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Integrating certainty factor into a web-based expert system for intelligent diagnosis of chili plant pathologies

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Abstract. Chili pepper plant diseases are a major problem that can reduce yield and quality. Farmers face difficulties in diagnosing chili plant diseases due to limited knowledge and resources. This study presents a web-based expert system that integrates the Certainty Factor (CF) method for intelligent diagnosis of chili plant diseases. This system was built to assist farmers and agricultural practitioners in identifying common chili plant pathologies through a user-friendly web interface. The system was evaluated through validation by domain experts and testing with real-world symptom cases, resulting in high accuracy and reliability. The system was tested and validated by experts on 40 test datasets compared with expert data and demonstrated an accuracy of 92%. The User Acceptance Test results from 15 respondents yielded an average score of 87.1%. These results indicate that the integration of the Certainty Factor method improves diagnostic precision under uncertain conditions, making this system a practical and accessible tool for early disease detection. This study contributes to the development of intelligent agricultural decision support systems, particularly in the context of digital agriculture and plant health management.

1 Introduction

Chili peppers (*Capsicum spp.*) are a high-value agricultural commodity with significant economic and culinary importance worldwide, particularly in tropical and subtropical regions. As a crucial component of the global food system and a major export product for many developing countries, chili cultivation supports the livelihoods of millions of smallholder farmers [9]. However, chili production is often threatened by a variety of plant diseases, such as anthracnose, bacterial wilt, phytophthora blight, and viral mosaic, which can cause yield losses of up to 70% if left undetected and untreated. Early and accurate diagnosis of these diseases is crucial for implementing timely interventions, minimizing economic losses, and ensuring sustainable agricultural practices [5].

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Although rapid disease identification is essential, farmers, especially in remote or resource-limited areas, often face significant challenges in accessing qualified agricultural professionals or sophisticated diagnostic facilities. Traditional diagnostic methods rely heavily on visual symptom recognition by trained agronomists, which is subjective, time-consuming, and prone to human error due to overlapping symptoms in some diseases [3]. Laboratory-based techniques, such as Polymerase Chain Reaction or Enzyme-Linked Immunosorbent Assay, offer higher accuracy but are expensive, require specialized equipment, and are inaccessible to most small-scale farmers. This gap in timely and affordable diagnostic support has led to delayed treatment, overuse of pesticides, and further degradation of soil and plant health [11].

To address these limitations, expert systems have emerged as a promising solution for agricultural decision support. Expert systems mimic the reasoning of human experts by encoding domain knowledge into a rule-based inference engine, enabling non-experts to diagnose complex problems [2]. However, conventional expert systems often face uncertainty, a common problem in agriculture where symptoms may be incomplete, ambiguous, or context dependent. For example, yellowing leaves may indicate nutrient deficiencies, viral infections, or water stress, rendering deterministic rule-based approaches inadequate. The Certainty Factor (CF) method, a computational model for handling uncertain and probabilistic reasoning, has attracted attention due to its ability to quantify the degree of confidence in diagnostic conclusions [8]. Unlike Bayesian networks, which require precise probability data often unavailable in agricultural contexts, CF utilizes heuristic rules and expert-assigned certainty values to estimate the likelihood of hypotheses. Recent studies have demonstrated its effectiveness in medical and engineering domains, but its application in agricultural expert systems, particularly for chili disease diagnosis, remains underexplored [4].

Furthermore, the proliferation of internet connectivity and mobile devices presents an opportunity to deliver expert systems through web-based platforms, ensuring wide accessibility, real-time updates, and cross-platform compatibility. While several web-based agricultural diagnostic tools exist, they largely rely on machine learning image recognition, which may fail in poor lighting conditions or with atypical symptom presentations [4, 8]. Integrating the CF method into a web-based expert system can bridge this gap by combining structured symptom-based reasoning with uncertainty management, resulting in a robust and user-centric diagnostic tool.

This study aims to design, develop, and validate a web-based expert system integrating the Certainty Factor method for intelligent diagnosis of chili plant diseases. By formalizing domain knowledge into a rule base with quantified certainty values and implementing it through an intuitive web interface, the system allows farmers to input observed symptoms and receive a probabilistic diagnosis along with actionable treatment recommendations. This study addresses three critical gaps: (1) the lack of uncertainty-sensitive diagnostic tools for chili pathologies, (2) the limited accessibility of expert knowledge in rural areas, and (3) the need for interpretable rule-based systems that complement data-driven approaches. Through expert validation and field testing, this study contributes to the advancement of intelligent agricultural decision support systems, which promote precision agriculture and sustainable crop management in the information technology era [8, 10].

