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Knowledge Based System for Diagnosis Tomato Diseases

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Abstract— ***Background:*** *Tomato diseases are among the most serious threats to agricultural production worldwide, causing significant reductions in crop yield, deterioration of fruit quality, and severe economic losses for farmers. According to global agricultural studies, plant pests and diseases account for nearly 40% of annual crop losses, with tomatoes being particularly vulnerable due to their perishable nature and susceptibility to multiple pathogens.* ***Objectives:*** *This paper presents TomatoPulse, a knowledge-based expert system designed to support the early detection and diagnosis of seven economically important tomato diseases: Fusarium Wilt, Bacterial Wilt, Early Blight, Late Blight, Gray Mold, Powdery Mildew, and Tomato Mosaic Virus. The primary goal is to assist farmers, agricultural engineers, and students in accurately identifying disease symptoms and recommending suitable treatment options.* ***Methods:*** *The system integrates a rule-based expert system implemented in CLIPS with a user-friendly interface developed in Delphi. The interface guides users through symptom selection and provides corresponding diagnostic outcomes. The knowledge base was constructed from validated agricultural datasets, expert consultations, and published scientific literature.* ***Results:*** *Preliminary evaluation by agricultural specialists and students indicated high satisfaction with the system's accuracy, response time, and ease of use. Diagnostic results demonstrated consistency with expert assessments and published agricultural guidelines.* ***Conclusion:*** *TomatoPulse highlights the potential of expert systems in agricultural decision support, offering a reliable and accessible diagnostic tool that reduces dependency on immediate expert availability, promotes informed disease management, and contributes to sustainable tomato production, particularly in resource-limited farming communities.*

Keywords— Tomato diseases, Expert system, CLIPS, Knowledge-based system, Agricultural diagnosis, Decision support.

1. INTRODUCTION

Tomato (*Solanum lycopersicum*) is one of the most important vegetable crops cultivated worldwide due to its nutritional value, economic significance, and versatile applications in food industries. Tomatoes are rich in vitamins, minerals, and antioxidants, making them a staple in diets across the globe and a key contributor to food security [1–3]. According to the Food and Agriculture Organization (FAO), tomato production represents a major source of income for millions of farmers, particularly in developing countries, but remains highly vulnerable to diseases caused by fungi, bacteria, and viruses [4,5]. These diseases can lead to severe yield losses, with annual global losses estimated to reach up to 40%, significantly impacting food supply chains and agricultural economies [6].

Figure 1: Healthy tomato plant.

In many rural and underserved farming regions, accurate and timely diagnosis of tomato diseases is challenging due to limited access to agricultural specialists and advanced diagnostic laboratories. Farmers often rely on traditional knowledge or visual inspection, which may lead to incorrect diagnoses and delayed treatments. This often exacerbates disease spread and contributes to unnecessary pesticide use, increased production costs, and environmental risks [7,8].

To address this gap, artificial intelligence (AI) applications, and in particular expert systems, have shown potential in revolutionizing agricultural diagnostics and supporting precision farming practices [9,10]. An expert system is a branch of AI designed to simulate the reasoning process of a human expert. It integrates three essential components: a knowledge base that stores domain-specific facts and rules, an inference engine that processes these rules to infer solutions, and a user interface developed using Delphi that enables efficient interaction with end-users [11–13].

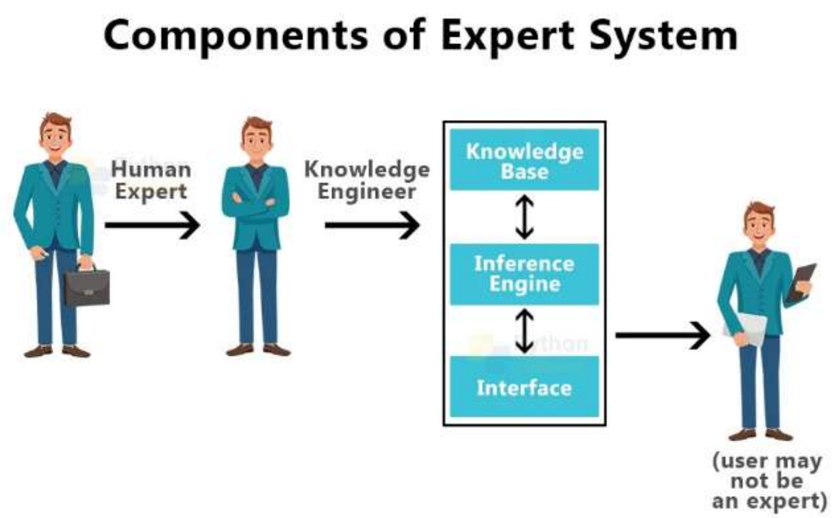

Figure 2: General Architecture of an Expert System for Plant Disease Diagnosis.

