Expert System for Hydroponic Vegetable Cultivation Using Forward and Backward Chaining Inference Technique

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Abstract— Hydroponics systems require tremendous attention both in nutrition, plant growth, the risk of pest and disease attacks. Thus, this hydroponic farming system requires high experience and expertise that is the main obstacle for business actors who want to start a vegetable cultivation business with a hydroponic system, especially for business actors who do not have a background in agriculture. The hydroponic cultivation expert system in this study aims to detect plant diseases and pests and provide solutions to these diseases. In addition, this expert system application also aims to monitor plant needs, so this application can help farmers grow up hydroponic vegetable cultivation businesses. The combination of the forward and backward chaining methods is applied to detect plant diseases and pests. Whereas the forward chaining method use to monitor plant needs. The combination of the forward and backward chaining methods in identifying plant diseases and pests can make it easier for users to determine the suffered by plants and provide information about these diseases. The application of the forward chaining method in monitoring plant needs can identify the level of fulfilment of entails of each component of plant needs according to the type of plant and the day after planting. The application of this hydroponic expert system can overcome the limited number of hydroponic experts in helping farmers identify plant diseases and pests and monitor plant needs.

Keyword— Expert System, Forward Chaining, Backward Chaining, Hydroponic, Vegetable, Cultivation

I. INTRODUCTION

The development of science and technology is very influential on progress in agriculture so that agriculture can become more efficient, increase production, increase added value, and others. Advances in agriculture can be a solution to agricultural problems with conventional systems, especially for urban communities. Agricultural problems with regular systems involve land that is the capital for farming, water use, risks, or cultivation problems related to soil, namely insects, fungi, and bacteria that live in the land, and so on [1]. These problems can be solved by extant of a hydroponic farming system that can be carried out on narrow land, more efficient use water, higher quality and production yields, and various other advantages.

Farming with a hydroponic system has various things that must be considered that can be a weakness of this system. This system requires tremendous attention both in nutrition, plant growth, the risk of pest and disease attacks. Thus, this hydroponic farming system requires high experience and expertise that is the main obstacle for business actors who want to start a vegetable cultivation business with a hydroponic system, especially for business actors who do not have a background in agriculture.

The study [2] revealed that the sources of risk in the case study spinach farming at *PT Kebun Sayur* include production risk, marketing risk, financial risk, and natural resource risk. The highest threat that dominates is in production, namely climate and weather, pest and disease attacks, and seedling death. Sources of marketing risk which include the highest risk are perishable products, the emergence of similar competitor products, and limited market. Sources of financial risk include big capital, fluctuations in production input prices, rising fuel prices, and basic electricity tariffs.

Research conducted by [3] revealed that the sources of risk in the case study hydroponic vegetable farming at *PT Kusuma Agrowisata* and *Puspa Agro* are weather, pests and diseases, quality of human resources, inputs, and damage to technical equipment and building frameworks. Based on these sources of risk, we need a system that knows about experts about agriculture with a hydroponic system that can help farmers who will start a hydroponic vegetable cultivation business as an effort to overcome the sources of risk in hydroponic vegetable cultivation that is easily accessible by the farmer.

Artificial intelligence methods for expert systems, including Naïve Bayes [4], K-Nearest Neighbor (K-NN) [5], and Forward Chainin method [6]. The research conducted by [7] for diagnosing rice plant disease using forward and backward methods revealed that these systems could help farmers diagnose disease and provide information about these diseases. The forward chaining method was also applied in [8] for rubber plant disease detection to help farmers consult the plant's maladies. But the forward chaining method has the drawback that this method cannot detect plant disease if one of the decision rules is not matching [9].

The backward chaining method is also applied to help farmers to avoid the problem of their plants. Research conduct by [10] revealed that the backward chaining method could diagnose nutrient deficiency in hydroponic plants. The backward chaining method was also applied to diagnose chili plant disease in the research conduct by [11]; this research revealed that this method is helpful for farmers to early

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detection to disease suffered by the plant and give the solution to overcome these diseases.

