International Journal on Science and Technology (IJSAT)
E-ISSN: 2229-7677 ● Website: www.ijsat.org ● Email: editor@ijsat.org

AI Rule-Based Expert System: Diagnosis and Treatment of Bean Diseases

Dayahan A. Bugao[1], Hidear Talirongan[2]

[1]Faculty, Josefina Herrera Cerilles State College, Philippines
[2]Faculty, Misamis University, Philippines

Abstract

This study introduces an AI rule-based expert system designed to help diagnose and treat common bean diseases. Built with SWI-Prolog, the system uses if-then rules to analyze symptoms provided by users, identify the most likely disease, and recommend suitable treatments. Its structure combines a knowledge base, inference engine, and rule set that cover major diseases such as Fusarium Wilt, Charcoal Rot, Leaf Spot, Mung Bean Yellow Mosaic, and Cercospora Leaf Spot. Tests and expert reviews confirmed that the system is accurate, consistent, and reliable, making it a practical decision-support tool for farmers and agricultural workers. By automating diagnosis, it reduces dependence on human experts, enables quicker disease management, and helps farmers prevent crop losses. The study also shows how SWI-Prolog supports clear and logical reasoning in agricultural applications. Future enhancements include expanding the knowledge base, improving the user interface, and linking the system with mobile or database platforms for wider access.

Keywords: Expert System, Decision Support System, Rule-Based System, Bean Disease, SWI-Prolog

1. Introduction

Beans are an important source of protein and belong to the legume family (Michael et al., 2023; Mu et al., 2022). However, their production is often affected by diseases that lower both yield and quality. Ensuring early and accurate diagnosis, along with proper treatment, is key to sustainable bean production and food security.

Previous studies have examined different ways of detecting and managing crop diseases, such as traditional practices and expert consultations (Lin & Liou, 2020; Elfatimi et al., 2022). While effective, these methods often depend on expert availability and personal judgment, which can delay decisions for farmers in remote or resource-limited areas (Al-Ghoul et al., 2022; Dheir et al., 2019).

Rule-based expert systems (RBS) have been recognized as an effective approach for automating diagnosis and treatment processes through structured if-then rules derived from expert knowledge (Papadopoulos et al., 2022; Hayes, 1985). These systems provide consistent and reliable decision support, enhancing disease management practices and minimizing crop losses.

While several expert systems have been applied in agriculture, there is still a lack of rule-based solutions specifically designed for bean diseases (Kapoor et al., 2023; Ling et al., 2023). This study seeks to bridge that gap by developing a rule-based expert system that encodes expert knowledge to accurately diagnose common bean diseases and recommend appropriate treatments. The system is intended to support farmers

and agricultural practitioners by enabling faster, more objective, and practical disease management strategies.

2. Literature Review

AI-based expert systems are computer programs that mimic human decision-making by applying a knowledge base and inference rules, typically structured in IF-THEN format (Nobre et al., 2023; Soliman et al., 2019; Sultan et al., 2020). In agriculture, these systems have proven valuable for crop management, pest control, and disease diagnosis (Elbasi et al., 2023; Gundu et al, 2021; Hafizal et al, 2022). By delivering consistent and timely recommendations, they support farmers and agricultural professionals in making better decisions. Over the years, expert systems have been applied to soil management, irrigation, and plant disease diagnosis (Chen & Lin, 2022; Arpay & Talirongan, 2024), offering particular benefits in areas with limited access to specialists. Ultimately, they enhance productivity and promote sustainable farming practices.

Rule-based expert systems use explicit "if-then" rules to represent expert knowledge and guide decision-making (Hayes, 1985; Yang et al, 2022). By linking conditions with specific conclusions, these systems can process data and provide logical outcomes (Sumaryanti et al., 2022; Al-Ghoul et al., 2022; Cai et al., 2020). They are especially effective when knowledge can be clearly expressed as rules, making them well-suited for agricultural applications such as diagnosing crop diseases, suggesting treatments, and managing pests. Their transparent structure helps users understand the reasoning process, building trust and supporting adoption. Research shows that rule-based systems deliver accurate, timely diagnoses, helping farmers improve disease management and reduce crop losses.