An expert system is a computer-based system that mimics the ability of a human expert to solve problems in a specific field, by adopting expert knowledge, facts, and reasoning techniques into a knowledge base and inference engine [7, 9]. The main goal is to transfer an expert's expertise into the system so that it can be used by others to obtain decision support, diagnosis, design, or other problem-solving activities [8]. The system to be developed applies the CF method in a web-based Expert System which is used to handle uncertainty in the decision-making process. This method allows the system to calculate and evaluate the level of confidence in a diagnosis or recommendation based on analysed data. In the context of a web-based system, CF is implemented to provide solutions in situations containing uncertainty, such as diagnosing a condition [6, 7].

The CF method was chosen because of its ability to define the level of certainty or confidence in a fact or rule in an expert system. By integrating it into a web-based system, users can obtain diagnosis or recommendation results accompanied by a numerical confidence value, thus helping in understanding how strongly the system supports the conclusion. This implementation usually involves knowledge-based design based on a specific process [5-7].

2 Materials and Methods

This study employed a structured development and validation approach to design, implement, and evaluate a web-based expert system that integrates the CF method for diagnosing chili plant diseases [7, 8]. The methodology consisted of five main phases: (1) Problem Identification and Requirement Analysis, (2) Knowledge Acquisition and Rule Base Development, (3) System Design and Architecture, (4) Implementation with Certainty Factor Integration, and (5) System Evaluation and Validation.

Fig.1. Research Methods

2.1 Problem Identification and Requirement Analysis

The initial stage of the research was to identify the main problems in chili disease diagnosis through a comprehensive literature review and interviews with an agricultural expert from the Agricultural Extension Centre of Jember Regency, East Java. Common diseases encountered, such as *Leaf Spot, Fusarium Wilt, Thrip Pests, Fruit Flies, Mites, Whiteflies, Fruit Rot, Phytophthora Rot, Armyworm, Bacterial Wilt, Gemini Virus*, and *Anthracnose* were prioritized based on their prevalence and economic impact. Functional requirements were collected through a survey distributed to 30 chili farmers in Jember Regency, East Java, with a focus on usability, accessibility, and diagnostic features needed in digital devices [6-8].

2.2 Knowledge Acquisition and Rule Base Development

Domain knowledge was extracted through direct consultations with two certified agronomists and validated using authoritative sources such as the FAO Plant Village database and peer-reviewed journals. Symptoms associated with each disease were categorized into observable attributes (e.g., leaf discoloration, stem lesions, fruit rot), and diagnostic rules were formulated in IF-THEN format [6-8]. For example:

"IF leaf shows yellow spots with dark margins AND humidity is high, THEN Cercospora leaf spot is suspected."

Each rule was assigned to a Measure of Belief (MB) and Measure of Disbelief (MD) by experts based on symptom reliability and frequency, forming the foundation for CF computation.

2.3 System Design and Architecture

The expert system developed uses a client-server architecture with three layers, namely the *Presentation Layer*, which is a responsive web interface built using Hypertext Markup Language 5 (HTML5), Cascading Style Sheets 3 (CSS3), and JavaScript for cross-device compatibility, then the *Application Layer* is the backend logic implemented in Node.js with the Express.js framework to manage user interaction and inference processes, and the *Data Layer* is a MySQL DB database that stores disease profiles, symptom rules, certainty values, and treatment recommendations. A use case diagram defined user roles (farmer, admin, expert), while sequence diagrams modelled the diagnostic workflow. Security measures included input validation and role-based access control [6, 9].