Other than disease detection, the other essential thing that needs to be noticed in hydroponic vegetable cultivation is the plant needs. Thus, this research will carry out the design and development of the hydroponic expert system for plant diseases detection, and plants need to help farmers consult for their plants. To supervise the preparation and research, the researcher limits the scope of the study, namely applying an android-based expert system application for hydroponic vegetable cultivation with a case study on spinach.

II. Research Methodology

This application consists of two main features, namely, identifying plant diseases and pests and monitoring plant need so that this application becomes a complete hydroponic vegetable cultivation expert system application, as shown in Figure 1.

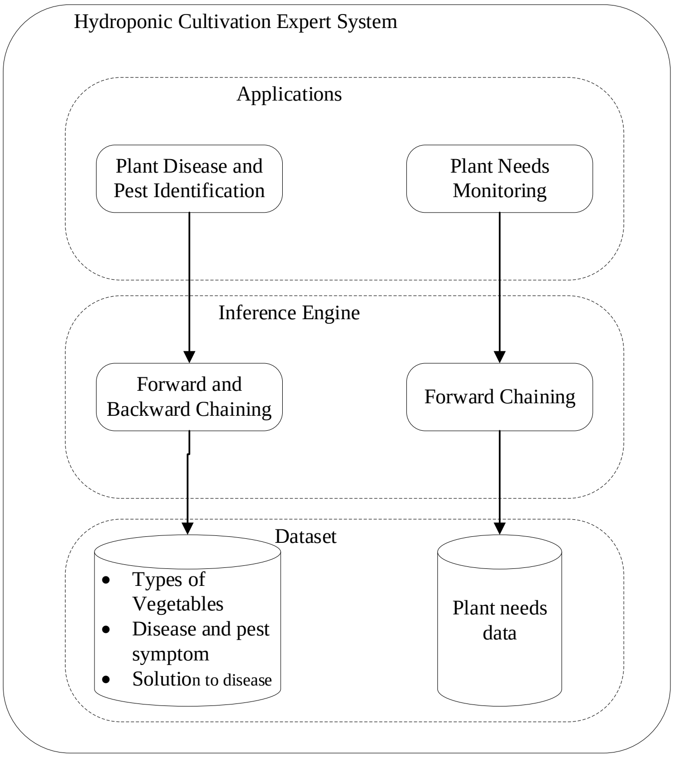

Figure 1. Application architecture of hydroponic vegetable cultivation expert system

A. Knowledge Base

The knowledge base used in this application needs information from the expert regarding the spinach as stated in the research limits. The knowledge base regarding spinach takes from [12] is visible in Table I.

TABLE I
SYMPTOMS OF PESTS AND DISEASES OF SPINACH PLANTS

Code	Types of Pests and Plant Diseases	Symptoms
K1	(P1) Spodoptera Plusia Hymenia	(G1) Perforated Leaves (G2) Leaving Bone Leaves
K2	(P2) Myzus- Persicae Thrips sp.	(G15) Crushed Leaves (G1) Perforated Leaves (G3) Withered Stem (G12) Withered Leaves
K3	(P3) Polyphagotarsonemus latus	(G15) Crushed Leaves (G1) Perforated Leaves (G3) Withered Stem
K4	(P4) Liriomyza sp.	(G15) Crushed Leaves (G1) Perforated Leaves (G3) Withered Stem (G2) Leaving Bone Leaves (G12) Withered Leaves
K5	(P5) Dumping Off	(G4) Sprout Growth is Not Normal (G3) Withered Stem (G5) Rotten Root (G6) Brownish Stem
K6	(P6) White Rust Disease	(G7) White Spots on Leaves (G8) Shrinking Leaves (G9) Leaf Roll-Up (G12) Withered Leaves (G10) Yellowish Leaf
K7	(P7) Downy Mildew	(G10) Yellowish Leaf (G11) Brownish Leaf
K8	(P8) Manganese Deficiency (Mn)	(G10) Yellowish Leaf (G13) Leaf Edges Become Curly (G4) Slow Leaf Growth
K9	(P9) Spinach Blight	(G8) Shrinking Leaves (G9) Leaf Roll-Up (G10) Yellowish Leaf
K10	(P10) Spot Leaf	(G11) Brownish Leaf (G15) Crushed Leaves

Based on the spinach diseases and pests knowledge base, then the decision rule is visible in Table II.

