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Development of an Expert System for Diagnosis of Pests and Diseases in Soybean Plants Using the Forward Chaining Method

Case Study: Badan Standarisasi Instrumen Pertanian (BSIP) Aneka Kacang Kendalpayak Malang

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***Abstract*— This research focuses on developing an expert system to detect pests and diseases affecting soybean plants (Glycine max), which often reduce yield. The system employs forward chaining with the best-first search decision-making algorithm, which was developed using the waterfall methodology. Data utilized includes comprehensive information on symptoms, types of pests, diseases, and their respective management solutions gathered through case studies and expert interviews. Users of the system can input observed symptoms in soybean plants, and the system provides diagnoses and treatment recommendations based on established knowledge rules. Feasibility testing of the system was conducted using the TAM approach to assess technology acceptance among users and BlackBox Testing to ensure system reliability from a technical perspective. Test results indicate that the expert system is viable, achieving a feasibility rate of 83.7% based on TAM criteria and 100% across eight modules using BlackBox Testing, demonstrating significant potential in effectively supporting the diagnosis and management of pests and diseases in soybean plants.**

Index Terms*— Expert System, Forward Chaining, Soybean, Pests, Diseases, Diagnosis

I. INTRODUCTION

The lack of knowledge among farmers about pests and diseases is one of the factors affecting crop yield quality [1]. To improve crop quality, farmers need to obtain information from sources knowledgeable in this field. Farmers should be aware of the pests and diseases that can damage crops and be able to promptly address them.

Badan Standarisasi Instrumen Pertanian (BSIP) Aneka Kacang is an organization under the auspices of the Ministry of Agriculture. BSIP Aneka Kacang is tasked with coordinating, formulating, implementing, maintaining, and harmonizing agricultural instrument standards. The secretariat of BSIP Aneka Kacang is located at Jl. Raya Kendalpayak no. 66, Segaran, Kendalpayak, Pakisaji, Malang, Jawa Timur.

BSIP Aneka Kacang Kendalpayak Malang has somewhat kept pace with technological advancements by implementing digital guest registration, digital employee attendance records, and other administrative processes. However, the organization still lacks a specialized detection tool for soybean plant pests and diseases, which would greatly aid soybean farmers in their cultivation practices. As an agricultural institution involved in standardizing agricultural instruments, acquiring such a tool is crucial to enhance farmers' knowledge about soybean pests and diseases.

One tool related to detecting pests and diseases in soybean plants is an Expert System. This aligns with rapid technological advancements where computer developments have also surged, benefiting users of all ages, from children to adults [2]. The use of computers and the internet enables more effective and efficient information delivery systems. The success of such information systems, however, relies heavily on skilled human resources to ensure they meet expectations and operate optimally [3].

An expert system is a computer system capable of imitating or simulating the intelligence of an expert. It is a form of artificial intelligence that combines knowledge and data analysis to solve problems typically requiring human expertise [3]. This view aligns with Pati's statement [4] that expert systems optimize specialized knowledge similar to how an expert addresses issues.

The application of Forward Chaining in expert systems has been widely utilized, particularly in agriculture. Previous research, as documented in a journal by Sholikhah et al. [5], applied Forward Chaining in an expert system for diagnosing pests and diseases in rice plants. The system development followed the Waterfall method. The study concluded that implementing Forward Chaining in diagnosing pests and diseases not only facilitated the process but also enhanced farmers' knowledge. While the research tested the Forward Chaining algorithm, details about the system's testing were not provided, leaving uncertainties regarding the overall system validation beyond the algorithm's accuracy rate of 75%.

Based on these considerations, this research proposes an expert system aimed at providing information on diagnosing pests and diseases in soybean plants, along with recommended solutions. The study aims to enhance farmers' knowledge, enabling better soybean plant care through the proposed system. The expert system in this research utilizes forward chaining with the waterfall model for software development. Programming languages include PHP version 8 for system development and MySQL for database storage. System testing involves user evaluation using the Technology Acceptance Model (TAM) and Black Box Testing by programmers.

Additionally, the use of TAM by users aims to ensure that the developed system is more readily accepted. TAM generally explains how internet technology can be accepted by society in specific contexts. TAM is a theory that reveals how individuals' perceptions of something can influence their behavior, ultimately shaping their attitudes toward information technology [6].

