SMARTROSE: AI-IOT PLATFORM FOR SMART GREENHOUSE ROSE FARMING IN SRI LANKA

25-26J-299

Project Proposal Report

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B.Sc. (Hons) Degree in Information Technology Specialized in Information Technology

Department of Information Technology

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Supervised by Mr. Junius Anjana

Co-supervised by Ms. Kaushika Kahatapitiya

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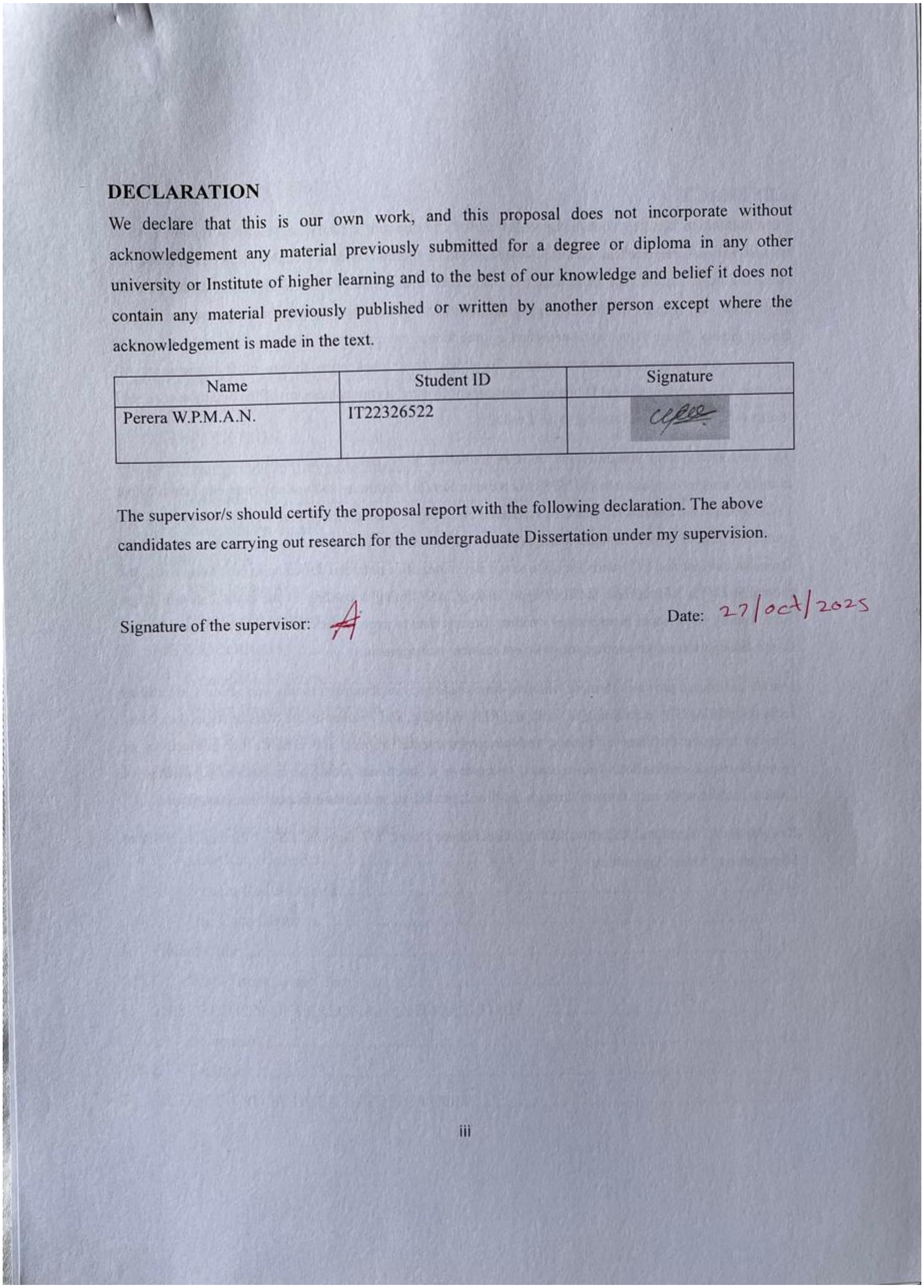
DECLARATION



DECLARATION

We declare that this is our own work, and this proposal does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other university or Institute of higher learning and to the best of our knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Name	Student ID	Signature
Perera W.P.M.A.N.	IT22326522	

The supervisor/s should certify the proposal report with the following declaration. The above candidates are carrying out research for the undergraduate Dissertation under my supervision.

Signature of the supervisor:

Date: 27/oct/2025

ABSTRACT

Rose cultivation is a key contributor to Sri Lanka's floriculture industry, especially in regions such as Nuwara Eliya, Kandy, and Bandarawela, where favorable climatic conditions enable year-round production. However, many small and medium-scale rose farmers continue to rely on intuition-based fertilizer application and manual monitoring, resulting in nutrient imbalances, salinity buildup, and inconsistent flower quality. These issues are intensified in greenhouse environments, where humidity and coir-based substrates require precise nutrient control. To address these challenges, this research proposes an AI-assisted, IoT-based Intelligent Nutrition Management System, a core component of the SmartRose: AI–IoT Platform for Smart Rose Farming in Sri Lanka.

The proposed system integrates IoT sensors including NPK, pH, EC, soil-moisture, temperature, and humidity sensors connected to an ESP32 microcontroller for continuous soil and environmental monitoring. Collected data are transmitted to a cloud database and analyzed using a ML model trained on agronomic fertilizer guidelines and greenhouse soil parameters. The model forecasts nutrient and EC trends for up to seven days, identifies potential deficiencies or salinity risks, and recommends the appropriate fertilizer type, dosage, and timing according to the plant's growth stage. Additionally, the system incorporates weather forecast data to prevent fertilizer loss under high humidity or rainfall conditions, promoting eco-efficient nutrient management.

Mobile dashboard provides farmers with real-time readings, visual nutrient trends, and actionable fertilizer recommendations. By combining IoT sensing, AI forecasting, and weather-aware decision logic, the system aims to improve fertilizer efficiency, reduce environmental impact, and enhance the productivity of greenhouse rose cultivation. The expected outcome is a functional prototype capable of supporting Sri Lankan middle-scale rose farmers through localized, predictive, and sustainable nutrient management.

