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Implementation of Forward Chaining And Certainty Factor Methods for Android-Based Red Onion Diagnosis

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Abstract

Shallots are among the crucial horticultural commodities in Indonesia, used across various social strata. Brebes is one of the main shallot-producing regions, with significant production growth. However, farmers often experience reduced yields due to disease attacks and a lack of guidance from experts. This researcher aims to develop an Android-based expert system that applies the Certainty Factor and Forward Chaining methods to identify diseases in shallot plants. This system uses rules to identify onion disease symptoms and calculates the confidence level for each possible diagnosis. The Forward Chaining method helps identify symptoms sequentially, while the Certainty Factor estimates the likelihood of disease. The research results show that this method is effective in providing accurate diagnoses of the 5 onion diseases tested by the recommended system, with a 98% accuracy. In conclusion, the expert system for diagnosing shallot plants using the Android-based forward-chaining and certainty-factor method was successfully developed.

Keywords: *Shallots, Android, Certainty Factor, Forward Chaining*

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I. INTRODUCTION

The agricultural sector, especially the horticultural subsector, has an important role in meeting people's food needs, including the need for shallot plants [1]. Shallots are among the crucial horticultural commodities in Indonesia, used across various social layers, both on a household and commercial scale [2, 3]. Consumption of shallots in Indonesia reaches an average of 78,292 tonnes per month, or around 939,504 tonnes per year [4]. Brebes is one of the main shallot-producing regions, with significant production growth, recording sales of up to 72.500 tonnes in the first three months of 2021 [5].

Despite high market demand, shallot farmers still face big challenges in maintaining crop yields due to disease attacks. Diseases in shallot plants, such as purple spot, which causes leaf tip drying, are a serious threat that reduces the quality and quantity of production [6, 7]. The lack of education and limited knowledge among farmers about how to identify and manage this disease further worsens the situation [8, 9, 10]. Early diagnosis and monitoring of plant health are urgent needs, especially to support measures to prevent and control the spread of disease in shallots.

As a solution, this research proposes the development of an Android-based expert system that combines the Forward Chaining and Certainty Factor methods in diagnosing shallot plant diseases. Expert systems enable the storage and retrieval of expert knowledge, providing practical, accurate diagnostic guidance to farmers. The Forward Chaining method identifies disease symptoms in stages, while the Certainty Factor quantifies the confidence in the disease diagnosis, resulting in a more accurate analysis. Combining these methods has been shown to be effective in several previous studies in related fields. In previous research, the Forward Chaining method was widely used and shown to be quite effective, achieving an expert correctness rate of up to 90% [11, 12, 13, 14, 15].

Android-based application development was chosen because it is easily accessible, open source, and supported by a broad ecosystem of applications. By combining a combination of two methods, namely forward chaining and certainty factor, which allows the system to diagnose shallot diseases more accurately and based on evidence. Forward chaining works by analyzing the user-entered symptoms in stages until reaching a final conclusion based on predetermined rules, making the diagnosis process more systematic. Meanwhile, the certainty factor addresses diagnostic uncertainty by providing a level of confidence in the likelihood of detecting the disease. By combining these two methods, the system can identify diseases more flexibly and accurately and provide more reliable recommendations to farmers.

Based on these problems, the purpose of this research is to design and develop an Android-based expert system that helps shallot farmers diagnose plant diseases early and accurately by combining the Forward Chaining and Certainty Factor methods. This system is expected to systematically identify disease symptoms, determine the type of disease using established rules, and provide confidence in diagnostic results, thereby reducing decision-making uncertainty. This research aims to improve farmers' understanding of shallot diseases, support disease prevention and control efforts, and ultimately enhance the quality and quantity of shallot production.

II. RESEARCH METHOD

This chapter discusses the research methods used in developing an expert system for diagnosing shallot plant diseases. The research methods were systematically structured to ensure that each stage was focused and aligned with the stated objectives. The research flow and stages implemented in this study are shown in Figure 1, which outlines the research process from problem formulation and literature review to the final conclusion.