Forward Chaining is a method applied in designing expert system applications to progressively perform forward tracing or reasoning [1]. Waterfall is one of the concepts within the System Development Life Cycle (SDLC) commonly used for developing software systems [7]. Expert systems are expected to assist farmers in soybean plant care, including the prevention and management of pests and diseases affecting soybean plants.

II. Literatur Review

A. Pests and Diseases

The term "pests" is used to describe any form of disturbance to humans, livestock, and crops. In the context of agriculture, the term "pest" is used to describe any animal that can damage crops or agricultural products, resulting in economic losses. A narrower definition of pests can be defined as any harmful animal activity in crop cultivation. Plant diseases are conditions where physiological disturbances appear in plants due to major factors, both biotic and abiotic, that occur at the level of plant cells or tissues. This disturbance can result in abnormal plants and can continue to cause losses because it can damage plant health and growth [8].

B. Soybean Plants

The soybean (Glycine max L.) has its origins in mainland China and has been cultivated since 2500 BC. In Indonesia, the soybean is a highly significant crop, ranking as the third most important food crop after rice and corn. Additionally, it serves as a vital source of vegetable protein in the Indonesian food industry [9].

The morphology of the soybean plant encompasses roots, leaves, stems, pods, and seeds. This plant exhibits an upright growth pattern, reaching a height of 30-100 cm, and is capable of producing 100-200 pods per tree in fertile soil (Erlanda et al., 2021). However, soybeans are susceptible to pests and diseases, including armyworm and root rot, which necessitate proper identification for effective control [11].

C. Expert System

An expert system is a system that utilizes human knowledge akin to that of an expert to solve problems requiring human expertise [5]. As part of artificial intelligence (AI), this system employs a knowledge base to tackle specific problems in various fields, including complex medical diagnostics [12]. The main components of an expert system include a knowledge base for storing information, an observation base for gathering data, and an inference engine for extracting knowledge and making decisions similar to those made by an expert [13].

An expert system is structured into two main environments: the development environment and the consultation environment [14]. The development environment is used to build the expert system in terms of developing components and the knowledge base. On the other hand, the consultation environment facilitates interaction with users who do not possess specialized expertise with the expert system to obtain solutions or information they require.

D. Waterfall Method

The waterfall method is a sequential software development process model, which is one of the earliest approaches in project management and product development. This method involves a series of linear and sequential stages, starting with requirements analysis, system design, implementation, testing, and maintenance [2].

E. Forward Chaining Method

Forward chaining is a method in the design of expert systems applications that involves a progressive process of tracing or reasoning forward [1]. The process begins with facts provided by the user, and then rules are applied to reach conclusions. This process follows a bottom-up model by checking each rule to see if the observed data meets its premises. If the premises are satisfied, the rule is executed to generate new facts that may be used by other rules. This process is also known as rule interpretation, conducted by the inference engine in knowledge-based systems [15].

III. RESEARCH METHODS

To develop an Expert System aligned with research goals, several stages are employed: utilizing the Forward Chaining algorithm, designing a database with a table structure, and creating a user interface to depict system objects. This development adheres to the waterfall model, a sequential software development process encompassing stages such as requirements gathering, system design, implementation—integrating the Forward Chaining algorithm—and subsequent testing and maintenance phases to ensure functionality and longevity.

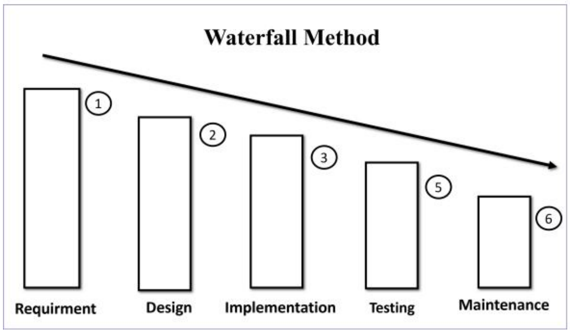

Fig. 1. Stages of the Waterfall Method

A. Requirement

To obtain valid and accurate data, researchers need to collect sources through two main methods. First, conduct a literature review to gather relevant references from books, websites, and journals, summarize them into a literature review, and formulate the research methodology. Secondly, conducting direct interviews with Mrs. Kurnia Paramita Sari, S.P., M.P., a Junior Expert Plant Pest Controller at BSIP Aneka Kacang, who provided insights into data input processes and relevant theories related to the research object, as well as with farmers to gather practical information regarding soybean farming processes. This approach ensures comprehensive data acquisition as follows:

TABLE I. PEST AND DISEASE DATA

Code	Pests and Diseases
P1	Bean Seed Fly Pests *(Ophiomyia Phaseoli)*
P2	Stem Fly Pests *(Melanagromyza Sojae)*
P3	Armyworm Pest
P4	Pest Caterpillars *(Chrysodeixis chalcites)*
P5	Soybean pod borer pest *(Etiella Zinckanella treit)*
P6	Anthracnose disease *(Collectrium demotion var truncatum dan C. Destrucvitum)*
P7	Falling of Sprouts, Leaf, and Pod Rot *(Rhizoctonia solan)*
P8	Stem blight *(Sclerotium roofs)*
P9	Blight, Leaf spot, and Purple seed spot *(Cercospora Kikuchi)*
P10	Mosaic Virus Disease

TABLE II. SYMPTOM DATA

Kode	Symptom
G1	Withered stems
G2	White spots on the first or second leaf
G3	Spots on young leaves
G4	There are larvae holes on the stem
G5	The leaves are gone and only the bones remain
G6	Young pods are damaged
G7	Leaves appear whitish
G8	The pod walls look damaged and irregular
G9	The stem is rotting
G10	Stems wilt and curl
G11	The number of seeds decreases
G12	Brown or black spots on the stem
G13	Brown spots on leaves
G14	Brown or black spots on pods
G15	Rot near the roots
G16	Stems rot
G17	Pods rot
G18	Leaves rot
G19	Red spots on the stem
G20	Stems become brittle
G21	The stem experiences shrinkage
G22	Seeds are purple
G23	Seeds Rough and Stiff
G24	The pattern of yellow spots on the leaves
G25	The pattern of yellow spots on the pods
G26	Redness on seeds

Based on the data on pests, diseases, and their symptoms, rules or production guidelines can be formulated to diagnose pests and diseases in soybean plants.

TABLE III. RULES

Code	Rule
R1	if G1 and G2 then P1
R2	if G3 and G4 then P2
R3	if G5 and G6 and G7 then P3
R4	if G8 and G9 then P4
R5	if G10 and G11 then P5
R6	if G12 and G13 and G14 then P6
R7	if G15 and G16 and G17 and G18 then P7
R8	if G19 and G20 and G21 then P8
R9	if G22 and G23 then P9
R10	if G24 and G25 and G26 then P10

In making decisions, expert systems use a decision tree with the Best-First Search method. The Best-First Search algorithm is a heuristic search method that combines the advantages of Breadth-First Search and Depth-First Search, prioritizing search efficiency at the expense of completeness [16].

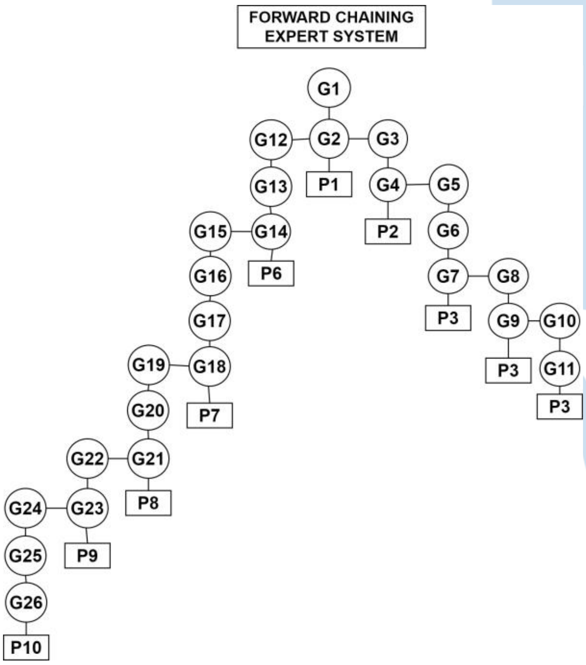

Fig. 2. Decision Tree

To determine the accuracy of the forward chaining method, weights are assigned to each symptom about the disease. The assignment of symptom weights utilizes the formula based on the probability of an event occurring [5].

$$P(A)\frac{Selected\ Symptoms}{Number\ of\ Symptoms\ of\ Disease} \times 100\% \quad (1)$$

B. Design

This stage involves analyzing the collected data and applying diagrams such as ERD (Entity-Relationship Diagram) for database design, as well as UML (Use Case Diagram, Activity Diagram, and Class Diagram) to visualize the system, and DFD (Data Flow Diagram) to illustrate its operational processes.

