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Development of Expert System for Diagnosing Pests and Diseases in Strawberry Plants Using the Certainty Factor

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Abstract

The increasing global demand for strawberries as a high-value crop requires effective management strategies for pests and diseases that can significantly reduce yields. This research develops an expert system to diagnose strawberry pests and diseases using the Certainty Factor (CF) method, utilizing data from previous studies to improve the accuracy and reliability of the diagnosis. The system integrates symptoms and CF values from two main studies and provides treatment recommendations that can be applied to the identified problems. The results show that in the trial on powdery mildew fungus, which has 4 symptoms, it can have the highest confidence value of 0.99977848. For other diseases themselves will have different confidence values according to the calculation of the CF value of each symptom. This approach provides a valuable tool for farmers with limited access to expert consultation, helping to improve decision-making and reduce economic losses. Performance analysis of the system shows its potential to support sustainable strawberry cultivation.

Keywords: Expert System; Certainty Factor; Pests; Diseases; Strawberry

INTRODUCTION

Strawberry has the scientific name Fragaria x ananassa var duchesne is a plant with small fruit in the Rosacea family and the genus Fragaria (Ngouana et al., 2023). This fruit, is one of the most popular fruits in the world with a sweet and fresh taste, and contains many important components in it because it contains many minerals and vitamins, making it a fruit that is beneficial for health (Khammayom et al., 2022). This brightly colored fruit, also has a fairly high selling value in the market and there is an increase in production that occurs every year throughout the world, this is because strawberries are also widely used as raw material in various processed products, such as juice, jam, ice cream and even cosmetic ingredients.

This plant, however, is susceptible to diseases and pests that can reduce its quality and production. Diseases that often attack this plant are Powdery Mildew and Botrytis Cinerea which can cause serious damage to strawberry leaves, flowers and fruit. While pests that often attack strawberry plants are Armyworms, Thrips Ticks, Spider Mites, and Aphids that cause vital damage to the physical parts of the plant, as well as disrupt its development and growth (Fransiska Simamora et al., 2021). These pests and diseases affect crop yields and result in economic losses (Siregar, 2023). This condition makes it important to develop technology or management strategies for pests and diseases in this crop.

Identifying and treating plant pests and diseases is often challenging and requires special skills to distinguish between diseases or pests. As a result, farmers make diagnoses based on their experience, which is not always accurate. This error can be detrimental because it will make the farmer's treatment inappropriate.

Thus, an innovation is needed that can assist farmers in diagnosing pests and diseases that attack these plants precisely, quickly, accurately and scientifically. One of the scientific elements is involving technology (Halid et al., 2024; Permana, Setiawan, et al., 2024). Technology that can be utilized is an expert system. This system can store the expertise of an expert in the form of a system by utilizing a knowledge base (Sabinus Lumbanbatu et al., n.d.). Thus, the system can mimic the decision-making process similar to an expert. In this case, the method used is Certainty Factor (CF). CF itself is a method used to prove a statement is certain or not with a level of confidence value in the form of a matrix commonly used in expert systems (Sucipto & Ahdan, 2019). This method makes it possible to calculate the level of certainty or confidence in the diagnosis results based on existing evidence or rules, such as the symptoms that appear (Sumiati et al., 2021).

Research related to expert systems for the diagnosis of plant pests and diseases, especially using the CF method, has been carried out before. Research Michael & Sulindawaty, (2022) build an expert system in diagnosing diseases and pests for bonsai plants with Certainty Factor. In other cases, Mujahiddin & Imran, (2023) develop an expert system to diagnose diseases in chili plants with Certainty Factor. While Kamil Siregar & Ihsan, (2022) Using Certainty Factor to build an expert system to diagnose diseases and pests in oil palm plants. At the same time Indriyono et al., (2022) also conducted research to diagnose diseases and pests that attack potato plants using the Certainty Factor expert system. Research Fonda et al., (2021) develop the application of the Certainty Factor expert system method to identify diseases and pests that attack crystal guava plants. Oktavia et al., (2022) developed a web that can be used to diagnose diseases in strawberry plants by using the Certainty Factor method to determine the diagnosis. Similar cases have been done Fransiska Simamora et al., (2021) Developing an expert system to diagnose aphid pests on strawberry plants using the Certainty Factor method.

