OPEN ACCESS
VOL. 7, NO. 1, PP.033-050, NOVEMBER 2024

ISSN : 2622-8106 (ONLINE)
DOI: 10.20895/INISTA.V7I1.1633

Journal of Informatics, Information Systems, Software Engineering and Applications (INISTA)

Expert System for Diagnosing Diseases in Coffee Plants Using Forward Chaining and Classic Probability Algorithms (Case Study: West Lampung)

Eka Revi Novita[1], Indra Gunawan [2], Wawan Gunawan[3]

[1,2,3,4]Information Systems, Raden Intan State Islamic University of Lampung, Indonesia
Jl. Lieutenant Colonel H. Endro Suratmin, Sukarame, Lampung, Indonesia

[1]ekarevi32@gmail.com
[2]indragunawan@radenintan.ac.id
[3]wawan.gunawan@radenintan.ac.id

Received on 28-10-2024, revised on 10-11-2024, accepted on 28-11-2024

Abstract

Coffee is the main commodity in Indonesia, and it has a high selling value as a source of foreign exchange. West Lampung Regency, one of the main coffee producers, produced around 56.054 tons in 2022. However, production is decreasing due to low productivity and quality. One of the main challenges is the limited knowledge of coffee farmers in West Lampung about coffee plant diseases, which causes inappropriate handling. Additionally, a lack of experts to help farmers manage the disease is exacerbating the problem. To overcome this, an expert system was developed to provide information and solutions regarding coffee plant diseases. This system uses the Waterfall method, which includes four stages: requirements analysis, design, implementation and testing. In the analysis stage, data about the disease, symptoms, rules, and solutions are collected. The design stage focuses on creating a system blueprint. Implementation involves applying the Forward Chaining algorithm to analyze symptoms entered by farmers, combined with the Classic Probability algorithm to calculate the probability of disease diagnosis. Testing is carried out using the black-box method for functional evaluation and expert testing to measure diagnostic accuracy. This web-based system helps farmers diagnose diseases early and recommend effective solutions. Expert testing results show an accuracy rate of 87.14%, indicating its reliability in providing the right diagnosis and solution. This proves that the Waterfall method approach combined with the Forward Chaining and Classic Probability algorithms effectively supports efforts to manage coffee plant diseases.

Keywords: Expert system, Forward Chaining, Classic probability, Diagnosing diseases

Corresponding Author:
* Wawan Gunawan
Information System, Raden Intan State Islamic University of Lampung, Indonesia
Jl. Lieutenant Colonel H. Endro Suratmin, Sukarame, Lampung, Indonesia.
E-mail: wawan.gunawan@radenintan.ac.id

I. INTRODUCTION

Coffee is one of the non-alcoholic drinks where most of the coffee production comes from South America and Central America. Coffee plants belong to the genus *Coffea* and belong to the *Rubiaceae family*. Commercially, the coffee that is widely cultivated is robusta and arabica. In Indonesia, most of the coffee produced comes from robusta coffee, which accounts for around 90% of the total, while the rest is arabica coffee [1]. Most Indonesian coffee plantations live in the highlands, especially in West Lampung Regency, which is an area with a superior commodity, namely coffee, with a coffee plantation area in West Lampung of 60.328 hectares of robusta coffee and 5 hectares of Arabica coffee.

West Lampung is the district with the largest coffee production in Lampung Province, namely around 56.054 tons in 2022 [2]. West Lampung Regency prioritizes the development of superior commodities, namely coffee, in order to encourage the regional economy and also the economy of the people as coffee farmers increase. The coffee plant is a product that is in great demand and is superior in Indonesia because coffee has a relatively high selling value and is also a source of foreign exchange for the country. However, in reality, the production of coffee plants is always decreasing because the productivity and

quality of coffee plantations are still very low. The decline in coffee productivity and quality is caused by several factors, one of which is the lack of knowledge of coffee farmers, especially coffee farmers in West Lampung, regarding diseases that arise in coffee plants so that the way to deal with them is not appropriate and causes the coffee plants to die. The quality of the coffee declined.

Apart from that, the factor causing the decline in the quality and productivity of coffee plants in West Lampung Regency is that West Lampung Regency still experiences limitations in the number and availability of experts or agricultural experts who have in-depth knowledge of coffee diseases. This limited number of experts can affect the ability of coffee farmers to detect early disease in coffee plants. Based on the problems above, coffee farmers need tools that can provide knowledge about diseases that exist in coffee plants and how to deal with these diseases. The tool in question can be in the form of an expert system application that uses expert knowledge to provide information about diseases in coffee plants and how to treat them.

The forward chaining algorithm was chosen because of its advantages in making inferences from symptoms inputted by the user to produce diagnostic conclusions in stages so that the system is easier for farmers to use without requiring special technical skills. This algorithm is very useful in a step-by-step process that allows users without expert knowledge to use the expert system still easily. However, this algorithm has a major drawback, namely its dependence on complete symptom data to achieve accurate results, because if the data is not fully available, the results can be less valid [3].

The Classic Probability algorithm is applied to calculate the level of certainty of diagnosis based on the frequency of symptom occurrence, which provides flexibility in measuring the probability of disease even though the symptom data is not completely complete.[4] The advantage of this algorithm is its ability to provide a probability of confidence in the diagnosis results, which allows the system to operate with a certain level of uncertainty. However, the weakness of this algorithm lies in the need for a large and accurate database to produce reliable results because insufficient or incomplete data will affect the accuracy of the diagnosis results [5].

The combination of these two algorithms is expected to provide an effective solution for coffee farmers in West Lampung in dealing with problems in diagnosing coffee diseases and increasing coffee plant productivity more efficiently and accurately. An expert system is an artificial intelligence program that combines a knowledge base with an inference system to imitate an expert intended to help make decisions or solve problems in a particular field. An expert system is a computer system that matches the decision-making abilities of an expert, which means that the expert system is expected to work like an expert. Expert systems have been developed since 1960. This system usually functions as an important key that can help a decision support system. With an expert system, the resulting output can be more organized, effective and precise [6].

The forward chaining algorithm is a method of reasoning data from existing facts to conclusions. Forward chaining starts from the premise (facts) to the conclusion (conclusion).[7] This search technique looks for known facts and then matches these facts into the IF part of the IF-THEN rule. If the IF fact is true, then it will be executed. Next, new facts (THEN) will be added to the database. Matching will stop if there are no more rules that can be executed [8]. Probability is the magnitude of the possibility that an event or event will occur. This probability theory in Equation (1) is used in an existing possibility or uncertainty [9]. The general formula for classical probability is defined as probability $P(a)$ where n is the number of events, $N(a)$ is the number of outcomes getting value A, then:

$$P(A) = \frac{N(a)}{N} \qquad (1)$$

$$Percentage \; = \; P(a) \; x \; 100\%$$

Where :
A: name of the disease
$P(a)$: probability of disease
N: total number of symptoms
$N(a)$: number of selected symptoms
The possibility table in Table I is as follows:

TABLE I. POSSIBILITY TABLE

Condition	Percentage
Definitely not	<10%
Do not know	10-19%

Condition	Percentage
Almost Maybe	20-39%
Maybe	40-59%
Probability of correctness	60-79%
Almost certainly	80-99%
definitely	100%

The coffee plant (Coffea sp.) is a type of tree-shaped plant belonging to the Rubiaceae family and the Coffea genus. Coffee plants grow branched, upright, and can reach 12 meters in height. The leaves of the coffee plant are egg-shaped with slightly tapered tips. Two commonly known varieties of coffee trees are Robusta Coffee (Coffea canephora) and Arabica Coffee (Coffea arabica)[10].

