DIAGNOSIS OF CUCUMBER PLANT DISEASES USING CERTAINTY FACTOR AND FORWARD CHAINING METHODS

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Abstract—*Cucumber plants spread and can live in tropical climates like Indonesia. The cucumber plant has many benefits and can be a beauty ingredient. Cucumbers, like other plants, can also have disease attacks, which can threaten farmers. This expert system can help farmers discover diseases that attack cucumber plants and how to control them. The certainty Factor is a method used to measure the certainty of facts to describe an expert's confidence in facing a problem. Forward Chaining is an approach method monitored by data starting from information in the form of facts and supported by rules to reach conclusions. Implementing an expert system for diagnosing cucumber diseases using certainty factor and forward chaining methods will make it easier for farmers and the public to cultivate cucumber plants and get good results. Applying the forward chaining method and factor certainty in this expert system can produce an accuracy level of 95.918%.*

Keywords*: certainty factor, cucumber plant diseases, expert systems, forward chaining.*

Intisari—*Tanaman mentimun merupakan tanaman yang menjalar dan bisa hidup pada iklim tropis seperti Indonesia. Tanaman mentimun memiliki banyak khasiat dan dapat digunakan pada bahan kecantikan. Pada dasarnya mentimun sama seperti tanaman lainnya yang juga dapat memiliki penyakit yang menyerang, hal ini dapat menjadi ancaman bagi para petani. Sistem pakar ini dapat membantu para petani untuk mengetahui penyakit yang menyerang tanaman timun serta cara pengendaliannya. Certainty Factor merupakan metode yang digunakan untuk mengukur kepastian terhadap fakta untuk menggambarkan keyakinan seorang pakar dalam menghadapi masalah. Forward Chaining merupakan metode pendekatan yang dimonitori oleh data dimulai dari informasi berupa fakta dan didukung dengan aturan aturan untuk mendapatkan kesimpulan. Implementasi sistem pakar diagnosis penyakit timun dengan metode certainty factor dan forward chaining ini harapannya dapat memudahkan petani maupun masyarakat dalam membudidayakan tanaman mentimun dan mendapatkan hasil yang baik. penerapan metode forward chaining dan kepastian faktor pada sistem pakar ini dapat menghasilkan tingkat akurasi sebesar 95,918%.*

Kata Kunci*: certainty factor, penyakit tanaman mentimun, sistem pakar, forward chaining.*

INTRODUCTION

Agriculture is the central sector in a country in a tropical region, including Indonesia. Indonesia is known as an agricultural country because it has fertile soil and gets lots of sunlight and high rainfall. Agriculture in Indonesia is the primary source of food security. Food is a sector that humans always need, and Indonesia has quite a large number of consumers. The economic sector can be optimized for cultivating plants and managing their benefits in agriculture (Pardin Lasaksi, 2023). Currently, the direction of agricultural development in Indonesia is towards modern agriculture. Modern agriculture refers to a series of technologies and innovations applied in the agricultural sector, including machinery developments, pest and disease control, and harvest and post-harvest processes. In Indonesia, the technology used to support modern agriculture depends on various factors, including skilled human resources, the availability of high-quality seeds, superior agricultural results, and the

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application of high-tech mechanisms. The advantage of modern agriculture lies in its ability to efficiently overcome current challenges, such as increasingly limited land, by producing abundant results in a relatively short time (Rachmawati, 2021; St Fatmawaty & Bijaksana, 2023).

Cucumber is a horticultural crop that is quite popular in Indonesia and can be managed using modern agricultural technology. Cucumber plants produce fruit, which has consumption value as a food ingredient. Cucumbers are rich in various nutrients such as protein, fat, carbohydrates, calcium, phosphorus, iron, and vitamins A, C, B1, B2, and B6 (Kasmin et al., 2023). Apart from that, cucumbers also contain water, potassium and sodium. One of the health benefits of cucumber is its ability to lower blood pressure. Cucumber fruit can be consumed fresh or further processed into various products. Besides being a food ingredient, cucumbers are also widely used in the beauty industry as raw materials. Even though it has excellent potential, cucumber production in Indonesia is still relatively low. However, cucumber plants are easy to cultivate because they are adaptable to various climatic conditions. With high market absorption, business opportunities in cucumber cultivation are still wide open (Agustin & Gunawan, 2019).