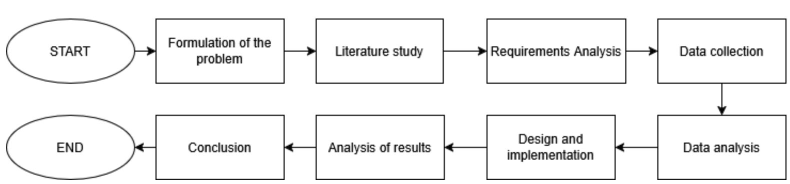

Fig. 1. Research Stages

Figure 1 presents the systematic research stages, structured as a guideline, for developing an expert system to diagnose shallot plant diseases. These stages illustrate the research flow, from problem formulation to conclusion drawing. The aim is to ensure that the system development process is carried out in a planned, evidence-based manner and produces a system that is accurate, effective, and meets user needs. Throughout these research stages, each process is interconnected and supports the achievement of the overall research objectives.

1. **Formulation of the Problem**
   Researchers define and formulate the research problem by determining the research field, theme, objectives, and methods. This research is motivated by the difficulty of accessing experts with sufficient knowledge of diagnosing and treating shallot plant diseases, as well as the need to evaluate the effectiveness and accuracy of the Forward Chaining and Certainty Factor methods in disease diagnosis. Therefore, the accuracy of diagnosing shallot plant diseases through an expert system needs to be validated. Although similar problems have been examined in previous studies, this research differs by using the Android platform and combining two reasoning methods: Forward Chaining and Certainty Factor.
2. **Literature Study**
   Researchers collect relevant data and information through a literature study. Previous studies on expert systems, plant disease diagnosis, Forward Chaining, and Certainty Factors are used as references to support problem-solving in this research. The sources include scientific journals, books, theses, and other relevant research publications. Computer programs that solve problems using inferential reasoning, like experts, and have a specialized knowledge base for a particular topic are called expert systems. It is a cutting-edge method for collecting and organizing knowledge. The strength of this system lies in its ability to solve real-world problems without specialists [3]. Expert systems, also known as knowledge-based systems, are computer programs that support decision-making and problem-solving in specialized fields. One advantage of an expert system is that it enables a person, such as an agricultural extension agent, to perform tasks that are often performed by an expert. Expert systems were first introduced by the AI community in the 1960s. General-Purpose Problem Solver (GPS), developed by Newel and Simon, was one of the first expert systems. However, GPS and similar programs don't work because their coverage is too broad, often leaving out important information [4]. Here is Figure 2, which shows the structure of the expert system.

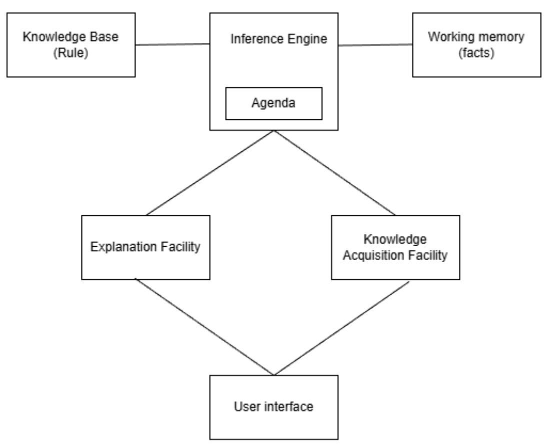

Fig. 2. Structural Expert System

3. **Requirements Analysis**
   Researchers conduct a requirements analysis to identify and gather all system requirements for developing an expert system to diagnose shallot plant diseases. In this stage, the Forward Chaining and Certainty Factor methods are selected as the main reasoning approaches. Through this analysis, it is expected that an efficient and effective expert system can be developed to assist in diagnosing diseases in shallot plants.
4. **Data Collection**
   Researchers collect data to identify shallot plant diseases. Data collection is conducted through several procedures, including expert interviews and literature reviews, to obtain accurate information on disease types, symptoms, and treatment options.
5. **Data Analysis**
   Researchers perform manual data analysis by first compiling all information obtained from interviews

and literature reviews into an Excel table. The collected data are then filtered to eliminate duplicate or similar data. Data with similar characteristics are selected as samples, while the remaining data are excluded. As a result of this process, 13 symptom samples and 5 disease types are identified. The Certainty Factor method is an element of certainty theory that is commonly used to evaluate information using terms such as almost certain, likely, and reasonable.

6. **Design and Implementation**
Researchers design and implement the system by defining the overall workflow, system architecture, and expert system model. This stage includes applying the Forward Chaining and Certainty Factor methods within the Android-based expert system.
7. **Results Analysis**
System evaluation is conducted using Black Box Testing and System Accuracy Testing. These testing methods assess system functionality and determine the accuracy of diagnostic results, ensuring the developed system operates properly and can be effectively used by users.
8. **Conclusion**
Researchers draw conclusions to summarize the study's main findings and provide a comprehensive interpretation of the research results. The conclusions are expected to demonstrate whether the research objectives have been achieved and to serve as a reference for future research in related fields.