In the cultivation process, coffee plants often face various diseases that can hamper their growth and productivity. Plant disease is a process of physiological disturbance in plants caused by pathogenic microorganisms such as bacteria, fungi and viruses. Coffee plant disease itself is a condition of health problems in coffee plants which can attack coffee plants either directly or indirectly, so that it can cause problems with growth and development as well as productivity [11].

To deal with these problems, the development of technology-based systems is important. One approach used in system development is the Waterfall method. The waterfall method is the most widely used system development model. The waterfall method is a sequential and systematic stage where each stage must be passed by waiting for the completion of the previous stage so that the next stage can be carried out [12].

Once the system is developed, testing is carried out to ensure its functionality meets user requirements. One testing method that is often used is black box testing. Black box testing is a type of software testing that focuses on the external functionality of the system without paying attention to its internal structure or details. This testing is based on system requirements specifications and does not require coding checks. This testing is only based on the user's view of whether the required function meets expectations [13].

This research aims to identify symptoms and diseases found in coffee plants by building an expert system that can diagnose diseases in coffee plants, evaluating and analyzing the use of forward chaining and classic probability algorithms in improving the performance of expert systems and providing solutions to overcome limited numbers and the availability of agricultural experts or specialists in West Lampung.

II. RESEARCH METHOD

A. Research Tools

The supporting tools required in this research are as follows:

1. Hardware
   The hardware used during this research was a laptop with the following specifications.
   a. VivoBook_ASUSlaptop X415JAB_A416JA
   b. Processor Intel(R) Core(TM) i3-1005G1 CPU @ 1.20GHz
   c. 4,000 mAh RAM
2. Software
   The software used in creating expert systems is:
   a. Operating system: Windows 11 Home Single Language 64-bit
   b. Application :
      1) Notepad++ as a source code editor
      2) XAMPP as a database server
      3) Google Chrome Web Browser to test the coding that has been created

B. Research Procedures

Research procedures are the steps that researchers will implement during the research. The research stages use the waterfall method, which is presented in Figure 1.

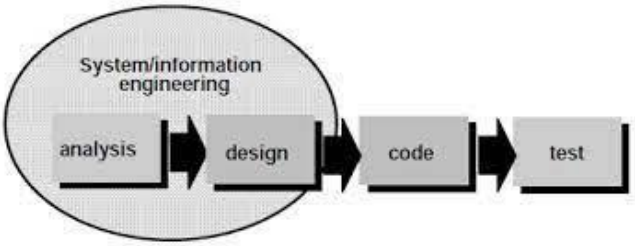

Fig. 1. research procedure[14]

1. Analysis requirements

The needs analysis stage is the most important in the research process, namely the data collection stage. The needs analysis stage was carried out by conducting interviews with coffee plant experts and literature studies. At the data collection stage, there are two methods, namely:

1. Literature study
   The literature study method uses various existing literature, namely from books about coffee plants and expert system books, journals or documents related to the research being carried out.
2. Interview
   This interview method was carried out with an expert in coffee plant diseases, which was carried out using a question-and-answer process in order to obtain more valid information.

From the results of interviews and literature studies conducted, the following information was obtained.

a) *Operational variables*

The variable in this research is a disease in coffee plants. The following diseases in coffee plants The variable in this research is a disease in coffee plants. The following diseases in coffee plants are listed in Table II:

TABLE II. DISEASES IN COFFEE PLANTS

Variable	Disease
Diseases in coffee plants	Leaf rust disease
	Leaf spot disease
	Fungal disease treatment
	Sooty mildew disease
	Black root and brown root disease
	Fruit disease
	Dead end disease

b) *Knowledge base design*

From the interview process with experts and also conducting literature studies from books on coffee cultivation techniques to obtain symptoms, causes and solutions related to diseases in coffee plants. The following data and information obtained are in Table III.

TABLE III. DISEASES, CAUSES, AND SOLUTIONS

Code	Disease	Reason	Solution
P01	Leaf rust disease	*The pathogen hemiplegia vastatrix B et Br*	• *Technical culture* includes *weeding*, *fertilization*, *pruning*, and *shade management*. • Chemical fungicides contain *copper* as the active ingredient, such as *copper oxide*, *copper chloride*, *copper hydroxide*, or *copper sulfate*. For example, *Nordox*, *Kocide*, *Cupravit*, *Dhitane* with a concentration of 0.3% (2-week interval), and *Bayleton*, *Anvil*, *Tilt* with a concentration of 0.1%.
P02	Leaf spot disease	*Cercospora coffeicola fungus*	• Sanitation by cutting diseased leaves and then burning them or burying them in the soil. • Provide sufficient shade • spraying bavistin 50wp 0.2%, cupravit ob 21, dithane m-45
P03	Fungal disease treatment	*Corticium salmonicolor*	• The diseased stem is cut 10 cm below the base of the diseased stem, the stem that has been cut is then burned,

Code	Disease	Reason	Solution
		fungus	• Sick branches are coated with a 10% concentration of copper fungicide such as Nordox, Cupravit, orfungicide calixin RM
P04	Sooty mold disease	*capnodium coffee*	• Spraying with water during the excretion period of sucking insects, cutting off the affected parts
P05	Black and brown root disease	*Rosellina mushroom bunodesand Rasellina arcuata. 2. Symptoms*	• Dismantle diseased plants until they are clean and then burn them • By spreading lime and urea fertilizer • Fungicide is applied to the base of the stem/roots of diseased plants or as a preventive measure, the biological agent Trichoderma sp. can be used.
P06	Fruit disease	*Cephaleuros coffea mushroom*	• Spray with fungicide when the fruit is still young, if the fruit is old it is better to pick it.
P07	terminal limb disease	*Rhizoctonia sp. fungus*	• Cut the diseased part of the plant, cutting is done until the wood is healthy. • do seeding and spray with copper fungicide [15]

Symptoms on coffee plants are listed in Table IV below:

TABLE IV. SYMPTOMS ON COFFEE PLANTS

Code	Symptoms
G01	Are the leaves turning yellow and falling off?
G02	Are the spots appearing on the leaves light yellow and turning dark yellow?
G03	Do the spots get bigger and merge over time?
G04	Are the trees becoming bare?
G05	Do the spots on the underside of the leaves contain orange or orange powdery urediospores?
G06	Are there spots on the leaves?
G07	Are the spots that appear on the leaves brown and circular, white in the center and red on the edges?
G08	Are there brown spots on the fruit?
G09	Are the mature fruits wrinkled and ripening prematurely?
G10	Did a branch or twig suddenly wilt?
G11	Are there pink crusts on the branches?
G12	Are there small reddish-orange spots on the branches?
G13	Does the plant look unhealthy?
G14	Are the plants drying out and turning black?
G15	Are the leaves yellowish green, dull, looking wilted all at once and hanging down?
G16	Is the root bark rotting?
G17	Are there visible weaves of blackish-brown fungal threads between the soil grains?
G18	Are there any sucking insects, such as green aphids, on the leaves?
G19	Is there thin, fibrous mycelium like a spider's web on the fruit/twigs/leaves?
G20	Does the branch die starting from the tip?
G21	Do the leaves tend to curl?
G22	Is there a white powder like flour on the surface of the leaves?
G23	Are there black spots on the skin of unripe fruit?
G24	Is the entire skin of the fruit dry and black?
G25	Are there fine hairs and red spores on the fruit spots?
G26	Is stem growth stunted?

