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Expert System for Diagnosing Diseases in Corn Plants using Forward Chaining and Certainty Methods Web-Based Factor

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Abstract

Corn is one of the main agricultural communities that plays an important role in supporting community food security. In Ndapayami Village, East Sumba Regency, corn farming is the main source of livelihood for the community. However, the productivity of corn crops often decreases due to disease attacks that are difficult for farmers to identify quickly. This study aims to design and build an expert system in diagnosing diseases in corn plants using the Forward Chaining method as an inference engine and Certainty Factor to measure the level of certainty of diagnosis. The expert system is designed to be computer-based so that it is easily accessible to farmers and agricultural extension workers in determining solutions to handle corn crop diseases. The system was developed using a rule-based approach and tested through the black-box testing method in 15 case scenarios. The research data was obtained through field observations, interviews, and documentation, and validated by agricultural experts. The test results show that the expert system has an accuracy rate of 80% and is able to give a confidence value to each diagnosis result. This system is expected to help speed up the disease diagnosis process, increase farmers' knowledge, and support increased productivity and food security in Ndapayami Village.

***Keywords**: Expert System, Corn Crop Diseases, Forward Chaining, Certainty Factor,*

1. Introduction

Indonesia is a country that produces various kinds of agricultural products, one of which is corn. Corn is one of the most important agricultural commodities in Indonesia and acts as a second source of carbohydrates after rice. Apart from being a foodstuff, corn is also an important raw material for the animal feed industry and various other sectors, so it has high economic value[1]

Based on data from the Central Statistics Agency (BPS), corn production in Indonesia in 2020 reached 22.5 million tons. However, this figure decreased by 0.38% compared to the previous year which reached 22.58 million tons. This condition shows that there are still challenges in maintaining the stability of corn production in Indonesia, so continuous efforts are needed to increase productivity and efficiency in the agricultural sector, especially in the corn commodity. The decrease in corn productivity is caused by disease attacks on corn plants which can significantly reduce the quality and quantity of crops

Common corn diseases include downy mildew, leaf spot, root and stem rot, and leaf rust, which have different symptoms but are often difficult for farmers to distinguish. Each disease has different symptoms Downy mildew disease is characterized by the appearance of elongated yellow stripes parallel to the leaf bones. Leaf spot disease is characterized by the appearance of small spots on the leaf surface, Root and stem rot has symptoms in the form of rotting roots and stem base and turning dark brown to black, Meanwhile, leaf rust disease is characterized by the appearance of small reddish-orange spots that can cover most of the leaf surface.

Many farmers still have limitations in recognizing diseases and determining the right treatment. This problem is also faced by farmers in Ndapayami Village, Katangang District, East Sumba Regency, East Nusa Tenggara Province. Based on the results of interviews with local residents, disease attacks have infected more than 60% of maize crops, resulting in a decrease in productivity of up to 40%. Farmers who depend on crops as their main source of income are greatly affected by this condition.

The solution to this problem is the use of technology in the form of a rules-based expert system that can help farmers carry out early detection of diseases and provide advice on appropriate handling. Farmers only need to enter the observed symptoms, then the system will provide the results of the disease diagnosis along with control suggestions. So that farmers are able to increase production and reduce the risk of crop failure, in Ndapayami Village.The Forward Chaining method was chosen because the diagnosis process begins with facts or symptoms observed in the field, then is traced until a suitable type of disease is found Meanwhile, the Certainty Factor method is applied to provide a level of certainty in the diagnosis results, considering that some diseases have similar symptoms so that it is necessary to calculate confidence in the results system inference. In this study, symptom, disease, and Certainty Factor value data were validated through consultation with Jidron Yuneldy Taifa, as the Coordinator of Plant Pest Organism Control (POPT) at the East Sumba Regency Agriculture Office. As the POPT Coordinator, experts have the task of observing, identifying, and controlling plant pests and diseases, especially in corn plants [2], so that his involvement ensures that the knowledge base used is in accordance with the field conditions in Ndapayami Village.

