Addis Ababa University

School of Graduate Studies

College of Natural Science

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Knowledge Based System for Oilseed Crop Disease Diagnosis and Treatment

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

By: Biruk Ambachew

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Name and Signature of the Members of Examining Board

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______________________	Advisor	____________	_____________

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LIST OF ACRONYMS

AI	Artificial Intelligence
DA	Development Agents
GDP	Gross Domestic Product
KBS	Knowledge based System
KR	Knowledge Representation
KBSODD	Knowledge Based System for Oilseed Disease Diagnosis

Abstract

Knowledge is currently attracting a great deal of interest in the business community including agriculture. Organizations are increasingly corning to regard their knowledge as a key asset and resource for organizational success. To manage organizational knowledge it is crucial to develop a knowledge based system that can facilitate intelligent and sound decision making.

In this study the researcher has tried to develop a knowledge base system for oilseed crop disease diagnosis and treatment. The knowledge is acquired from agricultural research center which is found in Holeta, Ethiopia and also from production manuals and books that was collected from, agricultural research center and the internet.

After acquiring the knowledge the next step was concept modeling and knowledge representation. Accordingly, decision tree was used for the knowledge modelling and rule based (if – then) method for the knowledge representation.

The final step was implementation and testing of the system. The prototype was implemented using visual prolog 7.5.

The performance of the prototype was evaluated by five domain experts and two development agents. The evaluation result shows that the prototype has rated 87.2 percent by the evaluators which is promising result.

The researcher has also tried to see the prospect of the system and how to make it applicable by discussing with experts.

The researcher believes that implementing the system with local language would greatly improve the system. The researcher also believes integrating the system with machine learning technique would greatly improve the performance of the system. Finally deploying the system on smart phones will make the system accessible to farmers and extension workers.

CHAPTER ONE
Introduction

1.1. Background of the study

As we know 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 [1]:

- It directly supports about 85% of the population in terms of employment and livelihood;
- It contributes about 50% of the country's gross domestic product (GDP);
- 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.

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 [1,3].

As per the information obtained from the document in the five year development strategic plan for sustainable development to end poverty (GTP), the Ethiopian government has been giving significant focus and attention for agriculture and rural development. This is accomplished by offering over 8 million acres of land to commercial farming investors. Expansion will open up opportunities for advanced farming technology, high value crops, progressive irrigation techniques, improved seeds, increased fertilizer use, and strategies to yield multiple harvests each year [1].

Furthermore, the productivity of the sub-sector is affected by poor management system and 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 quantity to feed the country's rapidly growing human population [1, 4, 5].

Ethiopia's export relies heavily on selected agricultural commodities originating mainly from smallholder peasant farming. Coffee, hides and skins, chat and oilseeds are the most important export items in the country [1, 5].

Oilseeds cover significant portion of the Ethiopian agriculture and play important role in the daily lives of its population, and hence are crucial in the national economic development efforts. Ethiopia is among the top five leading oilseed producing countries of the world [4, 6, 13].

The growing demand in the world market for these specialty products and the available capacity to expand production could make oilseeds turn into one of the engines of economic growth of Ethiopia in the 21st century [4, 6, 13]. As mentioned above oilseeds are the largest export earner for the country and already more than 3 million smallholders are involved in its production. Actually Oilseeds are not **only an export item**. There is also large demand for it in the domestic economy since it is used to produce edible oil and oilcake [4, 5].

The total earning from the oilseeds business, particularly from the export market, has increased over the past few years. Ministry of Trade confirmed that Ethiopia secured over 60 million USD from oilseed export in one month (February, 2012) [6].This shows the potential of oilseed for being among the number one export earner [6, 13].

To expand industrial development and increase overall economic growth, it's very essential to support and develop the agriculture sectors. This can be achieved when crop management and decisions are assisted with expert's knowledge and by utilizing up to date technologies [1, 4].

