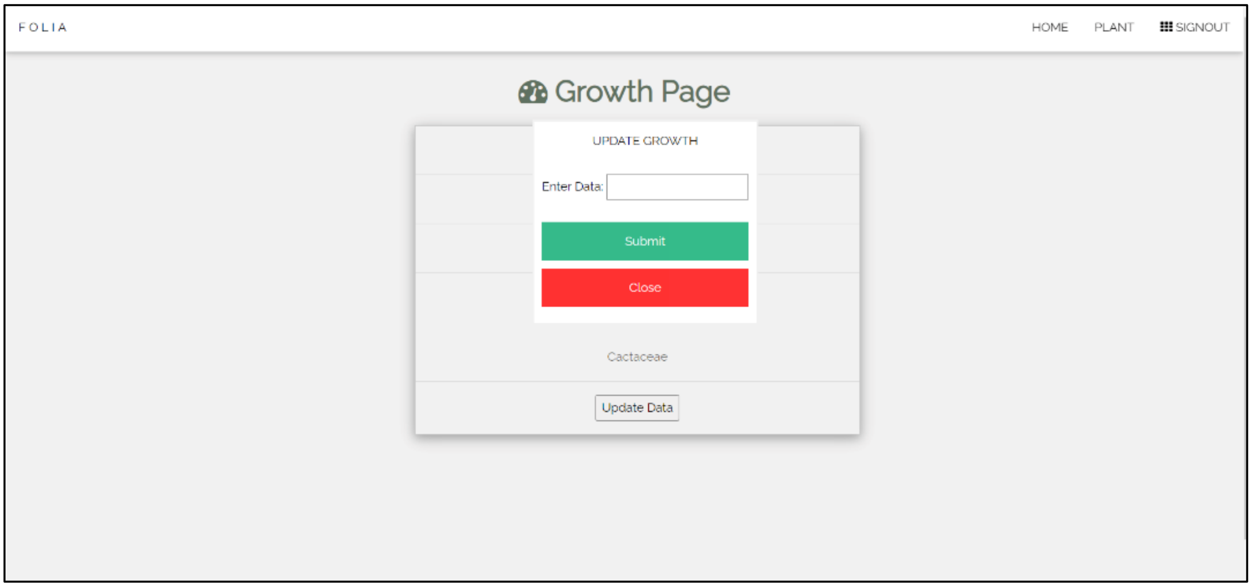
9.4 This was the plant page. Users saw their input plant on the plant page. In this section it was seen where the current temperature and humidity inside the system was sensed by the sensor used in the system which was DHT11. To add, it also included the required temperature and humidity for the plants to grow.



9.5 This was the notification when the users input more or less humidity. The value that was observed was the range temperature and humidity of the hardware and only within the value provided by the hardware.



9.6 The Growth page enabled the users to update their status of the plant but only on the length and width of the plant. There was a notification where the users knew if the growth of the plant was good or bad. If bad, then the web application suggested a link on what the users did to negate that result.

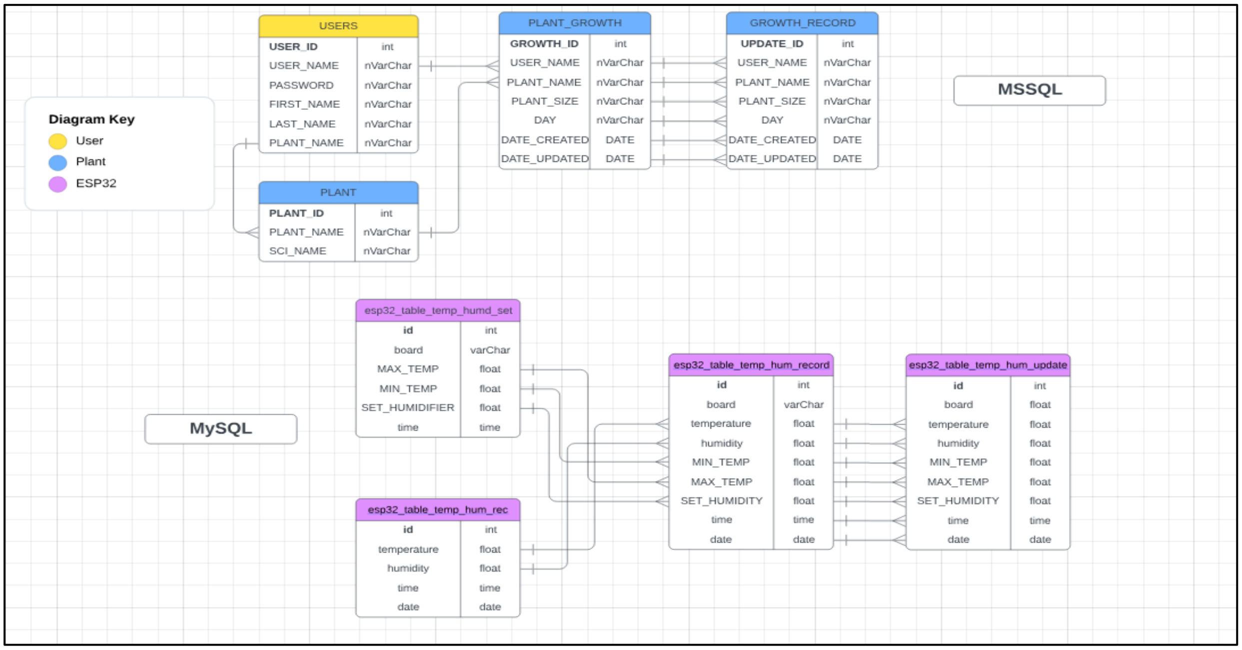


9.7 This was the form where the users input the change of their desired plant inside the system. Once it pressed submit, the growth page of their account was updated and its age also changed depending on when they updated it.

Database Design

Figure 10.1

Overall Database Design



10.1 The diagram above presents the overall design of a database for the said study (Smart Controllable Plant Growth Simulation System). This was designed to store and manage information about Users, Plant, Plant Growth, Record of Growth of Plants.

