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Research Paper

The Expert System for Diagnosing Pest and Disease in Pineapple Plant Using the Iterative Deepening Search (IDS) Method on the Android Platform

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Keywords

Certainty Factor, Expert System, Iterative Deepening Search, Pineapple Pests and Diseases

Abstract

This research was conducted to design and develop pineapple pests and diseases diagnosis expert system with Iterative Deepening Search (IDS). This expert system runs on android platform. The certainty factor of this expert system is initialized by an expert and the final certainty factor is computed by the system. The data used in this expert system consist of 5 types of pineapple pests, 6 types of pineapple diseases. 31 types of symptoms and 11 types of rules are used to diagnose pineapple pests and diseases. To validate this expert system, two types of tests were conducted, which are expert system verification and system evaluation by users. Expert system verification was conducted by comparing 10 results from the diagnosis system and the results of the diagnosis by an expert. The compare result shows that the expert system result 100% is similar to the result of the expert. To evaluate the system, 30 respondents were asked to evaluate using questionnaires, which were grouped into three groups, i.e. group I (pineapple experts), group II (pineapple farmers and agriculture students) and group III (computer science students). All three stated this expert system runs well (75.56%, 72.44%, and 79.83% respectively).

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1. INTRODUCTION

Indonesia has exported 1.84 million kg of pineapples, equivalent to US$ 1.13 million, as of July 2018. Pineapple plantations in Indonesia are reported to have reached a productivity of 117.5 tons per hectare of land as of July 2018 [1], making pineapples a potential flagship commodity for Indonesia. However, pineapple cultivation faces several obstacles that require solutions. These obstacles are related to productivity standards, quality, and food safety. All three of these factors are directly or indirectly linked to pest and disease attacks on pineapple plants during cultivation [2]. Therefore, a practical technology is needed that farmers can use to identify and recognize the pests and diseases that frequently attack pineapple plants.

This practical technology must be affordable for farmers and highly mobile in its use. The technology that has these features is embedded in smartphones. According to data from the eMarketer survey agency, there were 92 million smartphone users in Indonesia in 2019. This number will continue to grow in line with Indonesia's dynamic population growth each year [3]. Along with the increase in smartphone users, farmers can also utilize smartphones for their agricultural needs. User-generated content, such as multimedia, audio, video, and opinions, can be shared and discussed on a mobile phone, which is an internet-connected device. Even in rural places, this has altered how farmers interact and communicate nationwide [4]. Smartphone applications can be used as a medium to convey information to traditional farmers. Most of them became farmers because this profession is a hereditary occupation, and the problem they face is a lack of information and knowledge in the field of agriculture due to low formal education. Therefore, they only rely on knowledge from their families (non-formal) in farming, even though identifying pests and diseases needs to be done by experts to avoid misdiagnosis and incorrect treatment.

Currently, every farmer, even traditional farmers, has a smartphone. Smartphones can be used to identify pests and diseases affecting pineapple plants through an expert system installed on the smartphone. The expert system is expected to assist experts in diagnosing pests and diseases affecting pineapple plants and determining how to combat them. This expert system solution can reduce the problem of dependence on experts, whose numbers are very limited in Indonesia.

Several studies on pineapple expert systems have been conducted. Two of them are expert systems for pineapple plant diseases only. In a study of expert systems for diagnosing diseases in pineapple plants, a web-based Bayesian algorithm was used [5]. This expert system can diagnose 5 pineapple diseases with 17 symptoms, based on a case study at the Mangunan plantation in Yogyakarta. The application can only be accessed via a browser and is used for disease diagnosis. Another expert system is a desktop-based expert system for diagnosing pineapple plant diseases [6]. This expert system provides an overview of pineapple diseases, descriptions of the causes of pineapple diseases, and possible treatments or solutions to prevent these diseases. The design and implementation of this expert system utilize CLIPS and Delphi.

An expert system requires a searching algorithm for data retrieval. Some commonly applied searching algorithms in expert systems include breadth-first search (BFS), best-first search, and depth-first search (DFS). The BFS algorithm has been applied in an expert system for diagnosing cocoa plant diseases [7] and Areca Plant Diseases [8]. The data used in this expert system consists of 26 symptoms to detect 9 diseases. This application is web-based and can only be accessed via a browser.

A review of research and applications of expert system is given in [9]. The were fifteen categories discussed in this study, including diagnosis, repair, prediction, forecasting, monitoring, control, and so on which implemented in seven fields such as manufacturing, managements, engineering, military, medicals, education, and training.

