Dr. Wheat: A Web-based Expert System for Diagnosis of Diseases and Pests in Pakistani Wheat

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ABSTRACT

This paper presents a web-based expert system for wheat crop in Pakistan. Wheat is one of the major grain crops in Pakistan. It is cultivated in vast areas of Punjab followed by Sindh and ranked first as a cereal crop in the country. Our rule-based expert system covers two main classes of problems namely diseases and pests, normally encountered in wheat crop. The expert system is intended to help the farmers, researchers and students and provides an efficient and goal-oriented approach for solving common problems of wheat. The system gives results that are correct and consistent.

KEYWORDS: Web-based expert systems, Agriculture, Symptoms, Diseases, and e2gLite™ expert system shell.

1. INTRODUCTION

The agriculture sector plays an important role in the overall development of Pakistan's economy. Majority of the population is dependent on this sector. The sector contributes about 24 percent of Gross Domestic Product (GDP) and accounts for half of employed labour force [2]. Table 1 reflects the wheat production statistics come from the FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS (FAO). The quantities of wheat are in metric tons.

TABLE I
WHEAT PRODUCTION STATISTICS [3]

Country	2000	2001	2002	2003	2004	2005
China	100	94	90	86	92	97
India	76	70	73	66	72	72
USA	61	53	44	64	59	57
Russian	34	47	51	34	45	48
France	37.4	31.5	38.9	30.5	39.7	36.8
Canada	26.5	20.6	16.2	23.6	25.9	26.8
Australia	22.1	24.3	10.1	26.1	21.9	25.1
Germany	21.6	22.8	20.8	19.3	25.4	23.7
Pakistan	21.1	19.0	18.2	19.2	19.5	21.6

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The rapid development of World Wide Web has provided another way of using expert systems. Now developers can build expert systems and distribute them over web. In this way multiple users can use such systems where they may not exists enough experts to provide the required assistance. Such systems are successfully employed in the field of agriculture as the information doesn't need to be protected and it is a lower cost alternative.

The development of web-based expert systems is a difficult task. Duan et al. [7] mentioned that the development of such systems requires a general methodology and research. Dokas [5] described the development of web-based expert systems as a web engineering project that can be developed by combining an expert system and a website with application sub projects [6]. Grove [10] mentioned several factors that make the Internet an ideal base for expert system delivery by contrast to standalone platforms. Some of the factors are:

- The instant availability of internet.
- A common multimedia interface provided by web browsers.
- Web based applications are inherently portable.
- Several web based KBS development tools are available.

This paper discusses our experiences in developing a web-based expert system for Pakistani wheat. The expert system is constructed using e2gLite™ expert system shell available freely on the internet. This web-based expert system shell allows a JAVA interface to process its input and output sets. The system can act as a powerful tool with extensive potential in agriculture especially in situations where agricultural specialist assistance is not readily available when the farmer needs it. The remainder of this paper is organized as follows. In section 2, we give an introduction of expert systems in agriculture. In section 3, we present a brief description of ailments of wheat crop in Pakistan. Section 4 is about design and development of our expert system. Section 5 contains knowledge base elements of e2gLite expert system shell. Section 6 is dedicated to some screenshots of our working system. As for conclusions, they are provided in section 7.

2. EXPERT SYSTEMS IN AGRICULTURE

Expert systems have applications in many domains. They are mostly suited in situations where the expert is not

readily available. In order to develop an expert system the knowledge has to be extracted from domain expert. This knowledge is then converted into a computer program. Knowledge Engineer performs the task of extracting the knowledge from the domain expert. Rule based expert systems are the most commonly known type of knowledge based systems. The knowledge is represented in the form of IF-THEN rules. Figure 2 shows different modules for a rule-based expert system.

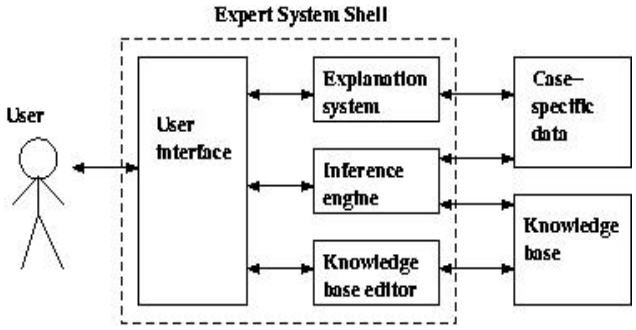

Figure 2: Expert System Architecture [1].