From several previous studies, most of them refer to certain types of plants, such as chili, potatoes or others, and there are only two studies that specifically discuss strawberry plants. However, the two studies are also still limited in the diseases or pests discussed in them. Where in the research Fransiska Simamora et al., (2021) focuses on the type of aphid pests only in it, while in the research Oktavia et al., (2022) have discussed pests and diseases but the pests in the study Fransiska Simamora et al., (2021) still not included in it. So this research will develop an expert system that diagnoses diseases and pests in strawberry plants with data on the two previous studies. In addition to only diagnosing diseases with a level of confidence obtained by the CF method, this system will also be designed to provide advice on handling or treating strawberry plants based on the disease diagnosed by the system later. With this, it can also further assist farmers in cultivating strawberry plants and developing the implementation of expert systems in the diagnosis of diseases and pests in strawberry plants in particular.

METHODS

In this study, the development of an expert system that can be used to make a diagnosis with a confidence value is carried out. This approach is carried out to find out how CF can perform calculations in making a diagnosis of strawberry pests and diseases.

Certainty Factor (CF)

This method is one of the methods in expert systems that expresses the level of trust by calculating the ambiguity in the flow of reasoning of an expert in making a decision. (Indriyono et al., 2022). CF is used to determine the level of certainty or truth of information based on available evidence. (Redy Susanto & Wantoro, 2022). Simply put CF is a measure of confidence as in equation 1.

$$CF(H,E) = MB(H,E) - MD(H,E)$$

$$MB(H,E) = \frac{Max[P(H|E),P(H)] - P(H)}{Max[1,0] - P(H)}$$

$$MD(H,E) = \frac{Min[P(H|E),P(H)] - P(H)}{Max[1,0] - P(H)}$$

Equation 1

Description Equation 1:

CF(H,E) = Certainty Factor in hypothesis H that is affected by fact E.

MB(H,E) = Measure of belief in hypothesis H, given fact E (between 0 and 1).

MD(H,E) = Measure of unbelief of evidence H, given evidence E (between 0 and 1).

P(H) = Probability of hypothesis H.

P(H|E) = The equation that H is true due to the fact E.

As for some combinations or combinations in the calculation of Certainty Factor on certain premises as in Equation 2:

1. Certainty Factor with one premise:

CF[h,e] = CF[e] * CF[rule]

= CF[user] * CF[expert]

2. Certainty Factor more than one premise:

CF[A v B] = Min(CF[a],CF[b]*CF[rule] CF[A ^ B]

= Min(CF[a],CF[b]*CF[rule]

3. Certainty factor with similar conclusions:

$$CFg[CF1.CF2] \; = \; CF1 \; + \; CF2 * (1 - CF1)$$

Equation 2

Data Collection

In this study, data was adopted from several existing studies. By following the literature review stage. Literature review itself is a method for systematically and explicitly identifying, evaluating and synthesizing scientific works (Jones et al., 2020). Starting to identify research topics to focus on the diagnosis of diseases or pests that attack strawberry plants based on expert systems. Then search for expert system literature in the diagnosis of strawberry plant diseases. Then the analysis is carried out to identify gaps in previous research (Ulhaq & Rahmayanti, 2020). Existing data processing is also carried out by paying attention to data validation in journals and also summarizing data obtained from several journals (Permana, Setemen, et al., 2024).

This research reviews the journal Penerapan Expert System Mendiagnosis Hama Chaetosiphon Fragaefolli (Kutu Daun) Pada Tanaman Strawberry Dengan Menggunakan Metode Certainty Factor (Fransiska Simamora et al., 2021) and Sistem Pakar Diagnosis Hama Dan Penyakit Tanaman Stroberi Dengan Metode Certainty Factor Berbasis Web (Oktavia et al., 2022).

Research Design

In developing this expert system, the research design carried out is as follows:

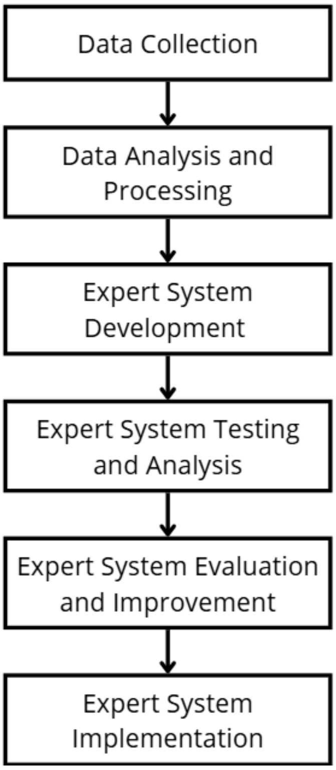

Figure 1 : Flow Of Expert System Development

In the data collection stage by searching for articles that include related research data. Sourced from these articles, data processing is then carried out, where in this study data is merged and also adjusting symptom data and CF values from the same symptoms in both articles. After that, the expert system development is carried out, which can receive input from the user in the form of symptom numbers. Furthermore, testing the program to find out the error gaps that can occur by providing various inputs and analyzing the output of the program. Evaluation and improvement of the program to overcome errors or bugs that may occur in the testing process. The last stage is implementation by building a simple system to accommodate an expert system using the prolog language with two main menus, pest and disease diagnosis, and pest or disease control checks.

RESULTS

Based on data processing sourced from two reference articles, the following data is obtained:

Table 1. Symptom Data and CF Value
(Source: Fransiska Simamora et al., 2021; Oktavia et al., 2022)

Code	Symptoms	CF
G01	Blackish spots on leaves	0,99
G02	Small shoots	0,97
G03	Curved leaf	0,77
G04	Curly leaf	0,74
G05	Retarded fruit formation	0,79
G06	Hollow leaves	0,98
G07	Bite marks on fruit	0,98
G08	Leaves appear transparent	0,96
G09	Brownish leaves	0,895
G10	Brownish green fruit	0,98
G11	White spots on leaves	0,78
G12	Leaves turn yellow	0,76
G13	Fruit is small in size	0,97
G14	Blackened strawberry seeds	0,96
G15	Leaf buds are bare	0,98
G16	Spider webs on leaves	0,99
G17	Purple spots on leaves	0,99
G18	White powdery hyphae on leaves/fruit	0,645
G19	Wet rot on fruit	0,99
G20	Dry rot on leaves	0,96
G21	Brownish mongering fruit	0,97
G22	Leaves appear to turn red and fall	0,30
G23	Leaflets appear wrinkled	0,20
G24	Leaflets curl	0,05
G25	Inhibition of flower formation occurs	0,38
G26	Yellow spots on leaves	0,26
G27	Leaf drying	0,56
G28	Leaf drop	0,33
G29	Stunted growth	0,19
G30	Hairless	0,83
G31	The leaves look thin	0,67
G32	Abnormal growth	0,12

Table 2. Pest and Disease Data

(Source: Fransiska Simamora et al., 2021; Oktavia et al., 2022)

Code	Hama/Penyakit
P1	Leaf-Boring Beetle (Chrysocus Auratus)
P2	Leaf-Damaging Mite (Tetranycus)
P3	Nematodes
P4	Aphid Pest
P5	Armyworm Pests
P6	Thrips Ticks
P7	Spider Mites
P8	Powdery Mildew Fungus
P9	Botrytis Fungus

Table 3. Production Rules

(Source: Fransiska Simamora et al., 2021; Oktavia et al., 2022)

Rule	Production Rules
R1	IF (G18 AND G22 AND G23 AND G24 AND G25 AND G32) THEN P1
R2	IF (G04 AND G09 AND G24 AND G27 AND G28) THEN P2
R3	IF (G29 AND G30 AND G31 AND G32) THEN P3
R4	IF (G01 AND G02 AND G03 AND G04 AND G05) THEN P4
R5	IF (G06 AND G07 AND G08) THEN P5
R6	IF (G03 AND G04 AND G09 AND G10 AND G11 AND G12 AND G13 AND G14) THEN P6
R7	IF (G11 AND G12 AND G15 AND G16) THEN P7
R8	IF (G04 AND G12 AND G17 AND G18) THEN P8
R9	IF (G19 AND G20 AND G21) THEN P9

There is also data on solutions that farmers can do to deal with pests or diseases that attack which all of this data is sourced from the website of the agriculture department https://distan.bulelengkab.go.id/ with the following data:

Table 4. Pest and Disease Management Data

(Source: https://distan.bulelengkab.go.id/)

Pests/Diseases	Handling
Leaf-boring Beetle (chrysocus auratus)	Insecticides Decis 2.5 EC, Perfekthion 400 EC, or Curacron 500 EC.
Leaf-damaging mite (tetranycus)	Insecticides Omite 570 EC, Mitac 200 EC, or Agrimec 18 EC.
Nematodes	Nematisida Trimaton 370 AS, Rugby 10 G, or Nemacur 10 G.
Aphid Pest	Insecticides Fastac 15 EC & Confidor 200 LC
Armyworm Pests	Insecticides with active ingredients Emamectin benzoate, spinetoram, etc.
Thrips Ticks	Insecticides with active ingredients Abamectin, Asefat, etc.
Spider Mites	Water, oil, insecticide, or soap sprays. Biological methods using natural predators.
Powdery Mildew Fungus	Plant-based, biological or chemical fungicides such as sulphur 80 WP and hexaconazole.
Botrytis fungus	Fungicide Benlate or Grosid 50 SD.

