ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

SCHOOL OF INFORMATION SCIENCE

DEVELOPING KNOWLEDGE BASED SYSTEM FOR CEREAL CROP DIAGNOSIS AND TREATMENT: THE CASE OF KULUMSA AGRICULTURE RESEARCH CENTER

BY:

EJIGU TEFERA

JUNE, 2012

ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

SCHOOL OF INFORMATION SCIENCE

DEVELOPING KNOWLEDGE BASED SYSTEM FOR CEREAL CROP DIAGNOSIS AND TREATMENT: THE CASE OF KULUMSA AGRICULTURE RESEARCH CENTER

BY:

EJIGU TEFERA

A Thesis Submitted to the School of Graduate Studies of Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Information Science

JUNE, 2012

ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

SCHOOL OF INFORMATION SCIENCE

DEVELOPING KNOWLEDGE BASED SYSTEM FOR CEREAL CROP DIAGNOSIS AND TREATMENT: THE CASE OF KULUMSA AGRICULTURE RESEARCH CENTER

BY:

EJIGU TEFERA

Name and Signature of the Members of Examining Board

Name	Title	Signature	Date
________________	Chairperson	______	______
________________	Advisor	______	______
________________	Examiner	________	______

ACKNOWLEDGEMENT

God and many people have helped me to accomplish the research work on time and in successful manner. I am grateful to all who supported me to complete the research paper. I especially thank my advisor Ato Getachew Jemaneh for his willingness to help me and providing constructive advices and comments from the initial to the finalization of this research work.

I would like to express my thanks to Kulumsa Agriculture Research Center Research experts: Dr. Ferdissa Eticha, Ato workneh Mekassa, Ato Shimelis Gezahegn who devoted their golden time for a number of days for the interview and system evaluation session for this research work.

I also would like to appreciate Adama University School of Agriculture academic staff Ato Shiferaw Denke and Ato Lemessa Gemedda who devoted their precious time for the interview and system evaluation of the research work.

Finally, I am indebted to my families who gave me the necessary support during my study stay.

Table of Contents

ACKNOWLEDGEMENT I

LIST OF TABLES VIII

LIST OF FIGURES IX

LIST OF ACRONYMS X

ABSTRACT XI

CHAPTER ONE 1

INTRODUCTION 1

1.1 Background of the Study 1

1.2 Knowledge Based System 2

1.3 Statement of the Problem 3

1.4 Objectives of the Study 6

1.4.1 General Objective of the Study 6

1.4.2 Specific Objectives of the Study 6

1.5 Scope and limitation of the Study 7

1.6 Significance of the Study 7

1.7. Research Design & Methodology 8

1.7.1 General Approach of the Research 8

1.7.2 Method of the Study 9

1.7.3 Knowledge Acquisition 9

1.7.4 Knowledge Representation Techniques and Tools 10

1.7.5 Testing and Evaluation 11

1.8 Organization of the Thesis 11

CHAPTER TWO 12

LITERATURE REVIEW 12

2.1 Introduction 12

2.2 Importance of Cereal Crops in Ethiopia as Household Diets 12

2.2.1 Wheat Crop 12

2.2.2 Barley Crop 13
2.3 An Overview of Artificial Intelligence and Knowledge Based Systems 14
2.4 Knowledge Based System 15
2.4.1 Advantages of Knowledge Based System 16
2.4.2 Knowledge Based System Architecture 17
2.5 Phases of Knowledge Based System Development 20
2.5.1 Knowledge Acquisition 20
2.5.2 Knowledge Elicitation 20
2.5.3 Knowledge Based System Modeling 21
2.5.4 Knowledge Representation 22
2.6 Knowledge Based Systems Development Tools 29
2.7 Knowledge Based System for Integrated Development 29
2.8 Knowledge Based System Application in Agriculture 31
2.9 Challenges for AI Research in Agriculture and Natural Resource Management 34
CHAPTER THREE 36
KNOWLEDGE ACQUISITION 36
3.1 Introduction 36
3.2 The Knowledge Acquisition Process 36
3.2.1 Reviewing Related Documents and Manuals 37
3.2.2 Interviewing Domain Experts 37
3.3 Cereal Crop Diseases 39
3.3.1 Wheat Crop Diseases 40
3.3.2 Barley Crop Diseases 44
3.4 Conceptual Modeling 48
3.4.1 Cereal Crops Diseases Diagnosis Modeling Using Decision Tree 49
CHAPTER FOUR 57
KNOWLEDGE BASED SYSTEM DEVELOPMENT 57
4.1 Introduction 57
4.2 Components of Cereal Crop Diagnosis Knowledge Based System 57
4.2.1 The Knowledge Base 58
4.2.2 The Inference Engine 62

4.2.3 The Fact Base........65
4.2.4 The User Interface........65
4.2.5 The Explanation Module........71
CHAPTER FIVE........73
5.1 CCDKBS PROTOTYPE EVALUATION........73
5.2 CCDKBS Evaluation Using Visual Interaction........73
5.3 Discussions........77
CHAPTER SIX........80
CONCLUSION AND RECOMMENDATIONS........80
6.1 Conclusion........80
6.2 Recommendations........82
REFERENCES........83
APPENDICES........91
Appendix I........91
Appendix II........93
Appendix III........97

LIST OF TABLES

Table 2.1 Application of Knowledge Based System for Development 31

Table 3.1 Domain Experts Profiles 38

Table 3.2 Symptoms of Wheat Crop Disease 43

Table 3.3 Symptoms of Wheat Crop Disease 44

Table 3.4 Symptoms of Barley Crop Diseases 47

Table 5.1 CCDKBS Performance Evaluation Through Visual Interaction...............................75

Table 5.2 Users Feedback on Closed Ended Question 78

LIST OF FIGURES

Figure 2.1 Knowledge Based System Architecture 17

Figure 2.2 Architecture of Case-Based Reasoning 26

Figure 3.1 Category of Cereal Crop Organs Affected by Disease...40

Figure 3.2 Decision Tree for Modeling Wheat Grain/Head Diseases Diagnosis 51

Figure 3.3 Decision Tree for Modeling Wheat Leaf Disease Diagnosis 53

Figure 3.4 Decision Tree for Modeling Wheat Lower Stem and Root Disease Diagnosis...........54

Figure 3.5 Decision Tree for Modeling Barley Head/Grain Disease Diagnosis. 54

Figure 3.6 Decision Tree for Modeling Barley Crop Leaf Disease Diagnosis. 55

Figure 4.1 Prototype Knowledge Based System Architecture 57

Figure 4.2 A Welcoming Dialog Window of CCDKBS User Interface. 65

Figure 4.3 Menu Option Dialog Window of Cereal Crop Diagnosis. 66

Figure 4.4 Sample Dialog Window When Fusarium Head Blight of Wheat Crop Disease is Diagosed. 67

Figure 4.5 Sample Dialogue Window When Wheat leaf Rust is Diagnosed 68

Figure 4.6 Sample Dialog Windows When the User Finishes the Consultation Service about wheat crop diagnosis. 69

Figure 4.7 Sample Dialog Windows When Barley Leaf Rust is Diagnosed. 70

Figure 4.8 Sample Dialogue Window When Barley Net Blotch is Diagnosed 71

Figure 4.9 Sample Dialog Window When More Explanation Provided About Wheat Crop Stem Disease...72

Figure 4.10 Sample Dialog Window When More Explanation Provided About Barley Yellow Dwarf Disease 72

LIST OF ACRONYMS

AI	Artificial Intelligence
CCDKBS	Cereal Crop Diagnosis Knowledge Based System
DA	Development Agents
GDP	Gross Domestic Product
KBS	Knowledge Based System

ABSTRACT

Cereal production and marketing are the means of livelihood for millions of households in Ethiopia. It is the single largest sub-sector within Ethiopia’s agriculture, far exceeding all others in terms of its share in rural employment, agricultural land use, calorie intake, and contribution to the national income.

However, cereal production in Ethiopia is constrained by technical and socio economic factors. Among the technical factors, cereal crop diseases are the major contributing factors to the low yield. This problem needs sufficient and knowledgeable experts to identify the diseases and describe the methods of treatment and protection at early stage of infestation. The aim of this research is to develop knowledge based system for cereal crop disease diagnosis and treatment that assists agriculture experts and development agents to make timely decisions.

To develop cereal crop diagnosis and treatment knowledge based system, important knowledge was acquired through interview and document analysis. Five domain experts were interviewed to elicit the required knowledge about major cereal crops diseases that affect wheat, barley and the symptoms of these diseases as well as treatment methods undertaken to control such diseases. The acquired knowledge was modeled using decision tree that represents the cause effect relationships of symptoms of cereal crop diseases and the pathogens that could be the cause of diseases occurrence.

The knowledge was represented using production rule as if-then rules and implemented using swi prolog programming tool. Cereal crop diagnosis knowledge based system (CCKBS) reasons using backward chaining inference mechanism. The inference engine identifies a type of cereal crop diseases as goals and checks the symptoms of cereal crop diseases caused by particular pathogens to diagnose the possible crop disease and provide description and treatment.

To determine its applicability in the domain area, the prototype CCKBS has been evaluated by the domain experts through visual interaction based on the criteria of easiness to use, time efficiency, accuracy in diagnosing cereal crop diseases and providing description and treatments. According to the evaluation through visual interaction 80.9% system performance is obtained.

This proposed system is applicable and promising for assisting development agents who are working in remote areas where skilled agricultural experts are unavailable for an early treatment to the infected crops before the condition get worse. The cereal crop diagnosis knowledge based system is efficient in solving agriculture problems to make immediate decisions for the outbreak of cereal crop diseases using the type of diseases and their symptoms stored as rules and facts in the knowledge base. The advisory system will improve the productivity of farmers by assisting development agents who advise farmers on their daily needs.

Further study should be conducted that incorporates the image of infested crops in the knowledge base to illustrate severity of infected crops and the economic threshold.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Agriculture is the corner stone of the development policy of the Government of Ethiopia. The country's economic development will depend, in large part on sustainable improvements in agriculture. Agriculture remains by far the most important sector in the Ethiopian economy for the following reasons: (i) It directly supports about 85% of the population in terms of employment and livelihood; (ii) It contributes about 50% of the country's gross domestic product (GDP); (iii) It generates about 90% of the export earnings. Agriculture is also the major source of food for the population and hence the prime contributing sector to food security (ICARDA, 2010).

In addition, agriculture is expected to play a key role in generating surplus capital to speed up the overall socio economic development of the country. A high rate of agricultural growth has far reaching positive implications for economic development of low income countries in terms of increasing employment and accelerating poverty reduction (Mellor and Dorosh, 2010).

Even though 85 percent of the country's Population lives in the rural areas, the performance of the agricultural sector in Ethiopia has remained weak and it is heavily influenced by weather condition (Mulat, 2009).

Furthermore, the productivity of the sub-sector is decreasing as a result of poor management systems, shortage of skilled experts who provide advice for farmers at woreda level. Despite the importance of agriculture in its economy, Ethiopia has been a food deficit country since the early 1970s. A closer look at the performance of the Ethiopian agriculture reveals that over the last three decades it has been unable to produce sufficient quantities to feed the country's rapidly growing human population (Kassa and Degnet, 2004).

Increasing productivity in smallholder agriculture is Government's top priority, recognizing the importance of the smallholder sub-sector, the high prevalence of rural poverty and the large productivity gap. Productivity enhancement however, must be complemented by efforts to help farmers graduate from purely subsistence farming to semi subsistence/semi commercial status practicing farming as a business. This leads to adopt more sustainable natural resource management practices in order to arrest and reverse environmental degradation (Demese, 2010).

Cereal production and marketing are the means of livelihood for millions of households in Ethiopia. It is the single largest sub-sector within Ethiopia's agriculture, far exceeding all others in terms of its share in rural employment, agricultural land use, calorie intake, and contribution to national income. The contribution of cereals to national income is also large (Rashid, 2010).

Seid (1996) noted that cereal crops cover 6.7 million hector which is about 82% of the total crop area. He also stated that cereal crops suffer from low productivity because number of biotic and a biotic agents. These include diseases, insect pests, weeds, low soil fertility and moisture stress. According to Seid (1996) controlling of pests, diseases and weeds is one of the fundamental requirements for profitable cereal production. However, the large number of organisms that can threaten a crop makes management challenging. In addition, legislative requirements in relation to chemical control measures are complex and ever changing.

In any agricultural production system, accumulation and integration of related knowledge and information from many diverse sources play an important role. In practice, there is no substitute for knowledge and experience in identifying problems and choosing the most appropriate management technique for addressing them. The advice of a basis qualified agronomist can be invaluable in identifying threats to the crops and the most appropriate strategy for their control (Calu Factsheet, 2009). In addition, a range of tools are available on the internet (or as hard copy books) to help identify weeds, pests and diseases and then to select the best plant protection product for the particular problem.

1.2 Knowledge Based System

The emergence of information technology has resulted in an ever increasing demand to use computers for the efficient management and dissemination of information. Keeping in view the strong need of farmers to collect important and updated information for interactive, flexible and quick decision making is an important task (Singh et al., 2008).

A knowledge based system can be defined as a computerized system that uses knowledge about some domain in order to deliver a solution concerning a problem. The first generation of knowledge based systems was expert systems using a set of facts and rules (Perry and Ammar-Khodj**,** 2010). Knowledge based systems (KBS) has been developed for a variety of reasons, including: the archiving of rare skills, preserving the knowledge of retiring personnel, support in decision making and to aggregate all of the available knowledge in a specific domain from several experts and/or machines (Tomas, 2004).

Since the structure of knowledge based system is as simulation of functional model of human system, the applications of knowledge based system is employed in the areas where human beings work. In this context the application areas vary from one area to another such as diagnosis, maintenance, performance, data base management, controlling, consultation, and manufacturing (Owaied et al., 2010). In this regard most frequent applications of knowledge based systems are in production, marketing, and customer service. Some of the more successful systems are scheduling which schedule work in chemistry, the metal industry, as well as in heart surgery.

Tomas (2004) also stated that a criticism by knowledge representation theorists is that a KB is not a truthful representation of the actual knowledge. Although this may be the case, the knowledge representation is good enough for knowledge based system to be accepted, implemented and used in industry.

1.3 Statement of the Problem

Diseases of cereal crops can be caused by various pathogens such as bacteria, viruses and fungi or combinations of these. Infections can be carried in the air, water, soil, or by insect vectors particularly aphids (Calu factsheet, 2009). According to Calu factsheet (2009), controlling diseases in cereals is not only important to minimize crop losses in the field; some of the diseases render the crop toxic (e.g. ergot infection produces toxic Mycotoxin) can be reduced as well. Mycotoxin is a chemical produced by fungi (molds) under certain conditions. This disease is toxic to animals and human health (Carlson and Ensley, 2003).

Agricultural production has evolved into a complex business requiring the accumulation and integration of knowledge and information from many diverse sources. In order to remain competitive, the modern farmer often relies on agricultural specialists and advisors who provide information for decision making (Prasad, 2006). Unfortunately, agricultural specialist assistance is not always available when the farmer needs it. In order to solve this problem, knowledge based system has been identified as a powerful tool with extensive potential in alleviating agricultural problems (Prasad, 2006).

Agriculture problems also requires information and application of knowledge from different interacting fields of science and engineering to make a suitable decision making that in turn depends on interplay of these data and knowledge. This needs agricultural specializations and technical awareness in farmer or a human expert to help the farmers in decision making (AbuNaser, 2008).

In Ethiopia, agriculture experts are not always available, may not be accessible to every farmer. Due to a shortage of extension agents, each agent has to serve on average 1090 farmers (Kassa and Degnet, 2004). According to Beintema and Menelik (2003), there are only 14 percent research experts out of total Ethiopian agriculture organization researchers focusing on controlling pests and diseases of crops.

Moreover, Abrham (2009) noted that farmers worry about a sustainability of partnership, limited option of available technologies and lack of appropriate and timely decision on tested technologies that improve farmers' productivity. According to Abrham (2009), lack of trained agents (experts), staff turnover for training purpose, weak exchange of information have been affected farmers' income and their economy. Abrham (2009) also noted that the feedback of farmers' problems to the research center to set research priorities based on current farmers' problems and production systems is not effectively addressed as the result of infrastructure and geographical barriers.

Limited dissemination of created and innovated knowledge from the research center to end users (extension agents, farmers) affects farmers' productivity. Whenever new knowledge is created from the research center, it is difficult to transfer the expert's knowledge to farmers and extension agents because this needs budget, high number of experts to train farmers and extension agents to share the knowledge created from the research center (Abrham, 2009).

Furthermore, the coordination of research center and extension workers is inadequate to the task of developing appropriate technologies and making them available to the producers. In the same areas research centers and extension agents make contradictory recommendations which clearly have an important impact on the dissemination of research findings (Amanuel, 2003).

Another important factors behind the limited adoption of technological packages (improved seed and fertilizer) and inefficiency of input use are lack of appropriate, timely, and quality extension services (including distribution and development assistance) to advise and promote more efficient use of inputs. This advice is important to accommodate risks associated with agricultural production, especially among small and poor households (Chamberlin and Schmidt, 2001).

Researches conducted on application of knowledge based in the area of agriculture are reviewed to justify the role of knowledge based system in solving agricultural problems and to check the problems identified to be addressed in this research is not addressed by other researchers.

For the purpose of implementing the importance of knowledge based system for solving agriculture problems, Tsegaw (2009) designed knowledge based reasoning system for agricultural crop management focusing on vegetable crops to develop an expert system model as an attempt to automate the reasoning strategy of human vegetable experts. He employed a hybrid of rule based and artificial neural network approach to implement the knowledge based system for fertilizer recommendation and diseases identification for vegetable crops. Still the area of cereal crops specifically barley and wheat crop problems which are by far the largest group in terms of their share in area cultivated, output, and consumption of Ethiopian household are not addressed. These crops are also highly affected by various diseases which need further research and management to reduce yield losses as the result of diseases.

Bethelehem (2010) also developed a knowledge based system to diagnose common diseases occurring in pepper plant. The focus of here study was to address problems of common diseases occurring in pepper plant using rule based reasoning approach. Rule based reasoning approach is also applicable for solving cereal crops problems caused by diseases in which the experience and knowledge of human experts are captured in the form of if-then rules and facts. This needs further study to be conducted in developing knowledge based system that diagnoses and treats cereal crops diseases using rule based reasoning approach.

Even though good attempts were made by the above researchers in developing knowledge based systems in the area of agriculture to support agricultural experts, little study was conducted to develop a knowledge based system that diagnoses and treats cereal crops diseases caused by different pathogens such as fungus, bacteria and viruses.

As the result, all these problems have prompted the researcher to develop knowledge based system which assists both research experts and development agents (DA) in diagnosing and managing cereal crops to make quality decision on daily needs of farmers. Hence, the aim of this research is to develop prototype knowledge based system for cereal crop disease diagnosis and treatment.

1.4 Objectives of the Study

1.4.1 General Objective of the Study

The general objective of this research work is to develop a knowledge based system which diagnoses cereal crop diseases and advises research experts and development agents in identification and treatment of cereal crop diseases.

1.4.2 Specific Objectives of the Study

To achieve the general objective of the study, the specific objectives of the study are:

- To review literatures on concept of knowledge based system that give deep understanding to conduct this research work.
- To asses and understand the existing cereal crop diseases diagnosis and treatment methods at the domain area of this study.
- To extract tacit & explicit knowledge on types of disease, symptoms and diagnosis techniques of cereal crops.
- To model and represent knowledge acquired from domain experts and codified sources.
- To build prototype knowledge based system which advises agriculture experts and development agents.

- To evaluate the performance of the prototype knowledge based system.
- To draw conclusions based on the findings and possible application of the developed knowledge based system and forward appropriate recommendations as future research directions in the area of knowledge based system.

1.5 Scope and limitation of the Study

There are five major cereals crops (maize, teff, wheat, barley and Sorghum) which are produced in Ethiopia. This research focuses on development of a prototype knowledge based system to diagnose and treat diseases that attack barley and wheat crops. The reason of developing prototype knowledge based system focusing on barley and wheat crop diseases diagnosis and treatment is that these crops are by far the largest group in terms of their share in area cultivated, output, and consumption of Ethiopian households. These crops are also highly affected by rust diseases as compared with other cereals like teff crop which suffers from fewer disease and pest problems (Bekabil et al., 2011). According to (Minale et al., 2011), the demand of barley for raw materials by the beverage industry and wheat for flour manufacturing is increased that need integrated disease management options to reduce disease epidemics and increase yield of these crops.

Moreover, this study is intended to design prototype knowledge based system which includes the task of knowledge acquisition, knowledge modeling, knowledge representation and knowledge based system development that addresses selected cereal crop diagnosis and treatment tasks. The prototype development includes knowledge base, inference mechanism, and simple user interface using swi prolog programming tool.

Due to time limitation and the existence of high number of fungal related diseases, the study does not consider pest related diseases and nutrient deficiency disorders of cereal crops.

1.6 Significance of the Study

The findings of this study will benefit agricultural researchers or experts in such away that experts and researchers can get easily and timely access to disease identification and diagnosis system to manage cereal crop diseases from knowledge base which stores the facts and rules that experts used to solve problem.

By replicating this system to different wheat and barley crop growing woredas, the system can increase production of cereal crops in agricultural sectors through provision of adequate knowledge from stored rules and facts on types of cereal crop diseases and treatment methods. Therefore, those development agents who assist farmers can consult and access the system to diagnose the types of cereal crop diseases and make appropriate decisions on farmers' daily needs. The system will benefit farmers through indirect means. This is through development agents can be trained and consulted from cereal crop diagnosis and treatment knowledge based system which can be implemented at woreda level with out limitation of distance and scarcity of human experts.

The system will help Kulumsa Agriculture Research Center to preserve expertise knowledge and by enabling others to make use of that expertise after the experts retire or have left research center. The output of this research work can also be used as an input for future works to develop full-fledged cereal crop diagnosis and treatment knowledge based system by other researchers.

1.7. Research Design & Methodology

In this section, the research design, methodology and type of information gathered have been elaborated. The techniques carried out in this study were knowledge acquisition, modeling, and knowledge representation and implementation method using appropriate knowledge programming tool.

1.7.1 General Approach of the Research

Before starting development of prototype knowledge based system, the researcher has investigated the problem area. Identify the limitation of cereal crop diseases diagnosis and identification mechanism by researchers and experts at the domain area. This helps the researcher to get fuller understanding about the problem and limitations that challenge the domain experts in controlling and managing cereal crop diseases. By understanding the types of cereal crop diseases and symptoms, the proposed system has been implemented based on the need of experts in the domain area.

The purpose of investigation of the domain area by the researcher was:

- To recognize the problem of cereal crop production in Ethiopia caused by disease.

- To get acquaint with the techniques that human experts apply to identify disease, methods of protection and remedies actions taken to treat cereal crops disease.

1.7.2 Method of the Study

In order to develop a knowledge based system that diagnoses and treats cereal crop diseases, the researcher has determined an appropriate source of data. To elicit the required knowledge for this study, purposive sampling technique was employed. Purposive sampling would be the best way to elicit the views of persons who have expertise and knowledge about specific domain (Tongco, 2007). Accordingly, employing purposive sampling in this study is its appropriateness to capture demonstrable experience and expertise of the experts. Thus domain experts from Kulumsa Agriculture Research Center and Adama University Asella school of Agriculture were selected purposively.

Sources of knowledge: knowledge for this research was extracted from primary and secondary sources. Primary sources include research expert of wheat and barley crops, and plant pathologist at Kulumsa Agriculture Research Center and Adama University Asella Agriculture campus plant science department staff. Secondary sources used as sources of knowledge in this research are: Internet resources, books, training guides and manuals. To acquire relevant knowledge for developing knowledge based system, Interview and document analysis techniques were employed.

Interview: both structured and unstructured interview were conducted to elicit tacit knowledge from domain experts. Interview was carried out with face to face communication. During face to face communication the information obtained from experts has been recorded manually.

Document Analysis: Document analysis was also carried out to acquire explicit knowledge from different source of knowledge on the area of crop protection and treatment. Different source books, Internet sources, plant disease protection guide lines and training manuals were analyzed and technical knowledge was extracted.

1.7.3 Knowledge Acquisition

In this research, to build knowledge based system that diagnoses and treats cereal crops disease, relevant knowledge were acquired through a process called knowledge acquisition. This is the process where by knowledge of group of experts or other sources such as books, manuals are gathered, verified, validated and put into the knowledge based system.

Knowledge modeling is a cross disciplinary approach to capture and model knowledge. Knowledge models view the knowledge based system using diagram and other structured representations such as trees, maps, and KBS construction methods typically provide tools for knowledge analysis in the form of conceptual models of knowledge. So, knowledge model provides an implementation independent specification of knowledge in an application domain (speel et al, 2001). In this study the acquired knowledge was modeled using decision tree that links the type of diseases and their associative symptoms to make appropriate decisions based on observed symptoms of cereal crop diseases.

1.7.4 Knowledge Representation Techniques and Tools

In this research work, rule based reasoning method is implemented to represent expert knowledge concerning cereal crops diseases and diagnosis techniques. The rule based approach is particularly useful because in many domains much of an expert's knowledge is amenable to expression in if-then rules, many of which are heuristic. The rule-based knowledge representation has many advantages compared with other knowledge representation methodologies (Mahaman et al., 2003).

