ADDIS ABABA UNIVERSITY
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# Expert System Development For Teff Variety Selection and Disorder Management

A Project paper 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 Computer Science

**By**

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## Abbreviations

ES: Expert System

EIAR: Ethiopian Institute of Agricultural Research

GDP: Gross Domestic Product

HTTP: Hyper Text Transfer Protocol

KB: Knowledge Base

IE: Inference Engine

WM: Working Memory

**Abstract**

This paper presents a web-based expert system for Teff crop in Ethiopia. Teff is one of the major cereal crops in Ethiopia. It is cultivated in vast areas and ranked first with regard to its area of coverage compared to other cereal crops of the country.

In Ethiopia, farmers obtain information about new agricultural technologies from agricultural extension workers who occupy a strategic position in the agricultural production cycle. They mediate between the farmers and researchers. The extension workers obtain information about Teff improved technologies when extension documents are distributed. This way of information transfer has its own limitation. The information is static, not easily available and may not respond to users' specific needs since the documents give general recommendation. During this situation the extension workers look for agricultural experts' assistance. But experts are not always available. This project is an effort in solving the problems faced by the extension workers when the services of the experts are not available.

In this project a web based expert system has been developed. The system would help users to easily select appropriate Teff varieties which reflects their agro ecological zone and their interest, and also provides proper consultation in relation to identifying the causes of the crop disorder and recommending possible measures to be taken.  The system has been evaluated by domain experts and extension workers. The analysis of the result shows that the system is acceptable.

**Keywords**: Agriculture expert system, web-based expert system, teff disorder management, teff variety selection.

# CHAPTER ONE: INTRODUCTION

## 1.1. Background

An Expert System (ES) is a computer program designed to simulate the problem-solving behavior of an expert in a narrow domain or discipline. Expert systems combine the experimental and experiential knowledge with the intuitive reasoning skills of a multitude of specialists to aid users in making the best decisions for their problems [1].

Expert systems were first used in the mid-1960s. Today, thousands of expert systems are in routine use world-wide, particularly in business, industry and government. Expert systems have been developed and applied to many fields [2]. 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. Agriculture expert systems are developed to give expert opinion to users that can get expert opinion on their specific problems like selection of most suitable crop variety, diagnosis or identification of plant disorder throughout the crop production cycle [3, 4, 5].

The agriculture sector plays an important role in the overall development of Ethiopian's economy. Majority of the population is dependent on this sector. According to [6], agriculture contributes about 51 percent of Gross Domestic Product (GDP) of the country and Teff, which is an important cereal crop in Ethiopia, contributes more than 5 billion Birr to GDP annually. The area under Teff cultivation is over two million hectares of land [7, 8] thereby covering about 21.54 percent (largest) of the total acreage of cereals [6]. The crop is highly adapted to diverse agro-ecological zones of the country. Moreover, outside Ethiopia there is a growing interest in using Teff. For example, commercial production of Teff has begun in a few areas of the USA, Canada and Australia. Teff has been introduced to South Africa and is cultivated as a forage crop, and in recent years it is cultivated as a cereal crop in northern Kenya [9]. Nowadays, Teff is known as gluten free crop and may be a potential food ingredient for people suffering from gluten intolerance or celiac disease. Therefore, Teff grain is an alternative to wheat and other cereals. For this reason, Teff is gaining attention in the US health food markets [10].

In Ethiopia, the Ethiopian Institute of Agricultural Research (EIAR) is responsible for conducting research, supply of improved agricultural technology, and popularization of improved technologies through extension workers [11]. EIAR is actively engaged in producing improved Teff technologies. It has released improved Teff varieties and has recommended different cultural practices for the proper management of the crop across different agro-ecological zones of the country [8]. General guidelines about the improved Teff technologies are distributed to extension workers nationwide.

### 1.2. Statement of the Problem

In spite of its numerous merits and considerable economic significance in Ethiopia, Teff is a very delicate and fragile crop that requires a lot of work and care, and it has one of the lowest yields of the cereal crops [10]. Yield of Teff under farmers' management is still far lower than that what can be obtained under research plots [11]. The national average grain yield of Teff is low (about 9.2 quintals/hectare) [8]. But with proper management of existing improved technology the yield can further be increased up to 36 quintals/hectare.

According to [9], plant diseases which can cause up to 25% yield reduction and insect pest damage which can cause up to 30% losses, as well as the lack of using the right type of improved seed varieties, are some of the major factors which limit the crop productivity. In order to manage these problems and to limit their negative impact on the crop production, correct variety recommendation, symptom identification and rapid diagnosis mechanism is essential.

Almost all Ethiopian farmers rely on information from agricultural extension workers [6]. Currently, there are more than 69,000 extension workers nationwide [11]. They occupy a strategic position in the agricultural production cycle. They mediate between the farmers and researchers so that a constant supply of timely and appropriate information to extension workers will enhance the quality of information they provide to farmers. The study conducted in 2004 [12, 13] showed that lack of having appropriate information by extension workers about new technologies had hampered the promotion and adoption of new agricultural technologies significantly.

The extension workers obtain information about Teff improved technologies when extension documents are distributed [14]. This way of information transfer has its own limitation. The information is static, not easily available and may not respond to users' specific needs since the documents give general recommendation. During this situation the extension workers look for agricultural experts' assistance. But experts are rarely able to devote adequate time to the assistance of all requests. Moreover, in many instances response by an expert is too untimely for farmers.

Therefore, this project is an effort in solving the problems faced by the extension workers when the services of the experts are not available.

## 1.3. Objective of the Project

### 1.3.1. General Objective

The general objective of the project is to develop a web based expert system for Teff crop variety selection and disorder management.

### 1.3.2. Specific Objectives

The specific objectives of the project which help to achieve the general objective are:

- Review related literature
- Develop knowledge base
- Develop a prototype
- Evaluate the prototype

## 1.4. Scope of the Project

The scope of the project is limited to the development of an expert system which helps users to select appropriate Teff variety on the basis of their interest, provides currently recommended cultural practices to the crop and helps users how they can identify and control the crop from insect pests and diseases. The project would not cover other cultural practices of the crop such as fertilizer quantity recommendation, land preparation and weed management.

## 1.5. Methodology

Appropriate data for the construction of the system were collected from domain experts, particularly from agricultural researchers through interview and from different related documents.

### 1.5.1. Tools

The following tools and programming languages: Java, e2Rule engine, Adobe Dreamweaver, Apache web server, MS Word, were used as programming language, expert system shell, web interface development, web server, and document preparation respectively.

### 1.5.2. System Evaluation

To evaluate the system, a survey was conducted to gather the user evaluation about the system. For this, a set of questionnaire was prepared that ask about the simplicity, usability, functionality of the system, and interface design used in the system.

## 1.6. Significance of the Project

The system will serve as a tool for agriculture extension workers to have immediate advisers about Teff crop management so that they can recommend currently available improved technologies to farmers. The result of the project will also demonstrate the significance of agricultural expert systems for other crops of the country.

## 1.7. Organization of the Report

This project report is organized into eight chapters including the current one. The second chapter reviews different literatures regarding Teff crop and expert systems with special focus on rule based expert system. The third chapter reviews some of the existing agricultural expert systems. The fourth and fifth chapters discuss the requirements analysis and system design part of the project respectively. The sixth chapter deals with the implementation aspect of the project. The seventh chapter discusses system evaluation. Finally, chapter eight deals with the conclusion and future works.

# CHAPTER TWO: LITERATURE REVIEW

In this chapter, literatures in the fields of Teff crop and expert system are discussed in brief. The chapter covers description of Teff crop, its geographic distribution, properties, and diseases and insect pests of the crop. Expert system with special focus on rule based approach, which is used in this project, is also discussed.

## 2.1. Brief Description of Teff Crop

Teff (*Eragrostis tef*) is endemic cereal crop to Ethiopia. It is believed to be cultivated for the first time in Ethiopia between 4000 BC and 1000 BC [9]. The word Teff is thought to originate from the Amharic word '*teffa'*, which means "lost" (due to small size of the grain) [15]. According to [16, 17], Ethiopia is the center and origin of Teff and the appropriate and most important center for the collection of Teff *germplasm*.

Teff grain is ground to flour which is mainly used for making popular pancake-like local bread called *'enjera'*. Teff straw, besides being the most appreciated feed for cattle, is also used to reinforce mud and plaster walls of houses.

In Ethiopia, the Ethiopian Institute of Agricultural Research (EIAR) particularly, *Debre Zeit* agriculture research center is actively engaged in conducting Teff research, supply of improved technology, and popularization of the technologies. So far, it has released 17 improved Teff varieties and has recommended different cultural practices for the proper management of the crop across different agro ecological zones of the country [8].

### 2.1.1. Geographic Distribution and Properties

Grain cultivation of Teff has been confined mainly to Ethiopia and to some extent to the highlands of Eritrea. It is also grown in northern Kenya. Small-scale commercial Teff production takes place in South Africa, the United States, Canada, Australia, Europe (the Netherlands) and Yemen. Teff is also grown as a forage grass, for instance in South Africa, Morocco, Australia, India and Pakistan. It has been introduced experimentally into other tropical countries, either for its grain or for hay, e.g. in other parts of East Africa and in southern Africa [18].

Within Ethiopia, Teff is grown in almost all regions of the country for home consumption and cash crop [15]. Most of the Ethiopian farmers use traditional landraces of Teff and these are distributed all over the country. Modern varieties are also used in many regions but in very small areas within each region [9].

The composition of Teff is similar to that of millet, although it contains generally higher amounts of the essential amino acids, including lysine, the most limiting amino acid [19]. It has also good mineral content [20].

According to [21, 22, 23], compared with other cereals Teff is reported to have higher iron content and reported that non-Teff consumers have a lower level of hemoglobin. On the other hand, since Teff eaters have higher levels of hemoglobin in their blood, they do not suffer from hookworm anemia even when infested. In addition, according to the same study, malaria is frequently found in the groups with lower hemoglobin levels. Moreover, consuming Teff is reported to prevent the anemia related to pregnancy. Teff contains more calcium, copper, zinc, aluminum and barium than winter wheat, barley and sorghum [21].

### 2.1.2. Diseases and Insect pests of Teff

A number of diseases (mainly caused by fungi) and pests are known to attack Teff in most parts of Teff growing areas [24]. Among the diseases, leaf rust (*Uromyceseragrostidis*), head smudge (*Helminthosporiummiyakei*) and damping off (*Drechslera spp. and Epicoccumnigrum*) are the most critical ones. As in all tropical countries, insect pests are major problems in Ethiopia, often causing considerable crop loss. So far 10 insect pests of Teff have been identified [24, 25]. A correct identification of disease and pest is the first step which leads to effective control or management of the disease and pest.

## 2.2. Rule Based Expert System

Rule-based expert systems use human expert knowledge to solve real-world problems that normally would require human intelligence. Expert knowledge is often represented in the form of *rules* or as *data* within the computer [26, 27]

### 2.2.1. The Architecture of Rule-Based Systems

The first rule-based systems were tightly integrated with the specific application they were developed for. Thus, new rule-based systems had to be written from the scratch. The EMYCIN, a derivate from MYCIN (stands for Empty MYCIN) was developed as a generic framework for rule-based systems, without the domain knowledge of the MYCIN. It was the first of its kind. This approach of developing a framework without a domain specific knowledge is followed by most modern rule-based systems [28].

According to [29], a rule-based system has the following basic components: working memory, knowledge base, and inference engine.

## Working Memory

The working memory (WM) represents the set of facts known about the domain. The elements reflect the current state of the world. In an expert system, the working memory typically contains information about the particular instance of the problem being addressed. For example, in a medical expert system, the working memory could contain the details of a particular patient being diagnosed [29]. The working memory is the storage medium in a rule based system and helps the system focus on its problem solving [30].

## Knowledge Base

The knowledge base is the set of rules which represents the knowledge about the domain. According to [25] the general form of a rule is:

*If cond1, cond2, cond3*

*...then action1, action2…*

The conditions cond1, cond2, cond3, etc. (also known as antecedents) are evaluated based on what is currently known about the problem being solved (i.e., the contents of the working memory).

Such rules are interpreted to mean that if the antecedents of the rule together evaluate to true (i.e., if the Boolean combination of the conditions is true), the actions in the consequents (i.e., action1, action2, etc.) can be executed [30]. Each antecedent of a rule typically checks if the particular problem instance satisfies some condition.