To the best of the author's knowledge, the iterative deepening search (IDS) algorithm has never been used for expert systems for identifying pests and diseases in pineapple plants. Therefore, the data search algorithm used in this expert system is IDS. This algorithm is a modification of DFS, which has low space complexity or requires little memory, with the advantages of BFS, which is complete and optimal. Searching in IDS is performed iteratively and explored in depth, starting from the zero-level boundary [9]

2. METHODS

2.1 Expert System

Designing intelligent computer systems that transform useful objects into necessities is the focus of artificial intelligence (AI) [10, 11]. The present increased awareness of AI can be attributed in large part to the Knowledge Based Expert System (KBES), which are computer systems that simulate human competence.

An expert system is an artificial program that has inference capabilities similar to the reasoning abilities of an expert in a particular field. Expert systems are a branch of artificial intelligence that combines knowledge bases and inference engines [12].

The characteristics of an expert system are as follows [13]:

1. Limited to a specific domain of expertise.
2. Able to provide reasoning for uncertain data.
3. Able to present a series of reasons in an understandable manner.
4. Based on specific rules or guidelines.
5. Designed to be developed gradually.
6. The output is in the form of recommendations.

The Expert System consists of two main parts, namely the development environment and the consultation environment [14].

(a) The development environment is used for expert system development, both in terms of component development and knowledge base development.

(b) The consultation environment is used by non-experts for consultation.

2.2 Iterative Deepening Search (IDS)

Iterative Deepening Search (IDS) is a search method that combines the advantages of BFS, which is complete and optimal, with the advantages of DFS, which has low space complexity or requires little memory but has high time complexity. IDS performs iterative searches using Depth-Limited Search (DLS) starting with a level 0 limit. If no solution is found, a second iteration is performed with a level 1 limit. This continues until a solution is found [15]. The use of DFS in IDS has shown to be an effective solution to problems related to artificial intelligence [16]. The time complexity of the IDS algorithm is expressed as polynomial time $O(b^d)$ and the space complexity as linear $O(bd$, where b denotes the branching factor and d is the depth of the decision tree.

2.3 Certainty Factor (CF)

The Certainty Factor (CF) theory was proposed by Shortliffe and Buchanan in 1975 to accommodate the uncertainty of an expert's reasoning (inexact reasoning). Experts often analyze existing information using expressions such as "maybe," "probably," or "almost certainly." One example of an expert system application using the CF method is MYCIN, an expert system for diagnosing bacterial infections in the blood [17].

CF values in expert systems are grouped into two categories [18]:

(a) The CF value of a rule that is attached to a specific rule, with the value assigned by an expert.

(b) The CF value assigned by the user to represent the degree of certainty/confidence in the premise (e.g., symptoms, conditions, characteristics) experienced by the user.

The combination of certainty factors used for expert systems is [19]:

1. Certainty Factor for rules with single premises/symptoms

(single premise rule $CF_{\text{sympton}} = CF_{\text{user}} \times CF_{\text{expert}}$
2. If there are rules with similar conclusions (similarly concluded rules) or more than one symptom, then CF is calculated using the following equation: $CF_{\text{combine}} = CF_{\text{old}} + CF_{\text{sympton}} \times (1 - CF_{\text{old}})$
3. Meanwhile, to calculate the percentage of pests/diseases, the following equation is used: $CF_{\text{persentase}} = CF_{\text{combine}} \times 100$

2.4 Data Collection

The data collected consists of information related to five pests and six diseases affecting pineapple plants, accompanied by descriptions, symptoms, and control measures for these pests and diseases. The decision on the number of pests and diseases was made after careful consideration so that it could be implemented as an expert system.

2.5 Pre processing

The data that has been successfully collected is then transformed into a decision table. This table is then expressed in the form of a decision tree to facilitate the application of the IDS method. In this study, the knowledge base of the data is represented in the form of if-then statements. The data representation process in this expert system produces 11 rules, which will later be implemented in the form of source code.

3. RESULTS AND DISCUSSION

The data required in developing this expert system includes data on pineapple pests and diseases, along with their symptoms and control measures. This data was obtained from various sources such as books, the internet, reports, scientific journals, and others. Most of the data came from the book "Technical Guidelines for Pineapple Cultivation" [17]. The review of these references resulted in data consisting of 5 pests and 6 diseases with 31 symptoms. The data was then structured and converted into the knowledge base of this expert system. Pest data is coded as "H," disease data as "P," and symptom data as "G." Table 1 gives the list of pest names, Table 2 displays the list of disease names , and Table 3 displays the list of symptoms.