TABLE II
DECISION RULES OF SYMPTOMS OF PESTS AND DISEASES OF SPINACH PLANTS

Rule	Condition
1	IF G1 AND G2, THEN P1
2	IF G1 AND G3 AND G12 AND G15, THEN P2
3	IF G1 AND G3 AND G15, THEN P3
4	IF G1 AND G3 AND G2 AND G12 AND G15, THEN P3
5	IF G3 AND G4 AND G5 AND G6, THEN P5
6	IF G7 AND G8 AND G9 AND G12 AND G10, THEN P6
7	IF G10 AND G11, THEN P7
8	IF G4 AND G10 AND G13, THEN K8
9	IF G8 AND G9 AND G10, THEN P9
10	IF G11 AND G15, THEN P10

The knowledge base for spinach plants needs take from the study of [13] is visible in Table III.

TABLE III
SPINACH PLANT NEEDS

Plant Needs	Optimum
pH	6-7
Humidity	50-60%
Temperature	17-28 oC
Nutrition	1200 µS/cm (5-10 HST) 1800 µS/cm (10-15 HST) 2100 µS/cm (15-25 HST)

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Based on the spinach plant needs knowledge base, the decision rule for the spinach plant's needs is visible in Table IV.

TABLE IV
PLANT NEEDS RULE

Rule	Condition
1	IF pH < pH Optimum, THEN Low status
2	IF temperature < temperature Optimum, THEN Low status
3	IF Nutrition < Nutrition Optimum, THEN Low status
4	IF Humidity < Humidity Optimum, THEN Low status
5	IF pH = pH Optimum THEN, THEN Good status
6	IF temperature = temperature Optimum, THEN Good status
7	IF Nutrition = Nutrition Optimum, THEN Good status
8.	IF Humidity = Humidity Optimum, THEN Good status
9.	IF pH > pH Optimum, THEN High status
10	IF temperature > temperature Optimum, THEN High status
11	IF Nutrition > Nutrition Optimum, THEN High status
12	IF Humidity > Humidity Optimum, THEN High status

B. Inference Engine

The inference engine is part of a computer program that provides a methodology in reasoning the information provided by the user with the information contained in the database to formulate conclusions [14].

1) Forward Chaining: The inference engine used in this expert system application is the forward chaining method with a fact-matching mechanism starting with a condition statement (IF) first with a rule (IF-THEN) which can be seen in Figure 2 [15].

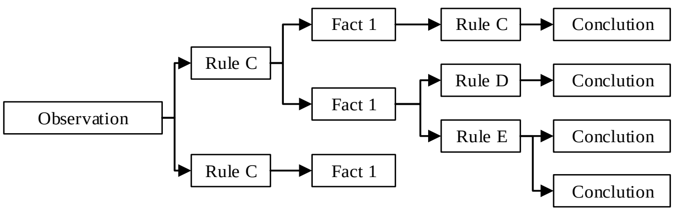

Figure 2. A forward-chaining inference engine

2) Backward Chaining: The backward chaining inference engine uses a goal-driven approach, starting with a goal that will occur, then looking for supporting evidence of that goal.

C. App Activity Diagram

The system requirement analysis results in two main features: plant needs monitoring and plant disease identification features. These features can be accessed by users when users open this application, as shown in Figure 3.

1) Identification of Plant Diseases and Pests: Users are provided with various types of vegetables to diagnose. Options of plant disease and pests symptoms appear to the user according to the kind of vegetable selected. The user enters the symptoms experienced by the plant and then forwards them to the expert system. The identification process of plant diseases and pests uses a combination of forward and backward chaining methods.

