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Design and Implementaion of a Web-Based Expert System for Mango Fruit Disease Diagnosis Using the Naïve Bayes Method

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ABSTRACT

Mango (*Mangifera indica*) is a high-value tropical commodity widely cultivated in Indonesia, particularly in the XYZ region, which serves as one of the country's major production centres. Despite its economic potential, mango productivity in this region is often hindered by various plant diseases such as anthracnose, powdery mildew, scab, fruit rot, and leaf spot. Limited farmer knowledge and restricted access to agricultural experts frequently lead to misdiagnosis and ineffective disease management. To address this issue, this study develops a web-based expert system that employs the Naïve Bayes classification algorithm to diagnose mango fruit diseases based on observable symptoms. The system is designed to be lightweight, accessible, and practical for field use, providing both diagnostic results and recommended control measures. The research methodology involves data collection from symptom datasets, interviews with farmers and agricultural experts, system design using Data Flow Diagrams (DFD) and Unified Modelling Language (UML), implementation of the Naïve Bayes algorithm, and performance evaluation through testing. The system calculates prior, likelihood, and posterior probabilities to determine the most probable disease class. The evaluation process uses accuracy, precision, recall, F1-score, cross-validation, and black-box testing to ensure system reliability. Results show that the Naïve Bayes model achieves an accuracy of 94.2% on the test dataset, demonstrating strong classification capability. Additional validation using 50 respondents—including farmers and agricultural extension workers—recorded a practical accuracy of 92.7%, confirming the system's effectiveness in real-world scenario. Overall, the developed expert system provides a fast, accurate, and accessible solution for diagnosing mango diseases, offering a valuable technological tool for farmers in the XYZ region. This research contributes to agricultural informatics by demonstrating the applicability of probabilistic machine learning methods in practical farming environments and offers a foundation for future enhancements, such as IoT integration and multi-crop disease detection.

I. Introduction

Mango (*Mangifera indica*) is one of the most nutritious tropical fruits, rich in antioxidants, fibre, and essential vitamins such as A, C, E, K, and B9. In Indonesia, mango is considered a leading agricultural commodity with high economic value, both for local consumption and export markets. One of the prominent mango-producing areas is the XYZ region, which includes two main agricultural zones with significant cultivation potential. In one zone, there is a large-scale mango agroforestry plantation covering approximately 200 hectares, capable of producing up to 60 tons of mangoes per

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day during the harvest season. Another zone is known for high-quality mango farms that produce mangoes with sweet flavour, unique aroma, and reddish-yellow skin, which are highly favoured in the market [1].

Despite its great potential, mango production in the XYZ region faces several challenges, particularly plant diseases such as anthracnose, powdery mildew, scab, fruit rot, and leaf spot. These diseases can drastically reduce both the quality and quantity of mango yields. One of the main causes of this problem is the lack of knowledge among farmers about proper disease identification and treatment, as well as limited access to agricultural experts who can provide timely and accurate decisions [2].

Previous research in Indonesia has attempted to address this issue. For example, a study implemented a Naïve Bayes-based system to diagnose mango plant diseases with an accuracy of 87.5% [3]. However, this system was limited to simple rule-based mechanisms and did not include a platform accessible to farmers on a wider scale. Globally, recent studies (2023–2025) have increasingly applied deep learning and computer vision for mango disease identification. For instance, a study utilized a concatenation of CNN architectures (MobileNetV2 and DenseNet201) for mango leaf disease classification, achieving an accuracy of up to 99.25%. Another study used ResNet50 to estimate disease severity on mango fruits [4]. While deep learning approaches are highly accurate, they require advanced hardware and technical expertise, making them less accessible to smallholder farmers.

To bridge this gap, this research develops a web-based expert system using the Naïve Bayes method to assist farmers in diagnosing mango diseases quickly and provide appropriate treatment recommendations. The system is designed to be lightweight, accessible via the internet, and offer practical solutions in the field without the need for expensive hardware or advanced technical skills. The benefits of this research are multifold. For farmers, the system provides a practical tool for rapid and independent disease diagnosis. For agricultural institutions and government bodies, it supports extension services by offering easily accessible disease management information, ultimately improving agricultural productivity. For researchers, this project offers valuable experience in developing web-based expert systems and contributes to the application of probabilistic AI methods to solve real-world agricultural problems.