Table 1. Pineapple Pest Data

Code	Name of Pest
H1	Whitefly
H2	Scale insect
H3	Thrips
H4	Nematodes
H5	Uret

- **Whitefly (*Dysmicocus brevipes*)**

This pest causes pineapple plants to stop growing because the root tissue dies and rots. To control this pest, pineapple seeds are soaked for 3 minutes in a solution of Chemitation or Diazinon 50 ml/liter of water, then the seedlings are drained vertically for 24 hours so that the solution is absorbed at the base of the leaves, and the plants are sprayed with pesticides such as Paration. Planting pineapples near host plants such as sugarcane, rice, coffee, bananas, soybeans, and peanuts should be avoided to reduce the risk of infestation by this pest [20].

Table 2. Pineapple Plant Disease Data

Code	Name of Diseases
P1	Fusarium stem rot
P2	Root and heart rot
P3	Fusariosis
P4	Wilt disease
P5	Pratylenchus Brachyurus Nematode
P6	Bacterial fruit rot

- **Scale Insect (*Diaspis bromeliae*)**

This pest causes the leaf surface to appear dry and spotted, and because the aphids suck the sap from the fruit, it becomes unattractive. To control this pest, pineapple seedlings are soaked in a solution of Chemitation or Diazinon at a concentration of 50 mL/liter of water for 3 minutes. The seedlings are then drained vertically for 24 hours so that the solution is absorbed at the base of the leaves. Spraying is done with Diazinon, Basudin, and Basaminon, and predatory beetles need to be monitored [20].

- **Thrips (*Thrips tabaci*)**

This pest causes young leaves to shrink and develop silvery red spots. To control this pest, weeds or plants that serve as hosts for thrips, such as moss and fungi, must be removed. Continuous planting on the same land should be avoided. Spraying is carried out using Mesurol 50 WP and Lannate 25 WP [20].

- **Nematodes (*Meloidogyne spp*)**

This pest causes the roots of pineapple plants to swell conspicuously, and in more severe attacks, the roots die and the pineapple plants also die. Anticipating this pest from the outset involves using pineapple seedlings that are resistant to nematodes. In addition, the planting area is left open for 2–3 weeks, and crop rotation is carried out [20].

- **Uret (*Lepidiota spp*)**

This pest causes plants to wilt systematically by damaging the roots, thereby disrupting the absorption of water and nutrients through the roots. In more severe attacks, it can cause death. This pest is controlled with insecticides mixed into the soil, either in liquid, dust, or granule form [21].

Below is a brief explanation of diseases that often attack pineapple plants. The names of these diseases and their codes can be found in Table 2.

- **Fusarium stem rot (*Ceratocystis paradoxa* and *C. moreau*)**

This disease causes the base of pineapple seedlings to turn brown due to soft rot. The rot can spread to the upper parts, to the leaves before or after the seedlings are transferred to the planting area. Another characteristic is the appearance of yellowish-white spots or short, wide lines on the leaves. Infected ripe fruit becomes rotten, turning yellow and eventually black. Infection typically begins at the cut site on the stem, which rots and emits a foul odor [20].

- Root and heart rot (*Phytopthora spp*)
This disease causes young plants to become chlorotic with necrotic tips. Due to rot at the base, young leaves are easily pulled out. The boundary of the rotted leaf area is brown. It typically attacks the upper soft stem of mature plants. Plant death is rarely caused by root rot. Many roots are damaged, growth becomes stunted, fruit formation is delayed, or no fruit is produced at all. To control this disease, soil aeration and drainage must be good. Infected plants and previous plant residues must be sanitized. Shoots should be soaked in fungicides such as Alietta and Ridomil before planting. Additionally, control measures include crop rotation with resistant crops like sugarcane, corn, soybeans, and legumes, as well as planting resistant varieties such as Queen and Smooth cayenne [20].

- Fusariosis (*Fusarium moniliforme var. subglutinans*)
This disease usually affects all parts of the plant, but the fruit and shoots are the most commonly affected parts. The plant becomes stunted, the leaves become chlorotic, and the tips of the stems become bent or die in certain cases. To control this disease, use disease-free pineapple seedlings, rotate crops, control flower-visiting insects—especially lepidoptera that can spread fungal spores—and apply the fungicide Captan during flowering and fruit development [21].

Fruitlet lesions and brown discoloration, rotten or sunken fruit skin and stem, gum exudation on some fruits, dry rot on leaves, stem bending, chlorosis, an increase in the number of leaves per spiral, and natural fruit cracks were common symptoms [22, 23, 24].