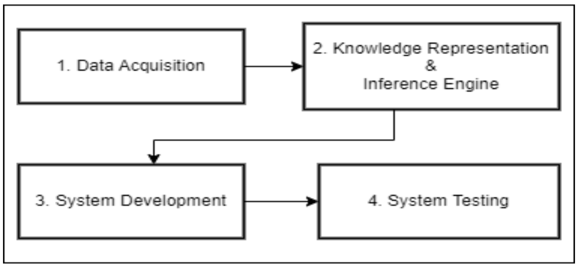
However, current conditions show that the productivity of cucumber plants in Indonesia could be much higher. They were caused by several factors, including climate factors, farming techniques such as tilling the land, fertilizing, irrigation, and pest and disease attacks (Handayani et al., 2020). One solution to overcome this problem, especially early detection of diseases suffered by cucumber plants, is to use the help of information technology in the form of an expert system. Various studies on implementing expert systems for the early detection of plant diseases have been developed recently (Armaya et al., 2022). Research related to the diagnosis of cucumber diseases was carried out by (Rahmi et al., 2019) using the Forward Chaining method for early detection of diseases in cucumber plants. The results of this research show that the resulting accuracy is 89%. Similar research was also carried out by (Armaya et al., 2022) using the Certainty Factor method to diagnose disease early in cucumber horticultural plants. This research shows that the Certainty Factor method can produce an accuracy value of 60% -80%. The research conducted by (Arifin et al., 2021; Pasaribu, 2019) used the Bayesian method to diagnose cucumber plants early in Indonesia. The results of both studies show that this method can be used to diagnose cucumber diseases. The level of accuracy produced by both ranges between 65% - 75%.

Early diagnosis systems for horticultural crops have been researched using expert systems. The majority of methods in expert systems used include Cased Based Reasoning (CBR) (Aldo et al., 2022), Forward Chaining (Alamsyah & Nonci, 2023; Suradi et al., 2023), Bayesian (Pasaribu, 2019), and Certainty Factor (Damayanti, 2020; Safitri & Murtiwiyati, 2023). However, each method has advantages and disadvantages. Based on most existing research, Certainty Factors and Forward Chaining methods perform well in diagnosing diseases in horticultural crops, including cucumbers.

Therefore, in this research, early disease diagnosis in cucumber plants used a combination of the Forward Chaining and Certainty Factor methods. The aim of doing this combination is to get better diagnostic results. There are two contributions to this research. First, the system built can help carry out early diagnosis of cucumber plants with accurate results. These two studies can be a reference in developing an expert system, especially for early diagnosis of cucumber plant diseases, which can later be used to help the agricultural sector in Indonesia.

MATERIALS AND METHODS

This section will discuss materials and methods with the flow of this research, which is divided into four main stages: Data Acquisition, Knowledge Representation, System Development and System Testing. Following figure 1 is the research workflow.



Source : (Research Results, 2024)
Figure 1. The Research Workflow

The following each step in this research are explained in points A to D.

A. *Data Acquisition*

Data acquisition is the initial stage in research. At this stage, data was collected to develop this expert system in the form of data on types of diseases in cucumber plants and supporting symptom data obtained from interviews with some horticultural plant experts at one of the Agricultural Agencies in the Provinces of Yogyakarta and Central Java.

B. Knowledge Representation

Knowledge representation in an expert system refers to the process of coding and storing knowledge information needed to carry out reasoning and decision-making in a particular domain. This representation aims to present the knowledge experts or experts possess in a form that a computer system can understand. Rules are one of expert systems' most commonly used forms of knowledge representation (Sudibyo et al., 2023). Rules consist of conditions (premises) and actions (conclusions) that are implemented if those conditions are met. Semantic networks describe the relationships between concepts in a knowledge domain by using nodes and connections that represent the relationships between these concepts (Hairani et al., 2021; Medianti & Maulana, 2022). After the knowledge representation is formed, the next stage is reasoning using an inference engine.

