Application of Certainty Factor Method in Diagnosing Nutrient Deficiency in Coffee and Coconut Plants

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Abstract

Plantation Coffee and coconut are superior export commodities that have a high investment value in maintaining the economy and balancing the balance of plantation commodities in Indonesia. One of the obstacles that is often experienced by managers of coffee and coconut cultivation is a lack of understanding in the diagnosis of plants that are deficient in macro and micro nutrients, as the main needs for quality of the results. On the other hand, the number of plantation crop experts is relatively small. Seeing these conditions, this study has built an expert system that is able to diagnose the symptoms of nutrient deficiency in coffee and coconut plants. The expert system is built by applying the certainty factor method, so that it can overcome the problem of uncertainty in diagnosing. The percentage level of certainty is obtained from the MB and MD assessment of an expert. This expert system was built using the Expert System Development Life Cycle method. The results of this study are a web-based expert system that is suitable for use by managers of coffee and coconut cultivation in diagnosing nutrient deficiencies, so that it can be known in detail independently and can reduce production costs.

Keywords *— Certainty Factors, Nutrient Deficiency*

1. INTRODUCTION

The progress of science and technology in Indonesia, which is increasingly developing, has a transitional impact on various industrial sectors. The development of plantation crops consisting of coffee and coconut is a plantation industry in Indonesia that is capable of leading to food self-sufficiency. Products from the plantation sector are a strategic component in supporting the development of domestic market share in order to increase foreign exchange export commodities. The role of the plantation sector has had a positive impact on increasing significant economic growth, such as Gross Domestic Product (GDP), value added foreign exchange exports, economic resilience and environmental aesthetics. Indonesia itself has a center for research and development of plantation crops which contribute to improvements in the field of information technology and constructive scientific value.

Coffee plantation (*Coffea spp*.) Is a grain commodity that grows and develops in tropical temperatures and is included in the category of shrub crops. However, the important contribution of coffee has a special appeal to the eyes of the world of plantations and international trade which accounts for half of the total exports of tropical commodities [1]. Commodities that have the benefit of caffeine levels to relieve fatigue and increase alertness for humans are prone to experiencing ups and downs in their productivity results. 2018 when viewed from its exploitation, the productivity of coffee commodities experienced a decrease of 28.14 thousand tons from the previous one in 2017 which had an increase in productivity of 32.16 thousand tons [2][3]. One of the problem factors affecting the level of development of the coffee variety industry is the lagging production technology where in general coffee factories in Indonesia are old and the machines used to produce coffee are not standardized [4] and in terms of maintenance and cultivation of commodities, it is still not optimal which

results in productivity. Depreciation due to the impact of nutrient deficiency symptoms. Depreciation due to the impact of nutrient deficiency symptoms. Likewise, coconut plantations (Cocos Nucifera L.), which can be called people's plants, also have a role as a superior commodity because they have a strategic position as raw material for making coconut oil. Adults, almost all members of the coconut plant body have, their respective benefits. It is possible if coconut varieties have great potential to become industrial exporters of the agricultural sub-sector and have a high enough selling value and demand for the survival of Indonesian farmers. However, there are still many problems with coconut commodity cultivation in Indonesia. Problems that often occur in the agricultural and plantation extension services are due to the lack of superior seed consumption and land maintenance, which is a factor in the influence of nutrient nutrition for plants. The results of the increase in coffee and coconut plantation commodities certainly cannot be separated from good and convincing production power, the possible productivity power can also experience depreciation if many varieties of groups experience disease attacks that lead to mass nutrient deficiency.

In the cultivation of coffee and coconut plantations, there are problems that must be handled by the extension officers. Likewise, the factor of low productivity or even crop failure of a commodity production result is caused by aging and damaged, untreated plants and also allows for reduced control in overcoming pests and handling massive nutritional deficiencies by utilizing technology as a whole.

Nutrient disturbance in crops is a major problem for farmers in the world, in addition to other important problems. Continuous cropping systems and increasing cropping intensity have resulted in greater nutrient disturbance problems [5]. Based on this description, a website-based technology was built in the plantation sector regarding an expert system for diagnosing nutrient deficiencies in coffee and coconut plantations. Expert systems have been developed with various methods in solving them. However, in this research, researchers used certainty factor inference techniques. The reason for certain researchers using this method is because the certainty factor is able to provide calculations based on the weight of certainty entered to give accurate results according to the weight of the given symptom value. Likewise certainty factors are able to state evidence of the results of uncertainty in the diagnostic process.

With this expert system development solution, it is hoped that plantation farmers and the general public can quickly solve problems in agricultural areas, moreover, be able to produce varieties that have competitiveness and technology that are able to maintain or even increase the best production so that they can compete in the local market. And internationally. This of course can be useful for coffee and coconut plantation farmers to find out directly the nutrients for these plantation crops.

1.1. Theoretical Basis

In this literature review section, researchers direct the search, find and study theoretical reference materials and other literature related to the concept of the research being carried out. The purpose of doing literacy here is to serve as a basis in forming a frame of mind and assist in the process of solving problems that have been recognized. Based on the formulation of the problem, in this study literacy is focused on concepts obtained from the results of a literature study that discusses expert systems for diagnosing nutritional deficiencies of coffee and coconut plantations with certainty factor methods and other methods such as forward chaining as an auxiliary process to trace forward search.

1.1.1. Expert System

Expert systems are intelligent computerized programs that are developed using various programming languages which are then implemented with the aim of substituting human insights into a knowledge base that is more flexible and has high performance. One of the objectives is to accommodate problems and also in addition to increasing the capability of

decision makers. Not that a smart system is built to replace the job duties of an expert. There are two important things from the expert systems section including the development environment and the consultative environment. The developer environment is used as an expert system development, both in terms of component development and knowledge base. "The consultation environment is used by users to consult so that users get knowledge and advice from an expert system as if consulting an expert" [6]. In its application, the expert system has a component which is packaged into a set known as the expert system architecture. Expert system architecture itself has two important elements and in it collects the driving components of the system, including the interface, knowledge base, inference engine, working memory, explanation facilities, knowledge acquisition, and knowledge improvement.