Even though the number of agricultural expert is increasing, as compared to the past, there is still a significant shortage of specialized experts to support the needy farmers. When development agents encounter technical difficulties in particular production areas, they usually request help from weredas or zones [1, 4]. There are situations where the experts are unable to respond to requests due to distance limitations. This will eventually affects yield potential and sometimes results in total crop loss due to delayed response for situations that need urgent technical support to farmers. Developing knowledge base system would benefit the knowledge seeker in this case the farmer and development agents (DA), when there is scarcity of knowledge expert [1, 3, 10].

This research is conducted with an aim of assisting oilseed crop management decisions; thus reducing the time and money required to provide expert advice to DAs and farmers.

1.2. Knowledge based system (KBS)

Knowledge as defined by Oxford dictionary is facts, information, and skills acquired by a person through experience or education; the theoretical or practical understanding of a subject.

Within business and knowledge management, two types of knowledge are usually defined, namely explicit and tacit knowledge [2, 24].

Tacit knowledge is the kind of knowledge that is difficult to transfer to another person by means of writing it down or verbalizing it. For example, that London is in the United Kingdom is a piece of explicit knowledge that can be written down, transmitted, and understood by a recipient. However, the ability to speak a language, knead dough, play a musical instrument or design and use complex equipment requires all sorts of knowledge that is not always known explicitly, even by expert practitioners, and which is difficult or impossible to explicitly transfer to other users [2, 24].

The term "tacit knowing" or "tacit knowledge" was first introduced into philosophy by Michael Polanyi in 1958 in his magnum opus Personal Knowledge. He famously summarizes the idea in his later work The Tacit Dimension with the assertion that "we can know more than we can tell.

Explicit knowledge is knowledge that can be readily articulated, codified, accessed and verbalized. It can be easily transmitted to others. Most forms of explicit knowledge can be stored in certain media. The information contained in encyclopedias and textbooks are good examples of explicit knowledge.

KBS is simply human knowledge stored on machine for use in problem-solving. KBS are computer applications which embody some non-algorithmic expertise for solving certain types of problems [2, 3].

In agriculture, KBS unite the accumulated expertise of individual disciplines into a framework that best addresses the specific, on-site needs of farmers. KBS combine the experimental and experiential knowledge with the intuitive reasoning skills of specialists to aid farmers and DA in making the best decisions for their crops [2, 3, 8].

KBS could be applied in many areas of agriculture including, disorder diagnosis, disorder treatment, irrigation scheduling, fertilization scheduling, fertilizer recommendation, plant care and other areas [7, 8, 16, 17, 20].

Since Ethiopia is a country with more than 80 % farmers from the whole population it's logical to assume shortage of experts in agricultural fields. KBS has a potential to help by being source of information when experts are not available.

KBS involves

1.3. Statement of the problem and its justification

1.3.1. Importance of agriculture and oilseed in Ethiopia

Agriculture constitutes the backbone of the Ethiopian economy with more than 80% of the population depend on it for their income [1]. All commercial crop production systems in existence today are potential candidates for KBSs [3, 7, 8, 10 15, 16].

Oilseeds cover significant portion of the Ethiopian agriculture and play important role in the daily lives of its population, and hence crucial in the national economic development efforts. In Ethiopia, oilseeds are the largest export earners among coffee and chat [4] for the country and are anticipated to play an important role in the five year Growth and Transformation Plan [1, 4].

1.3.2. Shortage of agricultural expert

Expert knowledge (including agricultural experts) is often scarce and valuable. KBS are computer programs that capture some of that knowledge and allow its dissemination to others [2, 7, 8, 14].

Agricultural production has evolved into a complex business requiring the accumulation and integration of knowledge and information from many diverse sources [7]. In order to remain competitive, the modern farmer often relies on agricultural specialists and advisors who provide information for decision making [3, 4, 7, 8, 13]. 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 [3, 7, 8].

In Ethiopia agricultural experts are not always available and, may not be accessible to every farmer. Due to shortage of DA, each agent has to serve on average more than thousand farmers [1, 3, 14].

As per personal communications with experts in **Holeta agricultural institute** there are limited oilseed expert in Ethiopia.

Currently, production and productivity levels of Ethiopian oilseeds are far lower than the potential. There is a big gap in the productivity of oilseeds at research and the farmer's field [4].