A. Forward Chaining

Rules are tested one by one in a predetermined order in a process known as forward chaining, or forward reasoning. Facts or knowledge base statements are matched by the inference engine to scenarios represented as IFs in rules. The next rule is tested and the IF rule is activated if the facts in the knowledge base match it. One rule at a time is tested in this way until each rule has been thoroughly checked. See the Forward Chaining method flow diagram in Figure 3 for more information.

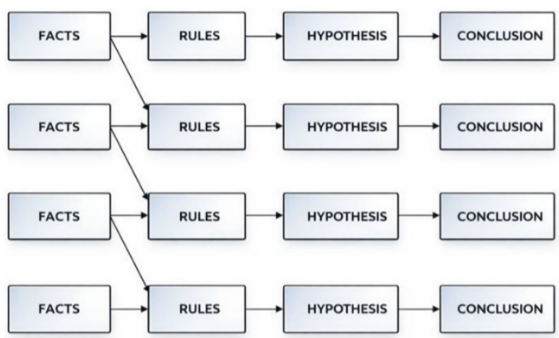

Fig. 3. Method Forward Chaining

B. Certainty Factor

The Certainty Factor method is an element of certainty theory that is commonly used to evaluate information using terms such as almost certain, likely, and reasonable. The Certainty Factor (CF) method is an approach to dealing with uncertainty in a system. The certainty factor for an event is based on evidence or expert opinion. The level of confidence the expert feels in the information functions as the Certainty Factor value. A significant benefit of this technique is its ability to maintain accuracy by combining two pieces of data in one calculation. This approach was chosen to carry out reasoning calculations as well as develop an expert system application that evaluates the health quality conditions of living spaces based on seven criteria [12].

The Cetainty Factor weight is calculated by combining the weights from experts and the weights from users using an equation Equation 1:

$$CF_{combine}(expert, user) = CF_{expert} \cdot CF_{user} \tag{1}$$

Information:
CF_{combine}[expert, user] = Certainty Factor
CF[expert] = Expert trust value

CF[user] = User trust value

Combining the Certainty Factor values of hypotheses that are influenced by symptoms (evidence) to obtain a combined Certainty Factor value in Equation 2.

$$CF_{\text{combine}}[h, e] = CF[h, e_1] + CF[h, e_2] \times (1 - CF[h, e_1]) \tag{2}$$

Information:
$CF_{\text{combine}}[h, e]$: Certainty Factor is a combination of hypotheses influenced by symptoms (evidence) e.
$CF[h, e_1]$: Confidence value of hypothesis H which is influenced by symptom e_1.
$CF[h, e_2]$: Confidence value of hypothesis H which is influenced by symptom e_2.

III. RESULT AND DISCUSSION

A. Data Collection

The information collected for this research includes diseases that attack shallot plants which are the main subject of research. It covers the specific types of diseases found on each onion plant along with the symptoms associated with each condition.

1) Disease Data

To outline the techniques applied in this research and the insights gathered from discussions with specialists. Next, details are collected in the form of understanding and system guidelines to reach a conclusion based on the available classification as shown in Table I.

TABLE I. ONION DISEASE DATA

Code	Disease
P01	Antraknosa
P02	Moler
P03	Trotol
P04	Embun bulu
P05	Ngelumpruk

2) Symtoms of Onion Desease

In Table II Symptoms of shallot disease are indicators of shallot disease for which disease symptom data will be analyzed.

TABLE II. SYMPTOMS OF ONION DISEASE

Code	Symptom
G01	White spots
G02	White or gray leaf spots
G03	Purple leaf spots
G04	Green spots
G05	Reddish-purple spots
G06	Brown leaf spots
G07	White leaf spots
G08	Yellowish-white leaf spots
G09	Yellowing leaves
G10	Leaves wilt
G11	Brown/white leaves
G12	Pale green/yellow striped leaves
G13	Dry leaves

3) Symptoms Of Each Disease and Expert CF Value

Symptoms associated with each type of disease on shallots are described in Table III.