From the data that has been obtained in Table 1 to Table 4, a prolog program with the following main logic is built:

```
1  % Manual intersection function definition to find the intersection of two lists
2  intersection([], _, []).
3  intersection([H|T], B, [H|C]) :-
4      member(H, B),
5      intersection(T, B, C).
6  intersection([_|T], B, C) :-
7      intersection(T, B, C).
8
9  % CF concatenation function to ensure results in the range [0, 1]
10 combined_cf(CF1, CF2, CombinedCF) :-
11     CombinedCF is CF1 + CF2 * (1 - CF1).
12
13 % Calculation of total CF by iterative merging
14 count_cf([], 0).
15 count_cf([CF], CF).
16 count_cf([CF1, CF2 | Tail], TotalCF) :-
17     combined_cf(CF1, CF2, CombinedCF),
18     count_cf([CombinedCF | Tail], TotalCF).
```

Figure 1: Code Calculation CF Diagnosis

The process in Figure 1 starts from a function to match the user's symptom input with the data in the program, then a function is made to accommodate the formula for CF itself. Lines 14 to 18 are functions to calculate the total CF obtained, for conditions if there is no input, for conditions with only one input and for inputs of two or more.

```
% Manual diagnosis that shows only the single biggest possibility
diagnose_manual :-
    write('List of available symptoms: '), nl,
    findall(Code-Name, symptom_name(Code, Name), SymptomList),
    show_symptom_number(SymptomList, 1),
    write('Enter a list of relevant symptom numbers (e.g. [1, 2, 3]): '), nl,
    read(NumbersSymptoms),
    (NumbersSymptoms == [] ->
        % If the symptom list is empty
        write('No symptoms were selected. Diagnosis cannot be made.'), nl;
        % If any symptoms are selected
        number_to_code(NumbersSymptoms, SymptomList, SymptomUser),
        findall(
            CF-Disease,
            (
                disease(Disease, _),
                symptom_disease(Disease, SymptomsDisease),
                intersection(SymptomUser, SymptomsDisease, RelatedSymptoms),
                findall(CF, (member(Symptoms, RelatedSymptoms), symptoms_cf(Symptoms, CF)), ListCF),
                count_cf(ListCF, CF)
            ),
            ResultsDiagnose
        ),
        (ResultsDiagnose == [] ->
            % If there is no diagnosis result
            write('No disease was found that matched the symptoms given.'), nl;
            % If there is a diagnosis result
            sort(ResultsDiagnose, ResultsSorted),
            reverse(ResultsSorted, [CFHighest-DiseaseHighest|_]),
            disease(DiseaseHighest, NameDisease),
            write('Detected diseases: '), write(NameDisease), nl,
            write('CF value: '), write(CFHighest), nl,
            show_control(DiseaseHighest)
        )
    ).
```

Figure 2: Code Receives Input and Displays Diagnosis Ouput

In this section is the code to run the process of receiving input from the user and displaying the output of the diagnosis results. The input given by the user itself is in the form of input numbers of symptoms such as [4, 12, 17, 18]. As for the output itself is text that displays the diagnosed pest or disease, the CF value of the diagnosis and how to control it.

Based on the program that has been built, testing is carried out on Powdery Mildew Fungus disease which has 4 symptoms with several conditions to produce the following data:

Table 5. Testing Results

(Source: Data processed 2024)

