Rice crop management expert system with forwarding chaining method and certainty factor

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Abstract. Rice plants are one of the focuses on food sustainability so that an increase in rice production needs to be done. Farmers need information and knowledge to improve rice crop production by practicing good planting methods that begin with the selection of superior varieties of seeds and handling plant pests properly. The problem that arises is that assistance from agricultural specialists is not always available when farmers need it, making it difficult for farmers to consult experts according to their needs at any time. Therefore, in this study, an expert system was proposed which was able to help farmers to obtain information according to their needs. This research builds an expert system for the management of rice plants including the selection of rice seed varieties and handling pest of rice plants. The method used in this expert system is forward chaining and certainty factor. Knowledgebase data was obtained from experts in agricultural extension, experts on plant pest organisms and literature from the agricultural service. From this study, an expert system was produced that was able to provide information on the selection of seed varieties and pest of rice plants according to the conditions and needs of the users.

1. Introduction

Academics and industry have shown interest in the development of information technology-based agricultural systems that aim to increase production in agriculture [1]. Because of communication, information exchange, transactions, knowledge transfer is very important in almost every aspect of agriculture in sustainable agriculture [2]. Rice plants are one of the focuses on food security because world rice production ranks third in all cereals after corn and wheat. But rice is the main carbohydrate source for the majority of the world’s population.

The management of rice plants starts from the selection of varieties to be planted by taking into account several factors such as land type, weather, and resistance to disease pests [3]. Then the stage of pest control by means of good agricultural practices, biological control, and seed varieties that are resistant to pests, and the use of chemical insecticides [4]. As well as the stage of fertilizing plants using fertilizer types and their numbers correctly in increasing crop yields because the use of improper doses
of fertilizer in the long term can cause an increase in soil acidity and degradation of soil physical status [5]. So that it can be concluded that managing rice plants well farmers need the right knowledge and information.

An expert system is information technology that can help meet information needs for farmers. Expert systems are computer programs that are designed to mimic logic and reasoning processes used by an expert to solve problems and find solutions in the fields they are engaged in using artificial intelligence technology [6].

Expert systems emerge as a branch of artificial intelligence, from the efforts of AI researchers to develop computer programs that can think as humans and many organizations have used this technology to increase productivity and profits through better business decisions [8]. An important aspect of building expert systems in formulating the scope of the problem and gathering information from expert sources from the domains needed to solve the problem [9]. The quality of knowledge contained in the knowledge base will determine the reliability of the expert system [10].

One of the problems in agriculture is that assistance from agricultural specialists is not always available when farmers need it [7] which makes it difficult for ordinary farmers to consult experts according to their needs at all times [11]. The transfer of knowledge about good planting practices is still carried out traditionally as well as the lack of facilities that facilitate communication between researchers and farmers which results in farmers not getting knowledge and recommendations on the problems they face on time [12]. Lack of access to information and knowledge about good planting practices eventually resulted in rice yields that were not optimal. To overcome this problem the expert system was identified as a powerful tool with broad potential in agriculture.

This research develops an expert system that aims to assist farmers in making decisions starting from selecting seeds and handling pests and disease. overcome the complexity of managing effectively by providing quick access to advice on agricultural issues in a timely, reliable and consistent manner. Expert systems can do this work by giving advice on problems faced by farmers such as suggesting appropriate plant seeds on the basis of resources, climatic conditions, type of soil available to farmers, and proper methods of controlling the pest.

2. literature review and theoretical basis
Some expert systems have been researched to help rice farmers such as prototype design and implementation of expert systems for diagnosis of rice plant disease [13], design and development of expert systems based on JESS architecture for diagnosing rice plant diseases [14], expert systems for pest diagnosis and plant disease with forward chaining and certainty factor [15], and an expert system proposal to increase RICEsmart rice production [12].

In its application, it is known that the expert system has the disadvantage that often the system produces answers that do not have full certainty so that the need for managing uncertainty in the expert system and one of the theories to resolve uncertainty in expert systems is the certainty factor theory. From research on Expert Systems Land, selection uses certainty factors and possibility theory methods [16] and expert systems for inference engine diagnosis based on certainty factor models [17] can be seen that expert systems designed with uncertainty management perform very well on the agricultural domain.

This study developed an expert system with rule-based forward-chaining methods and certainty factors in conducting seed selection and disease handling in the management of rice plants. The difference between this research and previous research is the difference in the variables and case studies that are used as the object of research and the use of certainty factor methods to be able to display the trust value of the output produced by the system.

