Expert System in Detecting Coffee Plant Diseases

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***Abstract*—Coffee is an important commodity in the world economy. But unfortunately, productivity and quality of those commodities results are still quite low. This is caused by the disease in coffee plants. The research objective is to create an application that can help researchers or observers working in coffee plantation to diagnose diseases of coffee plants. The method used is fuzzy logic-based expert systems, and decision tree using a hierarchical classification. Knowledge about coffee, its symptoms, and its disease is extracted from human expert and then is converted into a decision tree. It will result on the fuzzy logic-based expert systems. From the experiments, accuracy calculation of the system is about 85%. Based on the accuracy, it can be concluded that this application can be a bit much to help researchers or observers of the coffee plants in diagnosing coffee plants diseases earlier.**

***Index Terms*—expert system, fuzzy, decision tree, coffee, disease**

I. Introduction

Coffee is an important commodity in the world economy. It is one of the most primary products which have high selling in world trade after the oil as a source of foreign exchange for the country of the manufacturer. Coffee is very important in economic and political fields in developing countries, since many coffee exports to developing countries, generating more than 50 percent of foreign exchange earnings and commodities futures exchange traded commodities [1].

Coffee is also an important commodity in the plantations. In addition, request of worldwide coffee consumption has increased rapidly. Currently, Indonesia has reached the number of 600 thousand tons coffee production per year and more than 80 percent come from people's estates [2].

Unfortunately, the productivity and quality of the commodity plantation are still quite low. One contributing factor, among others, was caused by farmers who have not been paying attention to the cultivation of plants, agro-ecosystem and minimum applied of integrated pest control in the area of plantation, so that losses resulting from the attack of the Pest Plant Organisms are primarily pests and plant disease.

In Indonesia, one example of losses due to diseases of the coffee plants was caused by a Plant Pest Organisms such as Hypothenemus hampei. This pest can decrease the productivity of 40-50% of the production and cause shrinkage of 30-40% of the weight of the coffee beans [3].

Basically this issue can be easily prevented. It can be done if only the farmers know what kind of diseases that attack plants, and how to give the right treatment to coffee plant diseases.

Based on the data and facts obtained, we developed an expert system that supports diseases detection in coffee plants, especially in Indonesia.

II. About Coffee

Coffee is the type of pine wood *dicotyledonous* (seed-bearing two) plant, a descendant of the family *Rubiaceae*. It has many varieties of which are spread all over the world, but there are only 2 types of coffee being the main varieties to be developed, they are Arabica and Robusta. Coffeaarabica, which is known as Arabica coffee, accounts for 75-80 percent of the world production. *Coffeacanephora*, known as robusta coffee, accounts for about 20 percent of Arabica coffee and is different in terms of taste [4].

In 2010, Indonesia has 2 main types of coffee commodities produced, namely Arabica and Robusta coffee in which their production level reached on 9.129.000 sacks per year. The level of coffee consumption in Indonesia is also relatively high; it reached 0.86 kg per capita. The statistics also showed us that the number of exports of Arabica coffee per year i.e. 792.327 per sack/60 kg and exports Robusta coffee per year i.e. 4.462.620 per sack/60 kg so that the total value of income earned from exports of coffee to all commodities that 157 million US dollars per year [5].

According to the data from Directorate General of Plantations, there are several important coffee diseases:

A. Coffee Leaf Rust

Coffee Leaf Rust disease as depicted in Fig. 1 is caused by *H. vastatrix* that can strike at nursery to mature plants. Symptoms of infected plants are the leaves that are infected emerge yellow spots which are later turn brown. Then, in the surface patches on the undersides of leaves, there is *uredospora*, which is like orange or orange-colored powder.

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Figure 1. Coffee leaf rust

B. Brown Eye Spot of Coffee

The disease is caused by the fungus *C. coffeicola* that may arise in the nursery to mature plants as well as attacking the coffee fruit. Infected leaves emerge yellow spots surrounded by yellow halo edges. This condition can be seen in Fig. 2. Fruit which are attacked will raise a brown spot, usually on the side that receives more sunlight. These patches can be up to rot until the seed resulting in low quality coffee.

Figure 2. Brown eye spot of coffee

C. Nematode

Pratylenchus Coffeae and *Radopholus similis* are types of *nematode endoparasit* which is switching-moved. The life cycle of *P. Coffeae* is around 45 days while *R. similis* is approximately 1 month. Coffee plants that stricken with this disease will be invisible dwarf and the leaves will turn yellow and deciduous. *Nematode* is shown at the right side of the Fig. 3 below.