The following regulatory data contains a combination of symptoms caused by coffee plants and disease data in Table V:

TABLE V. RULES

Disease code	Symptom code
P01	G01, G02, G03, G04, G05
P02	G06, G07, G08, G09
P03	G10, G11, G12

Disease code	Symptom code
P04	G18, G19, G22
P05	G01, G13, G14, G15, G16, G17
P06	G23, G24, G25
P07	G01,G13,G20,G21,G26

Based on the rules above, the rules that will be used in the expert system can be obtained, namely:

1. *Rules*1 : IF G01 AND G02 AND G03 AND G04 AND G05 THEN P01
2. *Rules*2 : IF G06 AND G07 AND G08 AND G09 THEN P02
3. *Rules*3 : IF G10 AND G11 AND G12 THEN P03
4. *Rules*4 : IF G18 AND G19 AND G22 THEN P04
5. *Rules*5 : IF G01 AND G13 AND G14 AND G15 AND G16 AND G17 THEN P05
6. *Rules*6 : IF G23 AND G24 AND G25 THEN P06
7. *Rules*7 : IF G01 AND G13 AND G20 AND G21 AND G26 THEN P07

Based on the rules above, it can be explained as follows:

1. Suppose the visible symptoms are that the leaves turn yellow and fall. The spots that appear on the leaves are light yellow, which turns dark yellow. In that case, the spots get bigger and merge over time, and the tree becomes bald. The surface of the spots on the underside of the leaves contains orange or powdery urediospores. The coffee plant experiences leaf rust disease.
2. If the visible symptoms appear as spots on the leaves, the spots that appear on the leaves are brown in the shape of a circle, white in the middle and red at the edges, and brown spots appear on the fruit, wrinkled and ripe prematurely on the mature fruit, then the coffee plant has a disease. Leaf spot If the symptoms that appear are branches or twigs suddenly wilting, there is a pink crust on the branches and small reddish-orange spots on the branches, then the coffee plant has a fungal disease upas
3. If the symptoms that appear are sucking insects such as green aphids on the leaves, there is a thin and fibrous mycelium like a spider's web on the fruit/twigs/leaves, there is a white powder like flour on the surface of the leaves, then the coffee plant has sooty dew disease.
4. If the symptoms appear are that the leaves turn yellow and fall, the plant looks unhealthy, the plant dries up and is black, the leaves are yellowish green dull, appear to be wilting simultaneously and hanging, the root bark is rotting, the roots appear to have woven blackish brown fungal threads, then the coffee plant is experiencing disease. Black roots and brown roots
5. If the symptoms that appear on the skin of the immature fruit are black spots, the entire skin of the fruit is dry and black, and there are fine hairs and red spore granules on the fruit spots, then the coffee plant has fruit disease.
6. If the symptoms experienced are that the leaves turn yellow and fall off, the plant looks unhealthy, the twigs die starting at the tip, the leaves tend to curl, and stem growth is stunted, then the coffee plant is suffering from tip disease.

2. Design

Software Requirements Analysis

In this process, a description of the needs that users will use in building this expert system is carried out. A use case is designed to describe the user interface to carry out the analysis. Usecase diagram of the diagnostic expert system for coffee plants in Figure 2.

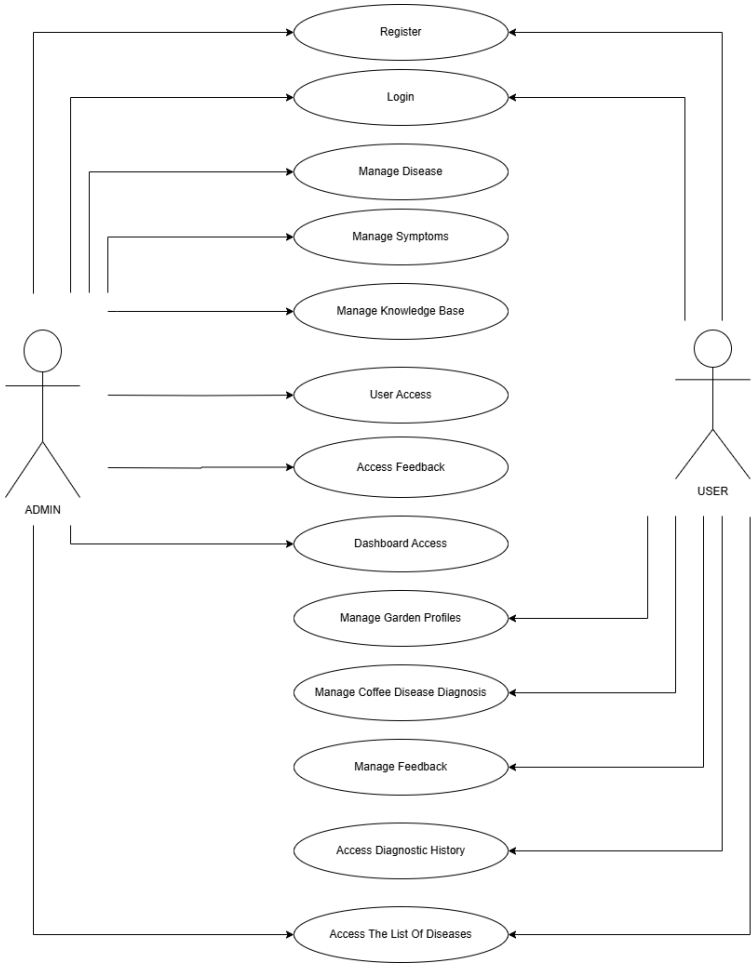

Fig. 2. Usecase diagram of an expert system for diagnosing diseases in coffee plants

The expert system for diagnosing diseases in coffee plants involves two main actors, namely admin and user (coffee farmers). Admin is an expert in the field of coffee plant diseases and is responsible for managing the system and maintaining data accuracy. Admins can log in to access features such as managing a knowledge base that includes a list of diagnosis rules, organizing disease data including adding or updating new diseases, and managing symptoms used in diagnosis. Admins can also view input from users, access user data via forms, access dashboards to monitor frequently occurring diseases and evaluate the success of solutions provided to users. Meanwhile, users are coffee farmers who use this system to help diagnose diseases in their coffee plants. Before using the system, users must register to create an account, then log in using the username and password that has been created. Once logged in, users can view a list of coffee plant diseases, make a diagnosis based on observed symptoms, manage the farm profile, provide feedback, and access the history of previous diagnoses.

Flowchart

In expert systems, flow diagrams are used to describe the activities carried out by actors in the system. The expert system for diagnosing diseases in coffee plants has two main actors, namely admin and user. The flowchart depiction in this system aims to explain the business processes that occur. A business process is defined as a group of interconnected activities designed to solve a problem or achieve a specific goal. In the coffee plant disease diagnosis expert system, there are two main business processes: the admin business process and the disease identification business process. The admin business process focuses on system and data management carried out by the admin, as shown in Figure 3. Meanwhile, the disease identification business process focuses on user activities in diagnosing coffee plant diseases, as explained in Figure 4.