TABLE III. SYTOMPS OF EACH DISEASE AND EXPERT VALUE

Symptom Code	Expert CF	Disease Code
G04	0.6	
G06	0.6	
G07	0.6	
G08	0.8	P01
G10	0.6	
G11	0.6	
G12	0.6	
G09	0.6	P02
G10	0.9	
G01	0.6	
G02	0.6	
G03	0.6	
G04	0.8	P03
G05	0.6	
G07	0.6	
G09	0.6	
G13	0.6	
G02	0.6	
G03	0.6	
G04	0.6	P04
G05	0.8	
G09	0.6	
G10	0.8	
G12	0.8	
G13	0.6	
G07	0.8	P05
G08	0.9	

In an Expert System, the Inference Engine functions as a guide to align information. The inference engine begins the process by correlating the information in the knowledge base with predefined rules derived from the Knowledge Base.

4) Input Symptoms

Stages of selecting symptoms that appear on shallots, each is given a weight based on the user's answer. If the answer is VERY SURE then the weight = 1.0, If the answer is SURE then the weight = 0.8, If the answer is QUITE SURE then the weight = 0.6, If the answer is LITTLE SURE then the weight = 0.4, If the answer is LESS SURE then the weight = 0.2, If the answer is NOT SURE then the weight = 0, If the user DOES NOT VOTE then the weight = 0, for the expert Cf weight it depends on the weight of each symptom which can be seen in Table IV.

TABLE IV. EXAMPLE OF SYMTOMS SELECTION BY THE USER

Symptom	User Value
White spots	0.8
White or gray leaf spots	0.8
Purple leaf spots	0.0
Green spots	0.0
Reddish-purple spots	0.6
Brown leaf spots	0.0
White leaf spots	0.0
Yellowish-white leaf spots	0.8
Yellowing leaves	0.0
Leaves wilt	0.0
Brown/white leaves	0.0
Pale green/yellow striped leaves	0.0
Dry leaves	0.0

Rule making refers to the guidelines used by a special system that come from knowledgeable individuals, where the individuals consulted are authorities regarding pests and diseases that attack shallots. Below is the structure of the guidelines that have been collected.

1. Rule 1 = If G04 and G06 and G07 and G08 and G10 and G11 and G12 then P01
2. Rule 2 = If G09 and G10 then P02
3. Rule 3 = If G01 and G02 and G03 and G04 and G05 and G07 and G09 and G13 then P03
4. Rule 4 = If G02 and G03 and G04 and G05 and G09 and G10 and G12 and G13 then P04
5. Rule 5 = If G07 and G08 then P05

Regarding the certainty factor equation, it can be seen in the Equation 3. Based on the rules and values given by the user, the disease recommendation results are PO1 Equation 4–Equation 6, P02 Equation 7–Equation 9, P03 Equation 10–Equation 12, P04 Equation 13–Equation 15, P05 Equation 16–Equation 18. Because the system still provides more than one result, the system will calculate the certainty factor to take the final value with the highest percentage.

$$CF_{\text{combine}} = CF(h, e_1) + CF(h, e_2)\,(1 - CF(h, e_1)) \tag{3}$$

B. Data Analysis

1. **Anthracnose Disease (P01)**

$$\begin{aligned} CF_{\text{combine}_1} &= CF_{GabP01G01} + CF_{GabP01G02}(1 - CF_{GabP01G01}) \\ &= 0 + 0(1-0) = 0 \end{aligned} \tag{4}$$

$$\begin{aligned} CF_{\text{combine}_2} &= CF_{\text{combine}_1} + CF_{GabP01G05}(1 - CF_{\text{combine}_1}) \\ &= 0 + 0(1-0) = 0 \end{aligned} \tag{5}$$

$$\begin{aligned} CF_{\text{combine}} &= CF_{\text{combine}_2} + CF_{GabP01G08}(1 - CF_{\text{combine}_2}) \\ &= 0 + 0.64(1-0) = 0.64 \end{aligned} \tag{6}$$

From the calculation above, a value of **64%** is obtained for Anthracnose disease (P01).

2. **Moler Disease (P02)**

$$\begin{aligned} CF_{\text{combine}_1} &= CF_{GabP02G01} + CF_{GabP02G02}(1 - CF_{GabP02G01}) \\ &= 0 + 0(1-0) = 0 \end{aligned} \tag{7}$$

$$\begin{aligned} CF_{\text{combine}_2} &= CF_{\text{combine}_1} + CF_{GabP02G05}(1 - CF_{\text{combine}_1}) \\ &= 0 + 0(1-0) = 0 \end{aligned} \tag{8}$$

$$\begin{aligned} CF_{\text{combine}} &= CF_{\text{combine}_2} + CF_{GabP02G08}(1 - CF_{\text{combine}_2}) \\ &= 0 + 0(1-0) = 0 \end{aligned} \tag{9}$$

From the calculation above, a value of **0%** is obtained for Moler disease (P02).