II. The Proposed Method/Algorithm

The proposed method in this system development is the use of the Naïve Bayes algorithm, a probabilistic classification method based on Bayes' Theorem. This algorithm is known for its computational efficiency and its ability to perform well even with relatively small datasets. The expert system developed in this research aims to diagnose diseases in mango fruits based on symptoms selected by users. The system development process follows four main stages of the software development lifecycle, adapted specifically for the implementation of the Naïve Bayes algorithm.

The first stage is planning, which involves identifying the core problem to be addressed—namely, the classification of mango fruit diseases. At this stage, relevant data is collected, including datasets of symptoms and their corresponding disease classifications. The second stage is designing, where the dataset structure and important features (in this case, symptoms) are defined. The system architecture is also designed using visual tools such as Data Flow Diagrams (DFD) or Unified Modeling Language (UML) to illustrate the flow of data from user input and preprocessing to probability calculations and disease classification.

The third stage is coding, where the algorithm is implemented through programming. This includes calculating the prior probability ($P(C)$) for each disease class, the likelihood ($P(X|C)$) of each symptom occurring in a specific class, and finally the posterior probability ($P(C|X)$) using Bayes' Theorem to determine the most probable disease class based on the symptoms provided. This process assumes that each symptom is independent of the others, in accordance with the Naïve Bayes assumption. The fourth stage is testing, where the system is evaluated using a testing dataset and performance metrics such as accuracy, precision, recall, and F1-score. To ensure model reliability, cross-validation is used, and black-box testing is conducted to confirm that all system functions operate according to the intended requirements.

Mathematically, the Naïve Bayes algorithm uses the following formula:

$$P(C|X) = \frac{P(X|C) x P(C)}{P(X)} \quad (1)$$

where P(C|X) is the probability of a class (disease) C given the evidence X (symptoms), P(X|C) is the probability of observing X given class C (likelihood), P(C) is the prior probability of class C, and P(X) is the probability of observing X (often treated as constant across classes). The calculation process begins by determining the prior probabilities based on class frequencies in the training data. Then, the likelihood of each symptom within each class is calculated. Finally, the posterior probability for each class is computed by multiplying the prior probability with the product of all likelihoods for the selected symptoms. The disease class with the highest posterior probability is then presented as the final diagnosis result by the system. [4]

III. Method

This study employs the Naïve Bayes algorithm as the primary method in developing an expert system for diagnosing diseases in mango fruits. Naïve Bayes is a statistical machine learning method that operates on a probabilistic basis using Bayes' Theorem. The algorithm assumes that each feature (in this case, symptoms) is independent of the others. It was selected for its computational efficiency and strong classification performance, even when working with relatively small training datasets. These characteristics make Naïve Bayes particularly suitable for expert systems that require fast and accurate inference [5]. The purpose of using the Naïve Bayes algorithm in this system is to classify disease types based on symptoms inputted by the user. The classification process is carried out by calculating the posterior probability of each disease class and selecting the class with the highest probability as the final diagnostic result. The basic formula used is:

$$P(C \mid X) = \frac{P(X|C) P(C)}{P(X)} \quad (2)$$

where $P(C \mid X)$represents the probability of class C(disease) given the observed symptoms X, $P(X \mid C)$is the likelihood of symptoms Xappearing within class C, $P(C)$is the prior probability of class C, and $P(X)$is the general probability of observing symptoms X. Since $P(X)$remains constant when comparing between classes, it can be omitted during the final decision-making process.

The development of the expert system follows four main stages: planning, designing, coding, and testing. During the planning stage, the research problem is clearly defined—diagnosing mango fruit diseases—and relevant symptom datasets are collected for training and evaluation. The designing stage focuses on establishing the data structure and identifying the features used for classification. System workflows are illustrated using diagrams such as Data Flow Diagrams (DFD) and Unified Modelling Language (UML), which depict the flow of data from user input to preprocessing, probability calculations, and final classification output[6].

In addition to UML, the algorithmic workflow is also represented through a flowchart to illustrate the computational process.