The reason for the choice of rule based reasoning is that this method is common one and it can be satisfyingly powerful from the perspective of building useful applications. Moreover, the experience and knowledge of domain experts are captured in the form of IF-THEN rules (Siew et al., 2005).

In this research work, prolog programming language is used to develop a prototype knowledge based system that diagnoses cereal crop diseases. The programming language in prolog (PROgramming in LOGic) is an implementation of predicate logic for computing and is therefore, a natural environment for using predicate to represent knowledge in the domain. Thus prolog language is chosen because of its built in pattern matching, rule based programming and backtracking execution.

1.7.5 Testing and Evaluation

The evaluation of knowledge based system is an important aspect of knowledge based system development that is required to prove whether a system fulfils it original objective. The evaluation is carried out by considering knowledge representation scheme such as adequacy, the right answers that the system come up with, knowledge consistency, its easiness to interact with the users and the facilities and capabilities do users need (Anumba and Scott, 2001).

In this study, the performance of cereal crop diagnosis knowledge based system is evaluated and validated by assessing user acceptance through visual interaction. Similarly users' acceptance is assessed and analyzed through questionnaire after users are exposed to interact with the system.

1.8 Organization of the Thesis

The study is organized in to six chapters. Chapter one is the introduction part, which contains the background, problems statements, objectives, scope, limitations of the study, significance and methodology to carry out the research. Chapter two discusses review of literature on cereals (wheat and barley) crops production in Ethiopia, knowledge based systems concepts and its application in the area of Agriculture. Chapter three discusses knowledge acquisition procedures and modeling techniques. Chapter four discusses knowledge representation and prototype development processes. Chapter five presents finding of the study by evaluating the prototype knowledge based system. Finally chapter six discusses the conclusion and recommendations for further research work on the application of knowledge based system in Agriculture.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter tries to discuss review of literatures on cereal crops particularly wheat and barley production in Ethiopia. It deeply elaborates knowledge based systems concepts, architecture, knowledge acquisition and representation methods. It also discusses knowledge based systems development tools and the application of knowledge based system (particularly) in Agriculture and its challenges.

2.2 Importance of Cereal Crops in Ethiopia as Household Diets

In terms of caloric intake, cereals dominate the diets of Ethiopian households. Rashid (2010**)** suggested that an average Ethiopian consumes 1858 kilocalories. Out of the total calorie consumption, five major cereals (maize, teff, wheat, barley and sorghum) account for more than 60 percent, with maize and wheat representing 20 percent each. The low share of teff in calorie consumption often come as surprise to urban Ethiopians as teff is the predominant staple food in the middle and high income households. Wheat is a staple crop in the highlands of Ethiopia. Most of the wheat grain produced by small-scale farmers was consumed or retained as seed on the farm and little surplus (19.4%) went to the market. Barley (Hordeum vulgare) is one of the most important cereal crops, mainly grown by smallholder farmers at mid- and high altitudes (Minale et al., 2011).

2.2.1 Wheat Crop

Wheat (Triticum aestivum L.) is one of the most important grain crops produced worldwide. Ethiopia is the largest wheat producer in sub-Saharan Africa with about 0.75 million ha of durum and bread wheat. Wheat crop is one of the major cereal crops grown in the Ethiopian highlands, which range between 6 and 16°N, 35 and 42°E, and from 1500 to 2800 m (Hailu, 2003). At present, it is produced solely under rain fed conditions. About 60% of the wheat area is covered by durum and 40% by bread wheat. The current total wheat production area is covered 75.5% areas which are located in Arsi, Bale and Shewa regions. Forty six percent of the 13 million ha classified as highly suitable for wheat production is located in Arsi and Shewa. The wheat belt of East Africa, Arsi and Bale are among the major wheat producing zones of Ethiopia (Hailu, 2003).

The wheat Varieties grown in Ethiopia are Durum, Emmer, and so called Bread wheat.

Durum wheat is often grown for domestic pasta fabrication. Emmer (aja in Amharic) is grown mainly in eastern Oromia (Arsi and. Bale) and Amhara (Shewa and Wollo). Bread wheat is widely grown throughout the highlands and transitional areas. Ethiopian wheat production typically takes place at altitudes of 1,600–3,200 masl, in areas with average annual rainfall of 400–1,200 mm and average annual temperatures of 15–25°C (Chamberlin, 2011).

Average national wheat yields are generally considered to be low particularly, under farmers' circumstance. The sub optimal yield is certainly attributable to some production constraints. The major wheat production constraints are categorized into two: Technical (soil fertility, incidence of weeds, diseases, insects and lack of seeds of improved variety) and socio-economic (unavailability of inputs such as seeds, fertilizers, pesticides). Wheat accounts for similar shares of national cereal production as sorghum with 17 percent of planted area and 19 percent of production (Hailu, 2003).

2.2.2 Barley Crop

Barley (Hordeum vulgare L.) is one of the most important cereal crops in the world next to maize, wheat, rice among ten top world plants. It is one of the main cereal crops produced in the Ethiopian highlands. It grows in the range of 1500–3500 masl, but is predominantly grown between altitudes of 2000 and 3000 masl. Barley ranks fourth in worldwide production of all cereals. It is an important cereal crop grown by subsistence farmers on small-scale farms. Among the major cereals, barley ranks fifth in area, productivity and total production in Ethiopia as a whole. Barley is an important food crop in the highland parts of Ethiopia. It is the crop matures early and an emergency crop bridging the critical food shortage occurs in September (Kemelew & Alemayehu, 2011).

Barley accounts for over 60% of the food of the people in the highlands of Ethiopia. It is used in diverse recipes that have deep roots in culture and tradition. Some recipes such as Besso (fine flour of well-roasted barley grain moistened with water, butter or oil), Zurbegonie (same type of flour used for besso dissolved in cold water with sugar) and Chiko (besso soaked with butter alone), which have long shelf life, can only be prepared from barley grain. Other recipes, such as Genfo (thick porridge), Kolo (de-hulled and roasted barley grain served as snack), Kinche (thick porridge) are most popular when made from barley grain, but can be prepared from other cereals also. Barley is the preferred grain, after tef, for making the traditional bread called Injera, which can be used either solely or in combination with tef flour or other cereal flours. Other recipes, such as Dabbo (bread), Kitta (thin, unleavened, dry bread) and Atmit (soup) can be prepared with only barley or blended with other cereal flours. Among local beverages Tella and Borde are prominent, and best made from barley grain (Grando, 2005).

In addition to its grain, barley straw is also useful, as it is a good source of livestock feed during the dry season when there is an acute shortage of good quality fodder. In general, barley is the most desirable crop in the highlands where there is no alternative crop, but this dependence on a single crop implies risk.

Although barley is the most important cereal crop in Ethiopia, the national yield has remained low at below1.3 t/ha whereas the potential yield goes up to 6 t/ha on experimental plots. The major determination of barley profitability is yield. To maximise yield, it is important to ensure that the crop has every chance to succeed several a biotic and biotic factors that have contributed to this low productivity. Some of the constraints are poor crop management practices, new introduced barley varieties are susceptible to mildew, barley yellow dwarf virus, net blotch and scald diseases and the limited availability of the very few improved cultivars released, weeds, insects and the inherently low yield potential of the prevalent local varieties (Bayehe & Stefania**,** 2011).

2.3 An Overview of Artificial Intelligence and Knowledge Based Systems

The term Artificial Intelligence (AI) refers to the activity of building intelligent systems. It is a technology of making computers to simulate human beings intelligence (Raza, 2009). Most people know the term Artificial Intelligence concerning about how to build an intelligent machine. This machine should have certain capabilities such as: behaves like a human being, smart, problem solver of unstructured and complex problems as human does, understands languages, learner, and able to reason and analyze data and information (Owaied et al., 2010).

The other definition of Artificial Intelligence (AI) is that it is the study of intelligent behavior achieved through computational means. The vision for dealing with three dimensions world represented together with the intention and the expectation in the scene. The speech for replace the keyboards for dealing with computerized Natural Language Processing System (either written or spoken). Knowledge Representation and Reasoning is the part of AI that is concerned with how an agent uses what it knows in deciding what to do. The application of Artificial Intelligence is rapidly increasing. Such applications are very affective in situations when the domain expert is not readily available. In agriculture applications of expert system are mainly found in the area of diseases diagnosis and pest controls. Many domain specific expert systems are being used at different levels (Ramana, 2010).

2.4 Knowledge Based System

Knowledge based systems are sophisticated interactive computer programs which use high quality, specialized knowledge in some narrow problem domain to solve complex problems in that domain. It is a software system that contains a significant amount of knowledge in an explicit and declarative form. Knowledge Based Systems (KBS) have been referred to with a variety of names such as expert systems, intelligent assistants, epistemological systems and design and analysis systems. The two terms most popular in common usage, often used synonymously, are KBS and expert systems (Raman & Prasad, 1987). Knowledge based system emulates the behavior of human expert within a well defined and narrow domain of knowledge (Chee-Fai Tan, 2008). It is a system that draws upon the knowledge of human experts captured in a knowledge base to solve problems that normally require human expertise.

The area of knowledge based systems (KBS) development has matured over the past two decades. It was started with first generation expert systems with a single flat knowledge base and a general reasoning engine, typically built in a rapid prototyping fashion. This has now been replaced by methodological approaches that have many similarities with general software engineering practice. Knowledge based system development is best seen as software engineering for a particular class of application problems. These applications problems typically require some form of reasoning to produce the required results (Chee-Fai Tan, 2008).

Knowledge Based System (KBS) is one of the major family members of the AI group (Sajja & Akerkar, 2010). With availability of advanced computing facilities and other resources, attention is now turning to more and more demanding tasks, which might require intelligence. The society and industry are becoming knowledge oriented and rely on different experts' decision making ability. Indeed, KBS can act as an expert on demand without wasting time, anytime and any where.

With the proper utilization of knowledge, the knowledge based systems increase productivity, document rare knowledge by capturing scare expertise and enhances problem solving capabilities in most flexible way (Sajja & Akerkar, 2010). According to Sajja & Akerkar, (2010), such systems also document knowledge for future use and training. This leads to increased quality in problem solving process; however, the scarcity and nature of knowledge make the KBS development process difficult and complex. The transparent and abstract nature of knowledge is mainly responsible for this. In addition, this field needs more guidelines to accelerate the development process.

2.4.1 Advantages of Knowledge Based System

Knowledge based systems is more useful in many situations than the traditional computer based information systems. Abdullah et al. (2006) highlighted the following advantages of knowledge based system:

- Time saving: the amount of time spent on doing the work manually is reduced.
- Quality improvement: the quality of decision made increases because there are fewer errors than if the decision performed by manually.
- Practical knowledge made available: knowledge based systems can assist experts in decision making even if they have that knowledge to hand; this improves the accuracy and timelines of the decision made.
- Infallible and complete: unless there are implementation errors, knowledge based systems will always produce the desired result as they will not leave out any rule (consideration) in the reasoning processes.
- Replication: human experts are scarce resources. They are physically bound to their geographical locations and can only available at one place at a time but knowledge based

system can be replicated and in effect to be transferred to any other locations to perform other task.

- All day, every day: human experts have fixed working hours or are only available for a limited time through out the day. They will also experience fatigue because of working long hours which might have a deleterious effect but Knowledge based system can work 24hr/days 7days/week.
- Updating knowledge. Knowledge based system can be updated easily by editing the rule base; but human expert take to retrain.

2.4.2 Knowledge Based System Architecture

Architecture is a blue print that helps to represent the structure of system. System architecture is a conceptual model that defines the structure and guidelines of the system. It also helps to describe set of convections, rules, tools and standards that should be incorporated in the corresponding systems. According to Poole (2009), knowledge based system has its own architecture that depicts its basic components as shown in Figure 2.1 below

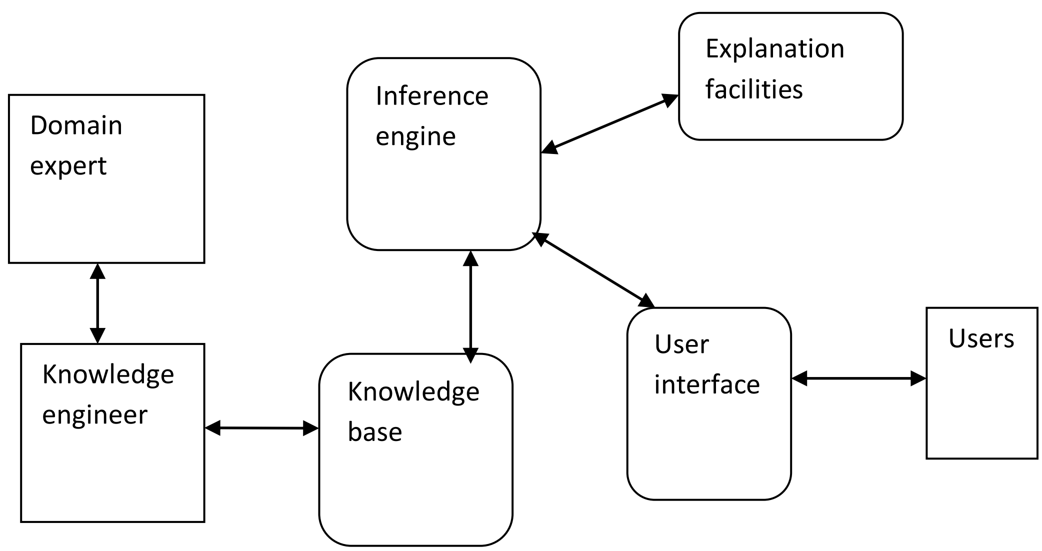

Figure 2.1 Knowledge Based System Architecture

Domain Expert: Domain Expert is a knowledgeable and skilled person capable of solving problems in a specific area or domain. This person has the greatest expertise in a given domain. In the knowledge based system development, the expertise has been captured in the knowledge based system. Therefore, the expert must be able to communicate his or her knowledge, be willing to participate in the knowledge based system development and commit a substantial amount of time to the program development. The domain expert is the most important player in the knowledge based system development team (Holland, 2011).

Knowledge Engineer*:* According to Gaines and Shaw (1992), Knowledge engineers someone who is capable of designing, building and testing knowledge based system including:

- The knowledge engineer interviews the expert to elicit his or her knowledge;
- The knowledge engineer encodes the elicited knowledge for the knowledge base;
- Interrogates the domain expert to find out how a particular problem is solved;
- Establishes what reasoning methods the expert uses to handle facts and rules and decides how to represent them in the knowledge based system;
- Chooses some development software or knowledge based system shell, or looks at programming languages for encoding the knowledge.

Knowledge Base: The knowledge base represents the repository of knowledge for specific and narrow domain. Usually in any knowledge base there are many facts, rules, and metaknowledge (Owaied et al., 2010). Knowledge base constitutes the problem solving rules, facts, or intuition that a human expert might use in solving problems in a given problem domain. The knowledge base is usually stored in terms of if–then rules. In the knowledge base, the working memory represents relevant data for the current problem being solved**.**

Inference Engine: The term inference engine refers to the part of knowledge based system that specifies the logical process by which new facts and belief are derived from known facts and beliefs (Hayes-Roth & Jacobstein, 1994). It also contains the control strategy that orders the search for an inferential solution. Inference engine is a generic control mechanism that applies the axiomatic knowledge in the knowledge base to the task specific data to arrive at some solution or conclusion (Bachman et al., 1988). Because of the strict control and coding structure of an inference engine, changes are made only if absolutely necessary to correct a bug or enhance the inferential process.

With pattern matching, rule based systems used automated reasoning methods to progress logically from data to conclusions. Process of problem solving in knowledge based systems is to create a series of inferences that from a “path” between the problem definition and its solution.

Such a series of inferences is called inference chain. The inference engine of knowledge based system is artificially representing all that sort of untouchable activities of human being (Owaied et al., 2010). An inference engine is the control mechanism that organizes the problem data and searches through the knowledge base for applicable rules. The purpose of the inference engine is to seek information and relationships from the knowledge base and to provide answers, predictions, and suggestions in the way a human expert would. Hence the inference engine must find the right facts, interpretations and rules and assemble them correctly (Abraham**,** 2005).

Explanations Facility: Knowledge based system typically able to provide explanation regarding to the conclusion it makes. It is essential in all nontrivial domains to provide explanations to users to understand how the system works and determining whether its reasoning is correct or not.

Moreover, the key characteristic of Knowledge based system is the explanation facility. With this capability, Knowledge based system can explain how it arrives at its conclusions. The user can ask questions dealing with the what, how, and why aspects of a problem. The Knowledge based system will then provide the user with a trace of the consultation process; pointing out the key reasoning paths followed during the consultation. Sometimes Knowledge based system is required to solve other problems, possibly not directly related to the specific problem at hand, but whose solution will have an impact on the total problem solving process. The explanation facility helps the Knowledge Based System to clarify and justify why such a digression might be needed (Bachman et al., 1988).

User Interface: The user interface simulates the communications with the environment unit of the functional model of human system, which means an interaction between the user of the knowledge based system and the system itself (Owaied et al., 2010). User interface is allowing the user to input information in response to questions generated by the system. It will also be able to give advice and (very importantly) explain why it is giving that advice (Bethune, 2007).

2.5 Phases of Knowledge Based System Development

2.5.1 Knowledge Acquisition

Knowledge acquisition is the process of eliciting, structuring and representing (formalizing) knowledge from some knowledge source in order to construct a knowledge based system. It is the process of transferring knowledge from the knowledge source to knowledge engineer (knowledge based system developer). Knowledge acquisition is a crucial stage in the knowledge based systems development process and recognized as the bottleneck of knowledge based system development.

In other words, knowledge acquisition is an important obstacle and time consuming when constructing knowledge based systems. It is one of the most difficult and error prone tasks that knowledge engineer does while building a knowledge based system (Rhem, 2001). The cost and performance of the application depends directly on the quality of the knowledge acquired. Knowledge acquisition is seen as a crucial problem concerning the success of an expert system and has always been regarded as the bottleneck in developing expert system (Abdallah, 2005).

In building knowledge based system, the knowledge acquisition process incorporates typical fact finding methods like interviews, questionnaires, record reviews and observation to acquire factual and explicit knowledge. However, these methods are not much effective to extract tacit knowledge which is stored in subconscious mind of experts and reflected in the mental models, insights, values, and actions of the experts. For this kind of knowledge, techniques like concept sorting, concept mapping, and protocol analysis are being used. These are important techniques for extracting or obtaining useful knowledge from experts for developing knowledge based systems (Okafor & Osuagwu, 2006).

Similarly, the goal of knowledge acquisition is to extract from human expertise and build the knowledge based system. The knowledge also has been extracted from an extensive literature review through related books, reports, projects and published papers.

2.5.2 Knowledge Elicitation

Knowledge elicitation is the process of explicating domain specific knowledge underlying human performance. It is also a sub process of knowledge acquisition, which is itself a sub process of knowledge engineering. The process of knowledge engineering involves knowledge acquisition which includes knowledge elicitation and other activities such as knowledge explication and conceptual modeling (Cooke, 1989).

Different knowledge elicitation techniques are applicable to different forms of knowledge. Knowledge elicitation is a critical first step in expert systems development. The performance of the expert systems depends upon the reliability, validity and accuracy of the elicited knowledge (Sagheb-Tehrani, 2009). However, Knowledge elicitation has its own problem such as communication between the expert and knowledge engineer.

2.5.3 Knowledge Based System Modeling

Models are used to capture the essential features of real systems by breaking them down into more manageable parts that are easy to understand and to manipulate. They are very much associated with the domain represented by them (Abdullah et al., 2002). This domain will define their practicing communities, modeling languages and the associated tools used. Moreover, models help people to appreciate and understand such complexity by enabling them to look at each particular area of the system in turn. Models are used in systems development activities to draw the blueprints of the system and to facilitate communication between different people in the team at different levels of abstraction.

More importantly, the modeling process constructs conceptual models of knowledge intensive activities in the knowledge based system development. During the knowledge acquisition stage, most of the knowledge is unstructured and often in tacit form. The knowledge engineer will try to understand both the tacit and the explicit part of the knowledge and then use simple visual diagrams to stimulate discussion amongst users and knowledge experts (Abdullah et al., 2002). This discussion process generates ideas and insights as to how the knowledge is used, how decisions are made, the factor that motivate and so on. The knowledge engineer then has to construct the conceptual model from what has been discussed during the knowledge acquisition stage. This communicates the knowledge to the information specialist who will transform the model into workable computer programs or codes. Before knowledge based system can be built, knowledge must somehow be identified and collected, and a model of domain knowledge must be constructed (Richard, 1999).

Experience has shown that eliciting and explicating knowledge is best seen as a modeling activity, also called conceptual modeling. This activity takes the form of a specialized type of requirements engineering. KBS construction methods typically provide tools for knowledge analysis in the form of so called conceptual models of knowledge or simply knowledge models (Speel, 2001).

As Speel (2001) also noted that a knowledge model provides an implementation independent specification of knowledge in an application domain. Typically, a knowledge model provides formats for writing down both static domain knowledge (rules, classes, relations) as well as reasoning strategies in which this domain knowledge is used to solve a particular problem. An important feature of knowledge engineering research is that it provides with predefined, reusable models for certain knowledge intensive tasks, also which is called problem solving methods.

2.5.4 Knowledge Representation

Knowledge Representation is the area of Artificial Intelligence (AI) concerned with how knowledge can be represented symbolically and manipulated in an automated way by reasoning programs (Brachman, 2003). It is an idea to enable an individual to determine consequences by thinking rather than acting, i.e., by reasoning about the world rather than taking action in it (Tanwar et. al., 2010). It is the field of study concerned with using formal symbols to represent a collection of propositions believed by some putative agent (Brachman, 2003). Structured knowledge representations were explored as a general representation for symbolic representation of declarative knowledge. The objective of knowledge representation is to express knowledge in a computer tractable form, so that it can be used to enable designed agents to perform well (Bullinaria, 2006).

In practice, the theoretical requirements for good knowledge representations can usually be achieved by dealing appropriately with a number of practical requirements:

1. The representations need to be complete so that everything that could possibly need to be represented;
2. They must be computable and implementable with standard computing procedures;
3. They should make the important objects and relations explicit and accessible so that it is easy to see what is going on, and how the various components interact;

4. They should suppress irrelevant detail so that rarely used details don't introduce unnecessary complications, but are still available when needed;
5. They should expose any natural constraints so that it is easy to express how one object or relation influences another;
6. They should be transparent so you can easily understand what is being said;
7. The implementation needs to be concise and fast so that information can be stored, retrieved and manipulated rapidly.

Furthermore, the acquired knowledge should be immediately documented in a knowledge representation scheme. At this initial stage, the selected knowledge representation strategy might not be permanent (Sajja & Akerkar, 2010). However, documented knowledge will lead the knowledge engineer/ developer to better understanding of the system and provides guidelines to proceed further. Rules, frames, scripts and semantic network are the typical examples of knowledge representation scheme. It is responsibility of the knowledge engineer to select appropriate knowledge representation scheme that is natural, efficient, and transparent and developer friendly. One may think for hybrid knowledge representation strategies like rules within the frames in slots like "on need" and "on request"; semantic network of default frames (Sajja & Akerkar, 2010).

Rule Based Systems: Rule based representation is one of the most popular knowledge representation and reasoning methods in knowledge based systems. Their popularity stems mainly from their naturalness, which facilitates comprehension of the represented knowledge (Kerber, 2004). The basic form of a rule can be represented as follows:

if < conditions >
then < conclusion >
where <conditions> represents the conditions of a rule, whereas <conclusion > represents its conclusion.

Prentzas and Hatzilygeroudis (2007) described the main advantages of rule based representations as follows.

- Compact representation of general knowledge: Rules can easily represent general knowledge about a problem domain in autonomous, relatively small chunks;

- Naturalness of representation: Rules are a very natural knowledge representation method, with a high level of comprehensibility, since they look like natural language expressions. Rules can emulate the expert's way of thinking in many application domains;
- Modularity: Each rule is a discrete knowledge unit that can be inserted into or removed from the knowledge base, without having to take care of any other technical detail (as long as other rules are not affected). This characteristic grants flexibility during the development of rule-based systems, because it enables incremental development of the knowledge base as well as partial testing.

However, according to Prentzas and Hatzilygeroudis (2007), the following are the main disadvantages of rule based knowledge representation.

- Knowledge acquisition bottleneck: The standard way of acquiring rules through interviews with experts is cumbersome and time consuming. The chief reasons are the inability of an expert to express his or her knowledge and the unavailability of experts;
- Brittleness of rules: It is not possible to draw conclusions from rules when there are missing values in the input data. For a specific rule, a certain number of condition values must be known in order to evaluate the logical function connecting its conditions. In addition, rules do not perform well in cases of unexpected input values or combinations of them;
- Inference efficiency problems: In certain cases, the performance of the inference engine is not the desired one, especially in very large rule bases. There are two main kinds of reasoning strategies employed in rule based systems which include forward and backward chaining mechanism.

Forward chaining: Forward chaining starts with the facts, and sees what rules apply (and hence what should be done) given the facts. In a forward chaining system facts are held in a working memory condition action rules represent actions to take when specified facts occur in working memory. Forward chaining is commonly referred to as data-driven reasoning (Bachman et al.1988). It is one of several inferential control strategies that use existing or deduced data to trigger future deduction and conclusions about the data. Forward chaining in rule based system begins by triggering all of the rules whose "if clause" are true. It is then uses the facts it has established to determine what additional rules might be executable because their "if clauses" are satisfied (Hayes-Roth & Jacobstein, 1994). In a forward chaining system, the initial facts are processed first, and keep using the rules to draw new conclusions given those facts.

