IOSR Journal of Computer Engineering (IOSR-JCE)
e-ISSN: 2278-0661,p-ISSN: 2278-8727, Volume 20, Issue 6, Ver. I (Nov - Dec 2018), PP 52-64
www.iosrjournals.org

Fuzzy Logic Expert System for the Diagnosis of Chili Diseases

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Abstract: *Chilli plant is one of the major cash crop in the world, many economy depends on its production. Chilli farmer has lost a lot of their crop due to diseases which in return causes farmers to loss lot of money and time such Chilli disease includes grey Mould, Bacterial soft/wilt, pepper mosaic virus, Anthracnose, Damping off, Chilli Wilt, Basal stem rot etc. The symptoms sometimes can be very difficult to identify by a human expert which often leads to the death of the chill plant. The goal of this research is to develop a Fuzzy logic system for diagnosing various types of Chilli plant diseases, and also to illustrate the architecture of fuzzy logic system. The knowledge base system holds the symptoms for Chilli diseases and a sequence of methodical and analytical decision steps that enhance the quality and meaning of the logic. The system eliminates the uncertainties often associated with human expert. The software used for the development of necessary Graphical User interfaces (GUI), for fuzzy modeling, fuzzy inference system editor, membership function editor, rule editor, rule editor, rule viewer and surface viewer is MATLAB. The system has been tested by some domain experts.*

Date of Submission: 29-10-2018 Date of acceptance: 12-11-2018

I. Introduction

Chili (Capsicum annuum L.) Generally, is an important vegetable spice crop grown in almost all parts of tropical and subtropical regions of the world. It belongs to the family Solanaceae and originated from South and Central America where it was domesticated around 7000 BC. The genus Capsicum includes 30 species, five of which are cultivated: Capsicum annuum L., C. Frutescens L., C. Chinense Jacq, C. pubescens R. & P. and C. Baccatum L.[1, 2.]

Throughout the world, chili is consumed fresh, dried or in powder [3]. It is rich in proteins, lipids, carbohydrates, fibers, mineral salts (Ca, P, Fe) and in vitamins A, D3, E, C, K, B2 and B12.The fruits are an excellent source of health-related phytochemical compounds, such as ascorbic acid (vitamin C), carotenoids (provitamin A), tocopherols (vitamin E), flavonoids, and capsaicinoids that are very important in preventing chronic diseases such as cancer, asthma, coughs, sore throats, toothache, diabetes and cardiovascular diseases [3,4].

Problem of Chilli production

They are many causes or problem that may hinder the production of Chilli which is listed below:

1. Pest and Disease attack
2. Non-availability of high breeds varieties
3. Increasing trend in cost of production
4. Inadequate finance
5. High cost of labour
6. High cost of fertilizers
7. High cost of pesticides
8. Poor incentive from the Government Non-availability of seedlings.

Chili has antioxidant, anti-mutagenesis, hypocholesterolemia and immunosuppressive properties [3] and also inhibits bacterial growth and platelet agglomeration [4]. At global level, chili is one of the spices that generate huge revenues for producers and therefore contributes to poverty alleviation and improvement of women's social status [5]. Despite its economic, food and medicinal importance, chili remains in many countries a neglected crop that is rarely of national priority in terms of agricultural development [6]. Therefore, its cultivation is still traditional and is facing many biotic (Pests, diseases), and abiotic (drought, high soil moisture, salinity, soil poverty, etc.) stresses that cause severe yield losses [7,8].

Origin of the Host Crop Chilli

Chili is originated from the Latin American tropical regions of the South (New Mexico and Guatemala) approximately 7500BC. The Mexico is considered the native home of Chilies. Portuguese's prior to 1585 brought hot chilies from Brazil to Indo-Pak subcontinent [9].

It has been the first ever domesticated crop of America. During the course of evolution, three important species of *Capsicum* i.e., *C. annuum, C. Frutescens* and *C. Chinense* evolved from a common ancestor that grew wildly in the North of the Amazon basin (NW-Brazil, Columbia) spreading to the other parts of America. Initially, people cultivated them with other crops in order to protect their crop from the damage caused by birds. By the end of eighteenth i.e. *C.annuum* L., *C.baccatum* L., *C.chinense* Jacq., *C.frutescens* L., and *C.pubescens* R.&P were domesticated in different parts of the America [10].

Fuzzy Logic

These are various type of experience can rarely be expressed or measured using statistical or probability theory. Fuzzy logic is an extension of Boolean logic by Lotfi Zadeh in 1965 based on the mathematical theory of fuzzy sets, which is a generalization of the classical set theory. By introducing the notion of degree in the verification of a condition, thus enabling a condition to be in a state other than true or false, fuzzy logic provides a very valuable flexibility for reasoning, which makes it possible to take into account inaccuracies and uncertainties. One advantage of fuzzy logic in order to formalize human reasoning is that the rules are set in natural language. Fuzzy logic provides a framework to model uncertainty, the human way of thinking, reasoning and the perception [11].