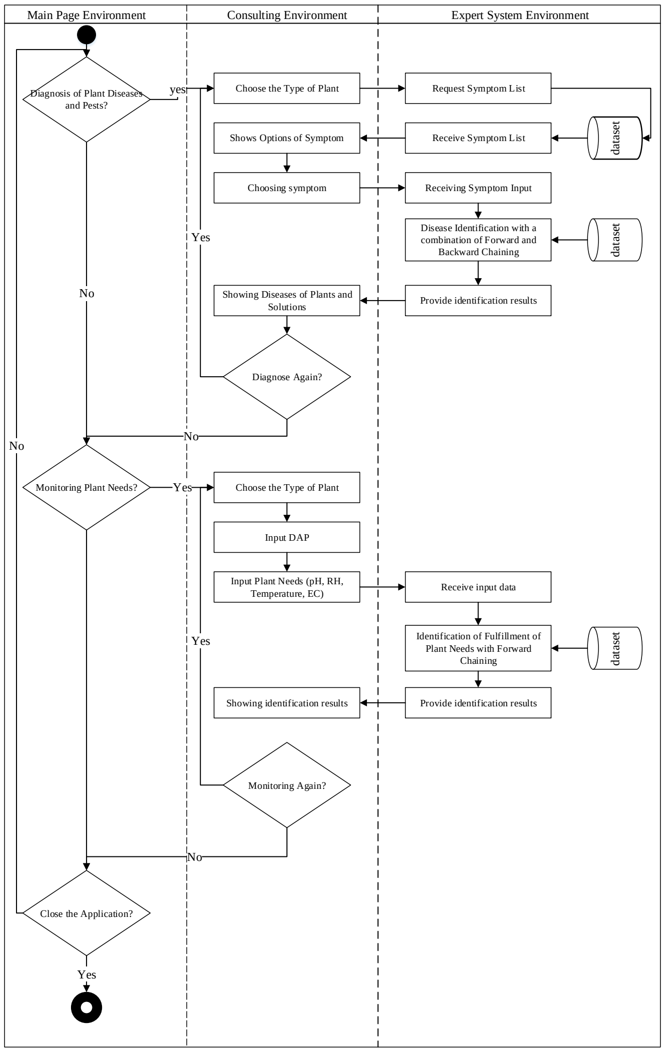

Figure 3. Application Activity Diagram

Diseases suffered by a plant can be more than one disease and make the user enter any symptoms found in the plant and cause the system to be unable to determine the disease suffered by the plant if the symptoms inputted are not by the rules. Therefore, the purpose of this combination of the forward and backward chaining methods is so that the system can determine more than one disease suffered by the plant. In addition, the application can return information on maladies suffered by plants even though the data entered is not entirely by the rules in the knowledge base. The result display to the users is the percentage of symptom fulfillment of a disease so that users can determine which is suffered by looking at the most percent.

The forward chaining method will give the disease related to the symptoms inputted by users. The backward chaining method will search for additional facts connected to these diseases that the whole of symptoms of the disease so the system can calculate the percentage of fulfillment by

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comparing the symptoms inputted by the user to the whole symptoms connected to these diseases. The combination of the forward chaining and backward chaining method can is visible in Figure 4.

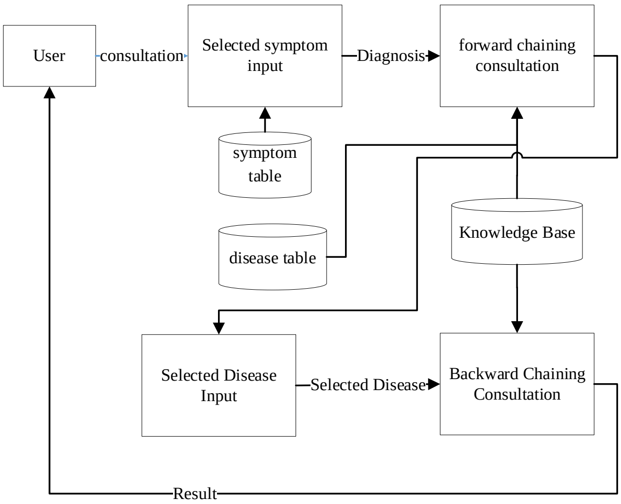

Figure 4. Combination of the forward and backward chaining methods

2.) Plant needs Monitoring: Users can monitoring plant needs for various types of plants. The spinner is available for users to choose the kind of plant that is available in the database. Users can diagnose pH, temperature, humidity, and nutrition in that feature by entered that data into the system. The identification process will result in the level fulfillment of the plant needs using the forward chaining method and return the result to the users.