The integration of expert systems in agriculture has been successfully applied to various crops, including coconut, apple, potato, and even livestock management, with significant improvements in diagnostic accuracy and decision-making speed [14–16]. However, systems specifically targeting tomato diseases are still limited despite their substantial economic and food security impact.

This paper introduces TomatoPulse, a knowledge-based expert system developed specifically for diagnosing seven common tomato diseases: Fusarium Wilt, Bacterial Wilt, Early Blight, Late Blight, Gray Mold, Powdery Mildew, and Tomato Mosaic Virus. The system leverages the CLIPS inference engine and includes a user-friendly interface developed using Delphi to ensure accessibility for farmers, agricultural engineers, and students. Users select observed symptoms from a visual checklist, and the system produces disease diagnoses along with recommended treatments and visual confirmation through images.

By providing early, accurate, and automated diagnosis, TomatoPulse aims to enhance disease management strategies, reduce unnecessary pesticide use, and minimize crop losses. This research demonstrates how AI-based expert systems can support sustainable agriculture and empower communities with limited access to plant pathology expertise.

2. MATERIALS AND METHODS

The TomatoPulse Expert System was designed and implemented to support early detection and diagnosis of tomato diseases. The system follows a **rule-based expert system approach**, utilizing **CLIPS** for knowledge representation and reasoning, and a user interface developed using Delphi for user interaction. This section outlines the materials and methodologies adopted during the development of the system.

2.1 Development Tools and Environment

The expert system was implemented using **CLIPS 6.3**, chosen for its wide adoption in expert system development, ease of knowledge representation, and efficient forward-chaining inference engine. A lightweight GUI framework was developed using Delphi to simplify interaction, ensuring usability for farmers with minimal technical background as well as agricultural engineers. The hardware requirements are minimal, allowing the system to run on standard personal computers and laptops without specialized hardware. Similar approaches using CLIPS have proven effective in prior agricultural expert systems [16–20].

2.2 Knowledge Acquisition

Knowledge for TomatoPulse was acquired from multiple reputable agricultural sources, including the Seminis Tomato Disease Guide [21], FAO reports [22], and peer-reviewed literature on tomato plant pathology [23–25]. Expert consultations were also conducted to verify the accuracy of symptom–disease relationships and treatment recommendations.

Table 1 summarizes the seven tomato diseases considered in TomatoPulse, highlighting key symptoms and representative images.

#	Disease Name	Description	Image
1.	Fusarium Wilt	Soil-borne fungal disease (Fusarium oxysporum f.sp. lycopersici) causing unilateral yellowing, vascular browning, and gradual wilting.	 *Table1-ImgA: Fusarium Wilt*
2.	Bacterial Wilt	Caused by *Ralstonia solanacearum*, leading to sudden wilting without yellowing and bacterial ooze from cut stems.	 *Table1-ImgB: Bacterial Wilt*
3.	Early Blight	Induced by *Alternaria solani*, producing concentric target-like lesions on older leaves and brown lesions on stems and fruits.	 *Table1-ImgC: Early Blight*

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4.	Late Blight	Caused by *Phytophthora infestans*, with water-soaked lesions, rapid decay, and white fungal growth under humid conditions.	 *Table1-ImgD: Late Blight*
5.	Gray Mold	Caused by *Botrytis cinerea*, recognizable by fuzzy gray mold on flowers, stems, and fruits.	 *Table1-ImgE: Gray Mold*
6.	Powdery Mildew	Fungal disease caused by *Oidium neolycopersici*, forming white, powdery fungal growth on leaf surfaces.	 *Table1-ImgF: Powdery Mildew*

7.	Tomato Mosaic Virus	Viral disease showing mosaic leaf patterns, curling, deformation, and stunted plant growth.	 *Table1-ImgG: Tomato Mosaic Virus*

Table 1: Tomato Diseases Summary

The knowledge base encodes these diseases as production rules that map symptom patterns to specific disease outcomes and associated treatment guidelines.