Keywords: AI Fertilizer Recommendation, Greenhouse Roses, IoT Sensors, Nutrient Management, Smart Agriculture

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LIST OF ABBREVIATIONS

Abbreviation	**Description**
IoT	Internet of Things
ML	Machine Learning
AI	Artificial Intelligence
NPK	Nitrogen, Phosphorus, and Potassium
pH	Potential of Hydrogen
EC	Electrical Conductivity

LIST OF APPENDICES

1. INTRODUCTION

1.1. Background & Literature Survey

Rose cultivation is one of the most profitable sectors in Sri Lanka’s floriculture industry, particularly in regions such as Nuwara Eliya, Kandy, and Bandarawela, where favorable climatic conditions allow year-round production. Despite this potential, many rose farmers still rely on manual, experience-based fertilizer and irrigation practices that often lead to nutrient imbalance, salinity buildup, and declining soil fertility. The absence of real-time soil and environmental data limits farmers’ ability to make timely, data-driven decisions [1], [2].

Recent research in precision agriculture demonstrates that integrating Internet of Things (IoT) sensing and artificial-intelligence (AI) analytics can greatly improve fertilizer efficiency and irrigation control [3]– [6]. IoT-based architectures employing NPK, pH, and soil-moisture sensors have successfully enabled continuous data collection and cloud-based visualization to assist farmers in decision-making [7],[8]. Machine-learning techniques such as artificial neural networks, random-forest regression, and fuzzy-logic systems have been used to predict fertilizer type and dosage from soil-nutrient datasets, achieving higher accuracy and better fertilizer-use efficiency [9], [10].

Studies on rose nutrition highlight the importance of maintaining balanced NPK concentrations, appropriate pH levels, and controlled salinity for sustained flower quality [10]– [13]. Optimal conditions such as pH 6.2–6.8, EC 1.2–1.8 mS cm^{-1}, and balanced nutrient ratios are essential to maximize stem length, bud size, and color intensity. Greenhouse research confirms that excess fertilizer and poor leaching cause rapid EC accumulation and salt stress, shortening the productive life of rose beds [12], [13]. Other investigations emphasize that temperature, humidity, and light conditions strongly influence nutrient uptake and fertilizer efficiency [14], [15].

Advancements in sustainable fertilizer practices focus on integrating the 4R nutrient-management framework right source, rate, time, and place within digital-farming ecosystems [7], [8], [16]. Modern approaches also highlight the role of weather forecasting and API-based monitoring to enable rain-adaptive and humidity-aware fertilizer scheduling, reducing nutrient losses and chemical runoff [4], [6]. In greenhouse systems, hybrid organic–inorganic fertilization and nano-nutrient applications have been shown to improve soil health, nutrient absorption, and post-harvest quality [15], [16].

Although global developments in smart fertilizer management show promising results, most existing systems are designed for broad-acre food crops rather than floricultural species such as roses, which require more delicate nutrient control. Furthermore, many IoT-based systems primarily provide data visualization or rule-based alerts rather than intelligent, AI-driven predictions. Within Sri Lanka, the gap is even more pronounced: middle-scale greenhouse rose farmers still depend on visual observation, and very few predictive nutrient-management tools exist that are tuned to local coir-based substrates and humid conditions [1], [2], [12].

To overcome these limitations, this research proposes an AI–IoT-integrated Intelligent Nutrition Management System that combines multivariate nutrient forecasting with real-time sensor data and weather-aware fertilizer scheduling. The proposed model predicts nutrient and salinity trends, recommends optimal fertilizer type and dosage according to the plant's growth stage, and delivers bilingual, user-friendly alerts to farmers. This predictive and locally adapted system addresses a significant research and technological gap in Sri Lanka's greenhouse floriculture sector and contributes toward sustainable, data-driven rose farming.

1.2. Research Gap

Recent advances in precision agriculture have demonstrated the value of integrating IoT-based sensing and AI-driven decision support to enhance productivity and sustainability in modern farming [1]– [3]. Many studies have developed IoT-enabled systems for soil monitoring, irrigation automation, and fertilizer management, enabling real-time data collection and visualization. Similarly, machine-learning and deep-learning models have been applied to predict fertilizer requirements and optimize nutrient balance across various crops [4]– [6]. In addition, research on sustainable and smart fertilizer technologies emphasizes the 4R principles the right type, dose, time, and place to improve fertilizer-use efficiency and reduce environmental impact [7], [8].

However, most of these studies remain crop-generic and are not optimized for floricultural species such as roses, which require more precise nutrient ratios and tighter pH and EC control. The IoT-based frameworks in [1]– [3] focus mainly on data acquisition or irrigation control but lack predictive nutrient modeling or adaptive scheduling features. Similarly, AI-driven fertilizer recommendation models in [4]– [6] have not been applied to rose-specific agronomic parameters such as stage-dependent NPK ratios or greenhouse salinity constraints. Reviews in [7] and [8] highlight smart-fertilizer principles but stop short of implementing real-time, data-driven control systems suitable for practical greenhouse environments.

Furthermore, agronomic studies focusing on roses [9]– [12] provide valuable insights into nutrient uptake, soil pH, and fertilizer response but are experimental or descriptive, lacking automation and integration with IoT or AI frameworks. None of these approaches address the Sri Lankan context, where mid-scale greenhouse rose farmers face issues such as high humidity, coir-based growing media, and limited access to digital decision-support tools.

Therefore, there exists a clear research gap in designing a localized, AI–IoT-based predictive nutrient management system for greenhouse rose cultivation in Sri Lanka. The proposed Intelligent Nutrition Management System addresses this gap by combining real-time soil sensing (NPK, pH, EC, moisture, temperature, humidity) with weather forecasts and predictive modeling. This integrated approach enables stage-specific, weather-aware, and proactive fertilizer recommendations, helping Sri Lankan greenhouse farmers achieve improved yield, reduced chemical waste, and enhanced sustainability.