The consequents of a rule typically alter the working memory, to incorporate the information obtained by application of the rule. This could mean adding more elements to the working memory, modifying an existing working memory element or even deleting working memory elements. They could also include actions such as reading input from a user, printing messages, accessing files, etc. When the consequents of a rule are executed, the rule is said to have been fired.

## Inference Engine

The inference engine is activated when the user initiates consultation session. The inference engine finds the rules that match the given facts, selects which rule to execute and executes the rule by adding the deduced fact to the working memory. The inference engine uses pattern matching to select the qualifying rules. The choice of which rule to fire is done by conflict resolution.

The most commonly used conflict resolution strategy is the first found strategy. The first applicable rule is executed [31] or fired by applying rule deduction or using formal logic. A new fact is concluded and added to the working memory and new patterns found that match the new fact. This sequence of steps and the linking of facts and patterns and rules are known as chaining [31].

The inference engine deduces facts or draws conclusions from the knowledge base based on the user input and the facts from the knowledge base and/or other sources. The basic techniques are identified when inferring facts or conclusions from the knowledge base: Forward chaining and backward chaining.

Forward chaining matches the current state with the rules' antecedents or conditions in the knowledge base. If the condition is true, the inference engine adds the conclusion to the list of known facts. Known facts imply other facts. This technique is also known as data driven. The data provided by the user is examined and new knowledge is concluded or asserted and responded to.

The second technique, backward chaining, also known as goal driven or directed, is more efficient if the number of goals is limited and involves the acquiring of information from the user in the form of questions to draw specific conclusions. This style is used to confirm diagnostic tasks and works backwards from what needs to be proved to the facts that might affect it. It is a goal-directed backward chaining of rules to try to prove a hypothesis made by the system. Sometimes stating the conclusions and trying to prove them are unhelpful because none of the multiple goals exist. If this is the case, forward chaining should rather be considered [32].

Most expert systems are developed using specialized software tools called shells [33, 34, 35]. There are many expert system shells available, such as Intermodeller, Jess, expert rule engine, CLIPS, Expert Builder, Flex, and Visirule. These shells come equipped with an inference mechanism (backward chaining, forward chaining, or both), and require knowledge to be entered according to a specified format [36]. The architecture of an ES Shell as [36] illustrates includes:

- A knowledge base that serves as a repository of rules for domain-specific knowledge
- An inference engine that drives the system in making inferences using the knowledge in the knowledge base
- A working memory, which is the data area where partial results of the problem being solved are stored, and

- A user interface where the user interacts with and executes the ES.

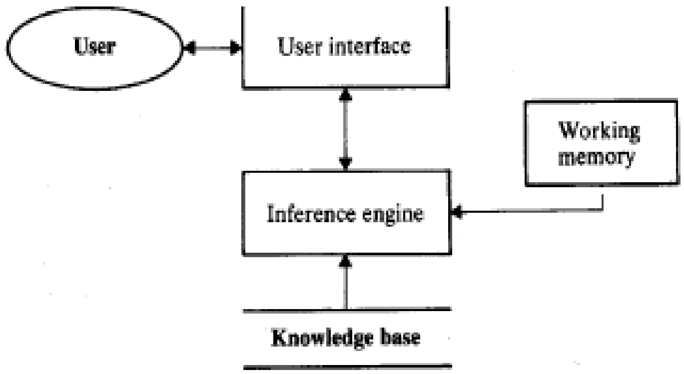


Figure 2.1: Expert system architecture

### 2.2.2. Expert System Features

In addition to reasoning chaining, knowledge representation and user interface, features which commonly exist in expert systems are coping with uncertainty and explanations [30]:

**Coping with Uncertainty**

Uncertainty is inherently part of most human decision making. Expert systems which seek to model human expertise in specific domains have to take care of uncertain information.

They, therefore, need methods to represent uncertainty in knowledge and data and should be able to reason with such uncertain information.

Approaches to handling uncertainty vary from system to system, depending on the type and cause of uncertainty in the domain of application.

According to [30], there are two types of uncertainty that we have to capture in a system that uses rules of this form for knowledge representation.

The first type of uncertainty is the uncertainty in the data used: To model this, we attach a numerical measure with every input that the user provides with the system. This measure, in general, models such aspects as inadequate information, unreliable sensors, ambiguous language, strength of belief in the data, etc. The second type of uncertainty is the uncertainty in the rule: This reflects the expert's confidence in the particular rule. Another numerical measure will be attached to every rule to represent this.

## Explanations

Expert systems today provide primarily two types of explanations that explain the reasoning process that it used to reach a recommendation, [30] discussed the two types of explanations as *Why* and *How* explanations.

*Asking Why*

When an expert system requests some data from the user, user may ask the question: “Why is this data required?". One way to answer the question is to show the user the general direction that the expert system is headed towards.

This is because it is useful to tell the user what the current goal is. The system could say something like: “I am currently trying to establish (goal) X. In order to prove X, I need to know if (sub-goals) X1, X2 are valid. To establish the truth of X2, I need information about parameter X21..."

Consider the rule with rule-identification number cf11 in the expert system
*rule (cf11, HD confirmation, true, 0.20) :-*
*is(complaint, swelling of feet),*
*is(age, 15.0),*
*is(age, 55.0),*
*is(sex, female),*
*isnot(pregnant, yes).*
*The English paraphrase of this rule says:*
*Rule: cf11*
*If complaint is swelling of feet*
*and age is in the range 15 to 55*
*and sex is female*
*and patient is not pregnant*
*then conclude HD confirmation with CF = 0.2*

While evaluating the antecedent of the rule, the system might ask the user “Is the patient pregnant?" The user may wonder why the system wants to know if the patient is pregnant. The system may then explain that it is needed to confirm the possibility of heart disease (HD), in the context of the evidence available so far.

The medical knowledge used in defining this rule is the following: Patients with certain types of heart diseases may exhibit, as one of their symptoms, a swelling of the feet. However, this symptom is also common in pregnancy.

So the question “Is the patient pregnant?" is used to distinguish patients who have swelling of feet due to cardiac problems, from those who exhibit this symptom because of pregnancy.

*Asking How*

When an expert system reaches some conclusion, the user may want to ask: "*How* did the system reach this conclusion?". This might involve explaining the reasoning involved in understanding and diagnosing the problem, and in formulating and executing problem solving strategies. The system may have to explain how intermediate conclusions are arrived at, and how parameter values are acquired or inferred. This essentially involves tracing the steps that the system took to reach the conclusion.

In particular, it will mean moving from specific conclusions through rules that led to these conclusions, to the data supplied by the user. According to [30, 37, 38], a good expert system has to provide reasonable answers to the user's *Why* and *How* questions.

## 2.3. Expert System Development Process

Expert system development process includes three core phases: knowledge acquisition, knowledge representation, and evaluation [39]. In the following sections, these phases are discussed in brief.

### 2.3.1. Knowledge Acquisition

Knowledge acquisition is to obtain facts and rules from the domain expert so that the system can draw expert level conclusions. It is the most important element in the development of expert system [40, 41]. It is a time consuming process in which the knowledge engineer works alongside the participating expert and extracts, structures and organizes the information to be represented in the expert system [42]. Knowledge acquisition requires a progressive number of personal interviews of the expert(s) to record information pertinent to the knowledgebase [43, 44].

Acquired knowledge should be played back to experts, perhaps using a different medium than the one used to acquire it [38]. During the knowledge acquisition phase, the knowledge engineer should identify the conclusions that the expert system should render and verify this knowledge as it is acquired. Knowledge acquisition should also be supplemented with a thorough review of current literature to provide the most available up-to-date information [37].

According to [31, 45], knowledge acquisition is composed of five stages:

- Identification or definition of the problem and the major characteristics of the problem
- Conceptualization or the choice of an appropriate representation medium such as rules and the acquiring of the knowledge associated with the certainty of the knowledge
- Designing of an architecture or deciding the formalism or acquisition methodology e.g. rules and deciding the process extracting knowledge from the experts
- Implementation, building or the programming of knowledge and the development of a prototype, and
- Testing and refining of the knowledge base by subjecting it to examples, examining the validity of the knowledge.

### 2.3.2. Knowledge Representation

After the domain has been identified and knowledge is acquired from a participating expert, a model for representing the knowledge must be developed. Numerous techniques for handling information in the knowledgebase are available; however, most expert systems utilize rule based approaches [37, 38].

### 2.3.3. Evaluation

When the knowledge engineer and the expert are satisfied that the expert system is complete, the system should be evaluated against agreed upon performance criteria. At this time other users can be invited to evaluate and use the system for testing purposes. Either real-world case scenarios or simulated cases can be used for testing purposes [46].

According to [51], there are no universally accepted standards for the evaluation of expert systems. However, there is a set of points that might be considered during evaluation. Issues that should be considered in evaluation are:

- Is the system user friendly and do the users accept the system?
- Does the system give correct results and is the logic of the system correct?
- Does the expert system offer an improvement over the practices it is intended to supplement?
- Is the system easy to learn and to become proficient on?
- Is the system useful as a training tool?
- Is the system in fact maintainable by the other than the developers?
- Can the system be used in the intended work environment?

# CHAPTER THREE: RELATED WORKS

Expert systems have been used in agriculture since the early 1980s. Many expert systems have been developed in different countries for plant-disorder diagnosis, management and other production aspects. This chapter presents some of the expert systems developed in agriculture field.

## 3.1. Wheat: Expert System on Wheat Crop Management (EXOWHEM)

EXOWHEM [47] has been developed and implemented by the scientists of (Indian Agriculture System Research Institute) IASRI in collaboration with two premier research institutions on wheat, namely Directorate of Wheat Research, Karnal and Indian Agricultural Research Institute, New Delhi. The system holds a collection of general principles that are potentially applied to solve a problem related to wheat crop management and is capable to extend expert advice to the researchers and wheat-growing farmers.

The system is designed to cover agricultural operations, variety selection, fertilizer application, and insecticide / pesticide application on one hand and economic benefits on the other hand. The system analyses the question given by the user and gives a piece of advice to the user.

This system has four modules: variety selection, plant protection, cultural practices and harvesting technology. The variety selection module specifies the variety from the farmer's point of view. Plant protection module is subdivided into pathological aspects, entomological aspects and weed management. In pathology, the system identifies micro diseases such as leaf rusts, blights and bunts etc. In entomology, the system identifies insects affecting plants and recommends control measures. The cultural practices module specifies the process of cultivation of the crop. The harvesting technology module helps in advising the appropriate method, machinery and time for the harvest.

The developed system extends the research done on the wheat crop to the farmers in effective way to help in getting instant solution to the problems faced by them. It encourages the dissemination of research findings and helps farmer’s where services of the experts are not available. It reduces the load from the experts and facilitates qualitative research on wheat supported by the knowledge base in the system.

### 3.2. Barley Expert System

The development of Barley Expert System for plant protection was developed in collaboration with International Centre for Agricultural Research in the Dry Areas (ICARDA) in 2003 [48]. The system contains four modules:

***Variety selection module****:* The input parameters identified by the domain expert are plant height, row type, and the pests that the variety needs to be resistant to. So, the only output is the varieties selected. Clicking on the variety selected the features of the variety is displayed.

***Cultural practice module****:* The cultural practice module covers 7 pest classes with a total of 38 pests. Once the user chooses certain pests the system responds by giving the cultural practices needed to be done as a preventive measure to inhibit their appearances.

***Pest identification module****:* The first thing that the system requests as input from the end user is the growth stage. The system covers the 8 growth stages of barley. If the user chooses one stage, say flowering, the system displays a screen that contains primary observation on plant, leaf, and grain. Entering the primary observation, the suspected causes are displayed.

***Pest control module**:* The pest Control module covers the same number of pests covered by the cultural practices module. The difference is that this module is used when a disorder appears and the pest that causes this disorder is diagnosed. For example, if leaf rust is diagnosed, the system asks first about the percentage of infected plants, the available pesticide, and then gives the recommendation.

### 3.3. Cucumber Production Management Under Plastic Tunnel (CUPTEX)

Cucumber production management under plastic tunnel (CUPTEX) has been developed to be used by agricultural extension service within the Egyptian Ministry of Agriculture. CUPTEX currently provides the following services: Disorder diagnosis, Disorder treatment, Irrigation scheduling, Fertilization scheduling and Plant care.

***Disorder diagnosis***: This subsystem provides the user with a diagnostic disorder which causes problems on plantation or verifies a user's assumption.