2.3 System Architecture

The TomatoPulse expert system is structured into three primary modules, each serving a critical role in ensuring accurate and efficient disease diagnosis:

1. **Knowledge Base** – Contains the domain-specific knowledge represented as production rules. These rules encode the relationships between observable symptoms and their corresponding tomato diseases, including associated treatment guidelines, ensuring the system's diagnostic reliability.
2. **Inference Engine** – Implements a forward-chaining reasoning mechanism to process the knowledge base rules. It systematically evaluates the selected symptoms, matches them with encoded patterns, and determines the most probable disease outcome with minimal computational overhead.
3. **User Interface (UI)** – Provides an intuitive and interactive environment for end-users, allowing them to input observed symptoms through a checklist format and to view diagnostic results and recommended treatments in a user-friendly visual layout. The UI is developed using Delphi, ensuring efficient interaction and accessibility for all users.

This modular design ensures scalability, maintainability, and ease of integration with future enhancements such as addition of new crops or more advanced reasoning capabilities.

Figure 3 illustrates the main interface of the TomatoPulse Expert System.

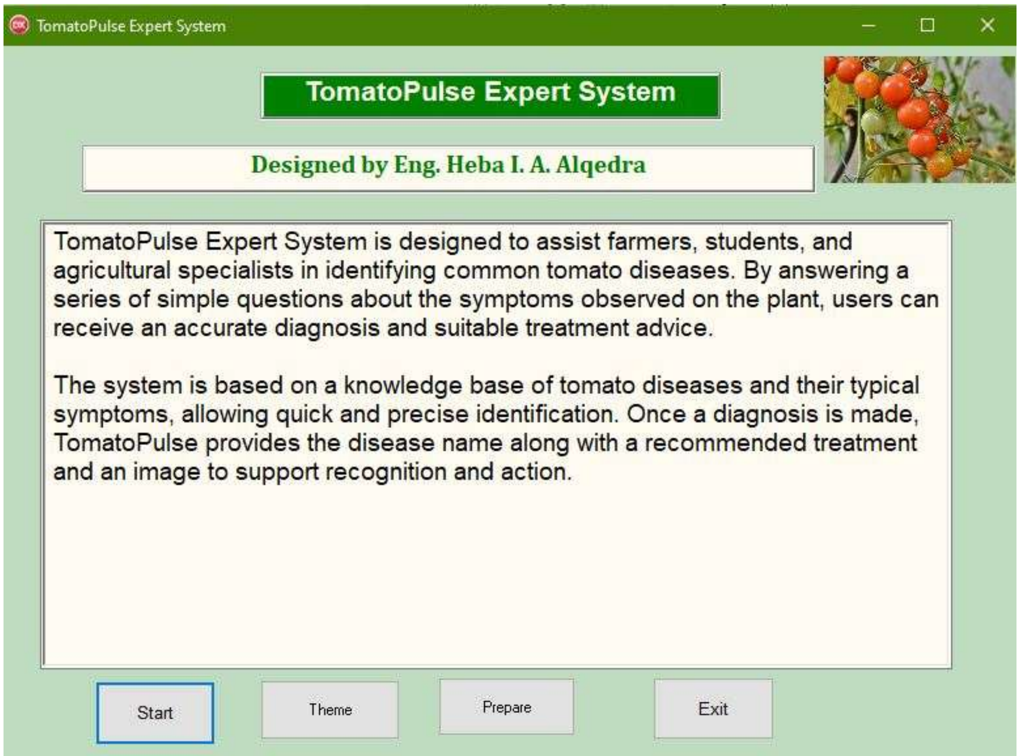

Figure 3: Home interface of TomatoPulse Expert System.

Figure 4 presents the symptom selection interface where users select observable symptoms on the tomato plant.