2. Literature Review

2.1. Corn Crops

Corn is an annual crop, one of its life cycles is completed in 80-150 days. In general, corn plants are between 1m - 3m high. Corn known as Zea mays is a cereal crop, Currently there are benefits associated with corn that include its use not only for food but also as animal feed. Based on the shape of the seed and the content of the endosperm, corn is grouped into seven types, namely horsetooth corn (Zea mays indentata), pearl corn (Zea mays indurata), starchy corn (Zea mays amylacia), brondong corn (Zea mays everta), sweet corn (Zea mays sachrata), waxy corn (Zea mays ceratina) and pea corn (Zea mays aunicula). The types of corn that are widely grown in Indonesia are horsetooth corn, pearl corn, popcorn and sweet corn [3]

Plant disease is a disease that causes damage caused by organisms belonging to the plant world such as parasitic plants, algae, fungi, bacteria, mycoplasma, and viruses. This damage can occur both in the field and after harvest. The damage caused by corn crop diseases causes enormous losses to the community. This damage not only causes the loss of crop yields, but can also cause disruption to consumers with toxins produced by fungi in agricultural products. The following are the types of diseases found in corn plants[4].

a. Sickle Cell Disease (Dowly Mildew)
   Downy mildew disease is caused by the fungus Peronosclerospora maydis. The disease is characterized by a change in the color of young leaves to yellowish-white, often parallel lines appear to the leaf bones, and the lower surface of the leaves appears floury. Downy mildew is one of the most detrimental diseases in corn because it can cause crop failure if the infection occurs in the early stages of growth. The disease spreads quickly in humid environmental conditions and relatively low temperatures
b. Leaf Spot
   Leaf spotting is caused by the fungus Helminthosporium turcicum or Bipolaris maydis. The symptoms are in the form of elongated brown patches on the leaves that gradually expand to cause necrosis (dead tissue). This disease attacks plants in the vegetative to generative phases and can reduce the ability to photosynthesize so that it affects the size of the cob and crop yields. Humid weather conditions favor the development of the disease
c. Root and Stem Rot
   Stem rot is caused by fungi such as Fusarium spp. and Diplodia maydis. Symptoms that appear include a softened, brownish stem, and easy to break. Attacks occur mainly on plants that are deficient in nutrients or grown on poorly drained land. This disease causes plants to collapse and cobs do not develop optimally
d. Rust Leaves (Rust)
   Leaf rust is caused by the fungus Puccinia sorghi. The symptoms are small, reddish-brown pustules (nodules) that resemble rust on the leaf surface. Heavy attacks cause the leaves to dry out faster, inhibit the process of photosynthesis, and have an impact on reduced cob yield. This disease commonly appears in humid weather or high rainfall.

2.1. Expert System

An expert system is a system designed to solve a specific problem and provide solutions by integrating human or expert knowledge in a particular field into a knowledge-based computer. Anyone who needs expertise to make decisions, even laypeople, can use the expert system. The development of expert systems began in the 1960s through Newell and Simon's research that introduced the General-Purpose Problem Solver (GPS). This system is an early prototype of artificial intelligence that tries to mimic human thinking processes in solving problems. Over time, this concept has developed in various fields, including medicine, agriculture, engineering, business, and education. One important milestone was the emergence of the MYCIN system used to diagnose infectious diseases, which later became the basis for the development of uncertainty assessment methods such as the Certainty Factor (CF). In general, expert systems have several main components, namely a knowledge base as a repository of expert information, an inference engine as a logic and reasoning processor, and a user interface that allows interaction between users and systems. In addition, there is an explanation facility that functions to provide reasons or system processes in making decisions, so that the results provided are more transparent and easy to understand [5].

2.3. Forward Chaining

Forward chaining is a type of reasoning that starts from a fact and then tests the truth of a hypothesis or compares facts or statements, starting from the left (IF). A forward chain is a group of double conclusions that explore from a problem to a solution. If the premises fit the situation, then the process will confirm its conclusions. The front chain is suitable for applications where the tree is not deep yet wide [6].