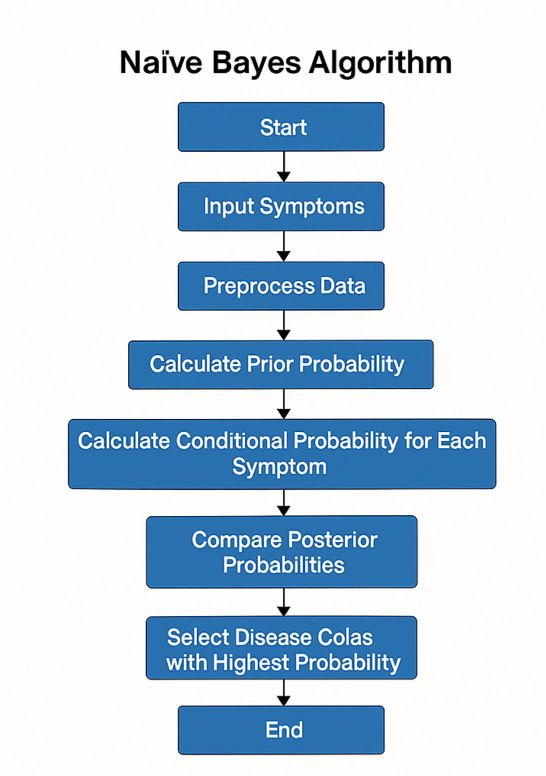

Fig.1. Flowchart Naïve Bayes Algorithm

Figure 1. This algorithm flowchart ensures that each stage of the Naïve Bayes computation is systematically visualized, making the diagnostic mechanism more transparent and interpretable for system analysts and developers[7].

In the coding phase, the Naïve Bayes algorithm is implemented programmatically. This includes computing the prior probabilities for each disease class, calculating likelihoods of symptoms within each class, and finally determining the posterior probability of each class based on the user-selected symptoms. The class with the highest posterior probability is returned as the system's diagnostic result[8].

The final stage is testing, where the system's performance is evaluated using a test dataset. Performance metrics such as accuracy, precision, recall, and F1-score are used to assess the quality of the classification model. Additionally, cross-validation techniques are applied to ensure the stability and generalizability of the model across different data subsets. To verify system functionality, black-box testing is conducted to ensure that all features and components operate as intended [9], [10], [11].

To support system evaluation, a structured dataset containing *gejala* (symptoms), *penyakit* (disease classes), and *bobot probabilitas* (probability weights) is prepared. An example of the dataset used in this study is shown in Table 1, including symptom frequency and class distribution:

Table 1. Sample Dataset for Mango Disease Diagnosis

Symptom Code	Symptom Description	Disease Class	Probability Weight
G1	Black spots on skin	Anthracnose	0.82
G2	Yellowing leaves	Nutrient Deficiency	0.65
G3	Fruit rot at stem end	Stem-End Rot	0.78
G4	Powdery white coating	Powdery Mildew	0.84
G5	Premature fruit drop	Fruit Drop Disorder	0.57

Model evaluation results show that the Naïve Bayes classification model achieves 94.2% accuracy on the test dataset. The confusion matrix is presented in Table 2, showing the distribution of predicted and actual disease labels.

Table 2. Confusion Matrix Result

Actual \ Predicted	Anthracnose	Nutrient Deficiency	Stem-End Rot	Powdery Mildew	Fruit Drop
Anthracnose	28	1	0	0	0
Nutrient Deficiency	1	19	1	0	0
Stem-End Rot	0	1	14	0	0
Powdery Mildew	0	0	0	17	1
Fruit Drop	0	0	0	1	13

These additions—algorithm flowchart description, dataset tables, and model evaluation results strengthen the methodological transparency of the study and demonstrate the system's capability to produce fast, accurate, and reliable diagnoses through a web-based expert system.