Backward chaining: Backward chaining is the reverse of forward chaining. It is used to backtrack from a goal to the paths that lead to the goal. Backward chaining is very good when all outcomes are known and the number of possible outcomes is not large. In this case, a goal is specified and the expert system tries to determine what conditions are needed to arrive at the specified goal. Backward chaining is thus also called goal-driven (Bachman et al., 1988). In a backward chaining system, the hypothesis (or solution/goal) need to reach is processed first, and keep looking for rules that would allow conclude that hypothesis. As the processing progresses, new sub goals are also set for validation.

Therefore, backward chaining starts with something to find out and looks for rules that will help in answering it given current fact (or requiring new inputs, e.g. Diagnostic tests). Same rules/facts may be processed differently, using backward chaining engine which starts with possible hypothesis, set this as a goal to prove or its inverse to disprove (as in resolution). It is initiated when user establishes some goals to be sought and the system identifies one or more rules whose consequents would satisfy the goal. The matching goal is triggered and if none the conjuncts in its antecedent clause is already known to be false, the system establishes sub goals for not yet believed conjuncts. Thus, the system works back through it rule until a question is asked or previously stored fact or belief is found. Back chaining is typically employed in a problem reduction or goal directed approaches to problem solving (Hayes-Roth and Jacobstein, 1994).

Case-Based Representation: Case-based reasoning means using old experiences to understand and solve new problems. In case-based reasoning, a reasoner remembers a previous situation similar to the current one and uses that to solve the new problem. Case based reasoning can mean adapting old solutions to meet new demands; using old cases to explain new situations; using old cases to critique new solutions; or reasoning from precedents to interpret a new situation (much like lawyers do) or create an equitable solution to a new problem (Kolodner, 1992). Case-based representations store a large set of previous cases with their solutions in the case base (or case library) and use them whenever a similar new case has to be dealt with. Case-based representations all concrete cases are keept that might have led to the learning by the experts stick to recording the concrete details of each case without generalizing experience into rules. It avoids the personal influence of individual experts. By pass the expert and look directly at the information that allowed them to learn and acquire their expertise (Memon, 2011). According to (Limam, et al., 2003), case-based reasoning architecture is represented as follows.

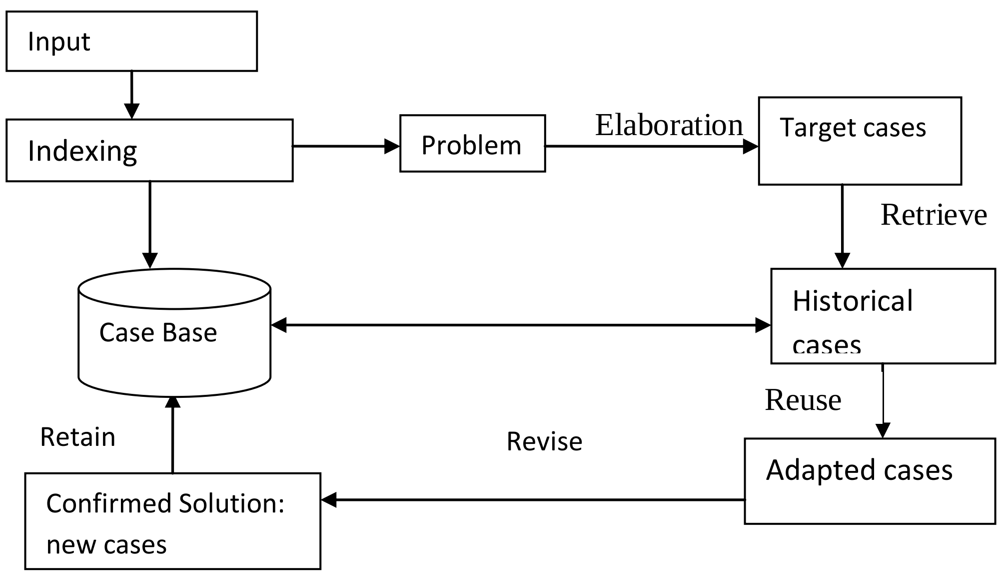

Figure 2.2 Architecture of Case-Based Reasoning

The main advantages of case-based representations are as follows.

- Ability to express specialized knowledge: This feature of cases among other advantages circumvents interpretation problems suffered by rules (due to their generality).
- Naturalness of representation: Cases are a simple knowledge representation method and very comprehensible to the user.
- Modularity: Each case is a discrete, independent knowledge unit that can be inserted into or removed from the case base without any problem.
- Easy knowledge acquisition: Knowledge acquisition in case-based representations is not usually a problem, due to the fact that cases are available in most application domains. However, there are domains where they are not.
- Self-updatability: Knowledge in the form of new cases faced during real-time operation can be incorporated into the case base extending the effectiveness of the system. This self-updatability also facilitates the maintenance of the case base.

- Handling unexpected or missing inputs: A case-based system can handle unexpected cases not recorded in the system or missing input values by assessing their similarity to stored cases and reusing relevant cases.

However, according to Prentzas and Hatzilygeroudis (2007), case-based representations are suffered from the following problems as:

- Inability to express general knowledge: Cases by their nature, express specialized knowledge. So, they cannot express general knowledge. This is a disadvantage compared to rule-based systems;
- Knowledge acquisition problems: Although knowledge acquisition is not a problem when a sufficient number of cases are available in a domain, various knowledge acquisition problems may arise when dealing with domains where cases either are unavailable or are available in a limited (insufficient) amount;
- Inference efficiency problems: The efficiency of the inference process in CBR is not always as good as desired. Efficiency problems involve two main aspects: case retrieval and adaptation;
- Provision of explanations: Some kind of explanation can be provided for the conclusions reached, but not in a straightforward manner as in rule-based systems. It is difficult to explain all reasoning steps.

Frame: Frames are a natural extension of Semantic Networks. A frame includes all the knowledge about an object. The knowledge in a frame is divided into slots. They consist of sets of slots filled by values, procedures for calculating values, or pointers to other frames. Frames provide visual context to guide scene interpretation. It tells the program what to look for and where to look for it (Crowley, 2011). A Frame is composed of a set of "slots" and "methods". A slot is a named place holder for a point. Slots point to other frames that represent entities that are described (or interpreted) by the frames.

Ultimately, some slots point to raw perceptions. Frames can be formalized as a set of relations between entities having certain properties. It is a collection of questions to be asked about a hypothetical situation and specifies issues to be raised and methods to be used in dealing with them.

Script: A script is a remembered precedent, consisting of tightly coupled, expectation suggesting primitive action and state change frames (Kerber, 2004). It is a structured representation describing a stereotyped sequence of events in a particular context. Scripts are data structure used to represent a sequence of events. They are used for interpreting stories (Crowley, 2011). They are frame based systems that describe stereotyped sequences of events and actions that enable an intelligent agent to perform appropriately in a particular context. Scripts have been used to:

1) Interpret, understand and reason about stories;
2) Understand and reason about observed events;
3) Reason about observed actions;
4) Plan actions to accomplish tasks.

Semantic Nets: A semantic network is widely used knowledge representation technique. As the name semantic network, it represents the connection between objects or class of objects (Tannar et al., 2010). It is composed of nodes and links (arcs) that show hierarchical relationships between objects. A semantic network is often used as a form of knowledge representation. It is a directed graph consisting of vertices which represent concepts and edges which represent semantic relations between the concepts. A semantic network represents knowledge as a set of labeled nodes and links.

Furthermore, semantic network is used as a form of knowledge representation for language understanding and translation (Crowley, 2011). Semantic nets are fine at representing relationships between two objects but for relationship with more than two objects it can not represent the relationship. However, Semantic Nets have Problems in knowledge representation including:

- No internal structure of nodes;
- Relationships between multiple nodes is not possible;
- No easy way to represent heuristic information;
- Extensions are possible, but cumbersome;
- Best suited for binary relationships.

2.6 Knowledge Based Systems Development Tools

A knowledge based development tool is a set of software instructions and utilities taken to be a software package designed to assist the development of knowledge based systems. Personal computers, typical programming languages like java and framework like .NET can be used in KBS development. These programming languages are general purpose and also being used to develop other application than Artificial intelligence applications. Knowledge based system (KBS) shell with the ready made utilities of self learning; explanation and inference like Java Expert System Shell (JESS), GURU, Vidwan are more specific and can also be useful to develop KBS (Nilsson & Maluszynski, 2000).

LISP is one of the oldest programming languages, and it is most useful for symbolic representation. However, using LISP to develop an expert system requires the most development time because desirable characteristics such as the user interface, inheritance and method of reasoning need to be specifically coded. Recently, expert system development tools (e.g., shells) developed in LISP, C, or Prolog offer built-in functions that have significantly simplified the task of building expert system. Prolog is a logic-based language based on first-order predicate calculus. It has its roots in formal logic, and unlike many other programming languages. The program logic is expressed in terms of relations, and execution is triggered by running queries over these relations (Kareem and Allen, 1990).

Furthermore, C Language Integrated Production System (CLIPS) is a productive development and delivery expert system tool that provides a complete environment for the construction of rule and/or object based expert systems. The CLIPS is a fact driven environment where rules are fired depending upon the pattern matching. CLIPS does not have its own database and facts stay in the memory of the CLIPS during its active state only. The key features of CLIPS are including: knowledge representation, portability, integration/extensibility, interactive development and verification/validation (Kulshrestha & Khosa, 2011).

2.7 Knowledge Based System for Integrated Development

The Knowledge based systems can be used for interpretation, prediction, diagnosis, design, planning, monitoring, debugging, repair, instruction and control (Sajja & Akerkar, 2010). This advanced technology should be made available in urban and rural areas to utilize expert knowledge for holistic development. Such systems also export knowledge in underdeveloped and remote area where expertise is rare and costly. Hence, knowledge based systems should be at the primary consideration while designing the development plan for a nation. According to Sajja & Akerkar(2010), the share of AI/KBS systems in IT is improved significantly.

In addition, today's KBS are easier to use, less expensive and integrate well with traditional technologies, so it can provide a fundamental technology to the majority of the applications for today's scenario. The four major dimensions of the rural development process that knowledge based system is being utilized are: Economical, Social, Physical and Health development. Major resources for development are considered as Natural Resources, Human Resources, Livestock and Agricultural Resources. According to Sajja and Akerkar (2010), the knowledge based system applications classified according to the above dimensions & resources can be represented in the Figure 2.3 below.

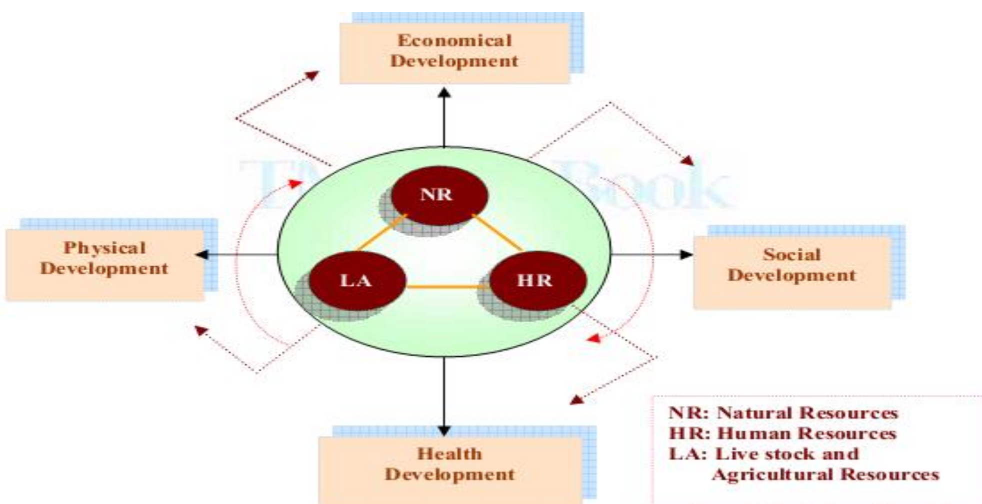

Figure 2.3 Dimensions of Development through Knowledge Based Systems.

Sajja and Akerkar (2010) described the Application of knowledge based systems in different dimensions as mentioned in the Table 2.1 below.

In Physical Development	In Social Development
- Knowledge-based planning for land use and land reform - Network monitoring systems - KBS for resource sand material management - KBS for river and land use management - KBS for soil health card for villagers - KBS for intelligent manufacturing and new product development	- Intelligent system to identify suitable beneficiaries for Government/NGO schemes - Child and women health/nutrition systems - Community health - E-learning - Education and training systems - Knowledge-based examination planning system - Games and entertainment KBS - Language translation and tutoring
In Economical Development	In Health Improvement
- Business selection advisory - Tax planning system - Knowledge-based planning of agricultural products - Knowledge-based planning for agricultural inputs - Knowledge-based diagnosis for plants and animal diseases - Crop land pattern matching system for Agriculture	- Government schemes information system - Diet planning system - Disease diagnostic system - Disease diagnostic system for cattle and live stock - Patient monitoring system - Medical insurance - KBS monitoring in surgical process - KBS for guided neuro-surgery

Table 2.1 Application of Knowledge Based System for Development

2.8 Knowledge Based System Application in Agriculture

The application of knowledge based system in Agriculture are the same as other KBS approach as they use the rule based approach which the experience and knowledge of human expert is captured in the form of IF-THEN rules and facts. These rules and facts are used to solve problem by answering questions on such diversified topics as pest control, the need spray, selection of chemicals to spray, mixing and application, on optimal machinery management practice, weather damage recovery such as freeze for drought etc. (Siew et al., 2005).

The domain of application for KBSs is widening persistently, as new research topics emerge. In the 1990's, their foreseen usage directions were: design (the embedding of design rules within applications), diagnosis, instruction, interpreting observed data, monitoring, prediction (by inferring likely outcomes of given situation), prescription of remedies for malfunctions (Avram, 2005). Since 1996, the applications of KBSs expanded a lot, today proliferating in speech recognition, computer vision, cognitive systems, and many others.

An Expert System also called a Knowledge Based System is a computer program designed to simulate the problem solving behavior of an expert in a narrow domain or discipline. In agriculture, expert systems unite the accumulated expertise of individual disciplines, e.g., plant pathology, entomology, horticulture and agricultural meteorology into a framework that best addresses the specific, on-site needs of farmers. Expert systems combine the experimental and experiential knowledge with the intuitive reasoning skills of a multitude of specialists to aid farmers in making the best decisions for their crops (Prasad, 2006).

In the 1990s, several expert systems have also been developed. POMME is an expert system for apple orchid management. POMME advises growers about when and what to spray on their apples to avoid infestations. The system also provides advice regarding treatment of winter injuries, drought control and multiple insect problems. In 1987 expert system technology was identified as an appropriate technology to speed up agricultural desert development in Egypt. In Egypt, at CALEX (Central Agriculture Laboratory Expert system) several expert systems have been developed. CALEX system has been developed for agriculture management. It is domain independent and can be used with any commodity. CALEX consists of three separate modules: an executive, a scheduler and an expert system shell (El-Helly et al., 2004).

An agro forestry expert system (UNU-AES) was designed to support land use officials, research scientists, farmers, and other individuals interested in maximizing benefits gained from applying agro-forestry management techniques in developing countries. UNU AES is a first attempt to apply expert systems technology to agro forestry (El-Helly et al., 2004).

Hogeveen et al. (1991) developed an integrated knowledge based system for dairy farms that serves diagnostic, problem solving, and advising role in controlling the health and production of a herd, including the financial consequences. It must provide the dairy farmer and advisors, such as the veterinarian and extension officer, with a tool that can detect deviations from optimal milk production and herd health situation as early as possible. Therefore, a logical set up of an integrated knowledge based system for the dairy farm contains three modules: a health module, a production module, and a financial module.

El-Beltagy et al. (2004) developed irrigation expert systems to produce an irrigation schedule for a particular crop in a particular farm. The output of schedule is a plan of water quantities to be applied and the time of application according to the requirements of the plant and the affecting factors like the soil type, climate, source of water, etc. Determining a crop's water requirements is nontrivial task, but is one that involves many equations that in turn involve an extensive number of complex variables relative to the soil, water, climate, crop etc. This work capitalizes on the fact that even though the irrigation requirements for various crops may vary, a number of basic concepts and irrigation determination techniques are shared among all. By recognizing this fact, a tool was built to hide all the complexities of an irrigation's system equations and knowledge from the developer, while highlighting any missing knowledge that can vary from one crop to another thus guiding the developer as to 'what' knowledge needs to be acquired. In a sense, the developer is simply offered an empty template for specifying the inputs and rules for determining or calculating the value of a property of some pre-identified concept.

King et al. (1991) developed a knowledge based system for malting barley management. a knowledge based system that will combine a numerical crop growth simulation model with crop-specific heuristic knowledge to provide decision support for malting barley growers. The system gives advice on fertilizer and water applications to maximize crop yield under strict quality constraints. The knowledge based system (KBS) has a modular` structure which has two main modules of the fertilizer and irrigation modules which are called by the central control module.

According to King et al. (1991), the fertilizer module's construction was based directly on a cognitive model of the Coors field agronomists who participated in the system's development. Fertilizer recommendations consist of nitrogen and phosphorous dosages and timing. For malting barley, fertilizer is generally applied prior to or at the time of planting.

Line and Cu **(**1994**)** developed an expert system for managing diseases of wheat that is both predictive and managerial for use in the Pacific Northwest (PNW) of the United States and is referred to by the acronym MoreCrop (Managerial Options for Reasonable Economical Control of Rusts and other Pathogens). The purpose of MoreCrop is to present outcomes that may happen and give options for control, not to make specific recommendations. The user evaluates the information that is provided when certain environmental conditions and managerial practices are selected and, by a process of reasoning, determines the most economical control.

Yelapure et al. (2011) developed Knowledge based System for Tomato Crop with Special Reference to Pesticides. This Knowledge Based System for Tomato crop helps farmers to control attack of different pests with help of the pesticide treatment. Researcher has developed workable Knowledge Based System to identify the pests and to suggest pesticide treatment to control it. The rules were developed by considering different growth stages of Tomato, symptoms of disease, insects attack on crop. As a pesticide treatment, this system suggests different pesticide to control single pest. Farmers, get choice of selecting pesticide by considering different companies and their prices so that farmers can select pesticides which is affordable to them. Pesticide ratio has been suggested in agriculture literature also, but in per hector terms which become complex to farmers to calculate ratio per knapsack sprayer. To decrease this complication, this system suggest exact ratio of pesticide required per knapsack sprayer.

2.9 Challenges for AI Research in Agriculture and Natural Resource Management

Agricultural problems naturally pose certain technical difficulties of interest to AI researchers. There is a technological and psychological problem in that attempts to apply knowledge based Systems in agriculture have often met with resistance. More attention to modeling end users' perceptions and emotions is needed. The fact that natural resource management affects the general public (through food and water quality, general public health, and the pocketbook) means that political questions might become important to decision making. The distributed nature and loose organization of the agriculture industry poses some practical problems as well (Stone and Engel, 1990). Implementing the technology in a dispersed and computer-poor industry is difficult. Knowledge distribution techniques for agricultural practitioners unfamiliar with computers must use better explanation and combined AI graphics systems.

Some specific technical issues must be addressed by AI research, the predominance of stochastic elements in agriculture and natural resource management demands better representations for dealing with processes such as the weather. Spatially referenced data and spatial variability must be incorporated into knowledge based systems. Time-based reasoning and the representation of coordinated multi agent processes are also needed to address issues of simulation and planning. Finally, because expertise in agriculture and natural resource management is diffuse and disorganized, AI researchers interested in knowledge acquisition that need to address the problems of synthesizing fractionalized expertise (Stone and Engel, 1990).

CHAPTER THREE

KNOWLEDGE ACQUISITION

3.1 Introduction

The main objective of this chapter is to acquire knowledge from domain experts and secondary sources on barley and wheat crops diseases and diagnosis techniques as well as modeling the acquired knowledge for representation.

Knowledge acquisition is the accumulation, structuring, organizing and studying knowledge for expertise from some knowledge source to a computer program for constructing or expanding the knowledge based systems (Tomar & Saxena, 2011). It is a prerequisite and an important phase of knowledge based system development that deals with the activities of capturing knowledge from human experts, books, documents or computer files. Knowledge acquisition is the process of eliciting, analyzing and interpreting the knowledge that human expert uses when solving problems and then transferring these knowledge in to machine representation. It is used to develop a computational problem solving model, specifically a program to be used in some consultative or advisory role (Hamilton, 1996). The knowledge which is captured in the knowledge acquisition process may be specific to the problem domain or to the problem solving procedures.

Moreover, in this chapter the following activities are carried out which include:

- ✓ Knowledge analysis, the process of making sense of the information collected during the knowledge elicitation.
- ✓ Knowledge structuring, the process of expressing the analyzed knowledge in an understandable and usable form.
- ✓ Knowledge modeling, the process of connecting the decision flow of the acquired knowledge and relationship between concepts. Expressing knowledge in a format that facilitates its representation and its handling by a computer.

3.2 The Knowledge Acquisition Process

The process of knowledge acquisition in this research work includes some basic activities such as gathering the required knowledge, analyzing that knowledge, identifying important concepts focusing on causes and symptoms of cereal crop diseases. In order to acquire required knowledge for this study both secondary and primary sources of knowledge are used. The techniques used to extract relevant knowledge from these sources are:

- Reviewing related documents and manuals
- Interviewing domain experts

3.2.1 Reviewing Related Documents and Manuals

Document analysis involves gathering knowledge from existing documentations. Hence, document analysis has been carried out to acquire explicit knowledge which is found in various secondary sources of knowledge. Accordingly, different source books, Internet resources and plant disease protection guide lines are reviewed and analyzed. As the result, relevant and technical knowledge were extracted and structured in a manner that suitable for knowledge modeling and finally knowledge representation.

3.2.2 Interviewing Domain Experts

Both structured and unstructured interviews were employed to elicit tacit knowledge from domain experts. Since one of the specific objectives of this research is extracting tacit knowledge which is embedded and personalized in experts mind. For this reason, three research experts from Kulumsa Agriculture Research Center were selected purposively for interview. Two Agriculture lecturers were also selected from Adama University Asella school of Agriculture campus. Thus, a total of five (5) experts who are crop specialist and plant pathologists have been participated in the interview for this study. These experts were interviewed about major cereal crops diseases that affect wheat, barley and the symptoms of these diseases as well as treatments undertaken to control such diseases. During face to face communication, the information obtained from experts has been recorded manually by using pen and paper sheet.

Profiles of domain experts participated in the interview process are presented in the Table 3.1 below.

No	Educational level of experts	Specialization	Work Experience	Occupational role
1	BSc	Crop protection	10 Year	Researcher
2	MSc	Plant pathology	5 Year	Teaching & research
3	MSc	Crop protection	8 Year	Teaching
4	PhD	Wheat breeding	15 Year	Researcher & national coordinator of wheat crop breeding
5	BSc	Barley breeding	2 Year	Joiner researcher

Table 3.1 Domain Experts Profiles

These experts indicated in the Table 3.1 above are crop professional conducting research and teaching in crop protection and production. Based on their profession and experience, these experts identified that the common diseases that affect cereal crops (wheat and barley) in Ethiopia are leaf rust, stem rust, barley yellow dwarf, fusarium, scald, take-all, Powdery mildew, smut, common bunt and net blotch. The experts responded that crop diseases diagnosis mostly carried out using visual identification through observation and laboratory examination.

Incase of visual identification through observation, the symptoms of crop diseases is identified by experienced crop experts by applying both tacit knowledge accumulated through experience and explicit knowledge such as using keys/ colored photos of crop history and guidelines or principles crop protection books. The experts responded that visual identification and diagnosis method more advantages regarding time and cost saving than laboratory examination method. They also assure that since laboratory examination takes time, it can not be used for providing immediate solution for outbreak of cereal crops diseases.

Hence, experienced and knowledgeable experts can identify the problem of crops through observation of symptoms and signs of diseases that attack cereal crops to make immediate decision. During the discussion with domain experts, domain experts stated that after particular pathogen that causes a particular crop disease is identified, appropriate control measure is taken to control such diseases. The experts also stated that the treatments provided to control cereal crop disease are the use of resistant varieties, spray fungicides and cultural control.

In deed the detail of this knowledge required for easy representation and prototype knowledge based system development that focuses on diagnosis and treatment of cereal crop diseases is discussed, structured and modeled in the following sections.

3.3 Cereal Crop Diseases

Basic knowledge of disease epidemiology is crucial to design effective control measures, but few efforts have been made in the area of cereal crops protection in Ethiopia (Bayehe, 2011). In addition, pathogenic fungi are by far the most important and yield limiting causes of diseases which attack cereal crops. Of these diseases the genera Puccinia (rusts), Usti/ago (smuts),Tilletia (bunts), Erysiphe (powdery mildews), Septoria, Alternaria, Helminthosporium, Fusarium Pythium are the most widespread and regularly occurring and potentially dangerous diseases throughout the world in general and have devastating impact in Ethiopia in particular are discussed in the following sections.

