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Short Paper*

Seedling Guard: Assessing Salinity, Nutrient Imbalance, and Temperature Stress on Eggplant Germination in Bogo City

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Abstract

Purpose – This study investigates the effects of abiotic stress on Long Purple Eggplant seedling germination, specifically temperature, salinity, and nutritional stress. The results are used as a basis for developing an IOT-based and/or embedded systems solution.

Method – Investigate the three abiotic stressors: salinity, nutritional imbalance, and temperature extremes. These stressors were chosen because they were repeatedly identified as frequent and visible difficulties in the area. A follow-up interview was used to validate the impact of abiotic stress on seedling development. Use of a Likert scale survey and follow-up interviews with local smallholder farmers.

Results – Smart seedling monitoring systems provide real-time monitoring of environmental factors such as temperature, salinity, and soil moisture, which benefits smallholding farmers. This allows for the early detection of stressors, which improves seedling monitoring and production during germination. Using sensors and data analytics, this strategy offers a cost-effective alternative that farmers with limited resources can implement. Finally, implementing this technology improves seedling management, increasing agricultural resilience and sustainability.

Conclusion – Abiotic stressors such as heat, salinity, and soil nitrogen imbalance have a major impact on smallholder farmers. These factors interact and impede seedling growth. Local soil management techniques may need to be improved to counterbalance them. Thus, incorporating automated monitoring and management with IoT is a feasible approach for addressing and mitigating these issues in smallholder farming.

Recommendations – Employ automated blind features, smart watering, and real-time information to help farmers reduce stress and promote sustainable seedling development in smallholder farming.

Research Implications – This study exhibits more possibilities for exploring other types of seedling germination to be applied with IOT-based and/or embedded systems.

Keywords – Abiotic stress, eggplant, germination, agricultural sustainability, IOT in agriculture

INTRODUCTION

One of the most common vegetable crops in the Philippines is eggplant, ranking first in planted area, number, and economic worth of production (Hautea & Narciso, 2007). Germination is the actual seedling growth process. It uses a process for propagating quality that is called the germination process. The problem arises from the lack of a regulated seed production system, which exposes seeds to severe temperatures and restricts access to effective soil amendment methods, which sum up as abiotic stress. According to Tester and Bacic (2005), abiotic stressors, particularly in temperature, water, and inorganic solute supply, typically limit eggplant development and production. Another study conducted by Vij and Tyagi (2007) stated that such abiotic stress conditions may reduce agricultural plant production by more than 50%, posing a substantial threat to agriculture. In addition, a study by El Sabagh et al. (2020) on the impact of salinity on the quality of diverse crops has received little attention. Soil salinization is one of the risks to agricultural potential and is associated with poor resource management. Lack of plant management can hinder many factors to its sustainability that could affect eggplant productivity and food security.

LITERATURE REVIEW

Eggplant Germination

From germination to harvest, a thorough awareness of each stage assists in care, resulting in plenty of yields and easy development of this essential vegetable. Eggplants start as little, spherical seeds. According to this research Growth Stages of Eggplant (2023), when seeds are placed under the right conditions, moisture causes them to germinate. During this phase, a small embryonic plant grows within the seed and breaks through the seed covering. The roots grow in the earth over time, while the shoot pushes up. The entire process, from planting the seed to seeing the first sprout, takes 7-10 days. Eggplants are produced synchronously in plants of various ages (4 to 9 months). According to Dufková et al. (2019), the most important step in developing eggplant is germination because it acts as the foundation for the entire growth process. Understanding the molecular problems of germination is important for developing eggplants that grow well.

Abiotic Stress

Abiotic stress, which affects crop or plant growth in the eggplant process, is one important factor. Numerous abiotic stresses, including salinity, drought, high temperatures, and climate change, continue to affect plants. According to Ningombam et al. (2021), abiotic stressors cause approximately 50% of all plant losses, with high temperatures, drought (9%), salinity (10%), low temperatures (7%), and other abiotic stressors accounting for the remaining 4%. Heat, salinity, and drought are abiotic variables that influence crop productivity and seeding. Taunk et al. (2019) noted salinity, drought, high temperatures, and cold as environmental stressors caused by abiotic stress.