Beans are prone to diseases caused by bacteria, fungi, and viruses, which threaten yield and quality. Common ones include bacterial blight, anthracnose, root rot, and rust, each showing distinct but sometimes overlapping symptoms (Michael et al., 2023; Elfatimi et al., 2022). Accurate diagnosis is often challenging without expert knowledge, yet it is essential for effective control. These diseases not only lower productivity and quality but also cause significant economic losses, underscoring the need for reliable decision-support tools in management.

Decision support systems (DSS) have become essential in plant disease management by offering farmers timely, evidence-based recommendations. These systems combine expert knowledge, data analysis, and inference to diagnose diseases and suggest treatments, with some applying fuzzy logic or IoT technologies (Senarlo & Talirongan, 2024; Varshney & Torra, 2023; Afzal, 2021). While DSS has been applied to various crops using rule-based approaches for clear and interpretable decision-making, most are broad in scope and not tailored specifically to beans. Accessibility also remains a challenge, particularly for farmers with limited technical skills. Developing a simple, specialized DSS for bean disease diagnosis can fill this gap, helping improve disease management and boost crop productivity.

SWI-Prolog is a popular open-source version of the Prolog programming language, known for its strong support of logic programming and symbolic reasoning (Lin et al., 2020). Its natural representation of knowledge as facts and rules, along with automated reasoning via backward chaining, makes it ideal for expert systems. With extensive libraries and development tools, SWI-Prolog has been successfully applied in medical diagnosis, environmental monitoring, and agriculture. Despite the availability of many expert systems in agriculture, animal health, and medicine, few focus specifically on diagnosing and treating bean diseases (Elfatimi et al., 2022; Soliman et al., 2019; Sumaryanti et al., 2020; Lin & Liou, 2020).

Existing systems are often too general, lack specificity, and do not fully address accessibility for smallholder farmers. This study addresses these gaps by proposing a user-friendly, rule-based expert system in SWI-Prolog, tailored for accurate diagnosis and treatment of bean diseases.

3. Methodology

This section presents a schematic diagram that illustrates the implementation of the AI Rule-Based Expert System. At its core, the system employs an inference engine designed to generate advice based on expert knowledge encoded in the knowledge base. The design of this framework was adapted and modified from the studies of Gundu et al. (2021) and Arpay & Talirongan (2024).