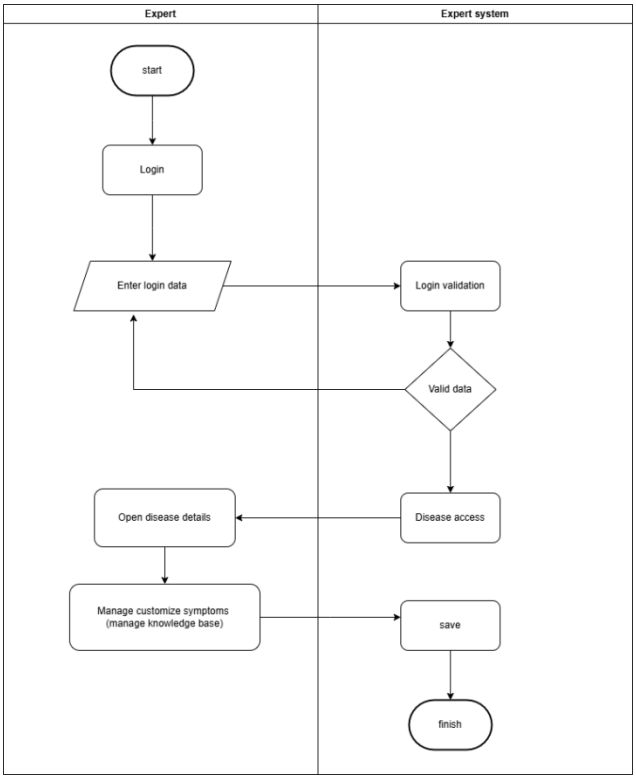

Fig. 3. Expert business process

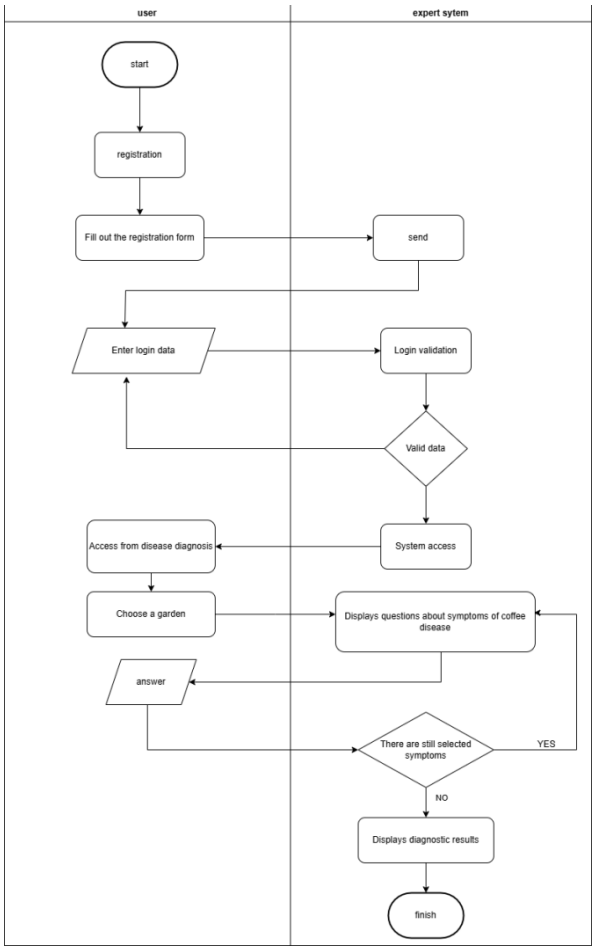

Fig. 4. User business process

The following entity relationship diagram process flow is in Figure 5.

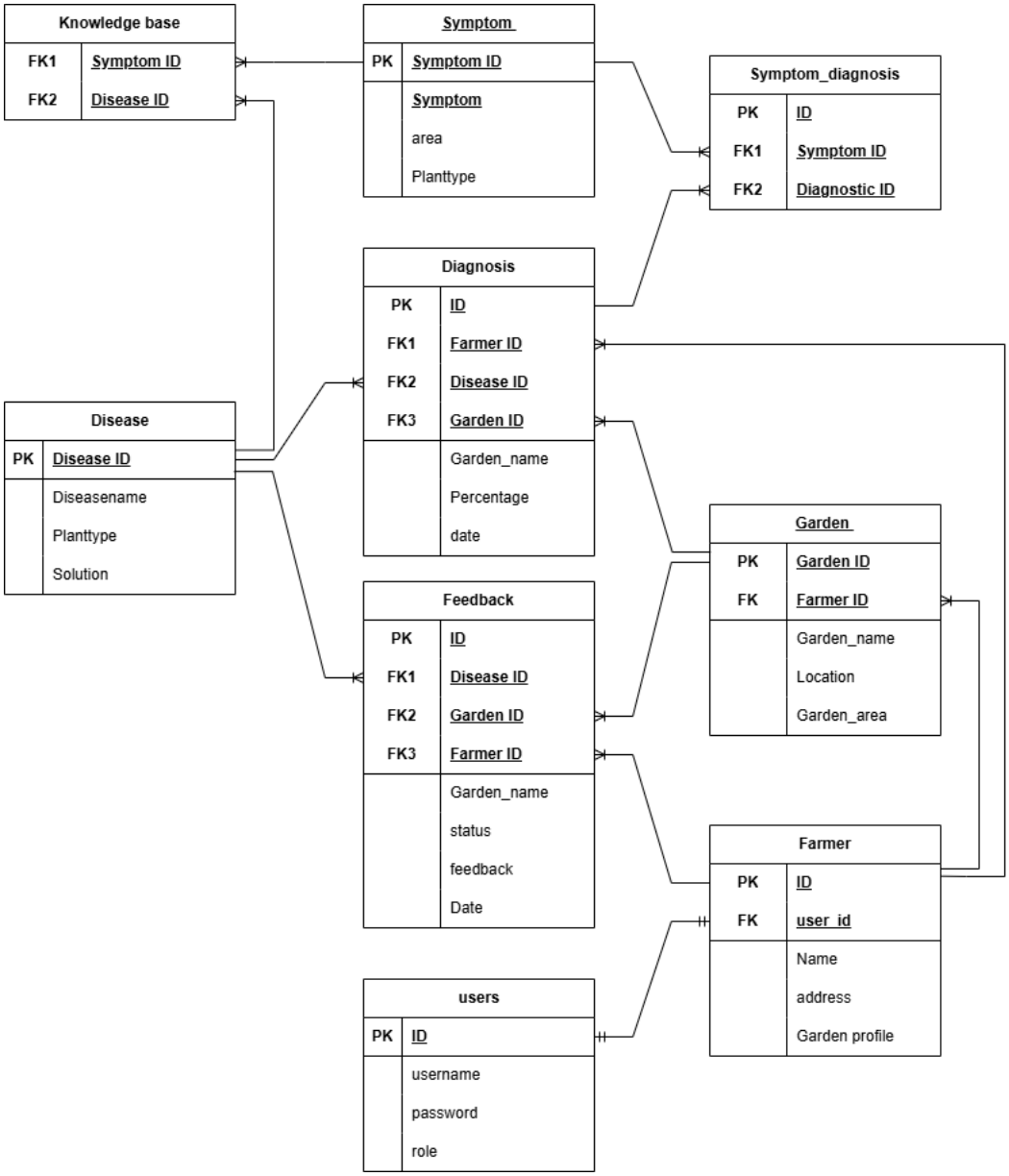

Fig. 5. Entity relationship diagram (ERD)

ERD (Entity Relationship Diagram) is a diagram used to describe the relationships between entities in a database.

1. *Implementation Stage* Or Writing Program Code

   Implementation is the stage of writing program code that is in accordance with the system design that has been created. The implementation of this research uses the PHP programming language and MySQL database.

2. *Testing Stage*

   The testing stage is carried out to ensure that the system functionality runs well to minimize errors in the program. System functional testing is carried out using the black box testing method and system expertise testing to determine the expertise of the expert system in making diagnoses.

III. RESULTS AND DISCUSSION

A. *Design Implementation Results*

The implementation of this expert system includes an input page for the admin, a disease diagnosis process for the user, and also output in the form of diagnosis results.

1. *Input page view (expert)*

In this expert system, experts input disease data, symptom data, and knowledge base data or rules. The symptom input form for experts is in Figure 6 below.