2.4 Implementation of the Certainty Factor Method

The core inference engine utilized the *Certainty Factor model* to handle uncertainty in symptom reporting. For each disease hypothesis *H* given evidence *E*, the *CF* was calculated as follows:

$$CF\ (H, E) = MB\ (H, E) - MD\ (H, E) \tag{1}$$

When multiple pieces of evidence were present, combined certainty factors were computed recursively:

$$CFcombined = CF1 + CF2(1 - CF1) \quad (for\ CF1, CF2 > 0) \tag{2}$$

Users selected observed symptoms via checkboxes or image uploads. The system processed inputs, applied relevant rules, computed CF values for all possible diseases, and ranked them by descending certainty score. Results were displayed alongside recommended treatments, preventive measures, and references. The application was deployed on a cloud server with HTTPS encryption to ensure availability and data privacy [6, 8].

2.5 System Evaluation and Validation

The developed expert system application underwent a rigorous evaluation through *Expert Validation*, where agricultural experts assessed the accuracy and completeness of 40 real-world disease cases. *Diagnostic accuracy* was measured using precision, recall, and the F1 score. Then, *Usability Testing*, where 25 farmers tested the system and completed a System Usability Scale questionnaire, was conducted. Feedback was analysed qualitatively and quantitatively. *Performance Testing*, which tested response time, error rate, and scalability under concurrent users, was evaluated using JMeter [6, 10].

3 Results and Discussion

Researchers gathered valid and reliable information regarding diseases that frequently attack chili plants. Data was collected through two main techniques: in-depth interviews and direct observation. The interview was conducted with an agricultural expert from the Agricultural Extension Center in Jember Regency, East Java. In this interview, the expert was asked to provide an explanation of various types of diseases that attack chili plants, as well as the signs that appear in each disease. In addition, the expert's confidence or certainty assessment of each disease symptom was also collected to support the analysis in the expert system. Data collection was also conducted through direct observation in the field by observing the condition of growing chili plants and analyzing possible disease symptoms.

Through this observation, researchers were able to compare the symptoms found in the field with the information obtained from the expert interview.

The data collected from these two methods will be used to design and develop a web-based expert system capable of diagnosing chili plant diseases with a high degree of accuracy. This system is expected to provide fast and precise solutions for chili farmers in dealing with various problems related to their plant health [10,11]. From the results of interviews and observations, data on disease types, symptom data, and Certainty Factor values were obtained from a chili plant expert, as shown in Table 1.

Table 1. Types of Disease, Symptom Data, and Expert CF Values.

ID	Types of Disease	Symptom	ID Symptom	CF Value
P1	Leaf Spot	Leaf Spots Yellowing Leaves Leaf Drop	G001 G002 G003	1,0 1,0 1,0
P2	Fusarium wilt	Withered in the morning Fresh in the afternoon Chocolate roots	G004 G005 G006	1,0 1,0 1,0
P3	Thrip Pests	Remove curled leaves Leaves roll up Silvery spots appear	G007 G008 G009	1,0 1,0 1,0
P4	Fruit Fly	There are black spots on the fruit There are black sting marks The chili fruit is rotting from the inside	G010 G011 G012	1,0 1,0 1,0
P5	Mites	Leaves curl downwards There are mite sucking marks on the underside of the leaves Leaves turn yellow and curl There are brownish spots on the leaves	G013 G014 G015 G016	1,0 1,0 0,8 1,0
P6	Black Flea	The tops of the leaves are yellow White ticks	G017 G018	1,0 1,0
P7	Fruit Rot	Juicy fruit Fruit dries Fruit falls Rotten fruit	G019 G020 G021 G022	1,0 1,0 1,0 1,0
P8	Phytophthora rot	Rotten stems are brownish in color Plant roots rot Plant growth is delayed There is mucus on the roots and base of the stem	G023 G024 G025 G026	1,0 1,0 1,0 1,0
P9	Army worm	Leaves with holes or eaten by caterpillars Stems and young shoots are cut off Fruit with holes and damage	G027 G028 G029	1,0 1,0 1,0
P10	Bacterial Wilt	Plants wilt suddenly Stems and roots produce slime when cut Stems become soft and smell rotten	G030 G031 G032	1,0 1,0 1,0
P11	Gemini virus	Leaves shrink and thicken One yellow stem	G033 G034	1,0 1,0
P12	Anthracnose	The fruit has black circles that dry up.	G035	1,0

Notes: P is Types of Disease ID

Furthermore, from the above data, a rule base is created which is used as a knowledge base containing a set of rules that connect the symptoms and types of diseases in chili plants. The rule base becomes the main foundation for a web-based expert system in carrying out the diagnosis process systematically and structured. This system utilizes the Certainty Factor method to calculate the level of confidence or certainty of each possible diagnosis generated. The Certainty Factor method plays a role in determining the confidence weight for each disease based on the symptom data input by the user, then calculating the percentage of confidence to select the diagnosis result with the highest probability value as the most likely disease [10, 12]. The rule base data as the knowledge base in this study is as shown in Table 2.