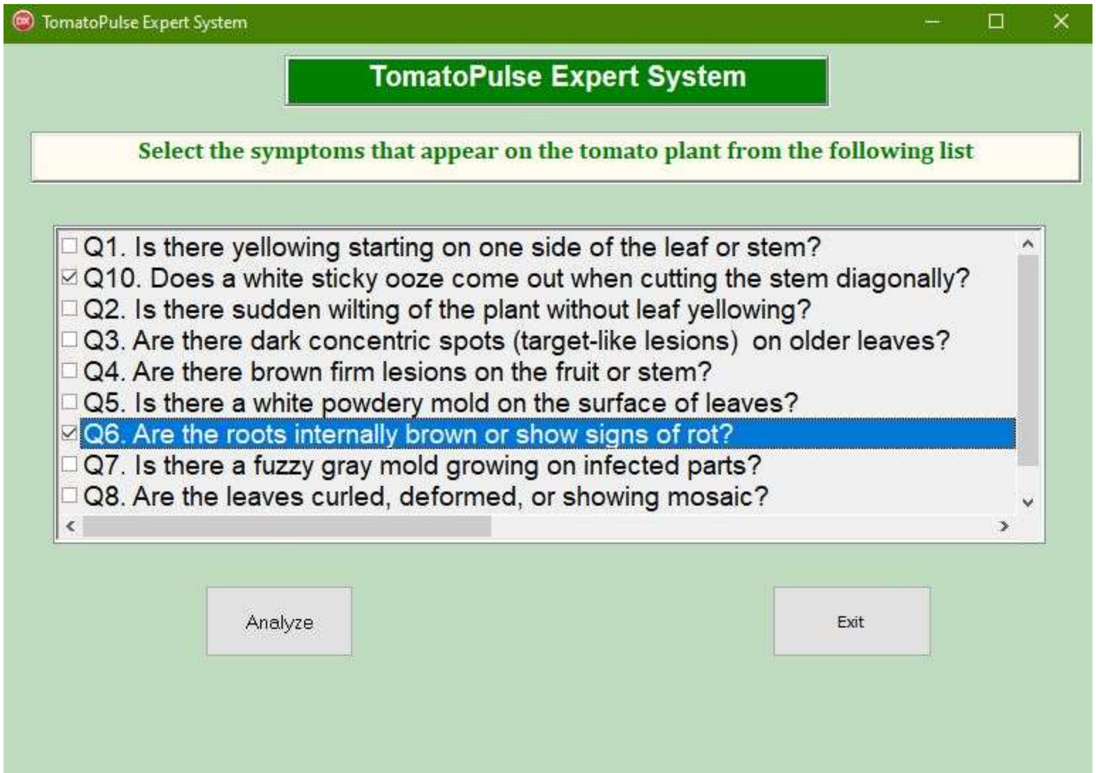

Figure 4: Symptoms selection Interface.

Figure 5 shows the diagnosis interface, displaying the identified disease and recommended treatment.