D. System Testing

System testing in this application uses black-box testing with various scenarios to find out the bug and system error that make execution failed. Black-box testing is application testing in terms of a functional system that carries to find whether the input and output are by the specification without testing the design and code of the program [16].

III. Result and Discussion

A. Plant Disease and Pest Identification

The consultation of plant diseases and pests started with selecting the kind of spinach then choose the symptoms suffered by the plant that is yellowish leaves and brownish leaves, as shown in Table V.

TABLE V
PLANT DISEASES AND PETS CONSULTATION

Plant Type	Diagnose
Spinach	Leaf Roll-Up Brownish Leaf

The identification process of plant diseases and pests suffered by the spinach based on selected symptoms is shown in Figure 5.

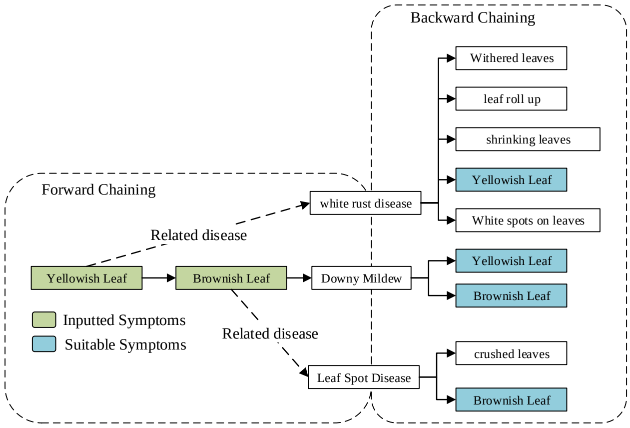

Figure 5. The identification process of plant diseases and pests

The selected symptoms will process by the forward chaining inference method. The facts of the symptoms will match with the information by the database with the IF-THEN rule, so the diseases related to the symptoms will appear. Based on these diseases, the symptoms connected to the disease will retrieve using the backward chaining method to found the supporting evidence. The data is visible in Table VI.

TABLE VI
CONSULTATION RULES BASED ON THE SELECTED SYMPTOMS

Plant Type	Disease	Symptoms
Spinach	Downy Mildew	Yellowish Leaf Brownish Leaf
Spinach	Spot Leaf	Brownish Leaf Crushed Leaves
Spinach	White Rust Disease	White Spots on Leaves Shrinking Leaves Leaf Roll-Up Withered Leaves Yellowish Leaf

All of the symptoms inputted by users were 100% fulfilled in Downy Mildew disease, 50% in Leaf Spot disease, and 20% in White Rust disease that visible in Table VII. Thus, the solution data to avoid these diseases can retrieve from the database. The result of plant disease and pets with the solution to these diseases will return to the users.

TABLE VII
PLANT DISEASE AND PEST DIAGNOSIS RESULT

Plant Type	Disease	Symptoms that must be met	symptoms are met	percentage (%)
Spinach	Downy Mildew	2	2	100
	Spot Leaf	2	1	50
	White Rust Disease	5	1	20

The next test is consultation with the case if symptoms are not by the decision rule designed before. The selected symptoms are shrinking leaves and leaf roll up as visible in Table VIII.

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TABLE VIII
PLANT DISEASES AND PETS CONSULTATION

Plant Type	Diagnose
Spinach	Shrinking Leaves Leaf Roll-Up

The identification process of plant diseases and pests suffered by the spinach based on selected symptoms is shown in Figure 6.

