SIMULATION OF A PREDICTIVE MODEL FOR THE CLASSIFICATION OF BACTERIAL DISEASES AFFECTING RICE PLANT USING FUZZY LOGIC

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CERTIFICATION

This Project titled, **SIMULATION OF A PREDICTIVE MODEL FOR THE CLASSIFICATION OF BACTERIAL DISEASES AFFECTING RICE PLANT USING FUZZY LOGIC**, prepared and submitted by **OZAGHA ALEXANDER JOEL** in partial fulfilment of the requirements for the degree of **BACHELOR OF SCIENCE (Computer Science)**, is hereby accepted.

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DEDICATION

This project is dedicated to God, my pillar, my source of inspiration, my wisdom, knowledge and intellect. Ultimately, he was the source of my energy. I also dedicate this study to my Project Supervisor who was of great support during the time of the research. My parents who encouraged me all the way and whose encouragement made sure I gave whatever it took to finish it.

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ABSTRACT

This project is based on Simulation of a Predictive Model for The Classification of Bacterial Diseases Affecting Rice Plant Using Fuzzy Logic. The likelihood of detecting disease sooner or before a diseased plant is symptomatic is a key outlook in this work. This project aims to apply fuzzy logic model to the classification of bacterial diseases affecting rice plant based on information about symptoms observed from part of the rice plant.

In order to achieve its aim and objectives, a review of the literature was conducted in order to identify the bacterial diseases affecting rice plant in Nigeria alongside symptoms associated with the risk of the bacterial diseases.

Formulate the fuzzy logic by the fuzzification of the symptoms. The fuzzy logic model was simulated using MATLAB R2018 software.

The predictive model developed will provide a means of early warning signal required for averting damages caused by bacterial infection. The resulting model will reduce the damage caused by bacterial diseases which affect rice and thus mitigating waste.

This would improve the detection of related diseases affecting the rice plant thereby improving the productivity of the plant. It is recommended that the system is improved upon to increase the scope and productivity of the system.

CHAPTER ONE

INTRODUCTION

1.1 Background to the study

According to Anon (2018), Rice with generic name *Oryza sativa* is the world's most commonly cultivated root crop and a significant source of calories for around two out of five Africans. For small-scale farms, especially in low-income, food-deficit areas, it is considered a food security crop as it provides adequate yields in low soil fertility conditions. Small-scale farmers, representing 85% of farmers worldwide, have a wide range of challenges facing their agricultural production, including climate change, market issues, and outbreaks of pests and diseases. Two arthropod pests were inadvertently introduced in the 1970s, the rice water weevil *Lissorhoptrus oryzophilusKuschel* and the rice stink bug *Oebalus pugnax*, being the most economically threatening pests.

According to Arora (2007), rice diseases have a longer history on the continent. The first to be recorded in Africa was Rice bacterial blight. The annual yield losses of Rice bacterial blight at production levels was between 60-80%. To perfect the detection and spread of rice diseases, early identification in the field is a crucial first step. Using visual symptoms that an agricultural specialist is able to refer to specific diseases in the plant is the state-of-the-art method of recognising diseases in plants in the field. Other approaches for conducting field-based diagnoses are a vital need for areas where experts are not available or where farmers' expertise is inadequate. The likelihood of detecting disease sooner or before a diseased plant is symptomatic is a key outlook in this work.

Fuzzy logic translates organised human intelligence into workable algorithms. In order to improve tractability, robustness and low-cost solutions for real world problems, this powerful tool was introduced to solve the problem of uncertainty.

According to Jeon (2000), in the last decade, fuzzy systems have replaced traditional technology in some science forecasting applications and engineering systems. In addition, Fuzzy logic articulates the complexity of human reasoning and transform expert information into computable numerical results.

1.2 Statement of the problem

According to Chen (2006), crop diseases are major causes of starvation and food shortages and it is estimated that annual crop yield losses of up to 38 percent globally can be accounted for by plant pathogens. In addition, existing strategies to combat numerous diseases include the massive use of crop safety products that are harmful to the environment and the consumer. According to Agrawal (2005), unfortunately, it is most difficult to implement such methods as a strategy, especially in developing countries such as Nigeria, where there is no repository available to store image-based rice disease information. There is a need to develop a predictive model which will depend on information about symptoms observed from the rice plant and knowledge elicited from experts about their relationship with bacterial.

1.3 Aims and objectives of the study

The aim of this study is to apply fuzzy logic model to the classification of bacterial diseases affecting rice plant based on information about symptoms observed from parts of the rice plant.

The specific research objectives are to

i. elicit knowledge about the symptoms associated with the classification of bacterial diseases affecting rice plant;
ii. formulate the model based on information collected in (i);
iii. simulate the model; and
iv. validate the model.

1.4 Research Methodology

In order to meet up with the aforementioned objectives, the methods which were adopted consist of the following.

a. A review of literature was conducted in order to identify the bacterial diseases affecting rice plant in Nigeria alongside symptoms associated with the risk of the bacterial diseases.
b. Formulate the fuzzy logic by the fuzzification of the input (symptoms) and output (risk of bacterial diseases) variables.
c. The inference engine was formulated by the creation of If-Then rules which adopted the symptoms as the antecedent part and the risk of bacterial diseases as the consequent part.
d. The fuzzy logic model was simulated using MATLAB R2018 software.

e. Then the model was validated using a simple dataset based on accuracy, such as none, fair and present.

1.5 Justification of the Study

In the formulation of a classification model for the risk of rice disease, the adoption of fuzzy logic will translate the human expert knowledge used on the field into an expert system which can be used by a non-expert. The resulting model will reduce the damage caused by bacterial diseases which affect rice and thus mitigating waste. The predictive model developed will provide a means of early warning signal required for averting damages caused by bacterial infection.

1.6 Scope and Limitations

This study is limited to the use of information observed from the leaves required for the detection of bacterial diseases and classification of diseases which are most popular in Nigeria.

1.7 Arrangement of thesis

The first chapter of the study which includes the study introduction, was introduced. Chapter two provides a literature review consisting of the identification of rice diseases and methods of detection, which described Fuzzy logic modelling in addition to predictive modelling. Chapter three is a summary of the research methods to be followed in this study in order to achieve the study's goals. The findings and discussions of the approaches adopted in this analysis are included in chapter four. The study overview, conclusion and recommendations are discussed in chapter five.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This section presents the different modelling that were adopted in this study in order to develop the classification model for the risk of rice disease based on expert systems. This section contains the expert systems that are associated with fuzzy logic modelling of rice diseases and its related works.

2.2 Predictive modelling

According to Idowu (2015), Predictive research has become increasingly common in medical research and seeks to predict future events or an outcome based on trends within a collection of variables. Accurate predictive models can warn patients and doctors about the potential course of an illness or the risk of disease development and thereby help direct screening and treatment decisions. Although predictive models provide insight into the outcome of the casualty, the casualty is neither a primary objective nor a variable inclusion prerequisite.

2.2.1 Predictive model types

According to Waijee (2010), using a range of prediction analytical tools, a variety of different techniques exist to build predictive algorithms and have been defined in detail in the literature. When several possible predictors are available and there are interactions between predictors, which are typical in engineering, biological and social causative processes, approaching a predictive problem without a clear causal hypothesis can be very successful.

2.2.2 Developing a predictive model

According to Royston (2009), by using conventional regression analysis, designing a predictive model is to pick appropriate candidate predictor variables for potential inclusion in the model; however, the best approach to do so is not accepted.

Regardless of their statistical significance, important predictor variables previously identified should normally be included in the final model, but the number of variables included is generally constrained by the sample size of the dataset.

2.3 The Rice Plant

According to Gao (2010), rice is the world's largest source of carbohydrates for human consumption, supplying more calories per unit of land for food than any other staple crop. The long-term effects of rice diseases are food security crises and widespread poverty, because rice is mainly grown for food and as a source of income by small-scale farmers. The rice disease pandemic slows the market diversification of rice use in the production of livestock feed, textiles, pharmaceuticals, alcohol and other beverages. Recently, there is continuous management of rice disease incidence, severity and also monitoring and forecasting rice disease prevalence over time and planning appropriate interventions to avert crises.

2.3.1 Rice plant diseases

According to Wang (2012), rice diseases include; Rice bacterial blight, Brown spot, grain rot and many others. These diseases are transmitted by a vector which poses a significant threat to Nigeria's rice community. A large team of experts for the continuous monitoring of crops and the detection of rice disease by visual signs is a more laborious process and can often prove to take longer. According to Luo (2004), in agricultural applications, data mining includes the conceptualization, design, development, estimation and implementation of modern ways of using rural information and communication technologies, including with the main objective of productivity in agriculture. The images below show the different type of rice plant diseases: Fig 2.1 shows the bacterial leaf blight; Fig 2.2 shows the leaf blast; Fig 2.3 shows the brown spot; Fig 2.4 shows the narrow brown leaf spot; Fig 2.5 shows the leaf scald; Fig 2.6 shows the leaf smut and Fig 2.7 shows the stack burn.

Figure 2.1: Bacterial leaf blight identified on the tip of the leaf (Abdel & Shabdana 2013).

Figure 2.2: Leaf blast identified by its small round, brown spots to oval spots on the leaf (Abdel & Shabdana 2013).

Figure 2.3: Brown spot identified by round to oval, dark-brown spots on the leaf (Abdel & Shabdana 2013).

Figure 2.4: Narrow brown leaf spot identified by long narrow brown lesions with white leaf veins (Abdel & Shabdana 2013).

Figure 2.5: Leaf scald identified by wide bands on the leaf tip (Abdel & Shabdana 2013).

Figure 2.6: Leaf smut identified by small black lesions on the leaf tip (Abdel & Shabdana 2013).

Figure 2.7: Stack burn identified by round white pale spot which is brown in colour on the leaf (Abdel & Shabdana 2013).

