

Expert System for Diagnosing Banana Plant Diseases Using the Forward Chaining Method: A Case Study in Mauliru Village

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Abstract

Bananas (*Musa spp.*) are a horticultural crop that plays a significant role in the Indonesian economy, particularly for farmers in Mauliru Village. However, the main obstacle faced by some farmers is disease attack such as affected by diseases such as blood disease, fusarium wilt, and *cercospora* leaf spot. These issues are further exacerbated by limited farmer knowledge and the lack of agricultural experts available to provide assistance. To address this problem, this study proposes the development of a web-based expert system to assist farmers in diagnosing banana plant diseases. The system employs the Forward Chaining method, which operates based on symptoms entered by the user, and integrates the Certainty Factor (CF) method to provide confidence levels for diagnostic results. This system offers information on the identified disease and recommended treatment solutions, enabling farmers to respond more quickly and effectively. Testing results indicate an accuracy rate of 80%, demonstrating that the system is a viable tool for identifying banana plant diseases, especially in regions with limited access to expert support.

Keywords: Expert System, Banana Plant, Disease Diagnosis, Forward Chaining, Certainty Factor

1. Introduction

Banana plants (*Musa spp.*) are horticultural crops originating from Southeast Asia and have long been cultivated by farmers worldwide as an important commodity [1]. In Indonesia, banana production reached 9.24 million tons in 2022, an increase of 5.77% from 8.74 million tons in the previous year, according to data from the Central Statistics Agency (BPS). While national production has risen, banana production in East Nusa Tenggara Province (NTT) has experienced a decline, dropping from 2,567,234 quintals in 2021 to 2,116,206 quintals in 2023 [2]. Similarly, in East Sumba Regency, banana production decreased significantly, from 25,776 quintals in 2022 to just 3,148 quintals in 2024 [3].

In Mauliru Village, which is located in East Sumba Regency, it is one of the areas in East Nusa Tenggara Province (NTT) that has extraordinary potential in the agricultural sector, including horticultural crops such as bananas. Bananas have an important role for the some mauliru farmers as a source of food and additional income. However, disease attacks often stop banana production in Mauliru Village, causing crop yields to decrease. Based on interviews with local communities, some farmers complained that more than 60% of banana fields were infected with diseases, which resulted in a 40% decrease in production. This condition further exacerbates the instability of farmers' economic. Some farmers report that they are often late in realizing disease attacks due to a lack of information and limited access to the of the disease, how to prevent it and how to treat it effectively.

To overcome diseases in banana plants, technology-based solutions are needed that make it easier for farmers to identify diseases early and provide appropriate handling recommendations. This study aims to develop a system that assists farmers in diagnosing diseases in banana plants. The system is designed using the Forward Chaining method, which enables it to identify potential diseases based on symptoms entered by the user. Once the symptoms are provided, the system generates possible diagnoses along with treatment recommendations quickly and accurately. By utilizing this expert system, farmers are expected to make better-informed decisions, thereby contributing to improved banana production in Mauliru Village.

2. Literature Review

2.1. Banana Plant

Bananas, a highly favored tropical fruit horticultural commodity, have enormous economic potential if managed intensively and focused on agribusiness. Bananas are the fourth most important food crop in the world after wheat, rice, and corn, in terms of production and amount of dubia's favorite fruit consumption [4].

Despite its potential, bananas are prone to diseases. Banana disease is a disorder in the banana plant caused by pathogens (fungi, bacteria, viruses, nematodes) or environmental factors, which lead to decreased productivity, tissue damage, or even plant death. The following types of diseases are found in banana plants:

- a. **Blood Disease:**
Blood Diseases/*Tattoo Disease*/Bacterial wilt caused by bacteria *Ralstonia (Pseudomonas) Solanacearum PV, celebensis*. Symptoms of blood disease are indicated by the mother bone of the leaf showing yellowish-brown stripes, if the roots/stems of the infected plant are cut off, a red liquid will come out (ooze/bacterial mucus) and yellowish fruits containing brownish-red bacterial fluid/mucus [5].
- b. **Fusarium wilt disease (Panama):**
Fusarium wilt disease or also known as *panama* disease is a disease caused by *Fusarium oxysporum f.sp. cubense*. Symptoms of Fusarium wilt disease are indicated by dark yellow underside of the leaves which if it gets worse will turn brown and dry, the petioles are broken, the outer layer of the false stem is split, and at the base of the stem that is split longitudinally there will be brown/black stripes [5].
- c. **Sigatoka Disease/Cercospora Leaf Spot:**
Sigatoka disease is caused by pathogen *Mycosphaerella musicola/Cercospora musae*. Symptoms of sigatoka disease are indicated by these spots then develop into dark brown-black patches that are long rounded. On the old leaves the center of the spot will dry out, turn light gray with dark brown edges, and be surrounded by a bright yellow halo [5].