1.3.3. Potential of KBS in agriculture

Knowledge management is currently attracting a great deal of interest in the business community including agriculture [2, 8].Decision-making processes have become somewhat more intelligent and intensively knowledge dependent. Decision making based on intensive knowledge becomes the key for success and survival of an enterprise. A topic of high importance is how to effectively use this intensive knowledge [2, 3, 9].

Ethiopia is one of the fastest growing economies in the world [1, 4]. Using the technology effectively will support the growth of the country. KBS is being used by many countries to support decision making process [7, 8, 9, 16, 17, 20].

Despite the fact that all production area is rural and doesn't have electricity access, the Ethiopian electric power corporation has a rural electrification program in its plan [1, 13, 14]. This will create favorite condition to get access to electric power for computer and other electronics devices. In addition solar and wind technologies are now becoming common source of power [1,3, 10].

The price of computer and electronics equipment is decreasing every year. Thus the trend is towards having access to low cost technology (computer, smart phone) and there is promising future for this resources to be affordable to everyone or organization [1, 3, 10].

KBS for agriculture would take the form of integrated crop management decision aids which would encompass crop diseases control, nutritional problems, fertilization, weed control-cultivation, herbicide application, and insect control [3, 7, 8, 10, 11, 15, 16, 20]. The advantage of KBSs is that once developed they can raise the performance of the average worker to the level of an expert [2, 8].

Expert decision making strategy can be automated by defining a set of condition action rules in the domain area. Rule-based KBSs developed using this method is excellent in providing correct decision and explanation to the user [3, 11, 20].Since these system bases their decision on the knowledge they already fed, their reliability is perfect provided that their knowledge base is rich and up to date [3, 7, 9, 10 11, 20].

The proposed system doesn’t require users to have advanced knowledge of computers. It only requires basic knowledge of how to open and close the computer and applications software. Since Information technology is given as one course starting from preparatory to university level all DAs already has the capacity to use the proposed system.

The present study therefore aim to develop a KBS that can be used for diagnosis and treatment of oilseed crop disease.

1.4. Objective of the study

1.4.1. General Objective

The general objective of this study is to develop knowledge base system for oilseed crop disease diagnosis and treatment, and to assess the prospect of the proposed system.

1.4.2. Specific Objectives

To achieve the general objective stated above, the following specific objectives were accomplished throughout the study. These specific objectives are:

- To review literatures on concept and features of knowledge based system. To understand better the research problem, what has been done and what can be done on the research problem.
- To collect (extract) expert knowledge from Holeta Agricultural research center using interview and questionnaire.
- To try to find a way to make the proposed system accessible and easy to use.
- To model the acquired knowledge using decision tree.
- To represent the knowledge (rules) using Horn clause chaining using IF THEN conditions.
- To build the prototype knowledge base system using visual prolog 7.5.
- To test and evaluate the performance of the prototype.

1.5. Scope and limitation of the study

There are six oilseed crops produced in Ethiopia, which are Linseed, Niger seed, Sesame, Groundnuts, Safflower and Rapeseed [4]. These are produced in different regions of the country including Tigray, Amhara, Oromia, and Beneshangul [4, 13]. Since it's very difficult to acquire knowledge and develop model for these entire oilseed, due to the limited resource and time; the researcher selected those which are more economically important namely Linseed (telba), Niger seed (Noug) and Ethiopian mustard (Gomenzer). These were selected based on the recommendation I got from an expert from Holeta Agricultural Research center.

Most of the knowledge about oilseed was collected from Holeta Agricultural Research center. Tacit knowledge in particular was collected from three experts from Holeta Agricultural Research center specifically from highland oil crops improvement project. These persons are involved in knowledge acquisition and testing the proposed system by giving their knowledge and by being evaluators of the system.

In this study modeling was done using decision tree and knowledge representation was done using if –then rule base. Modeling uncertainty like probability and Credibility are not included in this work, because of limitation of time and recourses.

Also an integration of the developed KBS with machine learning was not also implemented on this study.

1.6. Significance of the study

Experts spend a long time studying and practicing their skills and they do their jobs well. But the trouble with human experts is that they are scarce, they are not always reliably accessible (they might get sick), they require payment, and in the long run they die, thus taking much of their knowledge with them [3, 8, 9, 15].