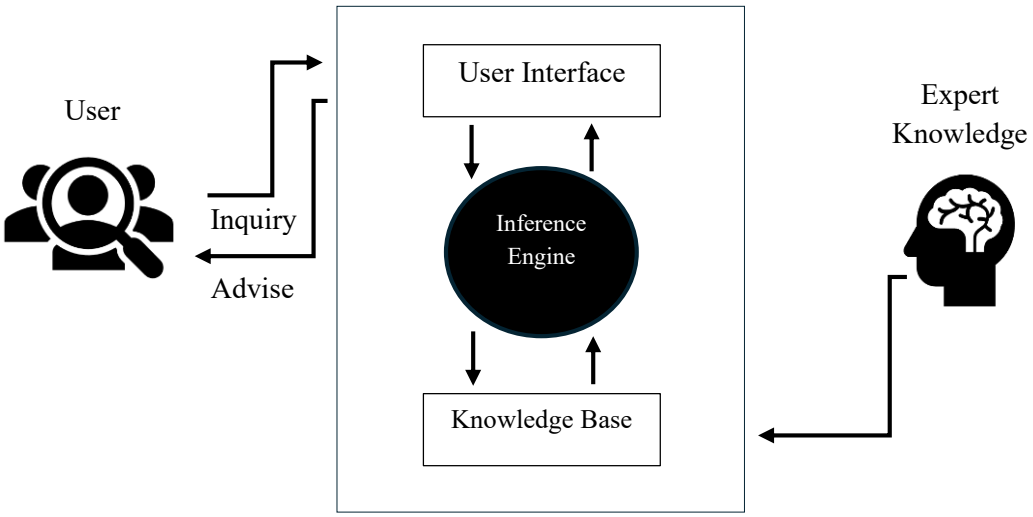


Figure 1. Expert System Architecture

Figure 1 illustrates the overall structure of the AI Rule-Based Expert System. The process begins when the user enters observed symptoms through the system's interface. These inputs are then analyzed by the inference engine, which consults the expert knowledge base to generate accurate advice or appropriate treatment recommendations.

3.1. Requirements Gathering

The researcher started by interviewing with experts to gather the information needed for the system. Several specialists were interviewed, including agricultural expert from the local municipality who shared helpful knowledge about common bean diseases, their symptoms, and how they are usually diagnosed. All these insights came together to build the knowledge base of the expert system, making sure it could give accurate and practical advice for identifying problems with beans.

3.2. Analysis and Design

In this phase, the collected requirements are carefully studied and translated into a system design that fits those needs. This step makes sure the system is built on a clear plan, so it can work effectively and meet the expectations of its users.

3.2.1 Legend. This section describes the symbols and abbreviations used in the AI Rule-Based Expert System. It serves as a reference to ensure that diseases and symptoms are represented in a clear and consistent manner. To simplify both identification and processing, each bean disease and its corresponding symptoms are assigned unique codes.

Table 1: AI Rule-Based Expert System

Common Bean Diseases	Code	Symptoms	Code	Common Bean Diseases	Code	Symptoms	Code
Fusarium Wilt	FW	Yellowing Leaves	YEL	**Mung bean Yellow Mosaic**	MYM	Yellow Patches on Leaves	YPL
		Wilting	WIL			Stunted Growth	STG
		Stunted Growth	STG			Leaf Distortion	LED
		Dark Brown Stem Discoloration	DBSD			Whiteflies Present	WHP
Charcoal Rot	CR	Yellowing Lower Leaves	YLL	**Cercospora leaf Spot**	CS	Rust Colored Leaf Spots	RCLS
		Stem Lesions	STL			Reddish Borders	REB
		Sudden Death	SUD			Leaf Falling	LEF
		Black Fungal Growth	BLFG			Black Fungus Growth	BFG
Leaf Spot	LS	Water Soaked Spots on Leaves	WSSL				
		Brown Spots with Yellow Halo	BSYH				
		Leaf Curling	LEC				
		Stem Lesions	STL				

3.2.2 Knowledge Tree. The knowledge tree represents a hierarchical structure that organizes the knowledge base of the AI Rule-Based Expert System. At the top level, it identifies common bean diseases, which are further classified into five specific diseases, each associated with their respective symptoms. This structure ensures systematic organization and clarity in representing domain knowledge within the system.