II. Related Works

History of Artificial Intelligence

In the 21st century artificial intelligence (AI) has become an important area of research in virtually all fields: engineering, science, education, medicine, business, accounting, finance, marketing, economics, stock market and law, among others [12]. In this brief history, the beginnings of artificial intelligence are traced to philosophy, fiction, and imagination. Early inventions in electronics, engineering, and many other disciplines have influenced AI. Some early milestones include work in problems solving which included basic work in learning, knowledge representation, and inference as well as demonstration programs in language understanding, translation, theorem proving, associative memory, and knowledge-based systems [13]. Philosophers have floated the possibility of intelligent machines as a literary device to help us define what it means to be human. How even the seed of modern AI were planted by philosophers who attempted to describe the process of how human thinks by manipulating mechanical symbols [14].

Review on Expert System

The discovery and development of expert systems recorded since in the early 1970s until today. The unique characteristic of the expert system is an explanation capability to review its own reasoning and explain its decisions [15]. It was built by extracting knowledge from human experts to be applied in a computer program for knowledge processing so that it can deal with quantitative and qualitative data. Compared to other conventional program that require sequences of step prescript called algorithm, expert system more intelligent as human being that allow inexact reasoning and can deal with incomplete data[16]. Expert system programming can be categorized based of the particular subject area and it purpose of applications, as such type of diagnosis [17], repair, instruction, interpretation, prediction [18], design and planning, simulate [19, 20], control, classification or identification and others many. Each type of expert system programming development would apply different rules, code, sequence of algorithm, interactive method between user and program etc. The main objective of the development of an expert fault diagnosis system is to achieve an integrated diagnostic procedure for air-conditioning development.

Major Component of an Expert System

The user interface: - the user interface is mean of communication between a user and expert system problem-solving processes. A good expert system is not very useful unless it has an effective interface it has to be able to able the queries or instruction in a form that the user enters and translate them into working instructions for the rest of the system it also has to be able to translate the answers, produced by the system, into a form that the user can understand [21].

Knowledge Base: - the knowledge base store all the facts and rules about a particular problem domain it makes these available to the inference engine in a form that it can use. The facts may be in form of background information built into the system. The rules include both the production rules that apply to the domain of the expert system and the heuristics and rules of thumb that are provided by the domain expert in order to make the system find solutions more efficiently by taking short cuts.

The shell or inference Engine: - the inference engine is the program that locates the appropriate knowledge in the knowledge base and infers new knowledge by applying logical processing and problem-solving strategies [22]. The inference engine can be considered the brain of the system and thus implements inferencing by utilizing the

IF THEN rule to draw conclusion as to which answer is to be retrieved for a relevant query or question this is shown in figure 1.

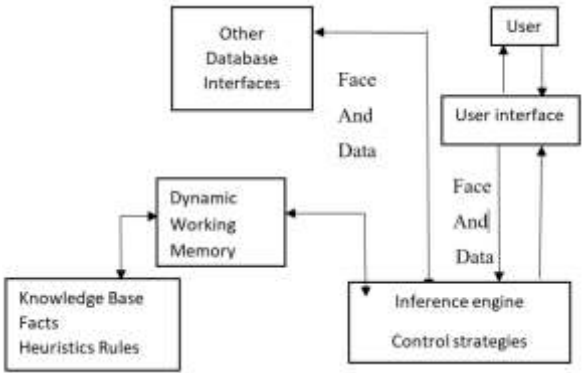

Fig 1. Component of an expert system

Adaptation of Fuzzy Inference Systems

Expert knowledge is often the main source to design the fuzzy expert systems with Parameters and components that need to be adapted for controlling a process. According to the performance measure of the problem environment, the membership functions, rule bases, and the inference mechanism are to be adapted [23]. Neural network learning, self-organizing maps and clustering methods could be used to generate rules. Gradient descent and its variants could be applied to fine-tune the parameters of parameterized input/output membership functions and fuzzy operators [24]. Adaptation of fuzzy inference systems using evolutionary the task is to develop a fuzzy expert system to forecast the reactive power (P) at time t + 1 by knowing the load current (/) and voltage (V) at time t. The experiment system consists of two stages: developing the fuzzy expert system, and performance evaluation using the test data. The model has two in-out variables (V and 1) and one output variable (P). Training and testing data sets were extracted randomly from the master dataset. Sixty percent of data was used for training and the remaining 40% for Testing [24]. This is shown in Figure 2

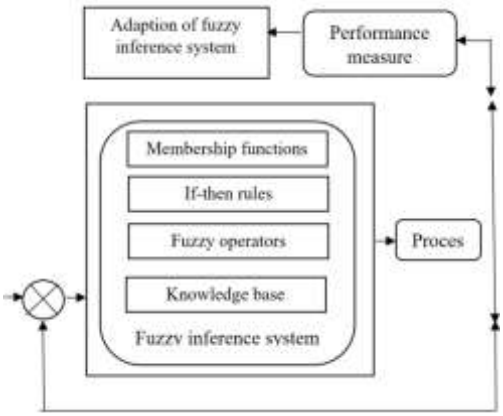

Figure 2. Adaptation of fuzzy inference systems

III. Methodology

Data for this study is gathered through reliable source. A set of parameter used to diagnosis (13 basic and major parameters) as presented in Table 1