Worldwide pineapple output is seriously threatened by wilt disease in pineapple plants, especially the Pineapple Mealybug Wilt-associated Virus (PMWaV) illness. Frequently accompanied with root rot, it is characterized by plant wilting, leaf curling, tip dieback, and reddening of the leaves. Fruit malformations and decreased yields are among the indications of this disease, which is carried by mealybugs.

- Pratylenchus Brachyurus Nematode (*Lesion nematodes*)
This disease causes nodules on the roots. Affected plants will have dark lesions and damage to the roots [25].

-Bakterial fruit rot (*Erwinia chrysanthemi*)
This disease causes decay in the fruit and produces an unpleasant odor [26].

To make it easier to identify the relationship between pests and diseases and their symptoms, a decision table was created. Next, the decision table was processed into a decision tree to facilitate the search for pests and diseases based on their symptoms.

Table 3. List of Symptoms

Code	Symptoms
G1	Dead root tissue
G2	Root tissue decay
G3	Leaves appear dry and spotted
G4	Fruit appearance unattractive
G5	Young leaves shrink in size
G6	Leaves appear silver-red spotted
G7	Plant roots swell conspicuously
G8	Root tissue damaged
G9	Wounds at the base of the stem
G10	Leaves and fruit easily pulled out
G11	Leaves wilt, turn yellow, and dry out
G12	Soft, brown rot at the base of pineapple seedlings
G13	Leaves show white-yellowish spots
G14	Ripened fruit turns black from yellow
G15	Root growth stops
G16	Rot at the base of the stem
G17	Lower sides of leaves turn yellow
G18	Stem base turns brown
G19	Rotten parts emit an unpleasant odor
G20	Plant growth is stunted
G21	Roots and stems have uret
G22	Young leaves are easily pulled out
G23	The rotting parts of the leaves have brown borders
G24	The plant becomes stunted
G25	Leaves are chlorotic
G26	The tips of the stems are bent or dead
G27	Leaves are curved
G28	There are whiteflies on the roots
G29	The leaves are brown
G30	There are nodules on the roots
G31	There are lesions on the root

3.1 Knowledge Representation

Knowledge representation is used to assist the search process in order to determine conclusions from the identification performed. In this study, the knowledge representation used is a knowledge base in the form of if-then statements. After the data is processed, this expert system has 11 rules.

3.2 Application of the IDS Method

The IDS method is applied when the system performs data searches. This data search process is carried out to find the goal/solution (goal node) which is visualized in the form of a tree. A tree is a representation of a data structure resembling a tree consisting of a collection of nodes/vertices (nodes) and edges. One special node called the root node is a node that has no parent. An edge is a line that connects each node/vertex.
The steps for implementing the IDS method are as follows:

1. Construct Decision Tree
   To develop this expert system, a decision table is needed as a guide to construct a decision tree. The decision table

Table 4. Iterative Deepening Search on Pineapple Plant Pests

Level	Iterative Deepening Search
0	G1
1	G1, G2, G3
2	G1, G2, G8, G7, G3, G4, G5
3	G1, G2, G8, G9, H1, G7, H4, G3, G4, H2, G5, G6
4	G1, G2, G8, G9, G10, H1, G7, H4, G3, G4, H2, G5, G6, H3
5	G1, G2, G8, G9, G10, G11, H1, G7, H4, G3, G4, H2, G5, G6, H3
6	G1, G2, G8, G9, G10, G11, H5, H1, G7, H4, G3, G4, H2, G5, G6, H3