1.1.2. Inference Engine

As a feature of expert system software that has the task of forming rules and reasoning engines in the knowledge base storage, the inference mechanism is part of an expert system that does reasoning by using the contents of a list of rules based on certain rules and patterns. During the consultation process between the system and the user, the inference mechanism tests the rules one by one until the rule conditions are correct. The function of the inference motor is proof of the hypothesis. When the hypothesis have been entered into the expert system, the inference motor first checks whether the hypothesis have already been in the database or not. If there is, then the hypothesis is considered a proven fact, so that the operation does not need to be continued [7]. The arrangement of the mechanism itself is carried out with a certain approach that involves the conversion and representation of knowledge into an inference mechanism. For example, the conversion of a decision tree into the If-Then rule. The forward chaining sequential search can be said to be a line of reasoning that is driven by facts from a portion of a data set and used as a result of conclusions and solutions to problems. The initial process carried out is looking for rules for facts that match the premise, which one by one is tracked until they are found for finding new facts until no more rules or premises are obtained. Fact tracing starts from the left to the right (if-then) as a production rule. The figure below describes the line of reasoning from the general method of forward chaining.

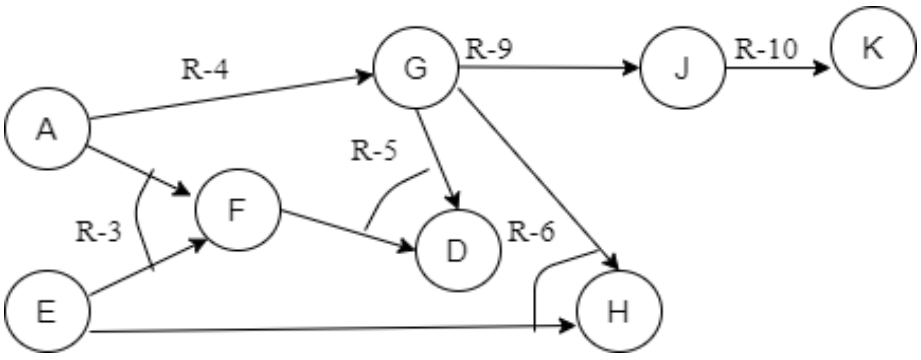

Figure 1. Forward Trace, Tracking Diagram [8]

1.1.3. Certainty Factor

The certainty factor method is a method introduced by Shortliffe and Buchanan to accommodate an uncertainty of thought (inexact reasoning) in the making of the MYCIN project [9]. Likewise, the certainty factor method is one of the clinical parameters given to the MYCIN project to show the level of confidence. By using the certainty factor method, it is very suitable to be used to find out or diagnose an answer to a problem that has no or uncertain level of confidence. Likewise, the certainty factor itself works using values to assume the

degree of certainty of an expert on a data. The following below is a definition of the certainty factor method:

$$\mathbf{CF\ [H, E] = MB\ [H, E] - MD\ [H, E]} \quad (1)$$

CF [H, E] = Certainty factor of hypothesis H is influenced by the premise (evidence) E. The size of the certainty of CF ranges from -1 to 1. The value of -1 is expressed as absolute uncertainty while the value of 1 is shown as absolute certainty.
MB [H, E] = Measure of Increased Belief (a measure of increased confidence) on hypothesis H, if evidence E is provided (between values 0 and 1).
MD [H, E] = Measure of Increased Disbelief (a measure of increased distrust) against hypothesis H, if evidence E (between values 0 and 1) is provided.
H = Hypothesis (Estimation)
E = Evidence (fact of event or evidence).

If the basic formulation has not been found in the value of CF for each premise that causes deficiency and if all, the premise statements against the antecedent (IF) are known with certainty, then the equation changes to CF [E, e] = CF [H, E]. The combination of CF that is used to diagnose is

a. Certainty factor with one premise:

$$\mathbf{CF[h,e] = CF[e] * CF[rule] = CF[user] * CF[expert]} \quad (2)$$

b. Certainty factor for a combination of rules with the same conclusion (similar conclusion rules) [10]:

$$\mathbf{CF\ combine[CF1, CF2] = CF[H,E]1 + CF[H,E]2 * (1 - CF[H,E]1)} \quad (3)$$

$$\mathbf{CF\ combine[CF}\mathit{old}\mathbf{,\ CF3] = CF[H,E]}\mathit{old}\mathbf{ + CF[H,E]3 * (1 – CF[H,E]}\mathit{old}\mathbf{)} \quad (4)$$

$$\mathbf{Confidence\ level = CF\ combines * 100.} \quad (5)$$

To determine the percentage confidence level, the CF combined results are multiplied by 100 [11]. Below is a table of interpretation of "term" symptom weight values from the representation of expert beliefs that have been converted into certainty factor values. Below is a table for the interpretation of certain factors.

Table 1. Certainty Factor Interpretation

No	Explanation (Certainty Term)	CF Value
1	Very confident	1
2	Sure	0,8
3	Pretty sure	0,6
4	Little sure	0,4
5	Don't Know Enough	0,2
6	Do not know	0.4
7	Very Unsure	0,11 - 0,15
8	Not sure	0,06 – 0,10
9	A little unsure	0 – 0,05

Table 2. Conclusion Percentage Rate

No	Percentage	Certainty Explanation
1	95% - 100%	Sure Yes
2	80 % - 95 %	Almost Certainly Yes
3	70% - 80%	Most likely Yes
4	51 % - 70%	Maybe
5	0 % - 50 %	Small possibility

1.1.4. Literature Review

To support the design process and research on expert systems, it is necessary to conduct a literature study to support the method applied, here are some other previous studies related to expert systems:

Wulandari, et al in 2018, conducted a study entitled "Designing a Website-Based Watermelon Plant Growth Detection Expert System with Certainty Factors". In this research, the system development process uses a Use case and SDLC (System Development Life Cycle) which consists of system planning, system analysis, system design, implementation, and maintenance. In this study using a certain method which produces an expert system that is used as a watermelon growth detector with the criteria for the value determined by the expert and has a certain level of 99.70% [12].

Mulyani, in 2020, conducted a research entitled "Expert System For Cupping Treatment Using Case Based Reasoning Method". The essence of this research is to build an expert system as a consulting tool that can provide knowledge about the therapist who determines the point of cupping as a fast and precise treatment. The reasoning method used in the research is a CBR (Case Based Reasoning) as a method of solving problems that are similar and have occurred in the past and then apply the information or knowledge as a source to solve other new problems. Expert applications produced using website technology and research flow using the waterfall method [13].

