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A Fuzzy Expert System for Diagnosis and Treatment of Maize Plant Diseases

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Abstract*— Maize is an important cereal crop grown widely throughout the world in a range of agro-ecological environments. The crop can be used for food and non-foods products. Nonetheless, despite the nutritional and economic significance of the maize crop, the diseases incidence on maize plantations is fast becoming a constraint in farmers' quest for a bountiful harvest. The efforts of agricultural extension agents seem not to be sufficient in tackling this menace since there is always a limit to how far the human capacity can be stretched in the face of highly demanding situations. Hence, this paper proposed the development of fuzzy expert system for diagnosis and treatment of maize disease. This would provide immediate and instant information to the possible disease affecting the life of maize with the consideration of several known symptoms supplied. It would fast-track information service delivery on the part of the large-scale industrial grain farmers which make use of it for emergency situations of disease outbreak on the farm, pending the arrival of the agricultural extension agent.

***Keywords*— Maize diseases, agricultural extension agents, Information Technology, fuzzy expert system**

I. INTRODUCTION

Maize (*Zea mays*) which is known in many English-speaking countries as corn is a grain domesticated by indigenous peoples in Mesoamerica in prehistoric times. The Aztecs and Mayans cultivated it in numerous varieties throughout central and southern Mexico, to cook or grind in a process called nixtamalization. Later the crop spread through much of the Americas. Between 1250 and 1700, nearly the whole continent had gained access to the crop. Any significant or dense populations in the region developed a great trade network based on surplus and varieties of maize crops. After European contact with the Americas in the late 15th and early 16th centuries, explorers and traders carried maize back to Europe and introduced it to other countries through trade [9]. Maize spread to the rest of the world due to its popularity and ability to grow in diverse climates thus explaining why it is one of the major staple food crops consumed in today's Nigerian society.

Maize is a cereal crop that is grown widely throughout the world. More maize is produced annually than any other grain. About 50 species exist and consist of different colors, textures and grain shapes and sizes. The white and yellow varieties are preferred by most people depending on the region [5]. Maize was introduced into Africa in the 1500s and has since become one of Africa's dominant food crops. It is consumed as a vegetable although it is a grain crop. The grains are rich in vitamins A, C and E, carbohydrates, and essential minerals, and contain 9% protein. They are also rich in dietary fiber and calories which are a good source of energy. Maize is known as staple food for more than 1.2 billion people in Sub-Sahara Africa and Latin America. All parts of the crop can be used for food and non-food products. In industrialized countries, maize is largely used as livestock feed and as a raw material for industrial products [9].

Sequel to the nutritional and economic significance of the maize crop, it is noteworthy to mention the fact that diseases incidence on maize plantations is fast becoming a constraint in farmers' quest for a bountiful harvest from their maize farms and efforts of agricultural extension agents seem not to be sufficient in tackling this menace. Maize diseases include but are not limited to downy mildew, rust, leaf blight, stalk and ear rots, leaf spot, and maize streak virus [7]. The Expert System for diagnosis and treatment of maize diseases is therefore a software package designed to further enable efficiency and effectiveness in maize diseases management in terms of diagnosis and treatment as required by agricultural extension agents and other end-users (large-scale maize industrial farmers) to enhance higher productivity.

II. OVERVIEW OF EXPERT SYSTEMS

Expert systems are most valuable to organizations that have a high-level of know-how experience and expertise that cannot be easily transferred to other members. They are designed to carry the intelligence and information found in the intellect of experts and provide this knowledge to other members of the organization for problem-solving purposes [3].

Expert systems capture scarce expert knowledge and render it archival. This is an advantage when losing the expert would be a significant loss to the organization. Distributing the expert knowledge enhances employee productivity by offering necessary assistance to make the best decision. 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. As such, they are well suited to model human activities and problems. Expert systems can reduce production downtime and, as a result, increase output and quality. Additionally, expert systems facilitate the transfer of expertise to remote locations using digital communications. In specific situations, ongoing use of an expert system may be cheaper and more consistent than the services of a human expert [8].

Expert systems can track production variables, tabulate statistics, and identify processes that don't match the expected patterns, signaling potential problems. Moreover, integrated expert systems can immediately notify the appropriate person to correct a problem in the manufacturing process [2].