Table 1: Research Gap

Research Gap	**Research [1] - [3]**	**Research [4] – [6]**	**Research [7] – [8]**	**Research [9] – [12]**	**Proposed System**
Specific focus on rose cultivation	✗	✗	✗	✓	✓
Use of AI/ML algorithms for fertilizer recommendations	✗	✓	✓	✗	✓
Provides real-time, data-driven recommendations	✓	✗	✗	✗	✓
Integration of weather data for eco-spraying and scheduling	✗	✗	✓	✗	✓
Stage-based fertilizer scheduling according to plant growth	✗	✗	✗	✓	✓
Considers local Sri Lankan greenhouse conditions	✗	✗	✗	✗	✓
Integration of multiple data sources (sensors + weather + agronomy)	✗	✗	✗	✗	✓

1.3. Research Problem

Although modern precision agriculture has demonstrated the potential of integrating IoT sensing and AI analytics for efficient and sustainable farm management, these technologies remain underutilized in Sri Lanka’s floriculture sector. Most rose farmers still depend on manual, experience-based fertilizer practices, which often result in nutrient wastage, salinity buildup, soil degradation, and inconsistent flower quality.

Existing IoT-based systems primarily focus on soil or irrigation monitoring [1]– [3] and lack predictive or stage-based nutrient intelligence. Similarly, AI-driven fertilizer models [4]– [6] are generally designed for food crops such as rice or maize, and do not consider the specific nutrient sensitivity and growth-stage requirements of roses. While sustainability-oriented studies [7], [8] explore smart fertilizer management principles, they do not implement real-time, sensor-driven decision frameworks applicable to greenhouse environments. Moreover, agronomic research on roses [9]– [12] provides valuable information on optimal NPK ratios, pH levels, and soil conditions but fails to translate these findings into automated, locally adaptable systems.

Consequently, there exists a clear gap in the application of AI–IoT technologies for real-time and predictive nutrient management in greenhouse rose cultivation. This research aims to address this problem by developing an Intelligent Nutrition Management System that integrates real-time soil data, weather forecasts, and AI-based nutrient forecasting. The system will deliver stage-specific fertilizer recommendations for Sri Lankan greenhouse conditions, thereby improving fertilizer efficiency, flower yield quality, and environmental sustainability.

2. OBJECTIVES

2.1. Main Objectives

To design and develop an AI-driven, IoT-based Intelligent Nutrition Management System for greenhouse rose cultivation in Sri Lanka that analyzes real-time soil and environmental data to predict nutrient behavior and recommend the optimal fertilizer type, dosage, and timing for each plant growth stage, thereby improving nutrient efficiency, yield quality, and environmental sustainability.

2.2. Specific Objectives

1. Deploy and calibrate IoT-based sensors including NPK, pH, EC, soil moisture, temperature, and humidity sensors connected to an ESP32 microcontroller to collect real-time greenhouse data.
2. Train and validate a predictive model using time-series sensor data, agronomic guidelines, and weather inputs to forecast nutrient (NPK), pH, and EC trends and determine fertilizer requirements for different rose growth stages (vegetative, flowering, and maintenance).
3. Integrate weather API data to incorporate rainfall probability, humidity, and temperature forecasts, enabling intelligent scheduling or postponement of fertilizer applications to prevent salinity buildup and nutrient loss.
4. Develop user-friendly mobile dashboard that visualizes soil and climate data, displays fertilizer recommendations, and provides real-time alerts for farmer accessibility and decision support.
5. Conduct prototype testing and validation using live sensor data from greenhouse-grown rose plants in Sri Lanka to evaluate model accuracy, usability, and its impact on fertilizer efficiency and flower yield quality.

3. METHODOLOGY

The methodology for the Intelligent Nutrition Management for Greenhouse Roses is designed to integrate IoT-based greenhouse soil sensing with AI-driven predictive modeling to deliver accurate, stage-specific fertilizer recommendations.

This approach ensures proactive nutrient management by forecasting changes in NPK, pH, and EC, and optimizing fertilizer use according to plant growth stage and weather conditions.

3.1. System Architecture

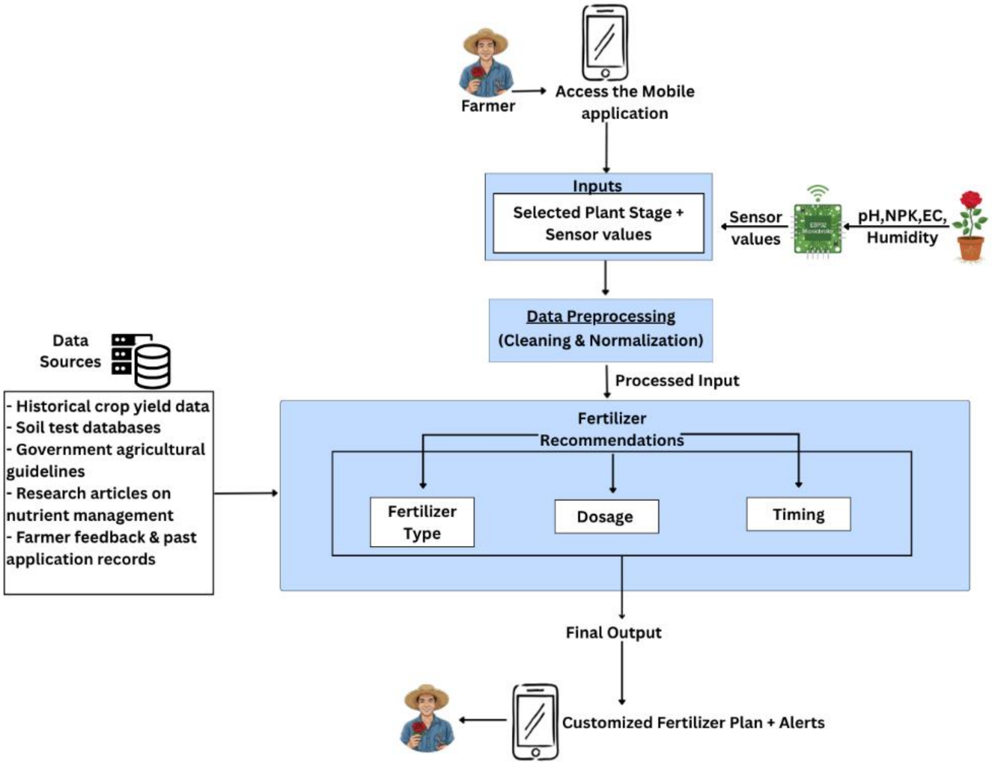

Figure 1:System Architecture Diagram

The workflow of the Intelligent Nutrition Management system describes how soil and environmental data are collected, processed, and transformed into real-time recommendations for greenhouse rose farmers. The system integrates IoT sensing, data preprocessing, ML prediction, and dashboard visualization, as illustrated in the system architecture diagram.