Table 2. Rule Base

Rule	Knowledge Base
R1	IF G001 G002 AND G003 THEN P01
R2	IF G004 G005 AND G006 THEN P02
R3	IF G007 G008 AND G009 THEN P03
R4	IF G010 G011 AND G012 THEN P04
R5	IF G013 G014 G015 AND G016 THEN P05
R6	IF G017 AND G018 THEN P06
R7	IF G019 G020 G021 AND G022 THEN P07
R8	IF G023 G024 G025 AND G026 THEN P08
R9	IF G027 G028 AND G029 THEN P09
R10	IF G030 G031 AND G032 THEN P10
R11	IF G33 AND G34 THEN P11
R12	IF G35 THEN P12

Notes: R is Rule Base ID

In this system, experts assign confidence value or weight (certainty) to each symptom related to a particular disease based on their experience and expertise. This confidence value describes how likely a symptom is related to a particular disease. In addition, users also assign confidence values to the selected symptoms during the diagnosis process, according to the actual conditions they observe in chili plants. By combining the confidence values from experts and users, the system can calculate a Certainty Factor value for each possible disease [12, 13]. The following is an example of a diagnostic process using the Certainty Factor method implemented in the system.

P001 $= CFComb_1[CF_1, CF_2] = CF_1 + CF_2 \text{ x } (1 - CF1)\ CFComb_1[CF_1, CF_2]$
$= 0{,}8 + 0{,}6 \text{ x } (1 - 0{,}8)$
$= 0{,}8 + 0{,}6 \text{ x } 0{,}2$
$= 0{,}8 + 0{,}12$
$= 0{,}92\ (CF\ Old_1)$

$CFComb_2[CF\ Old_1, CF_3] = CF\ Old_1 + CF_3 \text{ x } (1 - CF\ Old_1)\ CFComb_2[CF\ Old_1, CF_3]$
$= 0{,}92 + 0{,}6 \text{ x } (1 - 0{,}92)$

$= 0{,}92 + 0{,}6 \times 0{,}08$
$= 0{,}92 + 0{,}048$
$= 0{,}968$ (CF Old_2)
$= 96{,}8\%$

P03 $= CFComb_1[CF_1, CF_2] = CF_1 + CF_2 \times (1 - CF_1)\ CFComb_1[CF_1, CF_2]$
$= 0{,}4 + 0.4 \times (1 - 0{,}4)$
$= 0{,}4 + 0{,}4 \times 0{,}6$
$= 0{,}4 + 0{,}24$
$= 0{,}64$
$= 64\%$

The calculation results using the Certainty Factor method above concluded that the plant was diagnosed with Leaf Spot disease with a confidence percentage of 96.8%. From the results of data collection and analysis, a system flowchart can be created that illustrates the workflow of an expert system or application developed using a programming language. The purpose of this flow is to simplify the application implementation process [8]. To be able to use the diagnostic feature, the user must first log in. After successfully logging in, the user can select the symptoms they are experiencing. The system flowchart of this application can be seen in Figure 2.