Soil Amendment

Soil amendment emerged as a pressing concern in agriculture with extensive impacts. Challenges like soil salinity and nutrient imbalances in the soil contribute to agricultural depletion. A study conducted by Ong et al. (2018) investigated the potential of plant growth-promoting bacteria to mitigate the effects of soil on crop plant germination. This understanding helps assess its effects and devise mitigation strategies in the area. A study conducted by Hussain et al. (2022) investigated the development process of seedling growth through salinity effects as one of its implications is that salinity stresses the eventual germination percentage, germination speed, germination ability, shoot and root length, and seedling's dry mass were all significantly reduced and having the detrimental effects. Unfavorable characteristics include reduced leaf growth rate, insufficient water levels throughout the plant, and elongation, and a reduced photosynthetic rate characterize the observed conditions. Soil nutrient imbalances pose a significant challenge to agricultural sustainability and plant productivity.

Temperature Stress

Global climate change has increased the occurrence and frequency of temperature extremes, posing challenges for plant researchers worldwide. These extremes detrimentally affect plant metabolism, development, and growth (Hussain et al., 2019). In a study conducted by Zhang et al. (2019), discovered that high-temperature stress has a significant influence on the germination of eggplant seedlings. The findings suggest that high temperatures downregulate genes involved in anthocyanin biosynthesis in eggplants, affecting their growth. This highlights the impact of high-temperature stress on eggplants and their anthocyanin content, guiding the development of potential heat varieties. Low temperatures globally pose chronic stress on agricultural production, causing biological and biochemical changes in crops (Mehrotra et al., 2020). Plants' response to low temperatures is vital for developing resilient varieties and ensuring agricultural sustainability since extreme lows disrupt normal crop plant physiology necessitating strategies to improve stress tolerance and promote sustainable agriculture.

Crop Yield Loss

A study by Kopittke et al. (2019) emphasizes soil quality's vital role in reducing crop loss and securing food. The study reveals impacts of soil degradation including decreased organic matter and increased greenhouse gas emissions. Assessing soil quality parameters emphasizes the critical role of soil management in sustainable agriculture since crop yield loss due to abiotic stress factors like soil degradation is both an environmental and economic concern. Similarly, Rizzo et al. (2021) added that global crop losses, revealing that staple crops may experience up to a 30% loss in yield. This quantifies the economic impact of crop loss on food production. As a result, it emphasizes the need for effective mitigation strategies for abiotic stressors and ensures food security. Liliane & Charles (2020) high and low temperatures have a significant impact on eggplant seedling production. Each 1°C rise in temperature results in a daily yield reduction of 1.0- 1.7%. Similarly, low temperatures (0-15°C) cause poor germination and limited seedling growth, leading to crop loss.

METHODOLOGY

The study aimed to investigate the three abiotic stressors: salinity, nutritional imbalance, and temperature extremes. These stressors were chosen because they were repeatedly identified as frequent and visible difficulties in the area. A follow-up interview was used to validate the impact of abiotic stress on seedling development.

Research Environment

The environment in which the research was conducted was Bogo City, Northern Cebu, on a smallholding farm that grew eggplant, bitter gourd, tomato, and okra. The main focus was on the early long eggplant. It is appropriate for the researchers due to the following reasons: (1) It focused on smallholder farmers, common in the area; (2) It emphasized seedling germination in smallholder farming, which corresponds well with the chosen location.

Research Respondents

The study involved primary data gathering on seedling germination and practices, with the 15 local farmers from Bogo City, Cebu, who were actively involved in smallholder farming, confirming the data gathered.

Research Instrument

A survey-based approach was used to gather data from respondents of Bogo City, Cebu. The survey questionnaire uses a 5-point scale, with one representing "strongly disagree", two as "disagree", three as "neutral", four as "agree", and five as "strongly agree". To quantitatively ensure the survey's reliability, the questionnaire has been accurately constructed.