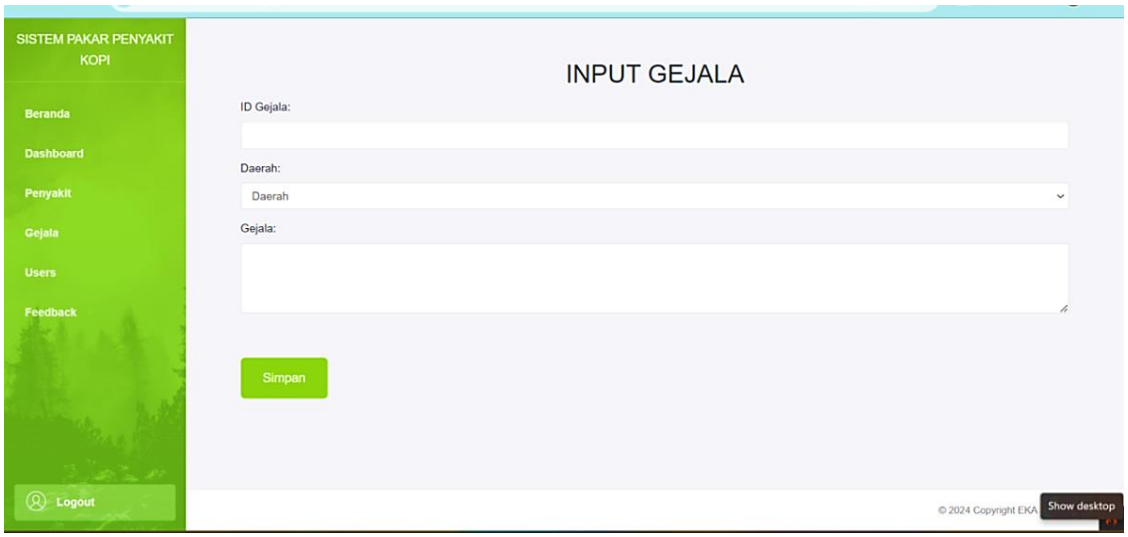

Fig. 6. Symptom input

The disease input form for experts is in Figure 7.

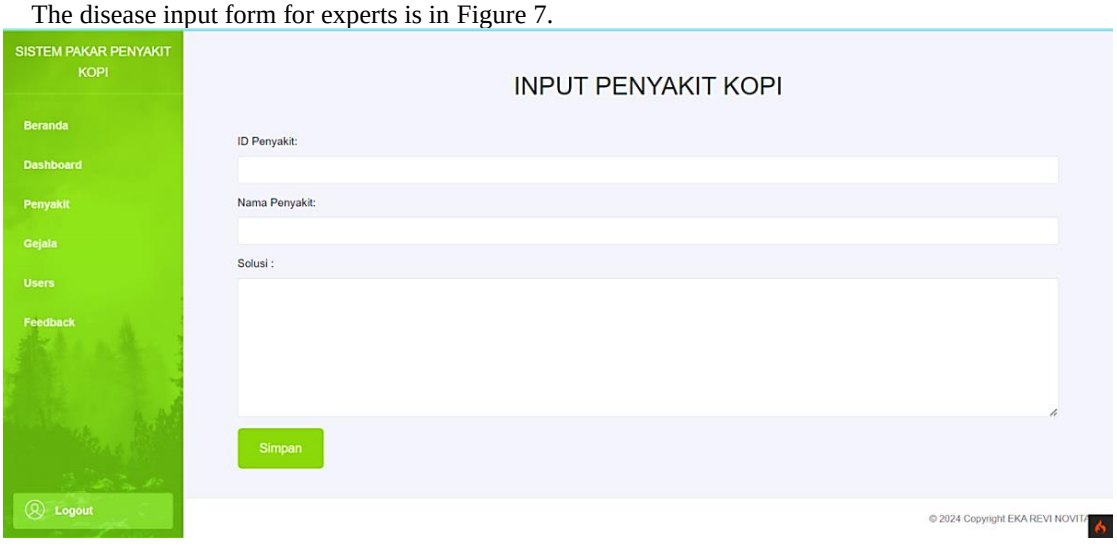

Fig. 7. Disease input

The input form for adjusting the symptoms or knowledge base is in Figure 8.

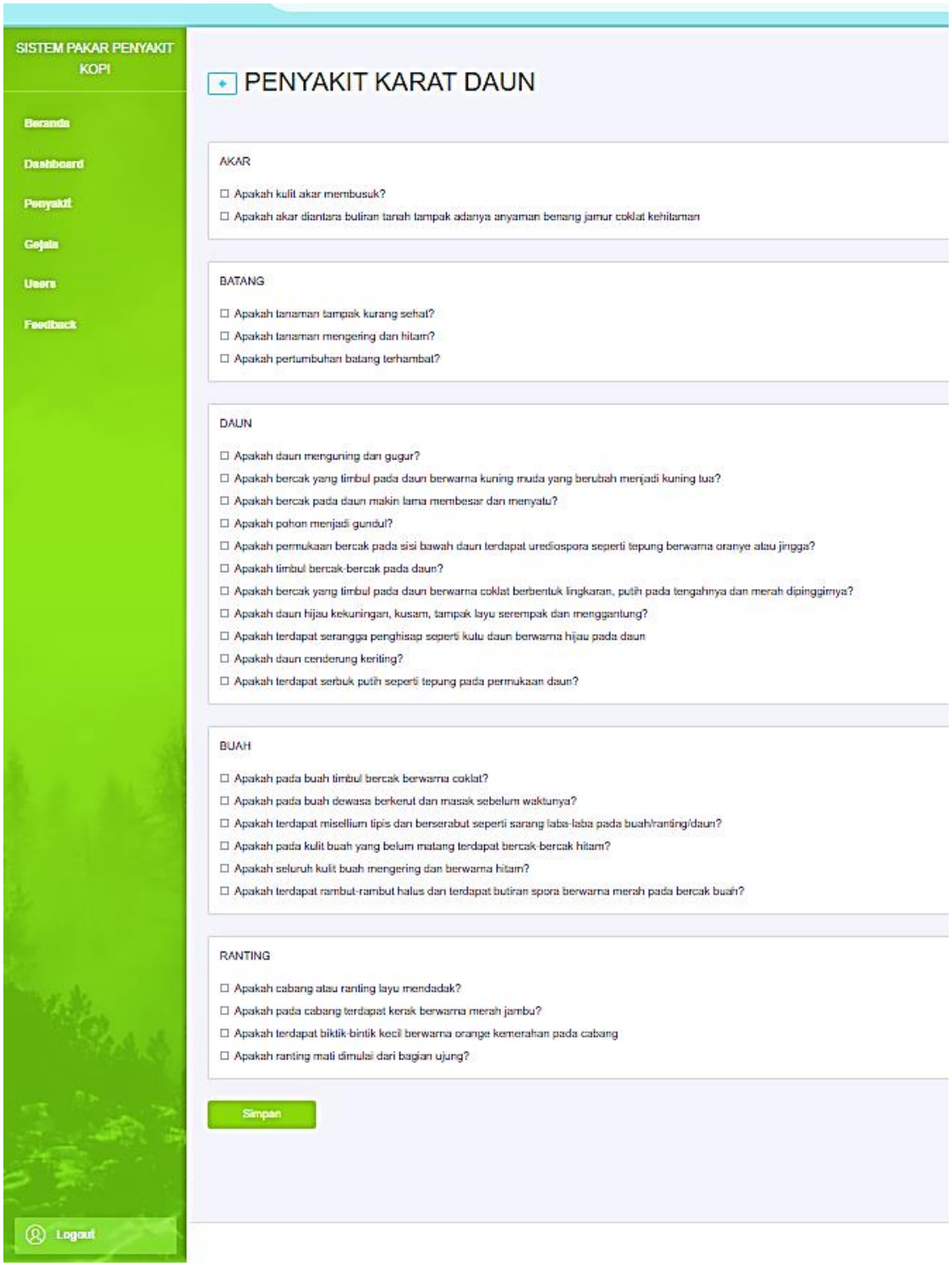

Fig. 8. Figure 8. adjust symptoms (knowledge base)

2. Diagnostic Process Page View (User)

Disease diagnosis is the main menu in this expert system for coffee plant diseases, but there are other menus on the user page, namely the profile page and the disease history page. The following user profile page is in Figure 9.