2.4 Expert systems

According to Agbonifo (2000), for organisations with knowledge and skills that cannot be easily passed to other stakeholders, expert systems are the most important. They are designed to hold the wisdom contained in the intellect of experts and for problem-solving purposes, offer this experience to other members of the company. Improvements in reliability and quality frequently appear when expert systems distribute expert advice, opinion, and explanation on demand. Expert systems are capable of handling enormously complex tasks and activities as well as an extremely rich knowledge-database structure and content. Expert systems can reduce production downtime and as a result, increase output and quality.

According to Delgado (2008), continuous use of an expert system may be cheaper and more reliable in particular cases than the services of a human expert. Expert systems can track output variables, tabulate statistics, and detect processes that do not fit the trends expected, signalling potential issues. Modern expert-system technology is used as an addition to conventional programming methods, and this hybrid approach allows the strengths of both approaches to be combined.

2.5 Fuzzy Logic Modelling

According to Zadeh (1965), the Law of Aristotle 's popular laws of thought which states that any proposition must either be yes or no attains the foregoing. A three-value logic was introduced in 1965 by Lukasiewicz as a systematic alternative to the bi-value logic of Aristotle. The terms of his method are real and wrong. This approach later led to a four-valued logic, which eventually gave birth to the infinite valued logic. The collection is defined by a membership function that assigns a range to each membership object. To such sets, the theories of convexity, connections, union, intersection, and complement, and so on, are applied. By comparison, in Boolean logic, only integer values of 0 or 1 can be the true values of variables.

2.5.1 Concept of fuzzy logic

According to Sharareh (2009), this powerful tool was introduced to enhance tractability, robustness and low-cost solutions for real-world problems. Fuzzy offers a realistic way to understand the mapping behaviour of functions and manually affect them. Generally speaking, fuzzy logic uses basic rules to identify the scheme of interest and this makes it simple to enforce. The conception of a fuzzy set began with fuzzy logic. In order to grasp the fuzzy set, it can contain components of members. If x is an element of set A, then $\mu A(x) = 1$ but if x is not an element of set A, then $\mu A(x) = 0$. In fuzzy logic, the truth of any statement becomes a matter of degree. Any statement can be fuzzy.

2.5.2 Fuzzy sets

According to MathWorks (2011), fuzzy set deals with inclusion and exclusion of any given element. Fuzzy sets represent simple linguistic concepts like yes or no, true or false, cold, warm or hot, low, medium or high and so on. A given element can belong to more than one fuzzy set at the same time. All fuzzy sets are characterized by membership functions. A number of membership functions have been proposed in the past few years, namely the triangular, trapezoidal and bell shape membership function. The input value is often referred to as the universe of discourse set, which contain all the possible elements of concern in each particular application. The MATLAB fuzzy logic toolbox includes 11 built-in membership function types. The simplest membership functions are formed using straight lines.

2.5.3 Fuzzy inference system

According to Alayon (2015), fuzzy inference is the process of formulating the mathematical model based on a mapping from an input set to an output value using fuzzy logic theory. The process of fuzzy inference involves logical operations, such as the use of If-Then rules and membership functions. The Fuzzy Inference System is used as a tool for representing different forms of knowledge about a problem. FIS is also used for modelling the interactions and relationships that exits between its variables.

i. **Fuzzification** - Modelling of the controller is data fragmentation into input that can be accepted by fuzzy logic. This is done by calling on some membership function. For example, an interval [a b c] where a and c correspond to the base of the triangle and b corresponds to the point where the apex of the triangle is located.

ii. **Rule production -** The rule-based system for the controller uses input variables to formulate possible results for the outputs of each rules formulated. As a result of this, the results of the rule production process are set of rules defined using IF-THEN statements.

iii. **Aggregation -** Each fuzzy rule formulated produces a number that represents the truth value of the output for that rule. All the output for each rule must be combined into one single output fuzzified using the process of aggregation. Two methods are commonly used to arrive at aggregation: the minimum and the product operation methods.

iv. **Defuzzification -** This involves the conversion of the single aggregated fuzzy output set into a single crisp value. The interval for which the defuzzied value belongs is used to determine the class with which the output is defined. There are several methods of defuzzification like centre of sums, mean of maxima and left-right maxima.

2.6 Related Works

Ramcharan et al. (2017), plant suffers from various diseases during their life span at any stage of growth. For farmers and agricultural expert's disease management is a critical matter which needs an immediate attention. It needs urgent diagnosis and preventive action in order to maintain quality as well as to minimize the loss. Many researchers contributed technologies for detection as well as classifying plant diseases so as to support quick disease diagnosis.

Awoyelu et al. (2015), developed an expert’s system for the diagnosis of cassava plant diseases. The study identified a number of symptoms that were taken from the leaves, stems and roots of cassava plant required for the diagnosis of 3 different cassava plant diseases. The study adopted the use of 3 triangular membership functions to formulate the 3 symptoms of each diseases identified alongside the level of disease risk.

Suhartono et al. (2013), developed an expert system for detecting coffee plant diseases. The method used is fuzzy logic-based expert systems, and decision tree using a hierarchical classification. Knowledge about coffee, its symptoms, and its disease was extracted from human expert and then converted into a decision tree.

Arowolo et al. (2012), developed an expert system for diagnosing poultry diseases. The study identified the factors that were required for assessing the presence of diseases among poultry animals from experts via interviews. The knowledge about the relationship between the factors was created using IF-THEN rules to create antecedent and consequent rules needed for the diagnosis of diseases among poultry.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This section presents the various methods that have been implemented in this analysis in order to establish a risk of rice disease classification model based on established associated risk factors. This section involves the identification of various risk of rice diseases.

3.2 Method of the identification of risk factors

A number of associated risk factors were identified for the risk of rice diseases. A variety of associated risk factors have been reported following the process of analysis of similar works over the internet. In addition, crisp values were suggested as a way for a user to quantify the response to each risk factor. As a result, intervals that increased the risk were given higher values, while intervals that reduced the risk of rice disease were given lower values.

3.2.1 Description of identified risk factors

A number of risk factors associated with the risk of rice disease have been defined, as mentioned previously, and have been explained in order to understand their respective risk of rice disease based on the value chosen. The risk of rice disease was measured by cumulating the values of all risk factors evaluated for the risk of rice disease.

a) **Discoloured leaves**

The variables are categorised as None, fair and present in such a way that none was associated with low risk, while Present was associated with high risk.

b) **Presence of blights**

Rice bacterial blight is associated with the presence of blights on the leaves of the rice plant. The variables were therefore classified as none, fair and present in such a way that None was associated with low risk, whereas the Present was associated with high risk.

c) **Presence of water – soaked patches**

Rice bacterial blight is also associated with the presence of water – soaked patches. Therefore, the variables were classified as none, fair and present such that None is associated with low risk while Present is associated with high risk.

d) **Presence of wilted leaves**

This is associated with the Rice bacterial blight. The variables were then categorised as none, fair and present in such a way that None was associated with a low risk, while Present was associated with a high risk.

e) **Stunted growth**

The appearance of stunted growth on the rice plant is associated with Rice bacterial blight. The variables were then categorised as none, fair and present in such a way None was associated with a low risk, while Present was associated with a high risk.

f) **Risk of Rice diseases**

According to this study which involved the classification model for the risk of rice diseases using fuzzy logic, a number of class was defined for the target variable. The target variable was stratified into four (4) classes: No Risk, Low Risk, Moderate Risk and High Risk.

3.2.2 Crisp and linguistic values of variables

A summary of the linguistic values and linguistic variables was rendered after the identification of all the risk of rice disease. For each variable listed, Table 3.1 and Table 3.2 provides a description of the crisp values and linguistic variables. The crisp values for each of the identified risk factor was done by allocating the values 0, 1 and 2 to some risk factors such that the value with the highest association with the risk of rice diseases was given the value of 2 while the value with the lowest risk of rice diseases was given a value of 0.

As a result of this the risk factors were classified as follows. The presence of discoloured leaves was divided in increasing order of risk rice diseases as None, fair and present hence was given 3 linguistic variables; the presence of stunted growth was divided in increasing order of risk as None, fair and present and hence was given 3 linguistic variables; the presence of blights was divided in increasing order of risk as None, fair and present and hence was given 3 linguistic variables; the presence of wilted leaves was divided in increasing order of risk as None, fair and present hence was given 3 linguistic variables; the presence of water-soaked patches was divided in increasing order of risk as None, fair and present hence was given 3 linguistic variables.

3.3 Fuzzy Logic formulation for Risk of Rice Diseases

Each defined variable was fuzzified using a triangular membership function for the purpose of developing a classification model for the risk of rice diseases using fuzzy logic theory. Three parameters consisting of the left base of the triangle (a), the central apex of the triangle (b) and the right base of the triangle (c) were given for the triangular membership function.

Table 3.1: Identification of crisp and linguistic values of risk factors

Risk Factor	Linguistic Variable	Crisp Value
Discoloured leaves	**None**	**0**
	Fair	**1**
	Present	**2**
Presence of blights	**None**	**0**
	Fair	**1**
	Present	**2**
Presence of water – soaked patches	**None**	**0**
	Fair	**1**
	Present	**2**
Wilted leaves	**None**	**0**
	Fair	**1**
	Present	**2**
Stunted growth	**None**	**0**
	Fair	**1**
	Present	**2**
Risk of Rice diseases	**No risk**	**0**
	Low risk	**1**
	Moderate risk	**2**
	High risk	**3**

Table 3.2: Description of Crisp intervals used during Fuzzy Model Formulation

Crisp value	Interval	a	b	C
0	(-0.5, 0.5)	-0.5	0	0.5
1	(0.5, 1.5)	0.5	1	1.5
2	(1.5, 2.5)	1.5	2	2.5

The interval of this parameter was used to define the crisp interval within which the linguistic variable was assigned to each crisp value. As a result of this, for each identified risk factor, there were 3 triangular membership functions, so that each linguistic variable was allocated to each identified risk factor as appropriate.