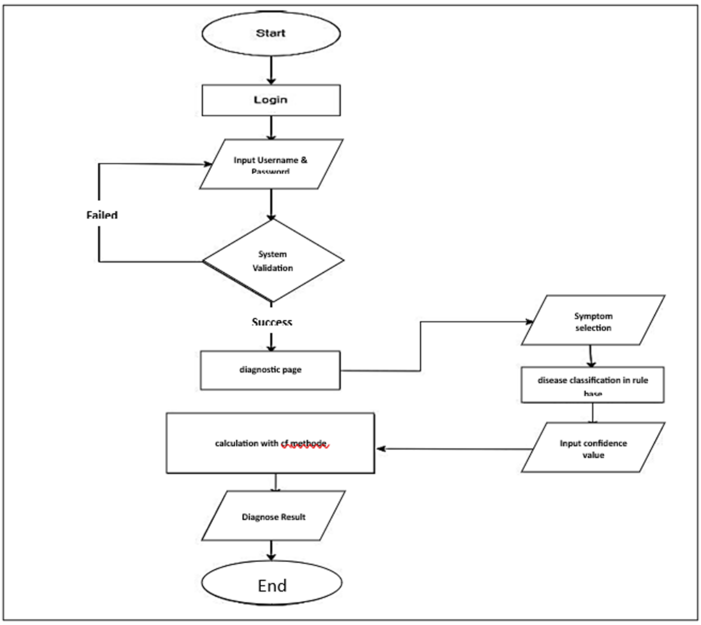

Fig. 2. Flowchart System

Next, the researcher created a use case diagram of an expert system. This system has two main factors, namely the user and admin actors. The user actor has access to register, login, and diagnose diseases, then the admin actor carries out login activities, Dashboard, disease diagnosis, diagnosis history, CRUD user list, CRUD symptom list, CRUD disease list and rules [8,10]. The use case diagram of the expert system in this study is depicted in Figure 3.

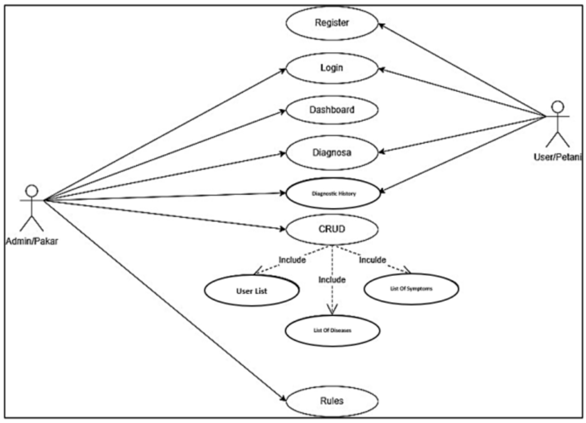

Fig. 3. Use Case Diagram

Database design is a systematic process of building an efficient and organized database structure to store, manage, and access data according to system requirements. This process includes identifying entities, attributes, and relationships between data, as well as determining table structures, data types, and relational keys to ensure data integrity and consistency. The main objective of database design is to create a data storage system in an expert system application that can support application operations well [8,11]. Figure 4 is a system modeling in a database.

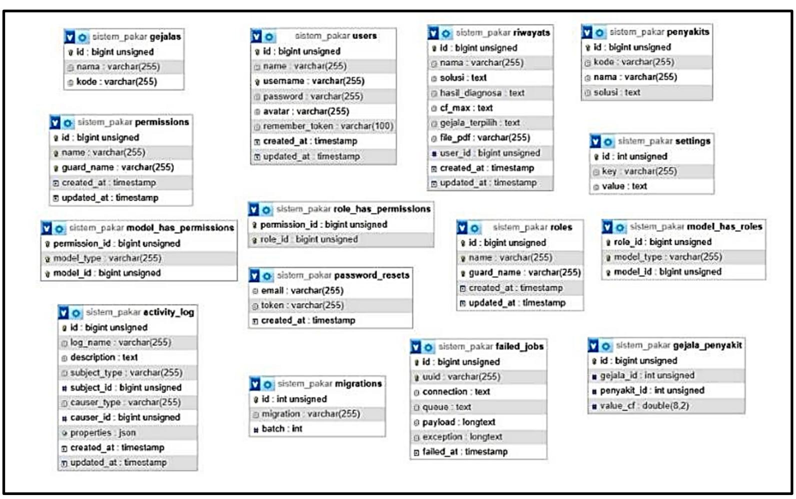

Fig. 4. Database System

After building the database, the next step was to create a web-based expert system application. This application was built using a client-server architecture with three layers: the Presentation Layer (a responsive web interface built using HTML5, CSS3, and JavaScript) for cross-device compatibility; the Application Layer (backend logic implemented in Node.js with the Express.js framework to manage user interactions and inference processes); and the Data Layer (a MySQL DB database that stores disease profiles, symptom rules, certainty values, and treatment recommendations) [8-11].

Figure 5 below shows the interface of an expert system designed to diagnose disease symptoms in chili plants, which has been successfully implemented as a code-based application. This system integrates expert logic components with an interactive user interface, making it easier for users to digitally perform the diagnosis process. Every feature in the system has been developed according to user needs, from symptom input to the presentation of informative diagnostic results [7, 9].