1. **Farmer Interaction and Input:** The process begins when the farmer opens the SmartRose mobile dashboard and selects the current plant growth stage Vegetative, Flowering, or Maintenance. This user input is essential to guide the AI model on nutrient requirements with each growth stage.
2. **Sensor Data Collection**: Simultaneously, the IoT sensor unit, consisting of an ESP32 microcontroller connected to NPK, pH, EC, soil-moisture, temperature, and humidity sensors, collects live readings from the rose cultivation setup. These data represent the real-time soil and environmental conditions that influence fertilizer decisions.
3. **Data Integration and Preprocessing:** The system merges the farmer's input with sensor readings. Before analysis, the data undergo cleaning and normalization to remove noise and convert all parameters to standard units. This step ensures that the input data is consistent, reliable, and ready for model processing.
4. **Predictive AI and Decision Engine:** The processed dataset is analyzed by the Recommendation Engine, which combines ML model forecasting and rule-based agronomic logic:
    - **ML Forecast Model:** Predicts 3–7day trends of NPK, pH, and EC to anticipate nutrient deficiencies or salt accumulation.
    - **Decision Logic Layer:** Applies agronomic rules and thresholds to recommend fertilizer actions.
    - **Optimization Output:**
        - **Fertilizer Type** – selects the best N:P: K ratio.
        - **Dosage** – computes quantity per plant or bed.
        - **Timing** – identifies safe application windows considering weather and soil moisture.
5. **Weather-Aware Adjustment:** The recommendation engine also connects with a Weather API to evaluate rainfall probability, and the fertilizer application is delayed or adjusted to prevent nutrient loss or EC buildup.
6. **Output Generation and Delivery:** The final output is a customized fertilizer and eco-spraying plan generated for the farmer.
    - Real-time soil readings and predicted 7-day nutrient trends.
    - Recommended fertilizer type, dosage, and timing.

  - Alerts and notifications and Status indicators.

7. **Feedback and Continuous Improvement:** After applying the fertilizer, the farmer can provide feedback or mark completion in the app. These records, along with updated sensor data, are stored for retraining the model, making the system progressively smarter and more adaptive to Sri Lankan greenhouses.

3.2. Project Execution Approach

The project will be carried out in five main phases:

1. Requirement Analysis & Literature Review
    - Conduct an in-depth literature review on greenhouse nutrient management, fertilizer scheduling, and soil health optimization for Rosa hybrida cultivation.
    - Study local rose greenhouse practices in areas such as Nuwara Eliya, Bandarawela, and Kandy to identify key issues in nutrient imbalance, salinity buildup, and manual fertilizer mixing.
    - Analyze existing precision agriculture and IoT-based nutrient management systems to identify suitable machine learning techniques (LSTM forecasting, Random Forest optimization) and low-cost sensor technologies.
    - Finalize the system requirements and parameters for sensor selection (NPK, pH, EC, moisture, temperature, humidity) and data collection frequency.
2. System Design and Architecture Development
    - Design the overall system architecture and data flow, including sensor-to-cloud transmission, AI model integration, and farmer interaction via a mobile dashboard.
    - Define data attributes, input output relationships, and API integration for weather forecasting.
    - Draft UML diagrams, component diagrams, and system architecture drawings.
    - Select technologies (ESP32, Node-RED, Firebase, Python, scikit-learn, TensorFlow Lite, etc.).

3. Data Collection and Model Training
    - Deploy IoT sensors in test pots or a small-scale greenhouse to collect real-time NPK, pH, EC, moisture, temperature, and humidity data.
    - Supplement sensor data with agronomic reference values and synthetic data for model training.
    - Preprocess and label the dataset with fertilizer type, amount, and timing recommendations.
    - Train and validate an LSTM-based predictive model to forecast nutrient and EC trends and integrate decision rules for fertilizer recommendations.
4. System Integration and Dashboard Development
    - Develop the backend to connect sensor data, predictive model outputs, and weather API inputs for real-time decision support.
    - Design a mobile dashboard for farmers to view live soil data, trend graphs, and fertilizer recommendations.
    - Implement alert and notification features to send messages.
    - Implement a feedback mechanism for farmers to confirm actions, enabling continuous model retraining.
5. Testing, Validation, and Evaluation
    - Test the prototype with 1–2 greenhouse rose setups or potted plants to assess data accuracy and model reliability.
    - Compare model recommendations against agronomist-verified fertilizer standards and analyze prediction accuracy using RMSE, MAE, and R^2 metrics.
    - Evaluate improvements in fertilizer efficiency, EC control, and flower yield quality compared to manual methods.
    - Conduct user evaluation local rose farmers and agriculture experts to assess usability, understandability, and practical value.

3.3. Data Requirements & Collection

- Data Requirements

Table 2: Data Requirements

Data Category	**Description**	**Source / Instrument**	**Purpose**
Soil Nutrient Data	Nitrogen (N), Phosphorus (P), and Potassium (K) concentrations (mg/kg)	NPK sensor module	To determine nutrient deficiencies and fertilizer requirements
Soil Acidity Data	Soil pH levels (3–9 range)	Analog pH sensor	To adjust fertilizer type (acidic vs. alkaline balancing)
Soil Moisture Data	Water percentage in soil (%)	Capacitive soil-moisture sensor	To decide optimal fertigation timing
Electrical Conductivity (EC) Data	Measures salt concentration in soil solution (mS/cm).	EC sensor	To monitor salinity buildup and schedule flushing or dilution actions.
Environmental Data	Ambient temperature and humidity	DHT22 sensor	To adjust nutrient predictions based on evaporation rate and humidity impact.
Plant Growth Stage	Rose plant growth phase (vegetative, flowering, maintenance)	Manual farmer input	To align nutrient requirements with growth stage
Fertilizer Records	Type, dosage, and timing of applied fertilizers	Expert input and synthetic dataset	Used to label training data for ML model
Agronomic Reference Data	Standard fertilizer recommendations for roses in Sri Lanka	Department of Agriculture, local floriculture studies	To validate system output and define nutrient levels.

