Expert System for Detecting Diseases of Potatoes of Granola Varieties Using Certainty Factor Method

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ABSTRACT

The low productivity of potatoes is caused by many factors, including the very low quality of the seeds used, poor storage, climate, capital, limited farmer knowledge, and attacks by plant-disturbing organisms, especially diseases. Not only that, many farmers are still unfamiliar with the various diseases that can attack potato plants, or their knowledge about potato plant diseases is incomplete. This study aims to design and develop an expert system web-based application technology using the Certainty Factor (CF) method to detect potato disease symptoms. The CF method defines a measure of the capacity of a fact or provision to express the level of an expert's belief in a matter experienced by the concept of belief or trust and distrust or uncertainty contained in the certainty factor. The results showed that the CF method could function optimally in detecting potato plant diseases which can help farmers based on the symptoms that appear with an accuracy value of 94%.

Keywords : Expert System; Detecting Diseases; Potato Plants; Certainty Factor; Smartphones; Android.

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I. INTRODUCTION

Potato (Solanum tuberosum, L.) is a tuber-type plant widely used as a source of carbohydrates or staple food for the world community after wheat, corn, and rice. As tubers, potatoes are quite prominent in their nutritional content. Potato tubers contain little fat and cholesterol but contain carbohydrates, sodium, fiber, protein, vitamin C, calcium, iron, and vitamin B6, which are quite high [1]. Potato is an important food crop in Indonesia, and this commodity has high economic value. Potatoes are indeed not the staple food of Indonesian society, but due to population growth, improved living standards, and an increasing number of foreign tourists living in Indonesia, potato consumption is increasing every year. Storage of potato tubers lasts longer than other vegetables [2].

Based on FAO data, potato productivity in Indonesia is still low, reaching < 30 tons/ha compared to developed countries such as Europe and America. Potato production in Indonesia in 2019 was 1,314,657 tons, up 2.3% from 2018 of 1,284,760 tons, according to the Central Bureau of Statistics (Potato Production by Province, 2011-2015, 2015). Factors for the low productivity of potatoes in Indonesia are the low quality of the seeds used, poor storage, climate, capital, limited knowledge of farmers, and attacks by plant-disturbing organisms, especially diseases. Not only that, there are still many farmers who do not recognize the many kinds of diseases that can hit potato plants, or their knowledge about potato plant diseases is not comprehensive. This causes a decrease in the success rate of potato production. And due to the lack of data on potato plant diseases that farmers can accept [3].

Indonesia's commonly grown potato varieties are granola, Atlantis, *cipanas*, and *gunungan* potatoes. Potato Granola is one of the most popular with its special characteristic of having an oval shape and yellow flesh. Has the highest market demand. A yearly positive price trend also accompanies the high demand for potato commodities. It's no wonder that many local potato farmers are interested in this granola potato variety [4].

Technology occupies a significant role, which cannot be separated from communication technology. It functions to store information without relying on constraints such as humans. One of the emerging technologies is smartphones. The existence of smartphones makes it easier for people to access anything and wherever they are. Android-based system design is easier, and many people use it. Through the application of technology, computers can reach the same findings or choices as people working on particular scientific subjects.

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The Certainty Factor (CF) method is a procedure that defines a measure of capacity against a reality or provision, in expressing the level of confidence of an expert in a case that is being experienced [5], the concept of belief or belief and disbelief or disbelief contained in the certainty factor. The CF method is a procedure that defines a measure of capability versus reality or provision in expressing the amount of confidence an expert has in a case that is a CF. This measure is used to express an expert's confidence level in a CF. To prevent incorrect diagnoses and make it simpler for the general public to learn about diseases that appear in potato plants at an early stage so that it is not too late to obtain treatment for them, In the interim between the formation of a system and the application of the CF approach, problem-solving assistance can be provided.

Literature studies on previous research concluded that the use of the CF method could be accurately implemented in many case studies for diagnosing symptoms of human and animal diseases, including the results of research [6]-[14]. The results of research that examines the use of artificial intelligence methods to diagnose potato diseases based on certain criteria, namely the results of researchers [15] using the Naive Bayes method, [16] using the KNN method. Based on the literature study, it can be concluded that the CF method is very good and optimal for detecting potato plant diseases. This research, it is hoped that it can support the community, especially potato farmers, to recognize potato plant diseases automatically.