Table 5. Iterative Deepening Search on Pineapple Plant Diseases

Level	Iterative Deepening Search
0	G31
1	G31, G30, G2
2	G31, G30, P5, G2, G10, G16
3	G31, G30, P5, G2, G10, G20, G16, G24, G27
4	G31, G30, P5, G2, G10, G20, G15, G16, G24, G22, G11, G27, G28
5	G31, G30, P5, G2, G10, G20, G15, G19, G16, G24, G22, G23, G11, G13, G25, G27, G28, G29
6	G31, G30, P5, G2, G10, G20, G15, G19, G8, G16, G24, G22, G23, P2, G11, G13, G14, G25, G26, G27, G28, G29, P4
7	G31, G30, P5, G2, G10, G20, G15, G19, G8, P6, G16, G24, G22, G23, P2, G11, G13, G14, G17, G25, G26, P3, G27, G28, G29, P4
8	G31, G30, P5, G2, G10, G20, G15, G19, G8, P6, G16, G24, G22, G23, P2, G11, G13, G14, G17, G18, G25, G26, P3, G27, G28, G29, P4
9	G31, G30, P5, G2, G10, G20, G15, G19, G8, P6, G16, G24, G22, G23, P2, G11, G13, G14, G17, G18, G9, G25, G26, P3, G27, G28, G29, P4
10	G31, G30, P5, G2, G10, G20, G15, G19, G8, P6, G16, G24, G22, G23, P2, G11, G13, G14, G17, G18, G9, G12, G25, G26, P3, G27, G28, G29, P4
11	G31, G30, P5, G2, G10, G20, G15, G19, G8, P6, G16, G24, G22, G23, P2, G11, G13, G14, G17, G18, G9, G12, G21, G25, G26, P3, G27, G28, G29, P4
12	G31, G30, P5, G2, G10, G20, G15, G19, G8, P6, G16, G24, G22, G23, P2, G11, G13, G14, G17, G18, G9, G12, G21, P1, G25, G26, P3, G27, G28, G29, P4

produces two decision trees. The decision trees produced are a decision tree for pineapple pests and a decision tree for pineapple diseases.

2. Construct the Iterative Deepening Search (IDS) Table
   The IDS table can be created based on a decision tree. The table contains levels and search sequences using IDS. Based on the decision tree, pineapple pests have 6 levels (7 iterations) and pineapple diseases have 12 levels (13 iterations). Table 4 displays the IDS table for pineapple pests, and Table 5 displays the IDS table for pineapple diseases.

The following is an example of searching for a goal node with code P2. Code P2 can be found at level 6. When searching for code P2, the process starts from the top node (root node), which is G31 at level 0. The search then continues to G30 at level 1. From node G30, the search continues to P5, which is at level 2. P5 is one of the goal nodes, but in this search, the target is P2. The IDS algorithm in this process moves to another branch that has not yet been explored. Thus, the search process continues to G2, which is at level 1.

From node G2, the search continues to G10, which is at level 2. After that, the search continues to G20, which is at level 3, then to G15, which is at level 4, then to G19, which is at level 5, and finally to G8, which is at level 6. Since G8 is at the maximum level in this search (level 6), the search then moves to the top node that shares a root with G10. That node is G16, which is at level 2. From node G16, the search continues to G24, which is at level 3. After that, the search continues to G22, which is at level 4, then continues to G23, which is at level 5, and then continues to P2, which is at level 6. Since the goal node has been found, the search does not need to be continued. Figure 1 displays the search scheme for code P2.

3.3 Weighting of Certainty Values

The weighting of certainty values in this expert system uses the Certainty Factor (CF) method. In the implementation of this expert system, it can be seen that the CF values obtained from users are based on the questions asked during the consultation session. The CF values of the rules are found in a rule/rule that is usually given by experts based on their experience, so they are highly subjective [15]. In this expert system, users can only choose one option from three possible answers: “Yes,” “Unsure,”

Table 6. The Rules for Pineapple Plant Pest

Rule
IF Rooting root tissue (G1) **AND** Rotting root tissue (G2) **THEN** Whitefly (H1)
IF Leaves appear dry patches (G3) **AND** Unattractive fruit appearance (G4) **THEN** Scale insect (H2)
IF Young leaves shrink in size (G5) **AND** Leaves show silvery red patches (G6) **THEN** Thrips (H3) **IF** Plant roots swell conspicuously (G7) **AND** Dead root tissue (G1) **THEN** Nematoda (H4)
IF Root tissue damaged (G8) **AND** Wounds at the base of the stem (G9) **AND** Leaves and fruit easily pulled out (G10) **AND** Rotting root tissue (G2) **AND** Dead root tissue (G1) **AND** Leaves wilt, turn yellow, and dry out (G11) **THEN** Uret (H5)

and "No." Each answer option has its own CF value: "Yes" has a value of 1, 'Unsure' has a value of 0.5, and "No" has a value of 0.

3.4 Rules for Detecting Pineapple Plant Pest and Disease

Table 6 shows the rules for pineapple plant pest, while Table 7 shows the rules for pineapple plant diseases.