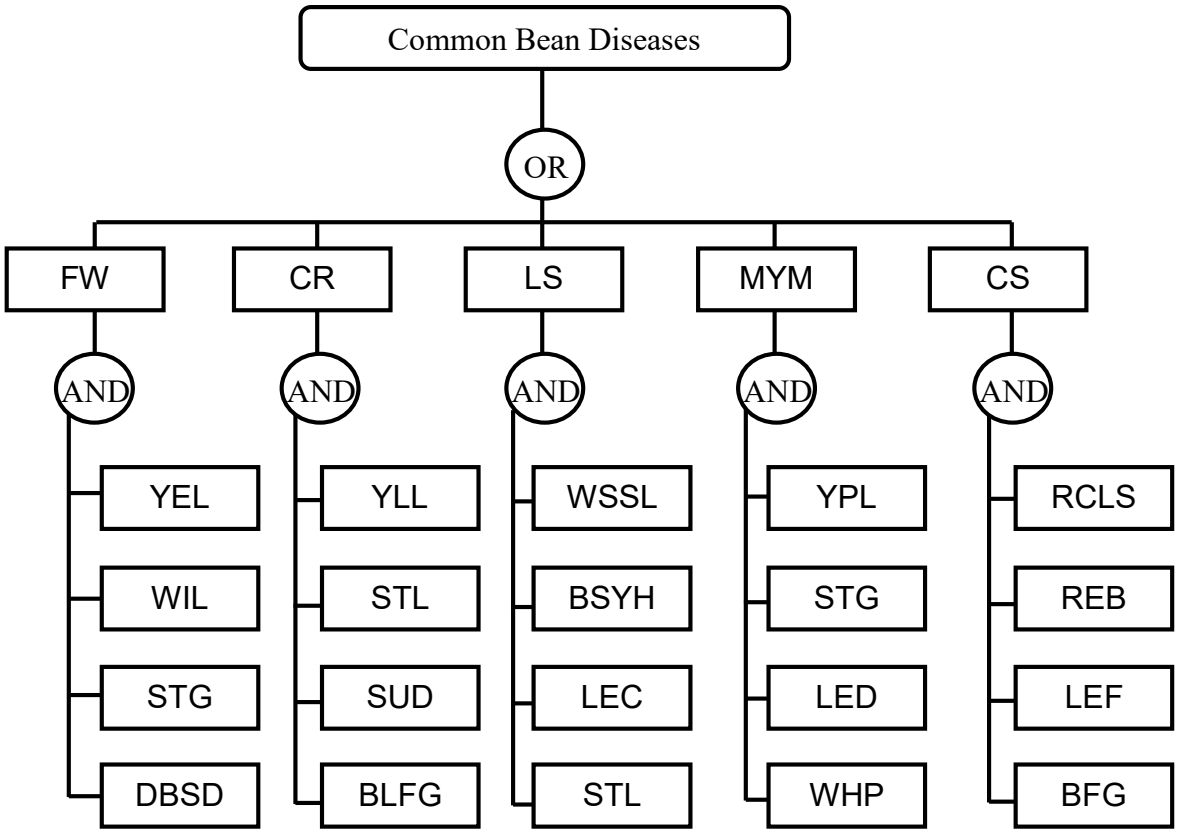


Figure 2. Knowledge Tree on AI Rule-Based Expert System

3.2.3 Predicates. This section defines the observations or symptoms associated with common bean diseases. Within the AI Rule-Based Expert System, predicates function as logical statements that establish the relationship between symptoms and diseases. By mapping each symptom to a potential condition, the system is able to reason systematically and generate accurate diagnoses of bean diseases.

Table 2. Predicates on AI Rule-Based Expert System

Predicates on Common Bean Diseases	
Fusarium Wilt	The Bean plant is likely affected by Yellowing Leaves
	The Bean plant is likely affected by Wilting
	The Bean plant is likely affected by Stunted Growth
	The Bean plant is likely affected by Dark Brown Stem Discoloration
Charcoal Rot	The Bean plant is likely affected by Yellowing Lower Leaves
	The Bean plant is likely affected by Stem Lesions
	The Bean plant is likely affected by Sudden Death
	The Bean plant is likely affected by Black Fungal Growth
Bacterial Leaf Spot	The Bean plant is likely affected by Water Soaked Spots on Leaves