Variable label (x; a, b, c) = $0; x \leq a$

$\frac{x-a}{b-a}; a < x \leq b$

$\frac{c-x}{c-b}; b < x \leq c$

$0; x > c$

The labels of the defined risk factors were formulated using 3 triangular membership functions using the crisp intervals (-0.5, 0.5), (0.5, 1.5) and (1.5, 2.5) to model the linguistic variables for 0, 1 and 2 respectively in such a way that the values 0, 1 and 2 are the centre b of each interval as shown in Table 3.3.

3.3.1 Fuzzification of the risk of rice diseases

There was a need to devise the target variable used to describe the risk of rice diseases. To formulate the target variable, crisp values of 0, 1 and 2 are assigned to target class labels, using the intervals (-0.5, 0.5), (0.5, 1.5), (1.5, 2.5) and (2.5, 3.5) respectively. The relationship between risk factors and the risk of rice disease using the fuzzy inference method was proposed using the definition.

3.3.2 Fuzzy inference system design

The fuzzy inference engine was introduced after formulating triangular membership functions to model the risk factors and the risk of rice diseases. For the purpose of developing a relationship between the non-invasive parameters established, experts have inferred rules.

Table 3.3: Formulation of the Risk of rice diseases

Target class	Interval	A	B	C
No risk	(-0.5. 0.5)	-0.5	0	0.5
Low risk	(0.5. 1.5)	0.5	1	1.5
Moderate risk	(1.5. 2.5)	1.5	2	2.5
High risk	(2.5. 3.5)	2.5	3	3.5

In order to construct the knowledge base of the classification model using fuzzy logic, a number of IF-THEN rules were used by combining the risk factors as the precedence while the risk of rice diseases was used as the consequent variable. A typical rule that can be inferred is as follows:

IF (Discoloured Leaves = “None”) AND (Presence of Blights = “None”) AND (Presence of Water – Soaked Patches = “None”) AND (Presence of Wilted Leaves = “None”) AND (Stunted Growth = “None”) THEN (Risk of rice Diseases = “No Risk”)

The fuzzy model was calculated for each variable from the product of the number of linguistic variables. Therefore, each of the considered variables has three linguistic variables each. Therefore, 243 (= 3^5) rules are the total number of rules.

3.4 Simulation environment used

MATLAB is an easy-to-use environment, it integrates computation, visualisation, and programming. Fuzzy Logic Toolbox provides MATLAB for analysing, designing, and simulating systems based on fuzzy logic. There are five main GUI tools (Elements of the MATLAB Fuzzy Logic System) for constructing, editing, and observing fuzzy inference systems in the toolbox for this study.

i. **Fuzzy Inference System (FIS) Editor**: Deals with the system's high-level issues: it was used to describe the names and number of models proposed.

ii. **Membership Function Editor:** The shapes of all membership features associated with each element have been used to describe them. The triangular membership feature was to formulate all variables.

iii. **Rule Editor:** Using a series of IF-THEN statements that combined the known risk factors with the risk of rice disease labels, the 243 rules that described the actions of the system were used to edit them.

iv. **Rule Viewer:** It is an environment-based MATLAB technical computing display of the fuzzy inference diagram that was used as a diagnosis.

v. **Surface Viewer:** Is used to display the dependency of one of the outputs on any one or two of the inputs.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Introduction

Based on the crisp intervals defined for each linguistic variable identified in this study, this section presents the results of formulating triangular membership functions. Therefore, since the same crisp interval was used, 3 triangular membership functions with centres 0, 1 and 2 were used to define the labels of each risk factor. The allocation of values was also focused on the increasing impact of the labels of the risk that were identified. Therefore, the results of the mathematical representation of the fuzzy logic model formulation using the triangular membership function for each of the labels is presented in equations (4.1a) to (4.1c)

$$Crisp - label\_0(x; -0.5, 0, 0.5) = \begin{cases} 0; x \leq -0.5 \\ \dfrac{x + 0.5}{0.5}; -0.5 < x \leq 0 \\ \dfrac{0.5 - x}{0.5}; 0 < x \leq 0.5 \\ 0; x > 0.5 \end{cases} \qquad (4.1a)$$

$$Crisp - label\_1(x; 0.5, 1, 1.5) = \begin{cases} 0; x \le 0.5 \\ \dfrac{x - 0.5}{0.5}\ ; 0.5 < x \le 1 \\ \dfrac{1.5 - x}{0.5}; 1 < x \le 1.5 \\ 0; x > 1.5 \end{cases} \qquad (4.1b)$$

$$Crisp - label\_2(x; 1.5, 2, 2.5) = \begin{cases} 0; x \le 1.5 \\ \dfrac{x - 1.5}{0.5}\ ; 1.5 < x \le 2 \\ \dfrac{2.5 - x}{0.5}; 2 < x \le 2.5 \\ 0; x > 2.5 \end{cases} \qquad (4.1c)$$

The linguistic variables for the classification of rice plant diseases were formulated using the 4 triangular membership functions indicated in the equations (4.1d) to (4.1g).

$$Crisp - no(x; -0.5, 0, 0.5) = \begin{cases} x \le -0.5 \\ \dfrac{x + 0.5}{0.5}\ ; -0.5 < x \le 0 \\ \dfrac{0.5 - x}{0.5}; 0 < x \le 0.5 \\ 0; x > 0.5 \end{cases} \qquad (4.1d)$$

$$Crisp - low(x; 0.5, 1, 1.5) = \begin{cases} 0; x \le 0.5 \\ \dfrac{x - 0.5}{0.5}\ ; 0.5 < x \le 1 \\ \dfrac{1.5 - x}{0.5}; 1 < x \le 1.5 \\ 0; x > 1.5 \end{cases} \qquad (4.1e)$$

$$Crisp - moderate(x; 1.5, 2, 2.5) = \begin{cases} 0; x \le 1.5 \\ \dfrac{x - 1.5}{0.5}\ ; 1.5 < x \le 2 \\ \dfrac{2.5 - x}{0.5}; 2 < x \le 2.5 \\ 0; x > 2.5 \end{cases} \qquad (4.1f)$$

$$Crisp - high(x; 2.5, 3, 3.5) = \begin{cases} 0; x \leq 2.5 \\ \frac{x - 2.5}{0.5}; 2.5 < x \leq 3 \\ \frac{3.5 - x}{0.5}; 3 < x \leq 3.5 \\ 0; x > 3.5 \end{cases} \qquad (4.1g)$$

4.2 Fuzzy Model for Classification of Rice Plant Diseases

Simulation of the membership functions and the rules of inference used to generate the final file which are presented in the following sections of the Fuzzy Logic Model.

4.2.1 Results of variables using the membership function editor

The use of MATLAB was used in getting the results of these variables and Fig 4.1 shows the MATLAB workspace. Therefore, simulation of the model for the presence of discoloured leaves is shown in Figure 4.2 such that the interval [-0.5, 0.5] with centre 0 was used to model none, [0.5, 1.5] with centre 1 was used to model fair while [1.5 2.5] with centre 2 was used to model present. Simulation of the model for the presence of blights is shown in Figure 4.3 such that the interval [-0.5, 0.5] with centre 0 was used to model none, [0.5, 1.5] with centre 1 was used to model fair while [1.5 2.5] with centre 2 was used to model present. Simulation of the model for water – soaked patches is shown in Figure 4.4 such that the interval [-0.5, 0.5] with centre 0 was used to model none, [0.5, 1.5] with centre 1 was used to model fair while [1.5 2.5] with centre 2 was used to model present. Simulation of the model for the presence of wilted leaves is shown in Figure 4.5 such that the interval [-0.5, 0.5] with centre 0 was used to model none, [0.5, 1.5] with centre 1 was used to model fair while [1.5 2.5] with centre 2 was used to model present. Simulation of the model for the presence of stunted growth is shown in Figure 4.6 such that the interval [-0.5, 0.5] with centre 0 was used to model none, [0.5, 1.5] with centre 1 was used to model fair while [1.5 2.5] with centre 2 was used to model present. The results of the simulation model for the classification of the risks is shown in Figure 4.7 such that the interval [-0.5, 0.5] with centre 0 was used to model none, [0.5, 1.5] with centre 1 was used to model low risk, [1.5, 2.5] with centre 2 was used to model moderate risk while [2.5, 3.5] with centre 3 was used to model high risk.