For example, a user consults about pests with the following symptoms:

1. Dead root tissue (G1, $CF_{\text{user}} = 0.5$)
2. Rotting root tissue (G2, $CF_{\text{user}} = 0.5$)
3. Noticeable swelling of the plant's roots (G7, $CF_{\text{user}} = 1$)

The selected symptoms are part of Rule 1 and Rule 4 found in the knowledge representation:

Rule 1
IF Dead root tissue ($CF_{\text{pakar}} = 0.4$)
AND Rotting root tissue ($CF_{\text{pakar}} = 0.4$)
THEN Nematode (H4)

Rule 4
IF Noticeable swelling of the plant's roots ($CF_{\text{pakar}} = 0.4$)
AND Dead root tissue ($CF_{\text{pakar}} = 0.4$)
THEN Nematode (H4)

Next, the system will calculate the certainty value of the rule. The following is an example of certainty value calculation according to the selected rule.

1. Rule 1
   G1 calculation on Rule 1

$$CF_{G1} = 0.5 \times 0.4 = 0.2$$

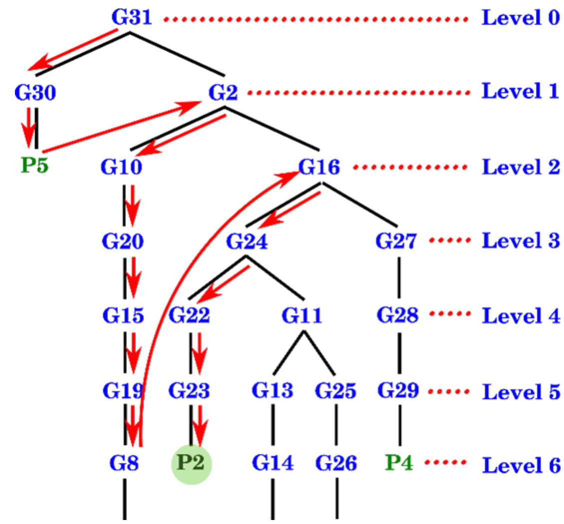

Figure 1. P2 Code Search Scheme

G2 calculation on Rule 1

$$CF_{G7} = 0.5 \times 0.4 = 0.2$$

$CF_{combine}$ calculation

$$CF_{combine} = 0.2 + 0.2 \times (1 - 0.2) = 0.36$$

$CF_{percentage}$ calculation

$$CF_{percentage} = 0.36 \times 100\% = 36\%$$

2. Rule 4
   G1 calculation on Rule 4

$$CF_{G1} = 0.5 \times 0.4 = 0.2$$

G2 calculation on Rule 4

$$CF_{G7} = 1 \times 0.4 = 0.4$$

$CF_{combine}$ calculation

$$CF_{combine} = 0.2 + 0.4 \times (1 - 0.2) = 0.52$$

$CF_{percentage}$ calculation

$$CF_{percentage} = 0.52 \times 100\% = 52\%$$

Based on the results of the calculations, it was concluded that pineapple plants were likely to be infected with nematode pests at a rate of 52%.

3.5 System Implementation

This expert system for diagnosing pests and diseases in pineapple plants was developed using Android Studio with the Java programming language. The application can be accessed via Android-based smartphones. Users can access the application to diagnose pests and diseases and view a list of pests and diseases

Table 7. The Rules for Pineapple Plant Diseases

Rule
IF Soft, brown rot at the base of pineapple seedlings (G12) **AND** Leaves show white-yellowish spots (G13) **AND** Ripened fruit turns black from yellow (G14) **AND** Leaves wilt, turn yellow, and dry out (G11) **AND** Root growth stops (G15) **AND** Rotting root tissue (G2) **AND** Rot at the base of the stem (G16) **AND** Lower sides of leaves turn yellow (G17) **AND** Stem base turns brown (G18) **AND** Rotten parts emit an unpleasant odor (G19) **AND** Plant growth is stunted (G20) **AND** Wounds at the base of the stem (G9) **AND** Roots and stems have uret (G21) **THEN** Fusarium stem rot (P1)
IF Young leaves are easily pulled out (G22) **AND** Rot at the base of the stem (G16) **AND** The rotting parts of the leaves have brown borders (G23) **AND** The plant becomes stunted (G24) **THEN** Root and heart rot (P2)
IF The plant becomes stunted (G24) **AND** Soft, brown rot at the base of pineapple seedlings (G12) **AND** Leaves show white-yellowish spots (G13) **AND** Ripened fruit turns black from yellow (G14) **AND** Leaves wilt, turn yellow, and dry out (G11) **AND** Root growth stops (G15) **AND** Rotting root tissue (G2) **AND** Rot at the base of the stem (G16) **AND** Lower sides of leaves turn yellow (G17) **AND** Leaves and fruit easily pulled out (G10) **AND** Rotten parts emit an unpleasant odor (G19) **AND** Plant growth is stunted (G20) **AND** Wounds at the base of the stem (G9) **AND** Roots and stems have uret (G21) **AND** Leaves are chlorotic (G25) **AND** The tips of the stems are bent or dead (G26) **THEN** Fusariosis (P3)
IF Leaves are curved (G27) **AND** There are whiteflies on the roots (G28) **AND** Leaves wilt, turn yellow, and dry out (G11) **AND** Root growth stops (G15) **AND** Rotting root tissue (G2) **AND** Rot at the base of the stem (G16) **AND** Lower sides of leaves turn yellow (G17) **AND** Leaves show white-yellowish spots (G13) **AND** Ripened fruit turns black from yellow (G14) **AND** Leaves and fruit easily pulled out (G10) **AND** The leaves are brown (G29) **AND** Plant growth is stunted (G20) **THEN** Wilt disease (P4)