Expert systems have been developed and applied to many fields. In agriculture, expert systems are developed to diagnose the diseases and pests of various crops. Farmers across the world face problems like soil erosion, increasing cost of chemical pesticides, weather damage recovery, the need to spray, mixing and application, yield loses and pest resistance. On the other hand researchers in the field of agriculture are constantly working on new management strategies to promote farm success. In many countries today, farming has become technologically advanced and expert systems are widely used in the field of agriculture. In this way farmers can get expert opinion on their specific problems like selection of most suitable crop variety, diagnosis or identification of livestock disorder, suggestion tactical decisions throughout production cycle etc. from the expert system. Symptoms of diseases, disorders and pests have due geographical variations. So there is always a need to develop a new expert system for a different geographical region. Using expert system technology in agriculture is not new. (POMI) (Gerevini et al, 1992), an expert system for integrated pest management of apple orchards has been developed in Italy. CUPTEX (Rafea et al, 1995) is an expert system for handling management of cucumber disorders. The NEPER wheat expert system (Kamel et al, 1995) is used for handling the production management aspects of wheat crops. Yialouris and Sideridis (1996) developed an expert system for tomato. It handles the tomato disease identification problem. The US Department of Agriculture has developed an expert system for cotton crop management to provide appropriate management recommendations to cotton growers [4]. Center for Informatics Research and Advancement Kerala has prepared an Expert System called AGREX. It helps the Agricultural field personnel give timely and correct advice to the farmers [4]. An expert system for integrated production of muskmelon can be found in Ref. [8]. TOMATEX is an expert system for tomatoes [9].

3. BRIEF DESCRIPTION OF AILMENTS OF PAKISTANI WHEAT

The scientific name of wheat is Triticum aestivum. Its local names are Kanak and Gandum. Wheat is a *Rabi* (winter) crop. It replaces rice and cotton in rice-wheat and cotton-wheat systems. A number of wheat diseases are responsible for reducing its overall production to a great extent. According to the Pakistan Agricultural Research Council (PARC), per capita wheat consumption of the country is 120 kg a year [11]. It is grown in all provinces of Pakistan. Although table 1 shows that Pakistan falls in the top 10 wheat producing countries, yet it is facing difficulties because rate of wheat production could not catch-up with the rate of population growth. Several factors such as weather, insects, viruses, fungi, bacteria and weeds etc. are important factors for wheat production.

In Pakistan several diseases are reported to occur [Anonymous, 2000]. The rusts are most destructive. It is also the most widely recognized diseases of wheat crop. The record showed that there has been severe attack of leaf rust of wheat in 1978 at all over wheat growing areas of Pakistan [12]. The important wheat diseases in Pakistan are Black Stem Rust of Wheat, Leaf Rust of Wheat, Bacterial Leaf Blight, Flag Smut of Wheat, Bunt of Wheat, Root Knot and Bacterial Leaf Streak. Weeds are also problematic in crop production. Weeds act as energy drains in the entire ecosystem such as agricultural crops, horticulture and forestry. Weeds also provide habitat for harmful insects and organisms. The crop faces competition with weeds for light, moisture and nutrients. In this way the cost of harvesting is increased. The common weeds are Phalaris minor (Dumbi sitti), Avena fatua (Wild oats), Chenopodium (Bathu), Cronopus didymus (*Jangli halon*) and Convolvulus (Lehli). The wheat plant is attacked by a number of insect pests including Aphids, Cereal Leaf Beetle, Sawfly and White Grubs. Thus Wheat may have wide range of ailments and problems. Our work presents most common diseases and pest problems. Due to wide range of problems an expert is required to provide diagnoses of ailments as an expert is familiar with the all the disease specific signs and symptoms. The constraints to wheat production in Pakistan have been addressed in [13].

4. EXPERT SYSTEM DESIGN AND DEVELOPMENT

A precise domain is required by an expert system. The domain must be compact and well organized. The quality of knowledge highly influences the quality of expert system. The first step in the development of any expert system is problem identification. The problem here is a diagnostic problem aimed to identify ailments in the wheat using symptoms of diseases and pests. The problems occur

frequently and the consequences on farmer's financial status are enormous. The demand for help is increasing rapidly. Experts are there to help but sometimes they are not readily available, especially in rural areas. Therefore expert systems are needed in those rural areas where the help to the farmers is not readily available.

