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AISG: IOT-DRIVEN IRRIGATION FOR AUGMENTED PLANT GROWTH

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Abstract: Information technology has become so pervasive in today's highly technological culture that it affects every aspect of human existence. The advent of information technology has proven beneficial to many different industries, including horticulture, both on a domestic and commercial. Gardeners frequently face difficulties in maintaining their gardens during vacations or periods of neglect, leading to plant withering, and these challenges arise due to environmental stressors like light, soil moisture, and water. This research introduces AISG that represent Automat-ed Irrigation Smart Gardening. It provides a solution by integrating an IoT system with a responsive web-based application to monitor a plant's development in real time, including access to relevant data and the ability to adjust settings as needed. This approach will assist the gardeners in managing their plants and irrigate appropriately depending on the specific needs of the plants. Besides, it may reduce water consumption and allow plants to be tended. the moisture sensor measures soil dryness at two distinct locations in the field and transmits the data to the Arduino system, which considers information from both devices to deter-mine the required amount of water. The system continues collecting sensor data until it detects sufficient soil moisture, at which point it automatically turn off the pump. Another benefit of this approach is the gardeners can control the irrigation system that watering their plants from their phone. The sensor's collected information is automatically updated on an hourly basis. In conclusion, the expected outcome of this implementation system enables a more organized and systematic approach to tending plants at home, resulting in improved care and maintenance.

Keywords: Arduino System, Irrigation System, Internet of Things (IoT), Smart Gardening

1. INTRODUCTION

The widespread use of the internet and the Internet of Things (IoT) has revolutionized various aspects of human life. The Internet of Things refer to a network of physical objects embedded with electronics, software, sensors, and connectivity that allows them to collect and exchange data [1]. As the world grappled with the COVID-19 pandemic, Malaysians [2,3], like many others, found solace and engagement in home gardening activities. Hence, with lockdowns and social distancing measures disrupting daily routines, home gardening emerged as a popular hobby [2,3]. Re-search [4] has demonstrated that plants possess the ability to decrease stress levels and enhance air quality.

However, time for gardening is sometimes limited by the demands of daily living, especially for people who have hectic lives. This limitation led to the exploration of AISG, especially in the post-COVID era, where governments are striving to ease restrictions and restore normalcy [5]. AISG presents an ascertain comprehensive system that enables users to monitor essential factors, including plant health, soil moisture levels, light exposure, and watering requirements. As a result, this resulted to a reduction in the amount of water that was wasted, which was beneficial because excessive watering of plants can result in the development of fungal infections, diseases, and a reduction in crop stability.

Therefore, this research is to develop AISG system using Arduino technology. The system incorporates a soil moisture sensor to determine the plant's moisture level and triggers the irrigation pump accordingly. Perhaps, by connecting sensors, such as moisture sensors, light sensors, and water level sensors, to the IoT network, gardeners can receive real-time data about the garden's conditions. gardeners can automate irrigation based on the garden's needs regardless of their location. This is achieved through the integration of sensors that monitor multiple parameters. To assess the practicality and performance of the AISG in real-world scenarios, it is necessary to evaluate its functionality and efficacy. In the next sections will delve into the meth-od, results, and discussions of this IoT-integrated irrigation system. This will show how it could help plants grow better in home gardens.

2. RELATED WORKS

This section presents an in-depth exploration and analysis of the literature pertaining to the techniques employed in the development of an AISG. The primary aim of this literature review is to identify and assimilate relevant research strategies and methodologies that can serve as valuable guidance for the implementation of the proposed system. Additionally, this chapter examines and discusses previous research studies and existing systems in the field.

According to the findings of the review research, there are currently three systems in existence, namely IoT-Based Smart Home Automation System [6], Smart Home Gardening system using IoT [7], and Automatic Plant Irrigation System using Arduino [8]. The research [6] team has devised a system for home automation that utilises the Internet of Things (IoT) technology. The qToggle system uses a robust and adaptable Application Programming Interface (API) as its core communication framework, enabling a streamlined and standardised means of interaction [6]. The integration of internet connectivity into household objects and devices allows the ability of gardeners to remotely monitor and control said objects and devices. These instances include technological advancements such as smartphone and voice-activated light switches, thermostats capable of regulating indoor temperatures and providing energy usage reports, and smart irrigation systems that can be programmed to initiate at specified times and schedules to mitigate water waste. Finally, an IoT-based smart home automation system was implemented using ESP8266 chips and Raspberry Pi boards as the fundamental components for home automation. Both options exhibit cost efficiency, compactness, and ease of handling. Furthermore, the qToggle system that has been suggested employs a fundamental core API, thereby enabling a network design that is more adaptable. The qToggle system is designed to serve as a comprehensive prototype for smart homes, offering a wide range of features such as automation, control, monitoring, and security. Besides, it is a system that can be capable of continual development and enhancement.