- Data Collection

1. **Sensor Data Collection:**

- IoT sensors (NPK, pH, EC, moisture, temperature, and humidity) are connected to an ESP32 microcontroller.
- The sensors are installed in 1–2 potted rose plants or within a small greenhouse rose bed to simulate realistic growing conditions.
- The ESP32 collects readings at regular time intervals and sends data to a Firebase or Node-RED dashboard.
- The data includes soil nutrient levels, pH, EC, temperature, humidity, and moisture.

2. **Weather Data Collection:**

- The system uses a weather API to get rainfall probability, humidity, and temperature forecasts.
- These data help the system decide whether to delay fertilizer or spraying activities during unfavorable weather conditions.

3. **Fertilizer and Growth Stage Data:**

- Farmers manually enter the current growth stage of the rose plant (vegetative, flowering, maintenance).
- Fertilizer details (type, quantity, and timing) are recorded to label and train the ML model.
- Local fertilizer guidelines from the Department of Agriculture and local agribusinesses.

4. **Synthetic Data Generation:**

- To increase the dataset size, additional data are created by simulating different soil conditions and fertilizer responses using known agronomic values.
- These synthetic records help the AI model learn to learn from a wider range of soil conditions and fertilizer responses.

5. **Data Preprocessing:**

- The collected data is exported to CSV files.
- Errors or missing values are cleaned, and numeric values (pH, NPK, EC, temperature) are normalized for model training.
- The final dataset is then split into training (80%) and testing (20%) sets.

4. PROJECT REQUIREMENTS

4.1. Functional Requirements

The system must provide the following functions:

1. Collect continuous soil and environmental data using NPK, pH, EC, soil-moisture, temperature, and humidity sensors connected to an ESP32 microcontroller.
2. Send all sensor readings to a cloud database for processing and visualization.
3. Analyze real-time and historical data using a trained ML model to forecast nutrient (NPK, pH, EC) trends and detect potential deficiencies or salinity risks.
4. Generate fertilizer recommendations (type, dosage, and timing) automatically based on predicted values, agronomic thresholds, and plant growth stage.
5. Optimize fertilizer timing and prevent nutrient loss during unfavorable soil conditions.
6. Display alerts and recommendations through a dashboard with visual indicators, graphs, and notification features for farmers.
7. Record historical fertilizer actions and model outputs for continuous learning, system improvement, and validation of AI prediction accuracy.

4.2. Non-Functional Requirements

1. Performance: The system must process incoming sensor readings and update fertilizer recommendations or alerts on the dashboard within 5 seconds of data receipt.
2. Scalability: Support multiple sensor nodes for different rose beds or locations.
3. Sustainability: Use low-cost, low-power hardware (ESP32) and locally available materials for ease of adoption by Sri Lankan middle-scale farmers.
4. Security: Ensure secure cloud communication.
5. Usability: Provide a simple, visually clear dashboard accessible on smartphones.
6. Maintainability: Modular architecture allowing separate updates for sensors, ML model, and UI without full redeployment.
7. Reliability: The system must recover from power or connectivity loss without losing recent sensor readings.

4.3. User Requirements

- Middle Scale Greenhouse Rose Farmers
    - A simple mobile interface to view soil readings (pH, N, P, K, EC, moisture).
    - Clear fertilizer and spraying recommendations showing type, quantity, and timing.
    - Alerts indicate when rainfall or humidity levels may affect spraying or fertilization.
    - Eco-friendly guidance to reduce fertilizer waste and avoid overuse.

4.4. System Requirements

Hardware Requirements

- **Microcontroller:** ESP32 Dev Board with built-in Wi-Fi connectivity.
- **Sensors:** NPK Sensor (for Nitrogen, Phosphorus, Potassium levels), pH Sensor (for soil acidity/alkalinity), EC sensors, Capacitive Moisture Sensor (for soil water content), DHT22 Sensor (for temperature and humidity monitoring)
- **Computer / Server:** Intel i5 processor or higher, 8–16 GB RAM, 1 TB storage for ML model training and hosting.
- **Connectivity:** Wi-Fi network or mobile hotspot for ESP32 to transmit sensor data to the cloud.

Software Requirements

- **Programming Languages:** Python, JavaScript
- **Frameworks / Libraries:** scikit-learn / TensorFlow, React or Flutter
- **Database:** MySQL
- **API Services:** OpenWeatherMap API
- **IDE / Tools:** Arduino IDE, VS Code, Jupyter Notebook, Figma / Draw.io for software development and design.
- **Deployment Environment:** AWS