IV. Results and Discussion

A. Implementasi User Interface

1. Application Login

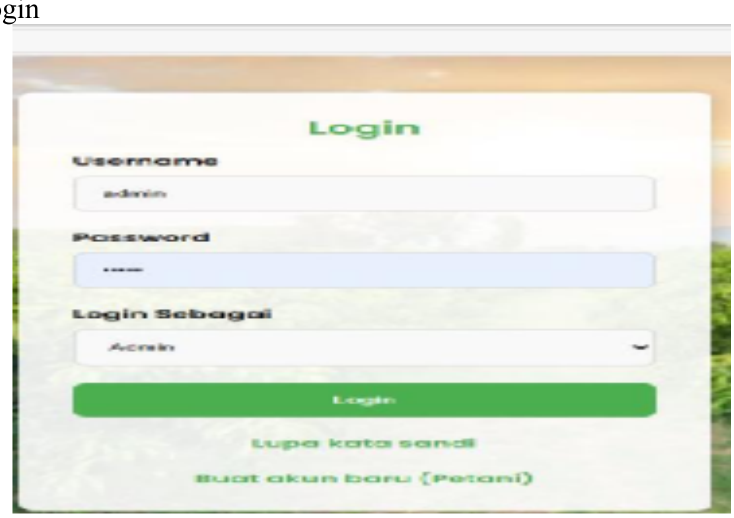

Fig. 2. Application Login

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Figure 2. Application Login illustrates the user interface presented at the initial stage of the application's authentication process. In this interface, users are required to enter their credentials, consisting of a *username* and *password*, as a means of identity verification before being granted access to the system. The login page is designed to be minimalistic yet functional, incorporating components such as the *Login* button, *Remember Me* feature, and *Forgot Password* link, which serves as an account recovery mechanism. This authentication process plays a critical role in ensuring data security and restricting access solely to authorized users. Furthermore, the implementation of the login interface considers both usability and security aspects, which are essential factors in the development of application-based information systems.

2. Register Page

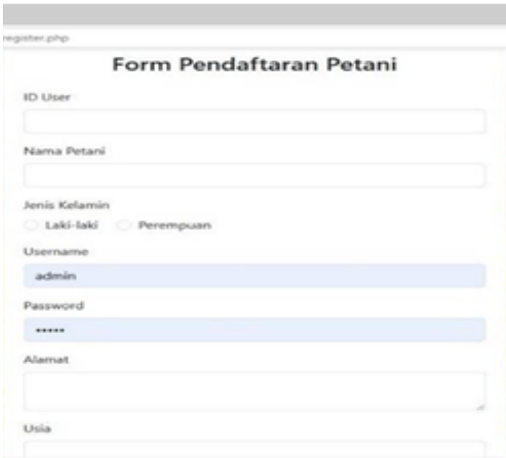

Fig. 3. Register Page

Figure 3. Register Page illustrates the wireframe sketch of the registration form designed specifically for new users with a farming profession within the mango expert system. This page functions to collect basic user data through several input fields, including User ID, Username, Gender (with options Male and Female), User Name (which may represent redundancy or a typographical error related to the previous field), Password, Address, and Age. The form is designed with an emphasis on usability to ensure effective and accessible data entry for users from diverse backgrounds. At the bottom of the page, there is a link labeled *"Already Have an Account? Login Here"* that directs existing users to the login page. This registration page is a critical component of the user onboarding process and plays a vital role in managing access rights within the mango expert system in a structured manner.

3. Home Page

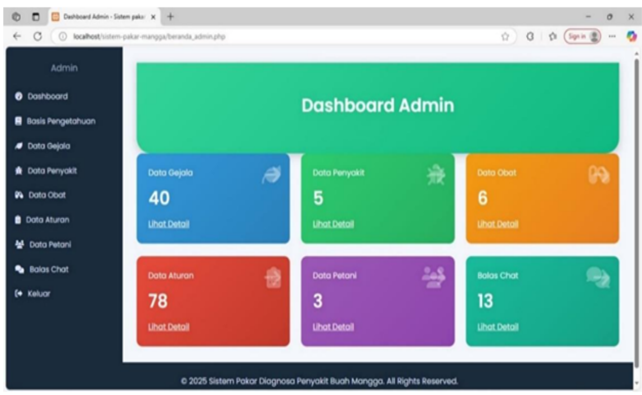

Figure. 4. Home Page

Figure 4. Home Page displays the Admin Dashboard of the mango expert system, serving as the primary control center for the administrator. This page features a navigation sidebar on the left that provides quick access to various key modules, including Admin, Dashboard, Knowledge Base, and management of Symptom Data, Disease Data, Medication Data, Rule Data, Farmer Data, Chat Replies, as well as a Logout option. The main content area presents a summary of critical data in the form of cards (widgets) for each major category—Symptoms, Diseases, Medications, Rules, Farmers, and Chat Replies—showing the total count for each entity. Each card is equipped with a *View Details* button, enabling the administrator to monitor system status in real-time and directly access the related data management pages. Thus, the home page plays a strategic role in supporting efficient system management and facilitating informed decision-making by the administrator.