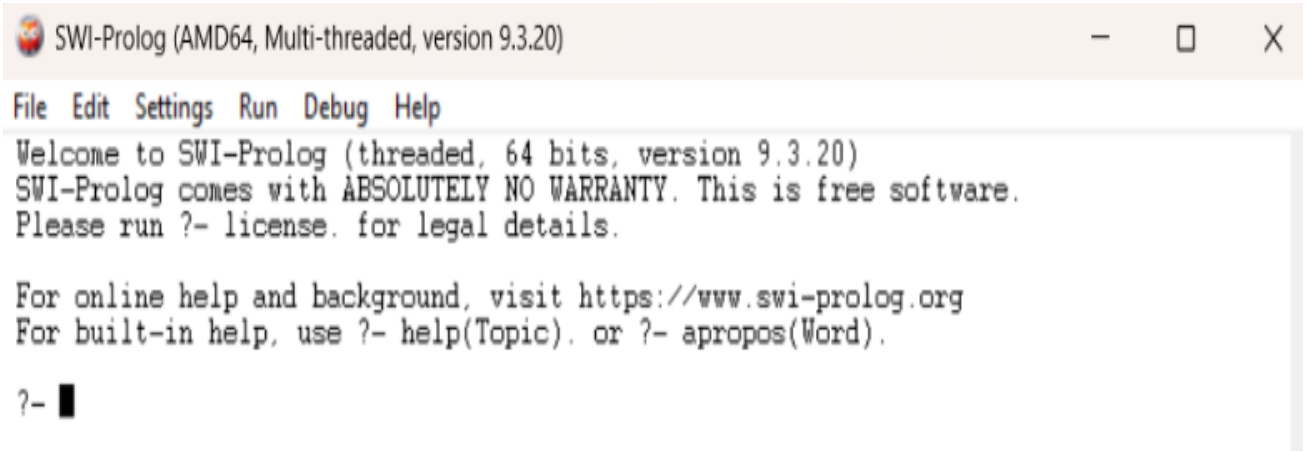
	The Bean plant is likely affected by Brown Spots with Yellow Halo
	The Bean plant is likely affected by Leaf Curling
	The Bean plant is likely affected by Stem Lesions
Mung Bean Yellow Mosaic	The Bean plant is likely affected by Yellow Patches on Leaves
	The Bean plant is likely affected by Stunted Growth
	The Bean plant is likely affected by Leaf Distortion
	The Bean plant is likely affected by Whiteflies Present
Cercospora Leaf Spot	The Bean plant is likely affected by Rust Colored Leaf Spots
	The Bean plant is likely affected by Reddish Borders
	The Bean plant is likely affected by Leaf Falling
	The Bean plant is likely affected by Black Fungus Growth