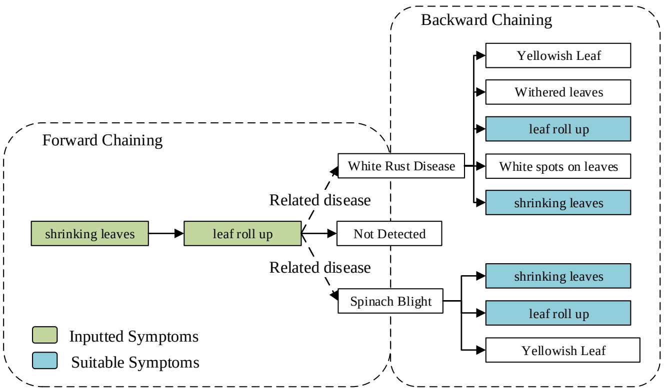

Figure 6. The identification process of plant diseases and pests with symptoms are not by rule

Each of these diseases has a relation with symptoms and solutions. Thus, the system can detect the shrinking leaves and roll-up leaves are related to the White Rust disease and Spinach Blight disease. The data is visible in Table IX.

TABLE IX
CONSULTATION RULES BASED ON THE SELECTED SYMPTOMS

Plant Type	Disease	Symptoms
Spinach	Spinach Blight	Shrinking Leaves Leaf Roll-Up Yellowish Leaf
Spinach	White Rust disease	White Spots on Leaves Shrinking Leaves Leaf Roll-Up Withered Leaves Yellowish Leaf

The symptoms inputted by users are met 40% in White Rust disease and 66,67% in Spinach Blight disease. So that, the disease suffered by the plant is Spinach Blight disease. The result is visible in Table X.

TABLE X
PLANT DISEASE AND PEST DIAGNOSIS RESULT

No	Plant Type	Disease	Symptoms that must be met	symptoms are met	percentage (%)
1.	Spinach	Spinach Blight	3	2	66.67
		White Rust disease	5	2	40

Hydroponics farmers, especially ones who do not have an agricultural background, sometimes cannot identify the symptoms suffered by the plant. Thus, the system cannot detect the disease if one of the symptoms in the rule is not fulfilled. So, the combination of the forward and backward chaining methods is helpful for plant disease and pest detection by searching for supporting evidence suitable with these diseases.

B. Plant needs Monitoring

The test was meet by selecting the type of spinach plant at the 20th DAP with three treatments, namely input data on plant needs according to plant needs, below plant needs, and above plant needs. Based on table 3, the necessity for pH, temperature, humidity, and nutrients for spinach plants at 20th DAP were 6-7, 17-28 oC, 50-60%, and 2100 S/cm, respectively. Experiments on each treatment are visible in Table XI.

TABLE XI
RESULTS OF THE PLANT NEED CONSULTATION AT 20 DAP

Plant Type	Plant Needs	HST	Treatment	Input	Output
Spinach	pH Temperature Humidity Nutrition	20	According to the needs of the plant	6 25 oC 60 % 2100 µS/cm	Good Good Good Good
	pH Temperature Humidity Nutrition		below plant needs	5 15 oC 45 % 1800 µS/cm	Low Low Low Low
	pH Temperature Humidity Nutrition		above plant needs	7.5 29 oC 80 % 2200 µS/cm	High High High High

All the results are following the needs of the spinach plant in 20 DAP. A "Good" output will appear in each of these components if by the needs, "Low" if each of these components is below the needs, and "High" if each of these components is above the needs.

C. Black-box Testing

The test was meet using the black-box test with various test scenarios for each feature with a resounding of 8 test scenarios. Based on the test results, all test scenarios were successfully executed, there are no bugs or application failures were found. Thus, the application could run all features correctly.

IV. CONCLUSION

The forward and backward chaining methods in identifying plant diseases and pests can make it easier for users to determine the suffered from the plants and provide information about these diseases. These combinations can resolve the problem of the identification process if the symptoms inputted by users are not by decision rule. These may help farmers that cannot see one of the symptoms in the decision rule, and the system will give the information in the most certainty percentage of the disease. The application of the forward chaining method in monitoring plant needs can identify the level of fulfillment of entails of each component of plant needs according to the type of plant and the day after planting. Based on the Black-box testing, this application could run well, with no bug or application failure were found. This application may help hydroponics vegetable cultivation farmers to avoid plant diseases and pests and may control the needs of the plants. This

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application may resolve the limited of hydroponics experts to help farmers consult their plants.

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