Rozita & Abdullah has introduced a Smart Home Gardening System based on IoT platforms [7]. This technology helps farmers efficiently manage plants and water them according to their needs. The present technology allows users to communicate with the system by pressing buttons on a Blynk application and using data from moisture sensors. The option to water the plants manually or automatically is made available to the user. Since the Agile Model has a lower failure rate than other methods, it was used to guide the development of this system. Due to the large cost of IT projects, failure can have a major impact on the organization. At this point, the user will go through the system and give each page a rating based on their overall impression of it. Hence, Users feedback will be used to make changes so the system fully meets the needs of its end users, the AGILE Model goes through iterative repetition of each step during this phase.

Hence, in [8] research paper used soil wetness detector, water flow detector, and temperature sensor (ds18b20). A detector can calculate the amount of water in the sector, a soil wetness detector can calculate the sector's wetness profile to prevent crops from water work problems, and a temperature sensing detector can check the crops' temperature because crops are temperature sensitive. However, in the field of crops, there is a lot of water and other resources that are not being used. To solve the problem mentioned above, researchers have set up an automated plant monitoring system using Arduino. This technology determines how much water is needed by monitoring the amount of moisture in the soil and then delivering the required amount. In addition, this system can track how the crop is growing and figure out how much water is left in the tank. So, when the soil is dry, the pump will automatically water the fields, and when the soil is wet, it will stop watering the fields. This saves time and eliminates the need for people to do the work. Lastly, the primary goal is to make this technology accessible from everywhere so farmers can monitor the area 24 hour. Arduino, a microcontroller, controls the setup, and ESP8266 modules send and receive data.

2.1 Internet of Things in Agriculture

The Internet of Things (IoT) has emerged as a revolutionary technology that enables the connecting of a wide variety of devices and, as a result, enhances individual lives and quality of life [9]. Concurrently, it presents businesses and industries with a significant potential to improve their resource management and reach higher levels of efficiency and cost-effectiveness. But any system or device that supports the Internet of Things may encounter challenges in either the design or implementation phases [10]. Internet of Things technology requires a number of key issues, including the storage and processing of data, communication and the network, as well as privacy and security. These features must be present in any new or updated IoT system for its applications to succeed [10]. Hence, agriculture and farming used Internet of Things application to simplify daily tasks. It helps streamline operations and improve efficiency in these industries.

In 2019, Aezwani and Mustafa Man [15] has introduced An Intelligent Stingless Bee System with Embedded Internet of Things Technology (iBees) to monitor and analyze the hives in real time mode. It uses a GPS, temperature and humidity sensor, and microprocessor to automatically monitor the beehive's temperature and humidity, which the user can monitor online. The iBees system obtains requisite data from a device comprising of a global positioning system (GPS), temperature and humidity sensor, and microcontroller, which is integrated with wireless fidelity (Wi-Fi). This data, including longitude, latitude, temperature, and humidity, is subsequently transmitted to an online cloud database. The implementation of iBees technology is necessary for the purpose of monitoring and preventing theft of stingless bee colonies. This indicates that the benefits of Internet of Things (IoT) are available to a wide variety of consumers.

Other than that, Internet of Things in Animal Healthcare (IoTAH) was develop by Karthick G.S and Sridhar M [16] to monitor the health status that use biosensors for real-time monitoring. The sensor unit, data transit, and data center comprised the components of the IoTAH framework. The health of animals is determined by various physiological parameters such as blood pressure, heart rate, respiratory rate, and other vital signs. These parameters aid carers in preventing severe illnesses and monitoring the location of animals, whether they are indoors or outdoors. The data were gathered and subsequently stored in cloud-based storage, thereby enabling their retrieval and use at a later point in time. Overall, The IoTAH system allows remote monitoring of the health and location of individual animals, enabling farmers to receive prompt emergency notifications in the event of abnormal conditions [16].