Yuwono, et al in 2017, conducted a study entitled "Application of Forward Chaining Methods and Certainty Factors in the Expert System for Diagnosing *Coelogyne Pandurata* Pests". In his research, the Coelogyne pandurata orchid can only grow in Kalimantan soil. Adults also to maintain the sustainability of this plant, which is better known as the black orchid, requires human intervention, because this plant is very susceptible to pest attack. But regarding the sustainability of the black orchid plant life, there are still many lay people who do not know explicitly the signs of symptoms due to pests and diseases that are difficult to recognize. Therefore, an expert system application was built that was able to diagnose black orchid plant pests using the forward chaining method and certainty factors and also using the basis of website technology [14].

From the exposure of other studies above, it can be concluded that expert systems have been developed in various industrial sectors of human work along with a combination of algorithmic methods that are applied as needed. Plus the mature technology base that has been widely applied to expert systems includes desktop, mobile, and the web.

So by comparing previous research or literature reviews, the problem to be discussed is adding more symptoms and existing nutrients, then a solution to the symptoms of the nutritional needs of coffee and coconut plantations. The input made by the user in this system is when the user selects a list of symptoms of nutritional deficiency with their respective possibilities and the output results in the percentage of nutrient levels needed by plants and solutions and details about recommended nutrient elements. This study uses the method of calculating certainty factor (CF) in calculating the percentage level of expertise or the degree of certainty and forward continuity as a future search process. The research data consisted of symptom data and nutrient data on coffee and coconut plants, as well as regulatory data. The expert system in the organization itself is aimed at adding value, increasing productivity and

managerial areas that can draw conclusions quickly. Likewise, the reason researchers use website technology is because it is very flexible if it is used in various devices and if there is an update or information, the developer only updates the server used and all users will get the information needed.

2. RESEARCH METHOD

The research methods and supporting materials used to produce the parameters needed in this study, among others:

2.1. Data Collection Technique

In writing this report the authors use various methods in the data collection process used are as follows:

Observation

An observation stage as material that involves collecting data on research through literacy sourced from books and journals related to expert research and plantations in the plantation sub-sector, theoretical secondary data from the internet and other supporting sources for compiling research reports.

Interview

The interview method is carried out directly by giving various questions about the deficiencies of coffee and coconut plantations in order to obtain useful information. Sources who are willing to be interviewed are Ir. Misgiyati Irian Mulyani with the position of Intermediate BPTPHP Central Java BPTPHP who is an expert in agriculture and plantation.

Literature Study

With this literature study method, it can support information to obtain secondary data from books related to references related to methods and problems experienced.

2.2. Research Design Stages

The following are the stages carried out in this research on the system that is being built and researched using the ESDLC method and other supporting methods such as knowledge acquisition, certainty factor inference engines and data collected through interviews and other literacy.

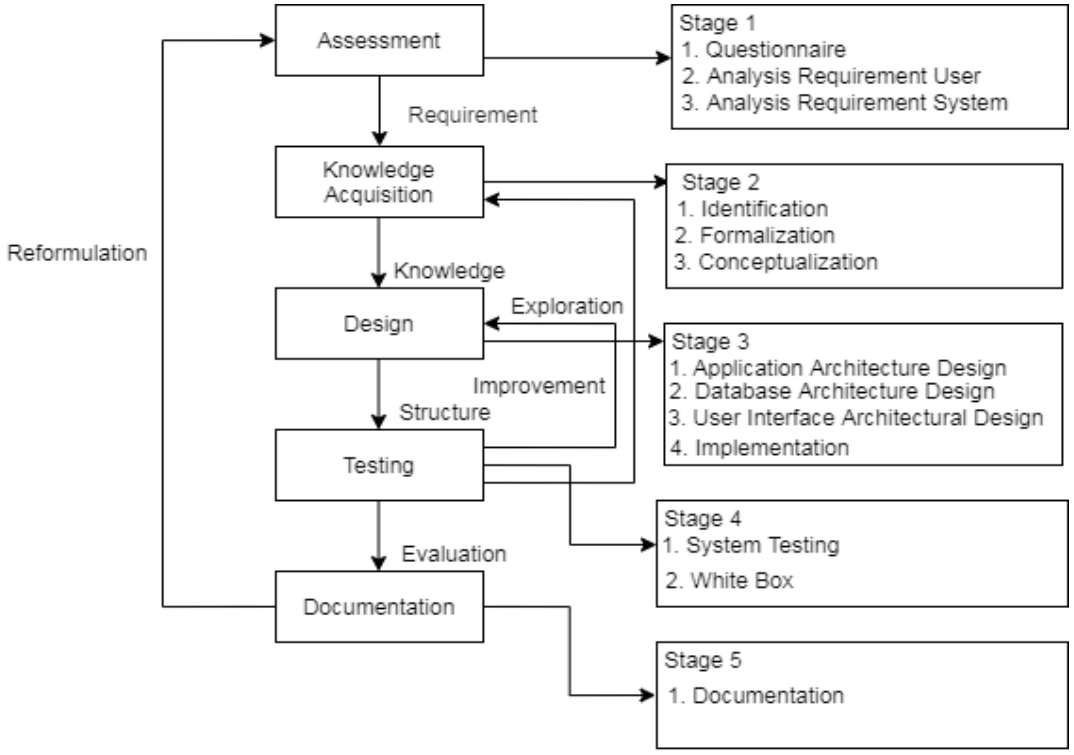

Figure 2. ESDLC Research Design Stages

3. RESULTS AND DISCUSSION

The main parameter in the expert system is the knowledge base which contains unique facts about several rules that are used as a basis for knowledge obtained from expert sources and other supportive literacy. In this case the production rule is needed to represent it in the IF-Then form. This section will discuss the results and discussion of the research that have been done.

3.1. Knowledge Acquisition

Knowledge acquisition is the process of extracting and gathering available knowledge sources and is an accumulation of problem solving from an expert as well as official documented sources and the potential to broaden the knowledge base. Knowledge acquisition is obtained from journals, proceedings, articles, books, and interviews with Ir. Misgiyati Irian Mulyani with the position of Intermediate POPT BPTPHP Central Java at the Salatiga Plantation Protection Center, located on Jl. Hasanuddin No. 833. Nutritional element data used are nutritional elements that are generally needed and are often used when a crop in the agricultural and plantation sectors is deficient in nutrient nutrients.

Below is a data table that explains the types of nutritional elements needed and the types of deficiencies needed by coffee and coconut plants which are addressed in table 3.