Data Analysis

The obtained survey responses were consolidated and statistically processed using the following procedures:

1. **Weighted Average.** Was calculated from the responses of local farmers in the form of the survey questionnaire, during the actual data collection procedure is as follows:

$$WA = \frac{1}{N}\sum_{i=1}^{5} i * X_i \qquad \textit{Equation 1}$$

Where:
WA = Weighted Average
X_i = The number of responses for the i^{th} Likert scale category
N = Total number of respondents

2. **Likert Scale.** Ranges and interpretations assessed respondent feedback (Table 1).

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Table 1. Interpretation of 5-point Likert Scale Range

Likert-Scale	Range	Likert-Scale Description
1	1.00 – 1.80	Strongly Disagree
2	1.81 – 2.60	Disagree
3	2.61 – 3.40	Neutral
4	3.41 – 4.20	Agree
5	4.21 – 5.00	Strongly Agree

Conceptual Framework

The Seedling Guard prototype, shown in Figure 1, will be created with precision and efficiency. It uses a variety of sensors, including temperature and humidity sensors, total dissolved solids, and soil moisture sensors, to monitor soil conditions within a nursery box. These sensors are monitored to ensure their functionality, with any non-working sensors. A microcontroller acts as the principal controller, combining data from all sensors via an algorithm. The processed data is then retained, allowing features to be activated and farmers to be notified of developments by SMS, as well as being saved in a database for future reference. The system provides real-time monitoring via SMS notifications and a web-based interface that shows current actions, status, and non-working sensors. Thresholds for data processes are set to trigger updates, ensuring farmers are informed even when they are not present. Updates are provided every 4 hours to ensure consistent monitoring, regardless of which features are engaged. The system is designed to scale smoothly and adheres to a predetermined maintenance schedule to maintain continuous accuracy and dependability in monitoring abiotic stresses in plants.

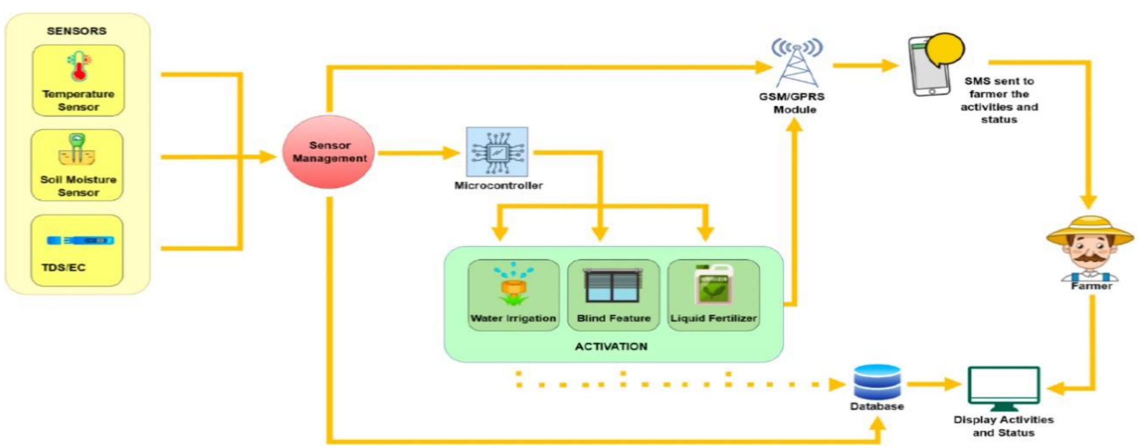

Figure 1. Conceptual Framework of Seedling Guard

The block diagram of the system, shown in Figure 2, begins by analyzing several sensors such as the Temperature Sensor, Soil Moisture Sensor, Total Dissolved Solids (TDS), and Electrical Conductivity (EC). Each sensor is operationally managed, with records stored in the database and analyzed. The primary controller receives the sensor

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inputs activate water and liquid fertilizer and manage blind feature operations. The resulting data is stored directly in the database. Current soil moisture, salinity, and temperature levels are displayed on the internet and sent to farmers, while non-operational sensors send updates to farmers. The web application enables farmers to monitor nursery seedling activity from any desktop device.