Compared to traditional programming techniques, expert system approaches provide the added flexibility and easier modifiability with the ability to model rules as data rather than as code. In situations where an organization's IT department is overwhelmed by a software-development backlog, rule-engines, by facilitating turnaround, provide a means that can allow organizations to adapt more readily to changing needs. In practice, modern expert-system technology is employed as an adjunct to traditional programming techniques, and this hybrid approach allows the combination of the strengths of both approaches. Thus, rule engines allow control through programs and user interfaces written in a traditional language, and also incorporate necessary functionality such as inter-operability with existing database technology.

According to Hayes-Roth *et al* [6], the following are some examples of expert systems which are now in commercial and research use in a number of fields:

1. CROP ADVISOR: This is an expert system that
performed prescription functions. Developed by ICI to advise cereal grain farmers on appropriate fertilisers and pesticides for their farms. The choice of chemical, amount, and time of application depends on such factors as crop to be grown, previous cropping, soil condition, acidity of soil, and weather. Farmers can access the system via the Internet. Given relevant data, the system produces various financial return projections for different application rates of different chemicals. The system uses statistical reasoning to come to these conclusions. If the question asked is outside the system's expertise, it refers the caller to a human expert. The chief advantages of this system have been that employees at ICI have been relieved of the need to provide lengthy telephone advice sessions, and the quality of the advice has become much more uniform, which has increased confidence in the company's products.
2. PLANT: It is used for prediction in agriculture. It forecasts future events, using a model based on past events predicted the damage to be expected when a corn crop was invaded by black cutworm. It was developed by a man called Boulanger, in 1983.
3. MOLGEN helps molecular biologists in planning DNA experiments.

Although expert systems have been a powerful tool in diagnosis, investigation and treatment of diseases, it has some limitations in its implementation. For instance, the programming language used in the implementation of the earliest versions is Prolog due its inadequacy for the problem; which is the complexity of generation of the knowledge base. Durkin [4] opined that the knowledge representation and acquisition are the most critical phases in the development of an expert system. Thus, it is very important to have a tool to generate automatically or semi-automatically the knowledge base from the expert knowledge.

III. TYPES OF DISEASES AFFECTING MAIZE, SYMPTOMS AND CONTROL

The section discussed the set of diseases affecting maize which is classified in groups depending on the causative organism and the associated symptoms [1]:

A. Bacterial Diseases

Bacterial are simple microscopic plants usually consisting of single prokaryotic cells, i.e. cells containing a single circular chromosome but no nuclear membranes or internal organelle comparable to chloroplast. Bacteria may be rod shaped, spherical, ellipsoidal, spiral, comma shaped or filamentous (i.e. threadlike). Some of symptoms associated with bacterial infections in maize plant include; leaf blight, soft rot of fruit, root, and storage organs, wilts, overgrowths, scabs, cankers etc.

B. Fungal Diseases

Fungi are small, general microscopic, plant lacking chlorophyll and conductive tissues. Most fungi are saprophytic living on dead organic matter which they help decompose. They cause local or general symptoms on their hosts and these may occur separately on different hosts, concurrently on the same host, or follow one another on the same host. In general fungi cause local or general necrotic or killing of plant tissues, hypertrophy and hypoplasia (or stunting of plant organs or entire plants), as well as hyperplasia or excessive growth of plant parts or whole plants. The most common necrotic symptoms of fungal infections are: leaf spots, blight, canker, root rot, damping off , basal stem rot, soft rots and dry rots, Anthracnose, scab, leaf rust, mildews, wilts, clubroots, stunting, galls, warts, leaf curls etc.

C. Parasitic (Nematodes) Diseases

Nematodes are one of the plant parasites belonging to the animal kingdom, they are sometimes called earthworm, are wormlike in appearance but quite distinct taxonomically from true worms. Some of the symptoms of Parasitic infections include root knots or root galls, roots lesions, excessive root branching, injured root tips and root rot, reduced growth, yellowing of foliage, excessive wilting in hot or dry weather, reduced yield and poor quality of products.

D. Viral Diseases

Virus are entities that are too small to be seen by with a light microscope, multiply only in living cells, and have the ability to cause diseases. More than half of all known viruses attack and cause diseases of plants. One virus may infect one or dozens of different species of plants, and one plant may be attacked by one or many different viruses. Generally viral diseases usually show the symptoms on the stem, roots, and cob. The most common types of plant symptoms produced by viral infection are: Mosaics is characterized by light-green, yellow, or white areas mingled with the normal green of the leaves. Depending on the intensity or pattern of discolorations, mosaic-type symptoms may be described as mottling, streak, ring pattern, line pattern, vein-clearing, vein-banding, chlorotic spotting, Ringspot – which is characterized by the appearance of chlorotic or necrotic rings on the leaves and sometimes on stem. In many ringspot diseases the symptoms, but not the virus, tend to disappear after onset only to reappear under certain environmental conditions.