Moreover, based on the discussion with domain experts during the interview and analyzing various secondary sources (books, manuals, Internet), the following knowledge has been elicited for the prototype development of this research work. This knowledge focuses on wheat and barley crop diseases, the symptoms of these diseases and the types of control measures undertaken for treatment. Figure3.1 represents the types of cereal crops organs affected by a particular disease from which crop experts can observe the symptoms of the diseases occurrence.

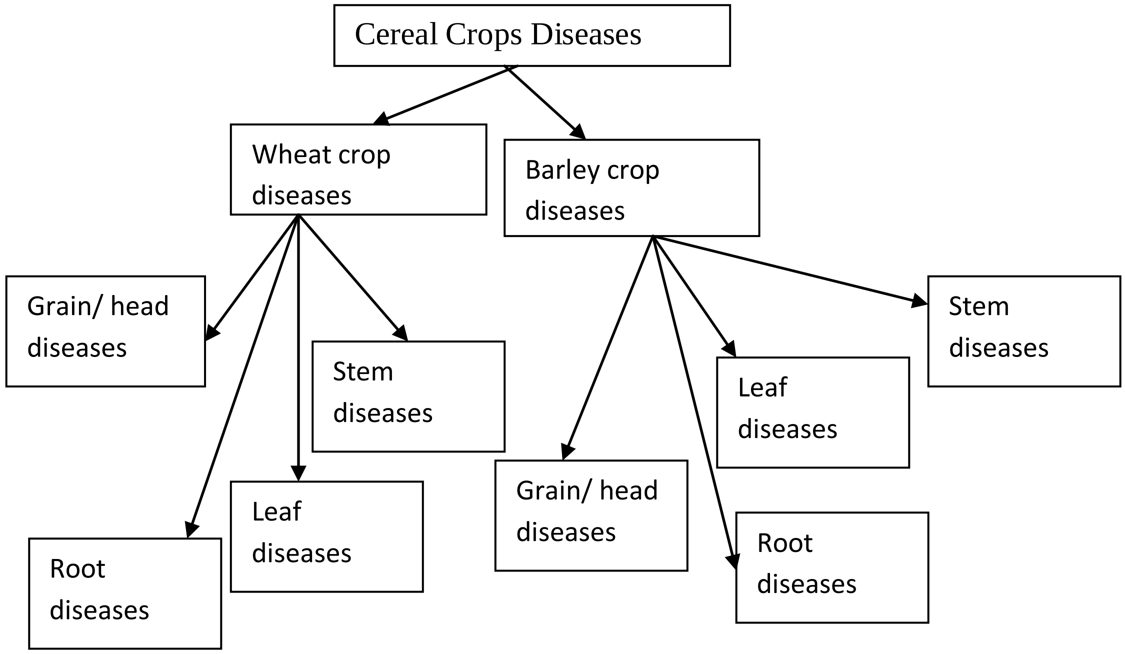

Figure 3.1 Category of Cereal Crop Organs Affected by Disease.

3.3.1 Wheat Crop Diseases

Ethiopia produces wheat on an area about 7500ha up to 60%, of this area is occupied by durum wheat while bread wheat covers the remaining 40% (Amanual, 2003). At present wheat yields are very low in Ethiopia (7 to 8 quintal per hectare as compared to about 12 quintals for the world average). According to Hailu (2003), Wheat production in Ethiopia is constrained by several factors can be categorized as technical and socio economic factors. Among the technical factors, disease is the major contributing factor to the low yield, in addition to low yielding varieties, poor cultural practices, and lack of fertilizers. The incidence of the different wheat diseases varies with altitude and other climatic factors. Stripe rust, for example, is limited mainly to high altitude, cooler areas but has now extended its adaptation to lower and warmer altitudes. The following are the major diseases that affect the productivity of wheat crop production in Ethiopia.

A. Common Bunt: It is caused by Tilletia caries / T. foetida pathogens. Wheat kernels infected by common bunt have a gray green color and are wider than healthy kernels. Diseased kernels can be seen in developing wheat heads but are often not detected until harvest. The outer layers of diseased kernels remain intact initially but are easily broken during grain harvest which resulted in releasing masses of black powdery spores. The fungus produces chemicals with a fishy odor, which used to identify this disease (McMullen et al., 2003).

B. Fusarium Head Blight: Fusarium head blight (FHB) epidemics have caused enormous yield and quality losses of wheat product. Frequent rainfalls and long durations of high relative humidity during flowering and grain fill favor infection by the causal fungus. The first symptoms of Fusarium head blight include a tan or brown discoloration at the base of a floret within the spikelets of the head. As the infection progresses, the diseased spikelets become light tan or bleached in appearance. Fusarium head blight affects the developing heads of small grains directly and yield losses that exceed 45 percent are common during years when disease is severe (De Wolf, 2003).

C. Wheat Rusts: Stem rust (caused by Puccinia graminis f. sp. tritici), leaf rust (caused by P. triticina), and stripe rust (caused by P. striiformis) are some of the most widely recognized diseases in wheat. Stem rust and leaf rust occur almost wherever wheat is grown whereas stripe rust is generally restricted to areas where temperature in the growing season is cool (McMullen et al., 2003). The symptoms of leaf rust diseases are small, orangish brown lesions are key features of leaf rust infections. These blister-like lesions are most common on leaves but can occur on the leaf sheath, which extends from the base of the leaf blade to the stem node. Lesions caused by leaf rust are normally smaller, more round, and cause less tearing of the leaf tissue than those caused by stem rust. Stripe rust commonly affects leaf blades, occasionally observed on heads when disease is very severe; infection of leaf sheaths or stems is rare**.** Small, round, blister- like lesions that merge to form stripes are symptoms of strip rust.

Moreover, the fear of stem rust was understandable because an apparently healthy crop 3 weeks before harvest could be reduced to a black tangle of broken stems and shriveled grain by harvest (Roelfs et al., 1992).

D. Leaf Spotting: Tan spot and Septoria leaf spot are the two most common wheat leaf diseases caused by the fungus. The adoption of minimum or no tillage is causing an increase in the incidence of these diseases due to increased crop residue on the soil surface.. Symptoms are both form very small, yellow spots on the leaves when the fungus first infects the leaf and expand into distinctive patterns. Avoid planting into wheat residue, tillage where appropriate, genetic resistance and foliar fungicides are used to control leaf spotting disease.

E. **Powdery mildew:** Powdery mildew is mainly occurs on all aerial parts of the wheat including head, leaf and stem but most common on lower leaves of the wheat crops. Powdery mildew is expressed as gray to white, cottony growth over the leaf surface. It is caused by fungus Erysiphe graminis f. sp. tritici. Powdery mildew can be controlled using genetic resistance and foliar fungicides. Growing mildew resistant varieties is the most economical way to control powdery mildew (Wegulo, 2010).

F. Barley yellow dwarf: it caused by BYD luteovirus aphid transmitted pathogens. Disease occurrence is favored by early planting, High populations of aphid vectors in fall. It is recognized by Small or large patches of yellow plants noticed around boot stage. Leaf tip turns yellow or purple, but midrib remains green (McMullen et al., 2003).

G. Common Root Rot (Cochliobolus sativus / Bipolaris sativus): It is a residue-borne disease that may increase in severity in no-till or when spring and winter wheat are cropped in successive years. Severe infections can lead to stunting of plants. Common root rot identified by brown discoloration of the roots and crown, and wheat heads having fewer seeds that may be shriveled. Common root rot may be managed with crop rotation and avoid successive cereal crops and can be managed by treating seed at planting with seed treatment (Moore, 2005).

H. Take-all (Gaeumanomyces graminis var tritici): Take all can occur from emergence onwards, but most obvious after flowering. More common in no-till crops and poorly defined patches. Take all affects root parts of wheat crops. This fungal disease causes wheat to die prematurely, resulting in patches of white heads in otherwise green fields of wheat. Plants infected by take-all normally have a black discoloration of the lower stem and roots. Frequently, the disease is most severe in wet areas of a field and near field edges where the fungus survives in association with grassy weeds (Wegulo, 2010).

The details of types of wheat crop disease and their symptom are identified in the table 3.2 below.

Types of Wheat crop diseases	Major identified Symptoms of Diseases	Favorable conditions
Common bunt (Tilletia caries)	kernels have gray green color and are wider than healthy kernels	Cool temperature
	Seeds are easily broken during grain harvest	
	Releasing masses of black powdery spores	
	Spores produce fishy odor	
Fusarium head blight (Calonectria nivalis)	Tan or light brown lesions on wheat heads	Wet and humid weather
	Dark brown discoloration at the base of portion of the glume	
	Wheat grain has White chalky appearance	
	Spores are released from the head	
Barley yellow dwarf (BYD luteovirus)	Wheat leaves to have a yellow or red discoloration	Vectored by an aphid
	A flame-like appearance of wheat leaves	
	Shorter length of the wheat crop than neighboring healthy wheat	
Leaf rust (Puccinia recondita)	Small, orangish-brown lesions of the leaves	Mild warm temperature (70s-80F°)
	Blister-like lesions are most common on leaves of the wheat	
	Smaller, more round lesions, and cause tearing of the leaf tissue	
Powdery mildew (Erysiphe grarninis f. sp. tritici)	White lesions on leaves and leaf sheaths.	Cool and wet weather
	White, cottony growth of the fungus	

Table 3.2 Symptoms of Wheat Crop Disease

The details of types of wheat crop disease and their symptom are identified in the Table 3.3. below.

Types of Wheat crop diseases	Major identified Symptoms of diseases	Favorable conditions
Septoria tritici blotch (Septoria tritici)	Tan, elongated lesions on wheat leaves	High moisture and high humidity
	Lesions may have a yellow margin	
	Darker color leaf blotch or tan spot	
Stem rust (Puccinia graminis f .sp. rritici)	Blister-like lesions on leaves of wheat	Moisture for night time dews
	Reddish-brown spores of the fungus	
	Bright yellow streaking	
Common root rot (Helminthosporium)	Premature death of wheat	Crop Residue in the farm
	Patches of white heads scattered throughout a field	
Take-all (Gaeumannomyces graminis f, sp. tritici)	Wheat to die prematurely	Soil and moisture
	Black discoloration of the lower stem and roots	
Bacterial streak (Bacillus megaterium pv. cerealis)	Water soaked areas between leaf veins	Wheat curl mite
	Water-soaked areas become tan streaks within a few days	
	Lesions dry to form a clear, thin film on leaf	
Stripe rust	Small, round, blister-like lesions that merge to form stripes	High moisture
	Yellow-orange color of lesions	

Table 3.3 Symptoms of Wheat Crop Disease

3.3.2 Barley Crop Diseases

Diseases occur when a susceptible host is exposed to a virulent pathogen under favourable environmental conditions. Control is best achieved by knowledge of the pathogens involved and manipulation of the interacting factors. Little can be done to modify the environment but growers can minimise the risk of diseases by sowing resistant varieties and adopting practices to reduce inoculums. The major diseases of barley are discussed as follows.

A. Smut: Smut diseases are caused by fungi that live as parasites on the host plant and produce soot-like spores in grains or ears. Smut fungi may be borne either on the inside or outside of the seed. On barley and rye, loose smut is caused by the fungus Ustilago tritici. Triticale is thought to be resistant to loose smut. Diseased plants appear normal until heading but may be taller and mature earlier than surrounding healthy plants. Infection and disease development are favored by cool and humid conditions which prolong the flowering period of the host plant (Prescott et al., 1986).

B. Barley Rust: Rust diseases are caused by Puccinia spp. and include stripe rust, leaf rust, and stem rust. All rust diseases are easily recognized by the yellow to reddish or brown pustules that develop on leaves and/or stems. Leaf rust symptoms appear as small, round, light orange brown pustules on the leaf blade and leaf sheath. They may also occur on heads of very susceptible cultivars in the advanced stages of an epidemic. Brown, oblong pustules appear later in cultivation season (Burrows, 2009).

C. Powdery mildew (Blumeria graminis f.sp. hordei): Powdery mildew occurs throughout the agricultural areas but is more common in areas where high humidity favors disease development. Symptoms appear as pure white, fluffy growth on the surface of the leaf. With fall rains, spores are released from cleistothecia and they infect nearby plants. Infection leads to premature yellowing and later death of the leaf parts of barley crops (Collins, 1995).

D. Barley Yellow Dwarf Virus (BYDV): Barley Yellow Dwarf Virus (BYDV) can infect barley, wheat, oats, triticale, and rye as well as several grasses. It is transmitted by aphid species that have fed on infected plants. The occurrence of BYDV therefore depends on conditions favorable for aphid build up and movement such as cool and moist weather that favors grass and cereal growth as well as aphid multiplication and migration**.** Symptoms appear as Infection of young plants may cause stunting, reduced grain formation, and grain filling. Late infection may not cause stunting but it may still reduce yield. Yellowing tips of the leaf color (Collins, 1995).

E. Leaf blotch: Leaf diseases common in barley include net blotch and spot blotch. Infections appear as dark and chocolate colored blotches. The spots merge and eventually forming irregular dead patches on the leaves. They can be distinguished based on their symptoms, but controlled using similar techniques. Symptoms begin as small spots on leaves or stems and expand the entire crops (Steffenson et al., 1999).

F. Scald: Scald is caused by the fungus Rhynchosporium secalis. It is a disease of both barley and rye. Yield loss occurs primarily through reduced kernel weight. Scald is easily recognized by pale gray or bluish gray lesion on leaves (Collins, 1995).

G. Take-All Root Rot: Take-all root rot, caused by the fungus Gaeumannomyces gramminis var. tritici, is one of the most serious root rotting diseases of barley. The most obvious symptom of take-all root rot is the development of white heads during the grain filling period. Roots of affected plants are dark brown to black because of fungal invasion (Collins, 1995).

H. Common Root Rot: Common root rot (Cochliobolus sativus) is also soil borne. It is widespread in barley crops and may cause yield losses of up to 15%. Common root rot recognized by brownish roots and coleoptiles. Older plants have small, oval, and brown lesions on roots, the lower leaf sheath, or the sub crown internodes (Collins, 1995).

The details of types of barley crop disease and their symptom are identified in the Table 3.4.below.

Types of barley diseases	Major identified symptoms of diseases	Favorable condition
Powdery Mildew	Pure white, fluffy growth on the surface of the leaf	High rain fall and winds
	Producing so many spores that the leaf appears powder	
	Premature yellowing and later death of the leaf	
Leaf Rust	Small, round, light orange brown pustules	Moist weather and temperatures
	Oblong pustules appear in the later season	
Spot Blotch	Spots develop on leaves and leaf sheaths	Warm, humid weather
	Lesions are round to oblong on barley leaf	
	Older lesions of leaf are olive colored	
Barley Yellow Dwarf	Yellow color on the tips of the leaf	Vectored by an aphid
	Reduced grain formation, and grain filling	
	Yield reduction of barley crops	
Loose smut (Ustilago tritici)	Heading crop taller and mature earlier than surrounding healthy crops	Crop residue in the farm
	Black powdery spores blow away to leave a bare stalk	
Scald	Pale gray, or bluish gray lesion on leaves	Rain splash
	Lesions dry out bleach become light gray, tan	
	Small, oval, and brown lesions on roots	
Stem rust	Reddish brown pustules on the stem of barley	Moist weather and temperatures
	Elongated shape of the pustules	
	Reddish brown pustules become black color	
Take-All Root Rot	Development of white heads during the grain filling period.	Cool and moist soil
	Roots changed from dark brown to black color as of fungal invasion	
	Plant can be easily pulled from the soil	
Net Blotch	Netting pattern on barley leaves	Infected crop residue
	Light brown lesion on leaf	
Common Root Rot	Dark brown to black discoloration of barley root	Cool and moist soil
	Tiller bases and surrounding leaf sheaths brown	
	Barley has pinched grain at harvest season	

Table 3.4 Symptoms of Barley Crop Diseases

3.4 Conceptual Modeling

Conceptual modeling is the activity of formally describing aspects of the physical and social world around us for purposes of understanding and communication. The conceptual modeler thus has to determine what aspects of the real world to be included and excluded from the model and at what level of detail to model each aspect (Faber, 2010). According to Faber (2010), the way that this is done depends on the needs of the potential users or stakeholders, the domain to be modeled and the objectives to be achieved. A principled set of conceptual modeling techniques are thus a vital necessity in the elaboration of resources that facilitate knowledge acquisition and understanding. Such resources would ideally allow non experts to understand a given domain by focusing on and capturing essential knowledge.

In addition, conceptual modeling is a technique that helps to clarify the structure of a knowledge intensive business tasks. The knowledge model of an application provides a specification of the data and knowledge structures required for the application. The model is developed as part of the analysis process (Speel, 2001). Knowledge modeling is widely recognized as the critical phase of knowledge acquisition. Before a knowledge based system can be built, knowledge must somehow be identified and collected and a model of domain knowledge must be constructed (Richard et al., 1999).

Hence, models are used to capture the essential features of real systems by breaking them down into more manageable parts that are easy to understand and to manipulate. A knowledge model provides an implementation independent specification of knowledge in an application domain. Typically, a knowledge model provides formats for writing down both static domain knowledge (rules, classes, relations) as well as reasoning strategies in which this domain knowledge is used to solve a particular problem. As the result, knowledge acquisition ends with the creation of a knowledge model which should be defined explicitly and independently from the methods of subsequent life cycle (Speel, 2001).

Generally, conceptual modeling in this research work is a vital step to understand and structure the problem domain and prepare concept relationships for knowledge representation. The logical relation of the identified concepts and facts are described using decision tree that are implemented in knowledge based system development in the next chapter of this study.

Decision trees are one of a modeling tool that used in variety of settings to organize and break down cluster of data. It is a graphical representation of the information in the factor table to determine a course of actions and models the possible consequences of a series of decisions in some situations (Bethune et al., 2007). Decision analysis is explicit because it forces the decision maker to separate the problem into its component parts with out losing the context of the big picture. It is an analytic approach forces the decision maker to consider explicitly the timing of choices that must be made, the data that must be acquired to make informed decisions.

Thus, decision tree takes as input an object or situation described by a set of properties, and outputs a yes/no decision. They are able to produce human readable descriptions of trends in the underlying relationships of a data set and can be used for classification and prediction tasks. A decision tree is formalism for expressing and mappings attributes linked to two or more sub-trees and leafs or decision nodes (Podgorelec et al., 2002).

Moreover, in this research decision tree has been used as knowledge modeling tool. The reason of choosing this modeling tool is that decision trees depict a strong sense of cause and effect relationships of types of cereal crop diseases and the associative symptoms that lead to the identification of those diseases. Purposefully, decision trees can easily be converted to the form of if-then rules that are suitable and understandable by computer programs. So, the conversion can be executed by a computer program**.**

3.4.1 Cereal Crops Diseases Diagnosis Modeling Using Decision Tree

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. In a typical abductive problem, the task of a diagnostic problem solving is to find a hypothesis that best explains a set of observation. Disease diagnosis involves identifying which disease, if any, a particular crop has on the basis of observable symptoms (Andreae, 1993). Similarly, crop diagnosis is the process of recognizing a disorder from its symptoms and signs whether the disorder is caused by something in the physical environment, an infectious organism (pathogen), or an insect. The diagnostic process should include looking at the entire plant as well as its separate parts, carefully analyzing the observations, and attempting to understand or explain why a disorder has occurred.

Furthermore, diagnosis of crop disease is the identification of specific crop disease through the symptoms and signs appear on the parts of the crops. In order to begin the treatment process, a disease has to be first diagnosed correctly and completely (wheat, 2008).

As the domain experts stated during the interview, in cereal crops diseases diagnosis plant pathologists/ experts follow some of the following steps.

- ✓ Look the appearances of crops how look like and compare diseased crops with the normal one.
- ✓ Identify the parts of the crop (head, leaf, stem root or the entire) infected by diseases.
- ✓ Understand the characteristics of the organisms that cause for the infestation of the crop.
- ✓ Observe the symptoms and signs associated with types of diseases that affect crops.
- ✓ And deciding the type of disease characterized such symptoms and take appropriate treatments for the identified cereal crop diseases.

For this the study the course of actions (knowledge) that are applied by plant experts/ pathologists have been identified, acquired and then the types of cereal crops disease and their symptoms are modeled using decision tree. Most of crop diagnosis activities are performed by applying observation of the symptoms appeared on the parts of the crops. So, in this research the symptoms of diseases associated with the types of diseases causing for the symptoms/ disorders are modeled using decision tree.

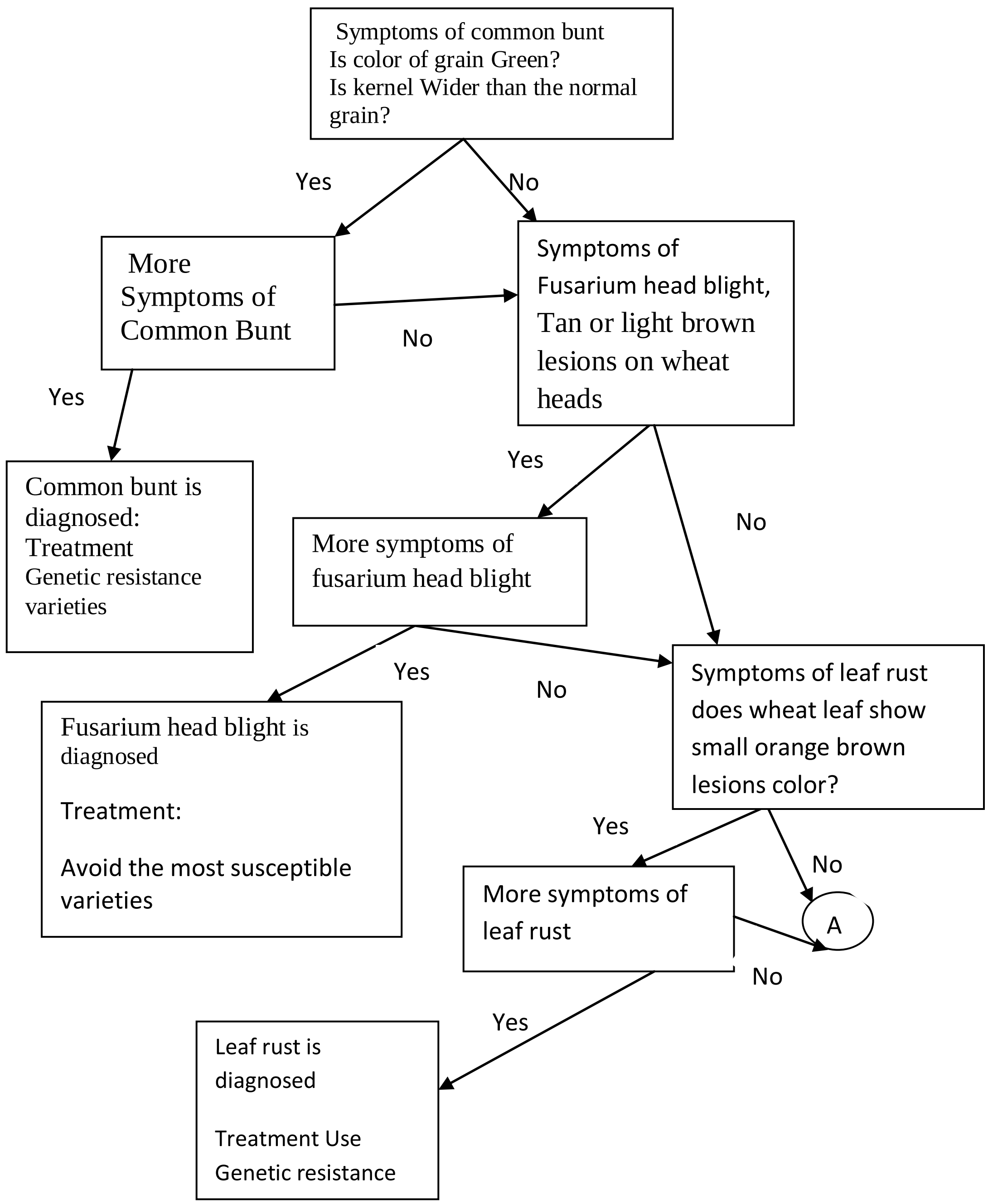

Figure 3.2 Decision Tree for Modeling Wheat Grain/Head Diseases Diagnosis

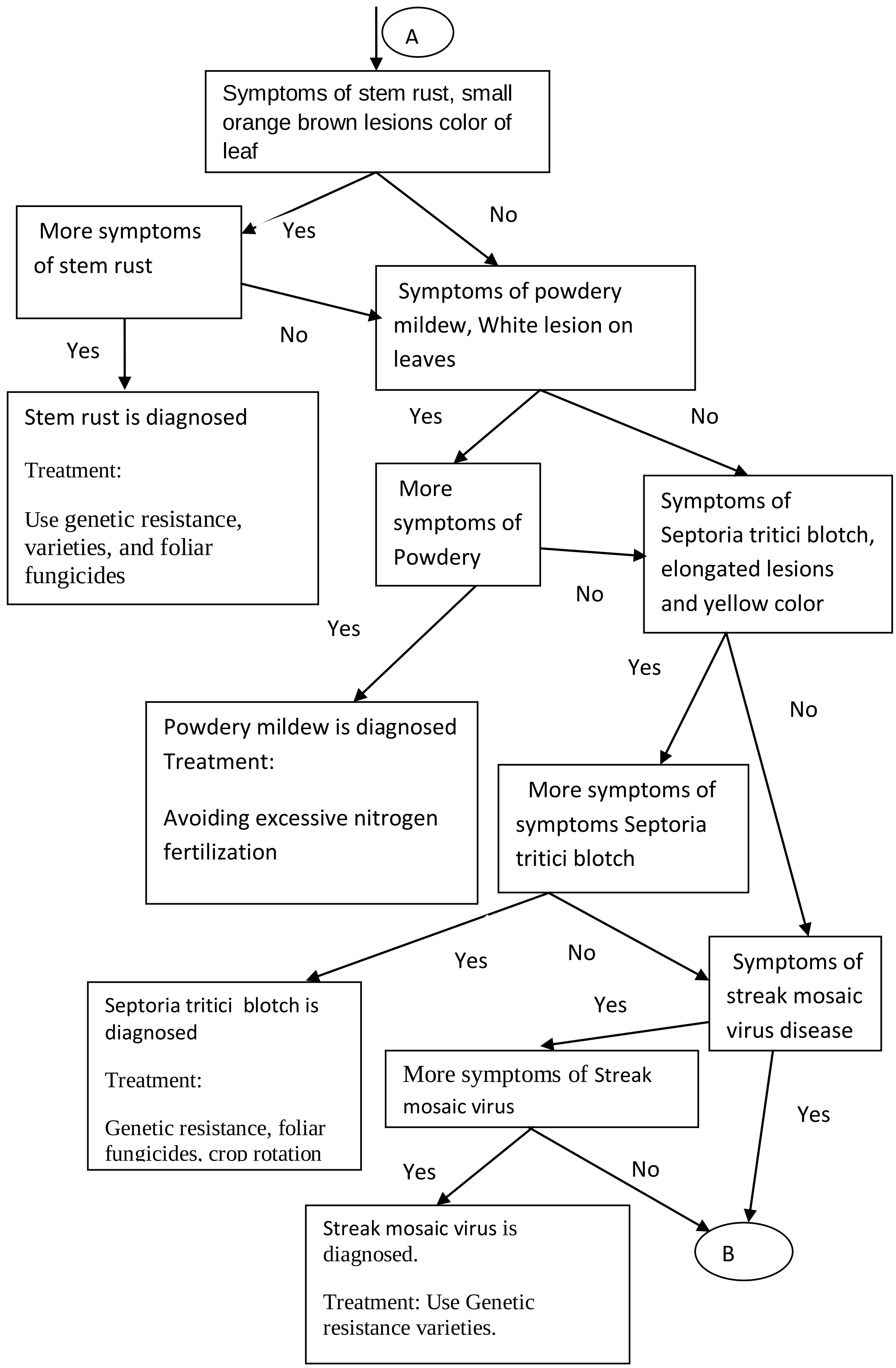
A
Symptoms of stem rust, small orange brown lesions color of leaf
Yes
No
More symptoms of stem rust
Yes
No
Stem rust is diagnosed
Treatment:
Use genetic resistance, varieties, and foliar fungicides
Symptoms of powdery mildew, White lesion on leaves
Yes
No
More symptoms of Powdery
No
Yes
Symptoms of Septoria tritici blotch, elongated lesions and yellow color
Yes
No
Powdery mildew is diagnosed
Treatment:
Avoiding excessive nitrogen fertilization
More symptoms of symptoms Septoria tritici blotch
Yes
No
Septoria tritici blotch is diagnosed
Treatment:
Genetic resistance, foliar fungicides, crop rotation
Symptoms of streak mosaic virus disease
Yes
More symptoms of Streak mosaic virus
Yes
Yes
No
Streak mosaic virus is diagnosed.
Treatment: Use Genetic resistance varieties.
B