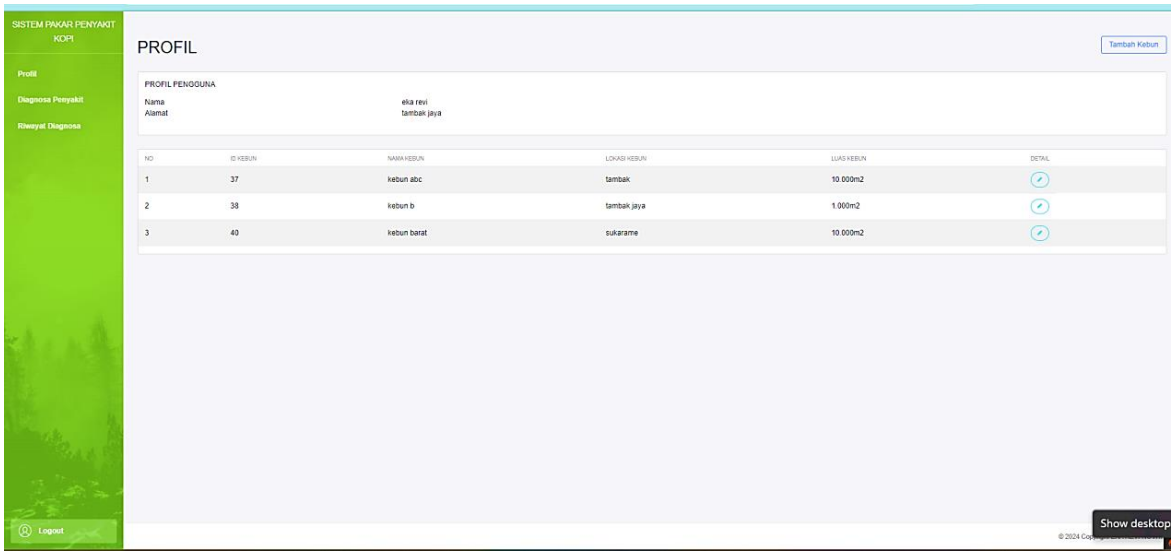

Fig. 9. User profile

The following page for adding gardens for users is in Figure 10.

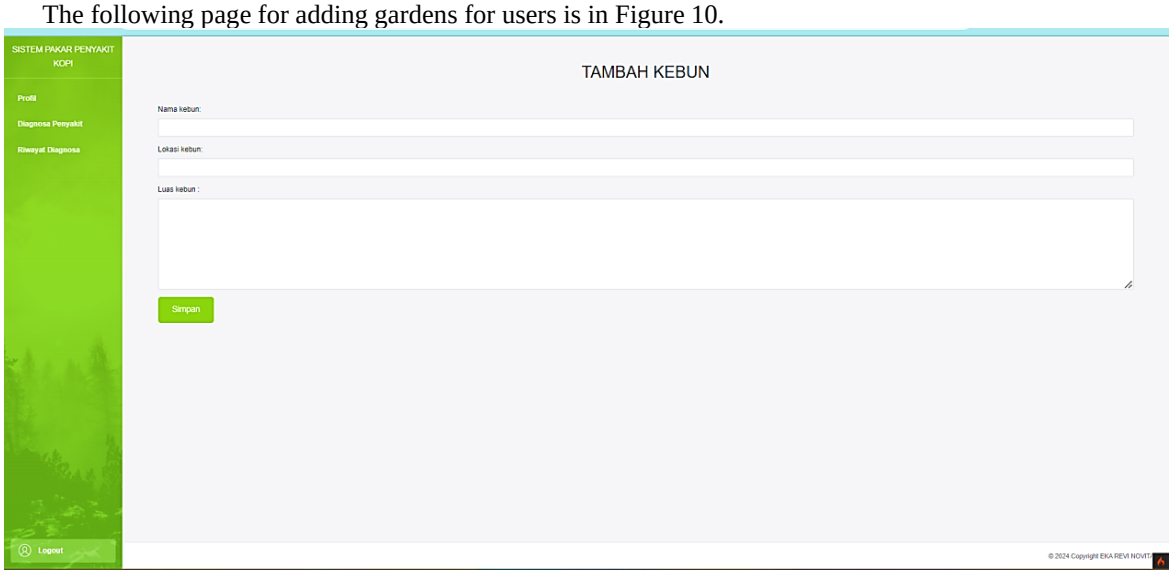

Fig. 10. Figure 10. garden input

The following disease diagnosis page for users is in Figure 11.

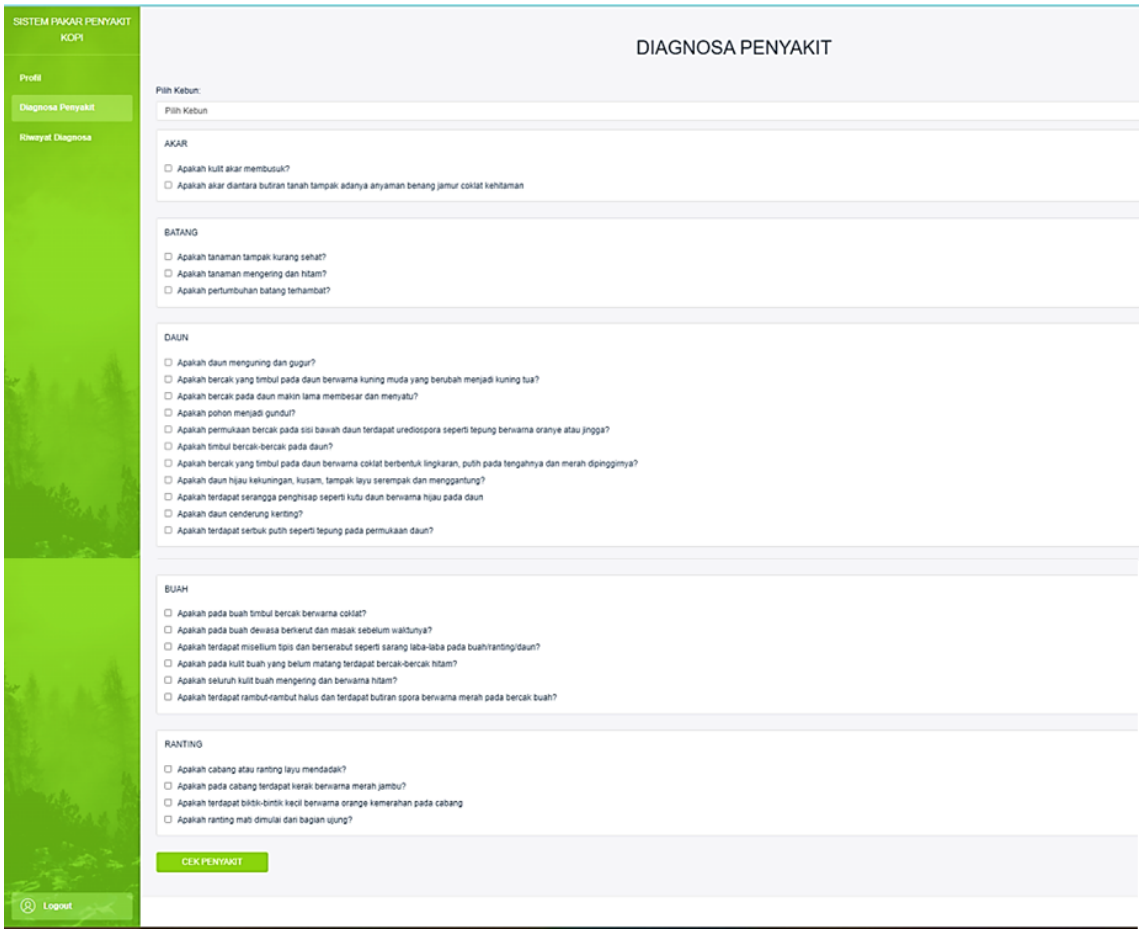

Fig. 11. Diagnostic page

3. Diagnostic Results Page View (User)

The diagnosis results page is a page of the diagnosis results that have been carried out. This page displays the symptoms that the user has selected and a table of diagnosis results containing the disease ID, disease name, and percentage of disease accuracy that has been calculated using the classic probability algorithm. The diagnosis results page is in Figure 12, and the disease details page is in Figure 13.