In this research, the inference engine used is the Forward Chaining method and the Certainty Factor method. The initial factor is the certainty factor, inputted by the expert alongside the rules. The second factor is the certainty level provided by the user. The computation of confidence percentage starts with rules associated with a single symptom. The following is equation 1 to calculate the CF (Certainty Factor) value from experts.

$$CF = [h,e] = MB\ [h,e] - MD\ [h,e] \ldots\ldots(1)$$

Where, CF [h,e] = Certainty factor, MB [h,e] = Measure of confidence in hypothesis h, given evidence e (between 0 and 1), and MD [h,e] = Measure of disbelief in hypothesis h, if given evidence e (between 0 and 1). The next process is to carry out calculations using the following equation 2.

$$CF = CF_{user} * CF_{pakar} \ldots\ldots(2)$$

The rules of the Certainty Factor method are as follows (Putra & Yuhandri, 2021; Rahmadhani et al., 2020; Sholeha et al., 2023; Sukiakhy et al., 2022). First, the rules for adding two positive Certainty Factor factors use equation 3.

$$(CF_a CF_b) = CF_a + CF_b * (1 - CF_a) \ldots\ldots(3)$$

The second is rules for adding two negative Certainty Factors use equation 4.

$$(CF_c CF_d) = CF_c + CF_d + (CF_c * CF_d) \ldots\ldots(4)$$

The third is rules for adding positive Certainty Factors and negative certainty factors are more complex using equation 5.

$$(CF_e CF_f) = \frac{CF_e + CF_f}{1 - (|CF_e|,|CF_f|)} \ldots\ldots(5)$$

C. System Development

In this research, system development follows the System Development Life Cycle (SDLC) approach, incorporating modelling through use case diagrams within the Unified Modeling Language (UML). Within the UML framework, use cases delineate system requirements and user interactions. Activity diagrams depict flows of activities between users and the system, while class diagrams illustrate object types and static relationships within the system. Sequence diagrams elucidate dynamic interactions among objects or entities within the system.

D. System Testing

The concluding phase of the study involves conducting tests on the system. This phase consists of two distinct scenarios for system testing. Initially, Black Box Testing is employed to assess the functionality of the features within the expert system. Subsequently, the accuracy of the developed expert system is evaluated through various test scenarios, aiming to ascertain its precision by comparing its outputs with those validated by an expert.

RESULTS AND DISCUSSION

In this section, the overall results obtained from this research will be discussed, especially in terms of the expert system developed based on the stages that have been carried out.

A. Data Acquisition

This study exclusively concentrates on the prevalent diseases observed in cucumber plants. The varieties of diseases affecting cucumber plants, as detailed in Table 1 of this expert system, have been the focal point. Furthermore, the disease data acquired underwent validation by horticultural plant experts affiliated with agricultural departments in Yogyakarta and Central Java, as part of this research.

Table 1. Cucumber Plants Diseases

Diseases Code	Diseases Name
P001	Fusarium Wilt
P002	Bacterial Wilt
P003	Leaf Blight
P004	Powdery Mildew
P005	Complex Viruses

Source : (Research Results, 2024)

Table 1 shows that in this study there were five cucumber plant diseases developed in the expert system in this study. In addition, it is also equipped with data on symptoms of cucumber plant diseases. The types of cucumber plant diseases symptoms found in this expert system are described in Table 2. In addition, the symptom data obtained has also been validated by horticultural plant experts affiliated with agricultural departments in Yogyakarta and Central Java, as part of this research.

Table 2. Cucumber Plants Diseases Symptoms

Symptoms Code	Symptoms Name
G001	Withered leaves
G002	Yellowing Leaf Stems
G003	Wilted Stems Excrete White Mucus
G004	Yellowing Leaves
G005	Moldy Leaves
G006	Leaves Blight Easily
G007	Leaves Turn Yellow and Dry Up
G008	There are white or moldy spots
G009	The surface of the striped leaves is light green
G010	Small Plants
G011	Yellow Spots Spreading to the Petioles
G012	Completely wilting of leaves
G013	Pale Green Stripes on the Grooved Surface of the Leaves
G014	Dried leaves
G015	Attacking Young Plants

Source : (Research Results, 2024)

Based on the results of interviews with cucumber plant experts, Table 3 shows that there are fifteen disease symptoms that are often encountered.