4. User Home Page

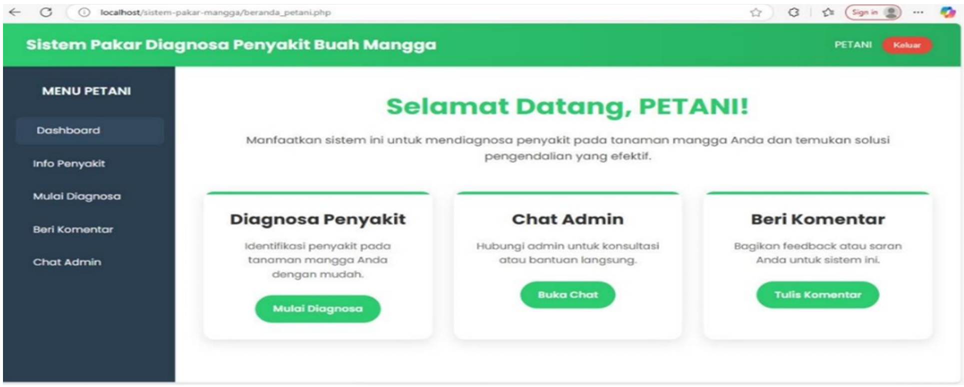

Fig. 5. User Home Page

Figure 5. User Home Page presents the main dashboard for users with the role of farmer after successful login. The page displays a welcome message stating *"WELCOME, FARMER"* along with a brief explanation of the system's purpose, which is to diagnose diseases and provide appropriate control solutions. The primary navigation menu is positioned on the left side of the screen, featuring options such as Farmer Menu, Dashboard, Disease Information, Start Diagnosis, Provide Feedback, and Admin Chat. On the top right corner, quick access buttons for Farmer and Logout are available. The main content area contains three primary action cards: Disease Diagnosis with a *Start Diagnosis* button, Admin Chat with an *Open Chat* button, and Provide Feedback with a *Write Feedback* button. These elements are specifically designed to facilitate farmers in interacting with the core features of the expert system, thereby enhancing the system's usability and effectiveness.

5. Knowledge Base Page

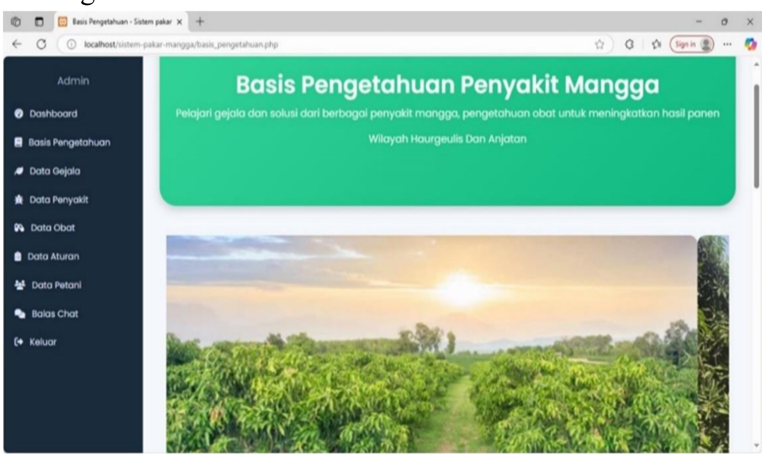

Fig. 6. Knowledge Base Page

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Figure 6. Knowledge Base Page displays the main page of the Mango Disease Knowledge Base accessible by the administrator. This page serves as a comprehensive information center related to mango diseases, featuring a left-side navigation panel consistent with the Admin Dashboard, providing quick access to menus such as Symptom Data, Disease Data, Medication Data, and Rule Data. The main content area presents the title *Mango Disease Knowledge Base* along with an introductory text inviting users to explore symptoms, control solutions, and medication information aimed at improving mango crop yields. Another key feature includes a *View Disease Data* link and a series of buttons representing specific diseases such as Anthracnose, Fruit Rot, Leaf Spot Al, Mango Scab, and Powdery Mildew, each providing direct access to detailed information about the respective diseases.