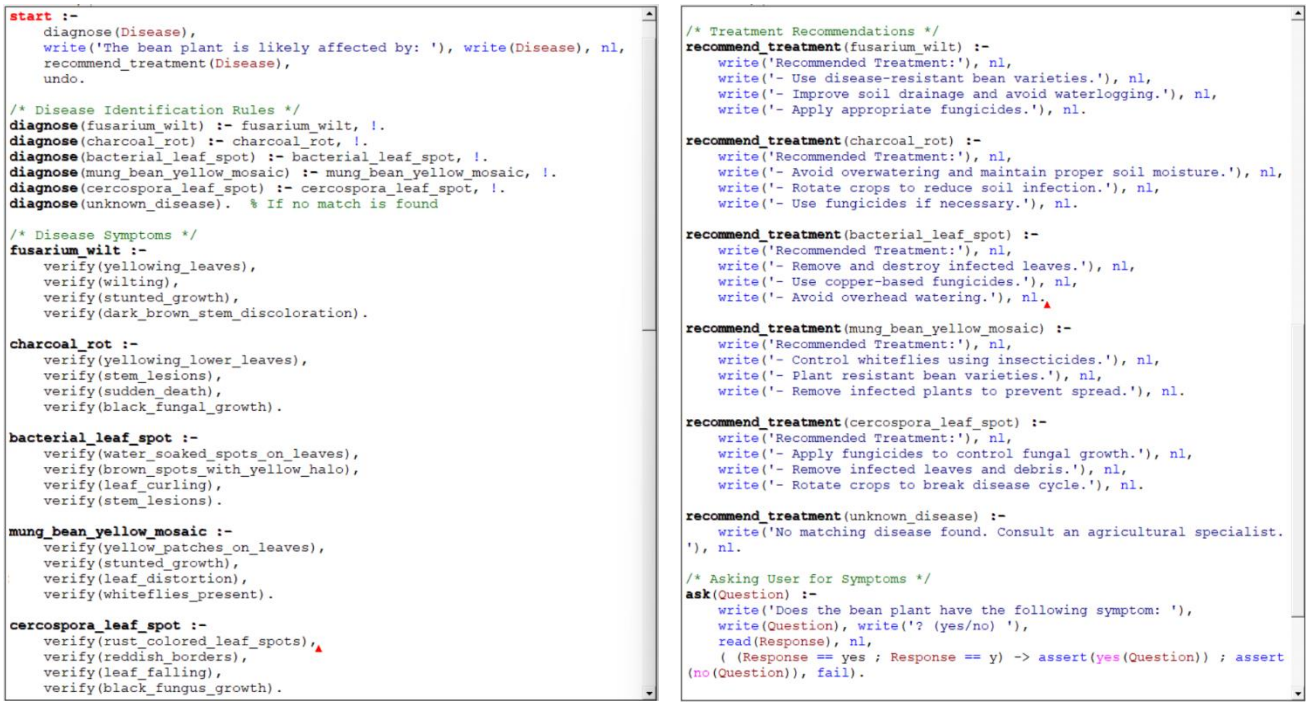
3.2.4 Rules. This section establishes the relationship between observed symptoms and specific bean diseases. The rules are expressed in an if–then structure, where the occurrence of particular symptoms results in the diagnosis of a corresponding disease. Through this logical framework, the system systematically analyzes user-provided inputs and identifies the most probable disease affecting the bean.

Table 3. Rules on AI Rule-Based Expert System

Rules on Common Bean Diseases	
RULE 1:	FW => YEL **AND** WIL **AND** STG **AND** DBSD
RULE 2:	CR => YLL **AND** STL **AND** SUD **AND** BLFG
RULE 3:	LS => WSSL **AND** BSYH **AND** LEC **AND** STL
RULE 4:	MYM => YPL **AND** STG **AND** LED **AND** WHP
RULE 5:	CS => RCLS **AND** REB **AND** LEF **AND** BFG