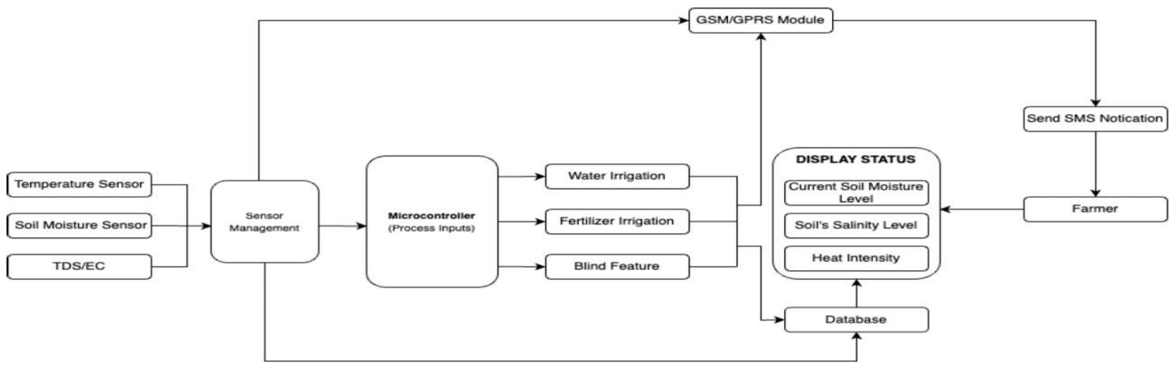

Figure 2. System Block Diagram

RESULTS

The data analysis used Likert scale interpretations (1 for "Strongly Disagree" to 5 for "Strongly Agree"). Weighted averages were calculated by multiplying each category's total responses by the Likert scale value, adding the results, and dividing by 15 (total respondents). The results were interpreted using the 5-point Likert range.

Temperature Stress

The respondents "Strongly Agree" having an average of 4.87 that regulating temperature to prevent heat stress is essential for the growth of seedlings and nutrient uptake, as shown in Table 2. Furthermore, respondents "Agree" with a 3.8 average that prolonged heat exposure reduces nutrient absorption, hence reducing seedling growth. Adequate exposure to both high and low temperatures was "Strongly Agreed" having an average of 4.8 to improve seedling survival rates, highlighting the necessity of the right temperature controls and regular monitoring. Nevertheless, respondents are "Neutral" on average of 3.2 on temperature limitations for cold stress, citing unusual incidents of low temperatures in the area. However, respondents "Strongly Agree" with an average of rating: 4.2 that cold exposure affects seedling growth processes, causing damage in certain areas.

The researchers discovered a significant impact of temperature changes on seedling growth, consistent with findings by Hussain et al. (2018), indicating that both low and high temperatures can stress seedling germination and potentially increase stress levels. The impact of high temperatures on seed development depends on duration, timing, and severity. In Cayang, Bogo City, temperatures frequently ranged from 34°C to 38°C, as measured by a thermal scanner. These environmental fluctuations, particularly during heat stress, could slow seedling growth.

Table 2. High and Low-Temperature Responses and Seedling Resilience

Statement	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Weighted Average	Interpretation
1. The sudden changes in temperature in the area impact seedling growth.	40	20	6	0	0	4.4	Strongly Agree
2. The changing temperature affects seedling growth in terms of heat stress.	65	8	0	0	0	4.87	Strongly Agree
3. Heat shock proteins, photosynthesis disruption, and other ways by which heat stress affects seedling growth.	5	44	6	2	0	3.8	Agree
4. Adequate exposure to heat and cold improves the survival rate of seedling.	60	12	0	0	0	4.8	Strongly Agree
5. The changing temperature thresholds affect seedling growth in terms of cold stress.	5	20	15	8	0	3.2	Neutral
6. The processes via which cold exposure impacts seedling growth, such as damage in development.	25	32	6	0	0	4.2	Strongly Agree

Soil Management

Table 3 summarizes smallholding farmers' responses to soil management measures, focusing on salinity control and nutrient balance. Soil management procedures include methods for improving fertility and soil quality to achieve land that is sustainable to use. A "Strongly Agree" rating of 4.47 from 15 respondents shows agreement on the effectiveness of soil amendment for enhancing soil quality. Salinity levels are crucial for seedling growth with a "Strongly Agree" score of 4.8, with regular monitoring twice a month averaging 4.4. Salinity stress significantly affects seedling growth, as shown by an average "Strongly Agree" rating of 4.27. The soil amendment strategy improves soil quality as an interpretation of “Agree” with an average rating of 3.93 while also respondents strongly agree on the importance of addressing nutrient quality issues as indicated by the average rating of 4.8 emphasizing its significance in the area.