2.2. Expert System

Expert system is a system that combines knowledge and data tracing to solve problems that normally require human expertise. Thus, an expert system is a computer application that is intended to help decision-making or problem solving in a specific field. This system works by using knowledge and analysis methods that have been defined in advance by experts who are in accordance with their field of expertise. The expert system consists of two main components, namely: the knowledge base and the usual inference tools knowledge is obtained from the accumulation of expert knowledge in a particular field, knowledge here is defined as a collection of data and a set of rules for manipulating or processing data to become new knowledge [6].

2.3. Forward Chaining

Forward chaining starts from the data set to the conclusion. A case conclusion is built on known facts (data driven). This method is known as data-based search, where the search is carried out from the initial facts to the final conclusion. This study chose the forward chaining method because it begins the reasoning process from known data or facts to reach a conclusion. This method is particularly well-suited for symptom-based disease diagnosis systems, as it can gradually infer disease outcomes based on symptom input from farmers.

3. Research Methodology

3.1 Research Flow

The research flow is a framework that will describe the stages that will be carried out. The research stage consists of several studies, namely:



Fig. 1: Research Flow

Figure 1 illustrates the research flow, beginning with the identification of the main problem: farmers' difficulty in diagnosing banana plant diseases quickly and accurately. The next stage involves data collection through observations and interviews with agricultural experts and farmers to gather the necessary information. In the system design phase, a Certainty Factor algorithm is developed to determine the confidence level of the diagnosis, while a Forward Chaining algorithm is created for the inference process. During implementation, the knowledge base is constructed using a programming language, integrating the Forward Chaining method for inference and the Certainty Factor for calculating diagnostic certainty. Finally, system testing is conducted to ensure the accuracy and reliability of the diagnostic results.

3.2 Development Methods

The research employed the waterfall method to develop the expert system for diagnosing diseases in banana plants. This method was chosen as it allows for systematic analysis and development of information systems, starting from needs analysis through to system design. The implementation of the waterfall model involves several sequential stages, which are as follows:

3.2.1 Needs Analysis

At this stage, collecting the needs of the system based on the problems faced by farmers is needed, namely a list of diseases and symptoms, disease codes, disease symptom codes in banana plants, list of symptoms, decision tables, knowledge bases as follows:

a) List of Diseases and Symptoms

Table 1: List of diseases and symptoms

No.	Disease	Symptom
1.	Blood	1. Bone leaves showing yellowish-brown stripes 2. Yellowish fruits that contain reddish-brown liquid/mucus. 3. If the roots/stems are cut, red liquid will come out
2.	Fusarium Wilt	1. Split outer layer of forged stem 2. The edges of the lower leaves are dark yellow if they get worse, they will be light brown. 3. Broken leaf stalks. 4. The base of the split stem will show dark brown stripes.
3.	<i>Sigatoka/Cercospora Leaf Spot</i>	1. There are elongated spots of pale yellow/brownish-green that are located parallel to the leaf bones. 2. These spots then develop into dark brown-black patches that are long rounded. 3. On the old leaves the center of the spots will dry out, the color becomes light gray with dark brown edges.

b) Disease Code

Table 2: Disease Code

Yes	Disease Code	Disease
1	P01	Blood
2	P02	Fusarium Wilt
3	P03	<i>Sigatoka/Cercospora Leaf Spot</i>

c) Disease Symptom Code

Table 3: Disease Symptom Code

Yes	Symptom Code	Symptoms of the disease
1	GP01	Bone leaves showing yellowish-brown stripes
2	GP02	Split outer layer of forged stem
3	GP03	The presence of elongated spots of pale yellow/brownish-green located parallel to the leaf bones.
4	GP04	Yellowish fruits that contain reddish-brown liquid/mucus.
5	GP05	The edges of the lower leaves are dark yellow if they get worse, they will be light brown.
6	GP06	These spots then develop into dark brown-black patches that are long rounded.
7	GP07	Broken leaf stalks.
8	GPO8	If the roots/stems are cut, a red liquid will come out.
9	GPO9	The base of the split stem will show dark brown stripes.
10	GP10	On the old leaves the center of the spot will dry out, the color becomes light gray.