The findings of this study will benefit agricultural researchers or experts in a way that experts and researchers can get easily and timely access to disease identification and diagnosis system to manage oilseed crop diseases from knowledge base which stores the facts and rules that experts used to solve problem [3, 8].

Even though good attempts were made by many local researchers [3, 10, and 11] in developing knowledge based systems in the area of agriculture to support DAs or farmers, no study was conducted to develop a knowledge based system for oilseed crops disease diagnosis on local researches.

As stated in the problem section, there is shortage of oilseed expert in Ethiopia. The proposed research would help to fill the gaps that exist, by supporting DAs or farmers with the necessary knowledge.

1.7. Methodology of the study

The actions carried out in this study includes, knowledge acquisition, knowledge modeling, and knowledge representation, implementation, testing and accessing the prospect of the prototype, using appropriate techniques and tools.

1.7.1. Knowledge Acquisition and Modeling

Knowledge acquisition is a prerequisite and tiresome phase of KBS development. It consists of collecting (acquiring), structuring, organizing and studying knowledge. To build KBS that diagnoses and treats oilseed crops disease, relevant knowledge was acquired through interview, questionnaire and document analysis. The modeling was done using decision tree.

Sampling technique

In order to develop a knowledge based system that diagnoses and treats oilseed crop diseases, the researcher has decided an appropriate source of data. To draw out the required knowledge for this study, purposive sampling technique was used.

Purposive sampling would be the best way to elicit the views of persons who have expertise and knowledge about specific domain [3]. Accordingly, employing purposive sampling in this study is its appropriateness to capture demonstrable experience and expertise of the experts. Thus domain experts from Holeta Agriculture Research Center were selected purposively.

There are six oilseed crops produced in Ethiopia, and there are many diseases affecting the crop, and since the researcher is using purposive sampling the researcher has selected those diseases which are **economically important**.

Data collection/knowledge acquisition

Knowledge for this research was extracted from primary and secondary sources.

Primary sources used in this study are experts of oilseed crops, and plant pathologist at Holeta Agriculture Research Center.

Secondary sources used in this study are: Internet resources, books, production manuals of oilseed collected from Holeta agricultural Research center.

To acquire relevant knowledge for developing KBS, Interview Questionnaire and document analysis techniques were employed.

Interview: unstructured interview were conducted to extract 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 with pen and papers and the researcher has also used sound recorder.

Questionnaire: was used because it was almost impossible to get all the necessary knowledge needed through interview, because it would consume more time and energy, the experts might not remember all the information (they might need to refer some books).

Mixed questionnaire were used in this work, few close ended (structured) questionnaire was used to evaluate and collect the views of agricultural expect on the KBS that is going to be develop.

Open ended questionnaire (unstructured) questions are more qualitative [3, 9].They do not require pre-defined categories and they allow the respondent to express their views and ideas openly. It is used in making intensive studies of the limited number of the cases. Thus unstructured questionnaire were used to collect knowledge from three experts even though one of the expert didn't return the questionnaire which makes it two experts.

Document Analysis: Document analysis was also carried out to acquire explicit knowledge from different source of knowledge on the area of Oilseed crop protection and treatment. Different related articles from Internet, source books and manuals collected from holeta agricultural research center, were analyzed and technical knowledge was extracted.

Knowledge modeling: In this study the acquired knowledge was modeled using **decision tree** that links the type of diseases and their associative symptoms with yes/no relations to make appropriate decision based on observed symptoms of oilseed crop diseases. The decision tree was drawn using smart draw trial version.

1.7.2. Knowledge Representation and inference Techniques and Tools

In this study, Horn clause logic method is implemented to represent expert knowledge concerning oilseed crops diseases and diagnosis techniques. The rule based approach is particularly useful because in many areas much of an expert's knowledge can be expressed in if-then rules, many of which are heuristic. Although different knowledge representation exists, rule based Knowledge representation is the most commonly used methodology in agriculture [3,8, 11,16, 17, 20].The reason for the choosing rule based reasoning is that this method is very common and it can be satisfyingly powerful from the perspective of building useful applications. [3, 9]

Goal driven reasoning or **backward** chaining inference technique was used for reasoning, because it's suitable for diagnosis system [3, 9, 12, 20].