2.1 Expert system
Expert systems are intelligent computer programs designed to simulate problem-solving by a human being who is expert in specific domains or disciplines. Expert systems represent knowledge of expertise as data or rules in computers [7]. In the expert system environment, there are three people involved, namely experts, knowledge engineers and users. Experts are people who have special knowledge,
opinions, experiences and methods, and the ability to apply these skills to solve problems. Knowledge engineering is a person who helps experts in compiling problem areas by interpreting and integrating expert answers to the questions posed, describing analogies and explaining conceptual difficulties. Knowledge is important to improve system efficiency [18]. Users in expert systems have 3 categories, namely experts, users not experts and expert system builders who want to increase and add knowledge bases [21].

The purpose of the expert system is to transfer the knowledge and expertise possessed by an expert into computer software which is then forwarded to other people who are not experts. The basic concept of expert systems can be seen in Figure 1.

![Figure 1. The basic concept of expert systems](image)

Figure 1 illustrates the basic concepts of expert systems. The expert system interacts with the user through the system interface to receive facts or information from the user, then the facts and information are processed by inference machines based on the knowledge base. The expert system knowledge base is designed by knowledge engineers with knowledge obtained from experts and literature. The expert system can provide feedback to users in the form of expertise or answers from experts based on knowledge stored on the knowledge base.

Expert systems have the main components in the structure, including:
1. The knowledgebase is a representation of knowledge possessed by an expert composed of facts and rules. Knowledgebase can be obtained directly from an expert or from historical data that contains data from the knowledge of an expert such as books and research journals.
2. Inference engine functions to guide the process of reasoning to a condition based on the available knowledge base.
3. The database is a collection of data consisting of all the necessary facts, where the facts are used to fulfill the conditions of the rules in the system.
4. The user interface is a facility that can be used as an intermediary for communication between users and computers in using expert systems. This interface makes it easy for expert system users who are not experts to work and act or make decisions like an expert. In designing the user interface for the system to be developed it is important to note that the user interface must be as user-friendly as possible because users who will use expert systems are usually people who are not experts [19].

2.2 Forward chaining

It is a way of reasoning by starting with the facts first to test the truth of the hypothesis or match facts or statements starting from the left side first (IF first). Forward Chaining is a group of multiple inferences that searches for a problem to the solution. If the premise is in accordance with the situation (TRUE value), the process will assert the conclusion. Forward chaining is suitable for an application that produces a wide and non-deep tree [20].
2.3 Certainty factor
Some conclusions or diagnostic results from expert systems often produce answers that do not have full certainty. This uncertain result can be caused by 2 factors, namely uncertain rules and uncertain answers from expert system users on a question posed in an expert system that causes the information to become incomplete, inconsistent and uncertain [20].

One theory that can be used to solve uncertainty problems in expert systems is the certainty factor theory. Certainty Factor or CF is a value for measuring expert confidence. The CF model was developed by Shortliffe and was first used in the MYCIN medical expert system. In the CF model for each hypothesis that is influenced by evidence e, the MB confidence level (H | E) and the level of MD uncertainty (H | E) are given which are then calculated to determine the CF certainty factor (H | E) [17].

CF shows a measure of certainty about a fact or rule. The highest value in CF is +1.0 (definitely true or Definitely), and the lowest value in CF is -1.0 (definitely wrong or Definitely not). Positive values represent degrees of confidence, while negative values represent degrees of uncertainty. Certainty Factor is defined as follows:

\[
\text{CF (H| E)} = \text{MB (H | E)} - \text{MD (H | E)}
\] (1)

Parallel CF is a CF obtained from several premises or facts that are recognized in a rule. The magnitude of the Parallel CF is influenced by CF for each premise and operator of the premise.

\[
\text{CF (x AND y)} = \text{Min (CF(x), CF(y))}
\] (2)

\[
\text{CF (x OR y)} = \text{Max (CF(x), CF(y))}
\] (3)

Sequential CF is obtained from the results of parallel CF calculations of all premises in one rule with CF rules given by experts. The formula for doing sequential CF calculations is as follows:

\[
\text{CF (x,y)} = \text{CF (x) . CF (y)}
\] (4)

3. Design and implementation
The expert system for managing rice is divided into two subsystems, namely: seed varieties selection, disease, and pest. Each of these subsystems has its own database. This ensures that each rule on the subsystem runs individually not connected to each other. This aims to facilitate users in using the expert system interface with ease. At each consultation session, the user will choose which subsystem fits their needs at the main layer of the application. The home interface of the expert system application can be seen in Figure 2.

![Figure 2. The home interface of the expert system](image-url)
In the rice seed varieties selection subsystem, users will be asked questions about the user's condition (season, land type, rice texture, etc.), then the system will generate suggestions based on the user's input. Suggestions generated in the form of recommendations for the right seeds in accordance with the user's condition and three other alternative seeds. Suggestions on the seed selection subsystem have an alternative because it is possible that the suggested seedlings are not always available and because of good planting practices that suggest that there is a need for seedling changes in each planting season to prevent pest infestation from rice varieties. Examples of questions and suggestions on this subsystem can be seen in table 1 and table 2.