***Disorder treatment***: This subsystem provides the user with the remediation of disorders after being verified or identified by the diagnosis subsystem.

***Irrigation scheduling***: The main goal of this function is to obtain an irrigation schedule for a particular plastic tunnel. An irrigation schedule demonstrates the water quantity related to each time instance. The calculated water quantity is adapted according to some plastic tunnel characteristics such as intensity of plants, the efficiency of drainage system, etc.

***Fertilization Scheduling***: The main goal of the fertilization subsystem is to determine the fertilization requirements for cucumbers. Fertilization requirements include several aspects such as the fertilizer's type, quantity, and the intervals between applications.

***Plant care***: The purpose of the plant care subsystem is mainly to predict from the last crop and plastic tunnel characteristics, the possibility of having a pest problem. Based on this information it produces a schedule of operations to be done to protect the plant from any expected disorder [49].

### 3.4. TOMATEX Expert System

TOMATEX is an expert system for tomatoes. The current version of the system (TOMATEX ver. 3), provides recommendations concerning disorder diagnosis and disorder treatment. ***Disorder diagnosis subsystem*****:** There are two purposes for this subsystem: it concludes the causes of user complaint and it verifies the user assumption. The output of this subsystem is:

If there are user complaints, the output is the causes (disorders) of these complaints. Each disorder must have a certainty factor. The certainty factor of the confirmed disorders is either "likely" or "most likely".

If the user knows the cause of the abnormal observations, and he wants treatment for the assumed disorders, this subsystem must verify the user's assumption.

***Disorder treatment subsystem:*** This subsystem is to advice the user about the treatment operation of the infected plant. The output of this subsystem is the treatment schedule. The output includes a complete specification about the treatment operation: disorder name, material name, material quantity, mode of entry, method of application, the tool used in the treatment operation, application time, and advice. The treatment subsystem takes into account the seriousness of the disorders, and so it orders the treatment operations according to their seriousness [50].

### 3.5. Summary

Some expert systems in the field of agriculture have been presented in this chapter. Two of the expert systems were built for cereal crops, wheat and barley and the others for horticulture crops, cucumber and tomato. Both the cereal expert systems give due emphasis for variety selection and disorder management while the other two systems deal with only disorder management. From this we can see that advice on variety selection on a specific crop and crop disorder management are two main areas where agriculture expert system should address.

# CHAPTER FOUR: REQUIREMENT ANALYSIS

In this chapter the functional and non-functional requirements of the system are described and modeled using UML models.

## 4.1. Functional Requirements

The functional requirements of the system include: recommend list of Teff varieties, identified insect pests and diseases that cause crop disorder, allow viewing variety, insect pest and disease detail and allow updating the knowledge base.

## 4.2. Nonfunctional Requirements

The non-functional requirement describes constrains for implementing the project. Some of the requirements are:

- The system should be easy to use
- It should be easy to incorporate additional knowledge in the system
- The system should allow access to its knowledge base to authorized persons only.

## 4.3. The Analysis Model

The analysis model describes the structure of the system or application. It consists of activity diagram and sequence diagram that describe the logical implementation of the functional requirements that are identified in the use case model.

The analysis model identifies the main objects in the system and contains a set of use case realizations that describe how the system will be built. Sequence diagrams realize the use cases by describing the flow of events in the use cases when they are executed. These use case realizations model how the parts of the system interact within the context of a specific use case.

### 4.3.1. Use Case Model

A set of events that occurs when an actor uses a system to complete a process is represented with use case diagram. The identified use cases are get variety list, get identified insect, get identified disease, update knowledge base, view variety detail, view insect detail, and view disease detail. Actors of the system are “extension workers”, “administrator”. The diagram depicted in Figure 4.1 shows the use case diagram of the system.

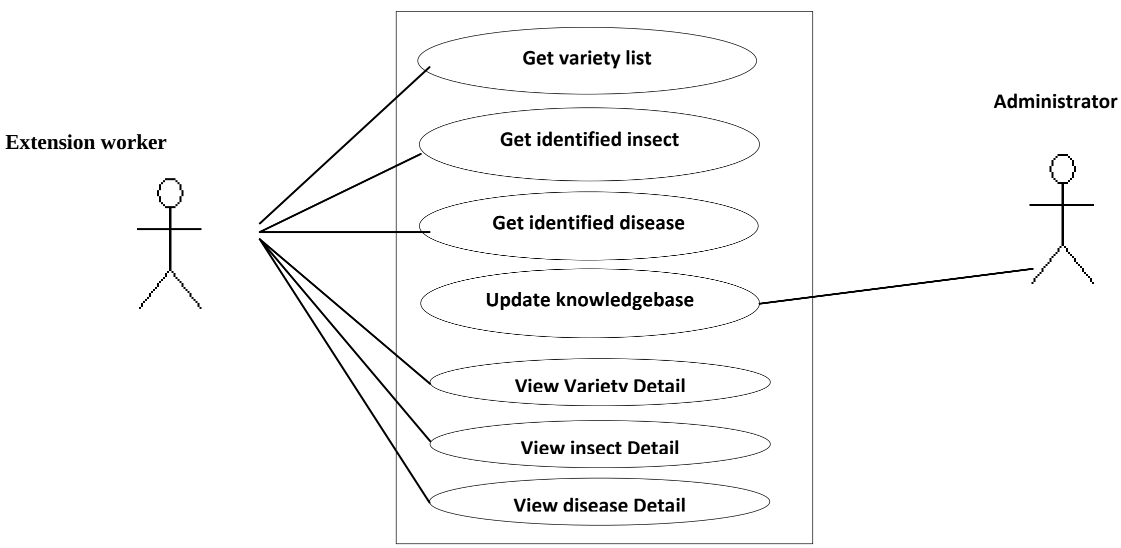


Figure 4.1: Use Case diagram of the system

## Actor Description

**Name**: Extension worker

**Description**: An extension worker is a person who mediates between the farmers and researchers and provides immediate assistance to farmers.

**Name**: Administrator

**Description**: An administrator is a person assigned to update the system domain knowledge.

### 4.3.2. Use Cases Description

Use Case Name: Get variety List

Actor: Extension worker

Description: To get list of recommended variety

Precondition: The user should know the website address of the system.

Post-condition: The user will see the recommended list of varieties.

Flow of Events:

1. The user will select variety selection hyperlink.
2. The system will present the main variety selector window.
3. The user will confirm to proceed to the system variety selector request window.
4. The system will request user to enter altitude and average annual rainfall amount of the area in numeric value format [A]
5. The system will request series of questions in forced choice format and user submit responses.
6. The system will display the recommended potential variety.
7. The use case ends.

Alternate Flows:

4A: The user enters inappropriate value.

1. The system requests user to re enter the appropriate response.
2. The use case returns to flow of events step 4 and continues.

Use Case Name: Get Identified insect

Actor: Extension worker

Description: To identify insect pest responsible for the observed disorder

Precondition: The user should know the website address of the system.

Post-condition: The user will see the potential list of insect pests that cause for the disorder.

Flow of Events:

1. The user will request to identify insect that causes for his/her crop disorder.
2. The system will present the main insect identification window.
3. The user will confirm to proceed to the system insect identification request window.

4. The system will request series of questions.
5. The system will display the potential list of insects that cause for the disorder
6. The use case ends.

Use Case Name: Get Identified Disease

Actor: Extension worker

Description: To identify disease responsible for the observed disorder

Precondition: The user should know the website address of the system.

Post-condition: The user will see the potential list of diseases that cause for the disorder.

Flow of Events:

1. The user will request to identify disease that causes for his/her crop disorder.
2. The system will present the main disease identification window.
3. The user will confirm to proceed to the system disease identification request window.
4. The system will request series of questions.
5. The system will display the potential list of diseases that cause for the disorder
6. The use case ends

Use Case Name: Update knowledgebase

Actor: Administrator

Description: To update the knowledgebase

Precondition: The Administrator should already have an account to log in

Post-condition: The knowledgebase is updated.

Flow of Events:

1. The user request to update knowledgebase
2. The user enter users ID and password
3. The user will log in as an administrator. [A]
4. The system will open the knowledgebase.
5. The user will update knowledgebase.
6. The user will close the updated knowledgebase file.
7. The use case ends.

Alternate Flow:

3A: User failed to provide correct user name and/or password

1. System displays “incorrect user Id or password” error Message
2. The use case returns to normal flow step 2 and continues.

Use Case Name: View Insect Detail

Actors: Extension worker

Description: To see identified insect details

Precondition: The system has displayed the potential insect pests

Post-condition: The user will see detail information about the insect pests

Flow of Events:

1. The user request to see insect detail
2. The system will display insect details.
3. The use case ends.

Use Case Name: View Disease Detail

Actor: Extension worker

Description: To see identified disease details

Precondition: The system has displayed the potential diseases

Post-condition: The user will see detail information about the diseases

Flow of Events:

1. The user request to see disease detail
2. The system will display disease details.
3. The use case ends

## 4.4. Activity Diagram

Activity diagrams describe the workflow behavior of a system. Activity diagrams are similar to state diagrams because activities are the state of doing something. The diagrams describe the state of activities by showing the sequence of activities performed. Activity diagrams can show activities that are conditional or parallel. Figure 4.2 shows the activity diagram of the system.

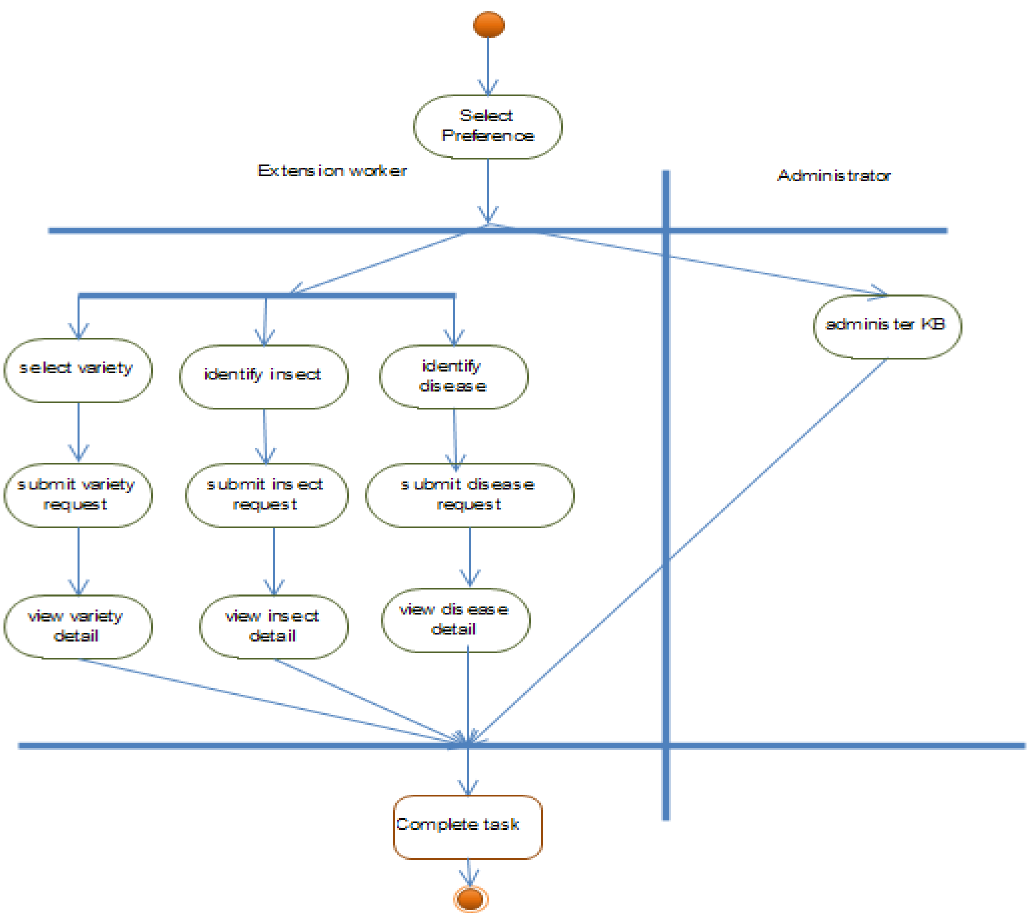


Figure 4.2: Activity diagram of the system.

### 4.5. Sequence Diagram

Sequence diagrams model the behavior of use cases by describing the way groups of objects interact to complete a task. Figures 4.3 – 4.8 show sequence diagrams for the identified use cases.