Meanwhile, the implementation of IoT plays a crucial role in enabling smart home gardening systems. It allows for the integration of various devices and sensors to create an interconnected network that can monitor, automate, and optimize gardening processes [12,13].

3. AISG FRAMEWORK

The method used in this research is based on the systematic development and implementation of AISG. By using the Agile Methodology, the research process intends to deal with problems more effectively, ensure projects beneath control, and make planning more structured.

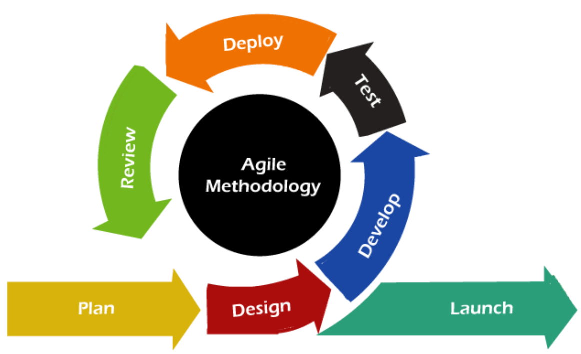

Figure 1 Agile Model

The Agile model [11] becoming a comprising iterative and incremental processes, emphasizes process adaptability and customer satisfaction through the rapid delivery of functional software. Each iteration normally lasts between one to four weeks, allowing for numerous adjustments and enhancements to be made throughout the development process. The division of the project into smaller segments reduces project risk and overall delivery time. There are a total of six stages involved in the Agile methodology: requirements gathering, design, iteration, testing, deployment, and feedback. AISG objective is to help gardeners with plant care, and a needs assessment led to the selection of two parameters, namely soil moisture and water level. In addition, during the design phases, diagrams of the system's context, data flow, and entity relationships were created. Arduino IDE, MySQL as the database management system, and PHP as the web interaction framework were used to design the prototype interface throughout the iterative phase. Deployment required making the system available via the internet once it had been tested to confirm its functionality and detect any bugs. In order to fix any problems or make any improvements, feedback from gardeners was collected.

The architecture of the AISG is presented in Fig 2, illustrating the overall framework and system flow. To access the plant dashboard status, gardeners are required to log in. The data collected from Arduino Uno is transmitted to MySQL (DBMS) via the Wi-Fi Shield Cytron for storage in the database. This process guarantees that the data related to the three parameters is securely stored. In addition, gardeners can only view reports, add the data of their plant record and the plant library, while the administrator controls all other data management functions.