Figure 10.2

Users Table

USERS	
USER_ID	int
USER_NAME	nVarChar
PASSWORD	nVarChar
FIRST_NAME	nVarChar
LAST_NAME	nVarChar
PLANT_NAME	nVarChar

USER_ID : Unique identifier for each user (Primary Key)

USER_NAME : User’s choice of username for login.

PASSWORD : User’s choice of password (Encrypted)

FIRST_NAME : User’s first name

LAST_NAME : User’s last name

PLANT_NAME : User’s choice of plant

Figure 10.3

Plant Table

PLANT	
PLANT_ID	int
PLANT_NAME	nVarChar
SCI_NAME	nVarChar

PLANT_ID : Unique identifier for each plant (Primary Key).

PLANT_NAME : Name of the plant

SCI_NAME : Scientific name of the plant

Figure 10.4

Plant Growth Table

PLANT_GROWTH	
GROWTH_ID	int
USER_NAME	nVarChar
PLANT_NAME	nVarChar
PLANT_SIZE	nVarChar
DAY	nVarChar
DATE_CREATED	DATE
DATE_UPDATED	DATE

GROWTH_ID : Unique identifier for each growth record (Primary Key)

USER_NAME : User's username

PLANT_NAME : User's choice of plant

PLANT_SIZE : Plant growth size

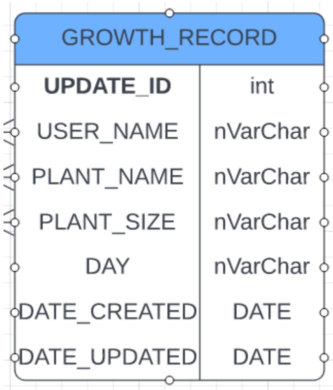
DAY : Number of days of the plant inside the system

DATE_CREATED : Date when the first plant was planted.

DATE_UPDATED : Date when the user updated its plant growth.

Figure 10.5

Growth Record Table



UPDATE_ID : Unique identifier for each growth record (Primary Key)

USER_NAME : User's username

PLANT_NAME : User's choice of plant

PLANT_SIZE : Plant growth size

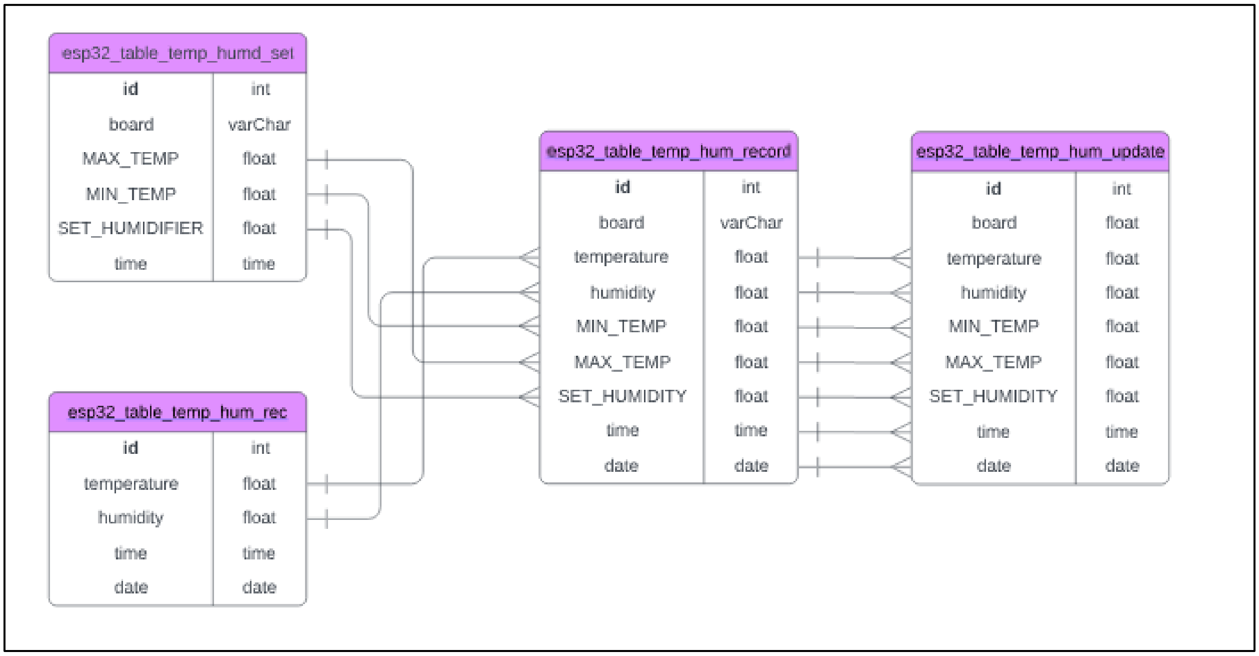
DAY : Number of days of the plant inside the system

DATE_CREATED : Date when the first plant was planted

DATE_UPDATED : Date when the user updated its plant growth

Figure 10.6

MYSQL Table



The table above shows the different kinds of database. The first ones were in MSSQL using Microsoft SQL Server while the pink/violet ones were in MYSQL using phpmyadmin. The tables inside the MYSQL also functioned similar as the ones that were inside the SQL Server. It helped the system to perform different functions and to display data for the users to see.

Data Gathering

End-Users Questionnaire Summary (Opinion and Suggestion)

The researchers asked various questions to students, IT professionals and Agriculture professionals as regards their opinion on the said study and their suggestion to the system. The following data are the summarized version of the said survey.