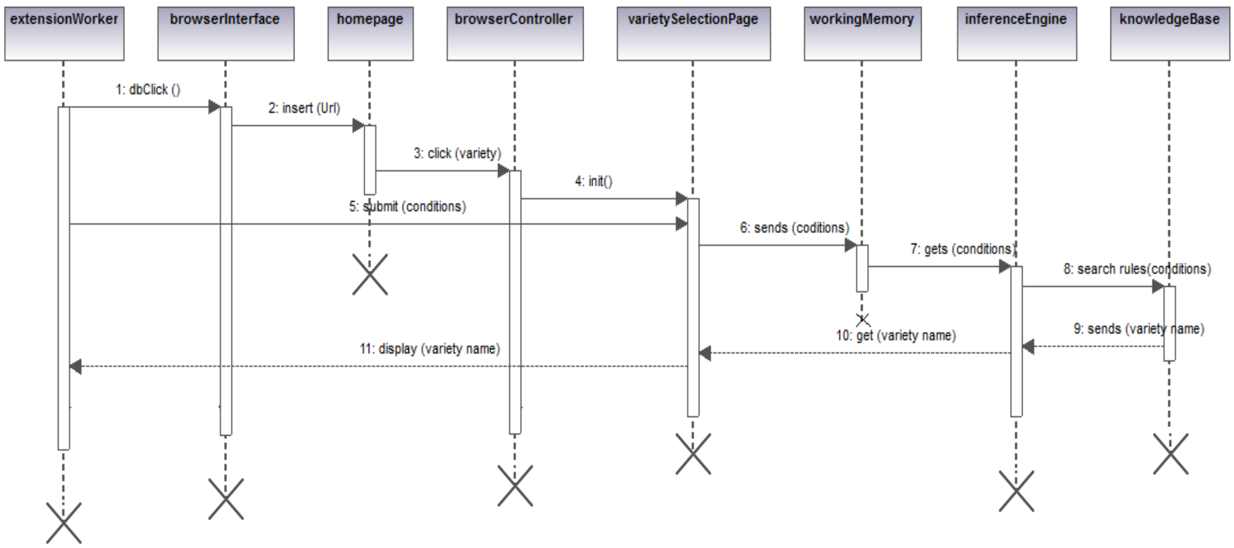


Figure 4.3: Sequence diagram for Get variety list use case

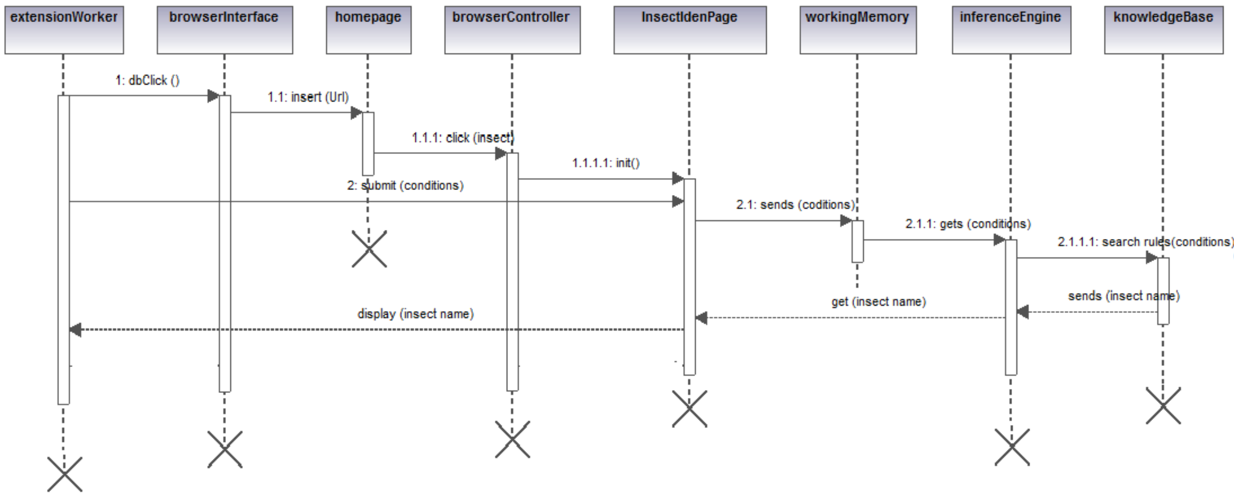


Figure 4.4: Sequence diagram for Get identified insect use case.

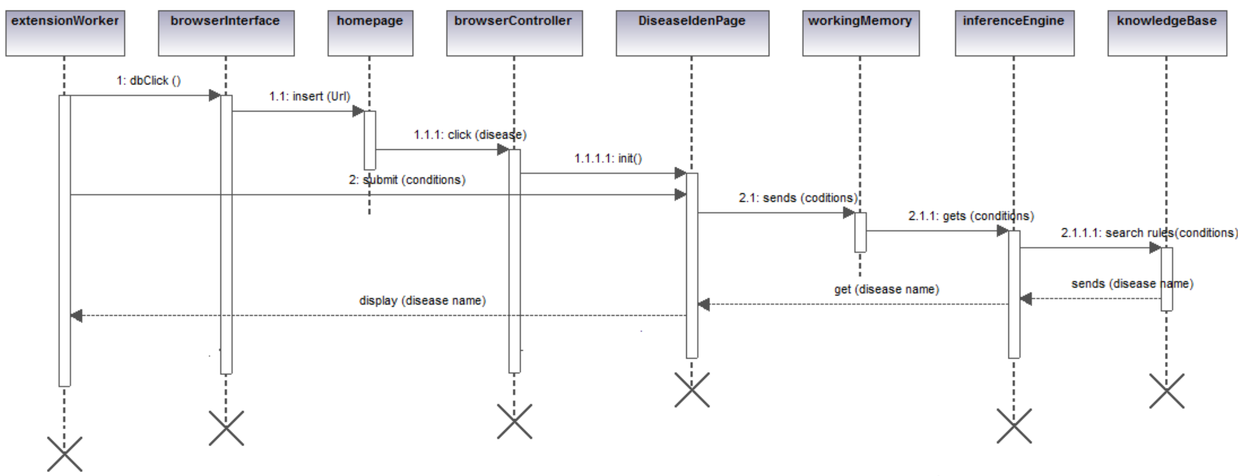


Figure 4.5: Sequence diagram for Get identified disease use case.

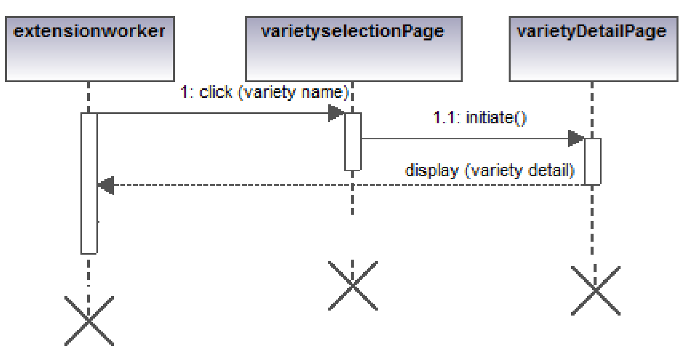


Figure 4.6: Sequence diagram for view variety detail use case.

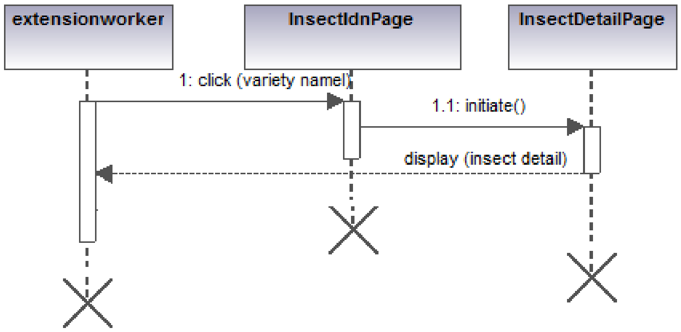


Figure 4.7: Sequence diagram for view insect detail use case.

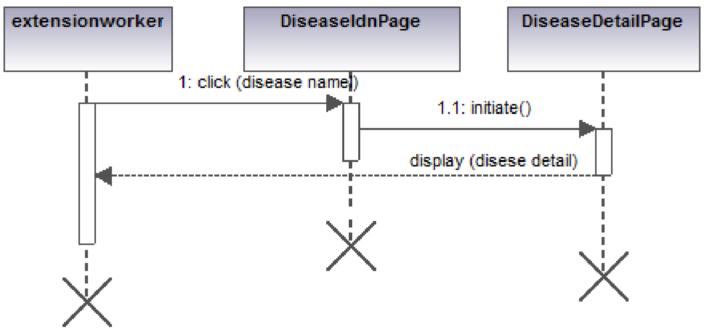


Figure 4.8: Sequence diagram for view disease detail use case.

# CHAPTER FIVE: SYSTEM DESIGN

In this chapter, how the knowledge is acquired, the architecture and subsystem decomposition of the system will be discussed briefly.

## 5.1. Knowledge Acquisition

To acquire the required knowledge, we followed the knowledge acquisition procedure discussed in [43, 44]. The knowledge of the varieties' details and various disorders were obtained from specific literatures [8, 9, 22, 25] and symptoms descriptions and rules from domain experts, i.e. entomologist and pathologists.

After the interviews with the experts and a thorough review of the literatures, we designed Teff variety, insect and symptom registration sheets (see appendix A). The Teff variety registration sheet gives information about agronomic characteristics and suitable agro ecological zones of the crop. The insect registration sheet gives information about insect morphology and insect damage; the disease registration sheet gives information about the affected organ of the crop, the disease symptoms appearances, color and appearance of pustules, color of fungal structure, appearance of the plant and color of the spot. After designing the registration sheets, variety selection, insect identification and disease diagnosis forms were designed as shown in tables 5.1, 5.2 and 5.3.

Table 5.1: Variety selection form

| |
|---|
| *Recommended Varieties: DZ-Cr-82, DZ-Cr-358*<br>*Altitude (masl) >= 1500 and < = 2300*<br>*Annual Average Rainfall (mm) > 900*<br>*Main plant species Acacia, Erythrina, Cordia, Ficus*<br>*Agro Ecological Zone Dry Medium Highland*<br>*Days to Maturity (Number of Days) Medium*<br>*Seed Color White* |

Table 5.2: Insect identification form

| |
|---|
| *Possible pests: Schistocerca gregaria*<br>*Insect on field Observed*<br>*Insect type Beetle-like*<br>*Insect Flier*<br>*Insect color grey brown*<br>*Feeding style eat leaves from the margin inwards* |

Table 5.3: Disease diagnosis form

| |
|---|
| *Possible Disease: Teff Rust (Uromyces eragrostidis*<br>*Symptoms appear on leaf or leaf sheath*<br>*Leaf Appearance Raised pustule*<br>*Color of Pustules dark or reddish brown*<br>*Pustules Appearance circular or slightly elliptica* |

### 5.2. Architecture of the System

The overall system structure is depicted in Figure 5.1. User – system interaction takes place via user interface which runs on the client machine. All it provides is a user interface to send user input and receive and display the output.

The user interface sends user response (answers to questions) to the working memory. The working memory holds all the responses as temporary data. The inference engine matches the data and rule's premises from the knowledge base. Finally, the solutions are delivered to the users.