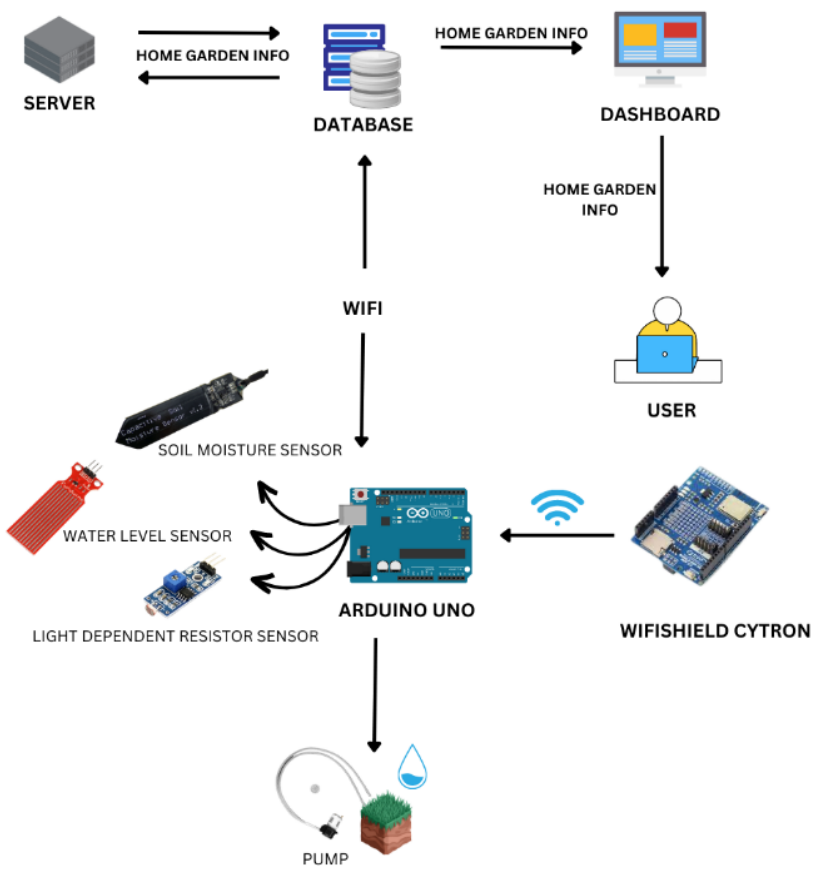

Figure 2 AISG Framework

The three sensors employed for plant health identification are the soil moisture sensor, light dependent resistance sensor, and water sensor. These sensors are an essential component in determining the overall state of a plant's health. The first factor, soil moisture, involves measuring the amount of water in the soil to figure out how much water a plant needs. The second factor, light-dependent resistance, uses a monitor to measure how much light the plant is getting. The pump is turned off when the light dependent resistance value increases due to lower light intensity (meaning night time). The third factor involves assessing the water requirements of the plants by comparing the soil moisture value to a predefined threshold set by the water level sensor, the appropriate amount of water is determined for irrigation. In order to examine the significant factors influencing plant growth, a predetermined dataset was utilized. Table 1 illustrates the dataset employed for this purpose.

Table 1. showcases the dataset containing the measurement factors and the corresponding of levels.

Measuring Factor	Low Level	High Level
Moisture Level	<80	>=80
Light (Photosynthesis)	<900	>=1000
Water Level	<200	>=300

A soil moisture sensor is used to obtain information about the soil's moisture, water level, and light intensity from the surrounding environment. The moisture range has been split into two categories, namely low and high, as shown in Table 3.1, so that it can accommodate a variety of various moisture circumstances. Therefore, the less water in the soil, the lower the conductivity and thus the higher the resistance which by measuring we can determine the soil moisture level, as a result when the water level falls below the minimum threshold, it will automatically water the plants to maintain the moisture level. When the moisture level reached the high range, the system provides the gardeners with a result indicating the soil as "wet" or "dry," which serves as an advisory against watering the plant until the water level decreases and falls within the desired range, specifically the minimum and average levels. Finally, regardless of their location, gardeners can monitor the health status of their plants through a comprehensive report that includes tables.

4. EXPERIMENTAL OBSERVATION

This section focuses on the implementation of code for the AIGS devices (sensors) and the establishment of a Wi-Fi connection. The microcontroller must be programmed to ensure the hardware and sensors work as intended. The code is written with Arduino IDE 1.8.13 and sent to Arduino ino through WiFiShield Cytron. Figs 3, 4, and 5 depict the AIGS code for the library, configuration, and setting up Wi-Fi and sensors. These illustrations provide a comprehensive overview of the code implementation process for the AIGS platform, enabling researchers and practitioners to replicate and adapt the system effectively. From the results obtained we observe the following:

```
#include "WiFiEsp.h"
#include <PubSubClient.h>
#include <ArduinoJson.h>

// Emulate Serial1 on pins 2/3 if not present
#ifndef HAVE_HWSERIAL1
  #include "SoftwareSerial.h"
  SoftwareSerial Serial1(2, 3); // RX, TX
#endif
```