II. METHOD

A. Data Collection Procedures

Finding the necessary data for research comprises many aspects, including the data-gathering method. A review of the relevant published material constituted the data-gathering method utilized in this investigation. In the case of potato plants, literature research is a method of data collection that involves conducting surveys and studies on previously published documents and journals. The process of developing a system may also make use of reference books in the capacity of a guide.

B. Data Analysis Techniques

All data obtained will then be processed and arranged as neatly as possible; the stages are:

- Editing is structuring the document after getting the results from previous research.
- Coding is an activity to develop logic following what the author wants. This activity also checks algorithms and words to match the application's original purpose.
- Tabulation is the process of compiling data, and the calculation process is then presented in tabular form to make it easier to understand.

C. Experiment Procedure

The method proposed in this study is the determination of confidence level (CF). The certainty factor can measure disease uncertainty where the calculation can only manage 2 data. The data is maintained with a value between -1 and 1.

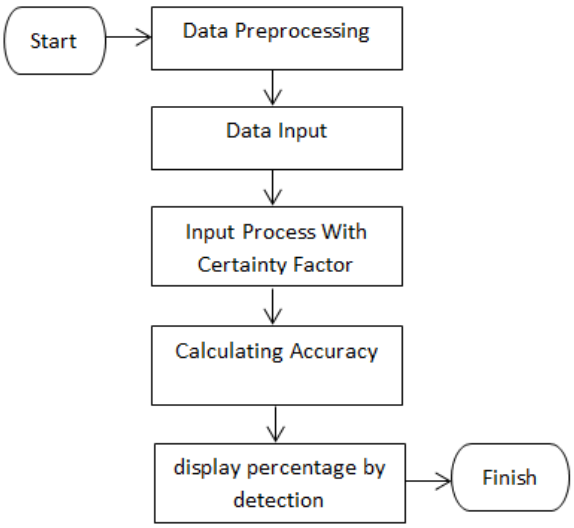

Fig. 1. The Experiment Procedure

Figure 1 describes the flow of the experimental procedure. Preprocessing data is manually grouping data according to the required data with the help of pre-existing data. Input data on symptoms of potato plant diseases following data obtained from books and journals. Input process with certainty factor is symptom data input made by the user will be processed by the system using the calculation rules of the Certainty Factor method. Calculating accuracy for the system will calculate the accuracy of disease detection. Display percentage and detection. The system has finished calculating the accuracy and displays the detection of the

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disease being suffered. The percentage of correctness obtained by the calculation is derived from the CF method, which is based on the symptoms that the user enters.

D. Case Description Symptoms and Diseases

For diseases of potato plants and the symptoms experienced can be seen in Tables I and II.

TABLE I
TYPE OF POTATO DISEASES

Code	NAME OF THE DISEASE
P1	Bacterial Wilt
P2	Fusarium wilt
P3	Rotten leaves
P4	Root rot
P5	Dry spots
P6	Disease caused by leaf roller virus
P7	Diseases caused by the X virus
P8	Diseases caused by the S virus

TABLE II
SYMPTOMS OF POTATO DISEASE

Code	NAME OF THE DISEASE
G1	The withering of shoots/growing point
G2	Withered growth points spread to old stems and leave to the roots
G3	Plants/clumps of plants wither and turn yellow thoroughly
G4	Dwarf growing
G5	The sudden withering of the plant
G6	Plants appear to be partially wilted (partially wilted clumps)
G7	If the stem is cut, it will show brown on the leaf stem tissue
G8	The leaves are yellow
G9	Drying plants
G10	Embossed spots are scattered in the middle and edges
G11	The patches are broad, round, and brown or black
G12	The attack starts from the old leaves
G13	The attack spreads to tubers, stems, and stalks
G14	Potato leaves turn yellow
G15	The leaves roll up, then wither and dry
G16	Yellow spots appear
G17	Young roots and tubers rot
G18	The attack spreads to the young leaves
G19	Drying and falling of leaves
G20	Leaf edges are straighter than healthy leaves and curl from the petiole
G21	Leaves are easy to break
G22	Leaves look stiff
G23	The appearance of stripes on pale yellow leaves between the bones of the leaves
G24	Leaf bones look sinking
G25	Looks protruding or uneven leaf surface
G26	Different colors between bones and leaves

E. Potato Plants

Because potatoes are so helpful for various day-to-day applications, their cultivation in Indonesia is prioritized as a root crop development project. This plant has the potential to be developed to support efforts to broaden the range of foods available. Due to potato plants' high protein content, the food diversification program utilizes them as a supporting product. The potato's protein content can offer adults beneficial nutrition [17].