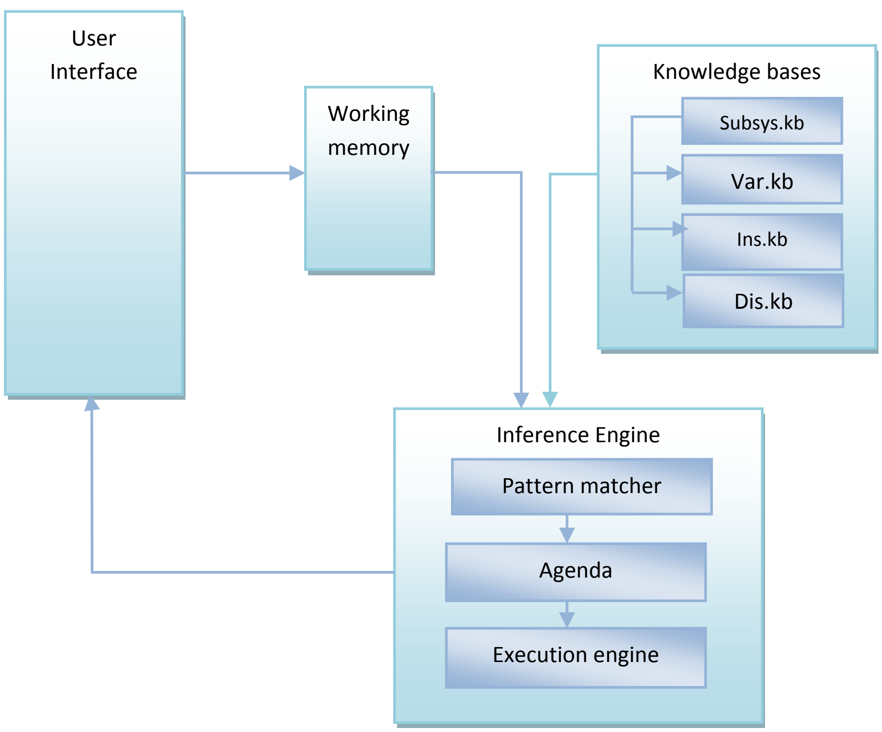


Figure 5.1: The architecture of the system

*The knowledge base*

Once all knowledge required to build the knowledge base is acquired through knowledge acquisition process as shown in the registration forms, the knowledge is represented so that the rule engine can understand it, shown as an example in prototype of the system part of this document. The *knowledge base* contains all the rules the system knows. The inference engine compares these rules' antecedent part with that of the users' response which is stored in the working memory.

*The inference engine*

The primary objective of the inference engine is to apply rules to data which is held with java applet object (working memory). The inference engine controls the whole process of applying the rules to the transient java object to obtain the outputs of the system. That makes the *inference engine* the central part of a rule engine.

The system collects relevant information from user and stores the information in the working memory as objects then the inference engine matches all the rules to the transient object (using the *pattern matcher*) to decide which ones should be activated. The activated rules together with any other rules activated in previous cycles will be ordered to form the agenda and the right-hand sides the rules will be executed or fired by *execution engine*.

*The working memory*

All data the inference engine operates on need to be held as transient object. The *working memory* contains all pieces of information the system is working with such as user responses to the system's request.

### 5.3. Subsystem Decomposition

In order to reduce the complexity of the system, the system is decomposed into simpler parts, called subsystems. Each subsystem can be represented as a directory containing all the files implementing the subsystem. The sub systems are variety selection, insect management and disease management. Each subsystem has its own knowledgebase and detail html pages. Figure 5.2 depicts the decomposition of the system.

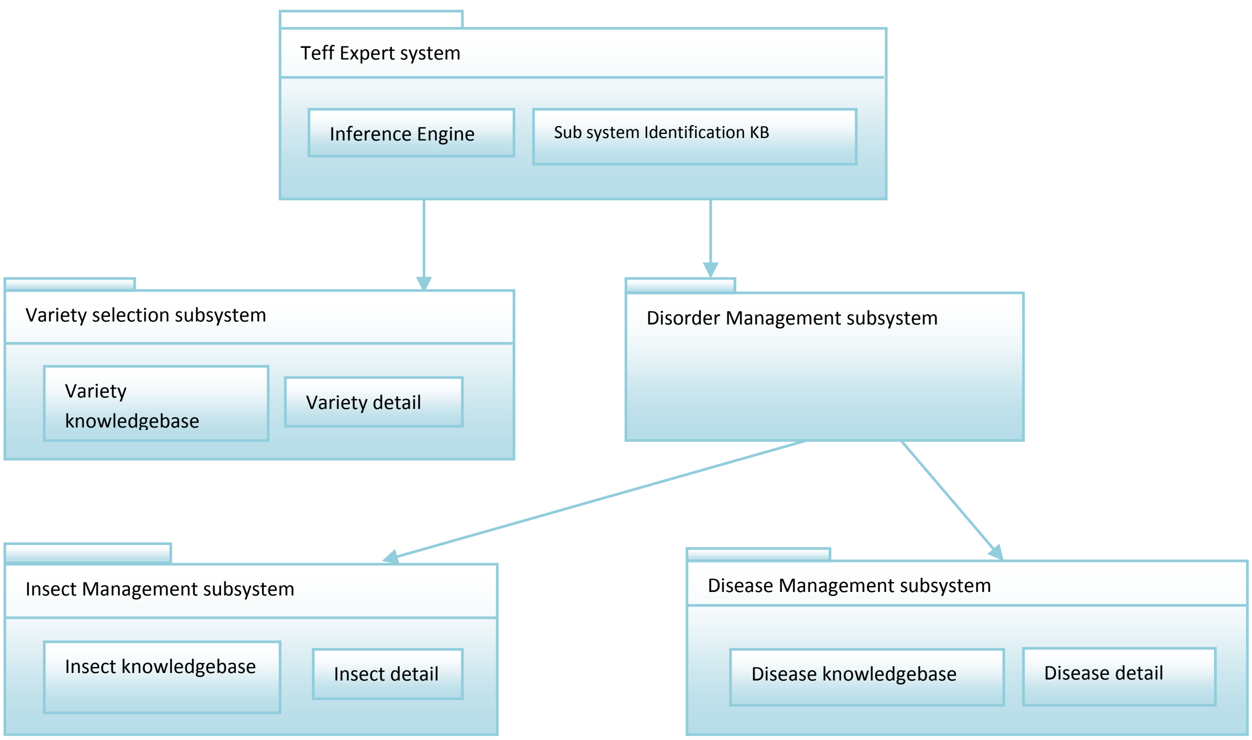


Figure 5.2 Subsystem Decomposition of the system

### 5.4. Deployment Diagram

Deployment diagram show the physical relationship between hardware and software in the system. The subsystems of the system identified in the preceding section are mapped onto the client and server nodes as shown in Figure 5.3.

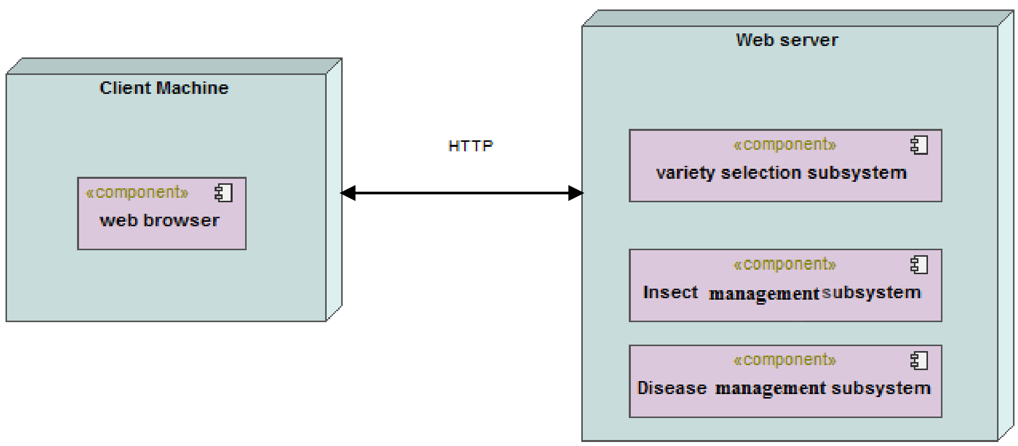


Figure 5.3 Deployment Diagram of the system

# CHAPTER SIX: IMPLEMENTATION

The requirements of the system and its analysis models have been identified and produced respectively. The domain knowledge has also been acquired and presented in Chapter Five. In this chapter, the representation of the acquired knowledge and the developed prototype of the system are discussed briefly.

## 6.1. Knowledge Representation

In the knowledge base of the expert system, a rule is defined by the keyword '**RULE**' followed by a short description of the rule enclosed in square brackets. This is followed by the rule premise with the keyword '**If**'. The logical expressions consist of an attribute name, any relational operator or any comparison quantity. The rule consequent is mentioned with keyword '**Then**'. Rule elements are not case sensitive. Attributes in the rule engine are string (text), numeric and boolean. The following example illustrates the knowledge representation.

## Example:

```
REM: VARIETY SELECTION FOR DRY MEDIUM HIGHLAND
RULE [DMH]
If [Varalt] < 2300masl and
[Varalt] > 1500masl and
[Varrain] < 900mm and
[VarDMH ps]: "Acacia" "Cordia" "Ficus"
Then [VarAez] = "Dry Medium Highland"
RULE [DMH]
If [VarAez] = "Dry Medium Highland” and
[Varmat]= "medium" and
[Varcolor] = "pale white"
Then [Recommended variety] = "DZ-01-354, DZ-01-787, DZ-01-974, DZ-Cr-1285"
RULE [R]
If [Varsymptoms appears on] = "leaf or leaf sheath" and
[Varleafappearance] = "Raised pustules" and
[VarColor of pustules]= "dark or reddish brown" and
[Vardarkpustules appearance] = "circular or slightly elliptical"
Then [Possible Diagnosis] = "teff Rust (Uromyces eragrostidis)"
RULE [FI]
If [field insect] = true and
[Vartype of insect] = "fly-like" and
[Varflyleaves appearance]= "long white stripes on the leaves"
Then [observed pest] = "Diuraphis noxia Mordvilko"
```

## 6.2. Prototype of the System

In this section of the chapter, the prototype of the system is described. How the user interacts with the system and some of the results of interaction with the system along with the screen shots are described.

When a user starts the application, he/she will see a home page of the system that is shown in Figure 6.1. The expert system would initially load the "subsystem Identification" knowledge base that would use prompts and rules to determine whether the "variety selection", “insect identification” or “disease identification” subsystems to be active. Then, the appropriate subsystem knowledge base would be loaded, and the consultation continues.

The expert system includes four knowledge bases: *subsystem identification* that contains meta-rules and prompts used to determine the next knowledge base to load, *variety* that contains rules and prompts to variety selection subsystem, *insect* that contains rules and prompts to insect identification subsystem and *disease* that contains rules and prompts to disease identification subsystem.

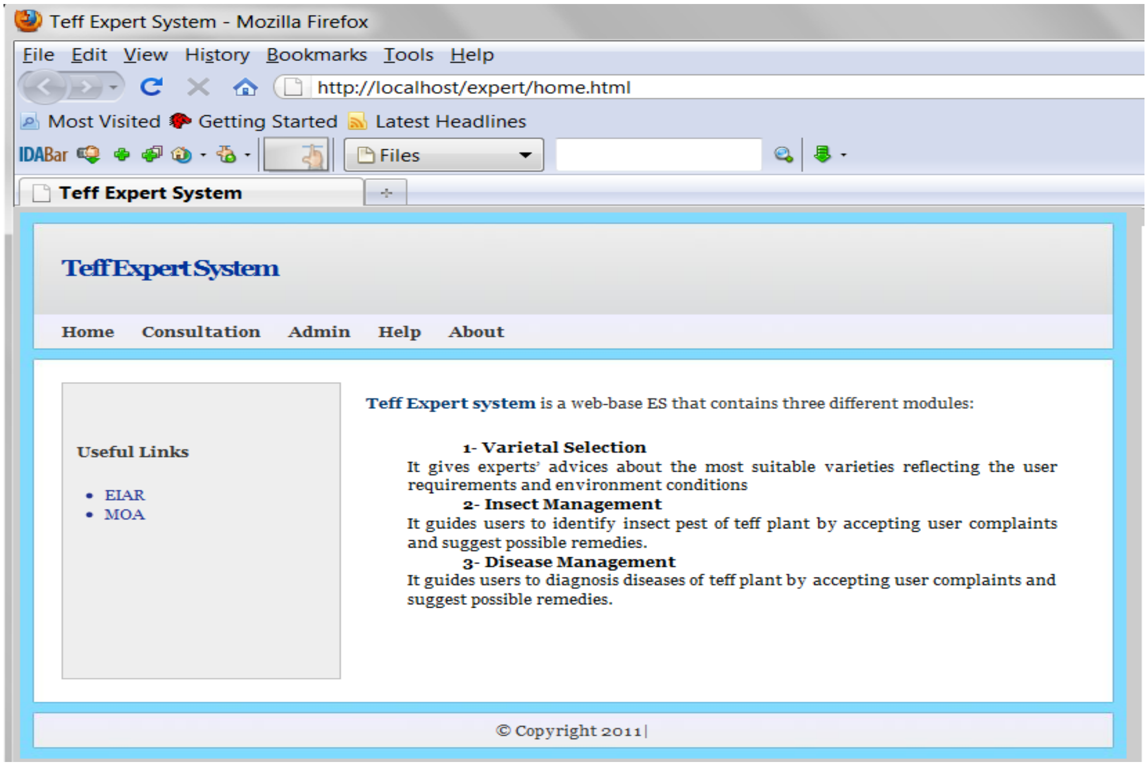

Figure 6.1 Home page of the system

When the "Consultation" menu is clicked on the home page, the knowledge base is loaded and prompt users to select what type of consultation he/ she wants to get as shown in Figure 6.2.