d) Knowledge Base

The knowledge base is an important part of the expert system that stores systematic information about disease diagnoses that includes facts and rules. The rules of production are written in the form of *IF-THEN* (if-then) statements, which means if [premise] then (conclusion). In the basic design of expert knowledge systems, the premise refers to the symptoms of the disease. Thus, the statement becomes IF [symptoms] THEN [Disease]. These symptoms are connected by using the AND logic operator, so the form of the question is: IF[Symptom 1]AND[Symptom2]AND[Symptom 3]THEN[Disease]

The *forward chaining* method uses current facts to reach a conclusion or solution. In this situation, when the symptoms are considered as facts, one can draw conclusions about the symptoms and diseases after all the data is collected. Rule-based reasoning, also known as rule-based reasoning, is the basis of applied knowledge.as follows:

Table 4: Disease Knowledge Base

Yes	Disease Rules
1	IF GP01 AND GP04 AND GP08 THEN Blood Diseases
2	IF GP02 AND GP05 AND GP07 AND GP09 THEN Fusarium Wilt Disease
3	IF GP03 AND GP06 AND GP10 THEN Sigatoka Disease

3.3 Forward Chaining and Certainty Factor Workflow

- a. Forward Chaining: The process begins by examining each symptom in the banana plant. If the symptoms are in accordance with the rules, then we can get a conclusion.
- b. Certainty Factor: If the rules are suitable, it will be continued with the calculation of the Certainty Factor based on the CF formula.

Table 5: Vulnerable Value Certainty Factor From 0-1

Certainty Factor Value	Categories of Each Certainty Value
1	Very Confident
0,6-0,9	Believe
0,1-0,5	Lack of confidence
0	Not Sure

3.4 Use Case Diagram

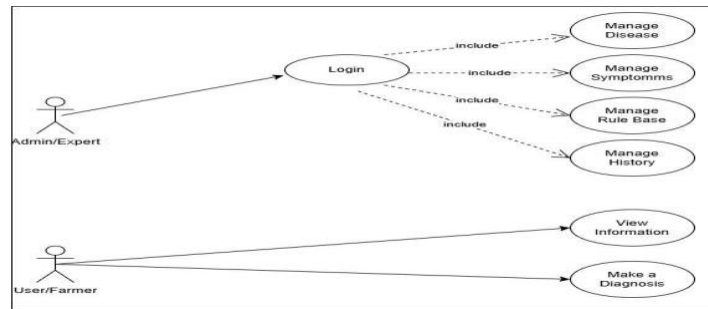


Fig. 2: Use Case Diagrams

In figure 2, there are 2 actors, namely experts and farmers. Administrators (admins) can log in, manage illnesses, manage the rule base, manage history. Meanwhile, farmers can only see information and diagnose banana plant diseases.

4. Analysis and discussion

4.1 System Implementation

This chapter describes the implementation stage of the system design the implementation process is shown through the interface of the banana plant disease diagnosis expert system. Each page in the system is displayed along with a brief explanation of its functions and uses. It aims to visually describe how the system works as well as provide an overview of the flow of the system's use by the user. This system has two access rights, namely admin (expert) and user (user). For now, the website of the expert system for diagnosing diseases on banana plants can only be accessed through localhost.

- a. Login Admin

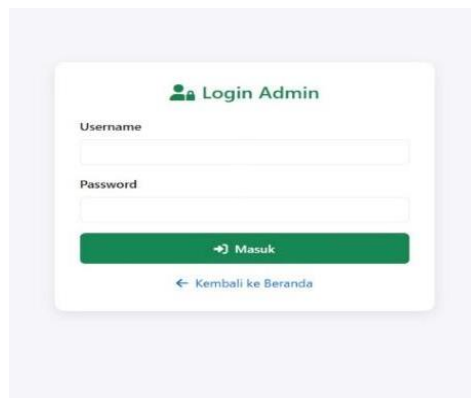


Fig. 3: Admin Login

Figure 3 represents the admin page to log in to the system by entering the username and password

b. Dashboard Appearance for Admin



Fig. 4: Dashboard Admin

In figure 4 displays the display when admin successfully logs in to the system, the admin will be directed to the dashboard page which displays several menus such as *Symptom Data*, *Disease Data*, *Rule Data*, *Diagnosis History*.