The potato, a tuber plant, has many carbohydrates and is often used as a stand-in for other types of food. The third most consumed crop on the planet, behind rice and wheat, potatoes are considered one of the world's most important foods. Because they include high-quality protein, vital amino acids, minerals, and microelements, the tuber portion of a potato's nutritional profile is regarded as among the best in the vegetable world. In addition to that, it is a source of vitamin C (ascorbic acid), numerous B vitamins (thiamine, niacin, and vitamin B6), as well as the minerals potassium, magnesium, and phosphorus [18].

F. Types of Potato Plants

There are wide different varieties of potato plants that may be found in Indonesia. Listed below are three varieties of superior potatoes, including the Granola potato, one of the superior potatoes that Tanijoy and Mitra Tani produce in North Sumatra and Central Java. This cultivar has the potential to produce substantial harvests. At least 26.5 tons of tubers may be harvested from a single hectare of soil. Granola potato tubers have an oval form, skin ranging in hue from yellow to white, and eyes cut very shallowly. However, the flesh of the potato is yellow in hue.

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As of 2018, the government has ceased importing vegetable potatoes because of the persistent rise in the productivity of potato seeds bred from Granola. This is because vegetable potato production increased by around 2% to approximately 1.18 million tons in 2018, as compared to 2017's total of 1.16 million tons. The granola potato plant matures between 100 and 115 days after sowing and can grow to a height of 65 centimeters. If the planted area of this variety accounts for 80–90% of the total varieties of vegetable potatoes grown in Indonesia, it is considered an important variety. The Granola potato variety is resistant to illnesses caused by Potato Virus A (PVA) and Potato Virus Y (PVY), in addition to having a high level of productivity and a planting age that is not too long for the plant to mature and being relatively easy to plant.

G. Certainty Factor Method

The Certainty Factor (CF) theory creates a value by asserting a level of confidence in specific principles; alternatively, one could say that it accommodates the ambiguity inside an expert's line of reasoning. It is possible to express uncertainty using phrases such as "probably, possibly true almost and surely." There are two (two) different types of certain factors that are employed, which are as follows:

- The certainty factor that has been obtained from an expert or expert.
- The certainty factor that has been obtained from the user (user).

The Certainty Factor (CF) method can be calculated using Equation (1). Where, the *H* hypothesis is influenced by factor Evidence (events or facts) *E*. The magnitude of *CF* ranges from -1 to 1. The value of -1 indicates absolute uncertainty, while 1 indicates absolute certainty. The *MB[H,E]* variable measures belief in the H hypothesis, which is influenced by symptom E (between 0 and 1). The *MD[H,E]* variable measures of disbelief (a measure of disbelief) against hypothesis H, which is influenced by symptom E (between 0 and 1).

$$[H,E]=[H,E]-MD[H,E] \quad (1)$$

The certainty factor of the hypothesis is influenced by evidence E based on Equation (2), which is known with certainty in the *CF[H,E]* variable. The *CF[E]* variable is certainty factor evidence that is influenced by evidence E, and the *CF[F]* variable is certainty factor evidence with the assumption that evidence is known with certainty when CF[E.e] equals 1. A certainty factor for rules with similarly contained rules (rules with similarly reached conclusions) utilizing Equations (3), and (4).

$$C[H,E]=CF[H]*CF[E]. \quad (2)$$

$$CFcombineCF[H,E]1,2=CF[H,E]1+CF[H,E]2*[1-CF[H,E]1] \quad (3)$$

$$CFcombineCF[H,E]old,3=CF[H,E]old+CF[H,E]3*[1-CF[H,E]old] \quad (4)$$

H. Framework of Thought

The problem faced in this study is the detection of potato plant diseases. The approach method used is the Certainty Factor method (certainty factor). This system is used to design a website-based application. The application is expected to assist users in determining solutions to problems arising from potato plant disease.