3.3 Development. In this phase, the conceptual design of the AI Rule-Based Expert System was transformed into a functional prototype using SWI-Prolog, a logic programming language well-suited for developing rule-based applications. SWI-Prolog was selected because of its powerful inference engine, which can efficiently process the logical rules necessary for diagnosing bean diseases. The subsequent screenshots illustrate the implementation of these rules as well as the overall system structure.





```
start :-
    diagnose(Disease),
    write('The bean plant is likely affected by: '), write(Disease), nl,
    recommend_treatment(Disease),
    undo.

/* Disease Identification Rules */
diagnose(fusarium_wilt) :- fusarium_wilt, !.
diagnose(charcoal_rot) :- charcoal_rot, !.
diagnose(bacterial_leaf_spot) :- bacterial_leaf_spot, !.
diagnose(mung_bean_yellow_mosaic) :- mung_bean_yellow_mosaic, !.
diagnose(cercospora_leaf_spot) :- cercospora_leaf_spot, !.
diagnose(unknown_disease).  % If no match is found

/* Disease Symptoms */
fusarium_wilt :-
    verify(yellowing_leaves),
    verify(wilting),
    verify(stunted_growth),
    verify(dark_brown_stem_discoloration).

charcoal_rot :-
    verify(yellowing_lower_leaves),
    verify(stem_lesions),
    verify(sudden_death),
    verify(black_fungal_growth).

bacterial_leaf_spot :-
    verify(water_soaked_spots_on_leaves),
    verify(brown_spots_with_yellow_halo),
    verify(leaf_curling),
    verify(stem_lesions).

mung_bean_yellow_mosaic :-
    verify(yellow_patches_on_leaves),
    verify(stunted_growth),
    verify(leaf_distortion),
    verify(whiteflies_present).

cercospora_leaf_spot :-
    verify(rust_colored_leaf_spots),
    verify(reddish_borders),
    verify(leaf_falling),
    verify(black_fungus_growth).
```

```
/* Treatment Recommendations */
recommend_treatment(fusarium_wilt) :-
    write('Recommended Treatment:'), nl,
    write('- Use disease-resistant bean varieties.'), nl,
    write('- Improve soil drainage and avoid waterlogging.'), nl,
    write('- Apply appropriate fungicides.'), nl.

recommend_treatment(charcoal_rot) :-
    write('Recommended Treatment:'), nl,
    write('- Avoid overwatering and maintain proper soil moisture.'), nl,
    write('- Rotate crops to reduce soil infection.'), nl,
    write('- Use fungicides if necessary.'), nl.

recommend_treatment(bacterial_leaf_spot) :-
    write('Recommended Treatment:'), nl,
    write('- Remove and destroy infected leaves.'), nl,
    write('- Use copper-based fungicides.'), nl,
    write('- Avoid overhead watering.'), nl.

recommend_treatment(mung_bean_yellow_mosaic) :-
    write('Recommended Treatment:'), nl,
    write('- Control whiteflies using insecticides.'), nl,
    write('- Plant resistant bean varieties.'), nl,
    write('- Remove infected plants to prevent spread.'), nl.

recommend_treatment(cercospora_leaf_spot) :-
    write('Recommended Treatment:'), nl,
    write('- Apply fungicides to control fungal growth.'), nl,
    write('- Remove infected leaves and debris.'), nl,
    write('- Rotate crops to break disease cycle.'), nl.

recommend_treatment(unknown_disease) :-
    write('No matching disease found. Consult an agricultural specialist.
'), nl.

/* Asking User for Symptoms */
ask(Question) :-
    write('Does the bean plant have the following symptom: '),
    write(Question), write('? (yes/no) '),
    read(Response), nl,
    ( (Response == yes ; Response == y) -> assert(yes(Question)) ; assert
(no(Question)), fail).
```

Figure 3. Screenshot on the development of AI Rule-Based Expert System

4. Result and Discussion

The AI Rule-Based Expert System was successfully developed to diagnose common bean diseases. Tests showed it could accurately identify issues like fusarium wilt, charcoal rot, bacterial leaf spot, mung bean yellow mosaic, and cercospora leaf spot based on user input. Its rule-based design ensures reliable results, while its simple interface makes it useful for farmers in rural areas. Since the system can be updated with new knowledge, it will remain accurate and effective over time.