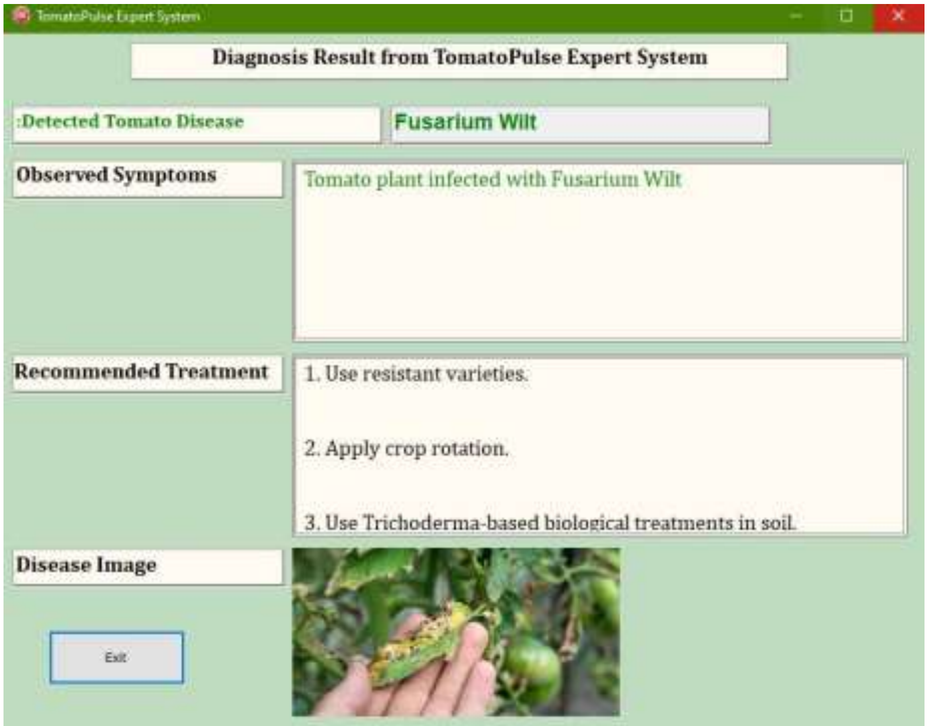

Figure 5: Diagnosis output interface.

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2.4 Workflow and Diagnosis Process

The TomatoPulse Expert System operates through a structured workflow that ensures accurate and efficient diagnosis:
1. Symptom Selection: Users select all observable symptoms from a checklist provided in the graphical interface developed using Delphi.
2. Rule Matching: The inference engine compares the selected symptoms with the encoded production rules stored in the knowledge base.
3. Disease Identification: Based on matched rules, the system determines the most probable disease affecting the tomato plant.
4. Treatment Recommendation: The system displays appropriate treatment guidelines, including preventive and curative measures tailored to the diagnosed disease.
5. Result Output: The final diagnosis and treatment recommendation are presented to the user in a clear and interpretable format.

This approach aligns with standard expert system methodologies used in agricultural decision support, ensuring both accuracy and usability in real-world farming environments [26–27].

3. LITERATURE REVIEW

Expert systems have become widely adopted in agriculture due to their ability to replicate expert reasoning and provide decision support in environments where access to human expertise is limited. These systems have been implemented across diverse domains such as disease diagnosis, irrigation scheduling, soil fertility assessment, and pest control [28–30]. Rule-based reasoning is particularly favored for its transparency, explainability, and ease of implementation, enabling both agricultural engineers and farmers to understand how conclusions are derived [31].

Numerous studies have demonstrated that expert systems significantly improve diagnostic accuracy and reduce error rates compared to manual field inspections. For instance, a rule-based system for coconut disease diagnosis enhanced detection performance by integrating structured symptom-based rules and visual cues for symptom recognition [32]. Similarly, research on potato disease expert systems showed how embedding domain knowledge from plant pathologists into computational reasoning frameworks can yield reliable diagnostic outputs and optimize treatment recommendations [33–34].

In the case of tomato diseases, recent research has focused primarily on image-based machine learning models for automated disease detection [35], hybrid systems combining rule-based reasoning with fuzzy logic [36], and mobile applications aimed at reaching farmers in remote areas [37-39]. While these solutions offer promise, they frequently require high computational resources, stable internet connectivity, or extensive user training — factors that limit their practicality in many resource-constrained agricultural setting [40-49]s.

To address these limitations, TomatoPulse was developed as a lightweight, standalone, and transparent rule-based expert system tailored for early diagnosis of seven major tomato diseases: *Fusarium Wilt, Bacterial Wilt, Early Blight, Late Blight, Gray Mold*, *Powdery Mildew*, and *Tomato Mosaic Virus*. The system leverages the advantages of rule-based logic, structured symptom encoding, and a graphical interface developed using Delphi., allowing it to run efficiently on low-specification devices without compromising diagnostic performance [50-59]

This literature review highlights the ongoing need for accessible, interpretable, and scalable expert systems in tomato disease management. By bridging the gap between advanced diagnostic techniques and real-world usability, TomatoPulse establishes itself as a robust decision-support tool for farmers, agricultural engineers, and students — particularly in underserved communities with limited access to plant pathology expertise.

4. KNOWLEDGE REPRESENTATION

The **TomatoPulse expert system** adopts a **rule-based knowledge representation** approach implemented in the **CLIPS** language. This method encodes expert knowledge on tomato diseases using production rules, making the system both transparent and machine interpretable [60-78].
Each rule in the system comprises two parts:

- **IF conditions**: Logical checks for specific observable symptoms.
- **THEN actions**: Diagnostic conclusions and result output once the conditions are satisfied.