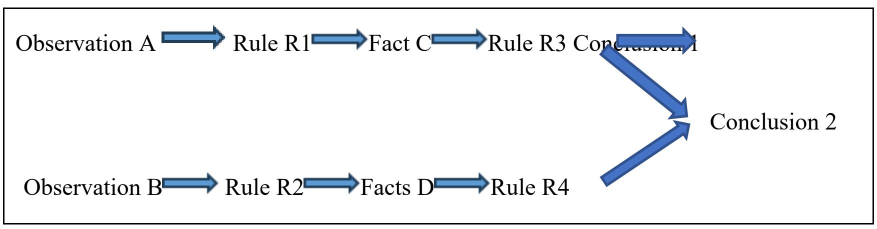

Fig. 1: Forward Chaining Workflow

2.4 Certainty Factor

The Certainty Factor (CF) method is used in expert systems to handle uncertainty in the process of diagnosing corn crop diseases. This uncertainty arises because the symptoms observed in the field are often incomplete and the level of expert confidence in the relationship between symptoms and diseases is not always absolute. Therefore, the main purpose of using the Certainty Factor method is to measure and represent the level of confidence in the diagnosis results based on the Measure of Belief (MB) and Measure of Disbelief (MD) values given by experts. With the application of this method, the system not only determines the type of maize plant disease, but also generates a diagnostic certainty value that reflects the level of confidence in the outcome based on the user's chosen combination of symptoms [7]. The basic formula of the Certainty Factor for one symptom is as follows:

$$CF(H,E) = MB(H,E) – MD(HE) \quad (1)$$

Description :

a. CF(H,E): The value of the Certainty Factor of the HHH hypothesis influenced by EEE evidence
b. MB(H,E): The level of expert confidence in the HHH hypothesis if given EEE evidence (value between 0 and 1)
c. MD(H,E): The level of expert skepticism about the HHH hypothesis if given EEE evidence (valued between 0 and 1).

3. Research Methods

3.1. Research Flow

This research was conducted in Ndapayami Village, Katangang District, East Sumba Regency, with an area of about 38 km² and a population of 758 people. Most of the residents of Ndapayami Village make a living as farmers, who generally produce maize crops. The research flow serves as a framework that describes the stages in the implementation of the study. These stages consist of several main components, namely:

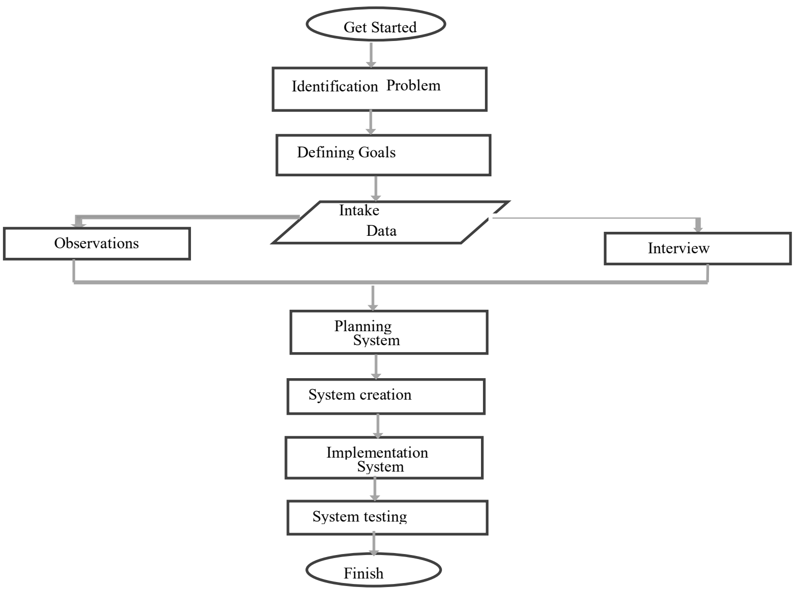

Fig. 2: Research Flow

Figure 2 illustrates the research flow that begins with the identification of the main problem, namely the difficulties faced by farmers in determining the type of plant disease quickly and accurately. The next stage is the determination of the research objectives, which is to build an expert system using forward chaining methods and certainty factors to assist farmers in diagnosing plant diseases. Data collection is carried out through observation, interviews, and documentation to obtain the information needed regarding the types of diseases, symptoms, and solutions for their treatment. After that, the system was designed by compiling a certainty factor algorithm to determine the level of certainty of the diagnosis and a forward chaining algorithm as an inference method. The stage of creating a system is carried out by developing a system using the PHP programming language, building a knowledge base and a rule base based on the relationship between symptoms and diseases. Furthermore, at the implementation stage, the knowledge base is integrated into the system by applying the forward chaining method for the inference process and the certainty factor for the calculation of diagnosis. The testing stage is carried out to ensure that the diagnostic results produced by the system are accurate and appropriate, while the evaluation stage is carried out by users (farmers) to assess the ease of use and benefits of the system in helping the plant disease diagnosis process.