IV. SYSTEM DESIGN

This is design of a fuzzy expert based model to detect and diagnose maize disease. The disease is determined by using a rule base, populated by rules extracted from experts for different types of maize disease. The algorithm uses the output of the rule base (i.e. the disease name) and the symptoms entered by the user; it also uses the priority and severity values to determine the disease if the maize. Both these results (disease name and stage) help the diagnostic logic to determine the treatment for the maize with accuracy. Expert from the field of agriculture deals with a complex analysis of all the information gathered about the symptoms. Domain expert's knowledge is gathered to generate rules and stored in the rule base and the rules are fired when there exist appropriate symptoms.

A *Fuzzy Algorithm of the Diagnosis*

The fuzzy rule-based system used in the diagnosis of maize disease, is composed of three components: fuzzification module, fuzzy rule base and fuzzy inference engine. The Fuzzification module maps the input numerical parameter into different fuzzy sets of the linguistic terms associated with that parameter. The membership function defined for each fuzzy set is applied on the input parameter to determine the degree of truth and rule premise. In fuzzy rule base, knowledge acquisition is the main concern of building an expert system. Knowledge in the form of IF–THEN rules was provided by experts and also extracted from data. Each rule has an antecedent part and a consequent part. The antecedent part is the collection of conditions connected by an AND logic operators and the consequent part represents its action. In fuzzy inference engine, the truth-value for the premise of each rule is computed and applied to the conclusion part of each rule. This results in one fuzzy subset being assigned to each output variable for each rule. The fuzzy algorithm for the development of the system includes the following:

STEP 1: Display symptoms, i.e. the interface displays a list of all the symptoms
STEP 2: Select the symptoms of uttermost concern (the weight of the symptoms are also put into consideration)
STEP 3: Select the level of severity for each selected symptoms (linguistic vales are assigned: V.H=0.93, H=0.76, M =0.57, L=0.38, V.L= 0.19)
STEP 4: For each selected symptoms, search the database for all the disease that has the symptoms and then select the weight, multiply it by the corresponding linguistic variable

For each selected symptom in all Disease
If symptom present in Disease

$$Disease_i = Symptomweight_i * \ SelectedLinguistic\ Value_i$$

$$Sum_{i\,=}\ Sum_i + \ Disease_i$$

End if
End for

$$\sum_{i=j}^{n} Symptomsweight_i \ * Linguistic\ Value_i$$

where n= number of Disease

STEP 5: Select the highest Disease (i.e. the Disease with the highest value) and display it as the Diagnosed Disease.

If $Disease_i \ > 0$
Select the highest Disease
End if

STEP 6: Display Disease

STEP 7: End

Table 1. Linguistic Variable and Membership Value

Linguistic Variable	**Linguistic Value**
Very High(V.H)	0.95
High(H)	0.76
Medium(M)	0.57
Low(L)	0.38
Very Low(V.L)	0.19

Table 2. Symptom Variable and Description

Symptom Variable	**Symptoms**
S_1	Black moldy growth on kernels and ear
S_2	Blighting
S_3	Cob Rot
S_4	Infected husks and kernel turn black
S_5	Seed Decay

Some of the rules showing the relationship between the fuzzy sets as shown in Table 1 and the symptoms shown in Table 2 are discussed below:

RULE 1: IF S_1 = V.H AND S_2 = V.H AND S_3 = V.H AND S_4 = V.H AND S_5 = V.H THEN X=BLACK KERNEL ROT"

RULE 2: IF S_1 = H AND S_2 = V.H AND S_3 = V.H AND S_4 = V.H AND S_5 = V.H THEN X= BLACK KERNEL ROT

RULE 3: IF S_1 = M AND S_2 = V.H AND S_3 = V.H AND S_4 = V.H AND S_5 = V.H THEN X= BLACK KERNEL ROT

RULE 4: IF S_1 = L AND S_2 = V.H AND S_3 = V.H AND S_4 = V.H AND S_5 = V.H THEN X= BLACK KERNEL ROT

RULE 5: IF S_1 = V.L AND S_2 = V.H AND S_3 = V.H AND S_4 = V.H AND S_5 = V.H THEN X= BLACK KERNEL ROT

RULE 6: IF S_1 = V.H AND S_2 = H AND S_3 = M AND S_4 = L AND S_5 = V.L THEN X= SOUTHERN LEAF BLIGHT

B. System Modules

The system comprises of two major modules that are accessed through user interface as described by conceptual schema as shown in Fig. 1. The first is the administrator module accessible only by the extension agent, responsible for registering complaints and takes the record of every complainant using the system, he has access to every page on system including the complainant record, disease control, plant information, and symptoms help. The second module is meant for the user(s) or complainants, who in this case is the farmer, once he has been registered by the extension agent in charge, then questions can be asked about the disease affecting his farm.