Figure 3.3 Decision Tree for Modeling Wheat Leaf Disease Diagnosis

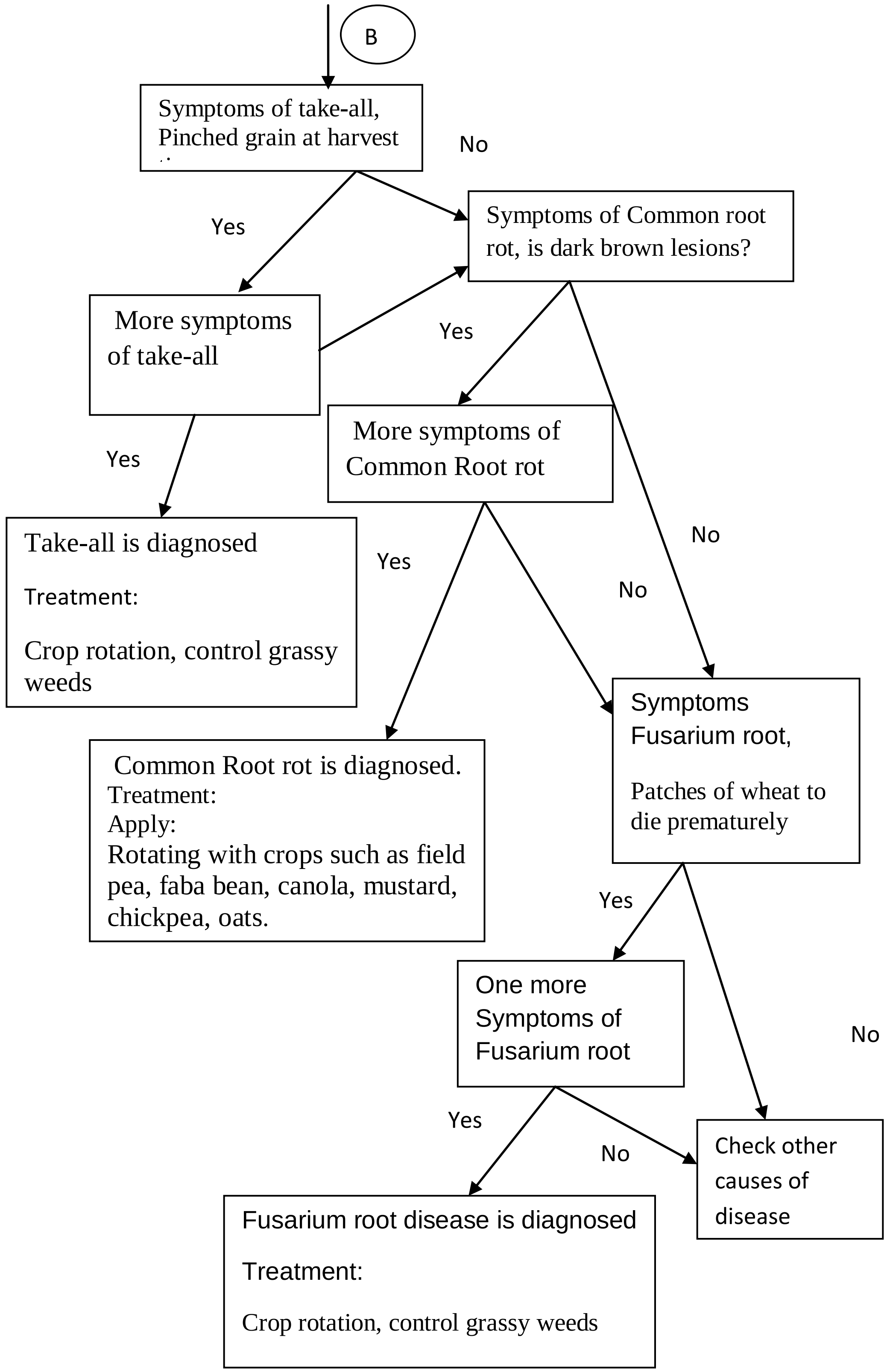

Figure 3.4 Decision Tree for Modeling Wheat Lower Stem and Root Disease Diagnosis

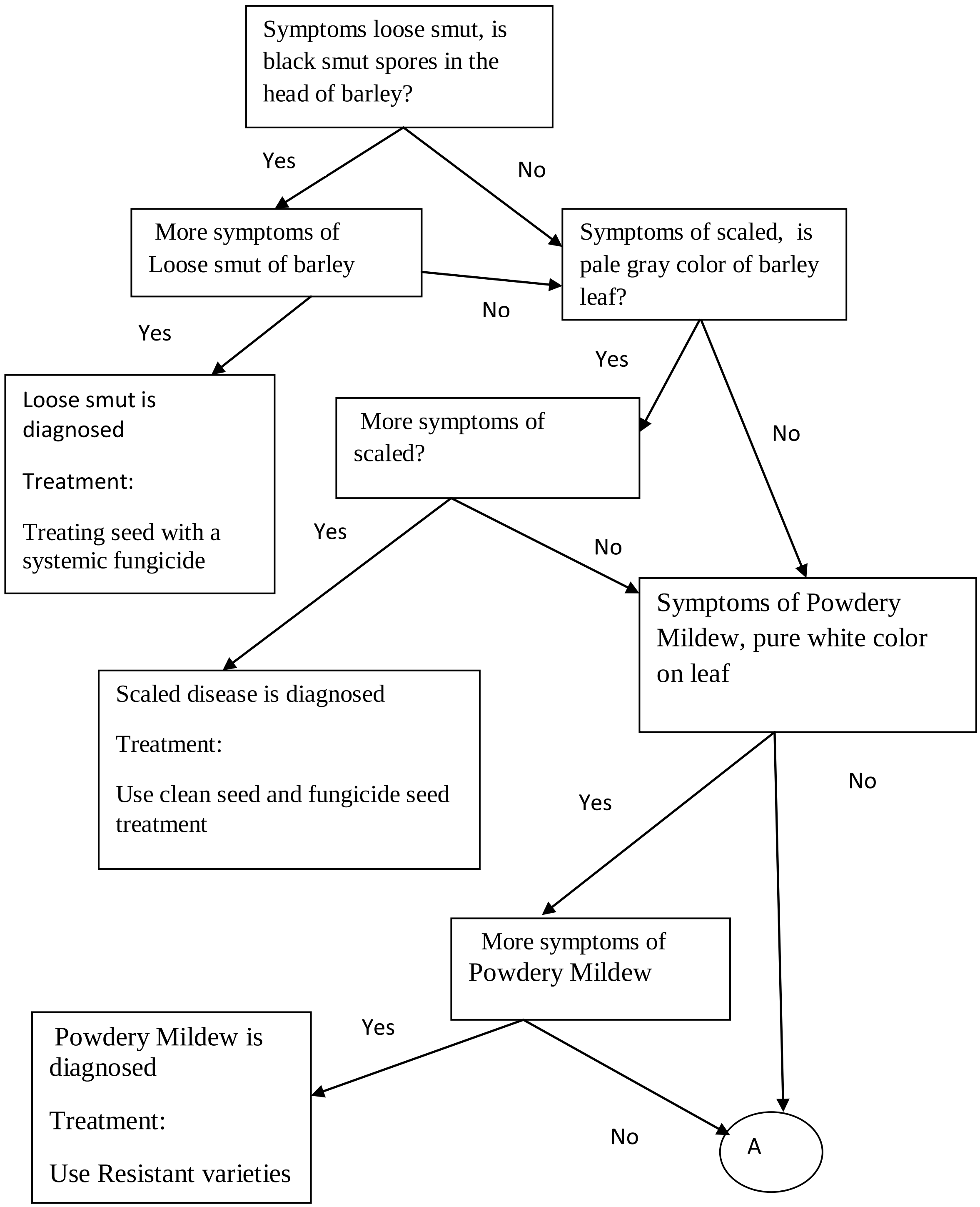

Figure 3.5 Decision Tree for Modeling Barley Head/Grain Disease Diagnosis.

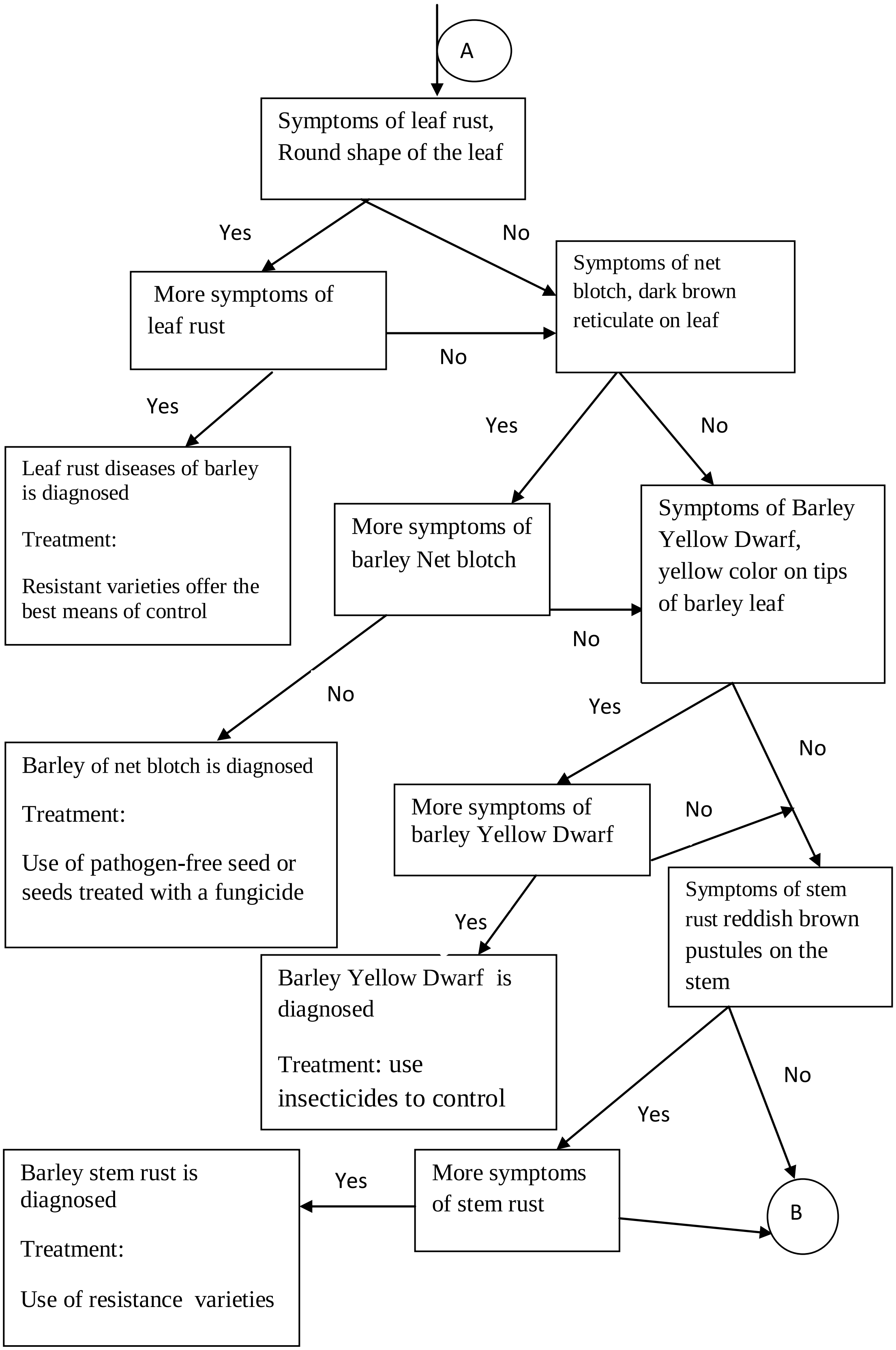

Figure 3.6 Decision Tree for Modeling Barley Crop Leaf Disease Diagnosis.

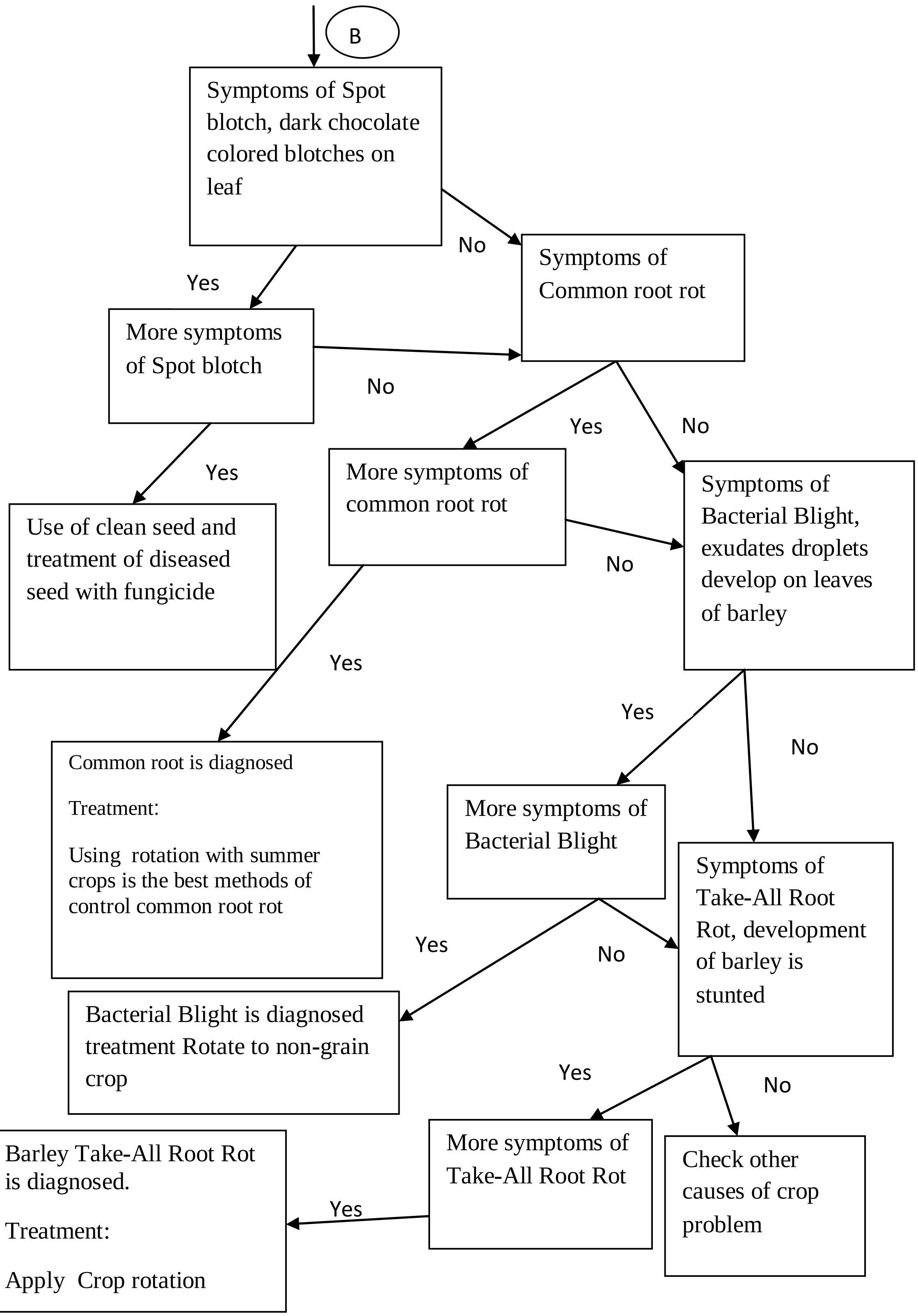

Figure 3.7 Decision Tree for Modeling Barley Crop Root Disease Diagnosis

CHAPTER FOUR

KNOWLEDGE BASED SYSTEM DEVELOPMENT

4.1 Introduction

This chapter discusses knowledge based system development that encompasses knowledge representation and coding process. Knowledge representation is one phase of knowledge based system development. It is the processes of formalizing the identified, structured concepts and facts that are acquired from the domain experts and different secondary sources.

The rule representation in this study involves selection of the types of crop diseases as goals (hypothesis) to be checked and the symptoms of each crop diseases as conditions to make conclusions for the rule to be fired or executed. Based on this representation formalism, the acquired knowledge is expressed in a manner that compatible with a computer representation which is implemented using backward chaining inference mechanism. This represented knowledge is encoded and implemented using appropriate programming tool. To implement cereal crops diagnosis knowledge based system (CCDKBS) in this study, swi prolog programming language has been used. The prototype knowledge based system developed in this research work has five components as indicated below.

4.2 Components of Cereal Crop Diagnosis Knowledge Based System

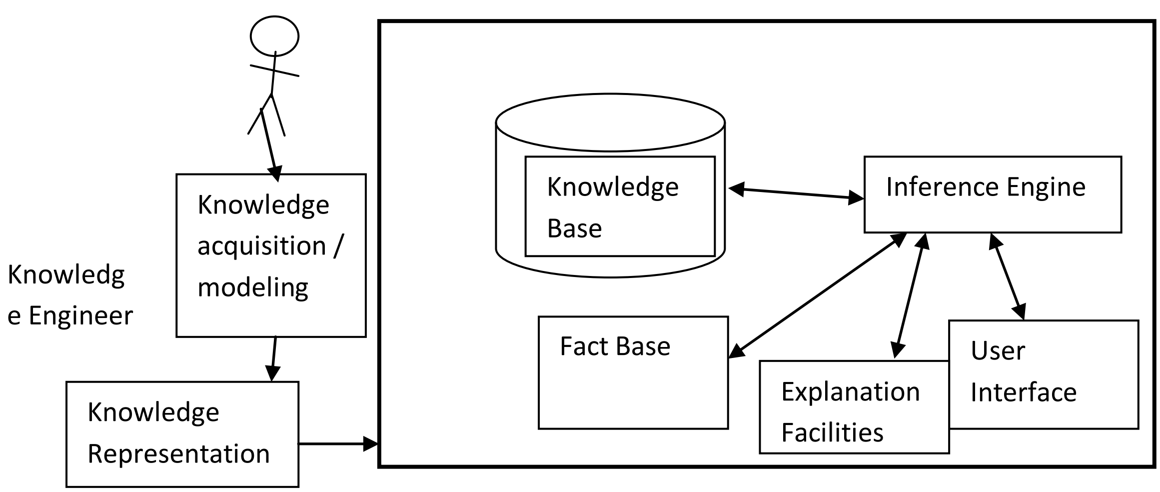

Figure 4.1 Prototype Knowledge Based System Architecture

4.2.1 The Knowledge Base

To implement the CCKBS prototype development, the acquired knowledge is represented using production rules as‘’if–then’’rules since rule based approach is applicable for which the experience and knowledge of human experts is captured in the form of IF-THEN rules and facts.

Similarly, in this study, the rules that contain the type of cereal crop diseases and their major symptoms are formulated in sequences and expression of the form of:

If first_premise ,

Second_premise,

Then conclusion.

If the premises are true, then the actions are executed. When premises are examined by the inference engine, conclusion is executed if the information supplied by the user satisfies the conditions part of the rules. Conditions are expressions involving attributes of major symptoms of cereal crop diseases and logical connective rules. These rules are the bases of knowledge base construction.

Furthermore, rules used in this study are developed based on the knowledge modeled using decision trees which are discussed in chapter three of knowledge modeling. The above rules are the same as prolog rules that work in backward chaining as indicated below:

Conclusion:-

First premise,

Second premise, …

As the result, the knowledge base of this prototype knowledge based system consists of all facts and domain expert knowledge about the descriptions of cereal crop diseases and treatments. It also includes the knowledge represented in the if–then rules in which facts in the conditional parts have the same parameter with the facts bases that are asked for the user to prove whether the disease occur or not.

Even though the above backward chaining reasoning mechanism is implemented in this study, for the convenience of communication the following sample rules are represented using the IF-THEN forms as presented below.

Sample rules for wheat crop diseases diagnosis

Rule1: If black powdery spores replaced the grain of wheat
And dark brown spores in the seed of wheat

And the seed produce a fishy odor

And Cool weather condition.

Then common bunt diseases will be diagnosed.

Rule2: If Light brown lesions on head part of wheat crop

And tan brown lesions of wheat kernel

And white chalky appearance some kernels may have a pink discoloration
And humid weather conditions

Then Fusarium head blight will be diagnosed.

Rule3: If Small, orangish-brown lesions are on leaf of wheat

And blister-like lesions occur on the leaf sheath of wheat

And round, and cause less tearing of the leaf tissue of wheat

And Mild warm temperature (70s-80F^{o})

Then Leaf rust will be diagnosed.

Rule4: If blister-like lesions on leaves of wheat

And the reddish-brown spores of the fungus cause considerable tearing of leaf

And lesions are more elongated on leaf

And moisture for night time dews.

Then Stem rust will be diagnosed

Rule5: If elongated lesions on wheat leaves

And Yellow color observed at margin of wheat leaves

Then Septoria tritici blotch will be diagnosed.

Rule6: If Cottony growth of the fungus on wheat leaves

And Powdery on wheat leaf

And White to light gray patches appear on leaves and stems of wheat

Then Powdery mildew will be diagnosed.

Rule7: If water soaked areas between leaf veins

And these water-soaked areas become tan streaks within a few days

And lesions dry to form a clear, thin film on leaf

And wheat curl mite are observed in the farm area

Then bacterial streak will be diagnosed.

Rule8: If yellow color on tip of affected wheat leaves

And red discoloration on wheat leaves

Then Barley yellow dwarf will be diagnosed.

Rule9: If small, round, blister-like lesions that merges to form stripes

And lesion color is yellow-orange

Then stripe rust will be diagnosed.