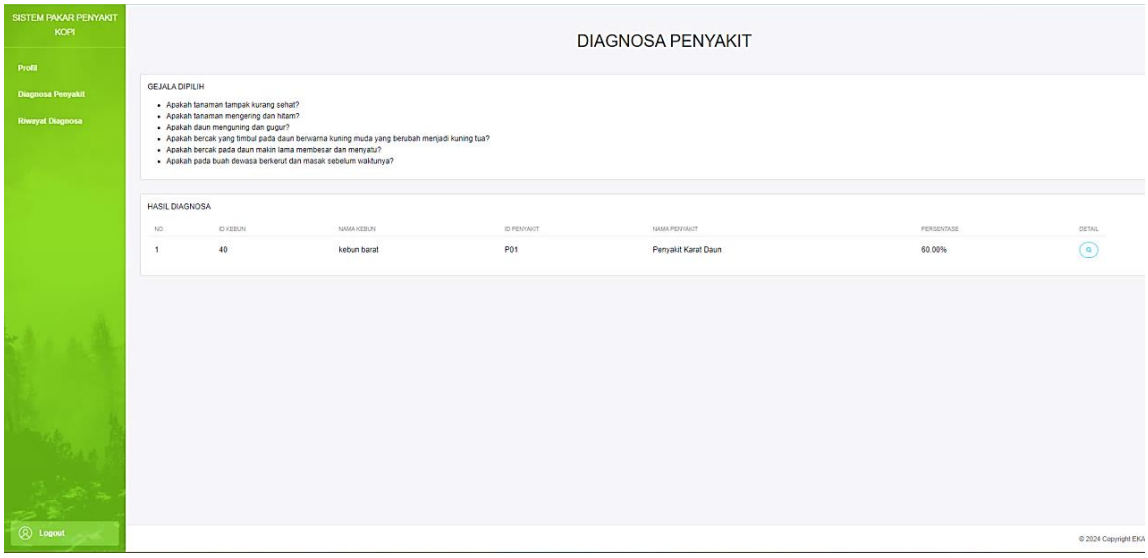

Fig. 12. Diagnostic results

Fig. 13. Disease details

B. System Testing

1. Functional testing

Functional testing of the system is carried out using the black box testing method and the equivalence partitioning method by dividing functions into test classes to obtain valid or non-valid test results. The following expert black box testing data is in Table VI.

TABLE VI. LIST OF EXPERT BLACKBOX TESTS

Number	Tester class	Test list	Test cases	Expected results	Results Obtained
1.	Register	Enter register data	Username Password Click send	Successfully submitted registration data	Succeed
2.	Login	Enter login data	Fill in the username and password Click login	Log in to the expert system homepage as admin	Succeed
3.	Home page	Testing displays the home menu for experts	Experts choose the home menu	Show home page	Succeed
4.	Disease menu	Testing displays the disease menu page	Experts choose disease menu	Show disease page	Succeed
		Add disease data	The expert enters the data completely and accesses the save button.	A popup appears saying "data saved successfully", and the data is entered into the database.	Succeed
		View disease data	Experts access the view button on one of the disease lists	Show disease page in detail	Succeed
		Edit disease data	Expert accesses the edit button on one of the disease lists The expert edits one of the disease data contents and then accesses the save button.	Show disease edit page Changes can be saved	Succeed Succeed
		Delete disease data	Expert accesses the delete button on one of the disease lists	The notification "data successfully deleted" appears.	Succeed
		Customize symptoms	Experts access the adjust symptoms button in the disease details and enter the data	Show page customize symptoms and the data is stored in	Succeed

Number	Tester class	Test list	Test cases	Expected results	Results Obtained
			completely and access the save button.	the database and displayed on the disease details page.	
		Testing displays the symptoms menu page	Experts choose symptoms menu	Show the symptoms list menu page	Succeed
		Add symptoms data	The expert enters the data completely and then accesses the save button.	A popup will appear saying "data successfully saved" and enter the database.	Succeed
5.	Symptoms menu	Edit symptom data	The expert presses the edit button on one of the symptom lists.	Show symptoms edit page	Succeed
			The expert changes one of the contents of the symptom list and then accesses the save button.	Changes can be saved	Succeed
		Delete symptoms data	Experts press the delete button on one of the symptoms	A notification appears saying "data successfully deleted"	Succeed
6.	Dashboard menu	Testing displays the dashboard page	Expert access dashboard menu	Display dashboard page	Succeed
7.	User menu	Testing displays the users page	Experts access the users menu	Show users page	Succeed
		View user data	Experts choose the view button	Show user data details	Succeed
8.	Feedback menu	Testing displays the feedback page	Experts choose the feedback menu	Show feedback page	Succeed
		View data	Experts choose the view button	Show details of selected feedback	Succeed
9.	Logout menu	Testing displays the logout page	Experts choose the logout menu	Successfully exited the admin page	Succeed

The following user black box testing data is in Table VII.

TABLE VII. LIST OF BLACK BOX USER TESTS

Number	Test class	Test list	Test cases	Expected results	Results Obtained
1.	Register	Enter register data	Username Password Name Address Click send	Successfully submitted registration data	Succeed
2.	Login	Enter login data	Fill in username and password Click login	Enter the expert system homepage as a user	Succeed
3.	Home menu	Testing displays the home page to the user	User selects the home menu	Show home page	Succeed
4.	Disease diagnosis menu	Garden Selection and Symptom Questions	User selects the garden and the user clicks the check mark on the desired symptoms, and accesses the check disease button	Display diagnostic results	Succeed
5.	Disease list menu	Testing Displays the disease list page	User select the disease list menu	Show the disease list page	Succeed
		View disease data	User access the view button on one of the desired diseases	Display the disease data page in detail	Succeed
6.	Profile Menu	Testing displays the user profile page	User select the profile menu	Show profile page	Succeed
		Add garden data	User Enter complete garden data and press the save button	Garden data is stored in a database and displayed in	Succeed

Number	Test class	Test list	Test cases	Expected results	Results Obtained
				the system.	
		Edit garden data	User Select the garden to be edited, then enter the data to be changed, then press the save button.	Changes are saved in the database and displayed in the system.	Succeed
		The test displays the diagnostic history page.	User select the diagnostic history menu	Display the diagnosis history page	Succeed
7.	Diagnosis history menu	View data	User Select the view button on one of the diagnostic results history	Displays detailed history of previously performed diagnoses.	Succeed
		Add feedback	User Select the add feedback button, enter the feedback data and click send	The feedback input page appears and the feedback has been successfully sent and entered into the database.	Succeed
8.	Menu about	Testing displays the about page	User select about page	Show about page	Succeed
9.	Logout menu	Testing displays the logout page	User selects the logout menu	Successfully exited the user page	Succeed
		Testing displays the feedback page	User select the feedback menu	Show feedback page	Succeed
10.	Feedback menu	Testing send feedback	User fill in the feedback then access the send button	A notification appears saying "data sent successfully", the data appears on the feedback page and the data is saved in the database.	Succeed

2. Expertise Testing

Expert testing is system testing carried out to determine the expertise of the expert system in diagnosing diseases on coffee plants according to existing facts. Expertise testing was carried out 7 times in case studies according to the disease data held by the system. The results of the skills test are in Table VIII.