Respondent ID	Age	Gender	Occupation	Opinion on the Topic	Suggestion
001	22	Female	Student	Positive	Growth Record
002	23	Male	Student	Negative	Growth Management
003	20	Female	Student	Negative	Automated Watering of Plants
004	19	Female	Student	Positive	Demonstration Visuals
005	20	Male	Student	Positive	Percentage of Growth
006	21	Male	Student	Negative	Simple Interface
007	22	Male	Student	Positive	Simple Interface
008	24	Male	Student	Positive	Simple Interface
009	37	Male	IT	Negative	Detailed Analytics and Data

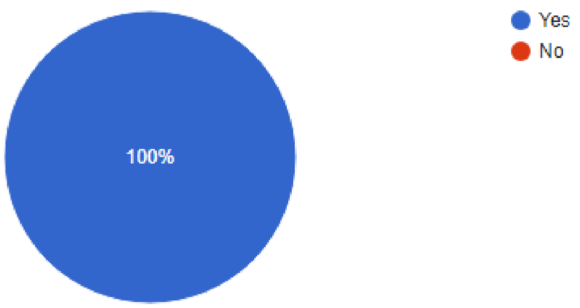
010	50	Male	Agriculture	Positive	Detailed Analytics and Data
011	36	Male	IT	Negative	Ease of Use
012	65	Female	Agriculture	Positive	Simple Interface
013	63	Female	Agriculture	Positive	Simple Interface
014	62	Male	Agriculture	Positive	Variety of Plants
015	55	Male	Engineer	Positive	Detailed Analytics and Data
016	37	Female	Engineer	Positive	Detailed Analytics and Data
017	35	Male	IT	Negative	Ease of Use
018	29	Female	Student	Positive	Detailed Analytics and Data
019	24	Male	Student	Positive	Ease of Use
020	23	Male	Student	Positive	Ease of Use

Figure 11.1

Summarize Photo

Section 2: Plant Growth and Automation

Have you ever been interested in gardening or plant cultivation? Copy



Have you ever used any automated systems for plant cultivation? Copy

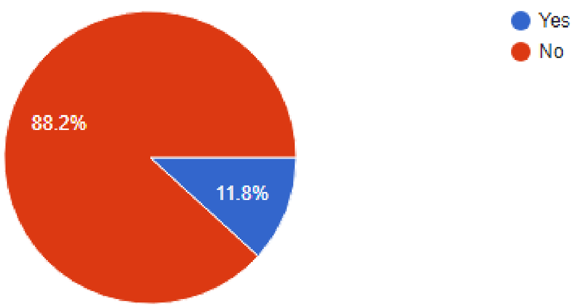


Figure 11.2

Suggestion of the Participants

What features would you like to see in a website or mobile app for managing the plant growth simulation system?

the growth every certain period of time
How to manage the growth of the plant app
I would like to see the part of the watering of the plants.
Demostration visual
No idea
An ETA for when my crops will be ready for harvest.
A percent status of the growth of plants
Presets, functions, or tutorials that will help new users to learn how to use it
Dials for different parameters

Design

The system provided an intuitive online application and user-friendly interface as part of its functionality. The main user interface for interacting with the system was the web application. It granted access to its powers and features.

The web application has a simple, contemporary user interface that was easy to use and provided a great user experience. Users conveniently used the program from their personal PC.

The software gave a text depiction of the plants' growth and development and offered real-time monitoring of computer-simulated plant growth.

Hardware setup entailed several components that worked together to produce the perfect conditions for mimicking and tracking plant growth. The hardware and plants were all covered by a square cage that housed the system.

System Testing

Test Case	Input	Expected Output	Actual Result #1	Actual Result #2	Passed/Failed
Test 1	Activate humidifier.	The humidifier ran for a few seconds.	Humidifier turned on for a few seconds.	Humidifier turned on for a few seconds.	Passed
Test 2	Input a random temperature.	The temperature was inputted, and the system adjusted to it.	Temperature added, system adjusted to it.	Temperature added, system did not adjust to it.	Failed
Test 3	Activate the aircon.	The mini-aircon ran for a few seconds.	The mini-aircon ran for a few seconds.	The mini-aircon ran for a few seconds.	Passed

Test 4	Trigger the automated light.	The LED strips inside the system was turned on.	The LED strips inside the system was turned on.	The LED strips inside the system was turned on.	Passed
Test 5	Activate all the components.	All the components inside the system ran for a few seconds.	All the components inside the system ran for a few seconds.	All the components inside the system ran for a few seconds.	Passed

Functionality Test

Test Case	**Functionality**	**Input**	**Expected Outcome**	**Actual Result #1**	**Actual Result #2**	**Passed/Failed**
Test 1	Humidifier Control	Set the humidity to 70%.	The humidity was set.	The humidity was set.	The humidity was set	Passed
Test 2	Temperature Control	Set the temperature	Temperature was set at 29 degrees.	Temperature was set at 29 degrees	Temperature was set at 29 degrees.	Passed

		at 29 degrees.				
Test 3	Plants Selection	Input a plant.	A plant was displayed on the web application.	Plant was displayed.	Plant was displayed.	Passed

Performance Test

Test Case	Performance Metric	Input	Expected Result	Actual Result
Test 1	Database Performance	Simulate a database in the web application.	The query was executed within 5 seconds.	The query was executed within 5 seconds.
Test 2	System Start-up Time	Restart the system and measure the time taken to reach full functionality.	System restarted and reached full functionality within 3 minutes.	System restarted and reached full functionality before 3 minutes.

Test 3	Data Retrieval Time	See history of data.	The user saw the history of data.	The user saw the history of data.
Test 4	Sensor Readings	Simulate a reading inside the system.	The sensor measured it accurately.	The sensor measured it accurately.
Test 5	Execution Time	Automation Task	Automation was completed in 20 seconds.	Automation was completed within 20 seconds.

Usability Test

Test Case	Usability Aspect	Task	User Feedback	Passed/Failed
Test 1	Ease of Use	Register and login in the Web Application	Users found it easy to login and register.	Passed
Test 2	Error Handling	Users observed how the	User appreciated when an error popped up.	Passed

		application handled errors.		
Test 3	System Feedback	The user needed to understand the error inside the system.	User appreciated that an error message popped up.	Passed
Test 4	Help and about	User wanted to know about the web application.	User found it and absorbed the information.	Passed

Compatibility Test

Compatibility Aspect	Environment	Input	Expected Result
Web Browsers	Chrome, Firefox, Safari	Access the website.	Website displayed correctly in all browsers.

Speed Test

Test Case	Metric	Test Conditions	Input	Expected Result
Test 1	Response Time	The system was tested under normal operating conditions, with all components and functionalities active.	User requested to retrieve the real-time sensor data for all plants in the system.	The system responded to the user request within 5 seconds.