- Flowchart system

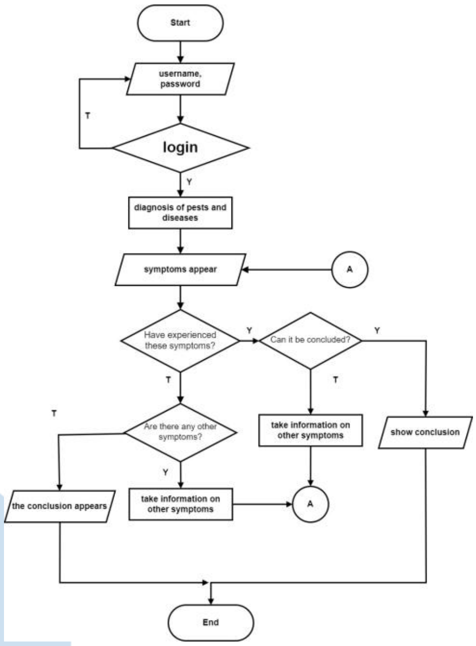

Fig. 3. Flowchart System

- Use Case Diagram

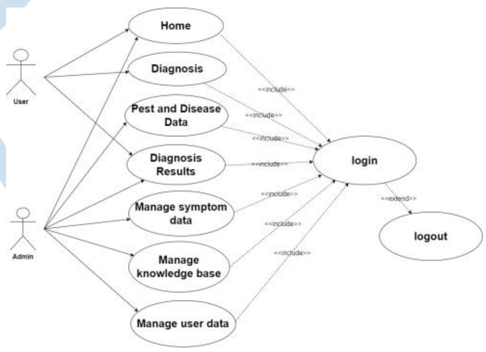

Fig. 4. Use Case Diagram

- Activity Diagram

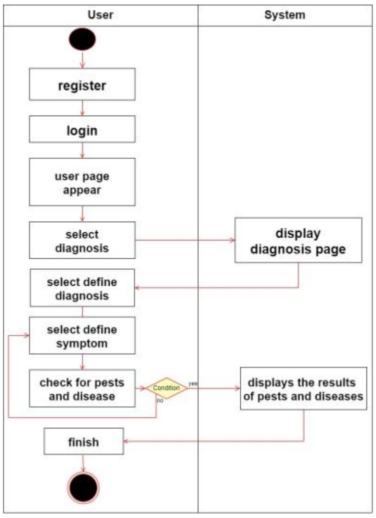

Fig. 5. Activity Diagram

Users log in as members, access the diagnosis menu to diagnose pests and diseases in soybean plants, and answer a series of questions about plant symptoms.

- Entity Relationship Diagram

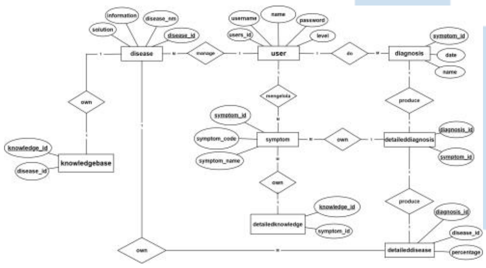

Fig. 6. Entity Relationship Diagram

The Entity-Relationship Diagram (ERD) of the system includes entities such as user, disease, symptom, knowledge base, knowledge detail, diagnosis, diagnosis detail, and disease detail.