Figure 3. Nematode (right side)

D. Upas Fungus

Fungus *C. salmonicolor* can attack the trunk, branches, twigs and berries. This fungal infection first occurs on the bottom side of the branch or twig. The attack began with the appearance of thin threads of fungi like a silk, spider-shaped nest. And later on it will appear necrosis then it is decomposed so the color will turn into dark brown or black. The condition of the infected coffee is shown in Fig. 4 below

Figure 4. Upas fungus

E. Brown, Black and White Root Fungus

There are three types of root fungal disease on coffee plants. They are the brown root fungus, black root fungus and white root fungus. All of those can be transmitted to infect others through root contact. These diseases can occur at any age of the plant and they can kill plants. Root condition is shown in Fig. 5.

Figure 5. Root fungus

III. Current Works

Expert System has been developed and applied in many fields. In Agriculture, some problems which are often faced by farmers are due to lack of knowledge and information on how to give the right treatments for plant diseases. Thus causing they spend much money to buy chemical pesticides, which actually it wouldn't be necessary at all because there's an alternative way to give the right treatments without chemical pesticides. Nowadays, in several countries, farming activity has applied advanced technology, such as expert systems. They can be easily used in the field of agriculture. Farmers can get expert advice without having to meet with the experts who would take more time and cost.

Some experts advise many solutions such as selection of most suitable crop variety, diagnosis or identification of plant diseases and suggestion for alternative way to the right treatment. Symptoms of diseases and pests have due geographical variation. So there is always a need to develop a new expert system for a different geographical region or countries.

In order to develop an expert system in agriculture, knowledge has to be extracted from human expert or domain expert. This knowledge is then converted into a computer program. While developing it, engineer must perform task of extracting the knowledge from the domain expert, so it can produce knowledge base. The knowledge is represented in the form of IF-THEN rules

According to statistics in Pakistan, there is an indicator that wheat is an important commodity. By that reason, engineers in Pakistan developed an application which aims to detect diseases and pests on crops of wheat called *Dr.Wheat*. *Dr.Wheat* uses IF-THEN rules method which is one approach that can be implemented on expert system or Knowledge Based System. IF-THEN rules method includes forward and backward chaining which represents the internal logic of inference engines. Forward chaining uses data patterns (data driven) while the backward chaining uses end goal patterns to achieve goal (goal driven) [6].

In India, Rapeseed-Mustard is an important oilseed crops and contributes around 23.2 % of the total oilseed production in India. The production of Rapeseed-Mustard is widely effected by rapeseed-mustard diseases. *Alternaria* blight, white rust, white rot downy mildew complex, powdery mildew and white rot of rapeseed-mustard are the diseases that are quoted frequently in the states where the crops are grown in India. Based on that fact, engineers in India has developed image based rapeseed-mustard diseases expert system for detecting rapeseed-mustard diseases with the feature which is image based. Image based rapeseed-mustard diseases expert system has another feature to classify as hierarchical each question for the purposes of diagnosis based on parts of plants such as leaves, roots or plants as a whole, thereby helping more specific diagnosis process [7].

Another group of engineer in India has developed expert system for the diagnosis of diseases in rice plant. In the development, there are several stages for the expert system engineer. The first process is by determining the main characteristics of the process of diagnosis on disease of rice plant. The second stage is by searching data with basic knowledge of human expert or domain expert. Data obtained from human expert or domain expert and then processed to the best conclusions drawn then converted into expert system. The last stage is by representing data processing that was specified in the previous stage. This application used methods which simplified the logic paradigm of IF-THEN rules that are part of a forward and backward chaining. This system classifies detection based on diseases on plants [8].

IV. Methodology

The knowledge base is a core component of the expert system for which information was obtained from an expert. Building a knowledge base with the help of an expert as a trusted source of information is the most important thing in the expert system so that the result will be correct and valid.

In this case, several methods are conducted, such as direct interviews with some expert of the coffee plant; examine documentation about coffee plant; doing some research in the field and survey to farmers. The Fig. 6 below shows the structure of expert system.