Table 1 Diseases Parameter of Chilli

DISEASE CODES	DISEASES OF CHILLI
P01	Bacterial Leafspot
P02	Pepper Mosaic Virus
P03	Bacterial soft rot/wilt
P04	Grey Mould
P05	Anthracnose (Rotten fruit)
P06	Basal Stem
P07	damping off (Seed Rot)
P08	Chilli wilt
P09	Fusarium wilt
P10	Phytophona (Root rot)

P11	Viral disease (dwarfing of leaves)
P12	Oomycete (Slow plant growth)
P13	Root knot nematode (Galls on roots)

The fuzzy expert Software used for the diagnosis is MATLAB. There are five primary GUI Tools for building, editing, and observing fuzzy inference system in the toolbox namely; Fuzzy system in the toolbox namely; Fuzzy Inference System (FIS) Editor, Membership Function Editor, Rule Editor, Rule Viewer, Surface Viewer

Fuzzy Expert System for Chilli Diagnosis

The most important application of fuzzy system (fuzzy logic) is in uncertain issues. When a Problem has dynamic behavior, fuzzy logic is a suitable tool that deals with this problem First step of fuzzy expert system designing is determination of input and output variables. There are 13 input variables and 1 output variable. After that, we must design membership functions (MF) of all variables. These membership functions determine the membership of objects to fuzzy sets.

P01.Bacterial Leafspot: This input variable supports 3 symptom types (Yellow/Green spot, Dry/Brittle leaf Edge and Fruits display Pale). We have defined a value in this system for each symptom type that we use these values for system testing. Each symptom type is a fuzzy set. In this field, fuzzy sets do not have overlap and sets define in form of crisp because the patient has just one symptom type on time. This is shown in Figure 3

INPUT FIELD	RANGE	FUZZY SET
Bacterial Leafspot	>2	Yellow/Green spot
	3-7	Dry/Brittle leaf Edge
	8>	Fruits display Pale

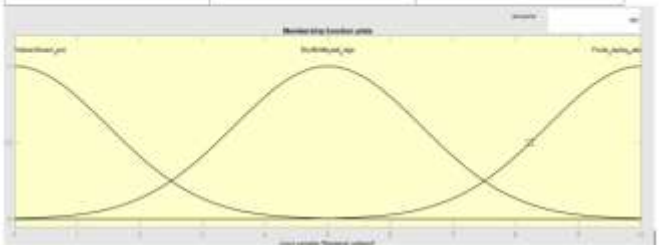

FIG 3. Membership function of Bacterial Leafspot

P02 ***Pepper Mosaic Virus:*** different value of Pepper Mosaic Virus changes the result easily. In this field, we use Pepper Mosaic Virus. This input variable has divided into 4 fuzzy sets. Fuzzy sets are "distorted Leaves", "Slow Growth", "poor yield", "green/yellow mosaic". We have defined fuzzy membership expressions for Pepper Mosaic Virus input filed. This shown in Figure 4.

INPUT FIELD	RANGE	FUZZY SET
Pepper Mosaic Virus	0-3	distorted Leaves
	1-7	Slow Growth
	5-10	poor yield
	7-10	green/yellow mosaic

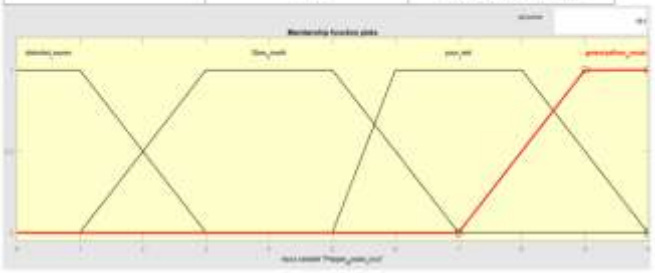

FIG 4. Membership function of Pepper Mosaic Virus

P03 ***Bacterial soft rot/wilt:*** it has salient affect on the result and can change it easily. For this input field, Bacterial soft field has 2 fuzzy sets (pod dissolves and pod smell/rot) these fuzzy sets in Table 2. Membership function set as trapezoidal. This is shown in Figure 5.

INPUT FIELD	RANGE	FUZZY SET
Bacterial soft rot/wilt	<3	pod dissolves
	3-10	pod smell/rot

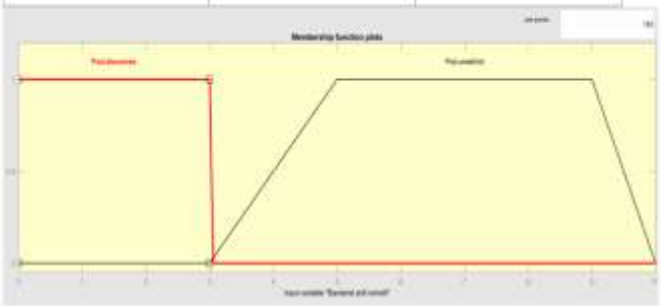

FIG 5. Membership function of Bacterial soft rot/wilt

P04 ***Grey Mould:*** this field is one of the most important factors in this system that changes the result. The input field has 4 fuzzy set. In this system, we have (fuzzy mould growth, tiny black seed, and Chilli soft/brown and bad/flower dies). Membership function of this fuzzy set is triangular. This is shown in Figure 6.