Table 3. Nutritional Elements

No	Nutritional Deficiency Codes	Types of Nutrient Deficiency
1	N01	Nitrogen (N)
2	N02	Phosphorus (P)
3	N03	Potassium (K)
4	N04	Calcium (Ca)

5	N05	Magnesium (Mg)
6	N06	Sulfur (S)
7	N07	Boron (B)
8	N08	Iron (Fe)
9	N09	Copper (Cu)
10	N10	Manganese (Mn)
11	N11	Molybdenum (Mo)
12	N12	Zinc (Zn)

Below is a table of symptoms where each of these symptoms is often experienced by coffee and coconut plantations. As explained above, the data used is secondary data obtained from direct observation of plants in plantations and other existing sources through literacy journals related to plantations and agriculture, expert systems, scientific articles, e-books, books, interviews with experts and Another reference source that supports and obtained quite plural is 73 symptom data which makes this study an advantage by adding a lot of deficiency symptoms and types of plant nutrient requirements. However, if there is a deficiency symptom regarding shoots, it is certain that this symptom is a symptom of coconut plants. Likewise, it does not mean that other related symptoms may occur in coconut plants and also allows the two commodities accordingly to have deficiency symptoms that are in line with the nutritional needs of the 12 nutrients mentioned in table 3 above.

Table 4. Symptoms of Plant Nutrient Deficiency

Symptom Codes	Symptom Name
G001	Old and young leaves are chlorotic and necrotic
G002	Young leaves turn pale green
G003	Stunted shoot growth
G004	Old leaves are pale green to yellowish shiny
G005	The leaves turn yellow, dry up and fall off, yellowing leaves start from the lower leaves and then the upper leaves and do not bloom
G006	Child bones, leaves and leaf blade shrink and roll inward
G007	The leaves are bright orange and brownish orange in color
G008	Leaving a few dark green leaves between the leaf bones
G009	Old leaf bone changes to a bright yellow color
G010	The appearance of brown spots is a sign of the death of the enlarged leaf tissue cells
G011	Stunted root growth
G012	Leaf bones are bright yellow
G013	The resulting fruit is small and ugly and ripens quickly
G014	The edges of the older leaves turn yellow followed by the appearance of brown spots
G015	Slow plant growth
G016	The spots are broad along the edge of the leaf with a dark edge that is predominantly yellow in color
G017	The resulting flowers fall off and fall easily
G018	There is a hole in the youngest leaf that has not opened
G019	The color of the leaves is faded and there are brown spots on the tips of the leaves
G020	Leaves dry yellow curl starting from old leaves
G021	Fruit fall easily
G022	Edge of the leaf blade like a V upside down and fall
G023	The drooping fronds are dull and pale
G024	The edges of the leaves are yellowish bronze and roll down

G025	Leaves fall off easily
G026	Coconut trunks are empty and rotten
G027	The base of the leaves has died
G028	Roots do not develop and are stunted
G029	Dead leaf buds
G030	Weak plant growth
G031	Older leaves that are exposed to sunlight will be yellowish green
G032	The leaf color turns brown and dries up from the side of the leaf blade
G033	The growth of seeds is weak and reduced
G034	Old leaves turn into yellow spots between the bones of the leaf
G035	The leaves are attacked by powdery mildew

3.2. Expert Knowledge Base

The knowledge base is a medium that contains phenomenal fact knowledge obtained from humans and transformed into a computer system. One of the goals of knowledge representation is to describe the features of the real world into formal language. Representation of knowledge itself against expert systems is a way that provides a standard strategy of production rules that relate antecedents and consequences in the form of IF-THEN (left side). IF is a prefix statement as an antecedent that carries out a premise or condition. Whereas THEN as a consequence is an action that is carried out if the conclusions applied are correct. Production rules themselves provide a general way of representing a rule and strategy. Below is a representation of the knowledge base rule into production rules:

Table 5. Expert Formation Rule

No	Expert Rule
1	**IF** Old and young leaves are chlorotic and necrotic (G001) = True, **AND** Young leaves turn pale green (G002) = True, **AND** Stunted shoot growth (G003) = True, **AND** Old leaves are pale green to yellowish shiny (G004) = True, **AND** The leaves turn yellow, dry up and fall off, yellowing leaves start from the lower leaves and then the upper leaves and do not bloom (G005) = True, **AND** Child bones, leaves and leaf blade shrink and roll inward (G006) = True, **AND** The leaves are bright orange and brownish orange in color (G007) = True, **AND** Old leaf bones change to a bright yellow color (G009) = True, **THEN** Nitrogen (N) (N01).
2	**IF** The leaves are bright orange and brownish orange in color (G007) = True, **AND** Leaving a few dark green leaves between the leaf bones (G008) = True, **AND** Old leaf bone changes to a bright yellow color (G009) = True, **AND** The appearance of brown spots is a sign of the death of the enlarged leaf tissue cells (G010) = True, **AND** Stunted root growth (G011) = True, **AND** Leaf bones are bright yellow (G012) = True, **AND** The resulting fruit is small and ugly and ripens quickly (G013) = True, **AND** The edges of old leaves turn yellow followed by the appearance of brown spots (G014) = True, **THEN** Phosphorus (P) (N02).
3	**IF** Slow plant growth (G015) = True, **AND** The spots are broad along the edge of the leaf with a dark edge that is predominantly yellow in color (G016) = True, **AND** The resulting flowers fall off and fall easily (G017) = True, **AND** There is a hole in the youngest leaf that has not opened (G018) = True, **AND** The color of the leaves is faded and there are brown spots on the tips of the leaves (G019)= True, **AND** Leaves dry yellow curls starting from old leaves (G020) = True, **AND** Fruit fall easily (G021) = True, **AND** Edge of the leaf blade like a V upside down and fall (G022) = True, **THEN** Potassium (K) (N03).