Figure 3 Library Coding in AISG

The WiFiEsp library allows an Arduino board to connect to a WiFi network using the Wi-Fi shield Cytron module. It also has methods for setting up, connecting to a network, making HTTP requests, and handling responses. The PubSubClient library allows the Arduino board post and subscribe to topics on a MQTT broker. This makes connecting, sending messages, and subscribing much easier. The ArduinoJson library makes it easier to work with JSON data on Arduino boards by giving it functions for parsing, creating, and dealing with structured JSON data.

```
//VARIABLES
#define WIFI_SSID               "UniSZA-WiFi"
#define WIFI_PASSWORD           "unisza2016"
#define MQTT_PUBLISH_TOPIC      "mira_tembila/iot/ldr1"
#define MQTT_PUBLISH_TOPIC1      "mira_tembila/iot/soil"
#define MQTT_PUBLISH_TOPIC2      "mira_tembila/iot/water"
#define MQTT_SUBSCRIBE_TOPIC1     "mira_tembila/iot/led1"
#define MQTT_SUBSCRIBE_TOPIC2     "mira_tembila/iot/led2"
#define MQTT_HOST               "broker.hivemq.com"

unsigned long lastMillis = 0;
int status = WL_IDLE_STATUS;      // the Wifi radio's status

int ldr = A0; //sensor 1
int LDRValue = 0;
int soil = A2; //sensor 2
int soilMoistureValue = 0; //
int sensorPin = A3; //sensor 3
int waterValue =0;
const int AirValue = 616;   //replace the value from calibration in air
const int WaterValue = 335;  //replace the value from calibration in water
int soilmoisturepercent=0;
```

Figure 4 Wi-Fi connection and sensors

The code snippet defines variables for WiFi network credentials, MQTT topics for publishing and subscribing, the MQTT broker's hostname, timing, WiFi status, analogue pins for ldr, soil moisture, and water level sensors, calibration values, calculated percentages for soil moisture and ldr, placeholders, a digital pin for sensor power, a character array for message storage, and a 200-byte JSON document for data manipulation.

```
  // this is because it is active low on the ESP-01
}

void connecttomqtt() {
  Serial.println("Connect to MQTT server >>>");
  // Loop until we're reconnected
  while (!mqttClient.connected()) {
    // Attempt to connect
    if (mqttClient.connect(NULL,NULL,NULL)) {
      Serial.print("Connected to ");
      Serial.println(MQTT_HOST);
      // Once connected, subscribe to topic
      mqttClient.subscribe(MQTT_SUBSCRIBE_TOPIC1);
      mqttClient.subscribe(MQTT_SUBSCRIBE_TOPIC2);
    } else {
      Serial.print("[Failed] rc=");
      Serial.print(mqttClient.state());
      Serial.println(" try again in 5 seconds");
      // Wait 5 seconds before retrying
      delay(5000);
    }
  }
```

Figure 5. Configuration MQTT (Real-time data)

The `connecttomqtt()` function establishes a connection to the MQTT server, attempts to connect and subscribe to specified topics, and handles reconnection attempts if the initial connection fails, with a delay of 5 seconds between retries.

Gardeners can view the soil moisture status on the interface display to ensure the functionality of AISG in facilitating their affairs. In addition, customers are able to discover how much water is required for the irrigation tank. Interfaces are designed to allow gardeners to insert the data of their plant before monitor the status of health plant. Fig. 6 depicts the login account interface to access the dashboard application to insert the data.

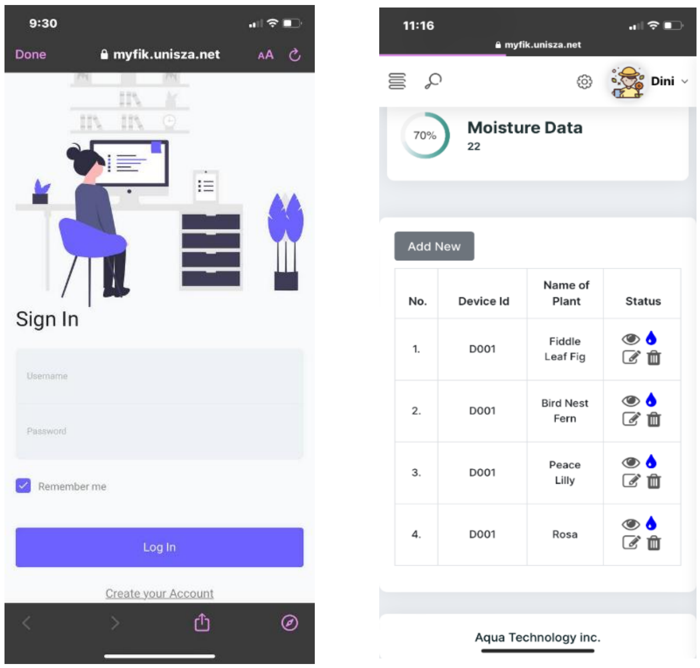

Figure 6 Login Account for AIGS and Dashboard data of plant

The interface simplifies the process for gardeners to enter the data related to their plants, monitor their progress through the data provided, and provides a convenient to modify or remove the data as required. Therefore, Fig. 7 illustrates the main interface of the developed application, exhibiting the presentation of significant data such as the soil moisture value and water level value.