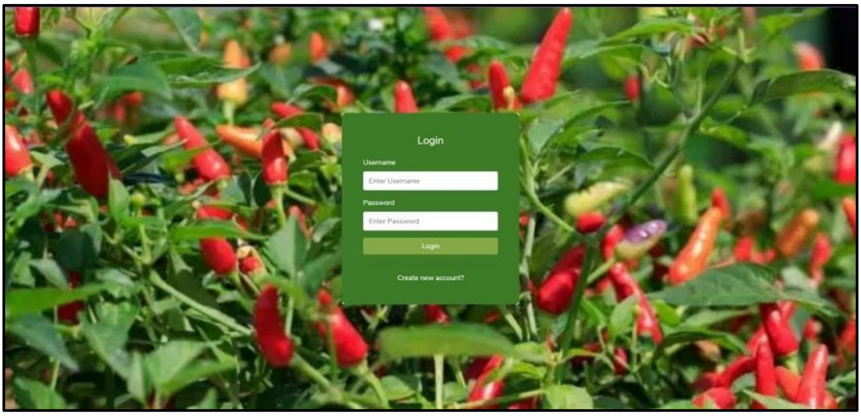

Fig. 5. Expert System View

The admin/expert page is the control center, providing full access to all system features. Experts can manage and monitor various data through menus such as the Dashboard, which provides a summary of important information, the diagnosis section, which allows for disease identification, and the Diagnosis History section, which allows for reviewing previous diagnostic results. Additionally, there's a User List menu for managing user data, a Disease List and a Symptom List for managing data used as the basis for diagnoses, and a Rule Base, which is used to determine the relationship between symptoms and diseases.

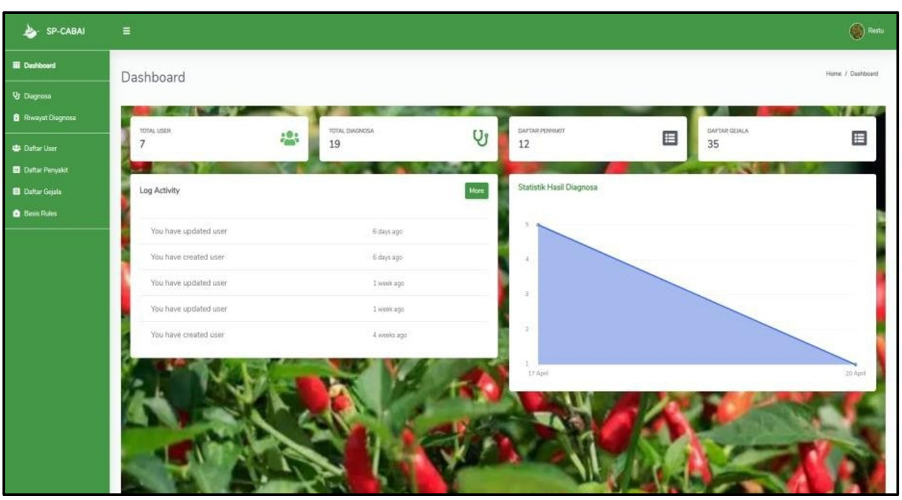

Fig. 6. Dashboard Expert System

The dashboard serves as a central information center, presenting a comprehensive summary of important data in a single view. It displays key information such as the total number of users (Total Users), the total number of diagnostic processes performed (Total Diagnoses), a complete list of diseases registered in the system, and a list of symptoms used as diagnostic references. The dashboard also displays a user activity log that records various interactions within the system, as well as statistical visualizations of diagnostic results that help understand disease trends and distribution.