4	**IF** Slow plant growth (G015) = True, **AND** The drooping fronds are dull and pale (G023) = True, **AND** The edges of the leaves are yellowish bronze and roll down (G024) = True, **AND** Leaves fall off easily (G025) = True, **AND** Coconut trunks are empty and rotten (G026) = True, **AND** The base of the leaves has died (G027) = True, **AND** Roots do not develop and are stunted (G028) = True, **AND** Dead leaf buds (G029) = True, **AND** Weak plant growth (G030) = True, **AND** The part of the leaf between the leaf bones turns yellow, wilted and narrow and rolls down (G067) = True, **THEN** Calcium (Ca) (N04).
5	**IF** Leaves dry yellow curls starting from old leaves (G020) = True, **AND** Older leaves that are exposed to sunlight will be yellowish green (G031) = True, **AND** Leaf color turns brown and dries up from the side of the leaf blade (G032) = True, **AND** The growth of seeds is weak and reduced (G033) = True, **AND** Old leaves turn into yellow spots between the bones of the leaf (G034) = True, **AND** The leaves are attacked by powdery mildew (G035) = True, **THEN** Magnesium (Mg) (N05).

3.3. Decision Tree

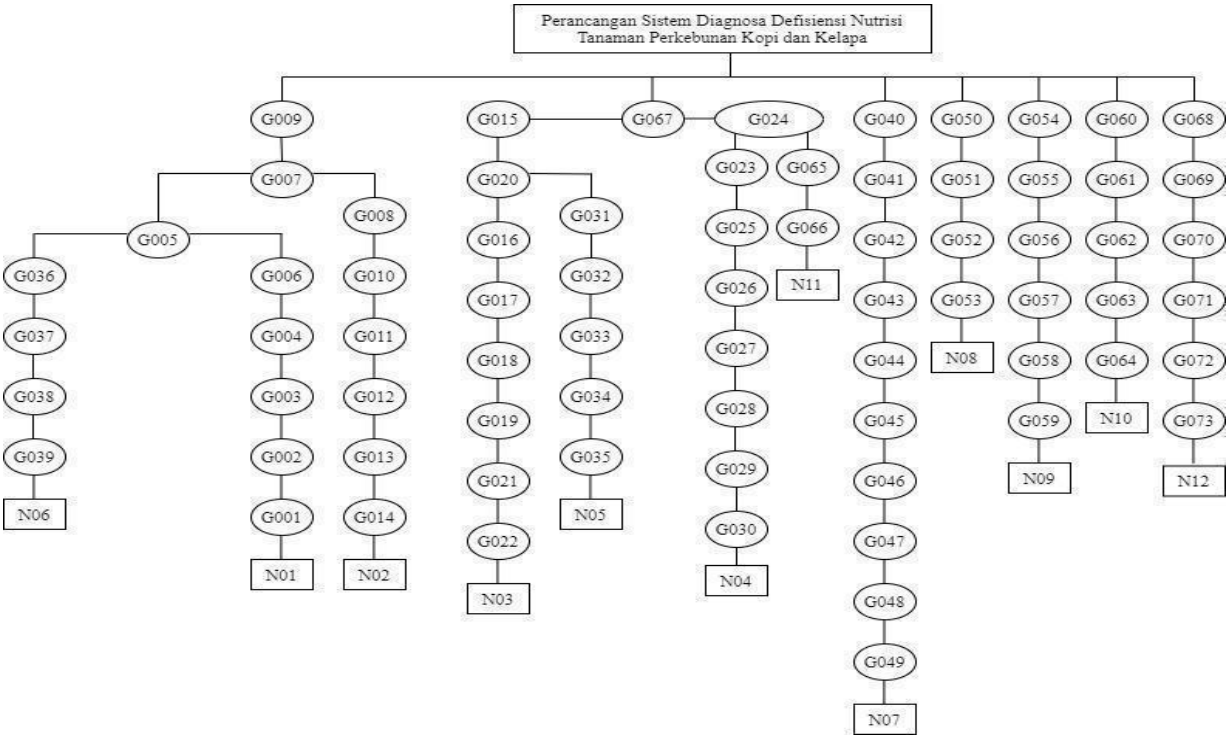

Figure 3. Decision Tree

3.4. System Design

The following below is a design architecture using UML in making the system.

3.4.1. Use Case Diagram

The use case designed in figure 4 represents actions taken by one or more actors. The use case below is used to find out the functions and several actors who are given access rights to carry out functions in the system. Below is the correlation between actors and the system.