Table 4 illustrates soil salinity interpretation using TDS/EC. A soil sample from Cayang, Bogo City, Cebu has a salinity level of approximately 1.30 mmhos/cm, making it inappropriate for seedlings. High salinity disturbs soil balance, preventing water and nutrient uptake, resulting in stress and slow seedling growth.

Table 3. Soil Practices for Salinity Control and Nutrient Balance

Statement	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Weighted Average	Interpretation
7.The current soil amendment approach effectively mitigates salinity levels in the soil.	35	32	0	0	0	4.47	Strongly Agree
8. Salinity Levels in the area have noticeable impact on seedling growth.	65	4	3	0	0	4.8	Strongly Agree
9. Monitoring and testing of soil salinity levels are conducted regularly.	40	20	6	0	0	4.4	Strongly Agree
10. Salinity stress hinders the development of healthy seedlings.	35	20	9	0	0	4.27	Strongly Agree
11. The soil amendment approach in the area improves soil quality for agricultural purposes.	15	20	24	0	0	3.93	Agree
12. The current soil amendment approach effectively addresses the imbalance in soil nutrient composition.	50	20	0	2	0	4.8	Strongly Agree

Table 4. Conductivity and Solids Concentration Analysis

Electrical Conductivity	Rating	Interpretation
±0-0.15	Very Low	Plants are starved of nutrient
±0.15 – 0.50	Low	The soil lacks organic matter
± 0.51 – 1.25	Medium	Okay range for established plants
± 1.26 – 1.75	High	Too high for seedlings or cuttings
± 1.76 – 2.00	Very High	Plants usually stunted or chlorotic
>± 2. 00	Excessively High	Plants are severely dwarfed and frequently killed.

While only one respondent 'Agreed' and most farmers strongly advocate soil management measures, particularly soil amendment and salinity monitoring, crucial for seedling growth in smallholding regions. High soil salinity levels hinder water and nutrient absorption. The interpreted data analysis supports Do et al. (2023) study, indicating soil salinity's adverse effect on mineral balance which leads to nutrient deficiencies hindering seedling growth. Effective soil management, including salinity reduction and diverse soil and compost use, improves soil quality and nutrient imbalances. Optimizing water irrigation and liquid fertilizer application fosters healthy seedling development and sustainable farming practices.

Temperature and Soil Amendment

Table 5 shows how temperature and soil management approaches affect production, sustainability, development, and economic effects. Respondents "Strongly Disagree" with the assumption that inaccurate soil amendment and exposure to fluctuating temperatures do not promote seedling durability, rating 1.4 on average. This shows that sufficient soil management and gradual temperature contact help seeds adapt and grow. Furthermore, respondents "Strongly Disagree" that ignoring soil management and temperature changes improves the production of seeds. An average score of 1.27 suggests that poor practices may not significantly boost seedling growth and may reduce survival rates. Respondents "Strongly Agree" on an average of 5 that effective soil management and gradual exposure improve production outcomes. Furthermore, respondents "Strongly Agree" with an average of 4.87 that nutritional tolerance accelerates seedling development by stressing adaptation to nutrient levels, fertilizer application, and irrigation. Respondents also "Strongly Agree" having an average of 4.4 that mitigating abiotic stressors can enhance seedling growth and the economy.