INPUT FIELD	RANGE	FUZZY SET
Grey Mould	0-1	fuzzy mould growth pod
	1-6	tiny black seed
	<3-7	chilli soft/brown
	5-10	bad/flower dies

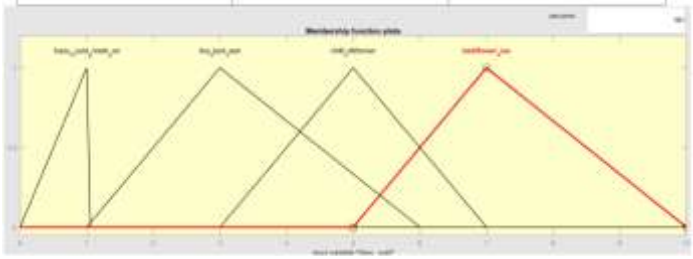

FIG 6. Membership function of Grey Mould

P05 ***Anthracnose (Rotten fruit)*****:** in this, we have 2 fuzzy sets (True or False) Membership functions of fuzzy sets are Gaussian "RANGE" column, we have defined a value for each fuzzy set in left side of each interval and we use just these values for the system testing. This is shown in figure 7.

INPUT FIELD	RANGE	FUZZY SET
Anthracnose (Rotten fruit)	0-5	True
	1-8	False

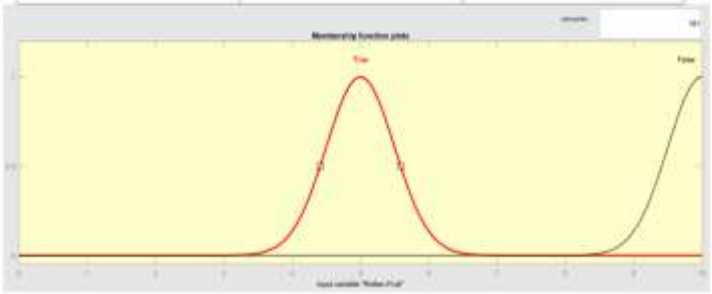

FIG 7. Membership function of Anthracnose (Rotten fruit)

P06 ***Basal Stem:*** in this, we have 2 fuzzy sets (small brown sclerotic or white Mycelcium) Membership functions of fuzzy sets are Gaussian "RANGE" column, we have defined a value for each fuzzy set in left side of each interval and we use just these values for the system testing. This is shown in figure 8.

INPUT FIELD	RANGE	FUZZY SET
	0-5	small brown sclerotic
Basal Stem	1-8	White Mycelcium

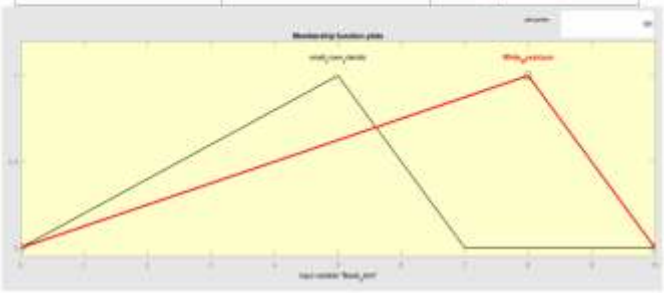

FIG 8. Membership function of Basal Stem

P07 ***damping off (Seed Rot) :*** in this, we have 2 fuzzy sets (True or False) Membership functions of fuzzy sets are Gaussian "RANGE" column, we have defined a value for each fuzzy set in left side of each interval and we use just these values for the system testing. This is shown in figure 9.

INPUT FIELD	RANGE	FUZZY SET
	0-5	True
damping off (Seed Rot)	5-10	False

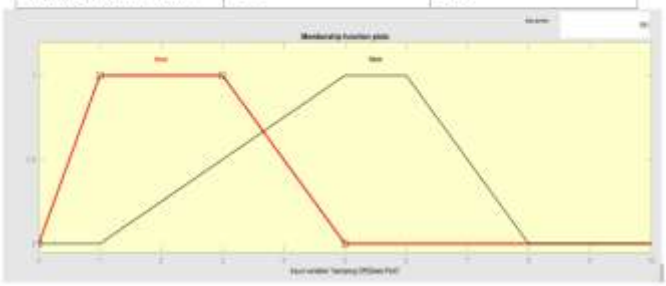

FIG 9 Membership function of damping off (Seed Rot)

P08 ***Chilli wilt*****:** this input field has 3 fuzzy set (blown/black patches, Dissolve fruits, Brown Stem) Membership functions of "blown/black patches", "Dissolve fruits" fuzzy sets are trapezoidal and membership function of "Brown Stem" fuzzy set is Triangular. This is shown in Figure 10.