Expert Test

Title of the Study	**Smart Controllable Plant Growth Simulation System Using Arduino**	
1.1. Did the system successfully measure and monitor humidity and temperature levels?	YES ■	NO ☐
1.2. Were the measured values accurate and reliable	YES ■	NO ☐
1.3. Did the system effectively adjust the humidity and temperature based on user preference?	YES ☐	NO ☐
1.4. Were there technical issues or limitations encountered during the testing phase?	YES ☐	NO ■
1.5. Was the overall user interface of the web application good?	YES ■	NO ☐

1.6. Was it easy to navigate through different sections and features of the application?	YES ■	NO ☐
1.7. Were the controls and options intuitive and user-friendly?	YES ■	NO ☐
1.8. Did the system provide clear and helpful instructions to guide users in adjusting parameters?	YES ☐	NO ■
1.9. Did you face any difficulties or confusions while using the web application?	YES ■	NO ☐
1.10. Were there functional limitations or errors encountered during the testing phase?	YES ■	NO ☐
1.11. Was the system be a way of improving plant growth practices?	YES ■	NO ☐
1.12 Was the overall design good for plants?	YES ■	NO ☐
1.13 Did you have any concerns or recommendations? • *Close the system. Make sure that the mist in the humidifier was circulating.* • *Add another humidifier or two.* • *The casing of the system was good, but it was too bulky. Make it light and include a plastic type of container not wood.*		

MARCELIA P. PULCAR **Signature over Printed Name of Reviewer**	June 15, 2023 **Review Date**

Accuracy Test

Test Case	Input	Expected Output	Result	Result 2	Accuracy
Test 1	Temperature	Automated temperature and manual temperature were accurate.	Minimal Error	Minimal Error	Had an accuracy error of 1.3%
Test 2	Humidity	Automated temperature and manual temperature were accurate.	Minimal Error	Minimal Error	Had an accuracy error of 1.0%

Figure 11.2

Before and After

Plant Growth Test

Test Run #1 (First Slot)

Plant Testing Parameters	**Description**	**Test Method**
Plant Species	Aloe Vera	Visual identification or documentation
Growth Environment	Prototype Automated System	Temperature: 25°C, Humidity: 70%, Light: 24 hours
Irrigation System	Humidifier	Automated Humidifier
Data Collection	Plant height	Measurements
Results	Measured via Measuring Equipment	Significant difference in plant height

Test Result

There was a significant difference in plant height of the first slot aloe vera which increased the height of the leaves of the aloe vera by 2cm in a span of 5 days.

Figure 12.1

Before and After

Test Run #1 (Second Slot)

Plant Testing Parameters	Description	Test Method
Plant Species	Aloe Vera	Visual identification or documentation
Growth Environment	Prototype Automated System	Temperature: 25°C, Humidity: 70%, Light: 24 hours
Irrigation System	Humidifier	Automated Humidifier
Data Collection	Plant height	Measurements
Results	Measured via Measuring Equipment	Significant difference in plant height

Test Result

There was a significant difference in plant height of the second slot aloe vera which increased the height of the leaves of the aloe vera by 4cm in a span of 5 days.

Figure 12.2

Before and After

Test Run #1 (Third Slot)

Plant Testing Parameters	Description	Test Method
Plant Species	Aloe Vera	Visual identification or documentation
Growth Environment	Prototype Automated System	Temperature: 26°C, Humidity: 70%, Light: 24 hours
Irrigation System	Humidifier	Automated Humidifier
Data Collection	Plant height	Measurements
Results	Measured via Measuring Equipment	Significant difference in plant height

Test Result

There was a significant difference in plant height of the third slot aloe vera which increased the height of the leaves of the aloe vera by 2cm in a span of 5 days.

Figure 12.3

Before and After

Test Run #2 (First Slot)

Plant Testing Parameters	Description	Test Method
Plant Species	Cactus	Visual identification or documentation
Growth Environment	Prototype Automated System	Temperature: 27°C, Humidity: 80%, Light: 24 hours
Irrigation System	Humidifier	Automated Humidifier
Data Collection	Plant height	Measurements
Results	Measured via Measuring Equipment	Significant difference in plant height

Test Result

A significant difference in plant height of the first slot cactus was not seen. It did not increase its height nor grew by width in a span of 5 days.

Figure 12.4

Before and After

Test Run #2 (Second Slot)

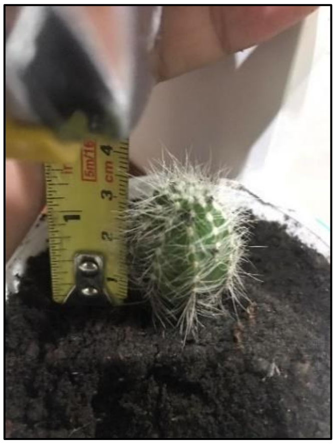
Plant Testing Parameters	Description	Test Method
Plant Species	Cactus	Visual identification or documentation
Growth Environment	Prototype Automated System	Temperature: 25°C, Humidity: 80%, Light: 24 hours
Irrigation System	Humidifier	Automated Humidifier
Data Collection	Plant height	Measurements
Results	Measured via Measuring Equipment	Significant difference in plant height

Test Result

There was a significant difference in second slot cactus which increased both its height and width by 3cm in a span of 5 days.

Figure 12.5

Before and After



Test Run #2 (Third Slot)

Plant Testing Parameters	Description	Test Method
Plant Species	Cactus	Visual identification or documentation
Growth Environment	Prototype Automated System	Temperature: 25°C, Humidity: 80%, Light: 24 hours
Irrigation System	Humidifier	Automated Humidifier
Data Collection	Plant height	Measurements
Results	Measured via Measuring Equipment	Significant difference in plant height

Test Result

A significant difference in plant height of the third slot cactus was not seen. It did not increase its height nor grew by width in a span of 5 days.

Figure 12.6

B*efore and After*

Test Run #3 (First Slot)

Plant Testing Parameters	Description	Test Method
Plant Species	Aloe Vera	Visual identification or documentation
Growth Environment	Prototype Automated System	Temperature: 25°C, Humidity: 70%, Light: 24 hours
Irrigation System	Humidifier	Automated Humidifier
Data Collection	Plant height	Measurements
Results	Measured via Measuring Equipment	Significant difference in plant height

Test Result

There was a significant difference in plant height of the first Slot aloe vera which increased the height its leaves by 2cm in a span of 5 days.