3. **Trotol Disease (P03)**

$$\begin{aligned} CF_{\text{combine}_1} &= CF_{GabP03G01} + CF_{GabP03G02}(1 - CF_{GabP03G01}) \\ &= 0.48 + 0.48(1-0.48) = 0.7296 \end{aligned} \tag{10}$$

$$\begin{aligned} CF_{\text{combine}_2} &= CF_{\text{combine}_1} + CF_{GabP03G05}(1 - CF_{\text{combine}_1}) = \\ &= 0.7296 + 0.36(1-0.7296) = 0.826944 \end{aligned} \tag{11}$$

$$\begin{aligned} CF_{\text{combine}} &= CF_{\text{combine}_2} + CF_{GabP03G08}(1 - CF_{\text{combine}_2}) \\ &= 0.826944 + 0(1-0.826944) = 0.826944 \end{aligned} \tag{12}$$

From the calculation above, a value of **83%** is obtained for Trotol disease (P03).

4. **Downy Dew Disease (P04)**

$$\begin{aligned} CF_{\text{combine}_1} &= CF_{GabP04G01} + CF_{GabP04G02}(1 - CF_{GabP04G01}) \\ &= 0 + 0.48(1-0) = 0.48 \end{aligned} \tag{13}$$

$$\begin{aligned} CF_{\text{combine}_2} &= CF_{\text{combine}_1} + CF_{GabP04G05}(1 - CF_{\text{combine}_1}) \\ &= 0.48 + 0.48(1-0.48) = 0.7296 \end{aligned} \tag{14}$$

$$\begin{aligned} CF_{\text{combine}} &= CF_{\text{combine}_2} + CF_{GabP04G08}(1 - CF_{\text{combine}_2}) \\ &= 0.7296 + 0(1-0.7296) = 0.7296 \end{aligned} \tag{15}$$

From the calculation above, a value of **73%** is obtained for Downy Dew disease (P04).

5. **Ngelumpruk Disease (P05)**

$$\begin{aligned} CF_{\text{combine}_1} &= CF_{GabP05G01} + CF_{GabP05G02}(1 - CF_{GabP05G01}) \\ &= 0 + 0(1-0) = 0 \end{aligned} \tag{16}$$

$$\begin{aligned} CF_{\text{combine}_2} &= CF_{\text{combine}_1} + CF_{GabP05G05}(1 - CF_{\text{combine}_1}) \\ &= 0 + 0(1-0) = 0 \end{aligned} \tag{17}$$

$$\begin{aligned} CF_{\text{combine}} &= CF_{\text{combine}_2} + CF_{GabP05G08}(1 - CF_{\text{combine}_2}) \\ &= 0 + 0.72(1-0) = 0.72 \end{aligned} \tag{18}$$

From the calculation above, a value of **72%** is obtained for Ngelumpruk disease (P05).

C. Input Symtomps

The symptom input process is an essential component of the application workflow, as it determines the data used in the diagnostic analysis. After the symptoms are entered and processed by the system, the application functionality is evaluated through testing to ensure that the system performs as expected.

D. Design and Implementation

In this research which focuses on disease detection in shallot plants, a combined technique of Forward Chaining and Certainty Factor is used so that the diagnosis system can utilize existing rules to identify symptoms in shallot plants and calculate the level of confidence in each possible disease. By considering the weight of certainty and combining that information, the system can provide a more detailed diagnosis and enable farmers to take appropriate action.