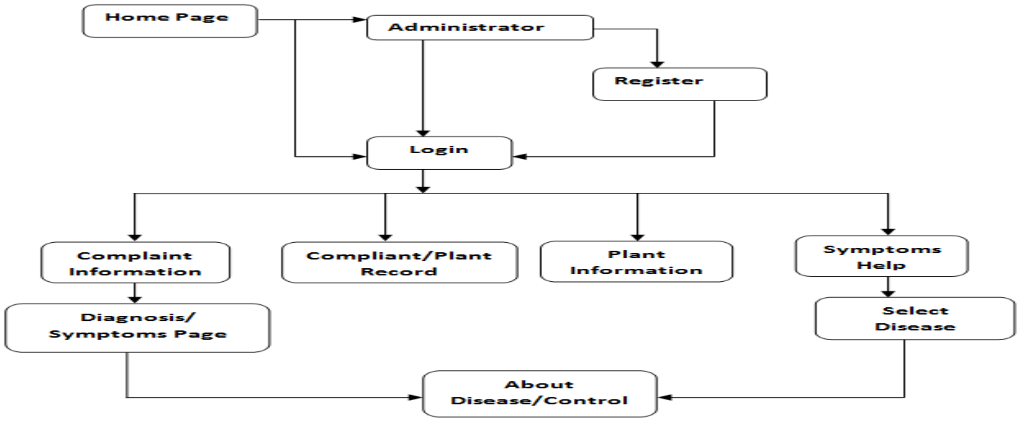

Fig. 1 Conceptual Schema of the System

1. Login/Register Page

The login page allows registered users with an account to enter their account information while the register page allows new users of the system to create an account before using the login page as shown in Fig. 2.

Fig. 2 Login/Register Page for users

2. Complainant Information Page

This page allows the administrator to enter information that contains complainant's personal information and information about the plant as in Fig. 3.

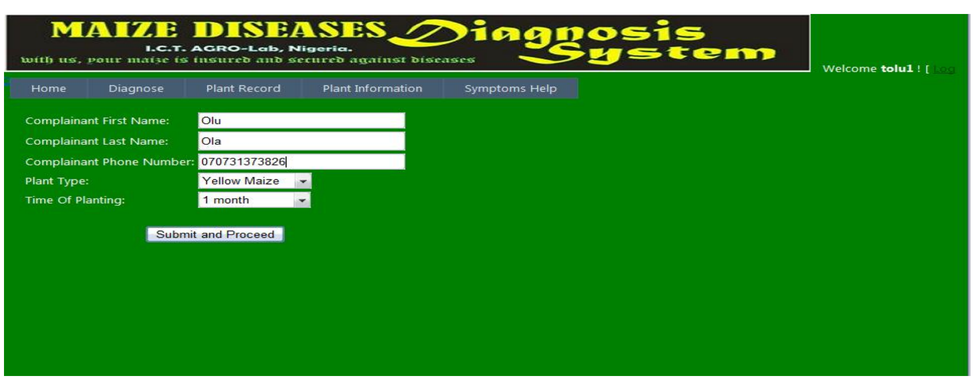

Fig. 3 Complainant Information Page

3. Diagnose Page

On this page there exist several symptoms in which the administrator asks complainant questions concerning the symptoms of the maize disease and the administrator selects the symptoms accordingly as shown in Fig. 4. After which a level of severity of the symptoms is also selected to the level or the degree in which the disease has eaten up the plant. Once the level of severity has been selected the diagnosis is done. Fuzzy helps to bring out a number of possible outputs ranging from the highest possible disease to the least. The administrator then clicks on any of the output to get detailed information of the disease and treatment to the disease as shown in Fig. 5.