The data that was used is the results of the previous study. The researchers obtain the necessary data. The application is constructed, and once it is finished, the application is evaluated to assess the amount of accuracy that follows the desired application. Figure 2 provides a summary of the conceptual framework that underpins this investigation.

<table>
<tr><td colspan="3">PROBLEMS:
Many farmers still lack knowledge about various diseases that affect potato plants, and their knowledge about plant diseases is incomplete potatoes.</td></tr>
<tr><td>IMPLEMENTATION:
DETECTING POTATO PLANT DISEASES</td><td>METHOD:
CERTAINTY FACTOR</td><td>APPLICATION:
WEB-BASED</td></tr>
<tr><td colspan="3">THE CERTAINTY PROCESS:
• Calculation of CF [H,E], where CF H (hypothesis) is influenced by CF E symptoms (evidence) MB calculation [H,E]
• MB [H,E] is a measure where the measure is the belief in the hypothesis (H), which is influenced by symptoms (E)
• Calculation of MD [H,E] is a measure, where the measure is the distrust of the hypothesis (H), which is influenced by symptoms (E)
• CF calculation [combination], where CF combines to determine the results of more than one disease risk that appears</td></tr>
<tr><td colspan="2">THE CERTAINTY PROCESS:
The test used is accuracy testing, where a calculation process compares the results of the system's accuracy with expert detection of the amount of data obtained.</td><td>RESULT:
Know the symptoms that appear and find the disease from the symptom conditions that have been found</td></tr>
</table>

Fig. 2. Framework of Thought

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I. Performance Accuracy

This test was conducted to test the accuracy of the design of the potato plant disease detection system. The potato plant disease detection system is compared with the detection results by real experts. This test determines the system accuracy level calculated by Equation (5).

$$\text{Level of accuracy} = \frac{\sum accurate\ sample\ data}{\sum data\ sample}\ x\ 100\% \quad (5)$$

III. RESULT AND DISCUSSION

In detecting the disease, it is necessary to know the symptoms that arise as the initial signs. Even though some of these symptoms are only visible immediately, conclusions can be drawn from the disease. Table III analyzes symptoms, diseases and how to treat these diseases.

TABLE III
ANALYSIS OF SYMPTOMS, DISEASES, AND HANDLING

NO	DISEASE	SYMPTOM	HANDLING
1	Bacterial Wilt	a. The withering of shoots/growing point b. Withered growth points spread to old stems and leave to roots c. Plants/clumps of plants withered and yellowed all over d. Growing dwarf	Handling that can be done by using water that is free from disease when watering plants, the land is cleaned of plant debris, the tubers to be planted should be soaked or dipped first in a pesticide solution, the land must have good drainage, plants that have been attacked immediately uprooted and burned, and preferably do rotational planting.
2	Fusarium Wilt	a. The sudden withering of the plant b. Plants look partially wilted c. If the stem is cut, it will show brown on the leaf stem tissue d. Yellow leaf bones e. Plants dry up	The recommended treatment is to avoid damage to weeds and tannins. Organic Fertilizers for Plant Disease Pest Control can also be used for prevention before or during planting.
3	Rotten Leaves	a. The raised spots are scattered in the middle and edges b. The patches are wide, round in shape, and brown or black in color c. The attack starts from the old leaves d. The attack spreads the tubers, stems, and stalks	This disease can be controlled by disinfecting the plants and can be prevented before or start planting with organic fertilizers to control plant pests.
4	Tuber Rot	a. Potato leaves turn yellow b. The leaves roll up, then wither and dry c. Yellow spots appear d. Young roots and tubers rot	The recommended treatment for this disease is crop rotation, garden sanitation, and the use of good seeds. It can be prevented before or started planting with organic fertilizers to control plant pests.
5	Dry Spots	a. Raised spots scattered in the center and edges b. The attack starts from the old leaves c. The attack spreads to the young leaves d. Drying and falling of leaves	Technically, the way to break this disease cycle is to avoid planting land that has been affected by dry spots, rotating crops, namely after planting potatoes, then planting crops such as corn or soybeans, and solarizing the soil to kill disease germs.
6	Disease caused by leaf roller virus	a. Leaf edges are straighter than healthy leaves and curl from the petiole b. Leaves are easy to break c. Leaves look stiff	The control measure is that no insecticide can fight this virus. Prevention and control are carried out by sowing virus-free seeds, cleaning tools, pruning, and burning diseased plants
7	Diseases caused by the X virus	a. Stripes appear on pale yellow leaves between the veins of the leaves b. Leaf bones look sinking c. Looks protruding or uneven surfaces both d. Different colors between bones and leaves	The control measure is that no insecticide can fight this virus. Prevention and control are carried out by sowing virus-free seeds, cleaning tools, pruning, and burning diseased plants
8	Diseases caused by the S virus	a. Leaf bones look sinking b. Looks protruding or uneven leaf surface c. Different colors between bones and leaves	The control measure is that no insecticide can fight this virus. Prevention and control are carried out by sowing virus-free seeds, cleaning tools, pruning, and burning diseased plants