- Data Flow Diagram

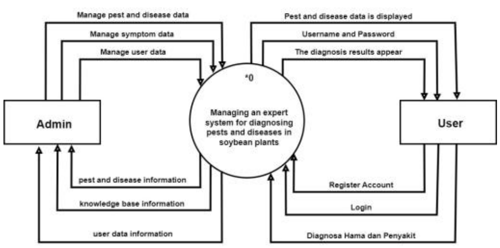

Fig. 7. Data Flow Diagram Level 0

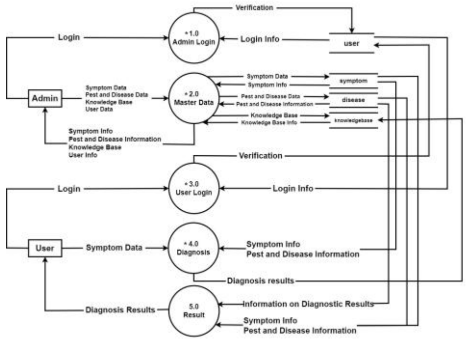

Fig. 8. Data Flow Diagram Level 1

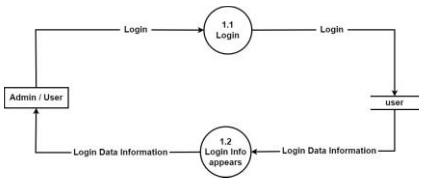

Fig. 9. Data Flow Diagram Level 2 Process 1

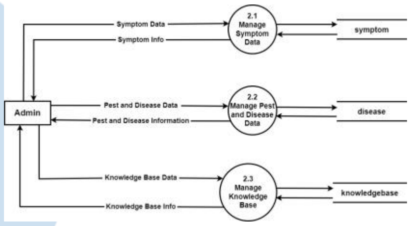

Fig. 10. Data Flow Diagram Level 2 Process 2

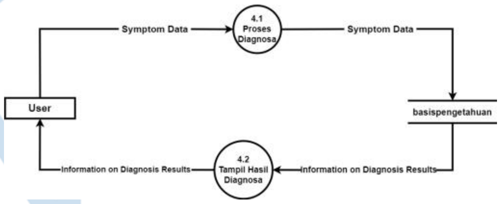

Fig. 11. Data Flow Diagram Level 2 Process 3

In the Expert System, the Level 0 Data Flow Diagram (DFD) illustrates that the Admin manages data on pests, diseases, symptoms, and users, with the system displaying relevant information. Farmers can register, log in, and perform diagnoses using symptom data, with the system showing diagnosis results and information on pests and diseases. In Level 1 DFD, the Admin manages symptom, pest, disease, and knowledge base data. Users input symptoms for diagnosis, and the system provides results based on predefined rules. In Level 2 DFD, the Admin logs in, the system validates identity and manages related data. Users input symptoms, the system processes the diagnosis, and displays the results.

- Class Diagram

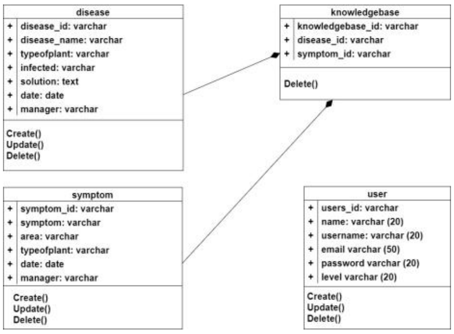

Fig. 12. Class Diagram

A class diagram is a diagram in software modeling that illustrates the static structure of an object-oriented programming system. It includes classes, attributes, methods, and relationships between these classes.

C. *Implementation*

During the implementation phase, the conceptual analysis and design concepts are executed to produce a functional system. Following implementation, thorough testing of the system is conducted to ensure its performance aligns with the planned specifications before it is put into operation.

D. *Testing*

Testing is conducted to identify errors in the system, aiming to minimize deficiencies so that the system functions as expected upon implementation. Testing occurs from two perspectives: first, system feasibility testing by users using the Technology Acceptance Model (TAM) method, focusing on perceived ease of use, usefulness, user attitudes towards use, behavioral intention to use, and actual system usage [17]. Second, system feasibility testing by programmers is done using the Black Box Testing method, which tests input values and disregards the internal mechanisms of the system [18].

E. *Maintenance*

System maintenance is performed periodically to ensure effective bug handling, while also updating the knowledge base data to remain relevant with developments in symptoms, pests, and diseases affecting soybean plants. This is crucial for maintaining the accuracy and quality of the expert system in diagnosing pests and diseases in soybean plants.

IV. Results and Discussion

Development of an Expert System for Pest and Disease Diagnosis in Soybean Plants using Forward Chaining Method with PHP 8 and MySQL as the Database, and CSS with Bootstrap 4 Framework for Website Interface.

A. *Main Menu Screen Display*

Fig. 13. Login Page

The main page of the expert system for diagnosing pests and diseases in soybean plants serves as the initial point for users accessing the system, featuring a login menu that grants access to diagnostic features upon successful login.