B. Knowledge Representation

Based on the disease data and symptoms obtained, the next step is to create a knowledge base using the Forward Chaining method with the IF [premise] THEN [result] rule. In this study, using the forward chaining method, if there is a symptom or complaint, then the result is the name of the disease. Meanwhile, the AND operator (&) is the link for each symptom entered by the patient/user. Based on the rules above, the statement is in the form IF [symptom 1] AND (&) [symptom 2] THEN [name of disease]. The relationship rules are described in Table 3 below.

Table 3. Knowledge Base

Rules	Condition
R1	IF G001, AND G002, AND G011 THEN P001
R2	IF G001, AND G003, AND G012 THEN P002
R3	IF G001, AND G004, AND G005, AND G006, THEN P003
R4	IF G006, AND G007, AND G008, AND G015 THEN P004
R5	IF G009, AND G010, AND G013, AND G014 THEN P005

Source : (Research Results, 2024)

Next, calculations will be carried out using the certainty factor method inference machine, which determines the certainty value and uncertainty value. The initial stage is determining the weight value for each symptom based on the MB trust value, which is a trust value, so the more significant the MB value, the greater the expert's trust. The belief value (MB) can be seen in Table 4 below.

Table 4. The belief value (MB)

No	The Belief Value	MB
1.	Definitely Not Sure	0,0
2.	Not Sure	0,2
3.	Maybe Yes	0,4
4.	Most Likely Yes	0,6
5.	Almost Certainly Yes	0,8
6.	Definitely Yes	1,0

Source : (Research Results, 2024)

Apart from determining the trust value, it is also necessary to determine the disbelief value or MD value, where the more significant the MD value, the smaller the trust value. The MD value can be seen in Table 5 below.

Table 5. The Disbelief value (MD)

No	The Belief Value	MD
1.	Definitely Not Sure	1,0
2.	Not Sure	0,8
3.	Maybe Yes	0,6
4.	Most Likely Yes	0,4
5.	Almost Certainly Yes	0,2
6.	Definitely Yes	0,0

Source : (Research Results, 2024)

The next stage is to determine the knowledge base value where there is disease, symptom, MB, MD and CF data where the MB and MD values are obtained by experts through expert interpretation values. In contrast, the CF value is obtained from the calculation of MB minus MD. The knowledge base value can be seen in Table 6 below.

Table 6. Knowledge Base Accompanied by CF Values

Diseases Code	Symptoms Code	MB Value	MD Value	CF Value
P001	G001	1,0	0,0	1,0
	G002	0,8	0,2	0,6
	G011	0,8	0,2	0,6
P002	G001	1,0	0,0	1,0
	G003	0,8	0,2	0,6
	G012	0,8	0,0	0,8
P003	G001	1,0	0,0	1,0
	G004	1,0	0,4	0,6
	G005	1,0	0,2	0,8
	G006	1,0	0,2	0,8
P004	G006	1,0	0,2	0,8
	G007	0,6	0,0	0,6
	G008	1,0	0,0	1,0
	G015	1,0	0,2	0,8
P005	G009	0,6	0,2	0,4
	G010	0,8	0,0	0,8
	G013	0,6	0,0	0,6
	G014	1,0	0,2	0,8

Source : (Research Results, 2024)

The next stage is to calculate using the certainty factor method, where the user will input data on symptoms that attack cucumber plants. The following is an example of calculations for diagnosing cucumber plant diseases using the certainty factor method.

An example of a disease that will be used as a calculation sample is Leaf Blight. The MB and MD values for leaf blight are known, with data on the MB and MD values obtained from interviews with experts, which can be seen in Table 7 below.

Table 7. MD and MB Values (from Expert) for Leaf Blight

No	Symptoms	MB	MD
1.	Withered leaves (G001)	1,0	0,0
2.	Yellowing Leaves (G004)	1,0	0,4
3.	Moldy Leaves (G005)	1,0	0,2
4.	Leaves Blight Easily (G006)	1,0	0,2

Source : (Research Results, 2024)

To get the expert CF value, we can use the following equation (1), which is accompanied by an explanation.

$$CF\ [h,e] = MB\ [h,e] - MD\ [h,e]$$

G001 → $CF = 1,0 - 0,0 = 1,0$

G004 → $CF = 1,0 - 0,4 = 0,6$

G005 → $CF = 1,0 - 0,2 = 0,8$

G006 → $CF = 1,0 - 0,2 = 0,8$

In the certainty factor method, the CF value is from experts and based on system user input. The following is a sample of CF user data entered in Table 8.