4.5. Use Case Diagram

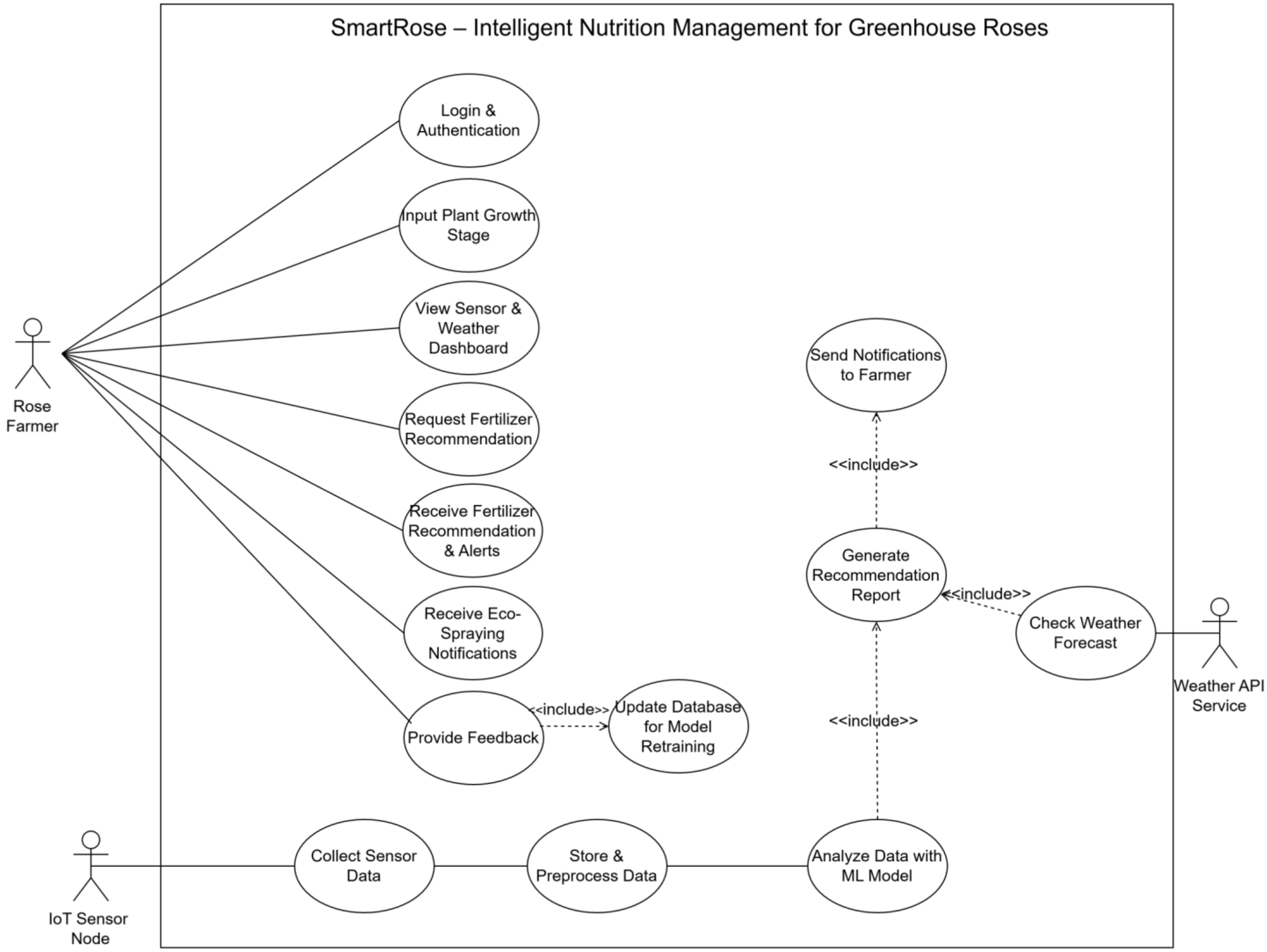

Figure 2:Use Case Diagram of Intelligent Nutrition Management for Greenhouse Roses