INPUT FIELD	RANGE	FUZZY SET
	1.4-4.8	blown/black patches
Chilli wilt	1.4-8	Dissolve fruits
	5>	Brown Stem

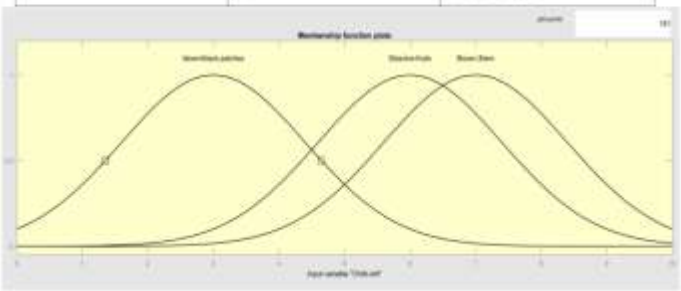

FIG 10. Membership function of Chilli wilt

P09 ***Fusarium wilt*****:** this input field consist 2 fuzzy sets: for each fuzzy set we have a value that we use them for testing. This is shown in figure 11.

INPUT FIELD	RANGE	FUZZY SET
Fusarium wilt	0-3	Yellowing of foliage
	0-4	Wilting spread

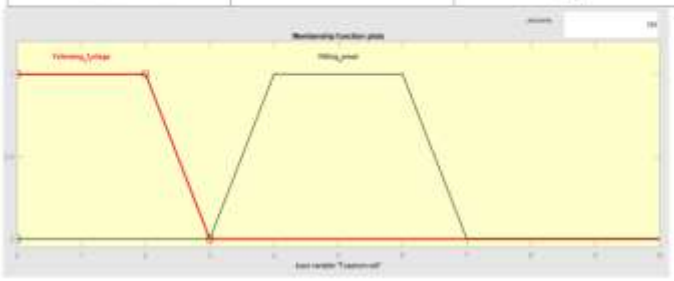

FIG 11. Membership function of Fusarium wilt

P10 ***Phytophona (Root rot):*** This input field just has 2 Value (0, 1) and sets (True or False).value 0 means that the root is not rotten, the value 1 means the root is rotten. This is shown in figure 12.

INPUT FIELD	RANGE	FUZZY SET
Phytophona(Root rot)	<10	True
	5-10	False

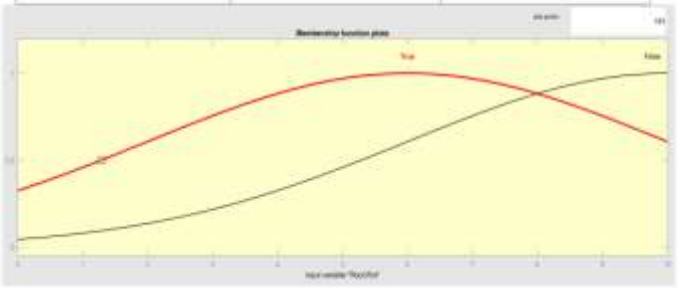

FIG 12. Membership function of Phytophona (Root rot)

P12 ***Oomycete (Slow plant growth):*** this input field is divides in two 2 fuzzy set (true or false) this is shown in figure 13.

INPUT FIELD	RANGE	FUZZY SET
Oomycete(Slow plant growth)	0-5	True
	5-10	False

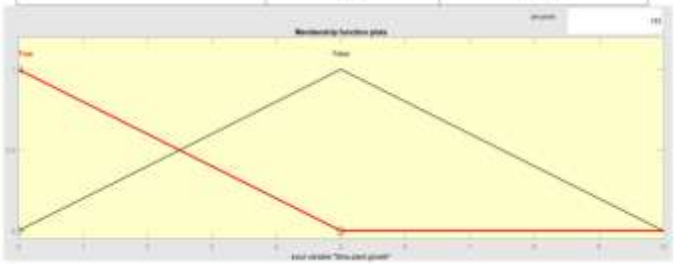

FIG 13 Membership function of Oomycete (Slow plant growth)

P13. ***Root knot nematode (Galls on roots):*** this input field has just 2 values (0, 1) which is shown in figure 14 below:

INPUT FIELD	RANGE	FUZZY SET
Root knot nematode (Galls on roots)	0-7 1-9	True False

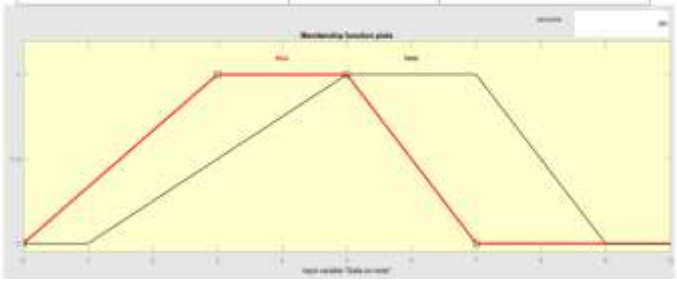

FIG 14. Membership function of Root knot nematode (Galls on roots)

Output Variable

The "goal" field refers to the presence of a disease or infection in the Chilli plant has integer value from 0 (no presence) to 3. By increasing of integer value, Chilli disease increase in the Chilli plant. In this system, we have considered a different output variable, which divide to 3 fuzzy sets (healthy Plant, might be infected and infected plant).Table 8 shows these fuzzy sets with their ranges. Membership functions of "healthy Plant", "might be infected" and "infected plant" fuzzy set are triangular. This is shown in Figure 15 Below:

INPUT FIELD	RANGE	FUZZY SET
Result	0-10 10-20 20-30	healthy Plant Might be infected Infected plant

FIG 15. Membership function of Output Variable Result

IV. Testing of the System

The system testing determines the integrity and reliability of the system. The testing of each modules program is made easier in which during the period of program testing. A number of point were visible, these include, the importance of generated result and the response time of generated result. The capacity and efficiency of the developed system has been tested by supplying new data (yes or no) to the program and examinee the output to see if the desired result are obtained. The flow diagram rule result is shown in fig 16 and we have defined a validity degree (k) for each rule as shown. This is shown in Fig. 17 to Fig. 28.