Figure 6.2 Subsystem selection page of the system

If the user clicks on variety selection option and clicks on submit your response button, the system will prompt sequence of questions to determine the agro ecological zone of the user. The following page as shown in Figure 6.3 will be displayed to ask user to enter the altitude of the location with user's certainty level. Whenever the user clicks on *why ask* button to see why such a question has been asked, the user will see the goal or sub goal of the inference engine is currently working on, the attribute it is trying to find and the rule that needs the value of this attribute.

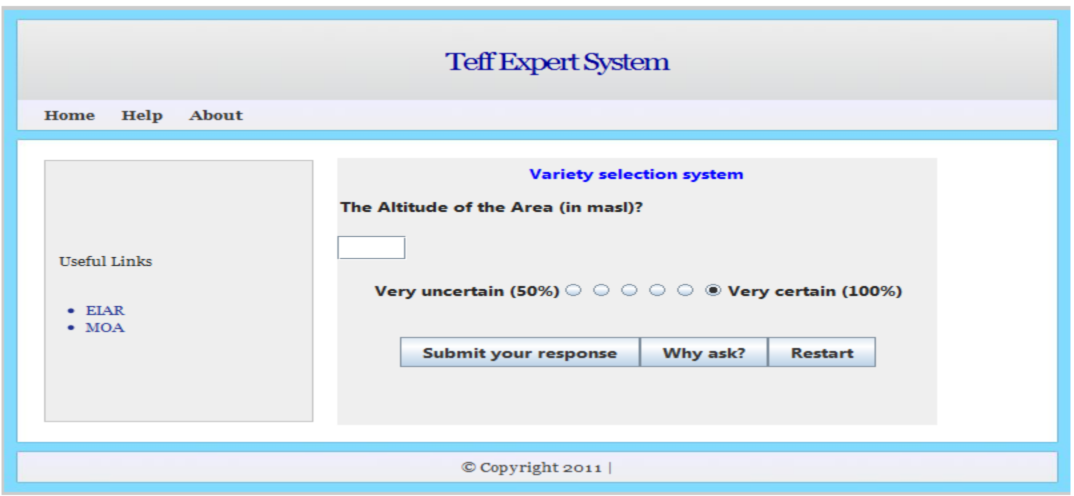


Figure 6.3 Altitude entry page

After entering the altitude and clicking the submit your response button, the following page as shown in Figure 6.4 will be displayed to prompt user to enter the annual average rainfall amount of the location with user's certainty level.

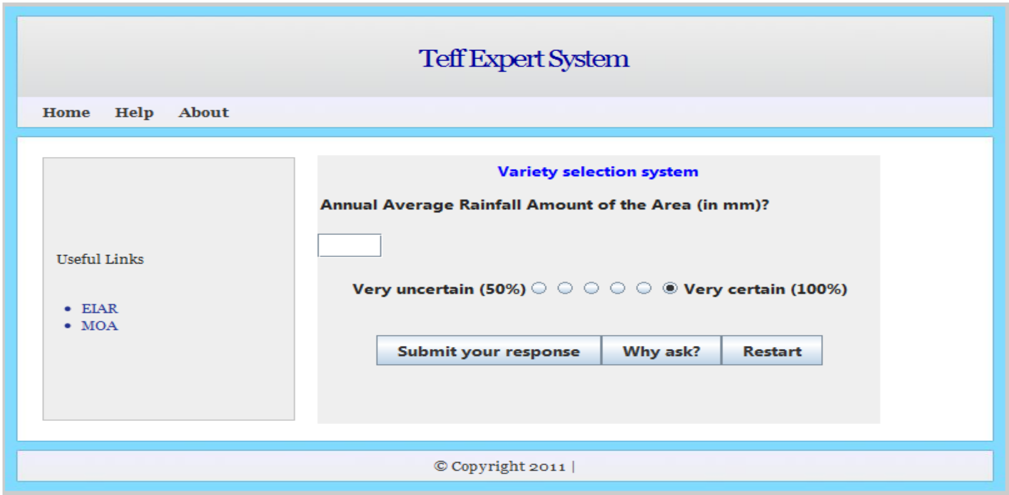

Figure 6.4 Rainfall amount entry page

The system also asks user to select the main plant species on the area as depicted in Figure 6.5.

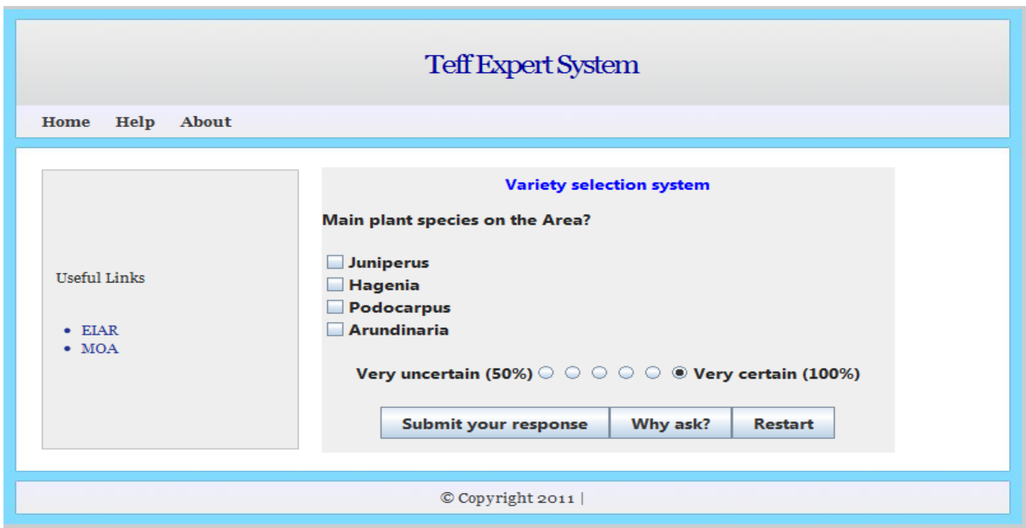

Figure 6.5 Dominant plant species selection page

When the user chooses the dominant plant species in the area and clicks on the Submit your response button, the system will be in a position to determine the agro ecological zone of the user. But to recommend the suitable variety to the user, the system needs additional inputs from the user which reflects user particular interest such as seed color, maturity days and variety status as shown in Figures 6.6 and 6.7.

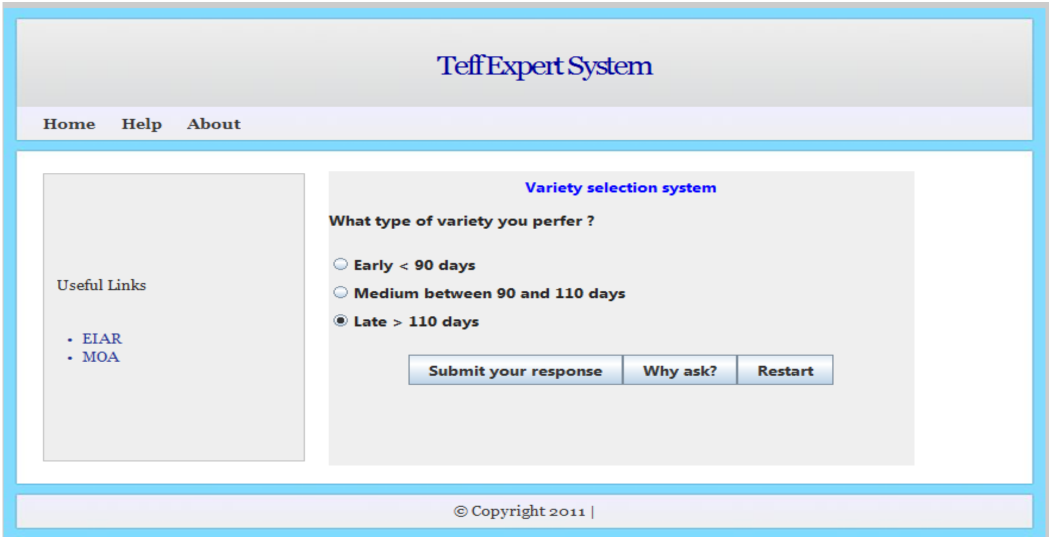


Figure 6.6 Variety status selection page

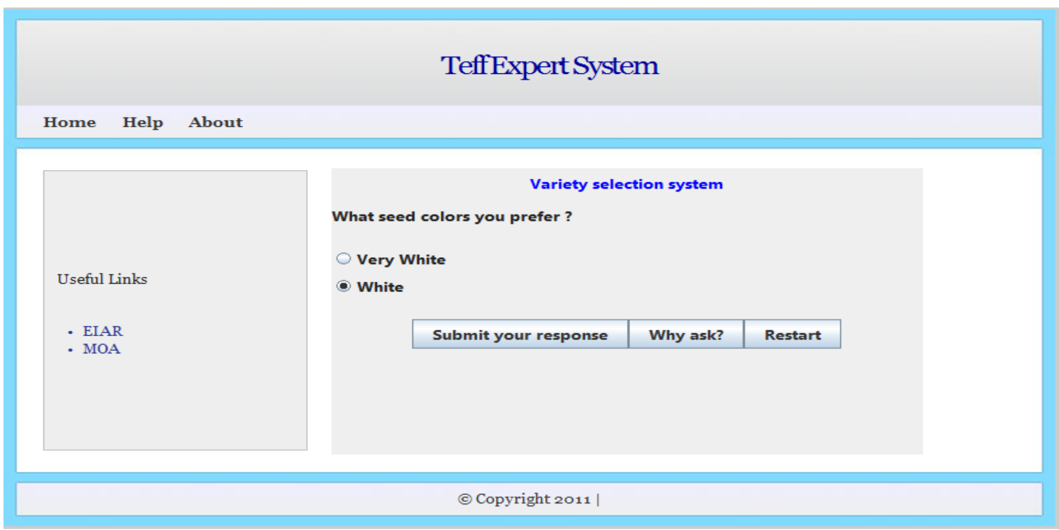


Figure 6.7 Seed color selection page

Finally, the system will recommend the potential list of varieties as shown in Figure 6.8. Detail information about the recommended variety can be seen by clicking on the name of the variety selected and the result will be displayed as shown in Figure 6.9.