Table 5. Abiotic Stress Factors Shaping Growth Outcomes

Statement	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Weighted Average	Interpretation
13. The impact of changing temperature and soil management malpractices enhances seedling sustainability.	0	0	3	8	10	1.4	Strongly Disagree
14. The impact of changing temperature and lack soil management practices enhances crop production.	0	0	0	8	11	1.27	Strongly Disagree
15. The impact of changing temperature and soil management malpractices has a bad contribution on economic outcomes.	55	20	0	0	0	5	Strongly Agree
16. Nutrient tolerance level corresponds to growing part of a seedling in a quicker development.	55	15	4	0	0	4.87	Strongly Agree
17. Addressing the factors of abiotic stress is crucial for seedling growth and to the economy.	35	28	3	0	0	4.4	Strongly Agree

Figure 3 shows the percentage values of abiotic stress factors that influence seedling growth, including heat stress, cold stress, salinity stress, and soil nutrient imbalance. These parameters are critical as these variables interact and limit seed growth. Salinity stress is the most prevalent concern, representing 38% of responses. Heat stress is responsible for 26%, soil nutrient imbalance for 25%, and cold stress for 11%. Salinity is the most common problem, preventing plant growth due to insufficient nutrients and acidic soil. Heat stress is the second common concern, affecting seed development and growth potential. Nutrient imbalance in the soil is also prevalent, emphasizing the necessity of soil nutrition for seedling development.

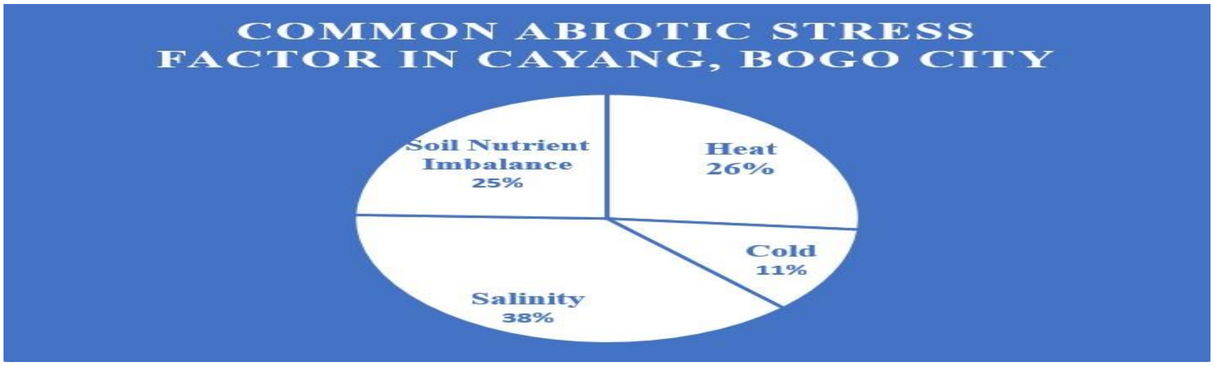

Figure 3. Assessment of Common Abiotic Stress Factors in the Area

Automation

Table 6 highlights the review of automated integration, particularly through the Internet of Things (IoT), to improve seedling handling in smallholder farming. Respondents. "Strongly Agree" with an average of 4.73 that using blind features and changing irrigation methods can successfully alleviate heat stress in seedlings. However, respondents are "Neutral" with an average of 3.33 about utilizing protective covers to reduce cold stress, as it is not a typical issue. Respondents "Strongly Agree" that soil watering strategies boost seedling growth by ensuring appropriate hydration with an average of 4.47. Also, a "Strongly Agree" interpretation for amendment and nutritional control is essential for long-term seedling growth having an average of 4.53.

In addition, respondents "Strongly Agree" with an average of 4.67 recognize the challenges encountered by abiotic stresses and support the use of IoT to solve these issues. The majority "Strongly Agree" that automated monitoring and management via IoT can assure consistent seedling development while reducing the labor of local farmers having an average of 4.87. The majority of the local farmers "Strongly Agree" on the inclusion of automation in seedling handling, and its usefulness in addressing farming difficulties, particularly those connected to abiotic stress. Automation, particularly through the Internet of Things (IoT), has viable options for managing heat, and improving methods of irrigation, resulting in more efficient and sustainable seedling growth.

Proposed Prototype

Figure 4 displays an isometric perspective of the prototype design, which has a central core and interconnected components. The design has two versions: one activated blind feature covering the seed sections and one without. Dimmed spots imply significant structural characteristics. The design involves an electronics compartment for safe storage, irrigation waterway pipes, and storage for water and liquid fertilizer containers. This figure representation focuses on the dynamic connections among components.