TABLE VIII. EXPERTISE TESTING RESULTS

Number	Fact	Expected Diagnostic Results	Diagnostic Results On System
1.	• Are the leaves turning yellow and falling off? • Are the spots appearing on the leaves light yellow and turning dark yellow? • Are the spots on the leaves getting bigger and merging? • Do the spots on the underside of the leaves contain orange or orange powdery urediospores? • Are there brown spots on the fruit?	Diagnosis: Leaf rust disease	Diagnosis: Leaf rust disease Percentage: 80% (almost certainly)
2.	• Do the spots on the underside of the leaves contain orange or orange powdery urediospores? • Do spots appear on the leaves? • Are the spots that appear on the leaves brown and circular, white in the center and red on the edges? • Are there brown spots on the fruit? • Are the mature fruits wrinkled and ripening prematurely?	Diagnosis: Leaf Spot Disease	Diagnosis: Leaf Spot Disease Percentage: 100% (Certainly)
3.	• Is there a thin, fibrous mycelium like a spider's web on the fruit/twigs/leaves? • Is the entire skin of the fruit dry and black? • Did a branch or twig suddenly wilt? • Are there pink crusts on the branches?	Diagnosis: Fungal Disease	Diagnosis: Fungal Disease Percentage: 100% (Certainly)

	• Are there small reddish orange spots on the branches?		
4.	• Are the trees becoming bare? • Are there any sucking insects such as green aphids on the leaves? • Is there a white powder like flour on the surface of the leaves? • Are there fine hairs and red spores on the fruit spots?	Diagnosis: Sooty mold disease	Diagnosis: Sooty mold disease Percentage: 67% (possibly true)
5.	• Is the root bark rotting? • Does the plant look unhealthy? • Are the plants drying out and turning black? • Are the leaves turning yellow and falling off? • Are the trees becoming bare? • Are the leaves yellowish green, dull, looking wilted all at once and hanging down?	Diagnosis: Black and brown root disease	Diagnosis: Black and brown root disease Percentage: 83% (almost certainly)
6.	• Are there brown spots on the fruit? • Are the mature fruits wrinkled and ripening prematurely? • Does the skin of immature fruit have black spots? • Is the entire skin of the fruit dry and black? • Are there fine hairs and red spores on the fruit spots?	Diagnosis: Fruit disease	Diagnosis: Fruit disease Percentage: 100% (Certainly)
7.	• Does the plant look unhealthy? • Are the leaves turning yellow and falling off? • Are the trees becoming bare? • Do the leaves tend to curl? • Does the branch die starting from the tip?	Diagnosis: Dead End Disease	Diagnosis: Dead End Disease Percentage: 80% (almost certainly)
Average accuracy/precision of diagnostic results			87.14%

Based on the results of expert system trials on 7 diagnostic cases, it can be concluded that the expert system for disease in coffee plants has an accuracy rate of 87.14%. This result is obtained from a comparison between the expected diagnosis from the expert and the diagnosis given by the expert system. The average accuracy was calculated by adding up the percentage of diagnostic concordance in each case and dividing it by the number of cases. These results show that the expert system works well and can provide an accurate diagnosis as expected. However, there is an inaccuracy of 12.86%, which can be influenced by several factors, including not all symptoms experienced by coffee plants, inaccuracies in collecting symptom data, as well as doubts or confusion in providing a diagnosis. Nevertheless, the system has achieved a fairly high level of accuracy and is reliable for diagnosing diseases in coffee plants.

IV. CONCLUSION

From the results of the research that has been carried out, it can be concluded that an expert system has been successfully built to diagnose diseases in coffee plants with the aim of providing more accurate information to coffee farmers regarding symptoms, diseases and appropriate solutions. This system makes it easier for farmers to speed up the process of diagnosing diseases in coffee plants based on the symptoms (facts) identified. The implementation of the Forward Chaining and Classic Probability algorithms was successfully used in this system, where Forward Chaining helps in tracing symptoms gradually until reaching a diagnostic conclusion. At the same time, classical probability provides a percentage for each possible disease so that the diagnosis results are more accurate. Based on functional testing using black box testing, all functions in the system are running well. Based on expert testing, this system shows an average accuracy of 87.14%, which can be concluded that this expert system has good performance in diagnosing coffee plant diseases. System measurements from the user's perspective are carried out by collecting direct feedback via forms. The results of this feedback provide insight into the effectiveness of the system in helping farmers. With a combination of functional testing, expert testing, and user feedback analysis, the results of this research show that the expert system developed can be an effective tool for farmers in identifying and treating diseases in coffee plants.

REFERENCES

[1] Y. Dwi Kartikasari and D. Arifianto, "Sistem Pakar Diagnosa Hama Dan Penyakit Tanaman Kopi Menggunakan Metode Backward Chaining Berbasis Web," *Jutisi*, vol. 5, pp. 1–12, 2016.

[2] "Badan Pusat Statistik Provinsi Lampung." https://lampung.bps.go.id/indicator/54/258/1/produksi-tanaman.html (accessed Mar. 04, 2024).

[3] N. J. Nilsson, "Artificial Intelligence_ A New Synthesis." 2014.

[4] M. Naca Anbi, G. Fitri Laxmi, F. Riana, C. Hermanto, and B. Pengkajian Teknologi Pertanian Jawa Timur, "Sistem Pakar Diagnosis Penyakit dan Hama Tanaman Pisang dengan Metode Classical Probability," *Krea-TIF J. Tek. Inform.*, vol. 10, no. 1, pp. 51–58, 2022, doi: 10.32832/krea-tif.v10i1.6993.

[5] P. N. Stuart J. Russel, "Artifical Intelligence A Modern Approach (fourth edition)," *Angew. Chemie Int. Ed. 6(11), 951–952.*, 2021.

[6] M. K. B.herawan hayadi,S.Kom, *Sistem pakar*. riau: deepublish, 2018.

[7] K. D. P. Novianti, I. M. D. K. Gunawan, and N. K. Sukerti, "Implementasi Forward Chaining Untuk Mendiagnosis Penyakit Tanaman Kopi," *Inser. Inf. Syst. Emerg. Technol. J.*, vol. 1, no. 2, p. 88, 2021, doi: 10.23887/insert.v1i2.30547.

[8] Z. Azmi and V. Yasin, *Pengantar Sistem Pakar Dan Metode*. Medan: mitra wacana media, 2017.

[9] usti fatimah puji sari ramadhan, *Mengenal metode sistem pakar*. medan: uwais inspirasi indonesia, 2018.

[10] muhammad rizwan, *Budidaya kopi*. sumatera utara: cv. azka pustaka, 2021.

[11] loekas soesanto, *Kompendium penyakit-penyakit kopi*. yogyakarta: lily publisher, 2020.

[12] A. Abdul Wahid, "Analisis Metode Waterfall Untuk Pengembangan Sistem Informasi," *J. Ilmu-ilmu Inform. dan Manaj. STMIK*, no. November, pp. 1–5, 2020.

[13] prihandoko monsya juansen, rg guntur alam, *Pengujian dan implementasi sistem informasi*. bengkulu: deepublish digital, 2024.

[14] P. . Roger S. Pressman, *Software Engineering A PRACTITIONER'S APPROACH*, 5th ed. Thomas Casson, 2001.

[15] M. Legita, *teknik budidaya tanaman kopi*. jogjakarta: trans idea publising.