IF There are nodules on the roots (G30) **AND** There are lesions on the root (G31) **THEN** Nematoda Pratylenchus Brachyurus (P5)
IF Root tissue damaged (G8) **AND** Root growth stops (G15) **AND** Rotting root tissue (G2) **AND** Leaves and fruit easily pulled out (G10) **AND** Rotten parts emit an unpleasant odor (G19) **AND** Plant growth is stunted (G20) **THEN** Bacterial fruit rot (P6)

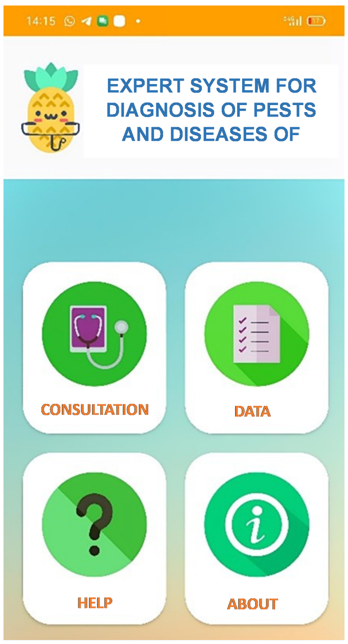

Figure 2. Main Menu Display

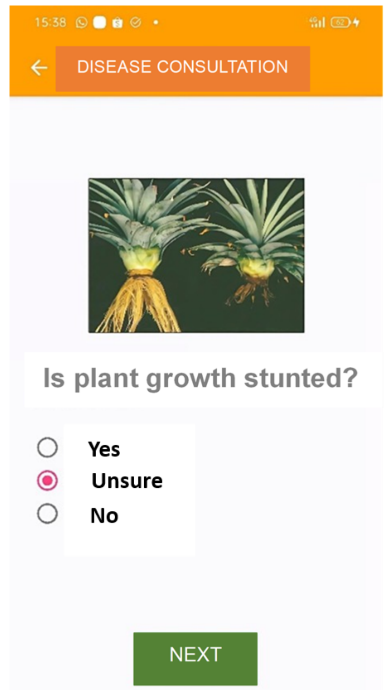

Figure 3. Consultation Menu Display (Questions)

affecting pineapple plants. Below is a screenshot of the application that will be used by users, along with an explanation of each screen.

The Main Menu consists of one header and four buttons. The header on the left displays the application logo, and on the right is the name of this expert system application. The main menu has four buttons that function to access the menus in this application, namely Consultation, Data, Help, and About. Figure 2 displays the view of the main menu.

The consultation menu consists of two options for users to choose whether they want to diagnose pests or diseases. After selecting what to diagnose, the application will display several questions related to the symptoms suffered by the pineapple plant. Users only need to select one of the three radio buttons representing the answers "Yes," "Unsure," or "No" to proceed to the next question. Figure 3 shows this menu. Users must select the "Next" button to display the next question. After all questions have been answered, the application will display the diagnosis results. Figure 4 shows the diagnosis results.

Figure Details of the questions that led to the conclusion of Hama Uret as shown in Figure 4. These questions are followed by user responses, which are then processed to obtain certainty values in Figure 4. These questions are followed by user responses, which are then processed to obtain certainty values in Figure 4. These questions are followed by user responses, which are then processed to obtain certainty values in Figure 4. These questions are followed by user responses, which are then processed to obtain certainty values (Certainty Factor).
The following are the details of the questions.