Table 6. Mitigation for Sustainable Seedling Growth with IoT Integration

Statement	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Weighted Average	Interpretation
18. Heat stress on seedlings can be efficiently mitigated by shade structures or adjusted irrigation.	65	4	0	2	0	4.73	Strongly Agree
19. The harmful effects of cold stress on seedlings, pre-conditioning or the use of protective covers should be used.	10	12	24	4	0	3.33	Neutral
20. Soil irrigation practices reduce the negative impact of seedling towards its development.	45	20	0	2	0	4.47	Strongly Agree
21. Usage of soil amendment or nutritional management contributes effectively to more sustainable seedlings.	45	20	3	0	0	4.53	Strongly Agree
22. Integration of Internet of Things for temperature, salinity and nutrient imbalance contributes development as a one factor to abiotic stress to seedling growth.	50	20	0	0	0	4.67	Strongly Agree
23. Automated Monitoring Management Integration of Internet of Things helps stabilize a constant seedling development in a better good and establish effective methods for agriculture.	65	8	0	0	0	4.87	Strongly Agree

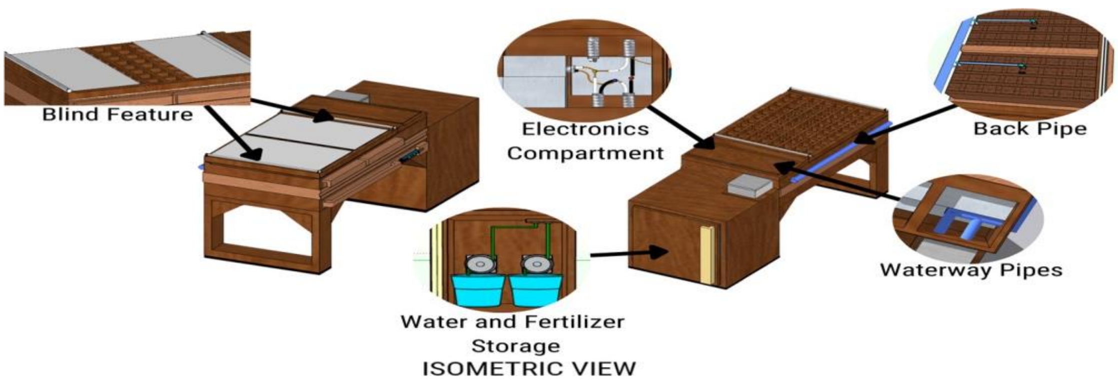

Figure 4. Isometric View

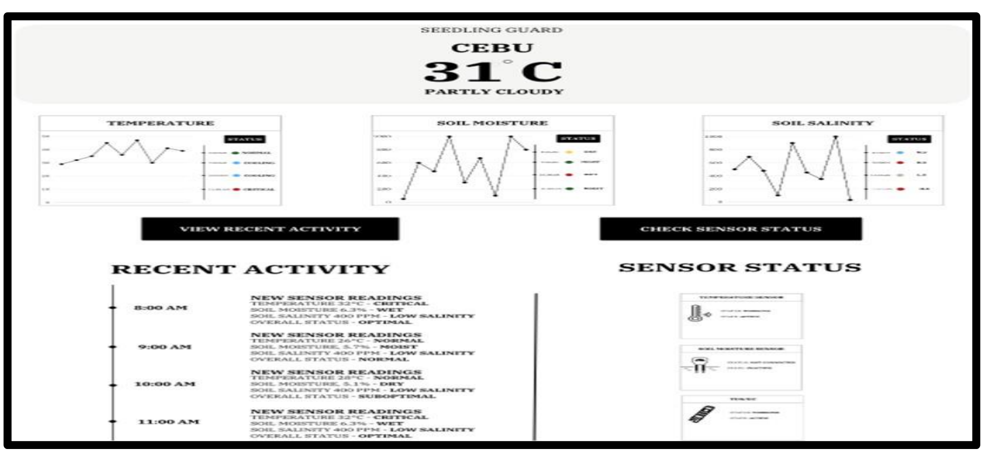

Figure 5. Sensor Devices Status Trend Desktop Display

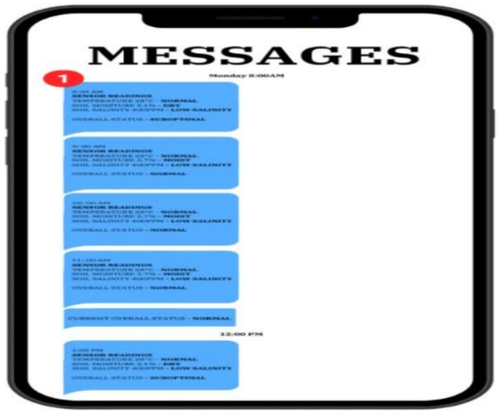

Figure 6. SMS Notification Display

Figure 5 displays the system wireframe, showing current weather status, sensor readings, and device status. These visuals are vital for users to quickly assess device status, identify irregularities, and analyze trends. They improve operational efficiency and decision-making by enabling real-time monitoring and data analysis. Figure 5 will be displayed on a desktop monitor, while Figure 6 will be displayed as an SMS for mobile phones. Utilizing SMS for mobile phones enhances the reach of the monitoring system, allowing users to stay informed and responsive even while on the go.

DISCUSSION

The study confirmed three major abiotic stressors that influence seedling growth: heat stress, salinity stress, and soil nutrient imbalance. Salinity stress is the most common, followed by heat stress. Soil nutrient imbalances add to the stress. Changing temperatures substantially influence seedling growth. Both high and low temperatures can hinder seed development, leading to damage and leaf wilting. High temperatures also impact nutrient uptake. Although low temperatures are uncommon, they still affect seedling growth and development. Gradual changes in temperature and proper soil management enhance healthy seedling growth as they indicate connections.

Based on the interpreted data, real-time updates and automated operations will improve efficiency and long-term seedling development. Based on the findings, these are the following recommendations:

Smart Irrigation for Water and Liquid Fertilizer - as salinity is the most common challenge that a farmer can experience, the researchers recommend smart irrigation for both soil moisture and salinity. Smart Irrigation is likely to benefit the farmer for it will regulate action based on the conditions automatically and regarding time efficiency.

Blind Feature - heat stress is also one problem for farmers, leading to lower survival rates. The researchers propose utilizing automated blind controls to adjust shade and irrigation to soil moisture and maintain proper temperature suitable for seedlings, which is made possible by Internet of Things technology.

Real-time Updates - With IoT integration, real-time updates continuously track plants via sensors, allowing data to be displayed also in a desktop and sent through SMS to farmers to be updated immediately.

Smart seedling monitoring systems provide real-time monitoring of environmental factors such as temperature, salinity, and soil moisture, which benefits smallholding farmers. This allows for the early detection of stressors, which improves seedling monitoring and production during germination. Using sensors and data analytics, this strategy offers a cost-effective alternative that farmers with limited resources can implement. Finally, implementing this technology improves seedling management, increasing agricultural resilience and sustainability.

CONCLUSIONS AND RECOMMENDATIONS

The study demonstrates that abiotic stressors such as heat, salinity, and soil nitrogen imbalance have a major impact on smallholder farmers. These factors interact and impede seedling growth. Local soil management techniques may need to be improved to counterbalance them. Thus, incorporating automated monitoring and management with IoT is a feasible approach for addressing and mitigating these issues in smallholder farming.

IMPLICATIONS

This study exhibits more possibilities for exploring other types of seedling germination to be applied with IOT-based and/or embedded systems.

ACKNOWLEDGEMENT

The researchers would like to appreciate the informative responses from the owner of the farmed land, the 15 eggplant farmers from Bogo City, Cebu as well as the consultant from the Department of Agriculture-7 and the LGU of Bogo City.

FUNDING

The study did not receive any funding from any government, private, or financing institutions.

DECLARATIONS

Conflict of Interest

The researcher declares no conflict of interest in this study.

Informed Consent

The researcher was able to get signed written consent from the land owner to conduct the survey and to interview the different farmers working in eggplant production.

Ethics Approval

The researcher does not need to obtain ethics approval as respondents are not from the critical group of people

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