Table 8. CF Values from User

No	Symptoms	CF User
1.	Withered leaves (G001)	Most Likely Yes (0.6)
2.	Yellowing Leaves (G004)	Maybe Yes (0.4)
3.	Moldy Leaves (G005)	Most Likely Yes (0.6)
4.	Leaves Blight Easily (G006)	Almost Definitely Yes (0.8)

Source : (Research Results, 2024)

The next stage is to calculate the CF value for each symptom by multiplying the expert's CF by the user's CF using the following equation (2) with an explanation.

$$CF\ Gejala = CF\ [user] * CF\ [pakar]$$

G001 → $CF = 0,6 * 1,0 = 0,6$
G004 → $CF = 0,4 * 0,6 = 0,24$
G005 → $CF = 0,6 * 0,8 = 0,48$
G006 → $CF = 0,8 * 0,8 = 0,64$

Next, calculate the combination of CF values for each symptom using the following equation (3) (4) and its explanation.

$$CF\ Combine = CF\ old + CF\ gejala * (1 - CF\ old)$$

$$\begin{aligned} CF\ (1,2) &= 0,6 + 0,24 * (1,0 - 0,6) \\ &= 0,6 + 0,24 * 0,4 \\ &= 0,6 + 0,096 \\ &= 0,696 \end{aligned}$$

$$\begin{aligned} CF\ (3,4) &= 0,696 + 0,48 * (1,0 - 0,696) \\ &= 0,696 + 0,48 * 0,304 \\ &= 0,696 + 0,14592 \\ &= 0,84192 \end{aligned}$$

$$\begin{aligned} CF\ (4,5) &= 0,84192 + 0,64 * (1,0 - 0,84192) \\ &= 0,84192 + 0,64 * 0,15808 \\ &= 0,84192 + 0,1011712 \\ &= 0,9430912 \end{aligned}$$

Based on these calculations, it can be seen that the diagnosis result with the highest level of confidence in the type of disease on cucumber plants is Leaf Blight, with a CF value percentage of 94.3%.

C. System Development

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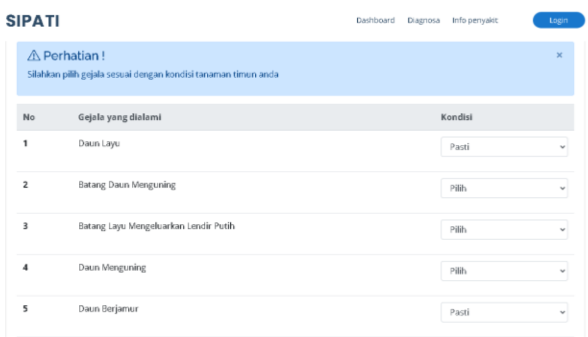
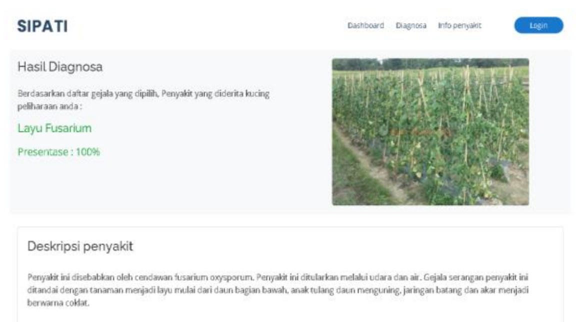
Within system development, the implementation of interfaces stands as a crucial stage, ensuring the alignment of user requirements with system interactions. Effective interface design profoundly aids users in comprehending system operations, thereby enhancing overall system efficiency. This section will present two key interface features integrated into the developed system: the diagnosis page interface and the diagnostic results page interface.

The diagnosis interface page facilitates symptom selection and condition specification, requiring users to designate their relevant symptoms to initiate system processes. Figure 2 illustrates the specifics of the diagnostic page interface.