1. Is te root tissue dead?
   User respon (CF_{user}) = 1
   CF_{pakar} = 0.4
2. Is root tissue rotting?
   User respon (CF_{user}) = 1
   CF_{pakar} = 0.4
3. Is root tissue damage?
   User respon (CF_{user}) = 1

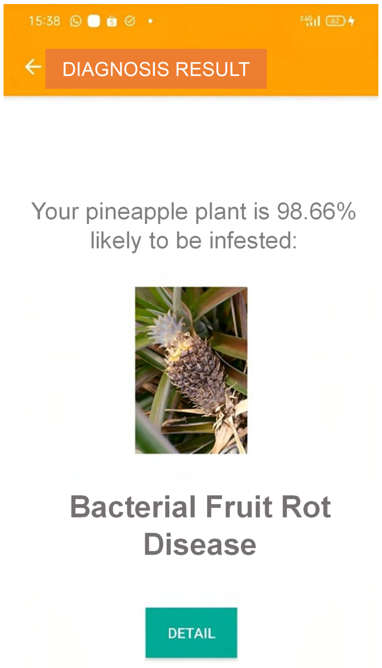

Figure 4. Consultation Menu Display (Diagnosis Results)

CF_{pakar} = 0.8

4. Are there any wounds at the base of the trunk?
   User respon (CF_{user}) = 1
   CF_{pakar} = 0.6
5. Are the leaves and fruit easy to remove?
   User respon (CF_{user}) = 1
   CF_{pakar} = 0.8
6. Are the leaves wilting, turning yellow, and drying out?
   User respon (CF_{user}) = 1
   CF_{pakar} = 0.8

With the answers provided above, the certainty of a Uret pest attack is 99.88

3.6 Testing

3.6.1 System Expertise Verification

System expertise verification is carried out by comparing the results of the system diagnosis and the results of the expert diagnosis. An example of this is when the system produces a diagnosis result of 88.00% and 64.00% for Thrips pests. The symptoms exhibited by pineapple plants when the Thrips pest diagnosis result is 88.00% include reduced leaf size (G5, CF_{user}=1) and leaves showing reddish-silver spots (G6, CF_{user}=1). For a Thrips pest diagnosis result of 64.00%, the symptoms exhibited by the pineapple plant are reduced leaf size (G5, CF_{user}=0.5) and leaves showing silver-red spots (G6, CF_{user}=1). After that, the system's diagnostic results were compared with those of the expert, and the expert stated that the results were the same as theirs. Based on the expert verification results, it can be concluded that the system's diagnostic results are the same as the expert's diagnostic results.

3.7 System Evaluation by Users

This evaluation involved 30 respondents divided into three groups. Group I consisted of 2 experts, group II consisted of 2 farmers and 13 students of the Faculty of Agriculture and group III consisting of 13 Computer Science students. The purpose of grouping questionnaire respondents is to compare the assessment results of questionnaire respondents who understand pests and diseases such as farmers and students of the Faculty of Agriculture, as well as those who do not understand pests and diseases such as Computer Science students. Table 8 shows the Respondent Assesment Criteria, while Figure 5 displays Satisfaction score about the application/system.

Table 8. Respondent Assessment Criteria

Answer	Description
0% - 19.99%	Poor
20% - 39.99%	Not Good
40% - 59.99%	Good enough
60% - 79.99%	Good
80% - 100%	Very Good

The evaluation results of the three groups show that this expert system application can be categorized as good based on the respondents' assessment criteria which can be seen in Figure 5.

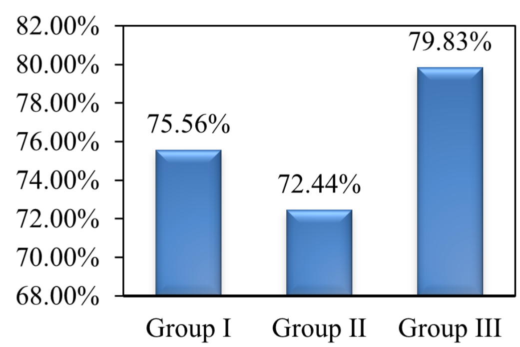

Figure 5. Satisfaction Score about the Application/system

4. CONCLUSIONS

Based on the discussion above we can conclude that the expert system developed can be used easily. The application uses 11 rules, five rules for detecting the pineapple plant pest and six rules for detecting the pineapple plant diseases. Moreover, based on the evaluation of the system by users, from 9 statements assessed by 3 groups of respondents with a total of 30 people, the satisfaction value of the application is 75.56% from group I (Experts) meaning that the application is categorized as good, 72.44% from group II (Farmers and Students of the Faculty of Agriculture) meaning that the application is categorized as good and 79.83% from group III (Computer Science Students) meaning that the application is categorized as good.

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