3.2. Development Methods

Method *waterfall* It is used in this study as an approach to develop an expert system to diagnose diseases in maize plants. This method was chosen because it is able to provide a systematic and structured development flow, starting from the needs analysis stage to the system design stage[8]

The application of *the waterfall* model is carried out through several successive stages, as described in the next section:

3.2.1. Needs Analysis

At this stage, the need for the system is determined based on the problems experienced by farmers, which includes the preparation of a knowledge base, data collection of disease types and symptoms, and the determination of appropriate disease codes and symptom codes to support the diagnosis process.

a. The knowledge base is the essence of creating an expert system which includes the representation of knowledge from an expert. A knowledge base contains a set of information about the rules that an expert system needs to understand and solve problems in a specific problem domain by applying the Forward Chaining method.

Table 1: Disease Knowledge Base

Yes	Rules of the disease
1	if the symptoms of GP01, GP05, GP06, and GP07 are met, then the diagnosed disease is Down Syndrome.
2	If the symptoms of GP02, GP08, and GP09 are met, then the diagnosed disease is Leaf Spot.
3	If the symptoms of GP03 and GP10 are met, then the diagnosed disease is Root and Stem Rot.
4	If the symptoms of GP04 are met, then the diagnosed disease is Leaf Rust

b. The list of diseases and symptoms is used as the main reference in the diagnosis process to ensure that the decisions produced by the system are valid and structured based on data. The details of the diseases and symptoms used in this specialist system are presented in the following table.

Table 2: List of Diseases and Symptoms

Yes	Diseases	Symptoms
1	Survival	1. Yellow stripes appear elongated parallel to the leaf bones. 2. Dwarf plants or shortened stems. 3. Cob formation is inhibited. 4. Cob is small in size.
2	Leaf Spot	1. There are small spots on the leaves. 2. Spots are round to oval. 3. Yellow spots on the leaves.
3	Root and Stem Rot	1. The roots rot and change color to dark brown to black. 2. The plant looks wet and easily collapses.
4	Karat Daun	1. Small reddish-orange (rust) spots appear on the leaves.

c. Disease Code
Disease codes are used to explain the relationship between disease symptoms so as to facilitate the diagnosis process based on the facts that have been grouped in Table 3. Furthermore, coding is done to simplify and speed up the diagnosis process in the system. The coding of diseases is presented as follows:

Table 3: Disease Code

Disease Code	Diseases
P1	Survival
P2	Leaf Spot
P3	Root and Stem Rot
P4	Carat Daun

d. A disease symptom code is a code for each symptom that appears to facilitate the disease identification process in the diagnosis system. After the disease coding is performed, the next stage is symptom coding, which is presented in the following table.

Table 4: Disease Symptom Code

Yes	Symptom codes	Symptoms of the disease
1	GP01	Elongated yellow stripes appear parallel to the leaf bones
2	GP02	There are small spots on the leaves
3	GP03	The roots rot and change color to dark brown to black
4	G0P4	There are small reddish-orange spots (rust)
5	GP05	Dwarf plants or shortened stems
6	GP06	Inhibited cob formation
7	GP07	Small-sized cobs
8	GP08	Spots round to oval
9	GP09	Yellow spots on the leaves
10	GP10	The plants appear to be swollen

3.3 Forward Chaining Workflow and Certainty Factor

1. Forward chaining: The reasoning process starts from the initial facts, namely the symptoms that appear in rice plants. Each input symptom will be matched to the rules that have been set. If the symptoms meet the existing rules, then the system will produce a conclusion.
2. Certainty factor: After the rules are met, the level of certainty of the diagnosis is calculated using the *certainty factor* (CF) formula to determine the level of confidence in the results of the diagnosis obtained.

Table 5: Range of Certainty Factor Values

Value of Certainty Factor	Categories of each certainty value
1	Very confident
0.6 – 0.9	Confident

0,1 – 0,5	Not sure
0	Not sure

3.4 System ModelingBefore the system modeling process is carried out, the initial stage is to compile a system design using *Unified Modeling Language* (UML). This modeling aims to represent the system workflow clearly, so that it can make it easier to understand and explain the program code to be developed. The system modeling used in this study is as follows:

1. Use Case Diagram

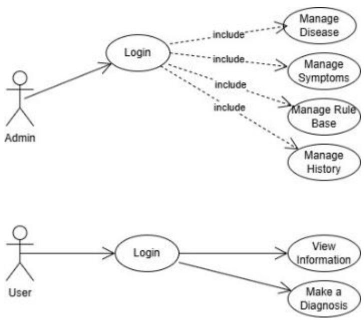

Fig. 3: Use Case Diagram

Figure 3, illustrates the use case diagram, which involves two actors : the admin and the user. The admin is required to log in by entering a username and password. Once logged in, the admin can perform various tasks, including managing diseases, symptoms, rules, and diagnostic history. In contrast, the user's role is to conduct a diagnosis by selecting the relevant symptoms.