Testing Conditions	Testing Results		
	Code Input	**Disease Detected**	**CF Value**
4 True Symptoms	4, 12, 17, 18	Powdery Mildew Fungus	0.99977848
3 True Symptoms	12, 4, 18	Powdery Mildew Fungus	0.977848
2 True Symptoms	4, 17	Powdery Mildew Fungus	0.9974
3 True Symptoms 1 False	4, 12, 17, 11	Powdery Mildew Fungus	0.999376
2 True Symptoms 2 False	4, 12, 6, 11	Thrips ticks	0.986272
1 True Symptoms 3 False	4, 21, 6, 11	Armyworm Pest	0.98
2 True Symptoms 3 False symptom but a symptom of Spider Mites disease	4, 11, 12, 19, 20	Botrytis Fungus	0.9996
2 Symptoms of Powdery Mildew Fungus 2 Symptoms of Spider Mites 2 Symptoms of Thrips ticks 1 Symptoms of Armyworm Pest	4, 8, 9, 12, 16	Spider Mites	0.9976
4 True Symptoms 4 False Symptoms	4, 12, 17, 18, 19, 20, 21, 1	Botrytis Fungus	0.999988
3 True Symptoms 3 False Symptoms	4, 6, 7, 8, 17, 18	Armyworm Pest	0.999984
3 True Symptoms 4 False Symptoms	1, 2, 3, 4, 12, 14, 17	Aphid Pest	0.99998206

In Table 5 testing is done with several conditions, starting from the input of symptoms of Powdery Mildew Fungus. Then 4 symptom inputs were made from experiments 4 to 6 with input of false symptoms, namely symptoms that are not from Powdery Mildew Fungus. Likewise in experiments 9 to 11, so it can be seen that in the fourth experiment the symptoms of Powdery Mildew Fungus mentioned obtained a value of 0.99977848 which is the maximum value that can be obtained from the diagnosis of this disease. Then in the second experiment with only three symptoms correct the value decreased by 0.00040248. Then the fifth trial the diagnosis results became Thrips ticks because referring to Table 3, the condition contained two symptoms of Powdery Mildew

Fungus, namely 4 and 12, and there were two symptoms of Thrips ticks, namely 11 and 12. In this case, if you refer to Table 1, the CF value of the inputted Thrips ticks symptoms is greater than the Powdery Mildew Fungus symptoms. In the sixth condition, each symptom is a symptom of one disease and there is no overlap with other diseases and results in a diagnosis of Armyworm because in Table 1 the symptom with the highest CF value in this condition is symptom 6 with a value of 0.98.

DISCUSSION

The research focuses more on building an expert system and analyzing the results of the system that has been created by experimenting with one case with a disease that has four symptoms with several conditions and obtaining results in the form of table 14. In contrast to the two previous studies which were also used as data sources, this research not only focuses on creating an expert system but also analyzing the performance of the expert system that has been developed. In terms of the amount of data, this research is also more than previous research because it is a combination of previous research. The results of the expert system also include solutions for all pests and diseases identified in the program, which can help farmers deal with diseases more effectively, especially for farmers who do not know how to handle pests or diseases that attack their strawberry plants.

In terms of development, this expert system has good potential because it can provide great benefits to farmers, especially those who do not have access to experts. In addition, with the analysis conducted, this research also explains how CF works in diagnosing pests and diseases of strawberry plants. This study also shows the relationship between the level of confidence and the amount of input data that matches the symptoms of the disease. Thus, this research provides a more in-depth explanation of the analysis of the expert system that has been developed, while complementing previous research with richer data and more comprehensive analysis.

CONCLUSION

This research successfully developed an expert system to diagnose pests and diseases in strawberry plants using the CF method. With this system, farmers can identify diseases or pests quickly, accurately and provide recommendations for handling them. By combining data from two previous research articles, this system can cover nine pests and diseases in strawberry plants with a higher level of diagnosis confidence. The analysis conducted in this study also shows that the expert system can provide relevant diagnoses with varying levels of confidence, depending on the number of symptoms entered by the user and also the CF value of the symptoms in the program as shown in table 5. Testing the case of Powdery Mildew Fungus disease shows that the system can distinguish symptoms well with the highest confidence value of 0.99977848 and provide the right solution. Even in the condition of incomplete or random input data, the system can still perform diagnosis such as the condition of only 3 symptoms obtaining a confidence value of 0.977848, as well as several other conditions as in table 5. In addition, this research can also have a good impact on farmers in diagnosing strawberry pests and diseases, especially for peacock farmers who have difficulty getting access to consult with experts. However, this research is only up to the development of an expert system that can still be developed into a web or application to facilitate its use. In addition, although it can diagnose effectively, this research still has limitations such as dependence on symptom data and also the possibility of differences in field conditions. Therefore, further system development by adding a symptom database and more sophisticated diagnosis methods in the future is highly recommended.

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