Diagnosis or diagnostic problem solving is the process of understanding what is wrong in a particular situation. Thus gathering of information and then interpreting the gathered information for determining what is wrong are of central importance in diagnostic problem solving [15]. In a typical abductive problem, the task of a diagnostic problem solving is to find a hypothesis that best explains a set of observations [14]. Whereas, the empirical classification rules collected from the domain expert are used in deductive or heuristics diagnosis [16]. By using formal causal theory abductive diagnosis can be expressed and implemented in the form of deductive diagnosis [15]. The details of abductive reasoning can be found in Ref. [20, 21, 22]. In the present work, we have used causal knowledge about ailments and symptoms to develop logical model of the diagnosis. Hence deductive diagnosis is used to diagnose ailments independently.

The knowledge base is the core component of any expert system. It contains knowledge acquired from the domain expert. Building the knowledge base with the help of domain expert is the responsibility of knowledge engineer. The first task in the development of knowledge base is knowledge acquisition. Knowledge acquisition [20] is considered as one of the most important phases in the expert system development life cycle [21]. Knowledge acquisition is to obtain facts and rules from the domain expert so that the system can draw expert level conclusions. The process of knowledge acquisition is difficult especially in case if the knowledge engineer is unfamiliar with the domain. Some commonly used approaches of knowledge acquisition are interviews, observations, taking experts through case studies and rule induction by machines [22]. Knowledge acquisition is crucial for the success of an expert system and regarded as a bottleneck in the development of an expert system [23]. The main reason for this bottleneck is communication difficulties between the knowledge engineer and the domain expert [24]. In our case, a detail survey and interview of several farmers has been conducted to understand and identify the problems. Human experts have also been consulted. Related articles and standard texts have also been followed. The interviews with domain experts provided a lot of help in getting the idea of the extent of knowledge required to solve the problems.

After the knowledge acquisition begins the process of representing that knowledge. There are many approaches used for knowledge representation, for example rules, logic expressions and semantic networks. The rule-based expert systems have been successfully used previously [28, 29]. Rules are made on the basis of the hierarchy and these rules lead to diagnoses of desire disease. Figure 3 shows the system structure of expert system.

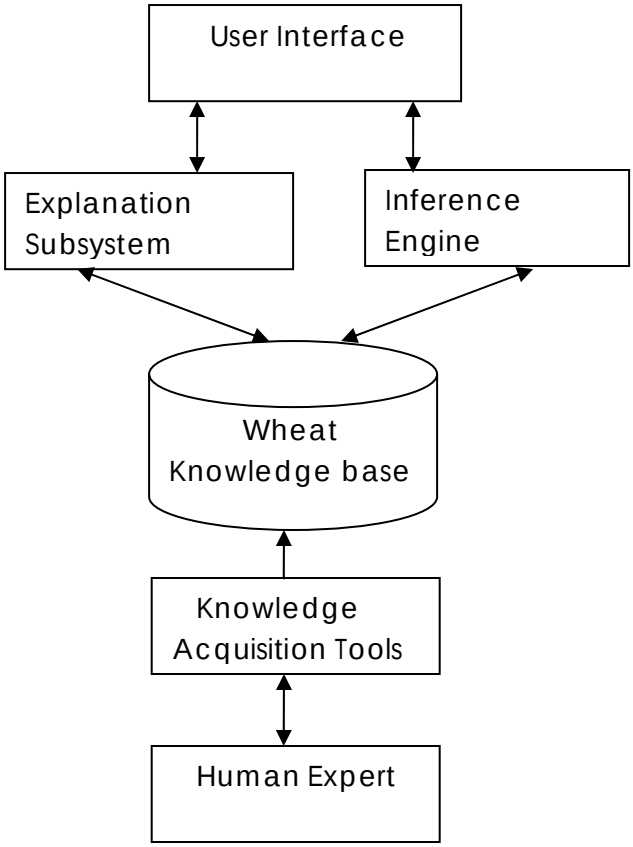

Figure 3: System structure of Wheat Expert System.

For example, in diagnosing diseases of wheat, the top level involves the following typical symptoms and recommendations.

Problem in leaves ➔disease may be Stem rust

Problem in leaves ➔disease may be Flag smut

The developmental process then adds additional information to help determine whether the hypothesis "disease is flag smut on leaves" is true. This is not as simple as it might look and other considerations include symptoms appeared on the defected parts including size of patches, color of spots, condition of defected organ and other information. So greater information is needed and the final recommendation will depend on the answer to questions that prove or disprove the hypothesis.

Problem in leaves➔ if stripes color is light green to grey black and leaves become rolled twisted and defected leaves become weakened frayed.