c. Symptom Data Display



Fig. 5: Symptom Data Display

Figure 5 is a symptom data page display, where this page contains symptoms, symptom codes, symptom names, and this page is also used by admins to add, edit and delete symptom data in the system.

d. Disease Data Display



Fig. 6: Disease Data Display

Figure 6 is a disease data page display, which contains the number of diseases, disease codes, disease names, and solutions, and this page is also used by admins to add, edit and delete disease data on the system.

e. View Of Relationship Rules

No	Kode & Gejala	Kode & Penyakit	MB	MD	Aksi
1	GP01 Ibu tulang daun menunjukkan garis-garis cokelat kekuningana	P01 Penyakit Darah	0.7	0.1	[Edit]
2	GP04 Buah menguning berisi cairan/lendir berwarna merah kecokelatan	P01 Penyakit Darah	0.8	0.2	[Edit]
3	GP08 Akar/batang dipotong keluar cairan merah	P01 Penyakit Darah	0.9	0.1	[Edit]
4	GP02 Lapisan luar batang palsu terbelah	P02 Layu Fusarium	0.6	0.2	[Edit]
5	GP05 Tepi daun bawah kuning tua, lalu cokelat kering	P02 Layu Fusarium	0.8	0.1	[Edit]
6	GP07 Tengkal daun patah	P02 Layu Fusarium	0.7	0.2	[Edit]
7	GP09 Pangkal batang dibelah tampak garis cokelat/hitam	P02 Layu Fusarium	0.9	0.1	[Edit]
8	GP03 Bintik-bintik memanjang berwarna kuning pucat/hijau kecokelatan sejajar tulang daun	P03 Bercak Daun Cercospora	0.7	0.1	[Edit]
9	GP06 Bintik coklat tua-hitam berbentuk bulat panjang pada daun	P03 Bercak Daun Cercospora	0.8	0.2	[Edit]
10	GP10 Pusat bercak pada daun tua mengering kelabu, tepi coklat gelap disekeliling halo kuning	P03 Bercak Daun Cercospora	0.9	0.1	[Edit]

Fig. 7: Rule View

Figure 7 is a rule view which contains the number of symptoms, symptom codes, disease codes, disease names, mb, md, and this page is also used by admins to add, edit and delete rule data on the system.

f. Display Diagnosis History

No	Nama Pengguna	Tanggal Diagnosa	Hasil Diagnosa	Nilai CF
1	User	15/07/2025 17:06	P02	0.5592
2	User	15/07/2025 16:59	P01	0.5904
3	User	15/07/2025 16:55	P01	0.5904
4	User	15/07/2025 16:51	P01	0.5904
5	Admin	27/06/2025 14:46	Penyakit Darah	0.6000
6	Admin	26/06/2025 14:13	Layu Fusarium	0.9400
7	Admin	26/06/2025 14:01	Penyakit Darah	0.8000
8	Admin	26/06/2025 13:58	Penyakit Darah	0.6000

Fig. 8: Display Diagnosis History

Figure 8 shows a page that contains a view of diagnostic records that have been performed by users and admins. The fields include: *Username*, who made the diagnosis, *Date of Diagnosis*, when the diagnosis was made, *Diagnosis Result*, and disease code (e.g. P01, P02), *CF value* – confidence factor value from the system calculation.

g. Dashboard User

Sistem Pakar Diagnosa Penyakit Tanaman Pisang

Temukan solusi dari gejala yang Anda alami untuk menjaga kesehatan tanaman pisang Anda.

- Informasi Penyakit**
Pelajari berbagai penyakit pisang dan gejalanya. [Lihat Informasi](#)
- Mulai Diagnosa**
Diagnosa penyakit berdasarkan gejala yang Anda alami. [Diagnosa Sekarang](#)
- Login Admin**
Masuk untuk mengelola data gejala, penyakit, dan hasil diagnosa. [Masuk Admin](#)

Fig. 9: User Dashboard Page

Figure 9 is a display that contains disease information, and users can also directly click on the start diagnosis menu.
 h. Information Display