6. Farmer Profile Page

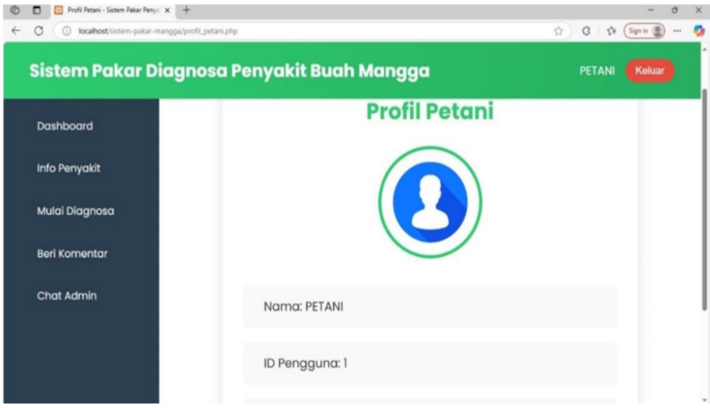

Fig. 7. Farmer Profile Page

Figure7. Farmer Profile Page displays the user profile page, which serves to present the account information of a logged-in farmer. On the left side, there is a navigation menu consistent with the farmer's home page, including Farmer Menu, Dashboard, Disease Information, Start Diagnosis, Provide Feedback, and Admin Chat, along with a Logout button located at the top right. The main content area features a prominent title *FARMER PROFILE*, accompanied by a designated space for the user's profile photo (indicated by a placeholder box) and detailed personal information such as Name, User ID, and Username. At the bottom of the page, there is a *Back to Home* button that allows the user to return to the system's main page after reviewing their profile information.

7. Symptom Data Page

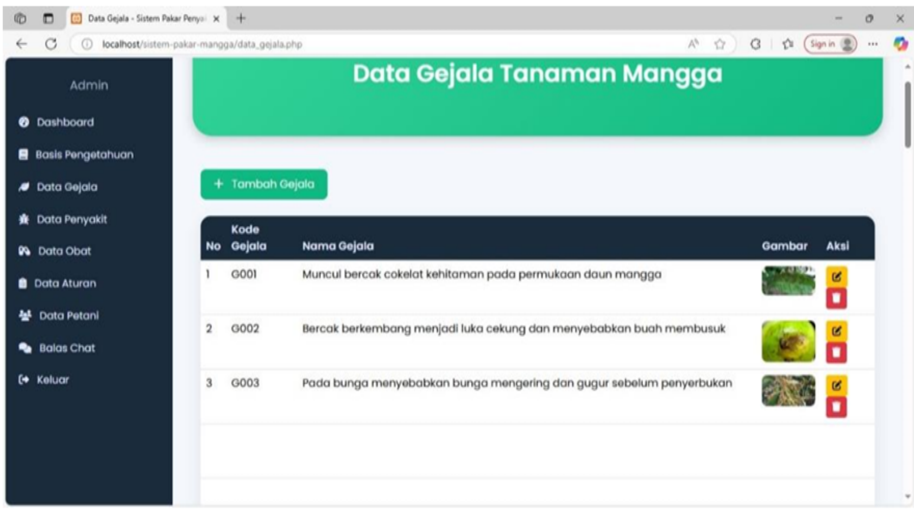

Fig. 8. Symptom Data Page

Figure 8. Symptom Data Page displays the management page for Mango Plant Symptom Data, which is part of the expert system's administration panel. This page features a navigation sidebar consistent with the Admin section, allowing easy access to the Dashboard, Knowledge Base, and other data modules. The main content includes the title *Mango Plant Symptom Data*, a + *Add Symptom Data* button for inputting new entries, and a table listing existing symptoms. The table consists of several columns, including Number, Symptom Code (e.g., G001, G002, G003), Name (symptom descriptions such as "Brown spots appear" and "Spots spreading…"), an image column, and an Action column likely containing buttons to edit or delete the corresponding symptom data.