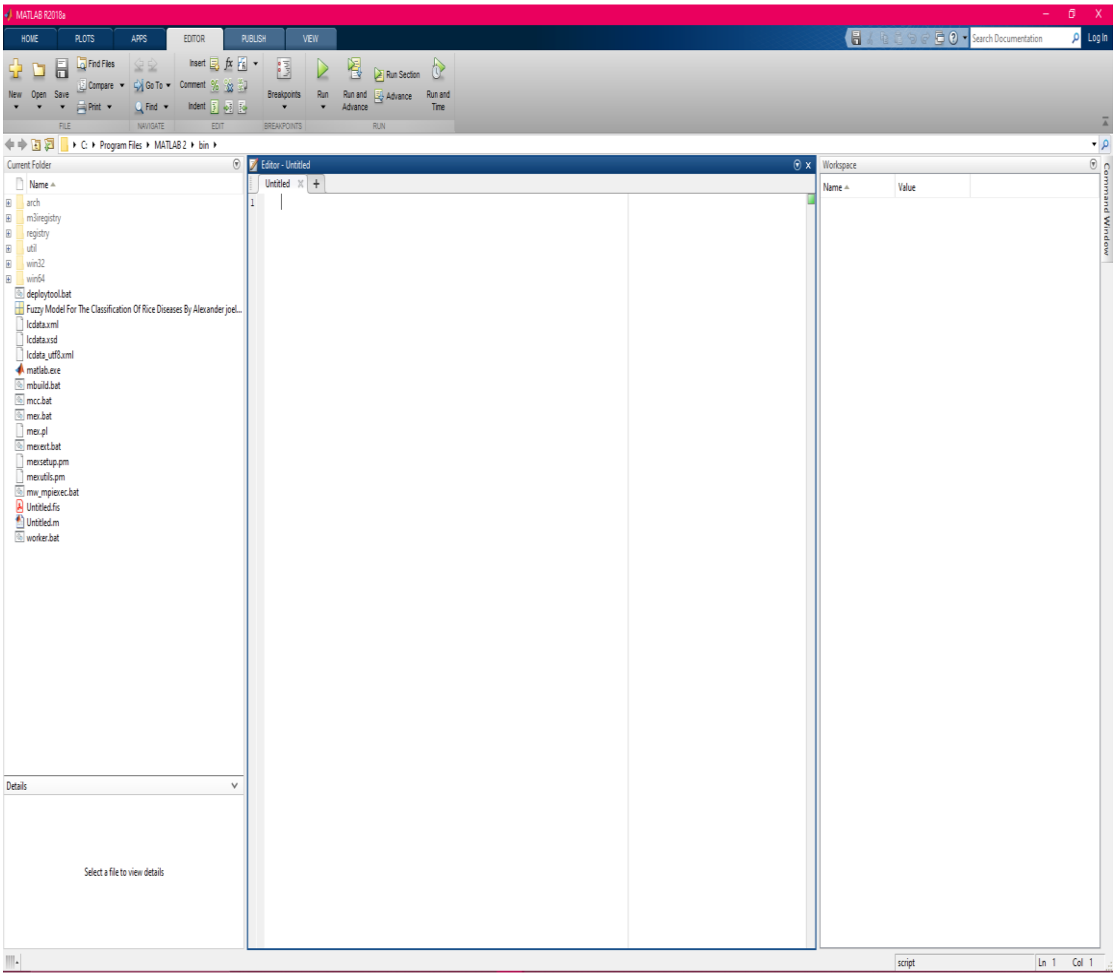

Figure 4.1: Workspace of MATLAB for fuzzification of rice diseases

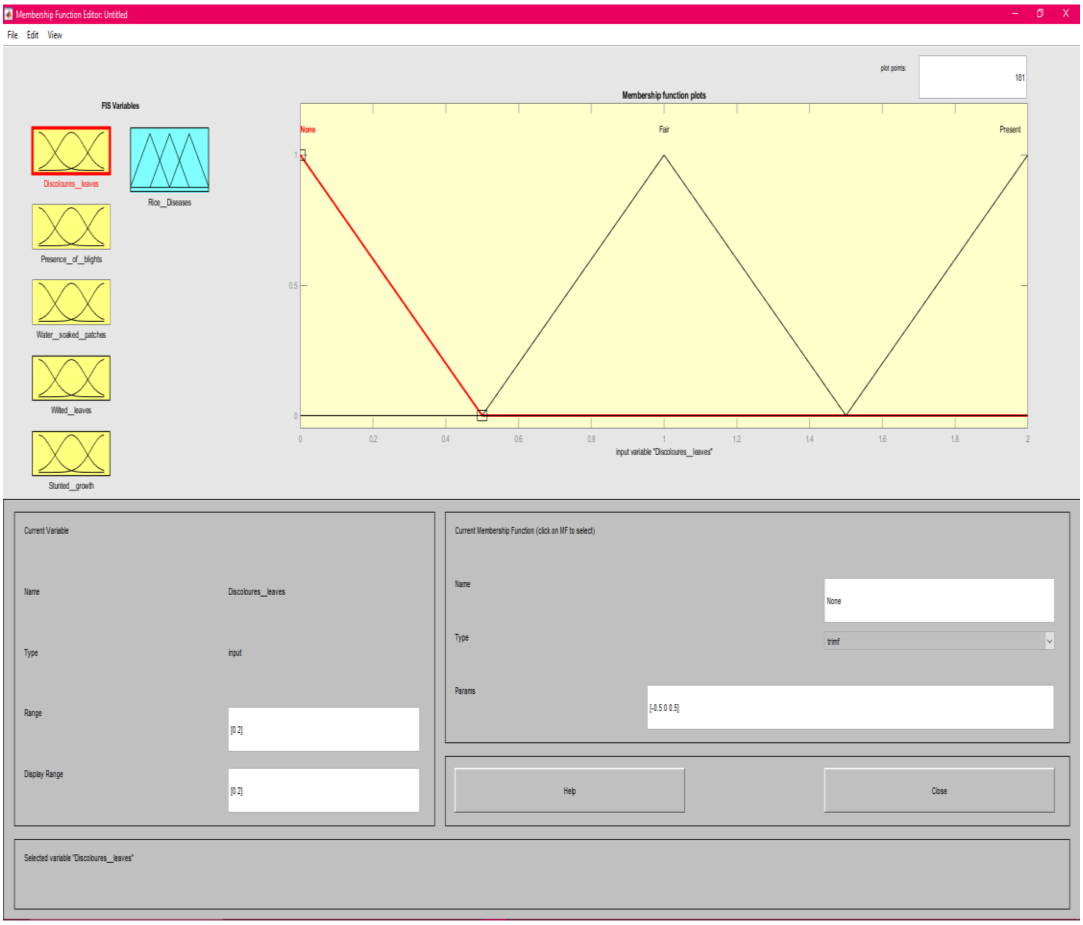

Figure 4.2: Fuzzification of the presence of discoloured leaves

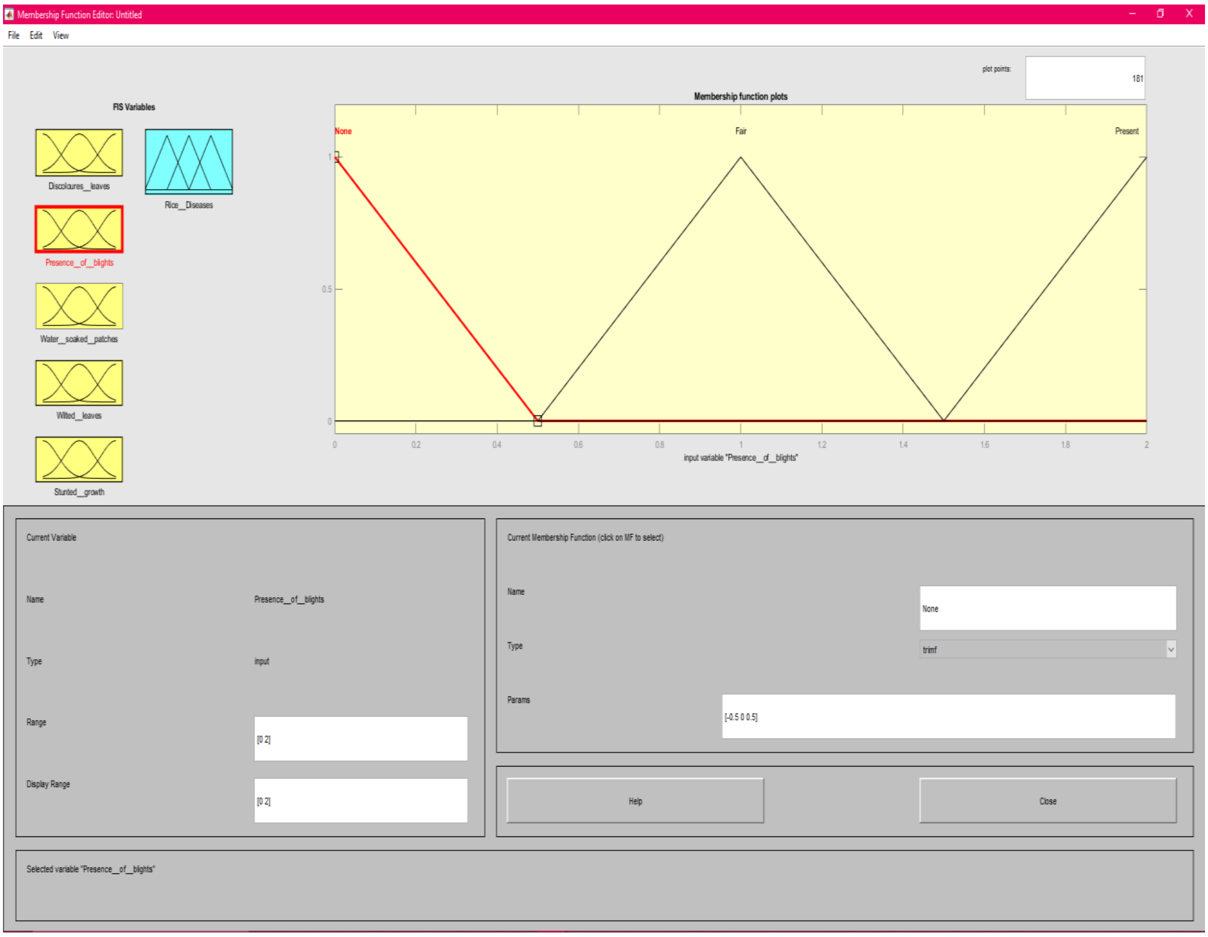

Figure 4.3: Fuzzification of the presence of blights

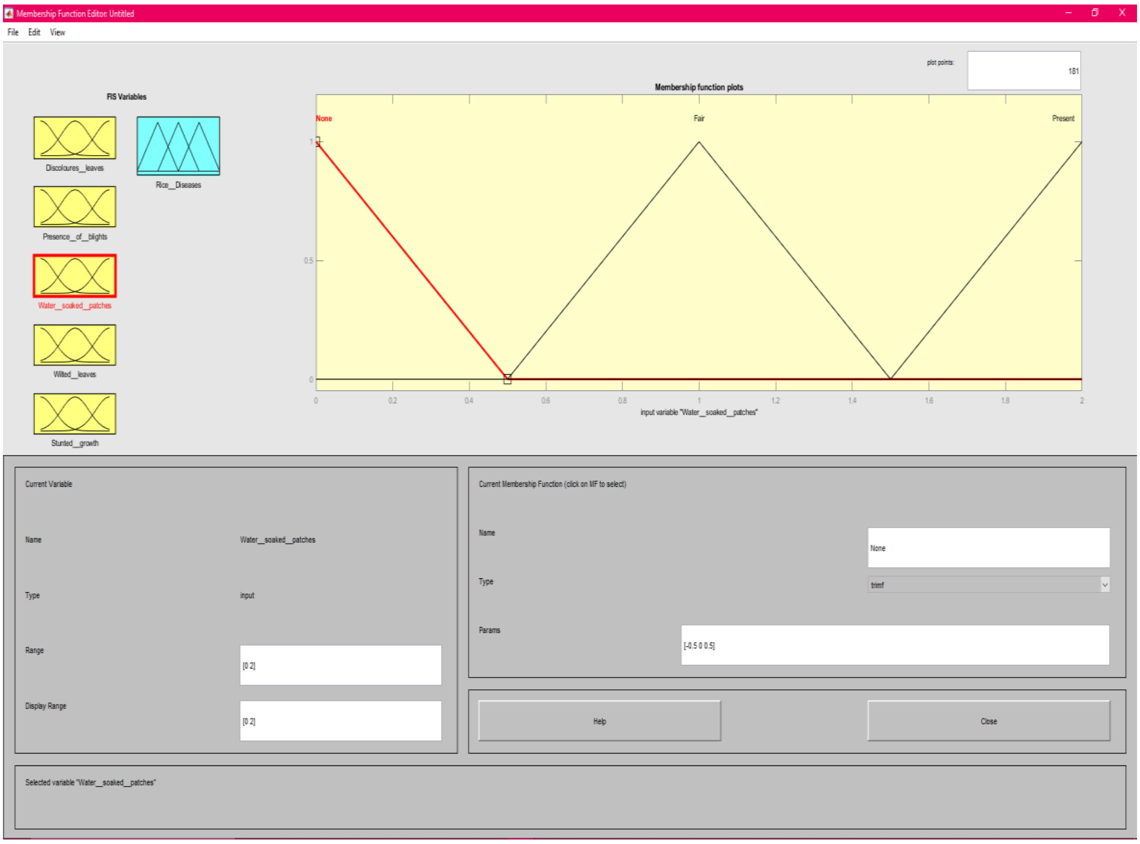

Figure 4.4: Fuzzification of the presence of water – soaked patches

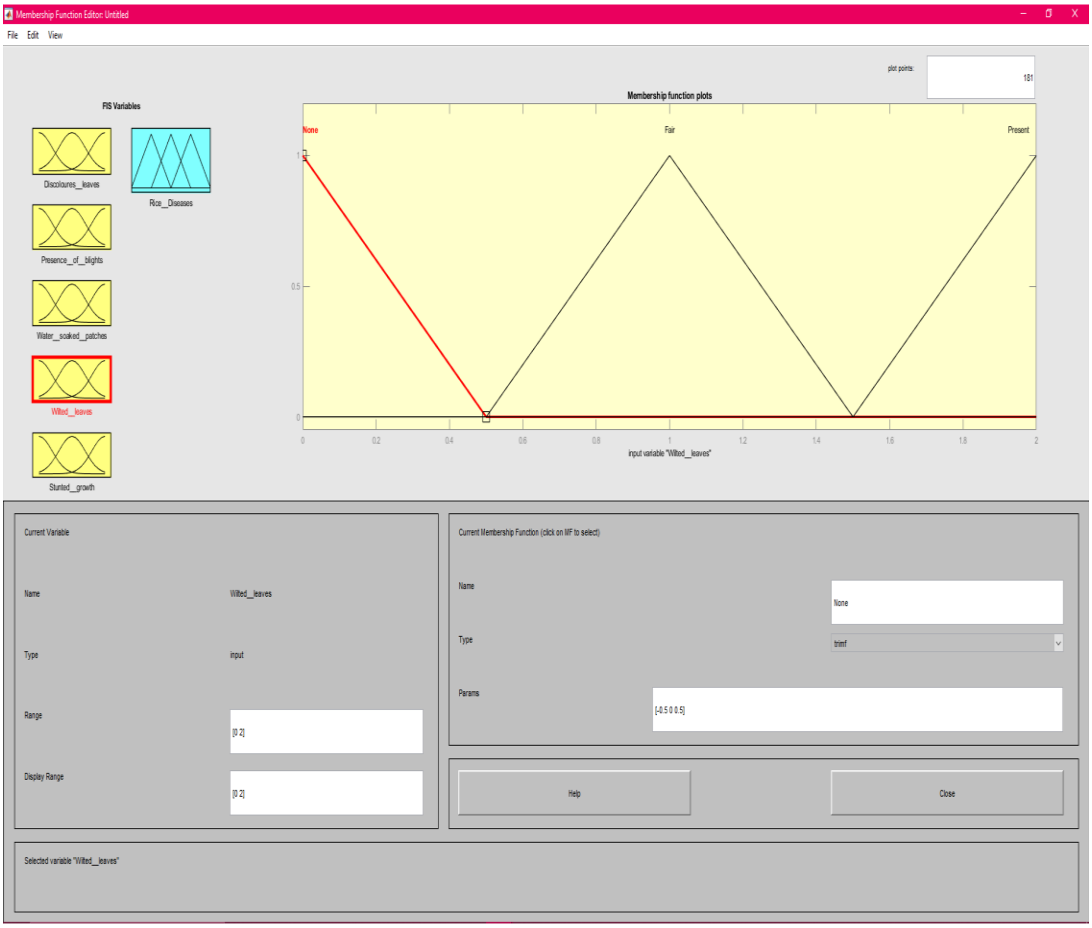

Figure 4.5: Fuzzification of the presence of wilted leaves

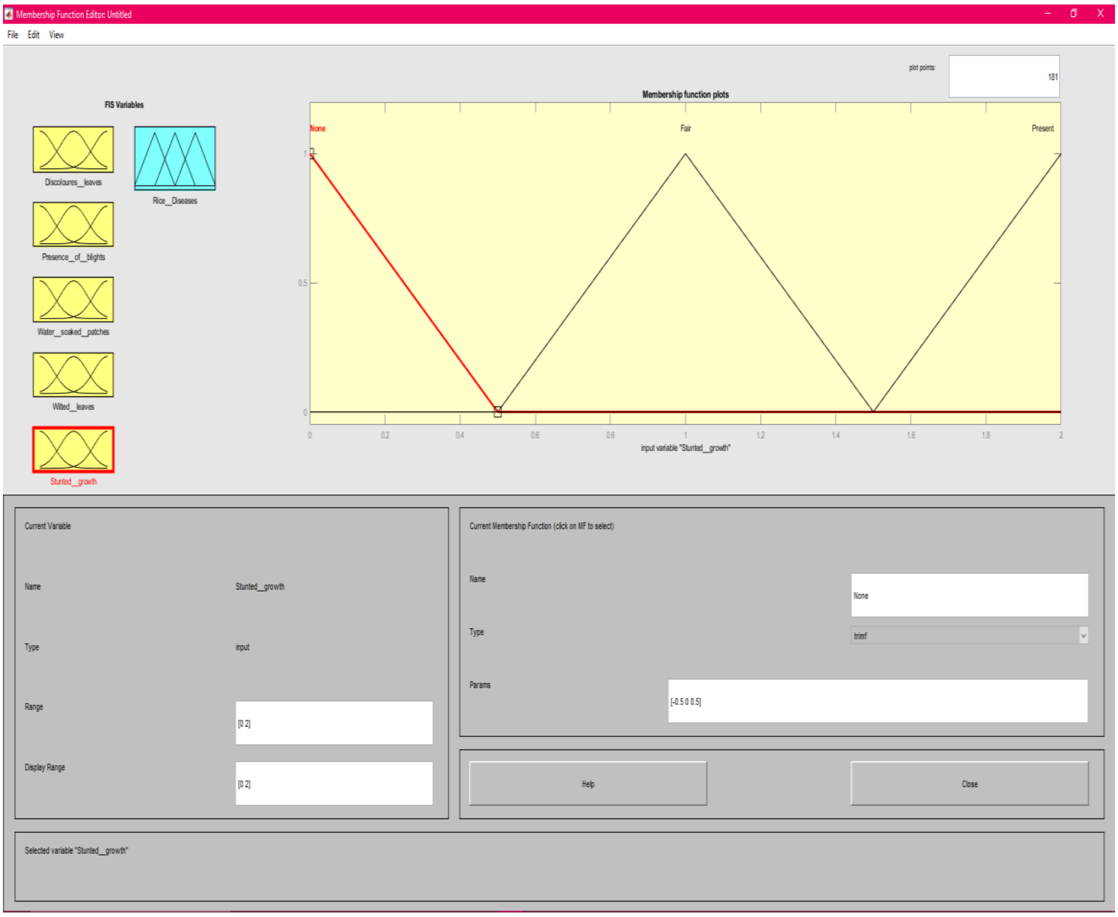

Figure 4.6: Fuzzification of the presence of stunted growth

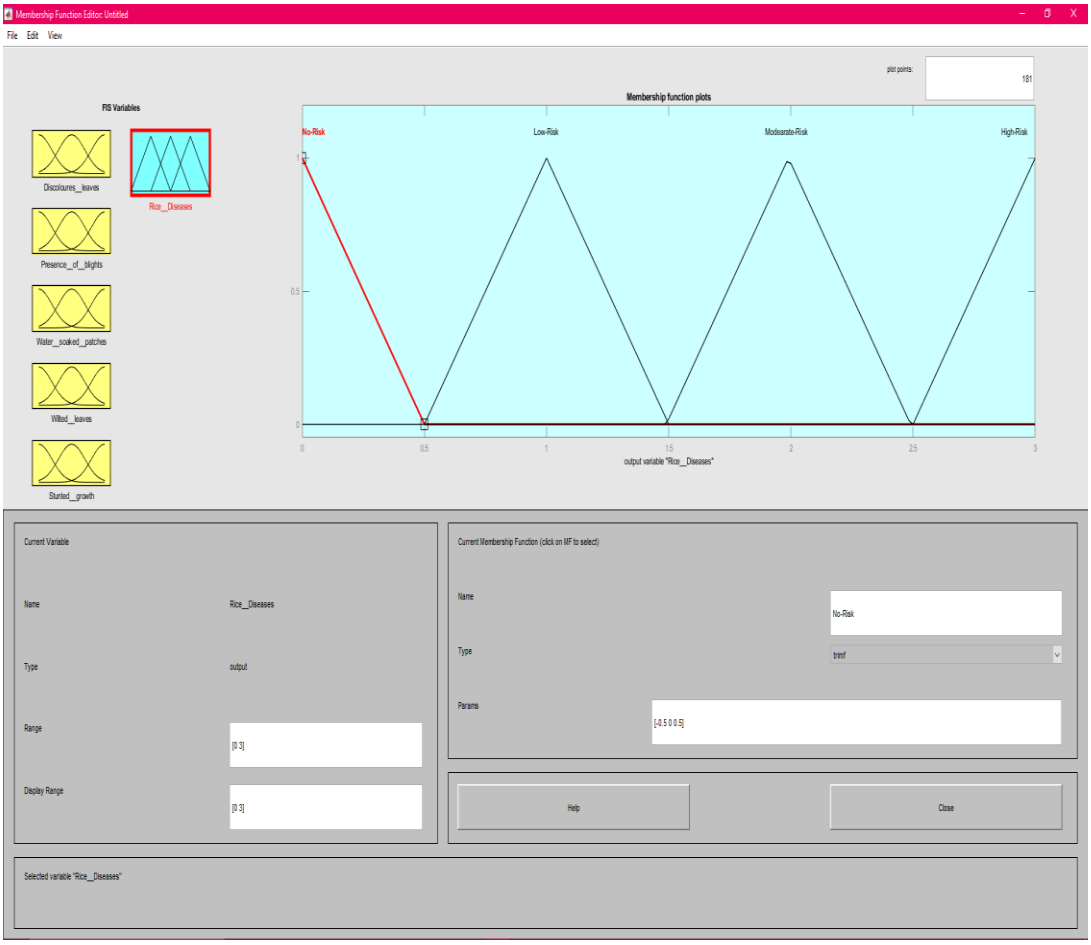

Figure 4.7: Fuzzification of the classification of Rice Plant Diseases

The screenshot of the final source code is shown in Figure 4.8 with A. Fis extension which was built from the simulation. Appendix II provides a detailed explanation of the various components of the .fis file, including the system components that describe the number of Mamdani input, output, model