Rule10: If elongated lesions on wheat leaves,

And yellow color margin on wheat leaves

And high moisture and high humidity

Then common root rot will be diagnosed.

Rule11: If Development of white heads during the grain filling period

And roots changed from dark brown to black color as of fungal invasion

And Plant can be easily pulled from the soil

And moisture availability in the soil

Then Take-All Root Rot disease will be diagnosed.

Sample rules for Barley Crop Disease diagnosis can be stated as follows:

Rule1: if the head of barley taller and mature earlier than surrounding healthy barley crop,

And Fungus grows rapidly and forms a compact spore mass to replace the cereal head,

And the black powdery spores blow away to leave a bare stalk.

Then smut disease of barley will be diagnosed.

Rule2: If pale gray color of barley leaves

And bluish gray lesion of barley leaves

And the centers of lesion dry out and become bleach

And dark brown color formation on the edge of barley leaves

Then barley scaled will be diagnosed.

Rule3: If pure white, fluffy growth on the surface of the barley leaf

And individual colonies of fungus producing so many spores leaf appears powdery

And premature yellowing and later death of the leaf of barley

And high rains fall and winds

Then Powdery mildew on barley will be diagnosed.

Rule4: If Round, light orange brown pustules on the leaf blade and leaf sheath,

And brown oblong, pustules appear later in the season of cultivation

And Prevalence of moist weather and temperatures

Then leaf rust of barley will be diagnosed.

Rule5: If distinctive dark brown reticulate (netting) pattern on barley leaves

And light brown lesion of barley leaves

Then Net Blotch disease of barley will be diagnosed.

Rule6: If small, circular patches of stunted of barley crops

And yellow color of barley leaves

And reduced grain formation and grain filling of barley

And cool and moist weather that favors an aphid

Then Barley Yellow Dwarf will be diagnosed.

Rule 7: If reddish brown pustules on the stem

And elongated shape of the pustules

And reddish brown pustules become black color

Then barley stem rust will be diagnosed.

Rule8: If Spots develop on leaves and leaf sheaths at all stages of plant development,

And lesions are round to oblong on leaf,

And older lesions are olive colored because of sporeluation of the fungus

And Warm humid weather

Then Spot Blotch will be diagnosed.

Rule9: If dark brown to black discoloration of barley root

And tiller bases and surrounding leaf sheaths brown

And barley has pinched grain at harvest season

Then barley common root rot disease will be diagnosed.

Rule10: If development of white heads during the grain filling period

And roots of affected plants are dark brown to black because of fungal invasion

And barley crop easily pulled from the soil

And cool, moist soil conditions

Then Take-All Root Rot will be diagnosed.

4.2.2 The Inference Engine

The inference engine mimics the human experts' reasoning process. It works from the facts in the working memory (fact base) and the knowledge base to drive (or infer) new facts. It achieves this by searching through knowledge base to find rules whose premises match the facts in the working memory (fact base). This process continues until the inference mechanism is unable to match any premise with the facts in the working memory.

As the result, this developed system uses backward chaining reasoning mechanism. During the reasoning processes, the inference engine starts from the consequents (types of crop disease may attack a cereal crops) and checks the symptoms of the occurrence of this disease to prove the hypothesis (types of disease). If certain antecedents (symptoms) are evaluated as true, then it logically follows the consequents are proved and appropriate description and treatment of the disease provided. As the decision tree models indicate in (chapter three), during cereal crop diagnosis, the real experts first observe the occurrence of crop diseases on leaf, stem, grain using the distinctive features of the symptoms. This leads to identify the causal pathogens characterized by such symptoms and prove if these disorder symptoms due to fungus related diseases such as smut, powdery mildew, net blotch, leaf rust, stem rust or viral diseases such as barley yellow dwarf, wheat streak mosaic. Likewise, this prototype knowledge based system follows the procedures that the experts apply during diagnosing of the affected crops.

The rule which used to check common bunt disease of wheat crop can be represented in swi prolog as indicated below

Rule1 wheat('Common bunt'):-

does_wheat_grain_have_gray_color,

does_seed_have_fishy_odor,

black_powdery_appearance_in_wheat_seeds,

is_the_temperature_cool.

In prolog rule (**R1**) the type of crop disease common bunt is a hypothesis and the symptoms wheat grain has gray color, seed has fishy odor, the appearance of black powdery spores in wheat seed are antecedents favored by cool temperature which help to prove whether common bunt attacks wheat grain.

From the above rule, common bunt attacks wheat crop if the four conditions wheat grain has gray color, seed has fishy odor, black powdery spores observed on wheat grain and cool temperature are checked against the facts responded by the users. If these conditions are matched (become true) with the facts supplied by the user as yes response, then inference engine makes a conclusion by matching the knowledge base that contains domain knowledge used to solve problems. As the result, the following descriptions and treatments are searched from the knowledge base stored for a particular rule executed and displayed for users. These descriptions and treatments are collection of facts and practical knowledge extracted from domain experts and manual and stored in the knowledge base to be displayed for users when the rules are fired. The following are sample knowledge base rules that are displayed for the user when the rules are fired and the inference mechanism reaches its conclusion.

description('Common bunt'):-

write('common bunt infects Wheat kernels and recognized by a gray green color'),nl,

write(kernel is wider than healthy kernel'),nl,

write('it produces large mass spore in the grain instead of seed'),nl,nl.

treatment('Common bunt'):-

write('1.controlable.'),nl,

write('2.use fungicide seed treatment.'),nl,

write('3.use disease-free seed source.'),nl.

If the hypothesis in Rule1: is not proved, the system traces to prove the next rule that whether wheat Fusarium head blight attacks the grain of the wheat. In this way, all rules will be checked sequentially and proved the hypothesis by matching the symptom in the knowledge base against the fact base asked by the system.

Rule2: wheat('wheat Fusarium head blight'):-

pink_discoloration_of_wheat_heads,

brown_lesions_of_wheat_kernels,

wheat_seeds_produce_fishy_odor,

Humid_weather_occurs.

In the same way if these conditions are satisfied, rule2 is fired. Then the description of the disease is searched and displayed from the knowledge base based on the relationships the rules represented with the same rule 'Fusarium head blight' in knowledge base contains facts matched with the condition part of the rules.

As indicated below, the description and treatment are displayed for users if Fusarium head blight is proved based on the users' response for asked questions by the system from the fact base.

description('Fusarium head blight'):-

write(' Fusarium is a residue-borne disease, overwintering on crop residue'),nl,

write(' such as wheat residue as well as'),nl,

write(' corn fodder and other plant material'),nl,nl.

treatment('Fusarium head blight'):-

write('1.Avoid the most susceptible variety'),nl,

write('2.planting into corn residue'),nl,

write('3.use foliar fungicide'),nl.

4.2.3 The Fact Base

The fact base of the prototype knowledge based system holds basic facts focusing on types of cereal crop diseases. Functionally, the fact base is used to match against the ‘’if (condition) part of the rules in knowledge base. It holds the information to the asked questions and the questions to be asked to find the occurrence of cereal crop disease.

Furthermore, the facts first matched with the cases represented in if-then form specifically the condition part (premises) of the rules. Then if the facts are proved to be true, the inference engine relates the same rule represented in the knowledge base. Then appropriate knowledge is searched and displayed for the users.

4.2.4 The User Interface

In this knowledge based system, the users interact with the system by which the system asks the user a series of questions and the user responds by saying “yes” or “no” based on the users question, the system provides conclusions for the user request by communicating through the user interface.

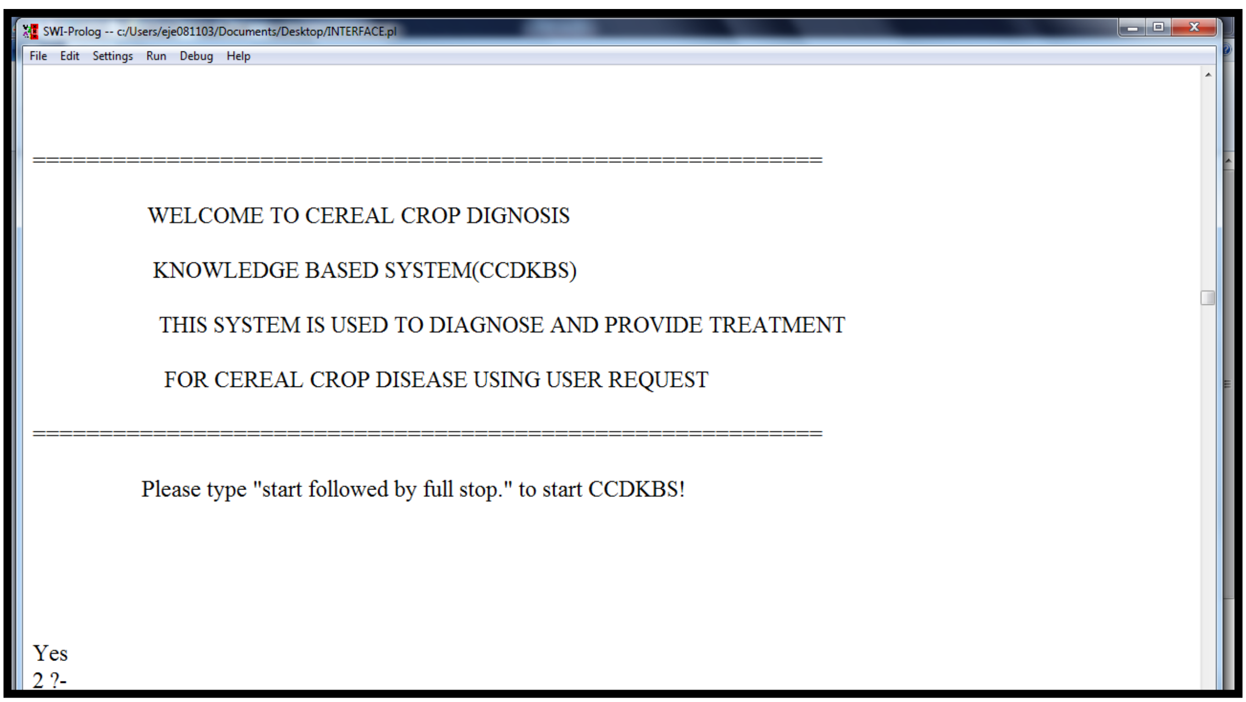

Figure 4.2 A Welcoming Dialog Window of CCDKBS User Interface.

After the welcoming window of CCDKBS user interface is displayed, the user interface allows the users to interact with the system by starting the system as indicated in Figure 4.3 below. The user can start the system by typing start and putting full stop at the end.

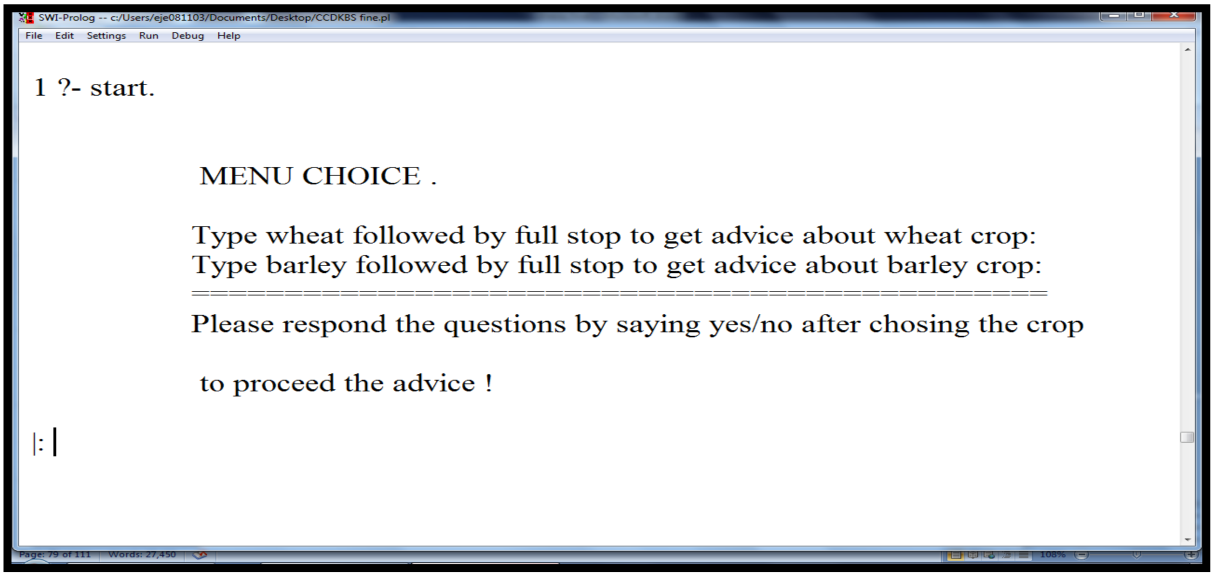

Figure 4.3 Menu Option Dialog Window of Cereal Crop Diagnosis.

After starting the system, the user can choose wheat or barley based on his/her needs to get advice about their crop problems as shown in Figure 4.4 below.

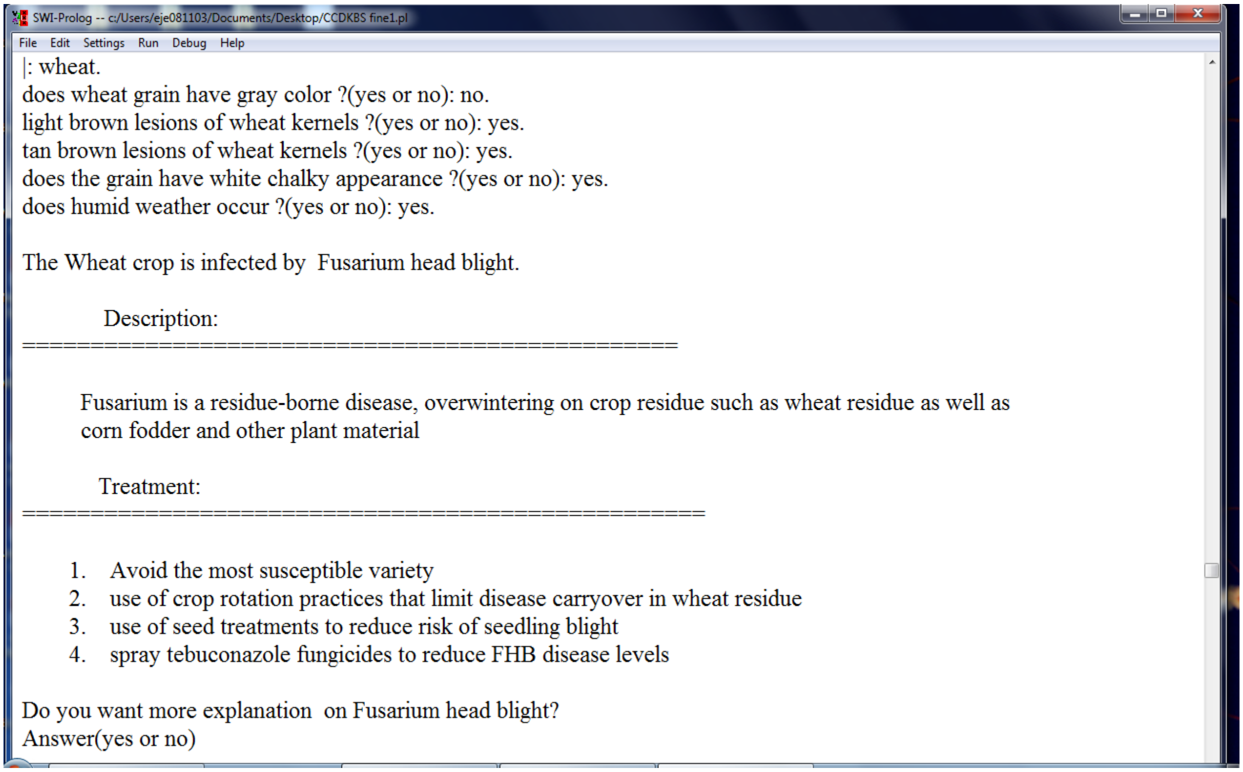

Figure 4.4 Sample Dialog Window When Fusarium Head Blight of Wheat Crop Disease is Diagosed.

When the users choose either wheat or barley, the system asks the users the symptoms of disease about the selected crop to diagnose each type of disease. For example, in Figure 4.4, the user chooses wheat to get advice about wheat crop disease, the system asks the user a series of questions and the user responds by saying “yes” or “no”. In this case the system asks the symptoms of the first disease to prove as the first goal (hypothesis), if the first symptoms is not observed on wheat crop and the user response is no, the system traces to next rule to ask the symptom the goal (hypothesis) of the second rule for checking to reach a decision sequentially. Since the users responded as yes for the first premise, the system continues to check all premises of the second rule to prove whether Fusarium Head Blight infects the grain of wheat. Since all conditions are satisfied as the user response yes for all premises of the second rule, and then the system proves that Fusarium head blight infects the wheat grain. As the result Fusarium head blight is diagnosed and appropriate description and treatment are searched and provided as the system reaches its conclusions by proofing Fusarium head blight disease since all conditions are satisfied.

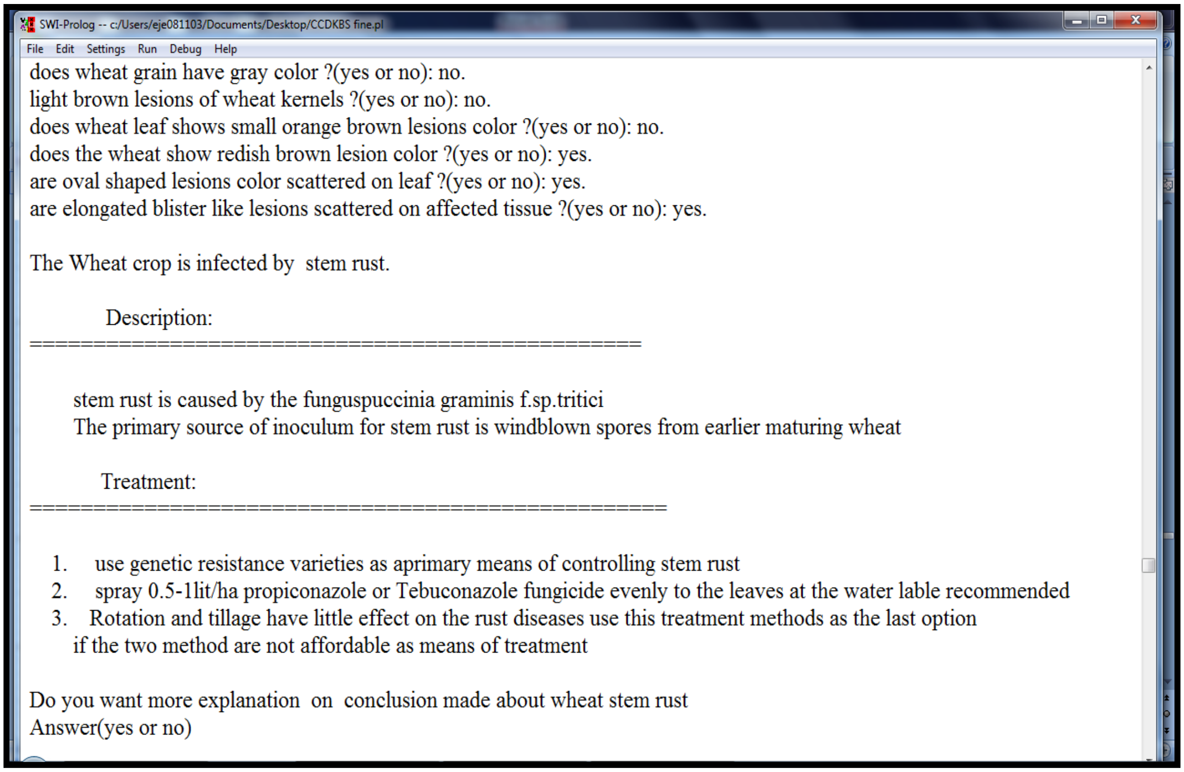

Figure 4.5 Sample Dialogue Window When Wheat leaf Rust is Diagnosed

If the user gets all advices concerning wheat crop, he/she can terminate the system by responding 'no' for the questions asked by the system as do you want to continue? As indicated in figure 4.6 below.

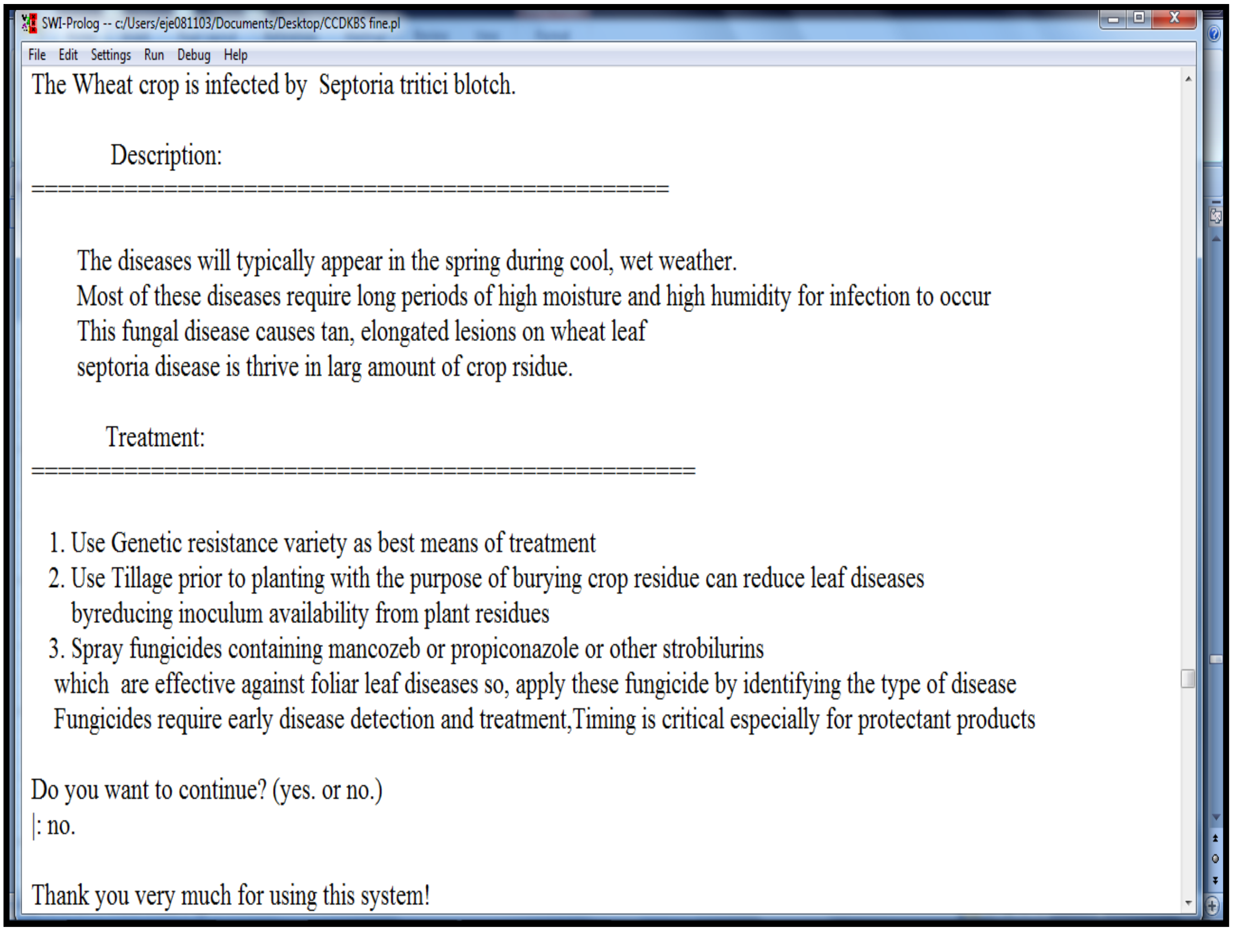

Figure 4.6 Sample Dialog Windows When the User Finishes the Consultation Service about wheat crop diagnosis.

As indicated in figure 4.2 of menu choice, the prototype knowledge based system covers barley and wheat crops. The user can choose one of the crops at time from MENU CHOICE to continue the advice. So, if the user is interested to get the advice about barley crop, he/she can proceed by choosing barley crop. Figure 4.7 below indicates when barley leaf rust is diagnosed.