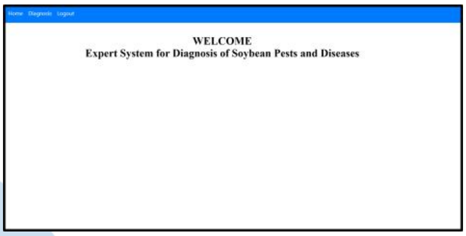

Fig. 14. Welcome Page

Fig. 15. Select Symptoms page

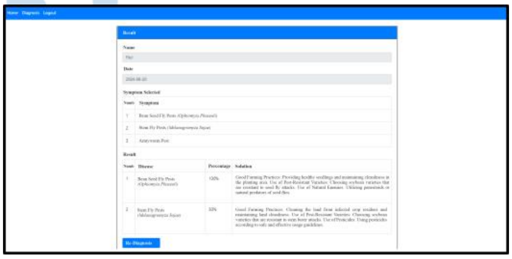

Fig. 16. Diagnosis Results Page

Figure 14 displays the welcome page. Figure 15 shows the symptom page, where users are instructed to select symptoms exhibited by the plant for pest or disease diagnosis. Figure 16 presents the diagnosis result page, where the expert system displays the diagnosis outcome based on the previously selected symptoms.

B. *Forward Chaining Trial Results*

The success of the expert system for diagnosing pests and diseases in soybean plants using the forward chaining method is determined through joint testing with experts. The system processes symptom inputs to obtain diagnostic information for pests and diseases affecting soybean plants.

- Selected symptoms

  Selected and detected symptoms in the knowledge base: G2 G6 G15 G16 G17

- Rules that have symptoms are detected.

  R1: if G1 and G2 then P1

$$P(A) = \frac{1}{2} \times 100\% = 50\%$$

  R3: if G5 and G6 and G7 then P3

$$P(A) = \frac{1}{3} \times 100\% = 33\%$$

  R7: if G15 and G16 and G17 and G18 then P7

$$P(A) = \frac{3}{4} \times 100\% = 75\%$$

  The possible diagnostic outcomes that can be obtained are as follows: Bean Seed Fly Pest with a probability of 50%, Armyworm Pest with 33%, and Falling-off, Leaf, and Pod Rot with 75%. Therefore, it is highly likely that the soybean plants are affected by Falling-off, Leaf, and Pod Rot, with a probability weight of 75%.

TABLE IV. COMPARISON OF SYSTEM AND EXPERT DIAGNOSIS RESULTS

System Diagnostics		Manual Diagnostics		Info
Indication	***Grade***	***Indication***	***Grade***	
Bean Seed Fly Pests	50%	Bean Seed Fly Pests	50%	Suitable
Armyworm Pest	33%	Armyworm Pest	33%	Suitable
Falling of Sprouts, Leaf, and Pod Rot	75%	Falling of Sprouts, Leaf, and Pod Rot	75%	Suitable

C. *Testing by User*

The population studied comprises prospective users of the expert system for pest and disease diagnosis in soybean plants at the Seed Management Unit of the BSIP Aneka Kacang, with a total of 153 employees as of June 27, 2024. The sampling method employed was Simple Random Sampling, where sample members were randomly selected from the population without consideration of strata.

The questionnaire was distributed to 30 respondents. The demographic characteristics of the sample can be outlined as follows:

- Gender: 43.8% of respondents were male and 56.2% were female.

- Age range: 67.4% of respondents were aged 25-35 years, 28.8% were aged 35-45 years, and 3.6% were aged 45-50 years, with no respondents above 50 years old.

The testing of the Expert System for Pest and Disease Diagnosis in Soybean Plants by users was conducted using a Likert Scale-based questionnaire. Each question had five answer choices with predefined scores: Excellent (E) 5, Good (G) 4, Fair (F) 3, Poor (P) 2, and Very Poor (VP) 1.