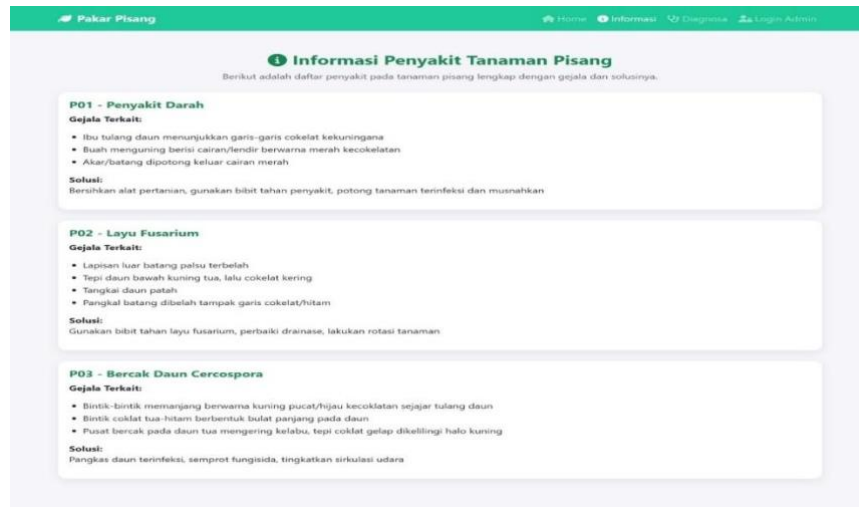


Fig. 10: Information Display

Figure 10 contains information on diseases, symptoms of diseases, solutions.

i. Diagnostic Display



Fig. 11: Diagnostic Display

Figure 11 is a diagnostic display where the user will select several symptoms

j. Display Diagnostic Results

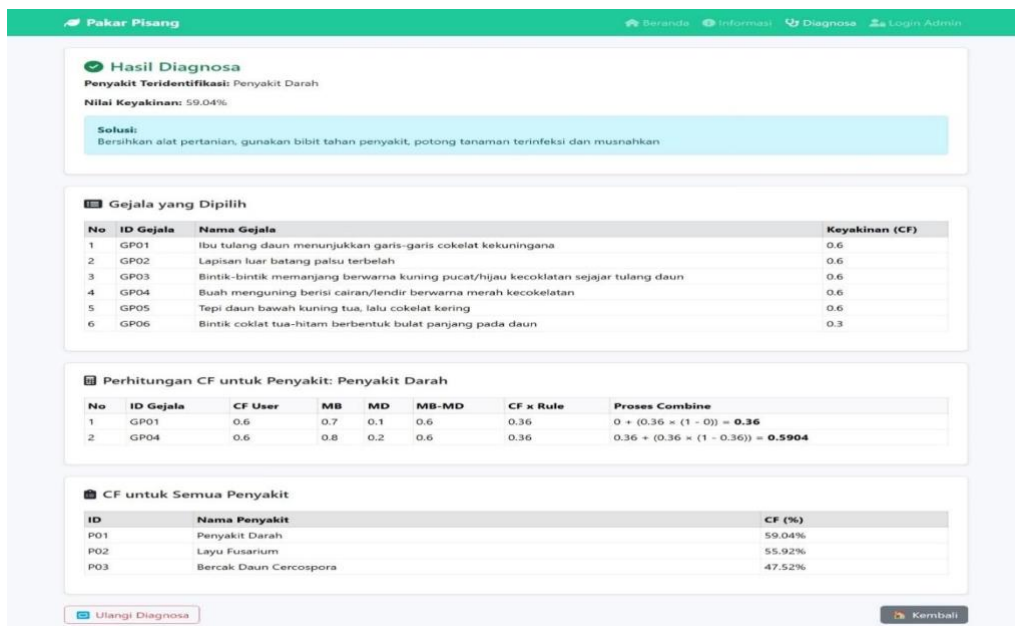


Fig.12: Display Diagnostic Result

Figure 12 is a display of diagnostic results which contains the diagnostic results.

4.2 Testing

At the testing stage, it is carried out using *black-box testing*, which is very important because it is able to test whether the system is working according to its function and providing accurate results. In addition, a trial scenario was also carried out using 10 case data based on a combination of symptoms from blood disease, fusarium wilt, and sigatoka/cercospora leaf spots.

5. Conclusion

Based on the results of this study, an expert system for diagnosing diseases in banana plants has been successfully developed to assist farmers in independently identifying diseases quickly and accurately. The system utilizes the Forward Chaining and Certainty Factor methods to generate diagnoses based on symptoms selected by the user. It provides diagnostic results along with a confidence level for each symptom, enabling the system to determine the most probable disease affecting the plant.

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