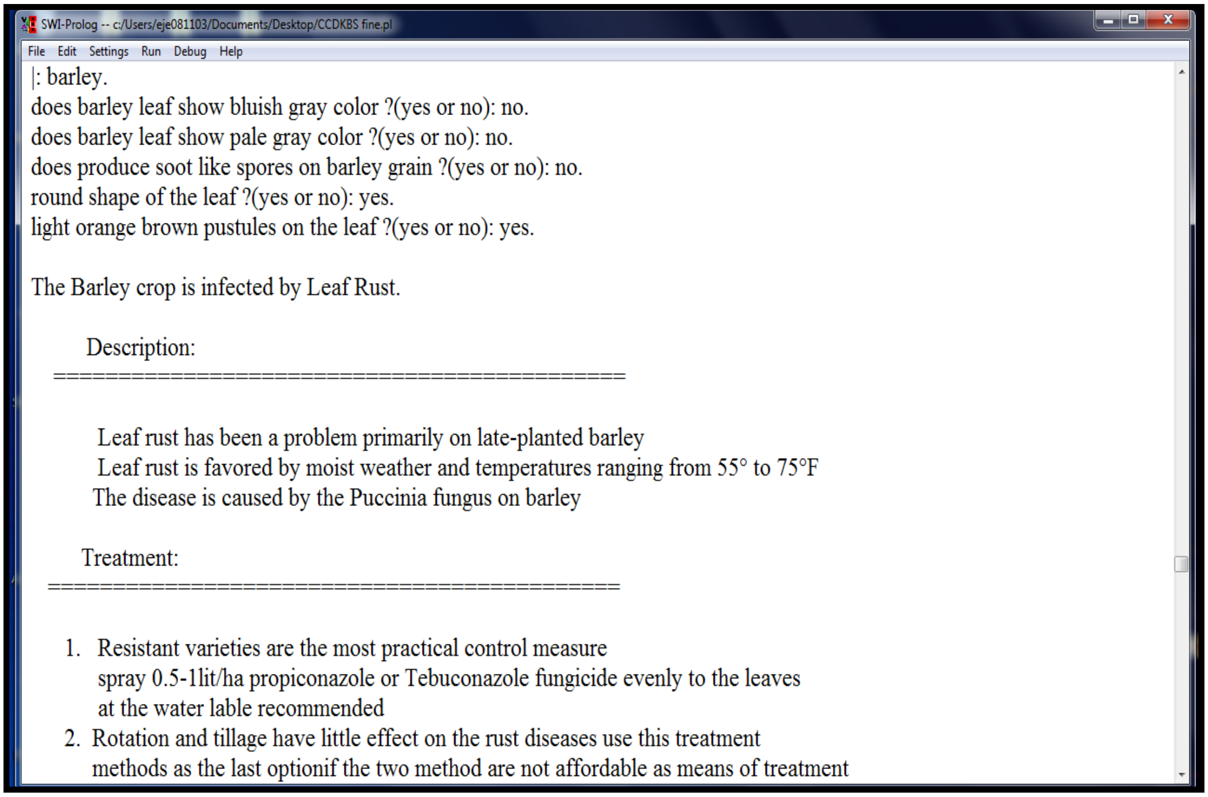

Figure 4.7 Sample Dialog Windows When Barley Leaf Rust is Diagnosed.

As Figure 4.7 above indicates, barley leaf rust has been diagnosed, if the conditions are satisfied. If the user is interested to get advice about the problem of their barley crop caused by other diseases which are incorporated in this knowledge based system, he/she can proceed by responding the questions asked by the system as indicted in figure 4.8 below.

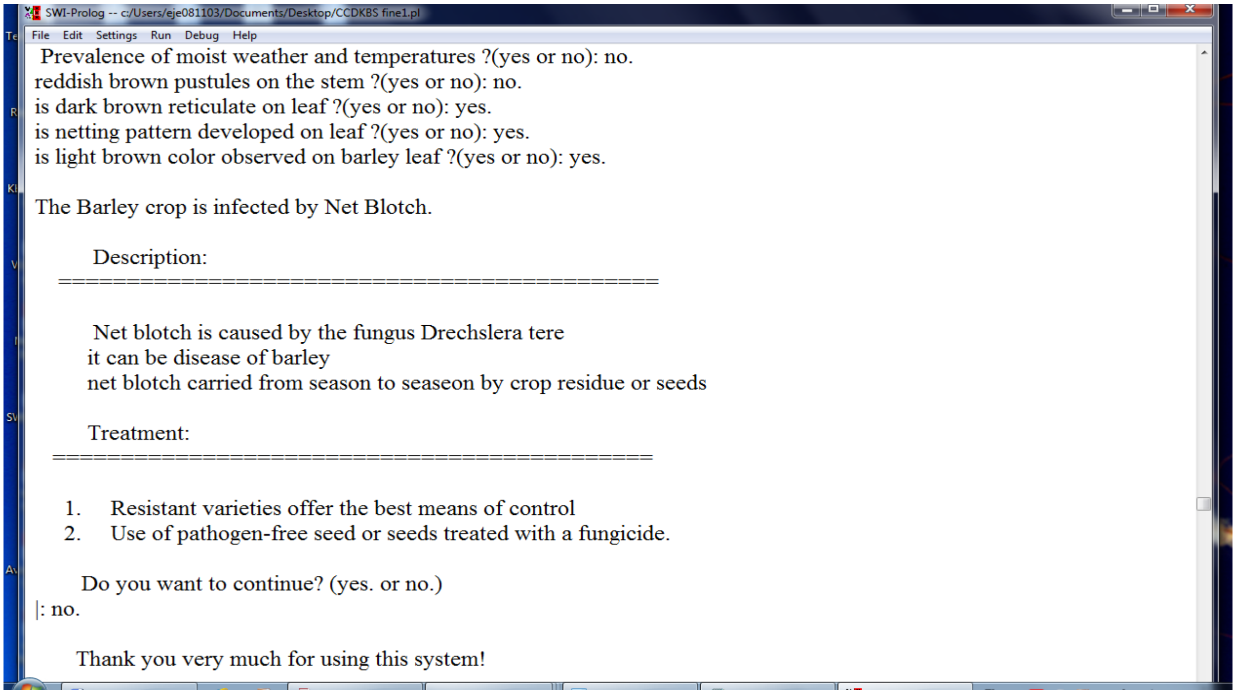

Figure 4.8 Sample Dialogue Window When Barley Net Blotch is Diagnosed

After deciding the description and treatment of barley net blotch by checking all cases of symptoms of net blotch, the system asks user as Do you want to continue? The user can continue the consultation concerning other barley crop disease by responding ‘yes’ for the questions asked by the system. If not interested or finished his\her consultation, the user would terminate the system by responding ‘no’ and the system reply the confirmation message ‘Thank you very much for using this system’ for users termination of consultation as indicated in Figure 4.8 above.

4.2.5 The Explanation Module

In this prototype knowledge based system, the explanation facility is added to give detail explanation about the disease diagnosed, description and treatment decided by the system. After the system deciding the type of disease (stem rust) affecting the wheat crop and the treatments undertaken to control as indicated in Figure 4.9 below, the system asks the user as Do you need more explanation about the decision made about stem rust disease? And explains how stem rust is occurred and the contributing factors for the out break of this disease as presented in Figure 4.9 below.

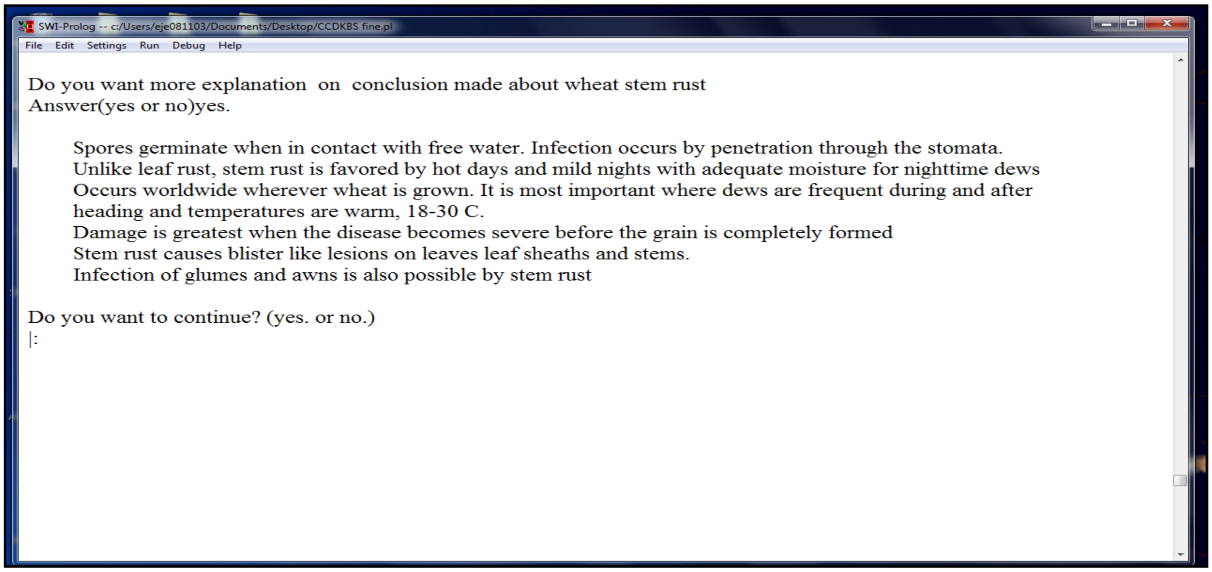

Figure 4.9 Sample Dialog Window When More Explanations Is Provided About Wheat Crop Stem Disease.

Similarly, the system can add an explanation for barley crop disease after identifying the possible disease based on the users' request. Figure 4.10 indicates when the system gives more explanation for the identified barley disease.

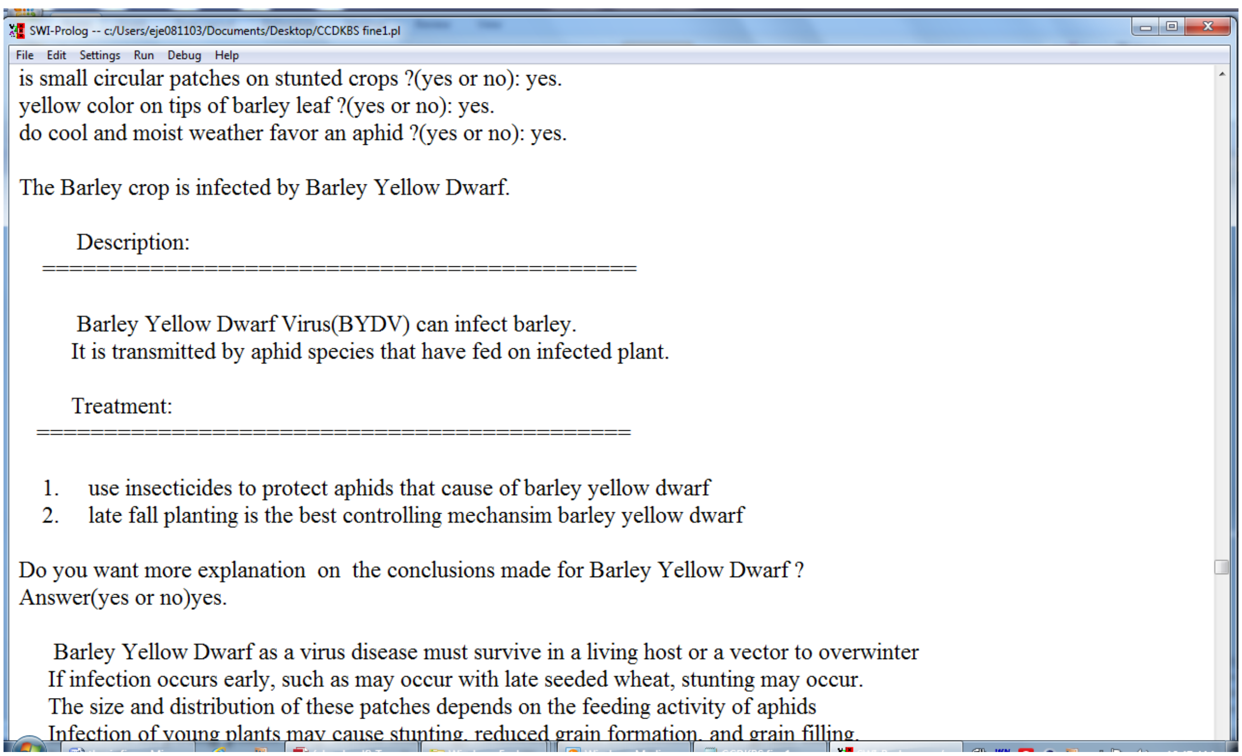

Figure 4.10 Sample Dialog Window When More Explanation Is Provided About Barley Yellow Dwarf Disease

CHAPTER FIVE

5.1 CCDKBS PROTOTYPE EVALUATION

Evaluation of the prototype knowledge based system is an important phase that helps to measure the performance of the developed system. In this study, CCDKBS is evaluated to recognize accuracy and efficiency of description and treatments provided by the system in diagnosing cereal crop diseases. It also helps to check whether the objective of this research work is achieved. More importantly, evaluation is carried out to determine users' acceptance and applicability of the prototype knowledge based system in the domain area.

Therefore, CCDKBS prototype of this research work is evaluated using visual interaction evaluation method to measure its reasoning and the descriptions and treatments decided by the system during diagnosing cereal crop diseases.

5.2 CCDKBS Evaluation Using Visual Interaction

Knowledge based System evaluation using visual interaction is used to ascertain how domain experts interact with developed system. This evaluation method allows expert to make comments while interacting the system (Anumba and Scott, 2001). It also helps to ensure the performance of the prototype by assessing the feedback of the experts towards the developed system and altering the parameter as desired.

To evaluate crop diagnosing knowledge based system (CCDKBS) in this study, six domain experts four (4) from Kulumsa Agriculture research center and two (2) from Adama University Assela School of Agriculture plant science department were selected as system evaluators. The experts were selected purposively, who are researchers on cereal crops from Kulumsa Agriculture Research Center and crop specialist from Adama University Asella School of Agriculture academic staff. Before starting the evaluation, the researcher explained the objective of the developed system and how the system interacts with the users. This explanation helps the evaluator get full understanding how they consult the system in getting advice.

Then after, the domain experts were allowed to interact with the system by running number of cases having similar parameter with the facts incorporated in the knowledge base. After the consultation of the system, to assess the user acceptance of the prototype knowledge based system, questionnaires were distributed. Using these questionnaires, domain experts' feedback towards this developed system was gathered for analysis.

The type of questionnaires distributed for feedback collection from the evaluators were closed ended and open ended questionnaires focusing on easiness, attractiveness, time efficiency, accuracy of Cereal Crop Diagnosis Knowledge Based System (CCDKBS). The questionnaires also focused on the applicability of the system in diagnosing cereal crop disease, problem solving ability and the significance of the system in the domain area.

The format of the questionnaire was adapted from Seblewongele (2011), which used to evaluate to anxiety diagnosis prototype knowledge based system and Anumbam and Scott (2001) performance evaluation of knowledge based System for subsidence management. The adapted questionnaires were modified in the context of crop diagnosing knowledge based system (CCDKBS).

The evaluators were allowed to rate the options as excellent, very good, good, fair, and poor for these closed ended questions. Therefore, for easiness of analyzing the relative performance of the prototype based on the user evaluation after the interaction with the system, the researcher assigned numeric value for each of the options given in words. The values are given as **Excellent** = 5, **Very good** = 4, **Good** = 3, **Fair** = 2, and **Poor** = 1. The Table below indicates the feedbacks obtained from the domain experts (evaluators) on systems interaction as calculated based on the given scales.

No	Questions	1	2	3	4	5	Average	%age
1	Is the prototype is easy to use and interact with it?	0	0	1	4	1	4.0	80%
2	How do you rate CCDKBS attractiveness?	0	0	0	5	1	4.2	84%
3	Is the system is more efficient in time?	0	0	1	1	4	4.5	90%
4	How accurately does a system reach a decision in diagnosing cereal crop disease?	0	0	1	5	0	3.8	76%
5	Does the system incorporate sufficient and practical knowledge?	0	0	2	4	0	3.6	72%
6	Does the system give right description and treatment for identified cereal crop disease?	0	0	2	2	2	4.0	80%
7	How do you rate the significance of the system in the domain area?	0	0	0	5	1	4.2	84%
		Total average					**4.04**	**80.9 %**

Table 5.1 CCDKBS Performance Evaluation Through Visual Interaction

As Table 5.1 indicates, 16.7% of the respondents reply easiness to use and to interact with the prototype as good and the same number of the respondent also rated that easiness to use and to interact with the prototype as excellent. But the highest number (66.7%) rated easiness to use and to interact with the prototype as very good. In case of attractiveness of the prototype 83.3% the respondents reply the prototype as very good and the remaining 16.7% evaluated the attractiveness of prototype as good. In case of time efficiency the same number of evaluators (16.7%) rated as good as well as very good and the remaining 66.7% rated as excellent. Additionally, 16.7% of the respondents evaluate the prototype as good and 83.3% as very good at deciding accurate description and treatment during diagnosing cereal crops disease. In the same way for criteria of the prototype incorporating sufficient knowledge, 33.3% the evaluator rated as good and the remaining 66.7% evaluated as very good. Similarly, in terms of the prototype providing right description and treatments for the diagnosed disease, 33.3% respondents evaluated as good, very good and excellent. Finally, concerning the significance the cereal crop diagnosis prototype knowledge based system, 83.3% of the evaluators responded as very good and 16.7 responded as excellent.

In addition to the closed ended questions, the evaluators were provided with open ended questions to forward their suggestions and opinions. These questions focusing on how the CCDKBS is differ from the human experts/pathologist in diagnosing cereal crop disease, what issues the CCDKBS covers during the diagnosis process. The contribution, strength and limitation of CCDKBS in solving problems in the domain areas is an other area of concern for the evaluation process of this prototype knowledge based system.

For the first open ended questions, the evaluators responded that the CCDKBS can solve problems based on the stored knowledge in knowledge base in time and cost wise but the human expert/crop pathologist use field manuals and laboratory examination which may take time and delay of timely decisions. For the second question what issues covered by CCDKBS, the evaluators responded that CCDKBS covers the tasks of diagnosing crop disease including providing of description and treatments of diagnosed crop disease. The evaluators point out the uncovered issues by CCDKBS. It is better if the image of disease and the image of the diseased crop are incorporated in the knowledge base for visual interaction and easy understanding the damage level of the affected crop.

The next open ended questions asked for the evaluators was that, do you believe that can a knowledge based system (prototype CCDKBS) handle cereal crop disease diagnosing tasks? The evaluators responded ‘yes’ and some of the respondents stated that it can diagnosis in a better way with time and cost efficiency.

The other open ended question asked to the evaluators was that, can CCDKBS contribute in diagnosing and treatment of cereal crops by assisting agriculture experts and development agent (DA) workers in the domain area? The evaluator responded that this system exactly contribute a lot, specially for those less experienced experts and development agent (DA) workers in giving timely decisions in the area thy have been working. It can be used as a training tool in the areas where shortage of skilled experts is available.

Lastly, the evaluators suggest the strength and the limitation of the prototype as they evaluate from its performance during the visual interaction with the system:

- ➢ The absence of image of the affected crops to visualize the severity of the infestation levels of the affected crops. They suggested incorporating high quality pictures which depict the earliest symptoms in order to perform early diagnosis and to identify the damage level of diseased crops that helps to know the severity of the infestation and its economic threshold is important.
- ➢ Users who lack computer skills and access might not implement it, especially those who have no computer access.
- ➢ The system interacts with the user using yes and no, the users want to interact with other query form rather than yes or no which limit flexibility.

The evaluators confirm some the strength of the system and its applicability in the domain area as:

- ➢ This kind of prototype knowledge based system helps to solve problems in the areas where experienced and skilled Agriculture experts are unavailable.
- ➢ The system is very helpful to solve problems timely with accumulated knowledge by avoiding laboratory experiments which takes time and can not give immediate solutions for the outbreak of crop disease in remote areas.
- ➢ The system can reduce the existed knowledge gap observed in remote areas where skilled agricultural professionals are not available. By being a sharing and training tool for development agent (DA) workers, it can improve the skill of development agent (DA) workers in cereal crop disease identification and decision making at farmers hand.

5.3 Discussions

The response from domain experts, who interacted with the system, is that the system is applicable and promising. Based on the feedback obtained from domain experts during visual interaction with the system and closed ended question, none of the evaluators responded the system as poor and fair. As Table 5.3 reveals that, the total average performance the prototype from the domain experts evaluation is 4.04 out of the six selected domain experts on the scale 5 = excellent, 4 = very good, 3 = good, 2 = fair, 1 = poor. Therefore, the total average performance of the prototype is found to be 80.9%. Table 5.2 indicates number of responses obtained for each of options that the respondents rate to evaluate the prototype.

Evaluators who respond as	Total number of response for each option of all seven questions	%age
Poor(1)	0	0
Fair (2)	0	0
Good (3)	7	16.7%
Very good (4)	26	61.9%
Excellent (5)	9	21.4%
Total average	**4.04**	**80.9%**

Table 5.2 Users' Feedback on Closed Ended Questionnaires

As shown in the above (Table 5.3), based on closed ended questions as evaluation criteria, the domain experts reply the prototype as very good twenty six times (61.9%). The experts also respond the prototype as excellent nine times (21.4%). The least response is good seven times (16.7%) regarding the prototype on its easiness, incorporation of sufficient knowledge.

In addition to the closed ended questions, the evaluators forwarded important feedbacks and comments to cereal crop diagnosis knowledge based system (CCDKBS) on open ended questionnaires. The evaluators stated that this prototype knowledge based system is helpful as it saves time, easily accessible and cost efficient in solving agriculture problems as most of our society are agrarian. This advisory system will improve the productivity of farmers by assisting crop experts who advise farmers on their daily needs.

Similarly, the respondents affirm that this kind of system can reduce existed knowledge gap in agriculture domain in such a way that most of development agent (DA) workers at woreda level are less qualified to diagnose and treat when cereal crop infestation is occurred. Therefore, by consulting and accessing experienced experts knowledge which is stored as facts and rules in this knowledge based system, development agents can assist and advice farmers about their cereal crop problems caused by diseases.

And the system is important to exploit and share experiences and rare skills of agricultural researcher which is stored in this system as rules and facts.

Generally, this prototype has got very good acceptance by domain experts in diagnosing crop disease including providing of description and treatments of diagnosed disease. With time efficiency and cost effectiveness, this prototype CCDKBS has great value in diagnosing and providing description as well as treatments from knowledge base stored as rules and facts of crop disease and their major symptoms when crop infestation is occurred in the areas it can be implemented.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

In terms of caloric intake, cereals dominate the diets of Ethiopian households. However, cereal production in Ethiopia is constrained by several factors. Diseases are the major contributing factors to the low yield, in addition to low yielding varieties, poor cultural practices, and lack of fertilizer.

To reduce yield losses caused by diseases, cereal crop diagnosing knowledge based has been developed which diagnoses infected crops and provides treatment solution. To develop the knowledge based system, the knowledge was acquired from domain experts and documented sources through interview and document analysis respectively.

The acquired knowledge focuses on concepts and facts of cereal crop diseases caused by fungus, bacteria and virus. These extracted facts and concepts were modeled using decision tree and the model has been converted into if–then rules of knowledge representation. To diagnose and recommend the treatments of possible crop disease, the system uses backward chaining inference mechanism. The inference engine first identifies the type of disease and checks the major symptoms of the possible crop disease to prove whether the identified crop disease infects the crops.

To assess its performance and users acceptance in the domain area, the CCKBS was evaluated using users' feed back through visual interaction method. After the users were exposed to interact with system, their opinion and suggestions were gathered.

Furthermore, this Prototype knowledge based system developed and tested in this research work is an important tool in timely crop protection as well as advising agriculture experts. Such system can be really useful in rural areas where a shortage of agricultural expert is available who works in closer to the farmers.

The significance of the system is also highly appreciated by domain experts in assisting agriculture experts' and development agents in areas skilled experts are not accessible. By being a sharing and training tool for development agent (DA) workers, the proposed system can improve the skill of development agent (DA) workers in cereal crop disease identification and decision making at farmers hand. By replicating this CCDKBS, it can reduce the existed knowledge gap observed in remote areas where transferring skilled experts is difficult.

The idea behind developing knowledge based system is that, it can enable many people to benefit from the knowledge of one expert in domain specific problems. So, Cereal Crop Diagnosing Knowledge Based System developed in this research is applicable and promising to apply the judgment and experiences of domain experts in diagnosing the infected crop and providing the descriptions and treatments of such crop diseases.

6.2 Recommendations

Based on the findings of the study, the following recommendations are suggested for further study on the applicability of knowledge based system in Agriculture.

- In this research, rule based knowledge based system has been developed and tested is found to be applicable for cereal crop diseases diagnosis and treatment caused by fungus, bacteria and virus. So, this rule based system should be expanded to incorporate other causes of cereal crops diseases such as pest related diseases and nutrient deficiency problems.
- The rule based knowledge based system developed in this research work reasons to diagnose cereal crop diseases based on represented fact and rules extracted from the domain expert. In the future, case-based reasoning should be conducted to incorporate high quality images of the infected crops to analyze and illustrate the percentages of infestation and the economic threshold of the infected crops using the colored photos of infected cereal crops.

- As this rule based knowledge base system is not self learning, in the future learning component should be integrated that reasons and remembers when new circumstances and unknown facts are asked by users to suggest soloutions.

- During the discussion with domain experts in interview phase of this study, domain experts noted that the outbreak of rust diseases that have devastating impact on cereal crops production in Ethiopian highlands is difficult to predicate in season, weather condition, types of seeds used and host plants. Therefore, in future data mining should be conducted to predict the determinants and pattern of the outbreak of such rust diseases to take appropriate protection for such diseases before occurrence.

REFERENCES

Abdallah, K., Mohamed , T., and Louis, F.(2005). Knowledge-Based Approach and System for Process of School/University Orientation: World Academy of Science Engineering and Technology.