TABLE V. ASSESSMENT INTERVAL

Number	Information	Initials
0-19%	Very Poor	VP
20-39%	Poor	P
40-59%	Fair	F
60-79%	Good	G
80-100%	Excellent	E

TABLE VI. STATEMENTS ON THE QUESTIONNAIRE

Numb	Indicator	Statement
1	Perceived Ease of Use	The expert system operates effectively
2		The expert system is easy to use
3		The expert system can process data quickly
4	Perceived Usefulness	The expert system can assist in identifying pests and diseases in soybean plants
5		The expert system can provide useful information regarding the management of soybean plants affected by pests or diseases
6		The expert system has comprehensive data that aligns with an expert's knowledge
7	Attitude Towards Using	The expert system has a well-designed interface
8	Behavioral Intention to Use	Motivations for continuing to use the system
9		Desire to use the system frequently
10	Actual System Usage	User satisfaction in using the expert system
11		The expert system is worth using

TABLE VII. TAM ASSESSMENT RESULTS

Numb	Evaluation					Total Score	%
	E	G	F	P	VP		
1	12	17	1	0	0	131	87.3%
2	2	26	2	0	0	120	80.0%
3	7	16	7	0	0	120	80.0%
4	10	17	3	0	0	127	84.7%

Numb	Evaluation					Total Score	%
	E	G	F	P	VP		
5	8	16	6	0	0	122	81.3%
6	9	14	7	0	0	122	81.3%
7	7	21	2	0	0	125	83.3%
8	8	19	3	0	0	125	83.3%
9	8	21	1	0	0	127	84.7%
10	9	19	2	0	0	127	84.7%
11	16	13	1	0	0	135	90.0%
Average							**83,7%**

Based on the testing results using the Likert Scale method, the system achieved an average percentage of 83.7%. This result indicates that the questionnaire-based evaluation meets the criteria for "Excellent," as per the assessment interval where 83.7% falls within the range of excellent (80% - 100%).

The testing results calculate the total score based on the cumulative value of each assessment. The percentage is derived using the formula where the total score is multiplied by 100% and divided by 150, which represents the maximum total score if all respondents choose "Excellent." For example, if 30 respondents choose "Excellent," the total score obtained is 30 x 5 = 150, equivalent to 100%.

D. Testing by Programmer

Testing the Expert System for Pest and Disease Diagnosis in Soybean Plants using the Black Box testing method involves testers evaluating the program based on its functional specifications without considering the internal code structure. The objective of using this method is to quickly detect errors or deficiencies within the system.

TABLE VIII. BLACK BOX TESTING RESULTS

Module	Expected output	Results	Info
Login	Users can access the system according to their respective levels using usernames and passwords	Users can access the system according to their respective levels using usernames and passwords	Succeed
Disease Page	Displaying disease data, adding disease data, editing disease data, Deleting disease data	Displaying disease data, adding disease data, editing disease data, Deleting disease data	Succeed
Symptoms Page	Displaying symptom data, adding symptom data, editing symptom data, Deleting symptom data	Displaying symptom data, adding symptom data, editing symptom data, Deleting symptom data	Succeed
Knowledge Base Page	Displaying knowledge base data, adding knowledge base data, displaying knowledge base details, editing knowledge base data, deleting knowledge base details, Deleting knowledge base data	Displaying knowledge base data, adding knowledge base data, displaying knowledge base details, editing knowledge base data, deleting knowledge base details, Deleting knowledge base data	Succeed
Diagnosis	Displaying symptom data, displaying diagnosis results, Displaying diagnosis history	Displaying symptom data, displaying diagnosis results, Displaying diagnosis history	Succeed
User	Displaying user data, adding user data, editing user data, Deleting user data	Displaying user data, adding user data, editing user data, Deleting user data	Succeed
Logout	Revoking user access rights from the system	Revoking user access rights from the system	Succeed

Based on the testing results, the developed expert system successfully diagnosed pests and diseases in soybean plants with a 100% success rate across eight testing modules, without encountering any errors.

V. CONCLUSION

Based on the research findings from the project "Development of Expert System for Pest and Disease Diagnosis in Soybean Plants Using Forward Chaining Method with Best-First Search Decision-Making Method and Waterfall Software Development Model," it can be concluded that the expert system can provide accurate pest and disease diagnosis results for soybean plants. The conclusions are based on the alignment of diagnosis outcomes with data obtained from plant pest and disease experts.

Based on the comprehensive evaluation, the expert system developed for diagnosing pests and diseases in soybean plants has proven highly feasible and effective. Evaluation using the Technology Acceptance Model (TAM) showed a system feasibility score of 87.3%, indicating excellent acceptance among users. Additionally, rigorous testing through BlackBox testing by programmers resulted in a flawless performance, achieving a 100% success rate across all eight testing modules. These results affirm the system's readiness and suitability for accurate pest and disease diagnosis in soybean plants, highlighting its reliability and usability in agricultural applications.

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