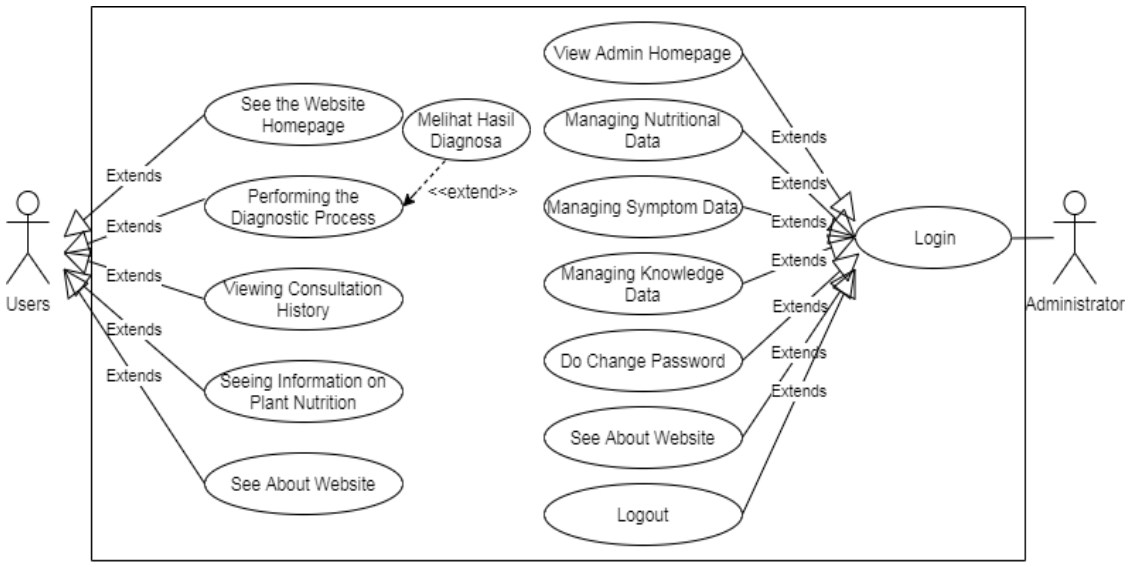

Figure 4. Use Case Diagram

3.4.2. Activity Diagram

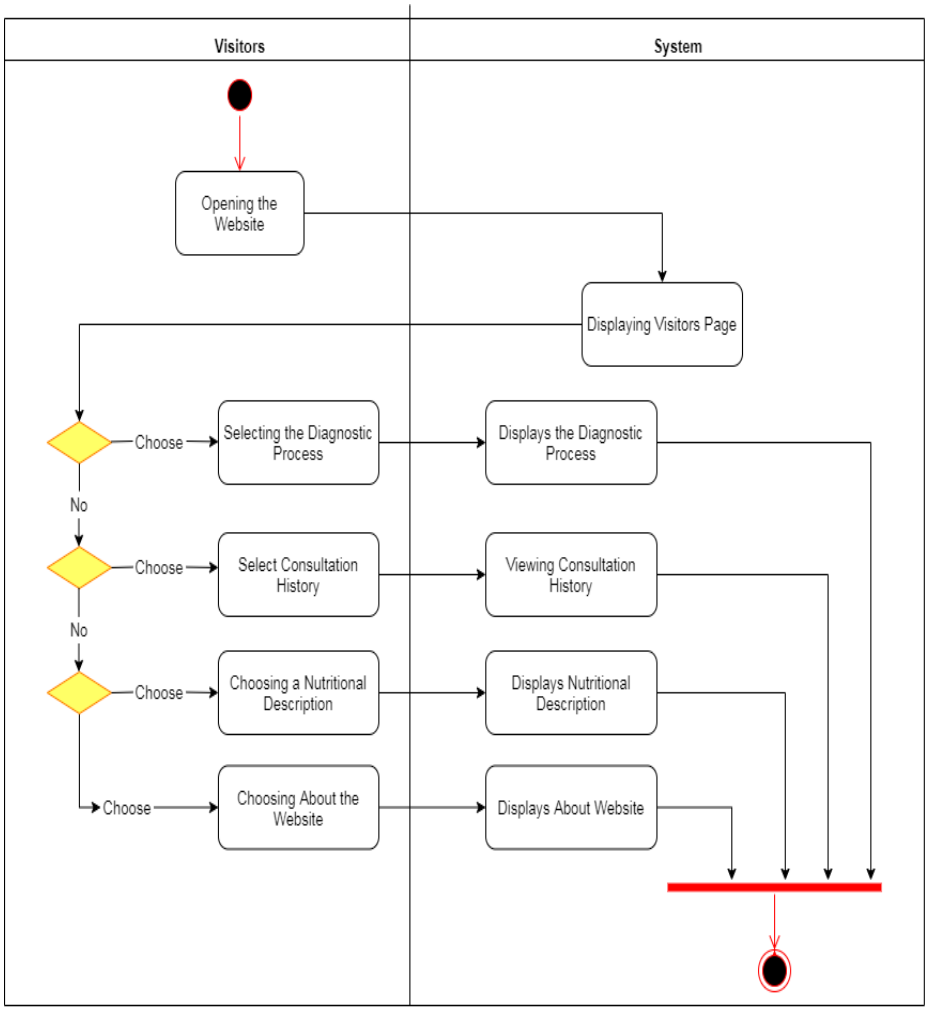

Figure 5. Visitor / User Activity Diagrams

3.4.3. Class Diagram

The class diagram that describes the system structure by modeling several classes and attributes between objects can be seen in figure 6 below.

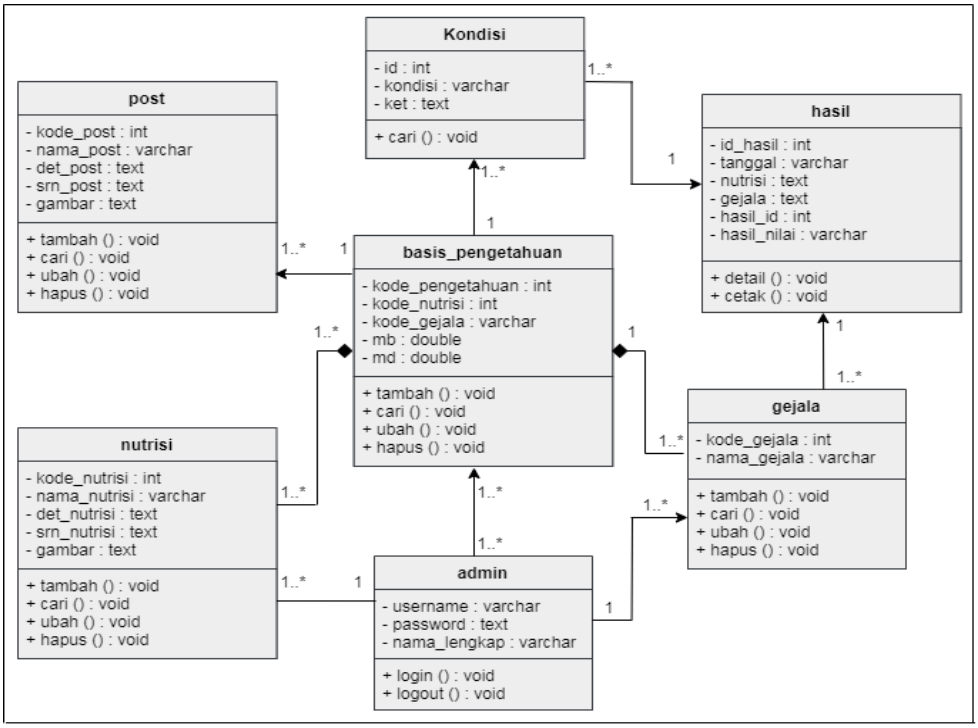

Figure 6. Class Diagram

3.5. Implementation of the Certainty Factor

The following is the application of the percentage level value of certainty factor method for one of the nutrient deficiencies that can be selected by the user based on the symptoms experienced by the commodity. Symptoms of deficiency in the expert system itself have their respective weight conditions and certainty ranges based on those selected by the user.

Table 6. Diagnostic Data Samples

No	Selected Symptoms	Selected Conditions	MB	MD	CF *User*
1	Old and young leaves are chlorotic and necrotic	Most likely Yes	0.70	0.07	0.63
2	Young leaves turn pale green	Sure Yes	0.80	0.06	0.74
3	Stunted shoot growth	Most likely Yes	0.70	0.8	0.62

The calculation for the first of the three symptoms of nutritional deficiency is as follows:

$$(0.63 + 0.74 + 0.62) / 3 = 0.66 * 100 (66\%) \quad (6)$$

Calculations for nutritional deficiency symptoms of the three above:

$$0.66/3 = 0.22 * 100 (22\%) \quad (7)$$

Dividing 3 is taken from the number of symptoms entered and the total result must be multiplied by 100%, neither less nor more. Percentage result

(66% + 22%) = 88% (8)

Based on the results of consultations using simple calculations, the percentage value of the level of certainty experienced by commodity users based on symptoms is 88% with a certainty level of "Almost Certainly Yes" which has a range of 80% - 95% along with nutritional deficiencies that are outputted is Nitrogen (N).