5. Ghantt Chart

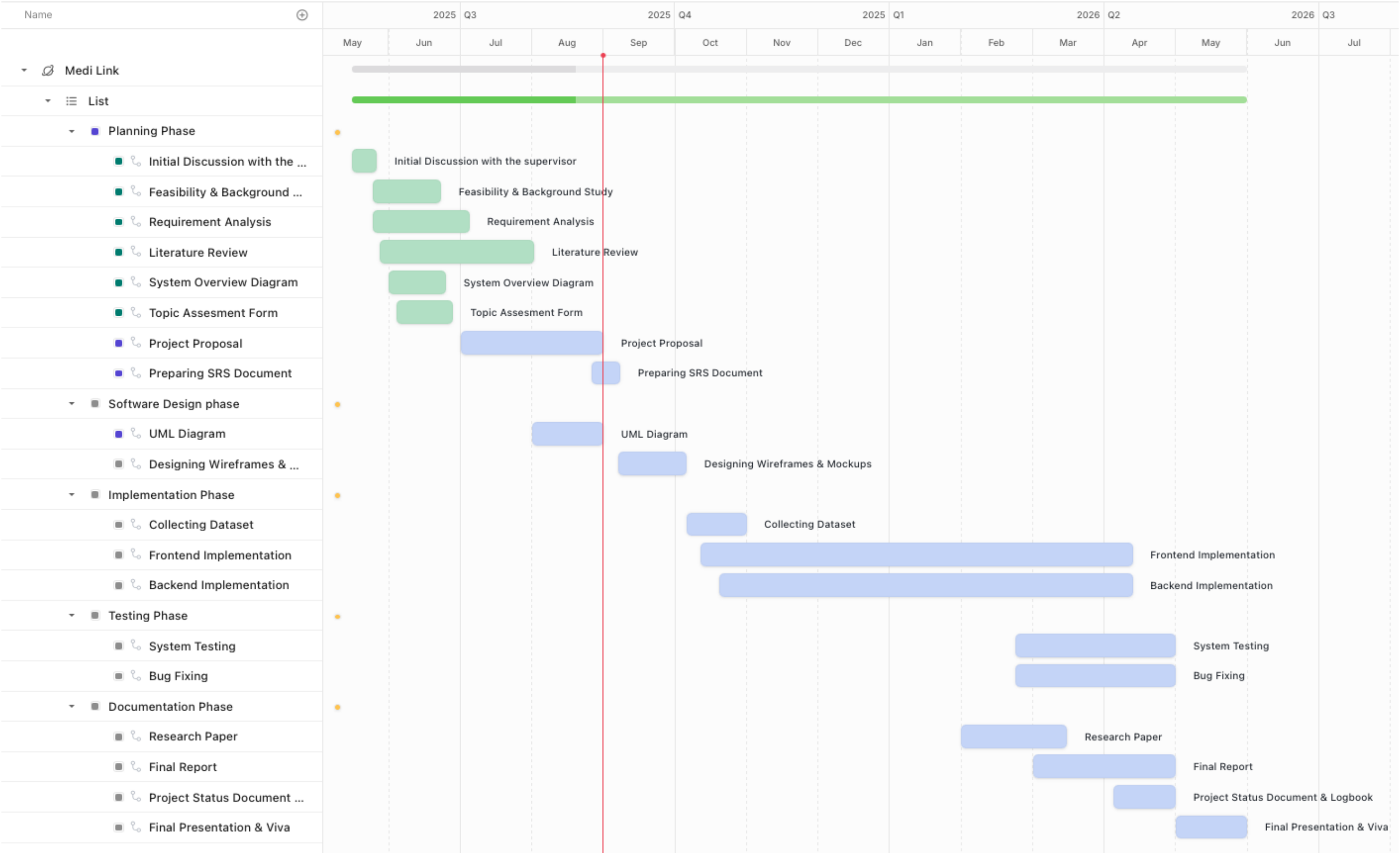

Figure 3:Ghantt Chart

5.1. Work Breakdown Chart

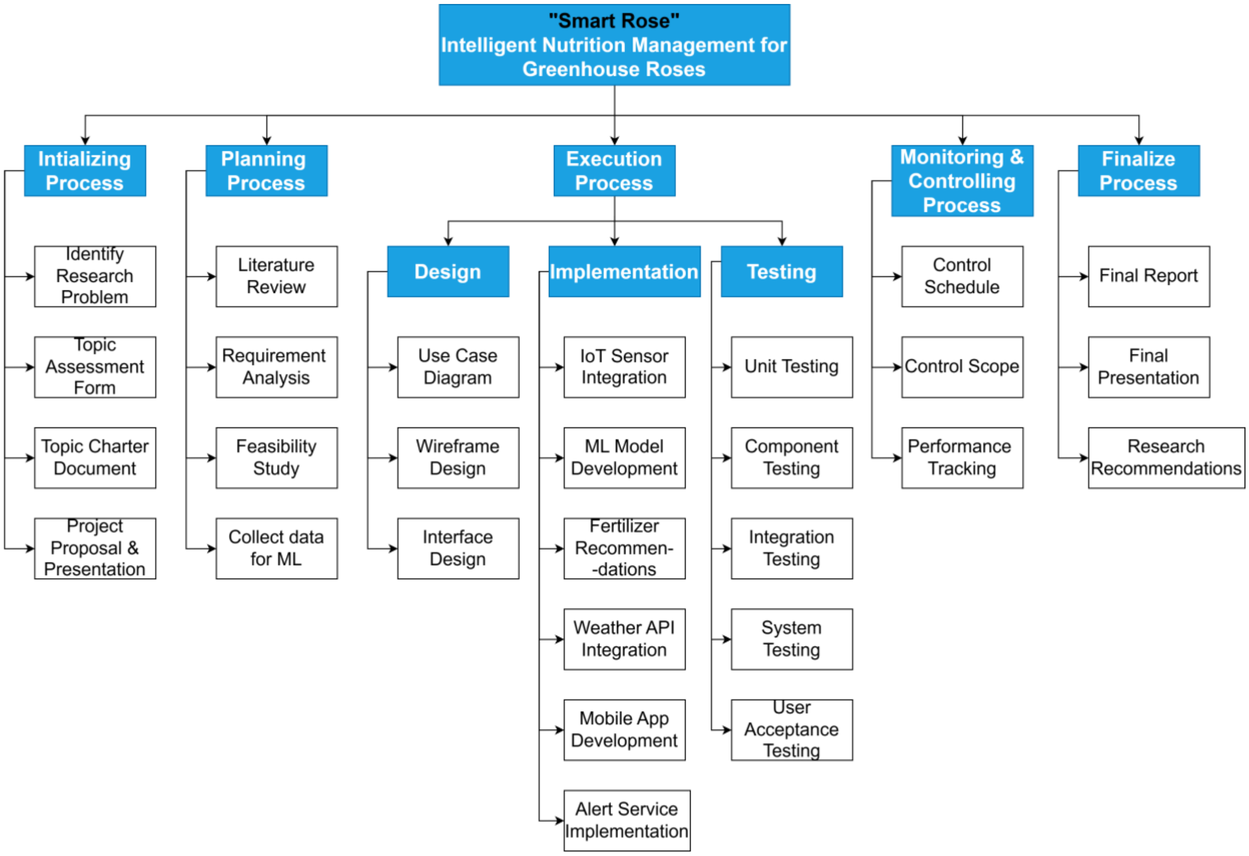

Figure 4:Work Breakdown Chart

6. DESCRIPTION OF PERSONAL AND FACILITIES

6.1. Personnel

This research is conducted individually by Perera W.P.M.A.N. (Student ID: IT22326522), an undergraduate student in the B.Sc. (Hons) in Information Technology program at the Sri Lanka Institute of Information Technology (SLIIT).The student is responsible for the design, development, and evaluation of the AI- and IoT-based Intelligent Fertilizer & Eco-Spraying Advisor, of the SmartRose: AI–IoT Platform for Smart Rose Farming in Sri Lanka project.

Key responsibilities include:

- Conducting literature review on smart agriculture, greenhouse management, fertilizer management, and IoT-based nutrient monitoring.
- Designing the IoT data-collection framework using ESP32 and soil/environmental sensors and developing and training the machine-learning model for fertilizer recommendation and eco-spraying decisions.
- Performing testing and validation using potted rose plants or within a small greenhouse rose bed to simulate realistic growing conditions.
- Preparing technical documentation, analysis reports, and the final research presentation.

The project is supervised by Dr. Junius Anjana (Supervisor) and Ms. Kaushika Kahatapitiya (Co-Supervisor), who provide expertise in artificial intelligence, healthcare informatics, and intelligent system design.

6.2. Facilities

The researcher will make use of the following facilities and resources to complete the project:

1. **Computing Facilities**: Personal laptop with Intel i7 processor and 16 GB RAM for software development, data analysis, and model training.
2. **Hardware and IoT Equipment**: ESP32 Dev Board, NPK sensor, pH sensor, EC sensor, DHT22 (temperature + humidity), capacitive soil-moisture sensor,1–2 potted rose plants for controlled data collection and system validation.

3. **Software and Development Tools:** Python, Arduino IDE for ESP32 programming, React or Flutter for user-interface development, Figma and Draw.io for system architecture and UI design diagrams.
4. **Cloud and Hosting Resources**: AWS cloud for data storage and model deployment and OpenWeatherMap API for weather data integration.
5. **University and Support Facilities**: Access to library resources, and Turnitin plagiarism checking and continuous consultation and progress reviews with supervisors.

These facilities ensure that the project can be successfully developed, tested, and evaluated within the scope of the undergraduate research framework.

7. BUDGET AND BUDGET JUSTIFICATION

Table 3: Comparison of Budget

Item	**Description**	**Estimated Cost (LKR)**
Laptop / PC (existing)	Development and ML model training (16GB RAM, i7 processor)	0 (already available)
Cloud Hosting (AWS)	Deployment and testing of prototype	15,000
Software Tools (IDE, GitHub, Figma, Draw.io)	Open source / free academic licenses (for design, version control, wireframes)	0
Travelling	Travelling to Rose Farms	30,000

Total Estimated Budget: LKR 45,000

8. COMMERCIALIZATION AND ENTREPRENEURSHIP POTENTIAL

The Intelligent Nutrition Management for Greenhouse Roses component has strong commercialization and entrepreneurship potential as both a stand-alone smart-farming solution and a key module within the broader SmartRose AI–IoT Platform.