type, followed by the section of variables that define the name and alongside their types with their respective crisp value interval for each linguistic variable.

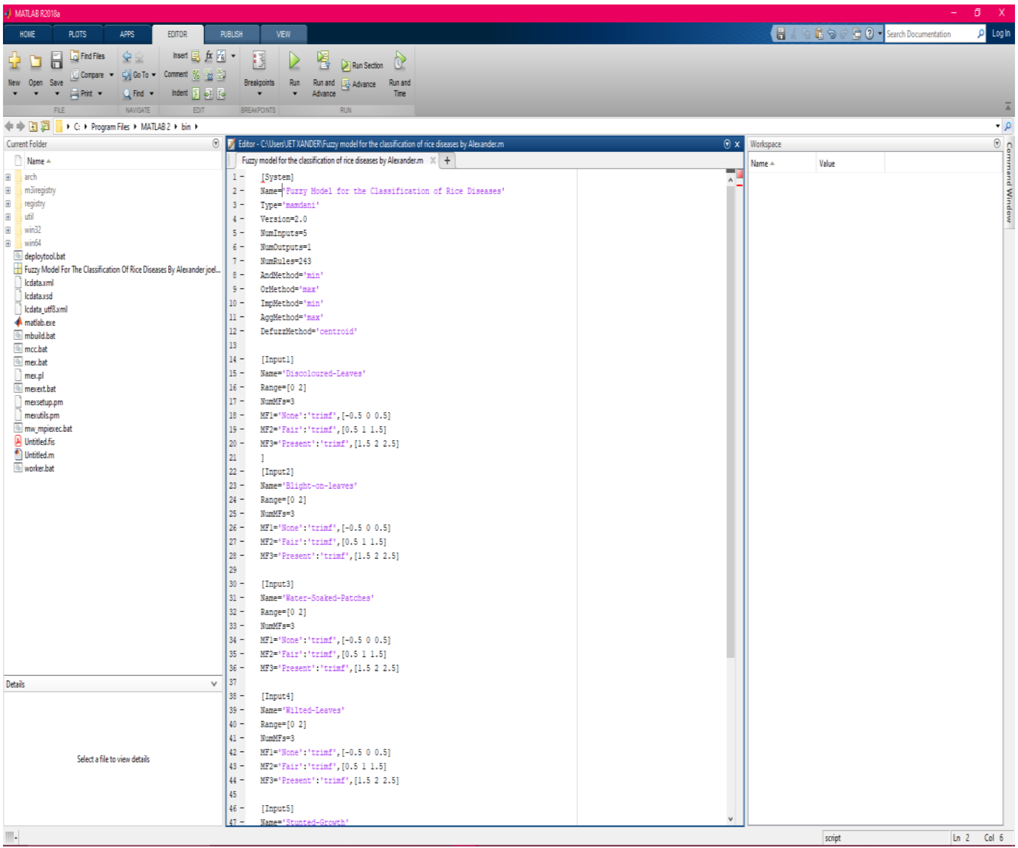

Figure 4.8: Source Code of. fis File of Fuzzy Model for Classification of Rice Plant Diseases

4.2.2 Results of the Model for Classification of Rice Plant Diseases

The rule editor interface was used to describe the 243 rules that have been inferred for deciding the classification of rice plant diseases. Figure 4.9 shows the full insertion of the 243 rules for determining the classification of rice plant diseases that have been inferred. It is obvious that each inferred rule is special and does not contain linguistic variables that occur in any of the established rules in the same pattern. The graphical area of each variable chosen by each law is shown in Figure 4.10 with respect to the linguistic variables of the rice plant disease classification.

4.3 Discussion of Results

To devise a classification model that can be used to detect a number of dependent factors observed from different parts of rice plants, this study adopted fuzzy logic. The study identified 5 risk factors for rice plant disease risk classification. A number of linguistic variables for which core crisp values were allocated based on the correlation with the risk used to describe each risk factor. For each of the identified risk factors, crisp values were achieved by assigning 0, 1 and 2 to risk factors with 3 values. Three sections of each risk factor were discretized, so that the values 0, 1 and 2 were assigned to each specified linguistic component.

In order to determine the relationship between the known non-invasive risk factors identified, 243 rules were drawn up to determine the relationship between the identified risk factors and the risk of rice plant diseases. A number of IF-THEN rules were used to build the knowledge base of the classification model using fuzzy logic by combining the risk factors as the precedence, while the risk was used as the resulting variable.