4. Analysis and Discussion

4.1. Analysis

Based on the results of observations and interviews conducted with farmers in Ndapayami Village, it is known that farmers are still experiencing obstacles in identifying diseases in corn plants. The limited availability of agricultural experts and the lack of supporting information often result in farmers handling diseases that are not appropriate. As a solution to this problem, a web-based expert system was developed that functions to analyze the symptoms of corn plant diseases based on user input, adjust them to the predetermined rule base, and produce diagnostic results that are equipped with a level of certainty value using *the forward chaining* and *certainty factor* methods. With this system, farmers can make an early diagnosis of corn plant diseases faster, more precisely, and more efficiently.

4.2. Planning

At the system design stage, the workflow as well as the structure of the system are thoroughly planned. The system was developed using *a rule-based reasoning* approach by integrating *a forward chaining* algorithm as an inference method and *a certainty factor method* to calculate the level of confidence in the diagnosis results. The knowledge base is structured in the form of IF–THEN rules, in which each disease of the corn crop is associated with a combination of specific symptoms formulated as a premise using the AND logic operator. The system supports two types of users, namely:

1. Users (farmers), who can access information and take advantage of the corn plant disease diagnosis feature.
2. Admins, who have the right to add, change, and delete symptom data, disease data, rules of the relationship between symptoms and diseases, and view the history of diagnoses made by users.

4.3 Implementation

The implementation stage focuses on the utilization of a web-based expert system by each user's'role in diagnosing corn crop diseases according to their respective functions. At this stage, the system is still accessed locally through *localhost*. The interface and functionality of the expert system that have been developed are shown in the following images

a. Login Page

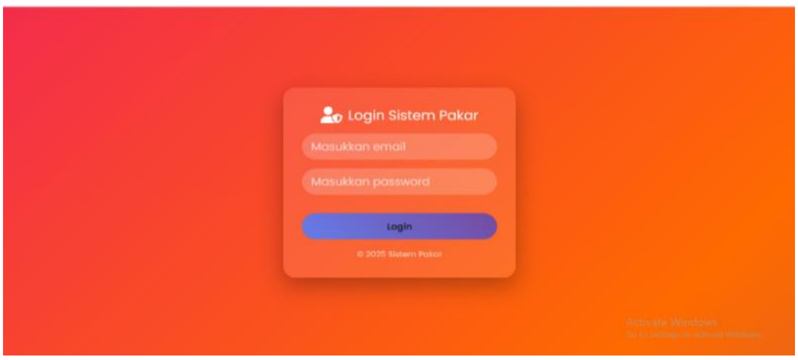

Fig. 4: Login Page

This view is used by admins to log in to the system by entering a username and password. This view is designed to make access rights easier .

b. Admin Page

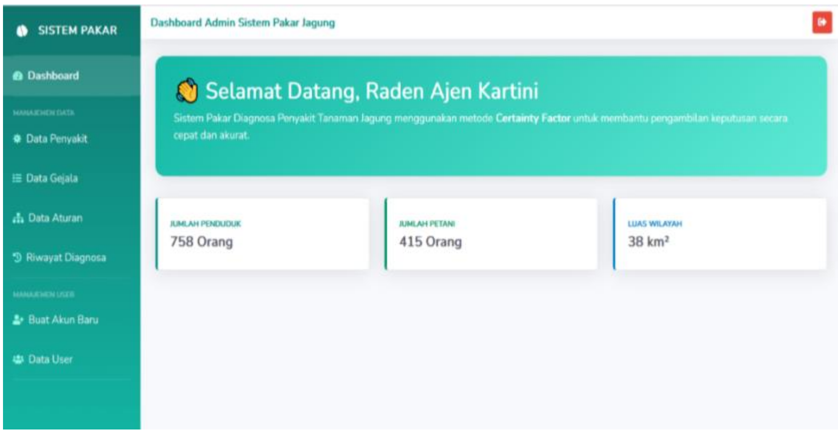

Fig. 5: Admin Page

After successfully logging in, the admin is directed to a dashboard page that displays information on the number of symptoms, diseases, and knowledge bases, as well as the navigation menu on the left side to access the Home, Disease Data, Symptom Data, Knowledge Base, and Logout features.