Figure 12.7

Before and After

Test Run #3 (Second Slot)

Plant Testing Parameters	Description	Test Method
Plant Species	Aloe Vera	Visual identification or documentation
Growth Environment	Prototype Automated System	Temperature: 25°C, Humidity: 70%, Light: 24 hours
Irrigation System	Humidifier	Automated Humidifier
Data Collection	Plant height	Measurements
Results	Measured via Measuring Equipment	Significant difference in plant height

Test Result

There was a significant difference in plant height of the second slot aloe vera which increased the height of the leaves by 3.5cm in a span of 5 days.

Figure 12.8

Before and After

Test Run #3 (Third Slot)

Plant Testing Parameters	Description	Test Method
Plant Species	Aloe Vera	Visual identification or documentation
Growth Environment	Prototype Automated System	Temperature: 26°C, Humidity: 70%, Light: 24 hours
Irrigation System	Humidifier	Automated Humidifier
Data Collection	Plant height	Measurements
Results	Measured via Measuring Equipment	Significant difference in plant height

Test Result

There was a significant difference in plant height of the third slot aloe vera which increased the height of its leaves by 3cm in a span of 5 days.

Figure 12.9

Before and After

Test Run #4 (First Slot)

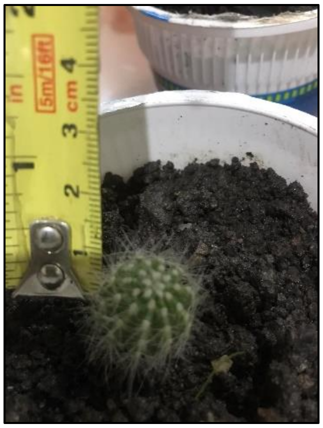
Plant Testing Parameters	Description	Test Method
Plant Species	Cactus	Visual identification or documentation
Growth Environment	Prototype Automated System	Temperature: 27°C, Humidity: 80%, Light: 24 hours
Irrigation System	Humidifier	Automated Humidifier
Data Collection	Plant height	Measurements
Results	Measured via Measuring Equipment	Significant difference in plant height

Test Result

A significant difference in plant height of the first slot cactus was observed. It increased its height by 2cm in a span of 5 days.

Figure 12.10

Before and After



Test Run #4 (Second Slot)

Plant Testing Parameters	Description	Test Method
Plant Species	Cactus	Visual identification or documentation
Growth Environment	Prototype Automated System	Temperature: 25°C, Humidity: 80%, Light: 24 hours
Irrigation System	Humidifier	Automated Humidifier
Data Collection	Plant height	Measurements
Results	Measured via Measuring Equipment	Significant difference in plant height

Test Result

There was a significant difference in plant height and width of the Second Slot Cactus wherein it increases the height and width of it by 2cm in the span of 5 days.

Figure 12.11

Before and After

Test Run #4 (Third Slot)

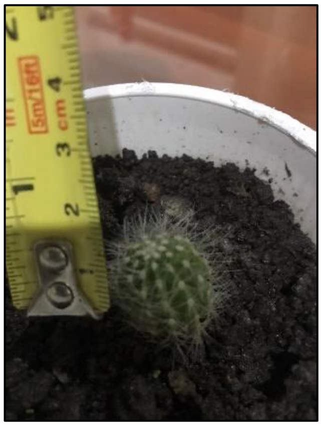
Plant Testing Parameters	Description	Test Method
Plant Species	Cactus	Visual identification or documentation
Growth Environment	Prototype Automated System	Temperature: 25°C, Humidity: 80%, Light: 24 hours
Irrigation System	Humidifier	Automated Humidifier
Data Collection	Plant height	Measurements
Results	Measured via Measuring Equipment	Significant difference in plant height

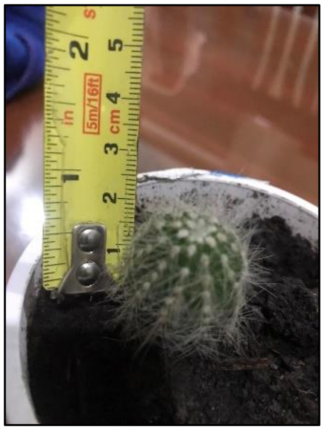
Test Result

A significant difference in plant height of the third slot cactus was observed. It increased its height by 1cm in a span of 5 days.