The knowledge base for e2glite expert system shell consists of simple if-then rules. The rules are usually fired on the

basis of internal logic of inference engine. Forward chaining and backward chaining techniques represent the fundamental reasoning approaches implemented in rule-based expert systems. Forward chaining is data driven whereas backward chaining is goal driven.

5. KNOWLEDGE BASE ELEMENTS IN e2gLite EXPERT SYSTEM SHELL

REM statement is used as a single line comment. These lines are ignored when the knowledge base is processed. A rule is defined by a RULE keyword followed by a short description of the rule enclosed in square brackets. This follows by the rule premise with keyword If. The logical expressions consist of an attribute name, any relational operator or any comparison quantity. The rule consequent is mentioned with keyword Then. Rule elements are not case sensitive. Attributes in e2gLite are String (text), Numeric and Boolean. In order to explain the rule structure, an example rule is given from the wheat knowledge base. The representation of *flag smut* disease is mentioned below.

RULE [Is it going to find the problem area which is flag smut?]

If [season] = "spring" and

[stage]="early" and

[problem_is_in]="leaves" and

[leave_part]="upper" and

[strip_color]="light_green_to_grey_black" and

[leave_becomes]="rolled_twisted" and

[disease_leave_becomes]="weekened_frayed"

Then [the problem] = "FALG SMUT IS DIAGNOSED" and

[recommendation 1]= "CAUSAL ORGANISM: Urocystic tritici" and

[recommendation 2]= "PERPETUATION: The disease is perpetuated through seed borne and/or soil borne spores, which can survive in the soil up to a period of three years" and

[recommendation 3]= "MANAGEMENT:

1. GROW RESISTANT CULTIVARS.

2. TREAT SEED WITH A SYSTEMATIC SEED TREATMENT FUNGICIDE.

3. ROTATE WHEAT WITH A RESISTANT HOST WITH AT LEAST 2 YEARS AND PREFERABLY FOR 3 YEARS.

4. DONOT SOW SEED DEEP SINCE SHALLOW SOWING PARTIALLY PREVENTS SOME INFECTION

5. EARLY PLANTING

6. USING THE WET METHOD OF SOWING. IRRIGATING JUST AFTER SOWING.

7. ROGUE OUT AND BURN THE INFECTED PLANT. "

Another example from the wheat knowledge base is presented here. The disease is *stem rust.* The visual symptoms can be stated as formation of long and narrow streaks on all plant body. The color of these streaks is brick red and black when the plant reaches its maturity.

RULE [Is it going to find the problem area which is stem rust?]

If [season] = "spring" and

[problem_is_in]="whole_plant" and

[spot]="bright_orange_to_yellow" and

[spore_color]="dark_brown_to_black" and

[pustules_color]="red_brown" and

[epidermis_rupture]="postules_are_jacked_and_racked_appearnce"

Then [the problem] = "STEM RUST IS DIAGNOSED"

[recommendation 1]= "CAUSAL ORGANISM: Puccinia graminis tritici" and

[recommendation 2]= "PERPETUATION: Wind-borne spores start the disease. In Murree the fungus completes its life cycle on barberry plants." and

[recommendation 3]= "MANAGEMENT:

1. GROW RESISTANT CULTIVARS.

2. CULTIVATION OF EARLY SOWING AND EARLY MATURING VARIETIES.

3. AVOID THICK SOWING.

4. AVOID HEAVY IRRIGATION.

5. DESTROY THE WEED PLANTS.

6. HEAVY DOSES OF NITROGENEOUS FERTILIZERS SHOULD BE AVOIDED. "

PROMPT command is used to interact with the user in order to ask question about a particular disease. An example of prompt is given below.

PROMPT [pustules_color] Multchoice

"Is it true that postules color is:"

"dark_brown_and_narrow_linear"

"red_brown"

"orange_yellow"

Figure 3: Starting the consultation with the system.

The objective of expert system is to find a value for goal variable. The GOAL command is used to retrieve the value of goal. The consultation ends when all goals are achieved. The whole tutorial on building a knowledge base in e2gLite expert system shell can be found at [27]. The next section contains some screenshots of our system.

6. SCREENSHOTS

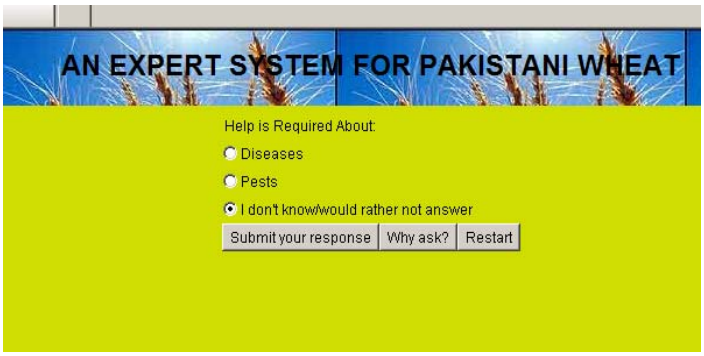

Figure 4: The classes of problems covered by the system.