c. User Home View

Fig. 6: User Home View

On this main page, admins and users can access the system, where users can directly select the Start Identification menu to go to the disease diagnosis page, as well as use the Home, Diagnosis, and Logout navigation.

d. Diagnosis Display

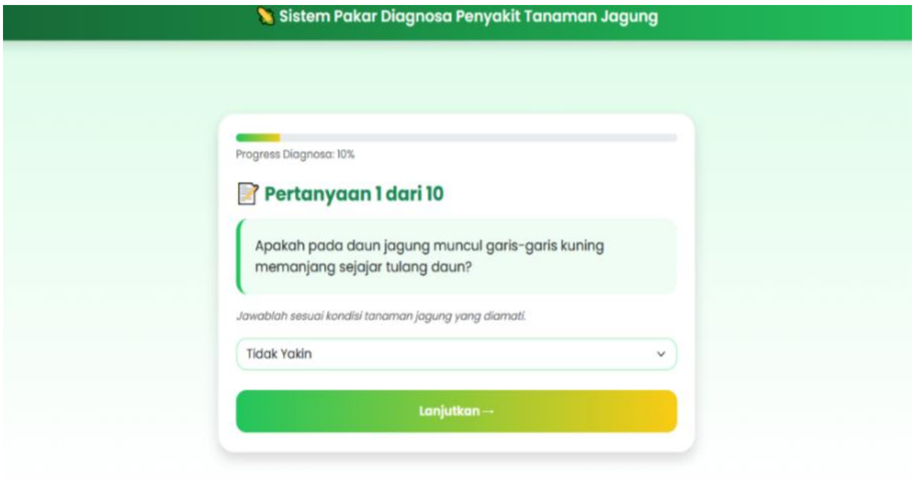

Fig. 8: Diagnosis View

Figure 8 shows the diagnosis page used by the farmer, where the user answers the available questions as well as selects a confidence level for each symptom experienced.

e. Display of Diagnosis Results

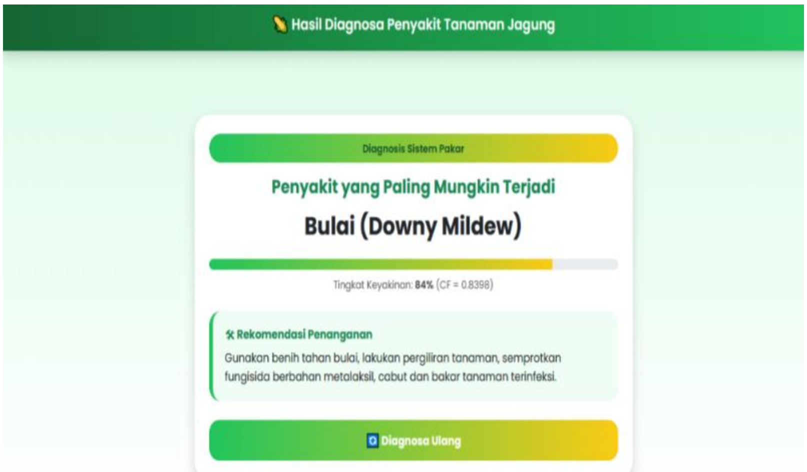

Fig. 9: Diagnosis Results

Figure 9 shows the results of the diagnosis which contains an explanation based on the symptoms inputted, the description of the disease, the value of the confidence level, and recommendations for disease management solutions.

5. Conclusion

This research succeeded in developing an expert system to diagnose diseases in corn plants by applying *the forward chaining* and *certainty factor* methods. The results of the study show that the system can be effectively implemented to assist farmers in Ndapayami Village, Kanatang District, East Sumba Regency in identifying maize plant diseases quickly and accurately. The system is able to produce a diagnosis equipped with a confidence level value, with an accuracy rate of 80% based on *the results of black-box testing* in 10 test case scenarios. The *forward chaining* method is used to trace the symptoms input by the user and match them to the rules available in the knowledge base, while the *certainty factor* method plays a role in calculating the level of confidence in the diagnosis results. As a web-based system, it allows farmers to access information and make diagnoses independently, thereby reducing reliance on agricultural experts and minimizing the risk of crop failure due to delays in disease management.

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