Figure 15. Flow diagram Rule Base

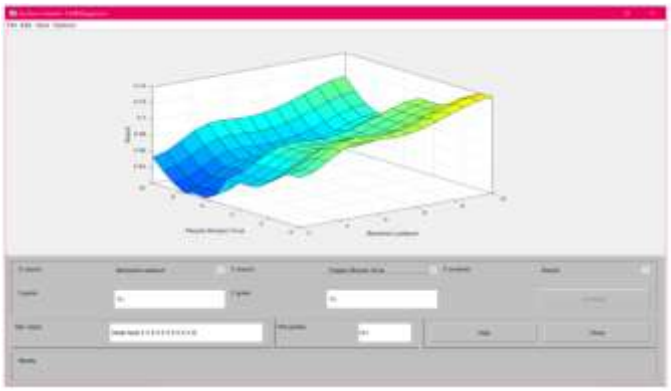

Fig 16. shows the surface of pepper mosaic virus and Bacterial leafspot

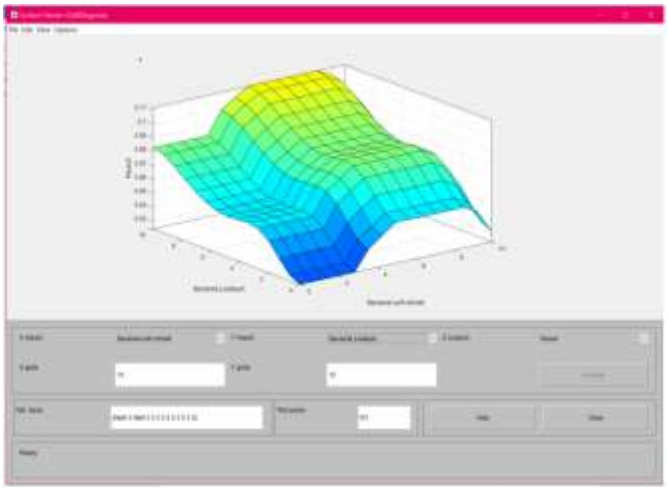

Fig 17. shows the surface of Bacterial soft/wilt and Bacterial leafspot

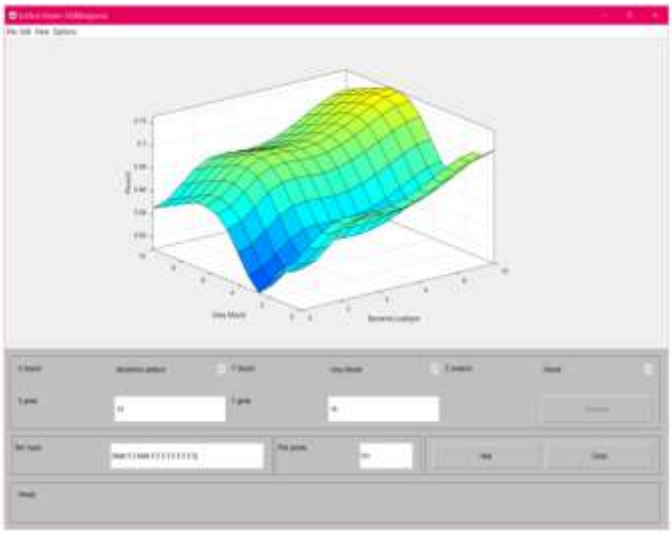

Fig 18. shows the surface of Grey Mould and Bacterial leafspot

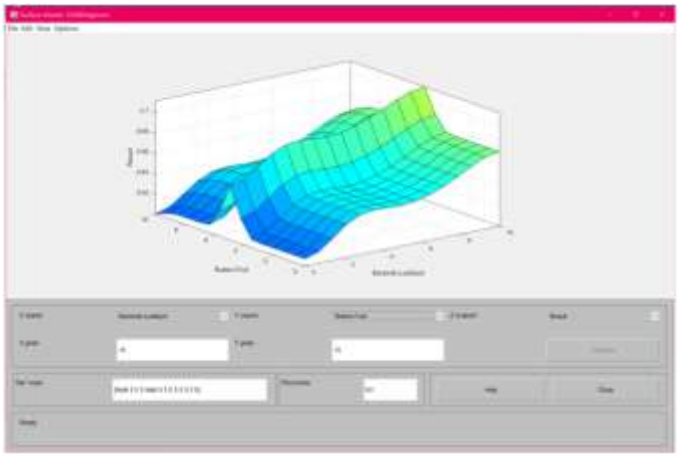

Fig 19. shows the surface of Anthracnose (Rotten Fruit) and Bacterial leafspot

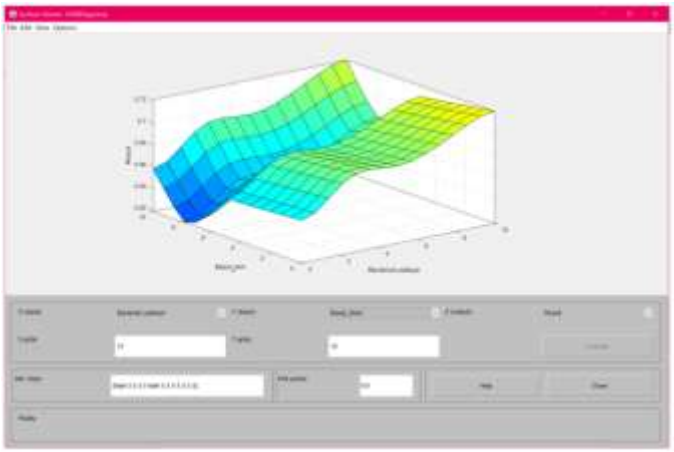

Fig 20. shows the surface of Basal Stem and Bacterial leafspot

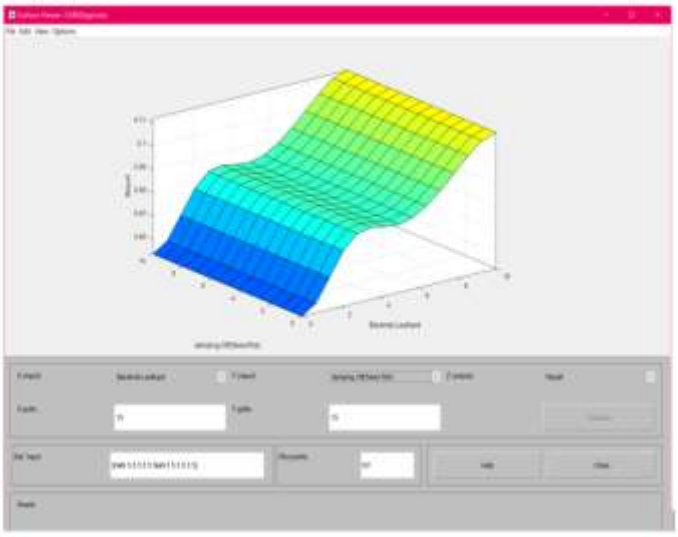

Fig 21 shows the surface of Damping Off (seed Rot) and Bacterial leafspot

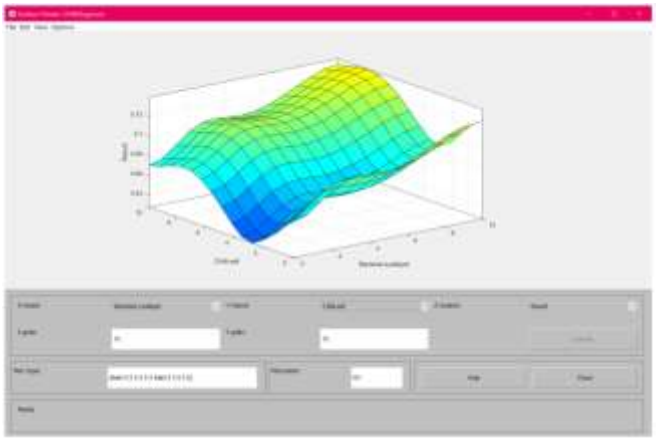

Fig 22. Shows the surface of Chilli wilt and Bacterial leafspot