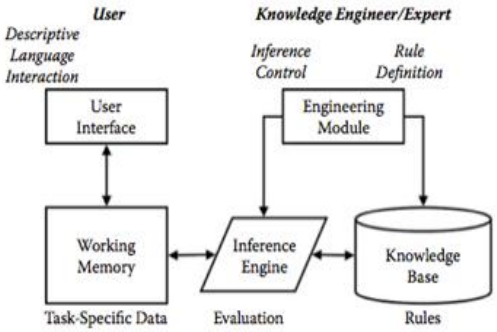

Figure 6. The structure of Expert System [9]

In the development of the knowledge base, working memory and inference engine are built to provide limitations in the expert system [9] and then built some rules with classification of decision tree concluded with IF-THEN rules with apply techniques of forward chaining, i.e. data driven, where the system began with delivers early initialization element [10] i.e. a symptom of coffee plant diseases and continue to apply the rule until no rules that can be applied or objective has been achieved.

Based on the facts about disease on coffee plants and the symptoms, the construction of the decision tree is shown in Fig. 7.

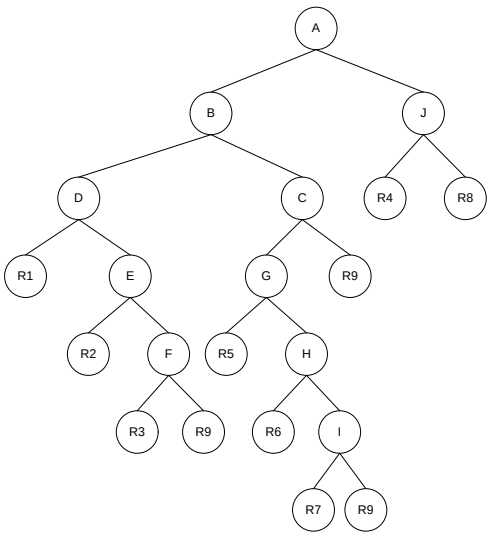

Figure 7. Decision Tree

TABLE I. DECISION TREE SYMPTOM DESCRIPTION

No.	Code	Description
1	A	Leaves becomes yellow
2	B	Brownish yellow spots appear on the leaf OR leaves becomes easily fallen
3	C	Dull, shriveled, and hang leaves
4	D	Leaves have orange powdery spots on the underside of leaves OR leaves become bald OR patches spreading leaves
5	E	Premature and empty leaves OR short stem OR decomposed and rotten root
6	F	Spots appear on fruit so it becomes rotten OR circular spots appear on fruit forming a halo
7	G	Roots covered by a crust of soil grains OR roots have woven yarn blackish brown fungus
8	H	Black spots on the roots OR black spots on the stem
9	I	Roots have woven threads of white fungus
10	J	Stem has a thin threads of fungi such as silk OR stem necrosis OR fruit necrosis

TABLE II. DECISION TREE DISEASE DESCRIPTION

No.	Code	Description
1	R1	Coffee Leaf Rust
2	R2	Nematode
3	R3	Brown Eye Spot of Coffee
4	R4	Upas Fungus
5	R5	Brown Root Fungus
6	R6	Black Root Fungus
7	R7	White Root Fungus
8	R8	Healthy Plants
9	R9	Disease Not Detected

Table I explains about the symptoms of the coffee diseases which is represented by the alphabetical start from A to J. Table II informs about the coffee condition either it has diseases or not. It starts from R1 to R9.

The system is moving forward from the current state to the goal state, whose goal state on the condition here is the coffee plant diseases (such as coffee leaf rust, brown eye spot of coffee, nematode and upas fungus) or other information such as “healthy plants” or “diseases not detected”.

Here is some example of the result of IF-THEN rules with classification of decision tree for coffee leaf rust.

IF (the leaves become yellow= YES) AND (the leaves arise with spotting brownish yellow = YES OR the leaves easy fall to the ground = YES) AND (the leaves have a powdery orange spots at the bottom of a leaf = YES OR the leaves in the tree becomes bare = YES OR the leaves arise scattered patches = YES) THEN the Coffee Leaf Rust.

After getting the results of the analysis above, The process of detecting diseases of the coffee plant, the value of "YES" was changed to 1 and the value "NO" is changed to 0, and then placed in the *pseudocode* for diagnosis logic we have built and compiled together with experts using fuzzy logic and classified into fuzzy reasoning.

Fuzzy logic is a method for reasoning with a logical expression describing a statement could be worth between 0 and 1 [11]. Fuzzy reasoning is fuzzy logic which is not necessary can be described thoroughly, in the sense that others are allegorical; human thought but without size or scale [12]. Here is some example of the *pseudocode* for diagnosis logic for coffe leaf rust.