Figure 12.12

Before and After

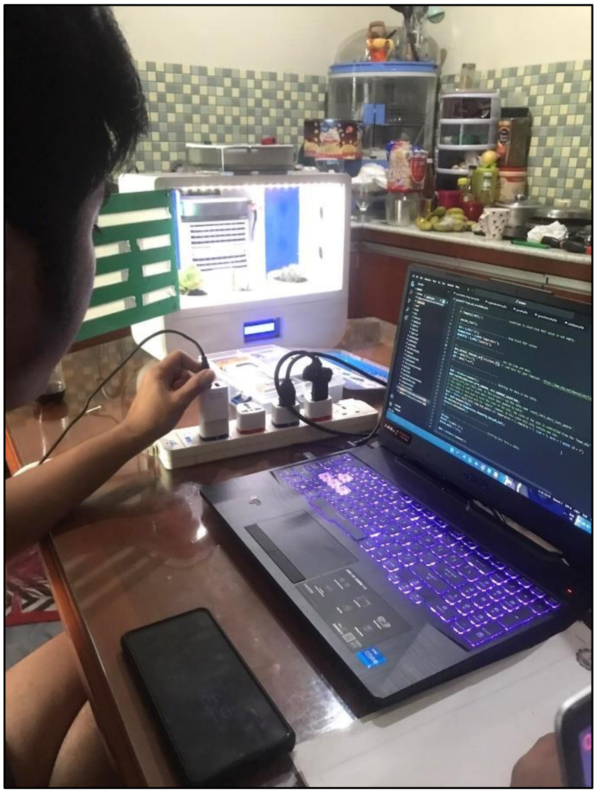




Documentation and Pictures

Figures 12.13

System Testing Part 1



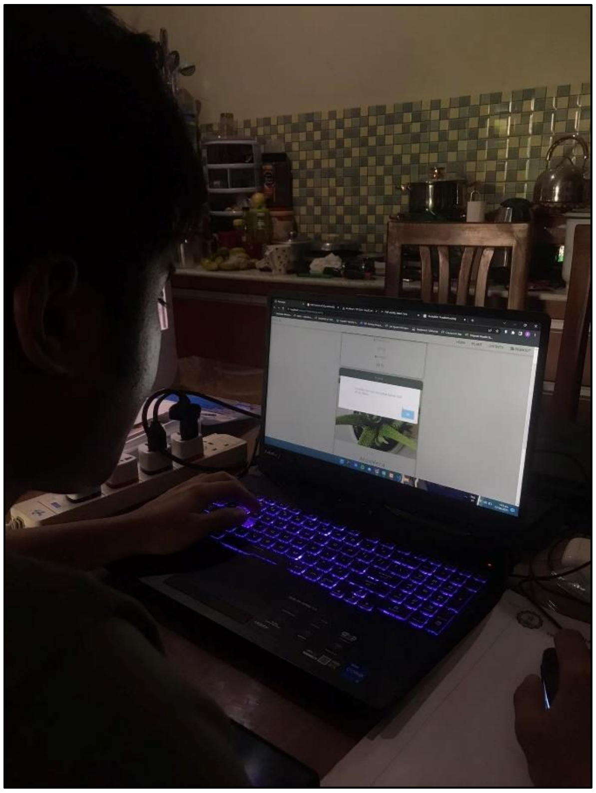
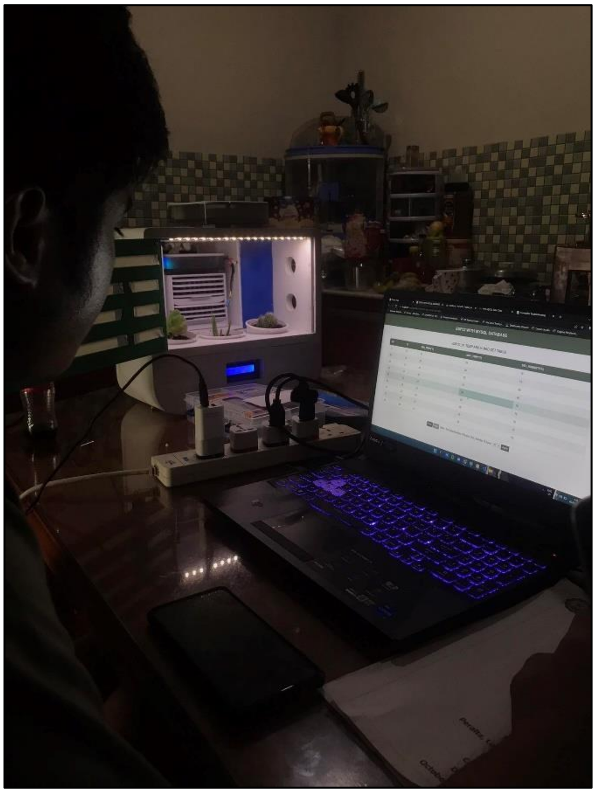


Figure 12.13 shows that the researchers were seen conducting a system test for the innovative prototype as part of their study. The system test included all the system testing like functionality test, speed test, etc.

Figure 12.14

System Testing Part 2



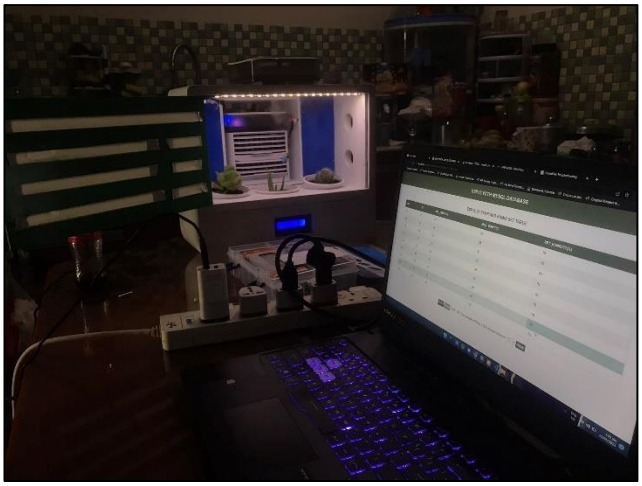


Figure 12.14 explains that the researchers were seen conducting a system test for the innovative prototype as part of their study. Another test was conducted to find out if the system was working all the time and had minimal errors only. The system test included all the system testing like functionality test, speed test, etc.

Figure 12.15

System Testing Part 2

Figure 12.15 shows the image of the two test runs on the growth of the plants inside the system. It consisted of three of the same plants each run, and a different kind of plant in the next run. The tabulated data were shown in the tables above (Plant Growth Test). The researchers only conducted two test runs because each run was 1 week (5-7 days).

Comparative Analysis Between manual and Automated

Aspects	Automated Plant Growth System	Manual Plant Growth System
Control and Precision	A precise regulation of environmental variables like temperature, humidity, and light output was observed.	Control over environmental factors was not precise since it was uncontrollable.
Efficiency	Automated procedures increased efficiency by requiring less work and using resources more effectively.	Manual operations used more time and effort, which resulted in decreased efficiency.
Consistency	It kept the environment constant and gave all the plants in the system the same treatment.	It led to errors, resulting in differences on how plants were cared for.
Maintenance	Sensors, equipment, and software changes needed to be updated on a regular basis for automated systems.	Care for plants, equipment, and the growth environment required manual maintenance.
Skill Requirements	It required technical expertise for automated component setup, programming, and troubleshooting.	It relied on manual dexterity, observational abilities, and knowledge of plant care.