Abdullah M.S., Benest, I. Evans, A. and Kimble, C.(2002). *Knowledge Modeling Techniques for Developing Knowledge Management Systems*, 3rd European Conference on Knowledge Management, Dublin, Ireland, ISBN:0-9540488-6-5, pp. 15-25.

Abraham, A Peter H. Sydenham and Richard T.(eds) (2005). Rule-based Expert Systems: Handbook of Measuring System Design. John Wiley & Sons, Ltd. ISBN: 0-470-021438.USA, pp909-919.

Abrham Tadesse (2004). Survey on farmers participation in agriculture technology transfer Ethiopian Agriculture Research Organization, Ethiopia.

Abu-Naser, S.S. Kashkash, K.A. and Fayyad, M. (2008). Developing an Expert System for Plant Disease Diagnosis. *Journal of Artificial Intelligence, 1: 78-85.*

Ahmad T. Al-Taani(2009). Expert system, Yarmouk University, retrieved October2011, from http://www.yu.edu.jo/AltaaniA.

Amanuel Gorfu(2003), Analysis of long term constraints to wheat production in Ethiopia, Kulumsa Agriculture Research Center, Ethiopia .

Andreae, P. and Plimmer, P. (1993). *Process Representation for Diagnosis of Crop Diseases:* Technical Report.Victoria University of Wellington, New Zealand.

Anumba, C J. and Scott, D. (2001). Performance Evaluation of Knowledge Based System for Subsidence Management: Structural survey. MCB University Press,volume 19, number5, pp222-232 ISSN 0263-080x.

Avram, G. (2005). Empirical Study on Knowledge Based Systems: *The Electronic Journal of Information Systems Evaluation*, Vol. 8, pp 11-20, ISSN: 1566-6379, available online at www.ejise.com, [accessed 23 January].

Bachman, Bruce, G., Smith, R. (1988). Fundamentals of Expert Systems, *Annual Review of Computer Science*: Vol. 3, ISBN:0-8243-3203-2 1988, Palo Alto, CA, USA.

Bayehe Mulatu and Stefania Grando (2011). Barley Research and Development in Ethiopia. International center for Agriculture research in the dry areas.

Beintema, M. and Menelik Solomon (2003). Agricultural Science and Technology Indicators: *A countries Brief Review.* International Food Policy Research Institute.

Bekabil Fufa, Befekadu Behute, Simons , R. and Tareke Berhe (2011). Strengthening the Tef Value Chain in Ethiopia. Ethiopian Agriculture Transformation agency.

Bethlehem Asferi (2010). Exploring Pest Management Practices and Development of Knowledge Base System for Pepper Disease Diagnosis: unpublished Master thesis Addis Ababa University, Ethiopia.

Bethune, D., Kelly, T., Liversidge, T. (2007). Scholar Study Guide Higher Information System: Expert Systems. Heriot-Watt University, United Kingdom.

Bullinaria, J. (2006). *Proceedings of the International Joint Conference on Neural Networks*, part of the IEEE World Congress on Computational Intelligence, IJCNN, Vancouver, BC Canada, 16-21 July 2006.

Burrows M., Olmstead, J. and Grey, W. (2009). Fungal, Bacterial, and Physiological Leaf Diseases of Cereal Crops (wheat, durum, barley**)**.Montana State University Extension, Bozeman, US.

CALU Factsheet (2009). Major Pests, Diseases and Weeds of Cereal Crops: retrieved October2011, from http://www.pesticides.gov.uk/.

Carlson, M.P. and Ensley, S.M. (2003). Understanding Fungal (Mold) Toxins (Mycotoxins). The board of Regent of the University Neberska on behalf of Neberaska-Lincoln Extension.

Chamberlin, J. and and Schmidt, E. (2011). Ethiopian Agriculture: A Dynamic Geographic Perspective. Development Strategy and Governance Division, International Food Policy Research Institute. Ethiopia Strategy Support Program II, Ethiopia.

Chee-Fai Tan (2008). A Prototype of Knowledge-Based System for Fault Diagnosis in Automatic Wire Bonding Machine, Tubitak, Melaka-MALAYSIA.

Cooke, N.M. (1989). The elicitation of domain-related ideas: Stage one of the knowledge Acquisition process. In C. Ellis (Ed.), Expert Knowledge and Explanation. Ellis Horwood Limited, England

Crowley, L (2011). Intelligent Systems: Reasoning and Recognition retrieved from prima.imag.fr/jlc/Courses/2011/ENSI2.SIRR/ENSI2.SIRR.S1.pdf.

Daniel J. Collins (1995). Diseases of Barley, Rye, and Triticale in Alabama, Alabama Cooperative Extension System.

De Wolf, E. (2003). Fusarium Head Blight: Field crop disease facts. The Pennsylvania State University.

Demese Chanyalew, Berhanu Adenew and Mellor, J. (2010). *Ethiopia's agricultural sector policy and investment framework (PIF) draft final report*. Ministry of Agriculture and Rural Development.

Duveiller E. Singh. RP, Nicol J. (2006).The Challenges of Maintaining Wheat Productivity: Pests, Diseases and Potential Epidemics. Global Wheat Program, CIMMYT, Mexico.

El-Helly, M., Rafea, A., El-Gamal, S. and Abd El Whab, R. (2004). Integrating Diagnostic expert system with image processing via loosely coupled Technique, Cairo University Agriculture Research.

Faber, P. and San Martín, A. (2010). Conceptual Modeling in Specialized Knowledge Resources. *International Journal "Information Technologies and Knowledge",* Vol. 4, Number 2, available at: http://ecolexicon.ugr.es/.

Gaines , B. R. and Shaw M. L. G. (1992). Eliciting Knowledge and transferring it effectively to a Knowledge-Based System. Knowledge Science Institute University of Calgary Alberta, Canada

Gorden ,J. (2000). Creating knowledge maps by exploiting dependent relationships: Knowledge based systems, Elsevier Science publisher. vol. 13 pages 71-79.

Grando, S. (2005). Food Uses of Barley. International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria.

Hailu Gebre-Mariam (2003). Wheat Production and Research in Ethiopia. IAR, Addis Ababa.

Hamilton, D. M. and Breslawski, S. (1996). Knowledge Acquisition for Multiple Site Related Domain Expert Systems: Expert Systems with Applications, Vol. 11, No. 3, pp. 377-389, Elsevier Science Ltd.

Hayes-Roth, F. & Jacobstein, N. (1994). The State of the art Knowledge Based System: Communication of the Association of Computing Machinery (ACM), Vol 37. No.3 Palo Alto, California.

Hein,G., McMullen, M., Jin Y. and Watkins, J. (2003). Pest Management Strategic Plan for wheat. Brookings, South Dakota.

Hogeveen, H, Noordhuizekstassen ,E. N., Schreinemakers, J. F. and Brand A.(1991). Our Industry Today Development of an Integrated Knowledge-Based System for Management Support on Dairy Farms. *Journal of Dairy Science Vol. 74, No. 12, 1991*.

Holland, A. (2011). Rule Based System: Intelligent Systems retrieved on February 16, 2012 from http://www.4c.ucc.ie/~aholland/udg/Girona_Lec2.pdf.

ICARDA. (2010). Ethiopia and ICARDA. Ties that Bind. No. 29. ISBN: 92-9127-245-0 ICARDA, Aleppo, Syria, iv+20 pp. En.

Janet L. Kolodner (1992). An Introduction to Case-Based Reasoning. Artificial Intelligence Review 6, 3--34, 1992. Morgan-Kaufmarm Publishers, Inc. College of Computing, Georgia Institute of Technology, Atlanta, GA 30332-0280, U.S.A.

Kareem, A. and Allen, R. H. (1990). Development of Knowledge-Based Systems in Wind Engineering. *Journal of Wind Engineering and Industrial Aerodynamics,* 36 (1990) 1245-1258 1245. Elsevier Science, Amsterdam.

Kassa Belay and Degnet Abebaw (2004). Challenges Facing Agricultural Extension Agents: Case Study from South-western Ethiopia. Blackwell Publishing Ltd.UK.

Kemelew Muhe and Alemayehu Assefa (2011). Diversity and Agronomic Potential of Barley (Hordeum vulgare L.) Landraces in Variable Production System, Ethiopia: *World Journal of Agricultural Sciences 7 (5): 599-603, 2011 ISSN 1817-3047.* IDOSI Publications.

Kerber, M. (2004). Knowledge Representation: Introduction to Artificial Intelligence, Prentice Hall, London, UK.

King, J.P., Broner, I., Croissant R. L., and Basham, C.W. (1991). Malting Barley Water and nutrient Management Knowledge-Based System. Emerging Technologies, Div.of ASAE.

Kulshrestha1,S. and Khosa, R. (2011). C Language Integrated Production System (CLIPS) Based Decision Support System for Water Distribution Networks. Copernicus Publications on behalf of the Delft University of Technology, Delhi, India.

Limam, S. A. Reijers, H A. & Marir, F. (2003). Case-Based Reasoning as a Technique for Knowledge Management in Business Process Redesign: *Electronic Journal on Knowledge Management, Volume 1 Issue 2 (2003) 113-124.* Academic Conferences Limited.

Line, R. F. and Cu, R. M. **(**1994**)**. An Expert Advisory System for Wheat Disease Management. The American Phytopathological Society, 1994.

Mahaman, B.D.. Passam, H.C, Sideridis, A.B.and Yialouris, C.P. (2003), DIARES-IPM: A Diagnostic Advisory Rule-Based Expert System for Integrated Pest Management in Solanaceous Crop Systems. ELSEVIER Science Ltd.

Mellor, J. and Dorosh, P. (2010). Agriculture and the Economic Transformation of Ethiopia Development Strategy and Governance Division: Ethiopia Strategy Support Program 2. International Food Policy Research Institute.

Memon, N. (2011). Preserving and Applying Human Expertise: Knowledge Based Systems and Case-base Reasoning university of Southern Denmark Retrieved On 16,February 2012, from http://www.mip.sdu.dk/~memon/IKM2011_lecture4.pdf

Minale Liben, Alemayehu Assefa and Tilahun Tadesse (2011)**.** Grain yield and malting quality of barley in relation to nitrogen application at mid- and high altitude in Northwest Ethiopia: *Journal of Science and Development 1 (1) 2011*

Moore, K. Simpfendorfer, S. Verrell, A. and Manning, B. (2005). Root and Crown Diseases of Wheat and Barley in Northern NSW. The State of New South Wales, NSW Department of Primary Industries.

Mulat Demeke (1999). Agricultural Technology, Economic Viability and poverty alleviation in Ethiopia, Addis Ababa University.

Nilsson, U. and Maluszynski, J. (2000). Logic programming and prolog 2nd ed.S.L: John Wiley & Sons Ltd.

Okafor, E. and OsuagwuC.(2006).The Underlying Issues in Knowledge Elicitation: *Interdisciplinary Journal of Information, Knowledge, and Management* Volume 1, 2006. InformingScience.org .

Owaied, H. H., Malek Abu-A'ra , M. and Farhan, H. A (2010). Application of Knowledge Based System: *(IJCSNS) International Journal of Computer Science and Networ Security, VOL.10 No.3*.

Oxley, S. and Burnett, F. (2008) Technical Note: Winter Wheat Disease Control. The Scottish Agricultural College. West Mains Road, Edinburgh EH9 3JG ISSN 0142 7695 .ISBN 1 85482 881 9.

Perry, N. and Ammar-Khodj A, S. (2010) knowledge engineering method for new product Development. *Journal of Decision System, Issue on: Emerging approaches, models and tools for managing Design and New Product Development in a collaborative environment,* Hermes Ed., ISSN 1246-0125.

Podgorelec, V., Kokol, P., Stiglic, B., Rozman I. (2002). Decision trees: an overview and their use in medicine, *Journal of Medical Systems*, Kluwer Academic/Plenum Press, Vol. 26, Num. 5, pp. 445-463, October 2002.

Poole, D., Mackworth ,A. and Goebel, R. (1999). Computational Intelligence. Oxford University Press.

Prasad G., Babu , V. A. (2006). A Study on Various Expert Systems in Agriculture: *Georgian Electronic Scientific Journal of Computer Science and Telecommunications. 2006, No.4(11).*

Prentzas, J. and Hatzilygeroudis (2007). Categorizing approaches combining rule-based and case-based reasoning: Expert Systems. Blackwell Publishing Ltd.

Prescott, J.M., P.A. Burnett, E.E. Saari, J., Ransom, J. Bowman, W. de Milliano, R.P. Singh, G. (1986). Wheat Diseases and Pests: A Guide for Field Identification. CIMMYT. , D.F. Mexico

Raman R.V. and K. Prasad V.K. (1987). *Applications of Knowledge Based Systems in Mining Engineering.* Proceedings of the Twentieth International Symposium on the Application of Computers and Mathematics in the Mineral Industries. Volume1. Johannesburg, SAIMM. pp. 167 - 180.

Rashid, S. (2010). Variation in staple food prices: International Food Policy Research institute, Addis Ababa, Ethiopia.

Richard, F., Violetta , G. and Mieczyslaw, O. (1999). *On Features of Decision Trees as a Technique of Knowledge Modelling:* Proceedings of the Workshop on Computer Science and Information Technologies CSIT' Moscow, Russia.

Roelfs, A.P., Singh, R.P. and Saari. E.E. (1992). Rust Diseases of Wheat: Concepts and methods of disease management. CIMMYT, D.F. Mexico.

Sagheb-Tehrani (2009). A Conceptual Model of Knowledge Elicitation: Bemidji State University Bemidji. EDSIG. USA.

Sajja, P. & Akerkar, R. (2010). Advanced Knowledge Based System: Models, Applications & Research, Vol 1, PP1-11, Jones & Bartlett publisher, Sudbury, MA, USA.

Seblewongele Eseyenew (2011). Prototype knowledge Based System for Anxiety Mental Disorder Diagnosis: Unpublished Master Thesis, Addis Ababa University.

Seid Ahamed (1996). *Annual report on Ethiopian agriculture research organization*. Ethiopian Agriculture Research Organization, Ethiopia.

Siew, K., Latif, A., Fairuz, .M. and Abd, A. (2005). System in real world applications available at http://www.generation5.org :80/articles asp?action=List and Topic=general.

Singh, M., Singh, P., and Singh, S. (2008). Decision Support System for Farm Management World Academy of Science, Engineering and Technology.

Speel, P-H., Schreiber A. Th , Joolingen, W. van, Heijst, G. van, and Beijer, G.J. (2001). Conceptual Modelling for Knowledge-Based Systems: Encyclopedia of Computer Science and Technology,vol.44, version II. New York: Marce Dekker Inc.

Steffenson,B. Pederson, J. and Pederson, V. (1999). Common barley disease in North Dakota : Hosts, Symptoms and Controls. North Dakota State University, Fargo.

Stone, N. and Engel, B. (1990). Knowledge-Based Systems in Agriculture and Natural Resource Management: AI Magazine Volume 11 Number 3 AAAI.

Tafa Jobie (2007). *Delia flavibasis stein as major pest of wheat in the major cereal belt south east Ethiopia:* African crop science proceedings vol.8.pp.9965-969.El-Minia, Egypt.

Tanwar, P., Prasad T. V. and Aswal, M. S. (2010). Comparative Study of Three Declarative Knowledge Representation Techniques: *International Journal on Computer Science*. Vol. 02, No. 07, 2010, 2274-2281.

Tomar, S. and Saxena, P.K. (2011). Architecture for Medical Diagnosis Using Rule-Based Technique: *Special Issue of the International Journal of the Computer, the Internet and Management, Vol. 19 No. SP1, June, 2011*.

Tongco, Ma. D. C. (2007). Purposive Sampling as a Tool for Informant Selection. *Journal of plants, people and applied research.*

Tsegaw Kelela (2009). Knowledge Based Reasoning for Agricultural Crop Management Decisions: An Experiment Using Rule Based and Artificial Neural Network Approach: unpublished Master thesis Addis Ababa University, Ethiopia.

Wegulo N.S. (2010). Powdery Mildew of Wheat. Unversity of Neberasak, Lincoln Extension, Institute of Agriculture and Natural Resource.

Wheat (2008). A Web-based Expert System for Diagnosis of Diseases and Pests in Pakistani Wheat: Proceedings of the World Congress on Engineering. Vol I, WCE. University of Nebraska- Lincoln.

Yelapure,S. J., Jadhav, S. K. and Babar, V. M.(2011). Knowledge based System for Tomato Crop with Special Reference to Pesticides. *International Journal of Computer Applications (IJCA) 25.*

APPENDICES

Appendix I

Addis Ababa University School of Graduate Studies

School of Information Science

Interview questions

The following structured interview questions are prepared for domain Experts/ researchers focusing on cereal crops (wheat, Barley) diseases diagnosis processes, in case of Kulumsa Agriculture Research Center.

The main objective of this study is to examine the application of knowledge based system for cereal crop diagnosis to improve the accuracy of decision made by cereal crop experts and development agents.

1. What are the challenges that face the research center to achieve its stated objectives?

2. Is there any factor that inhibits the research center in innovating, disseminating and transfer of knowledge and research outputs to stakeholders (farmers)?

3. If your answer in Question No 1, is yes, which of the following can be inhibiting factors?

a. Lack of experienced experts and high turnover of experts at the research center.

b. Lack of infrastructure like knowledge based and knowledge management systems at the research center.

c. Please specify others, if any____________________________?

Questions concerning cereal crop diseases

1. Describe the type of diseases that affect wheat crops particularly in **Ethiopia**
2. What are the symptoms of the diseases described in Question No.1?
3. Describe the type of diseases that affect barley crops particularly in **Ethiopia**
4. What are symptoms of these diseases described in Question No.3?

5. What are the identification techniques and procedures you applied to diagnose the diseases mentioned above?
6. Do you use standardized guidelines/manuals to diagnose each crop diseases?
7. What are the steps undertaken to diagnose the diseases each crops mentioned above?
8. What are the major issues covered during the diagnosis process of each crop?
9. After diagnosis of these diseases, what are the recommendation and treatments you provided?

Appendix II

Sample prolog rules from the knowledge base

```
menu:-nl,
       write('\n            MENU CHOICE .                                              '),nl,nl,
       write('         Type wheat followed by full stop to get advice about wheat crop:'),nl,
       write('        Type barley followed by full stop to get advice about barley crop:' ),nl,
       write('         ================================================='),nl,
       write('        Please respond the questions by saying yes/no after choosing the crop'),nl,
       write('    to proceed the advice !                                                    '),nl,
       read(Choice),case(Choice).
case(wheat):-diagnosis.
diagnosis:-
 retractall(known(_,_)),
 wheat(X),
 nl,write('The Wheat crop is infected by '),write(' '), write(X),write('.'),nl,nl,
 write('             Description:                                              '),nl,
 write('=================================================='),nl,nl,
description(X),
 write('            Treatment:                                                    '),nl,
 write('=================================================='),nl,nl,
treatment(X).
case(barley):-diagnosis.
diagnosis:-
 retractall(known(_,_)),
 barley(X),
 nl,write('The Barley crop is infected by'),write(' '), write(X),write('.'),nl,nl,
 write('          Description:                                              '),nl,
 write('    ============================================='),nl,nl,
description(X),
write('        Treatment: '),nl,
write('   ============================================='),nl,nl,
```

```
 treatment(X),
 continue.
/*------------------description of wheat crop disease-------------------------*/
description('Common bunt'):-
 write('common bunt infects Wheat kernels and recognized by a gray green color'),nl,
write('it produces large  mass spore in the grain instead of seed'),nl,nl.
 description('Fusarium head blight'):-
 write('Fusarium is a residue-borne disease, overwintering on crop residue such as wheat
residue'),nl,
 write('orange fungal mass along the lower portion of the glume is produced.'),nl,nl.
 description('leaf rust'):-
 write('leaf rust caused by p triticina fungus and affecting wheat leaf'),nl,
 write('Commonly occurs on leaf blades, but may also affect leaf sheaths'),nl,nl.
/*------------------treatment for diagnosed wheat crop diseases-------------------------*/
treatment('Common bunt'):-
 write('1.controlable.'),nl,
 write('2.use fungicide seed treatment.'),nl,
 write('3.use disease-free seed source.'),nl.

treatment('Fusarium head blight'):-
 write('1.Avoid the most susceptible varieties'),nl,
 write('2.use of crop rotation practices that limit disease carryover in wheat residue'),nl,
 write('3.use of seed treatments to reduce risk of seedling blight'),nl,
 write('4.spray tebuconazole fungicides to reduce FHB disease levels'),nl,nl.
 treatment('leaf rust'):-
 write('1.Use Genetic resistance varieties which is the most economical method to control rust
.'),nl,
 write('2.appropraite varieties should be selected based on the wheat growing environments'),nl,
 write('3.Spray with rate of 0.5-1 lit/ha propiconazole or Tebuconazolfungicid on diseased wheat
at five percent infection of the flag leaf.'),nl,nl.
```

```
/*-------------------rules to check wheat crop diseases-------------------*/
wheat('Common bunt'):-
 does_wheat_grain_have_gray_color,
 does_seed_have_fishy_odor,
 black_powdery_appearance_in_wheat_seed.
 wheat('Fusarium head blight'):-
 light_brown_lesions_of_wheat_kernels,
 tan_brown_lesions_of_wheat_kernels,
 does_the_grain_have_white_chalky_appearance.
wheat('leaf rust'):-
 does_wheat_leaf_show_small_orange_brown_lesions_color,
 are_round_blister_like_lesions_observed_on_wheat_leaf,
 are_elongated_blister_like_lesions_observed_on_wheat_leaf.
/*------------------description of barley crop disease--------------------------*/
description(scaled):-
 write('Scald is caused by the fungus Rhynchosporium secali'),nl,
 write('In severe infections both the number of kernels per head'),nl,
 write('and the number of heads per plant may be reduced.'),nl,nl.
description('loose smut'):-
 write(' Smut is caused by the fungus Ustilago tritici.fungus and affects grain of barley'),nl,
 write('Diseased plants appear normal until heading but may be taller and mature earlier than surrounding healthy plants'),nl,nl.
/*------------------treatment for diagnosed barley crop diseases--------------------------*/
treatment(scaled):-
 write('1.apply crop rotation using forage legume or plowing under infected residue and non host crop to reduce the speared of scaled by infected plants'),nl,nl.
treatment('loose smut'):-
 write('1.Loose smut is controlled by treating seeds'),nl,
 write('2.Use systemic fungicide that penetrates the developing seedling to kill the internal infection'),nl,nl.
```

```
/*-------------------rules to check barley crop disease-------------------*/
barley(scaled):-
 does_barley_leaf_show_bluish_gray_color,
 does_barley_leaf_show_pale_gray_color,
 does_barly_show_tan_color_on_leaves.
barley('loose smut'):-
 does_produce_soot_like_spores_on_barley_grain,
 is_head_of_barley_taller_than_the_normal_head,
 does_black_powdery_spores_blow_away.
```

Appendix III

Addis Ababa University School of Graduate Studies

School of Information Science

Questionnaires for Prototype Evaluation

These questionnaires are prepared to evaluate cereal crop diagnosis prototype knowledge based system based on the domain experts' opinion and feedback.

I. Please circle the options for each of the following questions given below.

1. Is the prototype easy to use and interact with it?

1. poor 2. Fair 3. Good 4. Very good 5. Excellent

2. How do you rate the attractiveness of CCDKBS?

1. poor 2. Fair 3. Good 4. Very good 5. Excellent

3.Is CCDKBS more efficient in time ?

1. poor 2. Fair 3. Good 4. Very good 5. Excellent

4. How accurately does the CCDKBS reach a decision to diagnose cereal crops?

1. Poor 2. Fair 3. Good 4. Very good 5. Excellent

5. Does the system incorporate sufficient and practical knowledge to diagnose cereal crops diseases?

1. Poor 2. Fair 3. Good 4. Very good 5. Excellent

6. Can the system give right description and treatment for identified cereal crops disease?

1. Poor 2. Fair 3. Good 4. Very good 5. Excellent

7. How do you rate the significance of the system in the domain area?

1. Poor 2. Fair 3. Good 4. Very good 5. Excellent

II. Please state your opinions and suggestions regarding the performance and applicability of the CCDKBS in the domain area.

8. How is CCDKBS differ in diagnosing the crop from the human experts (pathologists)?

9. What issues are covered by the CCDKBS Advisory system?

10. Please state your suggestion if you think that there are uncovered issues by prototype CCDKBS?

11. Do you believe that, can knowledge base system (CCDKBS) prototype handle cereal crop diagnosing tasks?

12. Do you think that, can CCDKBS contribute in diagnosing and treatment of cereal crops by assisting agricultural experts and DA workers in the domain area?

13. What are the limitations of CCDKBS as you see its performance when you are interacting with it?

14. What are the strengths of the CCDKBS in solving problems in the domain areas?

DECLARATION

I DECLARE THAT THIS THESIS IS MY ORIGINAL WORK AND HAS NOT BEEN PRESENTED FOR ANY DEGREE IN ANY OTHER UNIVERSITY AND THAT ALL SOURCE OF MATERIALS USED FOR THE THESIS HAVE BEEN DULY ACKNOWLEDGED.

EJIGU TEFERA

JUNE, 2012

THIS THESIS HAS BEEN SUBMITTED FOR THE EXAMINATION WITH MY APPROVAL AS THE UNIVERSITY ADVISOR.

ATO GETACHEW JEMANEH