3.6. Result of Expert System Running Process

This section discusses the implementation of software that has been built based on a needs analysis and the design process. Expert system design that has been done is using the PHP programming language and database storage media using MySql.

3.6.1. Diagnosis Page

Figure 7 shows the diagnosis page. On this page the user selects the condition of the symptoms suffered by plants and if it has been selected, the visitor clicks the magnifying glass button in the lower right corner.

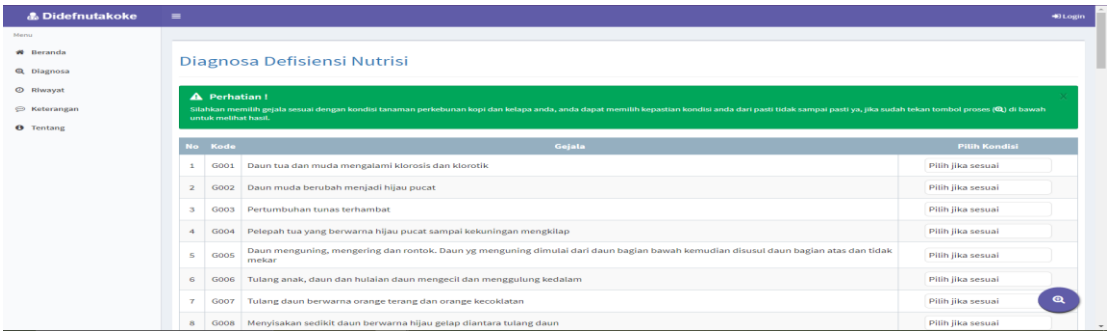

Figure 7. System Diagnostics Page

3.6.2. Diagnosis Results Page

After conducting the diagnosis, the results of the diagnosis form will output in the form of nutrients needed for related commodities and the results of the percentage level of certainty for the calculation of certain factors and solutions for handling, nutrient deficiencies of the selected symptoms and can print them by pressing the print button.

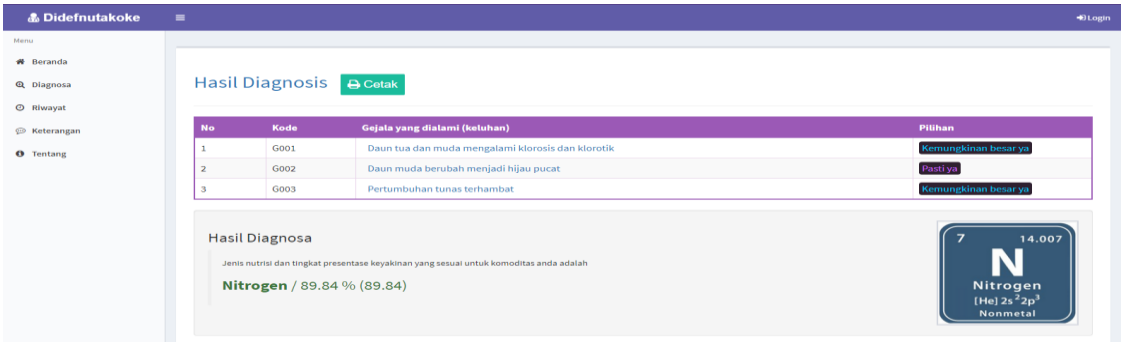

Figure 8. Diagnosis Results Page

3.7. System Testing

Testing this system using white box testing by testing expert algorithms taken from functions related to the main process and described by flow graph. Then the Cyclomatic complexity is calculated and explained in detail through the basis path.

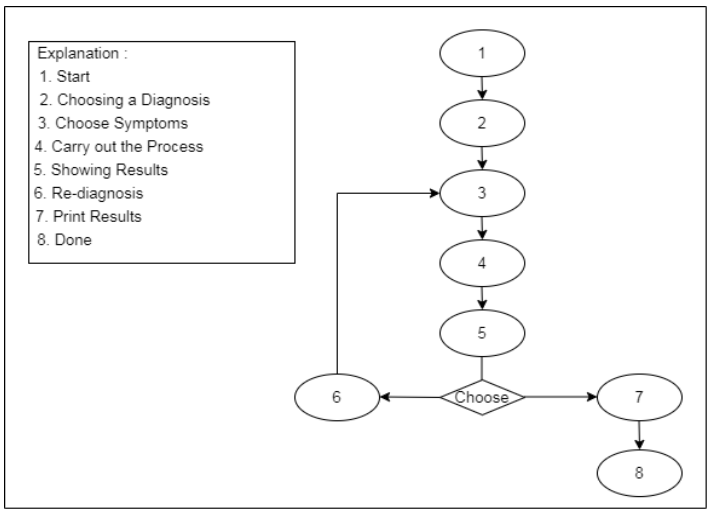

Figure 9. White Box Testing Path

The cyclone complexity (a quantitative measure of the logical complexity of a program) from a flow chart can be obtained by calculating:

$$\mathbf{V\ (G) = E\text{-}N + 2} \tag{9}$$

Where:
E = The number of edges of the flow chart indicated by arrows
N = The number of flow graph nodes indicated by the circle image
So its Cyclomatic complexity:
a. Number of Edge = 8
b. Number of vertices = 8
c. V (G) = E-N + 2 = 8-8 + 2 = 2
The base set generated from linearly independent paths is 2 paths as follows:
1-2-3-4-5-7-8
1-2-3-4-5-6-3-4-5-7-8

When the application is run, it shows that one of the resulting sets is 1-2-3-4-5-7-8 and it appears that the node has been executed once. Based on these provisions in terms of software eligibility, this system has met the requirements.