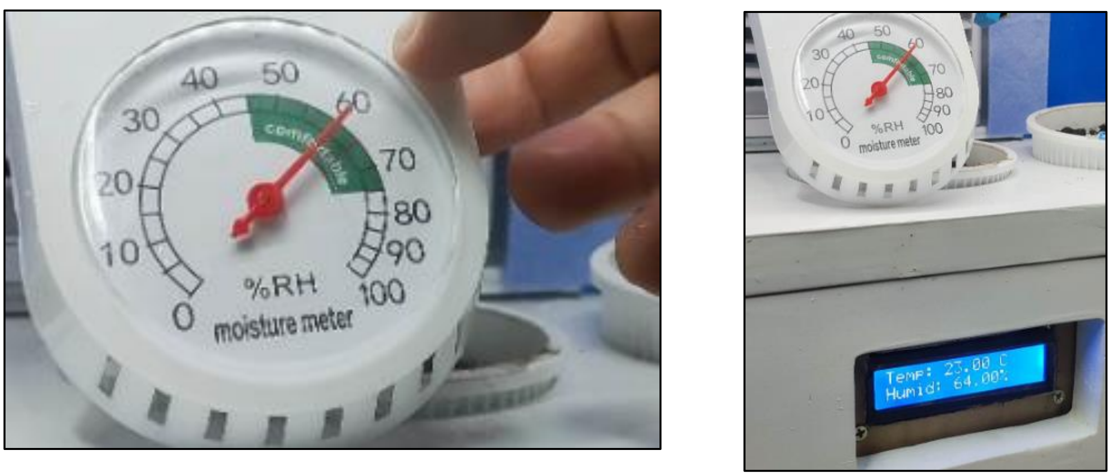
The Automated Plant Growth System demonstrated precise control and precision by maintaining temperature within user wants and humidity within user wants. In contrast, the Manual Plant Growth System experienced uncontrolled temperature variations, so temperature was conducted to have increased within 2°C, fluctuations in humidity within 10%, and inconsistent light output. The Automated system proved to be more efficient, resulting in a reduction in labor hours. This was proven by the researchers because the automated system did not need to observe from time to time. On the other hand, the Manual system required 15% more labor hours and a 10% increase in resource usage, leading to decreased efficiency. In terms of consistency, the Automated system ensured that all plants received identical treatment in terms of temperature, humidity, and light exposure. In contrast, the Manual system experienced slight variations in plant care due to temperature, humidity, and light exposure differences. Maintenance requirements differed as well. The Automated system necessitated quarterly updates and software upgrades for sensors and equipment. In comparison, the Manual system relied on regular manual maintenance tasks such as weekly watering, pruning, and pest control. Skill requirements also varied with the Automated system demanding technical expertise for initial setup, programming, and troubleshooting, while the Manual system relied on manual dexterity and plant care knowledge for tasks such as watering, pruning, and pest control. To add, the figures below show the similarities of temperature and humidity in manual and automated to verify that the temperature and humidity that were validated had minimal errors.

Figure 12.11

Comparison of Temperature

Figure 12.12

Comparison of Humidity



Cost Analysis

All financial implications in implementing the proposed solution were considered. This analysis included both the initial setup cost and the ongoing operational expenses.

1. **Initial Setup Costs**

The initial setup costs encompassed all expenditures required to establish the system and infrastructure. The following cost elements were considered:

Hardware Costs:

- Automated Plant Growth System (Casing) :P7,000
- Sensors and Control Devices, Components :P3,500

2. **Ongoing Operational Expenses**

Ongoing operational expenses included regular costs incurred during the operation and maintenance of the system. The following cost elements were considered and estimated monthly:

- Energy Consumption : P600
- Water Usage : P100

System Quality Matrices

Database

Performance Topic	Indicator	Implementation of Performance Measurement
Latency	How fast a single transaction was processed	The average time of query to request, plus feedback buttons was implemented.
Scalability	How the system handled an increasing number of users	Increase specs of the system.
Availability	The percentage of time that the system was available to use	System availability was 24/7 or nonstop until satisfaction of the user.
Security	The ability of the system to protect against unauthorized access or data breachers	Restriction data on the database was encrypted.
Backup and recovery	How the system quickly recovered from a failure	Product perception and code review timing were observed.

Web Application

Performance Topic	Indicator	Implementation of Performance Measurement
Load time	How fast it took the page to fully load and ready to use	There was an average time of query to request.
Response Time	How fast it took the server to respond	There was an average time of query to request.
User experience	How fast a user found the desired information	Feedback buttons, ease of navigation were observed.
Availability	The percentage of time that the system was available to use	The system was available 24/7 or nonstop until the user was satisfied.
Error Rate	The number of requests which were considered an error?	Code review, product perception, validation of data were observed.

Hardware System

Performance Topic	Indicator	Implementation of Performance Measurement
Power Consumption	How energy the system consumed	Power meters and software tools were seen.
Reliability	The probability that the system did not fail overtime	There were failure rate testing and monitoring.
Latency	How fast and numerous the task completed by the system	There were timing, benchmarking, and monitoring.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

The recommendations made by the researchers after analyzing the study on the "Smart Controllable Plant Growth Simulation System" are presented in this chapter. The development of the whole system was covered in earlier chapters, along with its capabilities for simulating and manipulating plant growth conditions. The main goal of this project was to create a system that regulates temperature and humidity based on user preferences to replicate and control environmental factors that affect plant growth. After gathering the data and analyzing the findings, several recommendations have been drawn from the study. These suggestions are meant to improve the smart controllable plant growth simulation system's usability, functionality, and other aspects for development in the fields of engineering and agriculture.

Conclusions

This study focused on the development of Smart Controllable Plant Growth Simulation System. The objective was to create a system that is automated and sets the temperature and humidity based on what the users wanted. The setting temperature and humidity based on the users were successful and maintained their value unless changed. Another objective explained that a program sends a notification if the humidity and temperature was too high or too low. Validation of this was also successful. In addition, other validations were integrated inside the web application for the users not to be confused on what the system was doing or not. Another objective was to develop a website application that allowed the users to select any given plant and help to monitor if that plant inside the system was growing or not. Developing a website application where the users select any given plant was successful. In addition, there was a page where they monitored and changed the temperature and humidity inside the system that was affecting their selected plants. To monitor and gather data of the width and length of the plant in plant growth simulation system by a ruler to differentiate the growth of the plant was its last objective. This was also successful wherein users have a page for them to update their monitored data of the growth of the plant. Not only that, users can also see its history and can differentiate and see the growth of their selected plant.