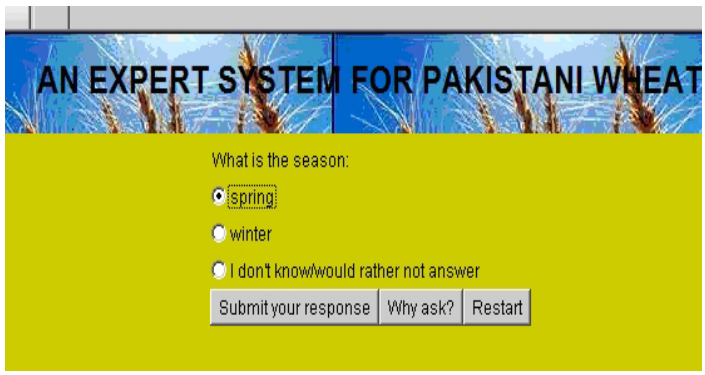

Figure 5: System asking about the cultivation season.

Figure 6: Towards problematic part of plant.

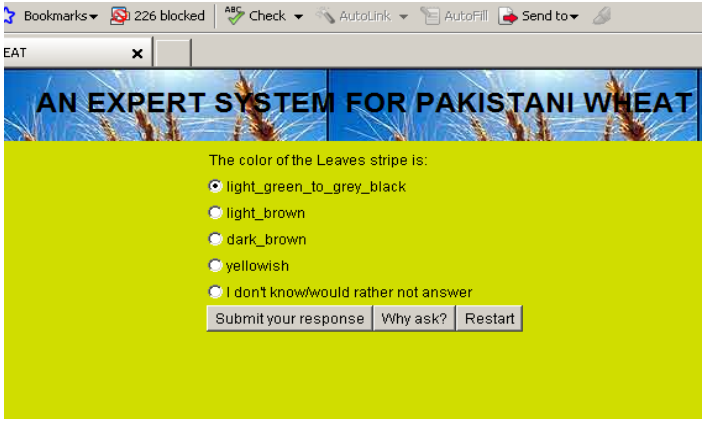

Figure 7: One of the series of questions to diagnose flag smut.

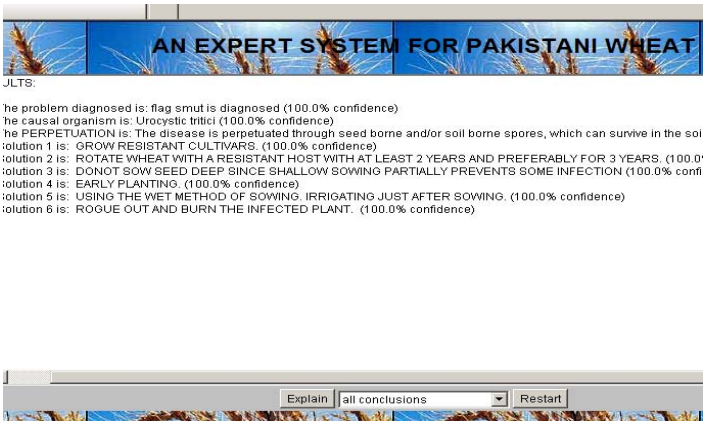

Figure 8: After a series of questions the system reaches to its conclusion.

7. CONCLUSIONS

This paper presents the use of expert systems in the agriculture domain in Pakistan. The rapid development of internet technology has changed the way of expert system development. It is easy to access the system via the internet. The experience and lessons leaned from the development of expert system suggest that the system is still useless for many farmers in its present form. Many farmers in the country are illiterate and knowledge of computers in rural areas is still a problem. The system needs to be developed in many regional languages. The system needed to be expanded and updated to accommodate new diseases and ailments of wheat in the region. There is also a need to include other diagnostic methods like laboratory tests, plant analysis report, soil test report, etc. The system also needs to include nutrition deficiency problems. In summary, general objective of an expert system is to provide expert knowledge to non experts. The use of internet technology has greatly enhanced the benefits of such systems. However the development of web-based expert systems poses new challenges and emphasis on more research to be carried out.

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