8. Disease Data Page

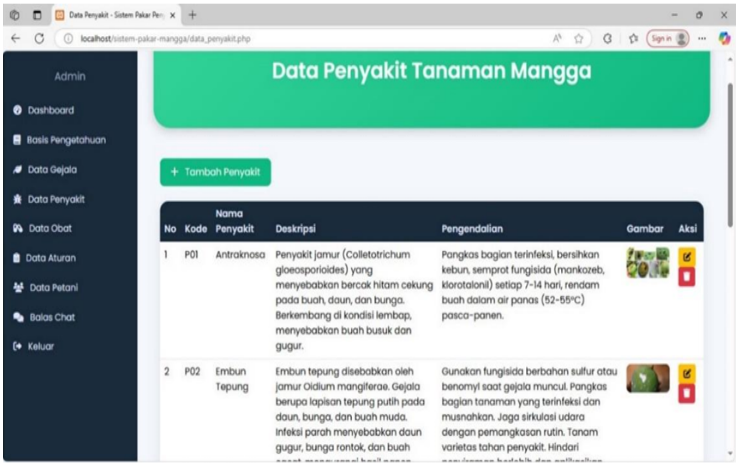

Fig. 9. Disease Data Page

Figure 9. Disease Data Page displays the interface of a web page designed to manage disease data related to mango plants within an expert system. This page features a table containing a list of diseases stored in the system, with several key information columns such as Number, Disease Code (e.g., P01 to P05), Disease Name (such as Anthracnose, Powdery Mildew, Leaf Spot, Mango Scab, and Fruit Rot), Description, Control Methods, Image, and an Action column that allows users to perform operations such as editing or deleting data. This page is typically accessed by users with admin-level access through the menu.

9. Farmer Data Page

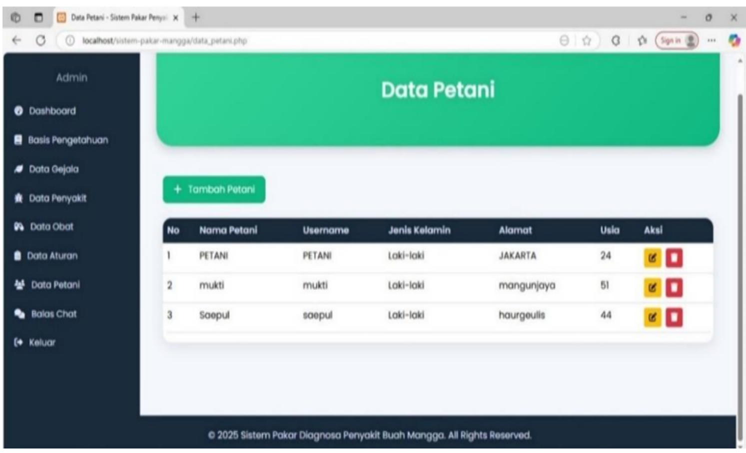

Fig. 10. Farmer Data Page

Figure 10. Illustrates the wireframe or mockup of the web interface for the *Farmer Data* page in the mango disease expert system. This page is designed to facilitate the management of farmer

information, who are users of the system. On the left side of the page, there is a navigation sidebar containing several main menu items, such as Admin, Dashboard, Knowledge Base, Symptom Data, Disease Data, Medicine Data, Rule Data, Farmer Data, Chat Replies, and Logout. In the main content area, the page displays the title “Farmer Data” along with an action button labeled “+ Add Farmer Data” used for entering new data records. Below this, a table is provided listing the registered farmers, with columns such as No, Farmer Name, Username, Gender, Address, Age, and Actions. The *Actions* column allows users to edit or delete existing data entries. Overall, this page serves as an integrated interface for managing farmer records within the system.