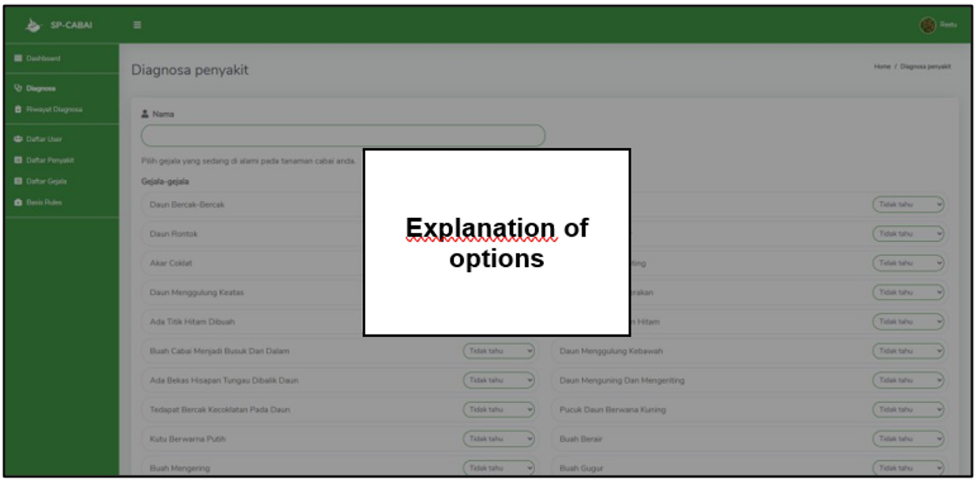

Fig. 7. Expert System Diagnosis

The diagnosis page is a key feature of the system, allowing users to identify diseases based on their symptoms. This page contains several key elements: a name field for entering the user's or patient's identity, a list of symptoms displayed as options to choose from based on the condition being experienced, and a Diagnose Now button that processes the input data to generate a diagnosis. The system then calculates a confidence level and provides a possible diagnosis based on the method used.

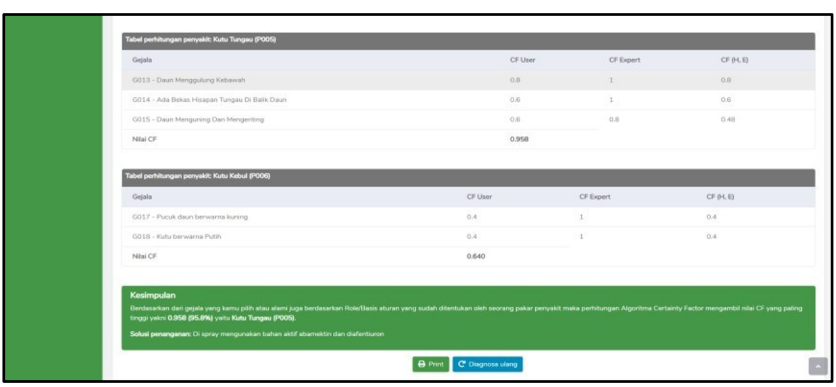

Fig. 8. Expert System Diagnosis Results

The diagnostic results page displays a complete summary of the diagnostic process performed by the user. On this page, the system displays a list of symptoms previously selected as the basis for analysis, along with a calculation table showing the data evaluation process using the methods used, such as the Certainty Factor. Furthermore, at the bottom of the page, there is a conclusion in the form of a diagnostic result, namely the possible disease suffered and its level of certainty. To make it easier for users, this page is also equipped with a Print button that allows the diagnostic results to be printed or saved in PDF format, as well as a Re-diagnosis button that can be used if the user wants to start the diagnostic process from the beginning [8, 11].

The User Acceptance Test (UAT) system was conducted on 15 respondents, consisting of farmers. Users were asked to try the system and rate its ease of use, clarity of information, speed of access, and level of confidence in the diagnostic results. The average UAT score was 87.1%, indicating the system was well-received and easy to use by the target audience. A responsive and interactive interface was a contributing factor to user experience.

4 Conclusion

Footnotes should be avoided whenever possible. If required, they should be used only for brief notes that do not fit conveniently into the text. Based on the research results on a Web-Based Expert System for Diagnosing Chili Plant Diseases Using the Certainty Factor Method, it can be concluded that disease symptoms were successfully identified through interviews with experts and direct observation, which were then used as a knowledge base in the system. The developed expert system can assist users in diagnosing chili plant diseases independently through a simple and responsive interface. The implementation of the Certainty Factor method in the system has proven effective in calculating the level of certainty of diagnosis based on a combination of symptoms selected by the user. From the test results on 40 scenarios, the system showed an accurate level of 92% and obtained a UAT value of 87.1%, which indicates that this system is accurate, easy to use, and well-received by users.

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