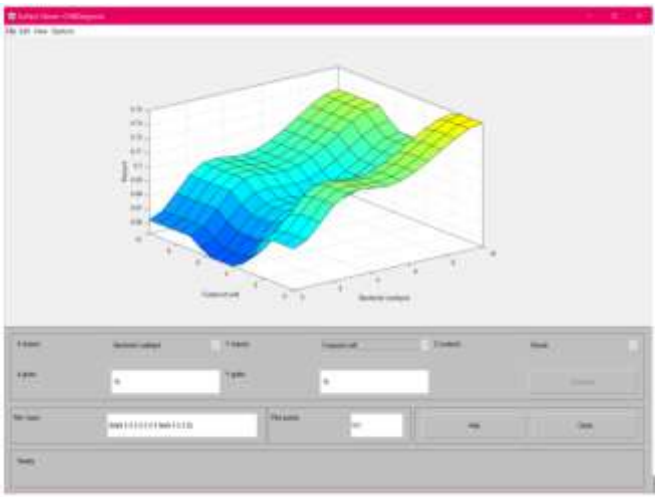

Fig 23. Shows the surface of Fusarium wilt and Bacterial leafspot

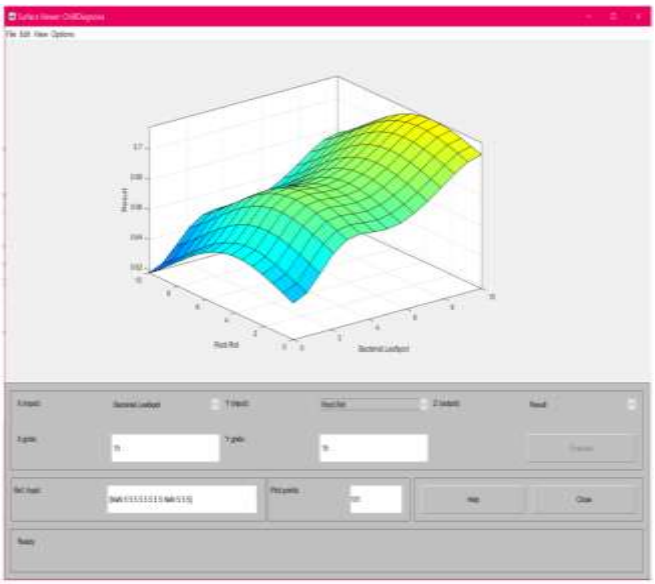

Fig 24. Shows the surface of Phytophona (Root rot) and Bacterial leafspot

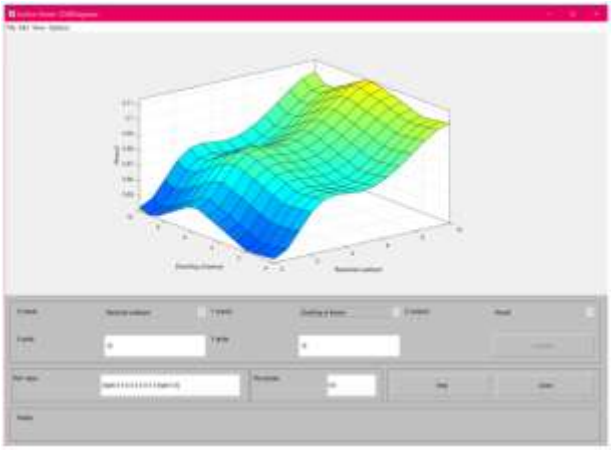

Fig 25 shows the surface of Dwarfing of Leaves and Bacterial leafspot

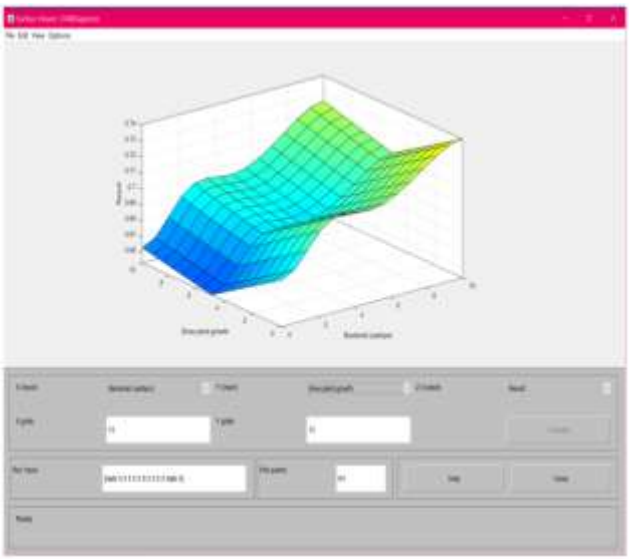

Fig 26 shows the surface of oomycete (Slow plant growth) and Bacterial leafspot

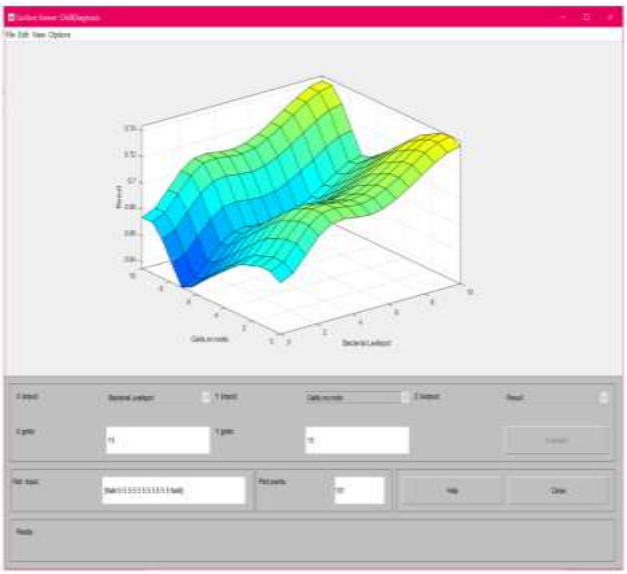

Fig 27 shows the surface of Root knot nematode (Galls on roots) and Bacterial leafspot

V. Conclusion

The need to design a system that would assist famers in Chilli diagnosis has become imperative and hence cannot be over emphasized. This study presents a diagnostic fuzzy logic system to help in diagnosis of Chilli diseases using a set of symptoms and demonstrates the practical application of ICT (Information and Communication Technology) in the domain of diagnostic pattern appraisal by determining the extent of membership of individual symptoms. This advanced system which uses a set of logic data set is more precise than the traditional system. The classification, verification and matching of symptoms to the three groups of logic was necessary especially in some complex scenarios. The fuzzy logic system designed and tested in this project appears to be a more natural and intelligent way of classification and matching of symptoms to Chilli disease.

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Amosa Babalola. " Fuzzy Logic Expert System for the Diagnosis of Chili Diseases " IOSR Journal of Computer Engineering (IOSR-JCE) 20.6 (2018): 52-64.