3.8. Pseudocode Application, Algorithm

The pseudocode design that has been made contains the algorithm certainty factor methods that are implemented in expert systems for diagnosing nutritional deficiencies in coffee and coconut plantations. The following is a pseudocode algorithm for diagnosis using certainty factors:

```
$sqlnutrisi = mysql_query("SELECT * FROM nutrisi order by kode_nutrisi");
$arnutrisi = array();
while ($rnutrisi = mysql_fetch_array($sqlnutrisi)) {
  $cftotal_temp = 0;
  $cf = 0;
  $sqlgejala=mysql_query("SELECT * FROM basis_pengetahuan where
```

```
                                kode_nutrisi=$rnutrisi[kode_nutrisi]");
        $cflama = 0;
        while ($rgejala = mysql_fetch_array($sqlgejala)) {
                $arkondisi = explode("_", $_POST['kondisi'][0]);
                $gejala = $arkondisi[0];
                for ($i = 0; $i < count($_POST['kondisi']); $i++) {
                        $arkondisi = explode("_", $_POST['kondisi'][$i]);
                        $gejala = $arkondisi[0];
                        if ($rgejala['kode_gejala'] == $gejala) {
                        $cf = ($rgejala['mb'] - $rgejala['md']) *
$arbobot[$arkondisi[1]];
                        if (($cf >= 0) && ($cf * $cflama >= 0)) {
                        $cflama = $cflama + ($cf * (1 - $cflama));
                        }
                        if ($cf * $cflama < 0) {
                        $cflama = ($cflama + $cf) / (1 - Math . Min(Math .
                        abs($cflama), Math . abs($cf)));}
                        if (($cf < 0) && ($cf * $cflama >= 0)) {
                                $cflama = $cflama + ($cf * (1 + $cflama));
                        }}}}
        if ($cflama > 0) {
          $arnutrisi += array($rnutrisi[kode_nutrisi] => number_format($cflama, 4));
        }}
        arsort($arnutrisi);
        $inpgejala = serialize($argejala);
        inpnutrisi = serialize($arnutrisi);
        $np1 = 0;
        foreach ($arnutrisi as $key1 => $value1) {
            $np1++;
            $idpkt1[$np1] = $key1;
            $vlpkt1[$np1] = $value1;
         }
        mysql_query("INSERT INTO hasil(tanggal, gejala, nutrisi, hasil_id, hasil_nilai)
VALUES('$inptanggal', '$inpgejala', '$inpnutrisi',   '$idpkt1[1]', '$vlpkt1[1]')");
```

3.9. System Accuracy Testing

The results of testing the level of accuracy of the application of an expert system for diagnosing nutritional deficiencies that have been designed by the user directly consist of two stages, the first is testing of the facts contained in the knowledge base, and the next stage of testing is carried out by analyzing 47 data. The first test results show that the system can correctly identify deficiencies according to the facts on the knowledge base. Then below is the conclusion of the second stage of testing to determine the level of system accuracy.

Table 7. Conclusion of Test Results

No	Types of Plant Nutrient Deficiency	Test Data	Correct Data Identification
1	Nitrogen (N)	14	13
2	Phosphorus (P)	9	8
3	Potassium (K)	6	5
4	Calcium (Ca)	6	5
5	Magnesium (Mg)	4	4
6	Sulfur (S)	4	3

7	Boron (B)	2	2
8	Iron (Fe)	1	1
9	Copper (Cu)	1	1
Amount		47	42

To find out whether a system is considered feasible, an evaluation is needed in diagnosing nutritional deficiencies in plantation crops. The steps for calculating the evaluation using the sensitivity and accuracy equation, formula are as follows.

$$\boldsymbol{sensitivity} = \frac{\boldsymbol{TP}}{\boldsymbol{TP+TN}} \quad (10)$$

$$\boldsymbol{accuracy} = \frac{\boldsymbol{TP+TN}}{\boldsymbol{TP+TN+FP+FN}} \quad (11)$$

Table 8. Confusion Matrix Test Results

Identification Model	Amount of Test Data	TP	TN	FP	FN
Deficiency of Nutrition in Coffee and Coconut Plantation Plants	47	45	0	2	0

$$\boldsymbol{Sensitivity} = \frac{\boldsymbol{42}}{\boldsymbol{42+0}} = \boldsymbol{100}\% \quad (12)$$

$$\boldsymbol{Accuracy} = \frac{\boldsymbol{45+0}}{\boldsymbol{42+5+0+0}} = \frac{\boldsymbol{42}}{\boldsymbol{47}} \boldsymbol{= 0.89 \text{ x } 100\% = 89\%} \quad (13)$$

3.10. Analysis of Design And Testing Results

The following is the result of the process of designing and testing an expert system for diagnosing nutritional deficiencies of coffee and coconut plants using the certainty factor algorithm method:

a. Users or visitors can only access the system to carry out the diagnostic process and view other information about the system.
b. The system displays the value of the certainty level of the resulting diagnostic results and is useful to increase the confidence of each user of the system about nutritional deficiencies in coffee and coconut plantations by farmers or planters.
c. The white box test results show when the application is run and a test is carried out regarding the user and admin flow graphs that the resulting base set has been executed and is in accordance with these conditions from the feasibility of the software and has met the requirements.
d. The expert system that is built only has one admin, so that the database can be processed by one admin.
e. System testing is also carried out by testing the level of system accuracy, so the results of the test are clearly visible or not in accordance with the calculations of experts and or manual calculations from certainty factor reasoning methods.
f. Based on the tests that have been carried out in the table above, a result of accuracy testing is obtained with an accuracy value of the expert system by 89%.

4. CONCLUSION

From the description of the writing of the chapters that have been described in the design of an expert system for diagnosing nutritional deficiencies of coffee and coconut plantations, it can be concluded as follows:

1. In making this expert system using the basic components of an expert system, namely the environment of consultation and development environment.
   a. The consulting environment is the user, the interface and the facts of the incident.
   b. The development environment is an inference engine, knowledge base, explanation facilities, workplace, experts and knowledge engineers.
2. Expert system application to diagnose nutritional deficiencies in coffee and coconut plantations is an application to diagnose nutrient deficiency (deficiency) in coffee and coconut plantations which often occurs based on knowledge from experts and literature studies.
3. The application of this expert system uses the certainty factor method with forward chaining and produces a program to identify nutritional needs in coffee and coconut plantations using the website.
4. The application of this expert system can be a means to store knowledge about nutrition and deficiencies in coffee and coconut commodity crops

5. SUGGESTED

Further research is needed is the development of mobile-based applications that can be accessed offline without an internet network connection.

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