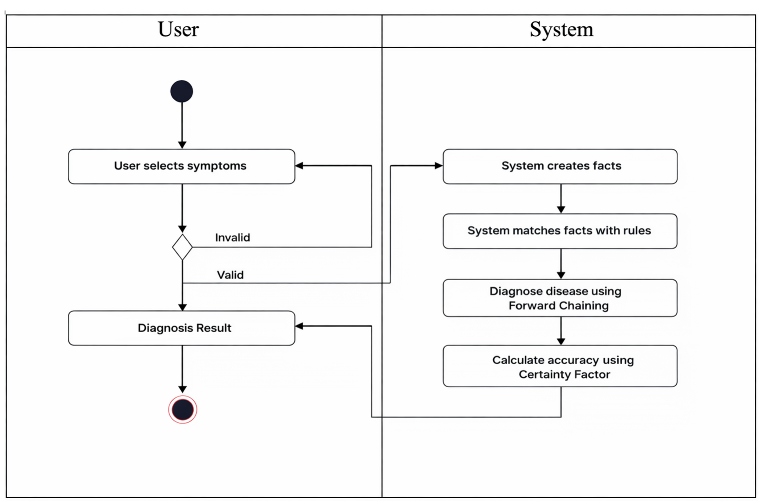

Fig. 4. Diagram Activity

In Figure 4 The expert system Activity diagram depicts the user flow from the beginning of selecting disease symptoms to obtaining diagnosis results. The system will carry out the disease search process using Forward Chaining and calculate accuracy using Certainty Factor.

Based on the calculation results above, it can be concluded that for Anthracnose disease it is 64%, Moler is 0%, Trotol is 83%, Bulai disease is 73%, and Ngelumpruk is 72%. From the evaluation results carried out on all shallot diseases, Trotol disease which shows the highest value of 83% is recommended as the type of disease to focus on. Furthermore, testing is carried out using the system illustrated in Figure 5.

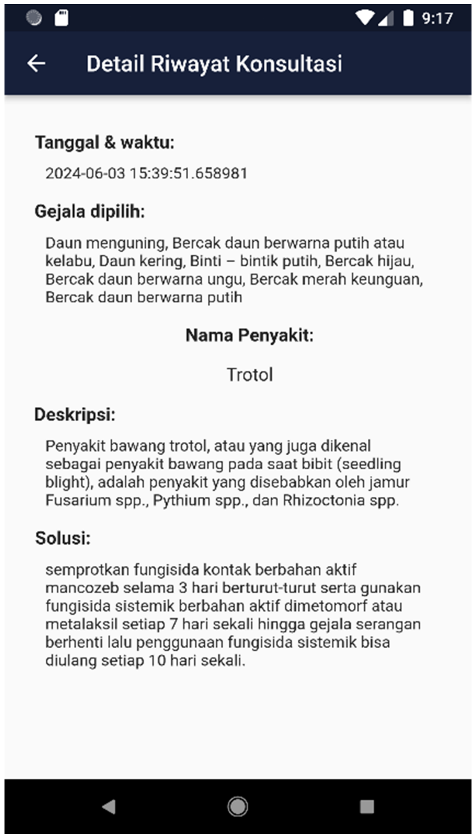

Fig. 5. System Test Results

E. *Test Android Application Functionality using Black Box Testing*

The functionality in Table V was tested by experts and the results were that there were no errors and the results were as expected.

TABLE V. TEST THE FUNCTIONALITY OF THE BLACK BOX TESTING APPLICATION

Test Case	**Expected Result**	**Result**	**Conclusion**
Enter homepage	Display the homepage containing the onion menu, disease types, symptom list, consultation, and about menu	Yes	Pass
Click onion menu	Display detailed information about onions	Yes	Pass
Click disease type menu	Display a list of disease types	Yes	Pass
Select a disease type	Display images and detailed information of the selected disease	Yes	Pass
Click symptom list menu	Display detailed symptom information from several diseases	Yes	Pass
Click consultation menu	Display a selection of symptoms for consultation	Yes	Pass

Test Case	Expected Result	Result	Conclusion
Click View Result	Display the selected symptoms, disease name, solution, and disease description	Yes	Pass
Click Guide menu	Display several guides for disease types, consultation, and history	Yes	Pass
Click About menu	Display information about the application developer	Yes	Pass
Click History menu	Display detailed history of previously performed diagnoses	Yes	Pass

IV. CONCLUSION

From the research and analysis stages carried out, it can be determined that this expert system can monitor the symptoms selected by the user, taking into account the condition of the population being observed. The results of recognizing onion diseases are associated with symptoms such as white spots and white or gray spots on the leaves, purplish red spots, then yellowish white leaf spots. The results obtained were based on the recommended rules for several diseases, namely Anthracnose, Trotol, Downy mildew and Ngelumpruk. Because the system still provides more than one result, the system will calculate the certainty factor to take the final value with the highest percentage. The results of the calculations were Anthracnose with a value of 64%, Moler 0%, Trotol 83%, Downy mildew 73%, Ngelumpruk 72%. From the results of calculations carried out on all shallot diseases, and taking into account the maximum value obtained, it can be concluded that the recommended type of disease is Trotol disease which has a value of 83%.

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