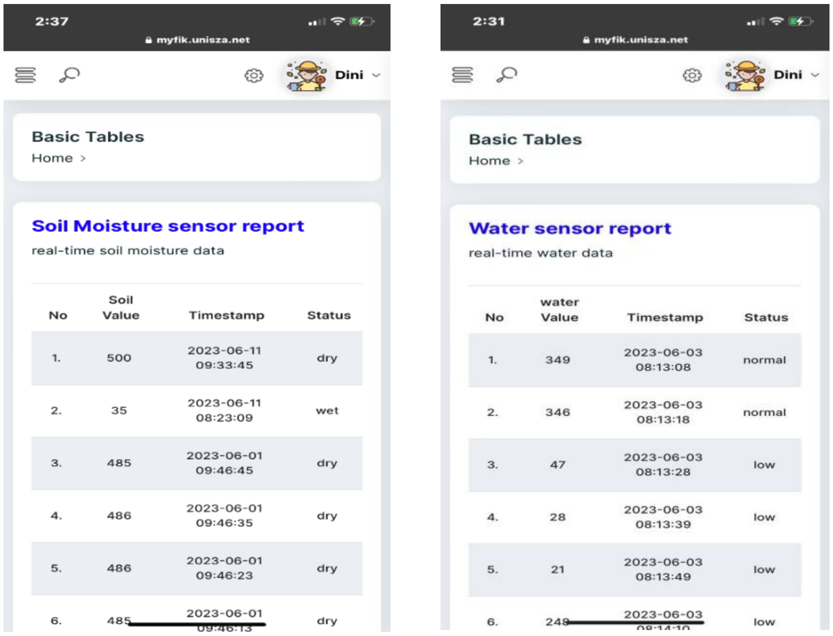

Figure 7 Display Values of two sensors

The interfaces enable gardeners to tend for their plants even when they are not physically present, resulting in improved plant growth based on the information received. Furthermore, the dashboard is designed to visualize the sensor data, providing gardeners with a clear and intuitive representation of soil moisture and water status for easier observation. Fig. 8 shown a visualized dashboard.

Figure 8 Display Visualized Dashboard

5. CONCLUSION

The integration of an AIGS system with a responsive web-based application for monitoring and managing plants in real time has the potential to revolutionize gardening practices. This research has presented a solution to the challenges faced by gardeners, such as maintaining gardens during vacations or periods of neglect, by focusing on the effects of environmental stressors such as light, soil moisture, and water. The system performs accurate measurements of the soil moisture, water level, and light to conduct an analysis of the data and determine the exact amount of water that is necessary for each individual plant. The results demonstrate the system's effectiveness in enhancing plant growth, as the data continuously collects sensor readings until sufficient soil moisture is detected. At that point, the system automatically turns off the pump, conserving water and ensuring appropriate irrigation. Moreover, the responsive web-based application enables gardeners to remotely monitor and control the irrigation system using their smartphones, providing convenient access to plant development and relevant data. Rigorous testing has been conducted to assess the overall operational performance of the system, resulting in the determination that it functions effectively and reliably. Overall, through further research and development, this technology can continue to evolve, contributing to the advancement of horticulture and promoting sustainable gardening practices in the future. To further enhance this research and explore potential future development, AIGS may be set up to measure the amount of moisture also known as the water content in accordance with the varying moisture requirements of the plants. This would make the system more intelligent, capable of predicting gardener's activities, assessing plant nutrition levels, and determining the optimal harvest time. However, this research [14] measures the amount of water generated by various microcontrollers and pumps. Because drip irrigation is the most water-efficient technology for watering gardens and the best way to water plants at ground level, the proper controller will deliver the right amount of water at the right time for optimal plant growth. Besides, future development efforts can focus on expanding the range of environmental factors monitored by the IoT system, such as temperature, humidity, sunlight intensity. By incorporating additional sensors, gardeners can obtain a more comprehensive understanding of their plants' needs and provide customized care accordingly. With such IoT advancements, plants can experience accelerated growth within a shorter timeframe.

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