From these data, if the calculation is done manually, then the results are obtained as presented in Table IV

TABLE IV
CERTAINTY FACTOR MANUAL CALCULATION

SELECTED SYMPTOMS	CODE	USER WEIGHT
The withering of shoots/growing point	G1	0.8
Plants/clumps of plants wither and turn yellow thoroughly	G3	0.7

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SELECTED SYMPTOMS	CODE	USER WEIGHT
The sudden withering of the plant	G5	0.8
Plants appear to be partially wilted (partially wilted clumps)	G6	0.8
If the stem is cut, it will show brown on the leaf stem tissue	G7	0.8
Leaf margins are straighter than healthy leaves and curl away from petioles	G20	0.8
Leaves break easily	G21	0.8
Leaves look stiff	G22	0.8

The following tests can be carried out to carry out system testing using the Certainty Factor method and based on the data in Tables I and II—calculation of disease (*P1*). The user in table V selects the symptom data.

TABLE V
CALCULATION OF DISEASE RISK *P1*

SYMPTOM	CODE
The withering of shoots/growing point	G1
Plants/clumps of plants wither and turn yellow thoroughly	G3
The sudden withering of the plant	G5
Plants appear to be partially wilted (partially wilted clumps)	G6
If the stem is cut, it will look brown in the leaf stem tissue	G7
Leaf edges are straighter than healthy leaves and curl from the petiole	G20
Leaves are easy to break	G21
Leaves look stiff	G22

There are 2 (two) similar symptoms for *P1* disease, namely *G1* with expert weight value (*P*) is 0.9, User (*U*) is 0.8, G3 with expert weight (*P*) is 0.8, User (*U*) is 0.7 where *G1* is a potato plant shoot wilt/growth point, and *G3* is the growth point that wilts spread to old stems and leaves to the roots, then it can be calculated as follows:

P1 (Bacterial Wilt):

- Calculation of the CF value of the first symptom
  *CF = CF(PE) * CF(U) = 0.9 x 0.8 = 0.72 (First symptom CF results (G1))*
- Calculation of the CF value of the second symptom
  *CF = CF(PE) * CF(U) = 0.8 x 0.7 = 0.56 (Second symptom CF results (G3))*

The combined CF calculation is performed on all selected symptoms:

- Combination of symptoms 1 and 2
  CFc1 = CFsymptom1+ (CFsymptom2(1-CFsymptom1)) = 0.72 + (0.56 x (1-0.72) = 0.8768*

The results of the CF combination of 2 symptoms that enter the symptomatic condition in bacterial wilt disease are 0.8768. The accuracy results on potato plants attacked by bacterial wilt disease are 0.8768 x 100% = **87.68%**—calculation of Disease Risk 2 (*P2*). The user selects the symptom data in table VI.

TABLE VI
CALCULATION OF THE RISK OF DISEASE P2

SYMPTOM	CODE
The withering of shoots/growing point	G1
Plants/clumps of plants wither and turn yellow thoroughly	G3
The sudden withering of the plant	G5
Plants appear to be partially wilted (partially wilted clumps)	G6
If the stem is cut, it will look brown in the leaf stem tissue	G7
Leaf edges are straighter than healthy leaves and curl from the petiole	G20
Leaves are easy to break	G21
Leaves look stiff	G22

There are 3 (three) similar symptoms, namely *G5* with the value of expert weight (*P*) is 0.6, User (*U*) is 0.8, G6 with expert weight (*P*) is 0.9, User (*U*) is 0.8, *G7* with expert weight (*P*) is 0.6, User (*U*) is 0.8, and *G5* is the sudden wilting of the plants, *G6* is the plants that appear to be partially wilted, and *G7* is the yellow veins.