Throughout this study, various experiments were conducted to gather data for the performance of the simulation system. It successfully created a controlled environment for the plant to grow. It also allowed precise manipulation of key variables like temperature and humidity by integrating a sensor and control algorithms. The findings of this study served as a valuable tool for researchers in the field of engineering, biology, and agriculture. Thus, it allowed them to have a controlled environment which they can experiment the growth of the plant.

Secondly, this simulation system has the potential to upgrade farming practices by providing farmers a platform or system to simulate and optimize the plant growth of their crops. This led to increased crop yields etc. The system's ability to monitor and adjust variables in real-time allowed for precise control over their plant growth.

Despite the achievements of this study, there were still areas that required further exploration and improvement. The integration of additional sensors to capture a wider range of environmental parameters etc. were recommended for future research and improvement to the development of the system and study.

In conclusion, the system of this study demonstrated a potential in advanced agricultural practices. It has been hoped that the findings and recommendations of this study can inspire further research and development.

Recommendations

The data analyzed in this study and its findings have provided valuable ideas or insights and recommendations for future research for improvement of the overall system. Based on the analysis, the following recommendations are presented:

1. Sensor Integration Enhancement

Additional sensors may capture a wide range of parameters. Doing this the system may provide more accurate data for plant growth simulation.

2. Extending Plant Species and their Growth Conditions

The current study only focused on 3 species of plants. It may be recommended that future researchers may include a range of plant species and growth conditions.

3. Decrease in Temperature

For the decrease in temperature, it may be recommended that the temperature be lowered more for the cold plants to manage their desired environmental conditions.

4. More Slots

It may be recommended that more slot inside the system may be considered. In this way, it can manage more tests in one run for plant growth for more data gathering.

5. Need More Irrigation

It may be recommended that more irrigations may be needed so that every plant slot has its own humidifier mist so the soil moistures for the plant to grow.

6. Incubator Lights

For a stable fast heating inside the system, incubator lights may be recommended.

7. PID Control

To regulate the temperature and other parameters inside the system PID control may be recommended.

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Appendix

Appendix A: Source Code

Each of the following sub-appendices contains the sample of important source code used for the development of the study.

A-1 Database Sample Codes

```
if(isset($_POST['submit4'])){

if($ErrMsg1==""&& $ErrMsg2==""&& $ErrMsg3==""

){ $serverName="LAPTOP-KMPHCVG3\SQLEXPRESS"; $connectionOptions=[

"Database"=>"DLSU",

"Uid"=>"",

"PWD"=>"" ];

$conn=sqlsrv_connect($serverName, $connectionOptions);

 if($conn==false)

die(print_r(sqlsrv_errors(),true)); $success = "Set Temperature and Humidity Success!";

echo '<script type="text/javascript">sweetAlert("'.$success.'");</script>'; } else{ echo

"Error!"; } echo '<script

type="text/javascript">sweetAlert("'.$ErrMsg1.'\n'.$ErrMsg2.'\n'.$ErrMsg3.'");</script>';
```

A-2 Web Application Sample Codes

```
<div class="content">

 <div class="cards">

 <div class="card header" style="border-radius: 15px;">

<h3 style="font-size: 0.7rem;">

LAST TIME RECEIVED DATA FROM ESP32 [

<span id="ESP32_01_LTRD"></span> ]</h3> <button
onclick="window.open('recordtable_temp_humd.php', '_blank');">Open DHT11
Table</button> <button onclick="window.open('min_max_temp_hum.php', '_blank');">Open
Temp and Hum Updates Table</button>

<h3 style="font-size: 0.7rem;">

</h3>

 </div>

</div>

</div>
```

A-3 Hardware Sample Codes

```
//=======================================================//

 // System Functions //=======================================================//

void check_parameters()

{ if (m_temp > m_max_temp_threshold) {

 // ON Aircon aircon_on(); }

 else { // OFF Aircon aircon_off();

 }

 if (m_humid < m_humid_threshold) {

// ON Humidifier humidifier_on();

 }

else { // OFF Humidifier humidifier_off();

 }

 }

 void display_parameters() {

lcd.clear(); lcd.setCursor(0, 0); lcd.print("Temp: ");

 lcd.print(m_temp);

lcd.print(" C");
```

```
lcd.setCursor(0, 1); lcd.print("Humid: ");

lcd.print(m_humid);

 lcd.print("%"); }
```

Appendix B: Experimental Setup

Experimental Setup used for evaluating the performance and effectiveness of the system are the following:

1. **Hardware Casing**
   - A rectangular casing or chamber where all the plants are and are in the controlled environment wherein the environment is optimal for the plant growth. The casing allows control of temperature and humidity with the help of a website application.
2. **Plant Species**
   - For the experiment we selected the plant of cactus and aloe vera, known for its sustainability. The plant is chosen based on their availability, and relevance to the study.
3. **Hardware Components (Irrigation System, Lighting System)**
   - For controlled watering A humidifier which will spray a mist to the controlled environment. For the light an LCD strip placed on the top of the system wherein if prolonged open will cause heat.

Appendix C: Questionnaires/Surveys

Name (Optional):

9 responses

Ayren

Lillian p gonzales

Maebel Peralta Malabug

Jerome

Kind

Stemarie Cris G. Lui

Rebecca P. Burgonio

Kaye Gonzales

Eleiser

Figure C1 “Summarize Name of the Survey”

What do you think are the benefits of using a smart controllable plant growth simulation system compared to traditional methods?

17 responses

it grows better?

I think the benefits is enhance the growth faster

I think by using a smart controllable plant growth simulation, you can monitor it more efficiently.

Fast and easy

More production

It may help reduce mistakes, especially for beginners.

More stable in terms of plant growth

It requires a system that can be used efficiently with less use of resources.

Parameters can be set and monitored with minimal human intervention.

Figure C2 “Sample Questions and Answers of the Survey”

How would you feel about having the ability to monitor and control your plant's growth remotely using a website and hardware system?

17 responses

good

Accuracy

Good because I can monitor it more conveniently.

Excited

No hassle

Makes it easier to monitor my plants even when I'm not around.

It will be easier for me to make the plants grow at the same time

At first, maybe it will feel like complicated but once you are able to know its pricess it will be easier. Then you will able to acquire the quality you want in your plant.

It would be an interesting breakthrough for regular people like me.

Figure C3 “Sample Questions and Answers of the Survey”