Table 1. Questions for the selection of seed varieties

| Seed Selection Questions                                                                 | Answer          |
|------------------------------------------------------------------------------------------|-----------------|
| 1  In what season will rice planting be carried out?                                       | Rainy           |
| 2  Type of land to be planted by rice seedlings?                                           | Rice fields     |
| 3  Rice Field Type?                                                                      | Irrigation      |
| 4  Which grain texture do you want to produce?                                           | Fluffier        |
| 5  What is the height of the planting location?                                          | Lowland-medium  |
| 6  How are conditions in the lowlands?                                                   | Normal          |
| 7  Plant disturbing organisms that commonly attack rice plants in the environment around | Brown planthopper |
|   the land will be planted with rice seedlings?                                           |                 |

Table 2. Results of suggestions for the selection of seed varieties

| Suggested varieties of seeds | Seed Names | Seed Type       | Grain texture | Potential Results | Age of crop harvesting | Resistant to disease | Description | Alternative                     |
|------------------------------|------------|-----------------|---------------|-------------------|------------------------|--------------------|-------------|---------------------------------|
|                              | Inpari 31  | Rice Fields with Irrigation | Fluffier | 6.00-8.50 ton/ha | 119 days              | Brown planthopper | To be planted in irrigated rice fields, resistant to fall during the rainy season | Inpari 18 Siliwangi Agritan Mustaban Agritan |

In the pest and disease subsystem, the diagnosis is based on the symptoms that appear on parts of the rice plant (stems, leaves, grain, etc). the identification process is done by the way the user chooses the appropriate symptoms that appear on the rice plant in the question. The results in this subsystem is an explanation and handling pests that attack rice plants with a certain certainty factor value. Pest and disease type can be seen in table 3.

Table 3. Pest and disease type

| ID  | Pest and Diseases                                      |
|-----|--------------------------------------------------------|
| PD1 | Bacterial leaf blight (Xanthomonas oryzae)             |
| PD2 | BLAS disease (Pyricularia grisea)                      |
| PD3 | Narrow brown leaf spot (Cercospora oryzae Miyake)     |
PD4 green leafhopper (*Nephotettix virescens*) and Tungro (*Rice tungro bacilliform virus*)
PD5 brown planthopper (*Nilaparvata lugens*)
PD6 Rice stem borer (*Scirpophaga incestuosa*)
PD7 black rice bug (*Scotinophara coarctata*)
PD8 rice field rat (*Rattus argentiventer*)
PD9 **Walang sangit** (*Leptocorisa acuta*)

Pest and disease subsystems use certainty factor value because the answers are not necessarily completely correct because some of the symptoms of damage that occur in rice plants are not only caused by a pest but also can be caused by other factors such as improper fertilization, bad weather, and land conditions. Certainty factor values are obtained by conducting interviews with experts on rice crops. Questions, symptoms, and values of the Certainty Factor of a pest can be seen in Table 4.

**Table 4. Questions, symptoms, and values of the Certainty Factor in the subsystem of pests and diseases**

| No | Questions in pests and diseases subsystems | CF | Damage type |
|----|-------------------------------------------|----|-------------|
| A  | symptoms of damage that exist in rice plants? |    |             |
| 1  | Leaves or edges of the leaves are brownish-gray | 0.95 | Damage to leaves |
| 2  | The leaves have brown spots shaped like a rhombus | 0.85 |             |
| 3  | The leaves have narrow, elongated brown spots | 0.60 |             |
| 4  | White patches on the leaves in the form of lines or dots and there are tubes or leaf rolls | 0.75 |             |
| 5  | The leaves are yellow to orange-yellow, visible green leafhoppers on the leaves | 0.70 |             |
| 6  | The stem dries and at the base of the stem looks brown planthopper | 0.85 | Damage to the stem |
| 7  | Shoots of rice stem dry and easily removed, | 0.95 |             |
| 8  | Inside the plant stem, there are larvae/caterpillars | 0.95 |             |
| 9  | The stem of the plant is yellow or brownish-red and there is a black bed | 0.95 |             |
| 10 | Rice stalks collapse, rats sighted | 0.75 | Damage to grain |
| 11 | Black spots in rice grains | 0.85 |             |
| 12 | The remaining rice seeds fall, birds in the fields | 0.85 |             |