Sri Lanka's floriculture industry, particularly greenhouse rose cultivation in regions such as Nuwara Eliya, Kandy, and Bandarawela is expanding rapidly. However, most middle-scale farmers still rely on manual fertilizer mixing and observation-based decisions, leading to nutrient imbalance and rising operational costs. This creates a clear opportunity for an affordable, predictive AI–IoT tool that improves fertilizer efficiency, yield, and long-term soil health.

Market Opportunity

- **Primary Market:** Middle-scale greenhouse rose farmers in Sri Lanka who face challenges with nutrient imbalance, salinity buildup, and inefficient fertilizer use.
- **Secondary Market:** Larger commercial flower farms, horticultural training institutes, and greenhouse operators seeking automation in nutrient and irrigation management.
- **Global Expansion:** The system can be adapted for other high-value greenhouse crops such as gerbera, chrysanthemum, and carnation, or tropical floriculture markets across South and Southeast Asia.

Revenue and Business Model

- **Software-as-a-Service (SaaS):** A subscription-based model where farmers or greenhouse owners pay a monthly or seasonal fee to access live nutrient forecasts and fertilizer recommendations.
- **Hardware Starter Kit:** A low-cost IoT kit (ESP32 + sensors) sold with one-year cloud access. Farmers can self-install and view readings through a bundled mobile app.
- **Enterprise Customization:** Larger farms and cooperatives can purchase customized dashboards, analytics modules, or multi-greenhouse integrations for a one-time setup fee.

Competitive Advantage

- **Localized Greenhouse Intelligence:** The first AI–IoT fertilizer management system specifically designed for Sri Lankan rose greenhouses.
- **Low-Cost Hardware:** Uses ESP32 and locally available sensors, making it affordable for small farmers.
- **Predictive AI Model:** Predict nutrient changes before deficiencies occur, improving precision and reducing waste.
- **Eco-Sustainable Design:** Weather-aware logic and EC control minimize fertilizer runoff, promoting environmentally responsible farming.
- **Scalability:** Modular design allows integration with other SmartRose components such as disease-control and freshness-monitoring modules.

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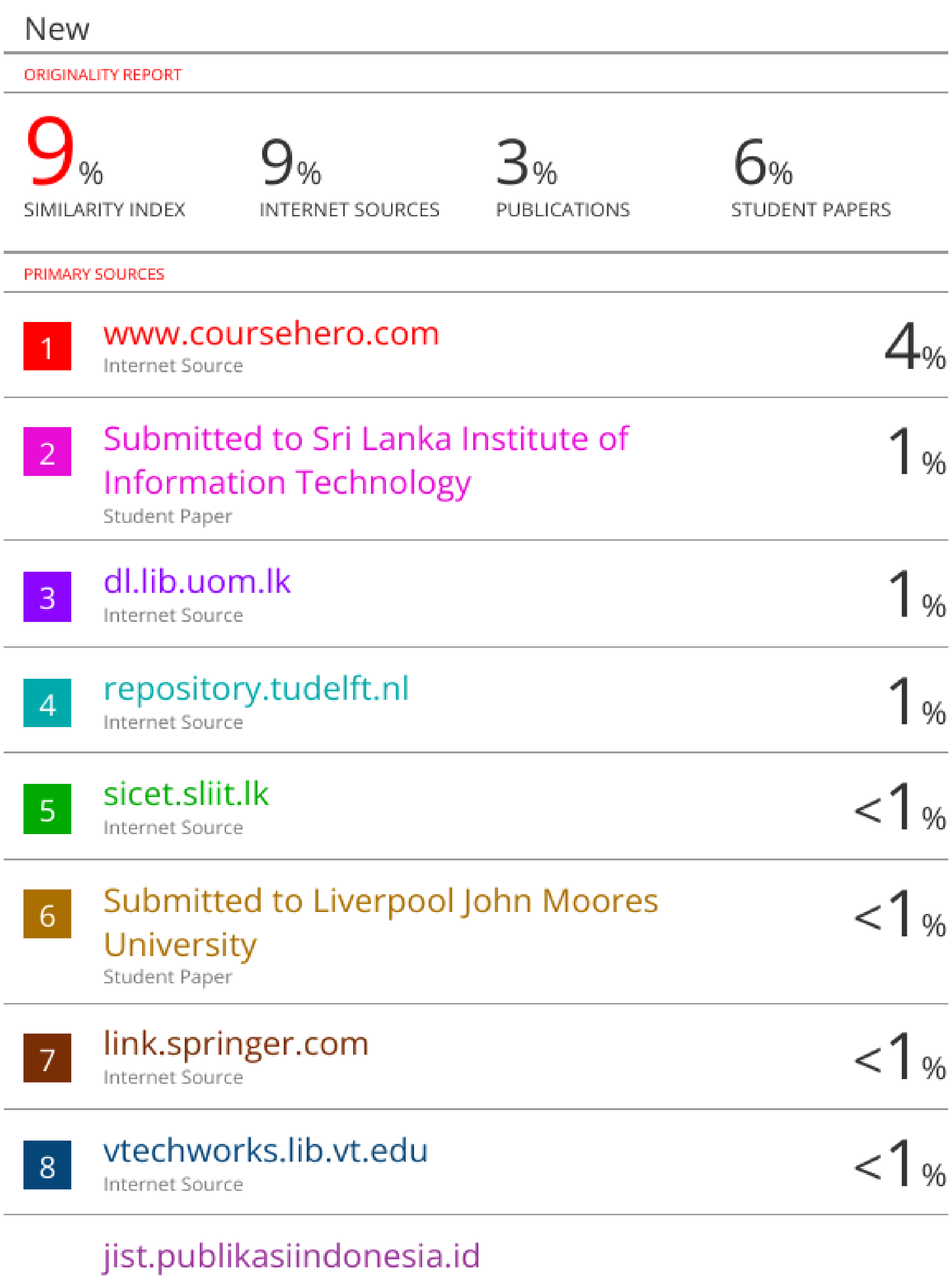
10.APPENDICES

10.1. Appendix A: Plagiarism Report



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Appendix A: Plagiarism Report