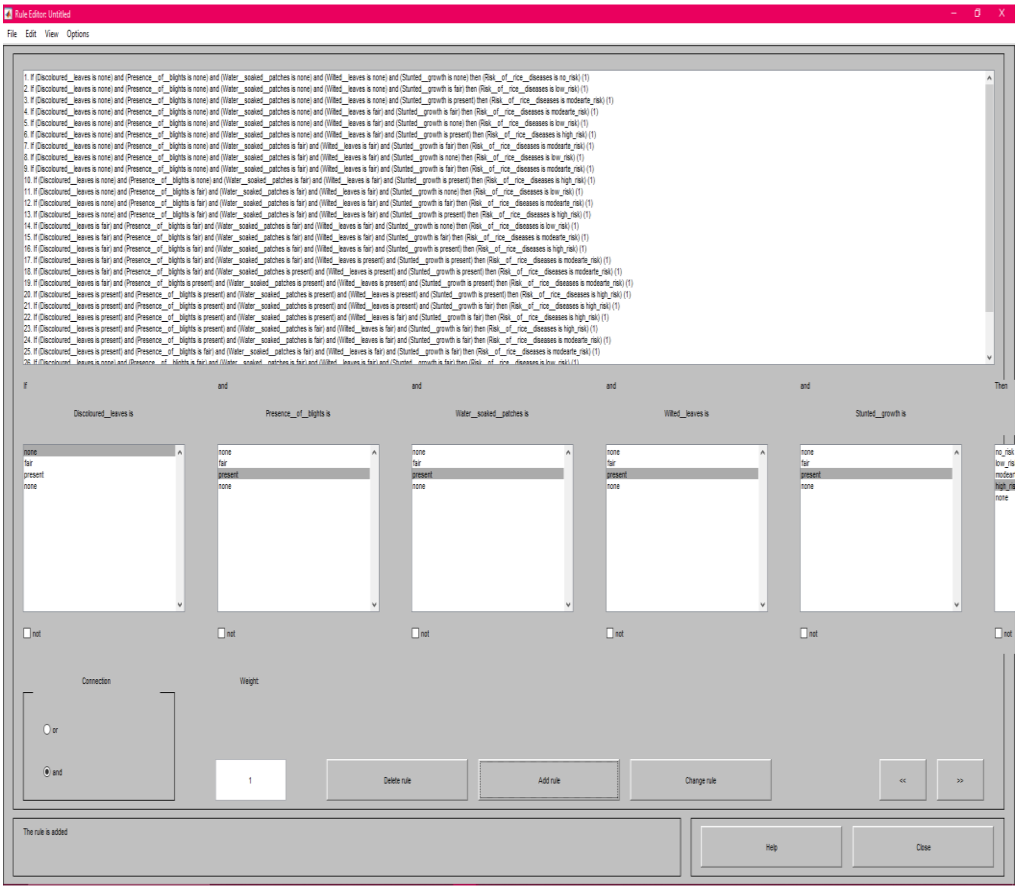

Figure 4.9: The Inferred Rules located in the Fuzzy Inference Engine

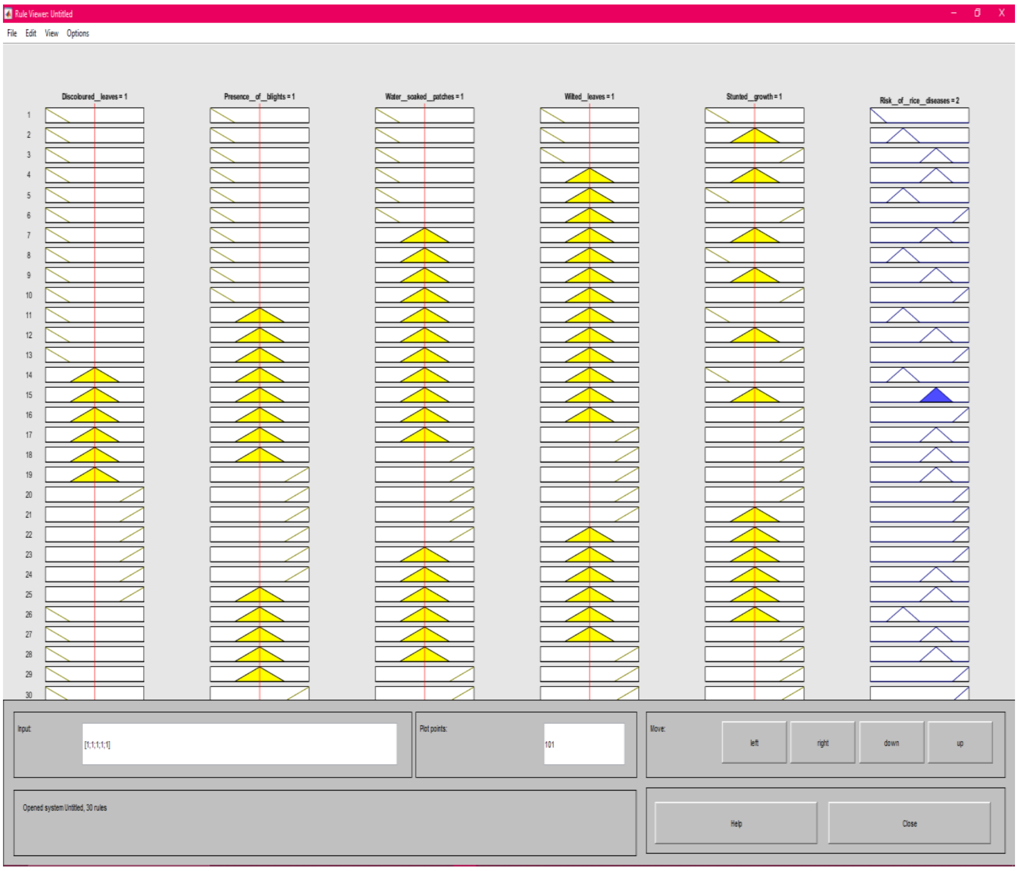

Figure 4.10: Testing the Validity of the Inference Engine

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Summary

This research was motivated by the need to provide a means by which cost-effective steps could be taken to estimate the risk of rice plant diseases on the basis of certain factors. This was done through the simulation of a fuzzy model used by experts to identify the risk of rice plant diseases using rules. The presence / absence of 5 variables was therefore used to assess the risk of rice disease.

5.2 Conclusion

In order to determine the impact of pests and diseases on the productivity of rice plants, this study developed a fuzzy logic-based model to classify rice plant diseases. The study therefore concluded that the presence and/or absence of risk factors could be used to predict the risk of diseases affecting the rice plant in such a way that the lower the risk of rice plant diseases, the lower the presence of such factors. The study also concluded that discoloured leaves, stunted growth, water-soaked patches, blight on leaves, wilted leaves were the 5 related factors found. For the formulation of the linguistic variables of the factors using acceptable linguistic variables, 3 triangular membership functions were suitable, whereas the goal yield was formulated using 4 triangular membership functions for linguistic variables with no risk, low risk, moderate risk and high risk.

5.3 Recommendation

This study recommends that botanists and agricultural scientists make additional efforts to recognize other important factors associated with rice plant disease risk. This would improve the detection of related diseases affecting the rice plant thereby improving the productivity of the plant.

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APPENDIX I

Inference Rules for the Risk of Rice Diseases

Rule	Discoloured leaves	Presence of blights	Water soaked patches	Wilted leaves	Stunted growth	Risk of Rice Diseases
1	None	None	None	None	None	None
2	Present	None	None	None	None	Low Risk
3	None	None	None	None	Present	Low Risk
4	None	None	None	Present	None	Low Risk
5	None	None	Present	None	None	Low Risk
6	None	Present	None	None	None	Low Risk
7	Present	None	None	None	None	Low Risk
8	None	Present	None	None	None	Low Risk
9	None	None	Present	None	None	Low Risk
10	None	None	None	Present	None	Low Risk
11	None	None	None	None	Present	Low Risk
12	None	None	None	Present	Present	Moderate Risk
13	Present	None	None	None	None	Low Risk

14	None	Present	None	None	None	Low Risk
15	None	None	Present	None	None	Low Risk
16	None	None	None	Present	None	Low Risk
17	None	Fair	None	None	Present	Low Risk
18	None	Fair	Present	None	None	Moderate Risk
19	None	None	Present	None	None	Low Risk
20	None	Fair	None	Present	None	Low Risk
21	None	None	None	None	Present	Low Risk
22	Present	Fair	None	None	Present	Moderate Risk
23	None	None	Present	Present	None	Moderate Risk
24	Present	Fair	None	None	None	Moderate Risk
25	None	Fair	None	Present	None	Low Risk
26	None	None	None	None	Present	Low Risk
27	Present	Fair	None	None	None	Low Risk
28	None	Fair	None	None	None	Low Risk
29	None	Fair	Present	None	None	Low Risk
30	None	None	None	Present	Present	Moderate Risk

31	None	Fair	None	None	Present	Low Risk
32	Present	None	None	None	None	Low Risk
33	None	Fair	None	None	Present	Low Risk
34	None	Fair	Present	None	None	Moderate Risk
35	Present	Fair	None	None	Present	Moderate Risk
36	None	None	Present	Present	None	Moderate Risk
37	Present	Fair	None	None	None	Low Risk
38	None	Fair	None	None	None	Low Risk
39	None	Fair	Present	None	None	Low Risk
40	Present	Fair	None	None	None	Moderate Risk
41	None	None	None	Present	Present	Moderate Risk
42	Present	Present	Present	None	None	Moderate Risk
43	None	None	Present	None	None	Low Risk
44	Present	None	None	Present	Present	Moderate Risk
45	Present	Present	Present	None	None	Moderate Risk
46	None	None	Present	Present	Present	Moderate Risk
47	Present	Present	None	None	Present	Moderate Risk
48	None	Present	Present	Present	None	Moderate Risk

49	None	None	None	Present	None	Low Risk
50	None	None	None	None	Present	Low Risk
51	Present	None	None	None	None	Low Risk
52	None	Present	None	None	None	Low Risk
53	None	None	Present	None	None	Low Risk
54	Present	None	None	Present	Present	Moderate Risk
55	None	None	None	Present	None	Low Risk
56	None	None	None	None	Present	Low Risk
57	Present	None	None	None	None	Low Risk
58	Present	Present	Present	None	None	Moderate Risk
59	None	None	Present	Present	Present	Moderate Risk
60	Present	Present	None	None	Present	Moderate Risk
61	None	Present	None	None	None	Low Risk
62	None	None	Present	None	None	Low Risk
63	None	None	None	Present	None	Low Risk
64	None	Present	Present	Present	None	Moderate Risk
65	Present	None	Fair	Present	Present	Moderate Risk
66	Present	Present	None	None	None	Moderate Risk

67	None	None	Fair	None	Present	Low Risk
68	None	None	None	Present	Present	Moderate Risk
69	Present	Present	Fair	None	Present	Moderate Risk
70	None	Present	None	Present	None	Moderate Risk
71	Present	None	Fair	Present	Present	Moderate Risk
72	Present	Present	None	None	None	Moderate Risk
73	Present	None	Fair	None	None	Low Risk
74	None	Present	None	None	None	Low Risk
75	None	None	Fair	None	None	Low Risk
76	None	None	None	Present	Present	Moderate Risk
77	Present	Present	Fair	None	Present	Moderate Risk
78	None	Present	None	Present	None	Moderate Risk
79	None	None	Fair	Present	None	Low Risk
80	Present	None	None	Present	Present	Moderate Risk
81	Present	Present	Fair	None	None	Moderate Risk
82	None	None	None	Present	Present	Moderate Risk
83	Present	Present	Fair	None	Present	Moderate Risk
84	None	Present	None	Present	None	Moderate Risk

85	None	None	Fair	None	Present	Low Risk
86	Present	None	None	Present	Present	Moderate Risk
87	Present	Present	Fair	None	None	Moderate Risk
88	None	None	Fair	Present	Present	Moderate Risk
89	Present	Present	None	None	None	Moderate Risk
90	None	None	None	Present	Present	Moderate Risk
91	None	Present	Present	None	None	Moderate Risk
92	Present	None	None	None	Present	Moderate Risk
93	None	None	Present	Present	None	Moderate Risk
94	Present	Present	None	None	None	Moderate Risk
95	None	None	None	Present	Present	Moderate Risk
96	Present	Present	Present	None	Present	High Risk
97	Present	None	None	None	None	Low Risk
98	None	Present	None	None	None	Low Risk
99	None	None	Present	None	None	Low Risk
100	None	None	None	Present	None	Low Risk
101	None	None	None	None	Present	Low Risk
102	None	Present	Present	None	None	Moderate Risk