Source : (Research Results, 2024)
Figure 2. The Diagnostic Page Interface

The diagnosis outcomes exhibit selected symptoms represented through CF and percentage values, accompanied by descriptions, visuals, and recommendations for managing the disorder. Further elaboration on the interface specifics for the diagnosis results page is depicted in Figure 3.



Source : (Research Results, 2024)
Figure 3. The Diagnostic Results Page Interface

D. System Testing

The last phase of the study involves system testing, which is delineated into two distinct scenarios. Initially, Black Box Testing is conducted to assess the functionality of the features within this expert system. Subsequently, the outcomes of the Black Box testing are presented in Table 9.

Table 9. Black Box Testing Results

No	Features	Scenarios	Results
1	Admin Login	Enter the registered username and password	Valid.
		Entering an unregistered username and password	Valid.
2	Diseases Data	Enter fault data	Valid.
		Editing fault data	Valid.
		Delete tampering data	Valid.
3	Symptoms Data	Enter symptom data	Valid.
		Edit symptom data	Valid.
		Delete symptom data	Valid.
4	Knowledge Data	Input knowledge data	Valid.
		Edit knowledge data	Valid.
		Deleting knowledge data	Valid.
5	Admin	Enter admin data	Valid.
		Edit admin data	Valid.
		Delete admin data	Valid.
6	Logout	Pressing the logout button	Valid.
7	Diagnosis	Choose the condition of the symptoms you are experiencing, then click the process button	Valid.

Source : (Research Results, 2024)

After conducting the tests, it can be concluded that the features embedded within this expert system have functioned smoothly. The findings presented in Table 10 affirm the absence of errors across all test scenarios executed. Subsequently, the accuracy of the developed expert system is evaluated through various test scenarios, aiming to validate its precision against expert-validated outputs. Table 11 provides an instance of the sample of accuracy testing scenario conducted within the expert system.

Table 11. Samples of Accuracy Testing Scenario

Symptoms	Manual	System	Expert	Results
• Withered leaves (G001) • Yellowing Leaves (G004) • Moldy Leaves (G005) • Leaves Blight	Leaf Blight (0,9432)	Leaf Blight (94.3 %)	Leaf Blight	Valid

Symptoms	Manual	System	Expert	Results
Easily (G006)				
• Wilted leaves (G001) • Yellowing of leaf stems (G002) • Yellow spots spreading to the petiole (G011)	Fusarium wilt (0,9027)	Fusarium wilt (90%)	Fusarium wilt	Valid

Source : (Research Results, 2024)

The objective of accuracy testing is to evaluate the proficiency of the expert system in delivering diagnoses for different types of cucumber diseases. At this stage, five cases encompassing diverse symptoms and diseases are employed to assess the accuracy of expert analysis values, which are then juxtaposed with the actual results obtained from the expert system. Out of the total five cases evaluated, all demonstrated consistency between the system diagnosis and the expert diagnosis. Then the accuracy value of this expert system can be calculated using the following equation 6.

$$Accuracy = \frac{True\ Diagnosis}{All\ Diagnosis} * 100\% \quad \text{.........(6)}$$

$$Accuracy = \frac{5}{5} * 100\%$$

$$Accuracy = 100\ \%$$

Upon reviewing the test outcomes, it can be deduced that the accuracy percentage obtained from the comparison of expert systems in diagnosing cucumber diseases utilizing the forward chaining method and certainty factor stands at 100%. This research has limitations related to the data used which was only obtained in the Yogyakarta and Central Java area.

CONCLUSION

The following conclusions were drawn based on the results of research on an expert system for early diagnosis of diseases in cucumber plants using the Forward Chaining Method and the Certainty Factor Method. First, the expert-based system being developed can help provide diagnostic results that are carried out before complaints arise and will be detected early to provide early prevention of disease in cucumber plants, which could be more severe. Second, applying the forward chaining method and Certainty Factors in this expert system can produce an accuracy level of around 90% to 94.3%. An expert, a horticultural crop expert affiliated with the agricultural department in Yogyakarta and Central Java, has also validated these results as part of this research. This research has limitations related to the data used which was only obtained in the Yogyakarta and Central Java area. Suggestions for further research are to add data from various regions and form a more accurate knowledge base by adding data on symptoms and disorders from various experts to produce a better diagnosis process.

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