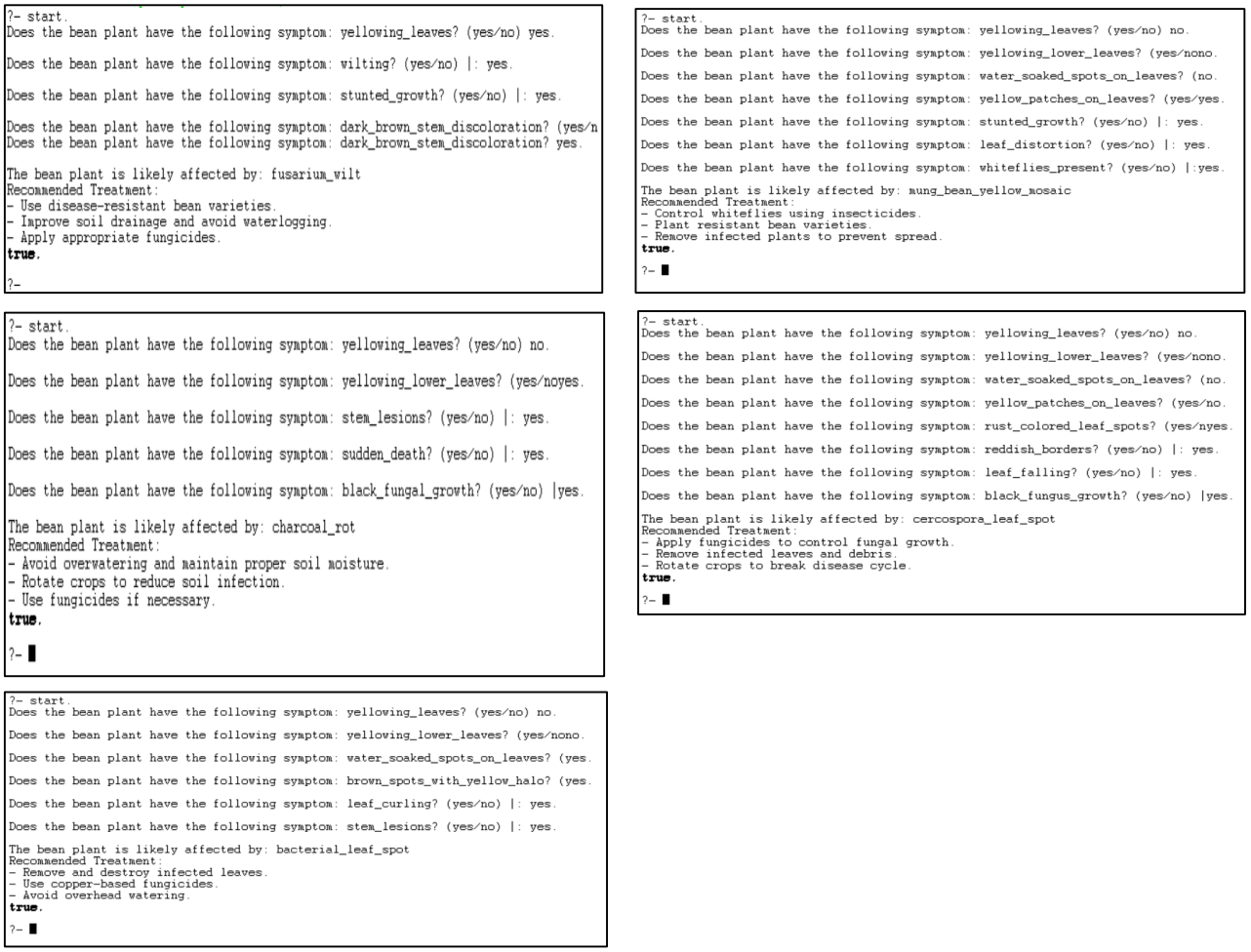


Figure 4. Testing output of AI Rule-Based Expert System

5. Conclusion and Recommendation

This study developed an AI rule-based expert system using SWI-Prolog to diagnose and treat common bean diseases. By applying if-then rules, the system identifies probable diseases from user symptoms and suggests treatments, with testing showing it to be reliable and easy to use for farmers and agricultural practitioners. SWI-Prolog's backward-chaining made the reasoning process clear and effective, addressing a gap in tools for bean disease management. Future improvements may include expanding the rule base, adding a graphical interface, and integrating with mobile platforms or agricultural databases. Overall, the system advances smart agricultural technologies and supports sustainable bean production by providing timely, expert-backed guidance.

Declarations

Source of Funding
This research did not receive any specific grant from funding agencies in the public, commercial, or non-profit sectors.

Competing Interests
The authors declare that they have no competing financial, professional, or personal interests related to this study.

Consent for Publication
The authors confirm their consent for the publication of this research work.

Acknowledgment of AI Assistance
The authors acknowledge the use of AI-based tools, specifically Grammarly for paraphrasing and for grammar and style refinement. All ideas, analyses, and conclusions presented in this work remain the sole responsibility of the authors, and no conflicts of interest arise from the use of these tools.

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