103	Present	None	None	None	None	Low Risk
104	None	Present	None	None	None	Low Risk
105	None	None	Present	None	None	Low Risk
106	Present	None	None	None	Present	Moderate Risk
107	None	None	Present	Present	None	Moderate Risk
108	Present	Present	None	None	None	Moderate Risk
109	None	None	None	Present	None	Low Risk
110	None	None	None	None	Present	Low Risk
111	Present	None	None	None	None	Low Risk
112	None	None	None	Present	Present	Moderate Risk
113	None	Present	Present	Fair	None	Moderate Risk
114	Present	None	None	None	Present	Moderate Risk
115	None	Present	None	Fair	None	Low Risk
116	None	None	Present	Fair	None	Moderate Risk
117	Present	Present	None	Fair	None	Moderate Risk
118	None	None	None	Fair	Present	Moderate Risk
119	None	Present	Present	Fair	None	Moderate Risk
120	Present	None	None	None	Present	Moderate Risk

121	None	None	Present	Fair	None	Low Risk
122	None	None	None	Fair	None	Low Risk
123	None	None	None	Fair	Present	Low Risk
124	None	None	Present	Fair	None	Moderate Risk
125	Present	Present	None	Fair	None	Moderate Risk
126	None	None	None	Fair	Present	Moderate Risk
127	Present	None	None	Fair	None	Low Risk
128	None	Present	Present	None	None	Moderate Risk
129	Present	None	None	Fair	Present	Moderate Risk
130	None	None	Present	Fair	None	Moderate Risk
131	Present	Present	None	Fair	None	Moderate Risk
132	None	None	None	Fair	Present	Moderate Risk
133	None	Present	None	Fair	None	Low Risk
134	None	Present	Present	None	None	Moderate Risk
135	Present	None	None	Fair	Present	Moderate Risk
136	None	None	Present	Fair	None	Moderate Risk
137	Present	Present	None	None	Present	Moderate Risk
138	None	Present	Present	Present	None	Moderate Risk

139	Present	None	None	Present	Present	Moderate Risk
140	Present	Present	Present	None	None	Moderate Risk
141	None	None	Present	Present	Present	Moderate Risk
142	Present	Present	None	None	Present	Moderate Risk
143	None	Present	Present	Present	None	Moderate Risk
144	Present	Present	Present	Present	Present	High Risk
145	None	None	Present	None	None	Low Risk
146	None	None	None	Present	None	Low Risk
147	None	None	None	None	Present	Low Risk
148	Present	None	None	Present	Present	Moderate Risk
149	Present	Present	Present	None	None	Moderate Risk
150	None	None	Present	Present	Present	Moderate Risk
151	Present	None	None	None	None	Low Risk
152	Present	Present	None	None	Present	Moderate Risk
153	None	Present	Present	Present	None	Moderate Risk
154	Present	None	None	Present	Present	Moderate Risk
155	Present	Present	Present	None	None	Moderate Risk
156	None	None	Present	Present	Present	Moderate Risk

157	None	Present	None	None	None	Low Risk
158	Present	Present	None	None	Present	Moderate Risk
159	None	Present	Present	Present	None	Moderate Risk
160	Present	None	None	Present	Present	Moderate Risk
161	Present	Present	Present	None	Fair	Moderate Risk
162	None	None	Present	Present	None	Moderate Risk
163	Present	Present	None	None	Fair	Moderate Risk
164	None	Present	Present	Present	None	Moderate Risk
165	Present	None	None	Present	Fair	Moderate Risk
166	Present	Present	Present	None	None	Moderate Risk
167	None	None	Present	Present	Fair	Moderate Risk
168	Present	Present	Present	Present	None	High Risk
169	None	None	Present	None	Fair	Low Risk
170	Present	Present	None	None	None	Moderate Risk
171	None	Present	Present	Present	Fair	Moderate Risk
172	Present	None	None	Present	None	Moderate Risk
173	Present	Present	Present	None	Fair	Moderate Risk
174	None	None	Present	Present	None	Moderate Risk

175	Present	Present	None	None	Fair	Moderate Risk
176	None	Present	Present	Present	None	Moderate Risk
177	Present	None	None	Present	Fair	Moderate Risk
178	Present	Present	Present	None	None	Moderate Risk
179	None	None	Present	Present	Fair	Moderate Risk
180	Present	Present	Present	Present	None	High Risk
181	Present	Present	None	None	Fair	Moderate Risk
182	None	Present	Present	Present	None	Moderate Risk
183	Present	None	None	Present	Fair	Moderate Risk
184	Present	Present	Present	None	Fair	Moderate Risk
185	None	None	None	Present	Present	Moderate Risk
186	Present	Present	Present	None	Present	High Risk
187	None	Present	Present	None	None	Moderate Risk
188	Present	None	None	None	Present	Moderate Risk
189	None	None	Present	Present	None	Moderate Risk
190	Present	Present	Present	Present	Present	High Risk
191	Present	Present	None	Present	Present	High Risk
192	Present	Present	Present	Present	Present	High Risk

193	None	None	None	Present	None	Low Risk
194	None	None	None	None	Present	Low Risk
195	Present	None	None	None	None	Low Risk
196	Present	Present	None	None	None	Moderate Risk
197	None	None	None	Present	Present	Moderate Risk
198	None	Present	Present	None	None	Moderate Risk
199	None	Present	None	None	None	Low Risk
200	Present	None	None	None	Present	Moderate Risk
201	None	None	Present	Present	None	Moderate Risk
202	Present	Present	None	None	None	Moderate Risk
203	None	None	None	Present	Present	Moderate Risk
204	None	Present	Present	None	None	Moderate Risk
205	None	None	Present	None	None	Low Risk
206	Present	None	None	None	Present	Moderate Risk
207	Present	None	None	None	Present	Moderate Risk
208	None	None	Present	Present	None	Moderate Risk
209	Fair	Present	None	None	None	Moderate Risk
210	None	None	None	Present	Present	Moderate Risk

211	Fair	Present	Present	None	None	Moderate Risk
212	Fair	None	None	None	Present	Moderate Risk
213	Fair	None	Present	Present	None	Moderate Risk
214	Fair	Present	None	None	None	Moderate Risk
215	Fair	None	None	Present	Present	Moderate Risk
216	Fair	None	Present	Present	Present	High Risk
217	Fair	None	None	Present	None	Low Risk
218	None	Present	Present	None	None	Moderate Risk
219	Fair	None	None	None	Present	Moderate Risk
220	None	None	Present	Present	None	Moderate Risk
221	Fair	Present	None	None	None	Moderate Risk
222	Fair	None	None	Present	Present	Moderate Risk
223	None	Present	Present	None	None	Moderate Risk
224	Fair	None	None	None	Present	Moderate Risk
225	None	None	Present	Present	None	Moderate Risk
226	Fair	Present	None	None	None	Moderate Risk
227	None	None	None	Present	Present	Moderate Risk
228	Fair	Present	Present	Present	Present	High Risk

229	None	Present	Present	None	None	Moderate Risk
230	Fair	None	None	None	Present	Moderate Risk
231	None	None	Present	Present	None	Moderate Risk
232	Fair	Present	None	None	None	Moderate Risk
233	None	None	Present	Present	Present	Moderate Risk
234	None	Present	Present	Present	Present	High Risk
235	Present	Present	None	None	Present	Moderate Risk
236	None	Present	Present	Present	None	Moderate Risk
237	Present	None	None	Present	Present	Moderate Risk
238	Present	Present	Present	Present	Present	High Risk
239	Present	Present	Present	Present	None	High Risk
240	Present	Present	Present	None	Present	High Risk
241	None	None	None	None	Present	Low Risk
242	Present	Present	Present	None	None	Moderate Risk
243	None	Present	Present	Present	Present	Moderate Risk

APPENDIX II

MATLAB Source Code of Fuzzy Model for Classification of Rice Plant Diseases

```
[System]
Name='Untitled'
Type='mamdani'
Version=2.0
NumInputs=5
NumOutputs=1
NumRules=1
AndMethod='min'
OrMethod='max'
ImpMethod='min'
AggMethod='max'
DefuzzMethod='centroid'

[Input1]
Name='Discoloured__leaves'
Range=[0 2]
NumMFs=3
MF1='None':'trimf',[-0.5 0 0.5]
MF2='Fair':'trimf',[0.5 1 1.5]
MF3='Present':'trimf',[1.5 2 2.5]

[Input2]
Name='Presence__of__blights'
Range=[0 2]
NumMFs=3
MF1='None':'trimf',[-0.5 0 0.5]
```

MF2='Fair':'trimf',[0.5 1 1.5]

MF3='Present':'trimf',[1.5 2 2.5]

[Input3]

Name='Water__soaked__patches'

Range=[0 2]

NumMFs=3

MF1='None':'trimf',[-0.5 0 0.5]

MF2='Fair':'trimf',[0.5 1 1.5]

MF3='Present':'trimf',[1.5 2 2.5]

[Input4]

Name='Wilted__leaves'

Range=[0 2]

NumMFs=3

MF1='None':'trimf',[-0.5 0 0.5]

MF2='Fair':'trimf',[0.5 1 1.5]

MF3='Present':'trimf',[1.5 2 2.5]

[Input5]

Name='Stunted__growth'

Range=[0 2]

NumMFs=3

MF1='None':'trimf',[-0.5 0 0.5]

MF2='Fair':'trimf',[0.5 1 1.5]

MF3='Present':'trimf',[1.5 2 2.5]

[Output1]

Name='Rice__Diseases'

Range=[0 3]

NumMFs=4

MF1='No-Risk':'trimf',[-0.5 0 0.5]

MF2='Low-Risk':'trimf',[0.5 1 1.5]

MF3='Modearate-Risk':'trimf',[1.49 1.99 2.49]

MF4='High-Risk':'trimf',[2.5 3 3.5]

[Rules]

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