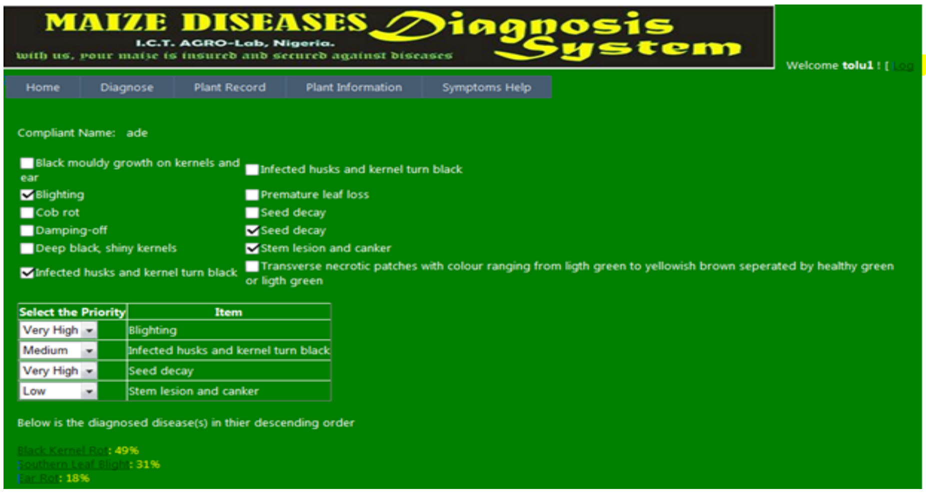

Fig. 4 Page Showing Diagnosed Disease Output

Fig. 5 Page Showing about Disease and its Control

V. RESULT AND DISCUSSION

The fuzzy rule based system developed was subjected to a test data to demonstrate the efficiency of the system. The observation from the tested data showed that the system was able to diagnose correctly the type of diseases affecting the maize on the farms based on the various observable symptoms that the complainants had earlier made and possible disease control as depicted in Fig. 6.

CompliantName	CompliantPhoneNumber	PlantType	DateOfPlanting	DiagnosedDisease	Remark
Olaide Ade	07031373826	Yellow Maize	1 month	Black Kernel Rot, Ear Rot, Southern Leaf Blight	Success
Olusoga Olalekan	08023642345	White Maize	2 month	Black Kernel Rot, Southern Leaf Blight, Ear Rot	Success
Adetono Tobiloba	08123456246	Yellow Maize	2 month	Black Kernel Rot, Ear Rot, Southern Leaf Blight	Success
Ajayi Akande	07054759362	Yellow Maize	1 month	Southern Leaf Blight	Success
Philip Steven	07034547692	Yellow Maize	1 month	Southern Leaf Blight, Ear Rot, Black Kernel Rot	Success
Oregbemi Tayo	08056723412	Yellow Maize	3 month	Black Kernel Rot, Ear Rot, Southern Leaf Blight	Success
Aladeniyi Kolawole	08153742845	Yellow Maize	1 month	Black Kernel Rot, Ear Rot, Southern Leaf Blight	Success
Rilwan Derin	07034556871	Yellow Maize	1 month	Ear Rot, Black Kernel Rot, Southern Leaf Blight	Success
Ogunleye Damola	08125345678	Yellow Maize	1 month	Southern Leaf Blight	Success
Oladele Abayomi	08156234627	Yellow Maize	2 month	Black Kernel Rot, Ear Rot, Southern Leaf Blight	Success
Ariwola Adeleye	08055443213	Yellow Maize	1 month	Ear Rot	Success
Sikiru Sule	08035683123	Yellow Maize	2 month	Black Kernel Rot, Ear Rot	Success
Olanihun Caleb	08127892347	Yellow Maize	1 month	Black Kernel Rot, Southern Leaf Blight	Success
Okikiola Ojo	07046759278	Yellow Maize	3 month	Southern Leaf Blight	Success
Nwokolo Emmanuel	08066823432	Yellow Maize	2 month	Black Kernel Rot, Ear Rot	Success
Asade Rotimi	08123456798	Yellow Maize	1 month	Black Kernel Rot, Ear Rot	Success
Adekunle Deji	07059625412	Yellow Maize	3 month	Black Kernel Rot	Success
Agbede Kunle	08095673421	Yellow Maize	2 month	Southern Leaf Blight	Success
Nwosu Clement	08134576890	Yellow Maize	3 month	Southern Leaf Blight, Ear Rot	Success

Fig. 6 Diagnosis Information Report of the complainants about maize

VI. CONCLUSION

In this paper, a fuzzy expert-based system was developed to provide immediate attention to the disease infested maize plantation as discovered by the educated agricultural farmers when agricultural extension agents are not present. This would also provide a means to preserve irreplaceable human knowledge expert. It would serve as a quick search for information on how to combat or disinfectant the infested maize plantation in order to get the desired quantity and quality of maize productivity.

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