P2 Fusarium wilt:

- Calculation of the first symptom CF value
  *CF = CF(PE) * CF(U) = 0.6 x 0.8 = 0.48* (First symptom CF results (G5))

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- Calculation of the *CF* value of the second symptom
  *CF = CF(PE) * CF(U) = 0.9 x 0.8 = 0.72* (Result of second symptom CF (G6))
- Calculation of CF value of the third symptom
  *CF = CF(PE) * CF(U) = 0.6 x 0.7 = 0.42* (Third symptom CF results (G7))

Then the combined CF calculation is performed on all selected symptoms:

- Combination of symptoms 1 and 2,
  CFc1 = CFsymptom1+ (CFsymptom2(1-CFsymptom1)) = 0.48 + (0.72 x (1-0.48)) = 0.8544*
- Combination of CF values (symptoms 1 and 2) with symptom 3,
  CFc2 = CFc1 + (Cfg3(1-CFc1)) = 0.8544 + (0.42 x (1-0.8544)) = 0.91555*

The results of the CF combination of 3 symptoms that enter into the symptomatic condition of Fusarium Wilt disease are 0.91555. So the accuracy results on potato plants attacked by Fusarium Wilt are 0.91555 multiplied by 100%, yielding **91.555%**. Calculation of Disease Risk 3 (P6). The symptom data selected by the user is as in Table VII.

TABLE VII
CALCULATION OF THE RISK OF DISEASE P6

SYMPTOM	CODE
The withering of shoots/growing point	G1
Plants/clumps of plants wither and turn yellow thoroughly	G3
The sudden withering of the plant	G5
Plants appear to be partially wilted (partially wilted clumps)	G6
If the stem is cut, it will show brown on the leaf stem tissue	G7
Leaf margins are straighter than healthy leaves and curl away from petioles	G20
Leaves break easily	G21
Leaves look stiff	G22

There are 3 (three) similar symptoms, namely *G20* with a value of expert weight (*P*) is 0.8, User (*U*) is 0.9, *G21* with an expert weight (*P*) is 0.6, User (*U*) is 0.8, and *G22* with an expert weight (*P*) is 0.8, User (*U*) is 0.8. Where, *G20* is a leaf edge that is straighter than a healthy leaf and curls up from the petiole, G21 is a leaf that breaks easily, and G22 is a leaf that looks stiff.
P6 Diseases Due to Leaf Roller Virus:

- Calculation of the CF value of the first symptom
  *CF = CF(PE) * CF(U) = 0.8 x 0.9 = 0.72* (First symptom CF results (G20))
- Calculation of the CF value of the second symptom
  *CF = CF(PE) * CF(U) = 0.6 x 0.8 = 0.48* (Result of second symptom CF (G21))
- Calculation of the CF value of the third symptom
  *CF = CF(PE) * CF(U) = 0.8 x 0.8 = 0.64* (Third symptom CF results (G22))

Then the combined CF calculation is performed on all selected symptoms :

- Combination of symptoms 1 and 2,
  CFc1 = CFsymptom1+ (CFsymptom2(1-CFsymptom1)) = 0.72 + (0.48 x (1-0.72)) = 0.8544P*
- Combination of CF values (symptoms 1 and 2) with symptom 3,
  CFc2 = CFc1 + (Cfg3(1-CFc1)) = 0.8544 + (0.64 x (1-0.8544)) = 0.947584*

The results of the CF combination of 3 symptoms included in the symptomatic condition of Fusarium Wilt disease were 0.947584. The results of accuracy on potato plants affected by Disease Caused by Leaf Roll Virus is equal to 0.947584 multiplied by 100%, yielding **94.7584%.**

IV. CONCLUSION

According to the findings of the experiments that were carried out, it is possible to conclude that the CF method is capable of being incorporated into an expert system that can diagnose potato plant diseases according to manual calculations and can function optimally in detecting potato plant diseases based on the symptoms that manifest themselves with an accuracy value of 94%.

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