**Table 5. Questions, symptoms, and values of the Certainty Factor in the subsystem of pests and diseases (cont.)**

| B  | Other symptoms: |    | Damage type |
|----|----------------|----|-------------|
| 1  | Yellow leaves then dry | 0.75 | Damage to leaves |
| 2  | The shoots or edges of the leaves are brownish-gray and then spread throughout the leaves | 0.85 |             |
| 3  | Shoots and leaf edges dry out and wither | 0.65 |             |
| 4  | Rice panicles are rotten or broken in the generative phase | 0.85 | Damage to the stem |
| 5  | The stems and midribs of the leaves are rotten so the plants fall | 0.45 |             |
| 6  | The rice pan stalk is broken and damaged | 0.85 |             |
| 7  | Few panicles and hollow rice grains | 0.75 |             |
Rice grains are not fully filled or empty 0.75 Damage to grain
The rice pane stands upright not fully filled or empty 0.95
The color of rice grains changes and the taste becomes unpleasant 0.75
There is a plant wilting and dying at the beginning of the growth 0.70 General damage
Yellow-orange plant leaves 0.75
Dwarf plant growth 0.70
Plant growth is inhibited 0.75
Young plants die and dry out 0.95
Excess use of N fertilizer 0.95
There are footprints and rat holes around the rice fields 0.85

The rules on the pest and disease subsystem can be seen in table 6.

| Rules | Then | ID  | Pest and Diseases                      | CF Rules |
|-------|------|-----|----------------------------------------|----------|
| A1 AND B2 AND B8 AND B11 AND B17 | P01  | Bacterial leaf blight | 0.70     |
| A2 AND B4 AND B8 AND B17 | P02  | BLAS disease | 0.80     |
| A3 AND B5 AND B8 AND B21 | P03  | Narrow brown leaf spot | 0.70     |
| A5 AND B8 AND B12 AND B14 AND B15 | P04  | Green leafhopper and tungro (*Rice tungro bacilliform virus*) | 0.90     |
| A6 AND B1 AND B8 AND B12 | P05  | Brown planthopper | 0.90     |
| A7 AND B8 AND B9 AND B16 | P06  | Rice stem borer | 0.90     |
| A8 AND B7 AND B13 AND B15 AND B18 | P07  | black rice bug | 0.70     |
| A9 AND B19 AND B20 | P08  | Rice field rat | 0.80     |
| A10 AND B10 | P09  | Stinky rice bug | 0.80     |

The process of diagnosis and calculation of certainty factor values in the subsystem of pests and diseases are as follows.

If it is known that the user's answer meets certain rule:

**IF A1 AND B2 AND B8 AND B11 AND B17 then bacterial leaf blight disease**

then the value of CF can be calculated with the following steps: A1 CF=0.95, B2 CF=0.85, B8 CF = 0.75, B11 CF=0.70, B17 CF=0.95 dan CF Rules for bacterial leaf blight disease is 0.70.

1. Calculating Parallel CF (2)

  Parallel CF: MIN (A1, B1, B2, B3, B4)

  : MIN (0.95, 0.85, 0.75, 0.70, 0.95)

  : 0.70

2. Calculating Sequential CF (4)

  Sequential CF: Parallel CF* CF Rules

  : 0.7 * 0.7

  : 0.49
From the above calculation, it is finally known that the probability of rice plants being affected by bacterial leaf blight pests is 0.49, which means that the results of the diagnosis show that the rice plants were exposed to bacterial leaf blight pests with a confidence value of 49%.

4. Result interface
This study developed a web-based expert application system for rice management. The application interface is designed with user needs in mind, easy to use, and easy to learn. From the home interface, users can choose to consult according to their needs. They can carry out consultations on the selection of seed varieties and detection of disease pests. The resulting interface selecting seed varieties and detecting pests can be seen in Figures 3 and 4 respectively.

**Figure 3. Interface for selecting rice seed varieties**
In the seed selection subsystem, the user consults by answering the questions given by the system. After the user has finished answering these questions, the system will then display an interface for the recommended seed variety that contains detailed information about the recommended seed and three alternative seed varieties, users can save the results of the consultation by pressing the print button (Fig 3).

At the interface of the pest and disease detection subsystem, the user consults by selecting symptoms that appear in rice plants that have been provided by the system. The system will then display the results interface that contains information about the disease pests detected by the system based on the symptoms chosen by the user. information provided in the form of a general description of the disease detected by the system, the value of certainty, symptoms, and solutions to deal with these pests (Fig 4).

5. Conclusion
The expert system for managing rice with the forward chaining and certainty factor method has been successfully developed. Data acquisition for the knowledge base is done by conducting interviews with rice plant experts and rice plant pest experts and from literature such as books and leaflets published by the agriculture department.

Rice plant management expert system provides two types of consultation according to user needs namely consultation for seed variety selection and pest detection consultation. users provide input by answering questions that have been provided by the system. the system then processes user input data with the forward chaining method and certainty factors which will then produce answers in the form of suggestions according to the conditions and needs of the user like an expert. At this time the system was developed for pc devices with web-based, the future plan of the system was also developed for mobile devices so that the system is more easily accessible by everyone.

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