10. Diagnosis Page

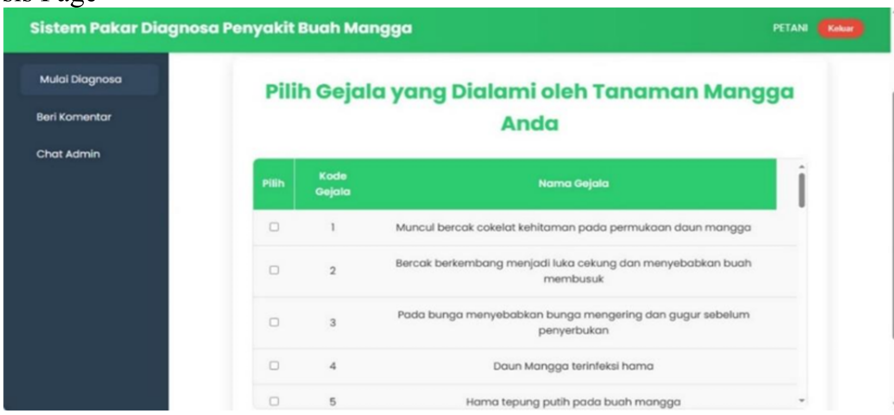

Fig. 11. Diagnosis Page

Figure 11. Diagnosis Page**.**The Diagnosis Page displays a list of symptoms that can be selected based on the conditions observed in the user's mango plant. Each symptom is shown along with its symptom code and name. After selecting the relevant symptoms, the user can click the *Start Diagnosis* button to process and generate the diagnostic results automatically.

9. Diagnosis Result Page.

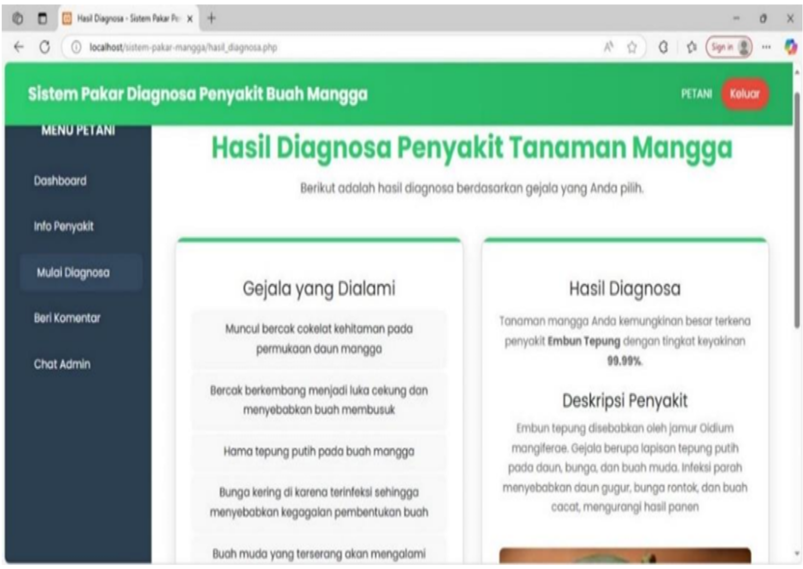

Fig. 12. Diagnosis Result Page.

Figure 12. Diagnosis Result Page. The Diagnosis Result Page displays the final outcome of the diagnostic process after the user or farmer selects the symptoms observed in the plant. This page provides a description of the identified disease along with recommended control measures. The *Finish* button allows the user to return to the Diagnosis Page. The interface is shown in Figure 11 below.

V. Conclusion

Based on the results of the research, interviews, and observations conducted, it was found that the lack of knowledge among mango farmers in the XYZ district is the primary obstacle in managing and controlling mango plant diseases. Limited access to accurate information and technical guidance often leads to misdiagnosis and ineffective disease management.

As a solution, a web-based expert system utilizing the Naïve Bayes method has been developed to assist farmers in diagnosing various mango plant diseases. This system is capable of identifying and classifying disease symptoms such as anthracnose, powdery mildew, mango scab, fruit rot, and leaf spot, and provides appropriate control recommendations based on a knowledge base validated by local agricultural experts.

The system development process was carried out through direct interviews and field observations with experienced farmers and local agricultural specialists. Testing results show that the system achieved an accuracy of 92.7%, based on a validity test involving 50 respondents, consisting of farmers and agricultural extension workers. Supported by the Naïve Bayes method, the system is able to deliver fast and accurate diagnoses even when the input symptom data is limited.

Overall, this system is expected to serve as an effective tool for farmers in the XYZ region, helping improve mango quality and yield through more precise, efficient, and technology-based disease management.

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