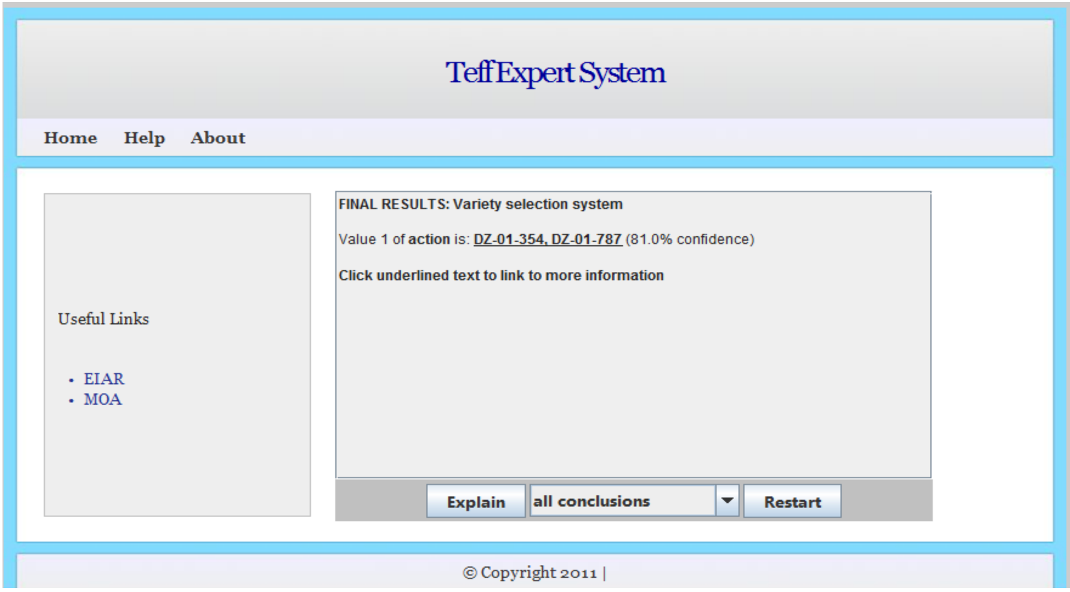


Figure 6.8 Recommended list of varieties page

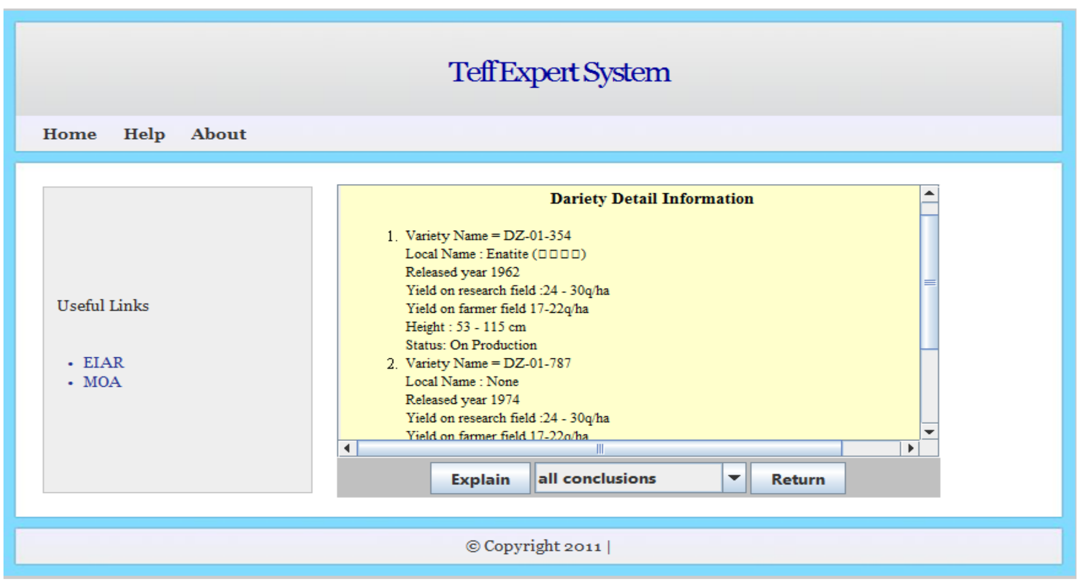


Figure 6.9 Detail description of the recommended list of varieties page

When the "restart" button is pressed anywhere during a consultation, control transfers to the subsystem identification startup knowledge base.

If the user clicks on the *Explain* button with *all conclusions* showing in the drop down list of resolved attribute values user will see detailed explanation of the recommendation. The explain button and restart button are used to see how the system arrives at a particular conclusion and clear all temporary data which stored on the working memory respectively.

When the user clicks on “Return” button in the page which displays detail description of the recommended list of varieties, control transfers to the page which displays the recommended list of varieties.

For disease and insect management, similar procedure will be followed.

**User uncertainty**

Users might not be sure about their responses. The user interface of this expert system provides users to represent their degree of confidence in a response with a numerical scale whenever necessary. They are given to an option to enter their certainty about to the response which ranges from 50% to 100%. If the user omits the certainty level, the system takes the default level which is 100%. The inference engine, before giving recommendation, compares all user confidence level about the response with that of the minimum certainty factor (threshold level) which is 70 %, set for the system to accept user response as valid.

Another approach used in this system to manage uncertainty is based on using simple inputs in the form of ‘‘Yes’’, ‘‘No’’ and ‘‘I don’t know’’. For example, in disorder cause identification, the user is first prompted with a question asking whether insect or larvae are observed on leaves or in the field. Selecting one of these answers (Yes, No, I don’t know) will increase the accuracy of the diagnosis by reducing the list of possible causes. The value ‘‘Yes’’ will eliminate the cause without insect, while the value ‘‘No’’ will minimize those with insect. The value ‘‘I don’t know’’ will take into account both types of causes, insect or disease.

# CHAPTER 7: SYSTEM EVALUATION

Expert system evaluation is the process of determining the quality of the expert system and the advice it provides. It is an important component of any software development effort to ensure correctness of the outputs and user satisfaction with the product in solving the given problem.

Two domain experts and thirteen extension workers were participated in the evaluation. There are a total of 15 respondents who were asked to assess the system. The respondents are provided the system evaluation questionnaire. In the questionnaire, users are required to evaluate the system using ordinal scale from strongly disagree (rating 1) to strongly agree (rating 5). From the result analysis, as shown in Figure 7.1, it can be concluded that the respondents agreed that the system satisfy the following criteria: usability, impact of the system in the behavior and decisions of the user, impact of the quality of the information provided to the user and usefulness. On the average, overall system performance was rated as acceptable. Please refer to the appendix B for the system evaluation questionnaire and appendix C for the result of system evaluation by the respondents.

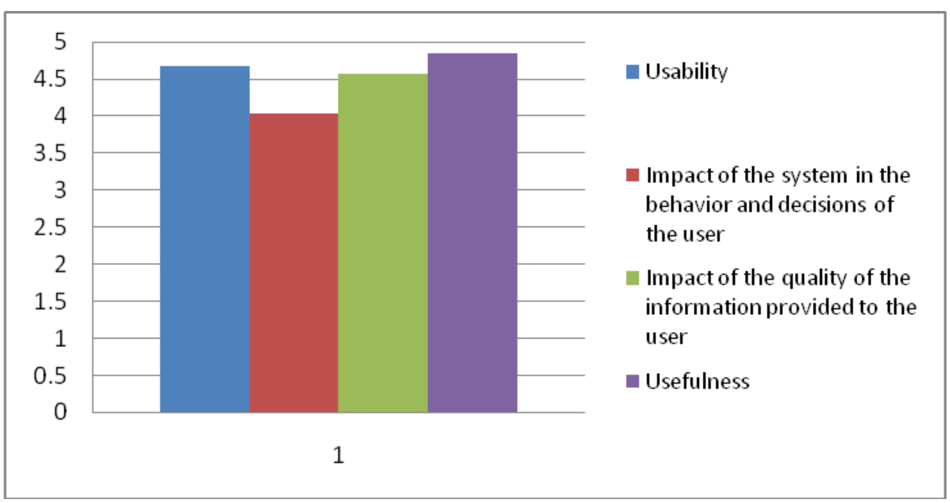


Figure 7.1 Result analysis of users' feedback towards the system

CHAPTER EIGHT: CONCLUSION AND FUTURE WORKS

## 8.1. Conclusion

Expert systems can be one of the most useful tools for accomplishing the task of providing farmers with the day-to-day, integrated decision support needed to grow their crops. Countries like Egypt, India and Pakistan have used agriculture expert system as a better mechanism to disseminate experts' knowledge.

However, in Ethiopia agricultural experts' assistance is not easily available. There should be a mechanism to make this assistance available to users. This project work is about designing and implementing a web based expert system for teff variety selection and disorder management.

This system will help users particularly agriculture extension workers in Ethiopia who are mediator between farmers and agriculture researchers to have immediate experts' assistance easily and quickly. Appropriate knowledge has been acquired and represented from the agriculture experts and also from related literatures. The system has three subsystems. A variety selection subsystem helps the users to select appropriate Teff variety which reflects their agro ecological zone and their particular interest. The insect management sub system helps the users to identify and control the possible insect pests responsible for the crop disorder and a disease management subsystem guides user to identify and manage diseases. The prototype has been evaluated by domain experts and extension workers and the analysis of the result shows that the system is acceptable.

## 8.2. Future Works

In order to improve the quality of the system developed in this project and extend it, the following points should be considered in the future.

- The system gives assistance only on parts of teff crop cultivation activities, it is better to give advices on land preparation, weed management, and fertilizer recommendation.
- Preparing the system in local languages other than English
- The expert system is restricted to the most economically critical damaging pests and diseases reported so far. It is better to incorporate all potential pests and diseases.

# REFERENCES

[1]. S. Sarma, K. Robindro and A. Singh, “An Expert System for Diagnosis of Diseases in Rice Plant”, International Journal of Artificial Intelligence and Expert Systems (IJAE), Vol. 1, No. 2, 2010, pp.26–31.

[2]. R. Grove, “Internet-based expert systems”, Expert Systems: Journal of knowledge engineering, Vol. 17, No. 3, 2000, pp. 129-135.

[3]. R. Ahmed, “Expert System Applications in Agriculture,” 1998, Available: http://www arc.sci.eg/narims_upload/claesfiles/3759.pdf accessed on August 29, 2010.

[4]. R.E. Plant and N.D, Stone, Knowledge-based Systems in Agriculture, McGraw-Hill New York, 1991.

[5]. T. Teklu, “An overview of teff and durum wheat production in Ethiopia,” Available: http://www.eap.gov.et/content/Production/tefanddurum.pdf, 1999 accessed on August 25, 2010.

[6]. Abebaw Y., Geerts V., Hailu M., Leuveld K., Lont C., Mohemed N., and Mulder M., “Making dry land research matter: Addressing the need for European-African partnership for Ethiopia and Niger”, The AIDA project. Project No- 2006-043863, Wageningen Univ., Netherlands,2009,Available:http://www.md.kth.se/rtc/aida.jiscinvolve.org/knowledge.cta.int/AIDAFinalreport_wur_act_Studentproject_MakingDrylandResearchMatter_JAF_YKE_March.pdf accessed on October 23, 2010.

[7]. Ethiopian Central Statistic Authority, “Area and production of crops and crop utilization,” 2010, Available: http://www.csa.gov.et/nada3/index.php/ddi-browser/170/download/524.pdf accessed on August 2, 2010.

[8]. Ethiopian Institute of Agricultural Research, “የ ጤፍ ቴክኖሎጂዎችና አጠቃቀም,” Available: http://www.EAI.gov/crop/teff.pdf accessed on August 20, 2010.

[9]. Seyfu Ketema, "Tef. Eragrostis tef (Zucc.) Trotter. Promoting the conservation and use of underutilized and neglected crops," 1997, Available: http://www.underutilized-species.org/documents/publications/teff.pdf accessed on September 24, 2010.

[10]. Don Miller,"Teff Grass Crop Overview and Forage Production Guide A guide for producers, extension, educators and seed marketers,"2009,Available: http://www.producerschoiceseed.com/doc/TeffGrassManagementGuide.pdf accessed on August 2, 2010.

[11]. T. Pascal, "Concerted Effort for a Better Future," Mirimir, Ethiopian Institute of Agricultural Research, Vol. 10. No. 3, pp. 3-4, 2010.

[12]. Ethiopian Agriculture Products,"Cereal crops agricultural commodities," Available: http:// www.eap.gov.et/Agricultural-Commodities/Crops/Cereals.asp accessed on August 2, 2010.

[13]. Kassa B. and Degnet A., "Challenges Facing Agricultural Extension Agents: A Case Study from South-western Ethiopia," Available: http:// www.eap.gov.et/ChallengesFacingAgExctAgents.pdf accessed on August 25, 2010.

[14]. Samuel G, "Intensification of Smallholder Agriculture in Ethiopia: Options and Scenarios", in future Agricultures, Consortium Meeting at the Institute of Development Studies, 2006, Available:http://www.future-agricultures.org/index.php/intensification-of-smallholder-agriculture-in-ethiopia-options-and-scenarios.pdf accessed on September, 25, 2010.

[15]. Tefera, H. & Belay, G., "Eragrostis tef (Zuccagni) Trotter: Cereals and pulses/Céréales et légumes secs", PROTA, 2006, Wageningen, Netherlands.

[16]. Kebebew Assefa, Seyfu Ketema, Hailu Tefera, Tiruneh Kefyalew and Fufa Chundera, "Trait diversity, heritability and genetic advance in selected germplasm lines of tef [Erugrostis ref (Zucc.) Trotter]," Hereditas, Vol. 133, 2000, pp. 29-37.

[17]. N.I. Vavilov, The origin, variation, immunity and breeding of cultivated plants, The Ronald Press, New York, 1951.

[18]. Tadesse Ebba, “Teff (Eragrostis tef) cultivars: morphology and classification,” Debre Zeit Agricultural Research, Bulletin No. 66, 1975.