The system employs a **forward-chaining reasoning** mechanism, where the inference engine evaluates user-selected symptoms against all defined rules to determine the most probable disease diagnosis.
For example, **Fusarium Wilt** is diagnosed when both **unilateral yellowing** and **root browning** are present. Figure 6 shows the corresponding CLIPS rule for this condition.

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Figure 6: CLIPS rule for Fusarium Wilt (Disease 1)

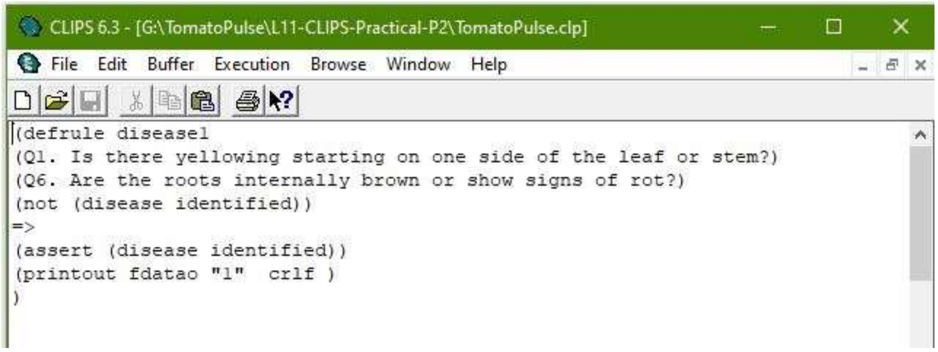

Figure 6: CLIPS rule for Fusarium Wilt (Disease 1).

This approach ensures clarity and interpretability—key advantages in agricultural expert systems used by farmers and agricultural engineers. Rule-based expert systems have been widely adopted in crop diagnostics for coconut, potato, apple, and other agricultural domains [38–40].

5. LIMITATION

The current version of TomatoPulse supports diagnosis for only seven specific tomato diseases: Fusarium Wilt, Bacterial Wilt, Early Blight, Late Blight, Gray Mold, Powdery Mildew, and Tomato Mosaic Virus. It relies entirely on user-provided symptom inputs and does not account for overlapping symptoms, co-infections, or ambiguous cases. Additionally, the system does not yet incorporate real-time image analysis or adaptive learning features.

6. SYSTEM EVALUATION

The TomatoPulse expert system was preliminarily evaluated by agricultural engineers, instructors, plant science students, and farmers. They reported overall satisfaction with its diagnostic accuracy, user-friendly interface, and ease of use.

7. FUTURE WORK

Future development of the TomatoPulse Expert System will focus on several key enhancements:

- **Expanding Disease Coverage**: Extending the knowledge base to include additional tomato diseases and support for other crops such as cucumber, pepper, and eggplant.
- **Image-Based Diagnosis**: Integrating machine learning techniques for visual analysis of leaf and fruit symptoms to complement the rule-based engine.
- **Mobile Application Deployment**: Developing a mobile version to increase accessibility for farmers in remote or low-resource environments.
- **Real-Time Data Integration**: Linking the system with weather and agricultural databases to enable dynamic updates and improve diagnostic accuracy.
- **Multilingual Support**: Adding support for multiple languages to ensure usability across diverse user groups and regions.

These enhancements aim to improve the system’s scalability, flexibility, and practical applicability in real-world agricultural settings.

8. CONCLUSION

This paper introduced **TomatoPulse**, a rule-based expert system developed to facilitate the early diagnosis of seven economically significant tomato diseases. By integrating the CLIPS inference engine with a user-friendly graphical interface, the system enables transparent, interpretable, and efficient diagnosis based on observable symptoms. **TomatoPulse** addresses a critical gap in agricultural diagnostics, particularly in underserved areas where access to plant pathology experts is limited. Preliminary evaluations indicated strong user satisfaction regarding the system’s usability, diagnostic accuracy, and responsiveness. Future improvements will aim to expand the system's scope by incorporating additional tomato diseases and other crops, integratinge-based diagnostic features powered by machine learning, and deploying mobile and multilingual versions to enhance accessibility. The

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successful development of **TomatoPulse** demonstrates the promising role of artificial intelligence in supporting sustainable, informed, and accessible agricultural decision-making.

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