A = The leaves become yellow

B = (The leaves arise with spotting brownish yellow OR The leaves easy fall to the ground)/2

C = (The leaves have a powdery orange spots at the bottom of the leaf OR The leaves in the tree becomes bare OR The leaves arise scattered patches) / 3

IF(A < 0.5) THEN A=0; IF(A >= 0.5) THEN A=1;
IF(B < 0.5) THEN B=0; IF(B >= 0.5) THEN B=1;
IF(C < 0.5) THEN C=0; IF(C >= 0.5) THEN C=1;

A value of 0.5 is the result discussed with the expert of the disease on the coffee plant that has been interviewed. When the final result is below 0.5, then it may produce an error, so the final value is 0. It will be declared as invalid. When the end result is above 0.5, then it can be accepted so the final value to 1. It will be declared as valid.

When value of a variable have been arranged to be valid, then the variable will be elaborated to become rules. It will be applied to the process of plant diseases coffee detection based on the result of analysis while developing the knowledge base.

IF A AND B AND D THEN COFFEE LEAF RUST

V. EVALUATION

After done in constructing the decision tree and the algorithm flow, then an application is created in order that the system can be tested either it is built well or not. We involve the expert to test this system. The data used to test the system are adopted from different varieties of robusta and arabica coffee plants. The results of the experiment can be seen in Table III.

1) Of the 20 samples randomly taken, 17 samples of specimens can be detected by the system
2) Of the 20 samples randomly taken, 3 samples of specimens cannot be detected by the system.
3) Expert system can detect several diseases at the coffee plant coffee leaf rust, brown eye spot of

coffee, upas fungus, nematodes, black root fungus, white root fungus and brown root fungus

4) Of the 20 samples taken specimens, 3 samples were not detected by the system, as it is caused by other symptoms such as Hama attacked by borers and caterpillars Soot Dew.

From the above experiments, accuracy calculation of the system can be adopted from the ratio of total sample that can be detected by the expert system with the total sample which is randomly taken.

$$(17/20) * 100\% = 85\%$$

TABLE III. DATA AND RESULT OF TESTING

Variety	Specimens Sample	1st Testing (by System)	2nd Testing (by Expert)
Lini S 795 (inside Pot) Arabica		White Root Fungus	White Root Fungus
Lini S 795 (inside Pot) Arabica		undetected	Soot dew
Lini S 795 Arabica		White Root Fungus	White Root Fungus
Anungsari Arabica		undetected	Borer cater-pillar pests
Anungsari Arabica		undetected	Soot dew
K. Timor Arabica		Coffee Leaf Rust	Coffee Leaf Rust
Lini S 795 Arabica		Brown Eye Spot of Coffee	Brown Eye Spot of Coffee
Local Arabica		Brown Eye Spot of Coffee	Brown Eye Spot of Coffee
Kartika (Segresi) Arabica		Coffee Leaf Rust	Coffee Leaf Rust
Kartika (Segresi) Arabika		Coffee Leaf Rust	Coffee Leaf Rust
Robusta Bandung		Coffee Leaf Rust	Coffee Leaf Rust
Lini S 795 Bandung Arabica		Coffee Leaf Rust	Coffee Leaf Rust
Local Sumedang Arabica		Coffee Leaf Rust	Coffee Leaf Rust
Mixed Locally Sumedang Arabica		Coffee Leaf Rust	Coffee Leaf Rust
Ateng Arabica		Nematode	Nemato-de

Kartika Garut Arabica		Coffee Leaf Rust	Coffee Leaf Rust
Robusta		Upas Fungus	Upas Fungus
Lini S 28		Coffee Leaf Rust	Coffee Leaf Rust
Robusta		Upas Fungus	Upas Fungus
Lini S 795 Arabica		Coffee Leaf Rust	Coffee Leaf Rust

VI. Conclusion

This research presents the use of expert systems in the agriculture in Indonesia. The rapid development of technology has changed the way of expert system development. The system needed to be expanded and updated to accommodate new diseases of coffee plant. Adding variable such as weather and temperature is needed to improve the result of diagnose In summary, the main objective of an expert system is to provide expert knowledge to non experts, in this case is farmer of coffee plant in Indonesia.

1) By using this approach, researcher in coffee plants and farmer could be helped to identify the disease earlier
2) Detecting plant disease especially in coffee plants by using expert system reaches 85% accuracy
3) To make a better detection of the coffee plants disease, additional variables such as weather and temperature are needed. In this research, those variables have not been used yet as the limitation of data source of them.

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