[19]. G.R Jansen, L.R. Dimaio, and N.L. Hause, “Amino acid composition and lysine supplementation of teff,” Journal of Agricultural and Food Chemistry, Vol. 10, 1962, pp. 62-64.

[20]. Mulugeta A. “Floral morphogenesis, temperature effect on growth and development and variation in nutritional composition and distribution among cultivars in Eragrostis tef (Zucc.) Trotter,” doctoral dissertation, Wisconsin Madison Univ., Wisconsin, 1978.

[21]. Melak H. Mengesha, “Chemical composition of teff (Eragrostis tef) compared with that of wheat, barley and grain sorghum,” Economic Botany, Vol. 20, No. 3, 1966, pp. 268-273.

[22]. E. Tadesse, “Teff (Eragrostis tef): The cultivation, usage and some of the known diseases and insect pests,” DebreZeit Agricultural Experiment Station Bulletin No. 60, 1969.

[23]. L. Molineaux and Biru Mengesha, “Teff consumption, hookworm infestation, and hemoglobin levels: a preliminary report,” Journal of Health. Vol.7, No. 3, 1965, pp. 123-126.

[24]. AlemayehuR.,“Teff:Post-harvestOperations,”Available: http://www.fao.org/inpho/content/compend/text.html accessed on September 10, 2010

[25]. Hein B., “insect pests of cereals in Ethiopia identification and control methods,” FAO/UNDP Project ETH/86/029 Crop Protection Phase II, Addis Ababa, 1989, Available: http://ethiopia.ipm-info.org accessed on August 15, 2010.

[26]. Hayes-Roth, “Rule-based systems,” Communications of the ACM, Vol. 28, No.9, 1985, pp.921–932.

[27]. J.P. Ignizio, Introduction to Expert Systems: The Development and Implementation of Rule-Based Expert Systems, McGraw-Hill, Inc, New York, 1991.

[28]. Harmon, P. and D. King, "Artificial Intelligence in Business: Introduction to Expert Systems: MYCIN," 1985, Available: http://www.psy.haifa.ac.il/MYCIN.pdf accessed on September 12, 2010.

[29]. Ernest Friedman Hill, Jess in Action: Java Rule-Based Systems, Manning Publications Co., Greenwich, 2003.

[30]. Sasikumar, Ramani, Muthu, Raman KSR. Anjaneyulu and Chandrasekar, A Practical Introduction to Rule Based Expert Systems, Narosa Publishing House, New Delhi, 2007.

[31]. M.R. Klein and L.B. Methlie, Knowledge-based Decision Support Systems with Applications in Business, 2nd Ed., John Wiley & Son, New York, 1995.

[32]. W.A. Donald, A Guide to Expert Systems, Addison Wesley, Boston, 1986.

[33]. Khan, Razzaq, Irfan, Maqbool, Farid, Illahi and T. ul amin, "Dr. Wheat: A Web-based Expert System for Diagnosis of Diseases and Pests in Pakistani Wheat," In Proceedings of the World Congress on Engineering, London, U.K, 2008.

[34]. Gary Riley,"what is CLIPS," 2007, Available: http://www.ghg.net/clips/WhatIsCLIPS.html accessed on December 25, 2010.

[35]. William van Melle, Edward H. Shortliffe, and Bruce G. Buchanan, Rule-Based Expert Systems: The MYCIN Experiments of the Stanford Heuristic Programming Project, Addison Wesley, MA, 1984.

[36]. Schmuller, J. and Yingsheng, M., "Expert System Shells at Work," 1992, Available: http://www.pcai.com/web/ai_info/expert_systems.html accessed on October 5, 2010

[37]. P. Sell, Expert Systems: A Practical Introduction, Halsted Press, New York, 1985.

[38]. C. Townsend, Mastering Expert Systems with Turbo Prolog. Macmillan Inc., Indonesia, 1987.

[39]. J. Liebowitz and D. DeSalvo, Structuring Expert Systems, Yourdon Press, Englewood, 1989.

[40]. Erika de Kock, “Decentralizing the codification of rules in a decision support expert knowledge base, M.S. thesis, Faculty of Engineering, Department of Computer Science, Pretoria Univ. , 2003, Available: http://upetd.up.ac.za/thesis/available/etd-03042004-105746 accessed on October 13, 2010.

[41]. Niwa, K., Sasaki, K. and Ihara, H, “An Experimental Comparison of Knowledge Representation Schemes, in Principles of Expert Systems,” IEEE Press, New York, 1988, available http://www.aaai.org/ojs/index.php/aimagazine/article/download/435/371.pdf accessed on December 10, 2010.

[42]. K.A. Bergsma, “Developing and testing an expert system for diagnosing chilling injury of fresh fruits and vegetables”, M.S. thesis, Florida Univ., Florida, U.S.A, 1993, Available: http://www.uf.edu/expert accessed on December, 2010.

[43]. K. McGraw and Harbison-Briggs, Knowledge Acquisition, Principles and Guidelines, Prentice-Hall International Editions, London, 1989.

[44]. Wada, T., Motoda, H., Washio, T., “Knowledge acquisition from both human expert and data”,SpringerVerlag,Berlin,2001,Available:http://www.springerlink.com/index/4qm8vrwb592r8a0q.pdf accessed on December, 25, 2010.

[45]. E. Turban, Decision Support and Expert Systems: Management Support Systems, 4th ed., Prentice-Hall, NJ, 1995.

[46]. S.R. Harrison, “Validation of Agricultural Expert Systems,” Agricultural Systems, Vol.35. No.4, 1991, pp.265-285.

[47]. Jha, Iti, Deb, D. Malhotra, P.K., Bhatia, V.K. and Parsad, Rajender "Expert System on Wheat Crop Management", 2007, Project Report, IASRI Publication, Available: http://www.iasri.res.in/Sovenior/Article_15.pdf accessed on November 13, 2010.

[48]. Central Laboratory for Agricultural Expert Systems, "Barely Expert System," Available: http://es.claes.sci.eg/barley/ accessed on September 20, 2010.

[49]. Rafea, A., El-Azhari, S. Ibrahim, I., Edres, S., Mahmoud, M., "Experience with the development and deployment of expert systems in agriculture," In Proceedings of IAAI-95, Montreal, Canada, 1998.

[50]. Rafea A. "Agricultural expert systems development in Egypt," In Proceeding of International Conference on Expert Systems for Development (ICES), Bangkok, Thailand, 1994.

[51]. Paula M., Pedro I., and Manuel C., "Expert systems evaluation proposal," In Proceedings of the conference on Human interface: Part I, Springer-Verlag Berlin, Heidelberg, 2007.

APPENDIX A: Variety registration sheet

| ***Attribute*** | ***Value*** |
|---|---|
| *Altitude (masl)* | |
| | *> 2300 and 3200* |
| | *<2300 and >=1500* |
| | *< 1500* |
| *Annual Average Rainfall (mm)* | |
| | *> 900* |
| | *<=900* |
| *Days to maturity* | |
| | *Early (< 90 days)* |
| | *Medium (90- 110 days)* |
| | *Late (> 110 days)* |
| *Main Plant species in the area* | |
| | *Junipers* |
| | *Hagenia* |
| | *Podocarpus* |
| | *Arundinaria* |
| | *Erythrina* |
| | *Cordia* |
| | *Ficus* |
| | *Acacia* |
| *Variety status* | *Under production* |
| | *New release* |
| *Variety Seed color* | *Very white* |
| | *White* |
| | *Pale white* |
| | *Brown* |
| *Agri. Zone* | *Moist Highland* |
| | *Dry Highland* |
| | *Moist Medium Highland* |
| | *Dry Medium Highland* |
| | *Dry Highland* |
| | *Moist Lowland* |
| | *Dry Lowland* |

APPENDIX B: System Evaluation Questionnaire

**Expert System for Teff crop Management**
**System Evaluation Questionnaire**

Objective:
This survey is conducted to gather data on the user evaluation of Teff Expert system.

**Instruction**: Choose and circle the most appropriate score for each question given below.

| | Score |
|---|---|
| Strongly Disagree | 1 |
| Disagree | 2 |
| Neutral | 3 |
| Agree | 4 |
| Strongly Agree | 5 |

| | **Evaluation Questions** | **Rating Scales** | | | | |
|---|---|---|---|---|---|---|
| 1. | Easiness to Learn | 1 | 2 | 3 | 4 | 5 |
| 2. | Easiness to Use | 1 | 2 | 3 | 4 | 5 |
| 3. | Instructions given are easy | 1 | 2 | 3 | 4 | 5 |
| 4. | User interface design has consistent looks and feels. | 1 | 2 | 3 | 4 | 5 |
| 5. | The navigation links are easy to understand | 1 | 2 | 3 | 4 | 5 |
| 6. | The system increases the users' confidence | 1 | 2 | 3 | 4 | 5 |
| 7. | The system enables users to take decisions and provides guidance | 1 | 2 | 3 | 4 | 5 |
| 8. | The system will improve user performance | 1 | 2 | 3 | 4 | 5 |
| 9. | The system provides adequate explanations (How and why the decision was taken) | 1 | 2 | 3 | 4 | 5 |
| 10. | The system is complete enough to provide the intended advice | 1 | 2 | 3 | 4 | 5 |
| 11. | The decisions made by the system is correct compared to what the experts consider to be right | 1 | 2 | 3 | 4 | 5 |
| 12. | The system response quickly to inputs | 1 | 2 | 3 | 4 | 5 |
| 13. | The system can be used as a training tool to transfer the knowledge of the expert to middle level agriculture extension workers | 1 | 2 | 3 | 4 | 5 |
| 14. | The system is helpful to the user | 1 | 2 | 3 | 4 | 5 |
| 15. | The system can be used in the intended work environment | 1 | 2 | 3 | 4 | 5 |

APPENDIX C: Result analysis of users' feedback towards the system

| Evaluation Criteria | Q No | Questions | Rating Scales | | | | | Total Score | Average Score | Overall |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | | | |
| Usability | 1 | Easiness to Learn | 0 | 0 | 0 | 2 | 13 | 73 | 4.87 | 4.67 |
| | 2 | Easiness to Use | 0 | 0 | 0 | 10 | 5 | 75 | 4.33 | |
| | 3 | Instructions given are easy | 0 | 0 | 1 | 5 | 9 | 68 | 4.53 | |
| | 4 | User interface design has consistent looks and feels. | 0 | 0 | 0 | 2 | 13 | 73 | 4.87 | |
| | 5 | The navigation links are easy to understand | 0 | 0 | 0 | 3 | 12 | 72 | 4.8 | |
| Impact of the system in the behavior and decisions of the user | 6 | The system increases the users' confidence | 0 | 0 | 5 | 9 | 1 | 56 | 3.73 | 4.04 |
| | 7 | The system enables users to take decisions and provides guidance | 0 | 0 | 1 | 8 | 6 | 65 | 4.33 | |
| | 8 | The system will improve user performance | 0 | 0 | 4 | 6 | 5 | 61 | 4.07 | |
| Impact of the quality of the information provided to the user | 9 | The system provides adequate explanations (How and why the decision was taken) | 0 | 0 | 5 | 9 | 1 | 56 | 3.73 | 4.57 |
| | 10 | The system is complete enough to provide the intended service | 0 | 1 | 3 | 3 | 8 | 63 | 4.2 | |
| | 11 | The decisions made by the system is correct compared to what the experts consider to be right | 0 | 0 | 0 | 4 | 11 | 71 | 4.73 | |
| | 12 | The system response quickly to inputs | 0 | 0 | 0 | 1 | 14 | 74 | 4.93 | |
| Usefulness | 13 | The system can be used as a training tool to transfer the knowledge of the expert to middle level agriculture extension workers | 0 | 0 | 0 | 4 | 11 | 71 | 4.73 | 4.84 |
| | 14 | The system is helpful to the user | 0 | 0 | 0 | 2 | 13 | 73 | 4.87 | |
| | 15 | The system can be used in the intended work environment | 0 | 0 | 0 | 1 | 14 | 74 | 4.93 | |
| | | | | | | | | | | ***Overall evaluation = 4.53*** |

## Declaration

I, the undersigned, declare that this project is my original work and has not been presented for degree in any other university, and that all sources of materials used for the project have been acknowledged.

**Declared by:**

Name: ____________________________________

Signature: _________________________________

Date: _____________________________________

**Confirmed by advisor:**

Name: ___________________________________

Signature: ________________________________

Date: ____________________________________

Place and date of submission: Addis Ababa, February 2011.