In this work, visual prolog programming language is used to develop a prototype knowledge based system that diagnoses cereal crop diseases [12]. Prolog is a symbolic programming language based on declarative programming, not procedural programming. The researcher chooses prolog because in prolog it's simple to declare facts and rules, and search for those rules.

1.7.3. Evaluation technique

The evaluation of KBS is an important aspect of KBS development that is required to verify whether the system fulfils its original objective [3, 9, 11].

The researcher used questionnaire to assess the performance of the prototype. The evaluators were five agricultural experts from Holeta and ambo agricultural research center, and two DAs from Ambo plant protection research center.

1.8. Organization of the thesis

The study is organized in to six chapters. Chapter one is the introduction part, which contains the background, statement of problem, objectives, and the scope of the study, and methodology to carry out the research. Chapter two discusses review of literature on oilseed crop (such as Noug, linseed and Gomenzer) production and uses 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 and also discusses the prospect of the 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 Importance of Oilseed crops in Ethiopia

Oilseed is the third most important export item in Ethiopian foreign trade. It has registered a high export growth rate over recent years both in terms of volume and value. Besides its growing share in export, it is widely used for the extraction of edible oil and oilcake that is supplied to the domestic market [4, 5].

Oilseeds cover significant portion of the Ethiopian agriculture and play Important role in the daily lives of its population, and hence crucial in the national economic development efforts. In Ethiopia, oilseeds are the second largest export earners for the country and are anticipated to play an important role in the five year Growth and Transformation Plan [1, 4].

The word market has shown a growing demand for exports of sesame and noug for the last five years. If production volume is increased and required quality is attained, safflower, caster bean and linseed have also good export potential. The growing demand in the world market for these specialty products and the available capacity to expand production could make oilseeds turn into one of the engines of economic growth of Ethiopia in the 21st century. However it would be very difficult for Ethiopia to compete on the world market on oilseed commodities due to the relatively low volume of production, high handling and transport costs, lack of uniformity in color, taste, dryness and purity. To secure the current trade relationship, to penetrate the stringent market segments of Europe, USA and Japan and sustain supply, the country has to produce high quality oilseeds. Extra efforts are required from the public and private sectors to focus on the improvement of productivity and quality of oilseeds and invest more in value additions of cleaning, processing, packing and transporting facilities [4].

Currently, production and productivity levels of Ethiopian oilseeds are far lower than the potential. There is a big gap in the productivity of oilseeds at research and the farmers' fields. To achieve self-sufficiency and tap the gap, the present production levels must be doubled and to meet the later areas where we are lacking, technology, information and knowledge must be identified and tackled systematically [4].

Recently, Ethiopia has emerged as one of the largest importer of edible oil in the world market and more than 85 percent of domestic demand is met through imports, which is of great concern when international prices are increasing. Therefore the public private partnership project should expert its maximum efforts on building capacity of local oil mills and find ways of engaging smallholder farmers in the production of oilseeds, especially sunflower, soybean, noug and safflower, so as to meet the national requirements for edible oil and protein cake. Such production would make full use of the capacity of the domestic processing industry and would create jobs on farms, oil and the feed cake processing mills and substitute imports [4].

2.1.1. Noug

Noug (Niger Seed) is an oil-seed crop, indigenous to Ethiopia and holds significant promise for improving rural livelihoods in Sub-Saharan Africa. IT is the most important Oil Crop in Ethiopia. It constitutes about 50% of Ethiopian Oil Seed production. Its seed contains 40% oil and produces high quality oil due to the presence of about 70% linoleic acid [4].

Ethiopian Farmers grow Noug primarily for its oil and as the meal remaining after the oil extraction is free from any toxic substance, its seed cake is an invaluable protein rich animal feed supplement. Moreover: Noug oil serves as an indispensable cash crop to the Ethiopian peasant farmers, oil for lightning, as lubricant, for soap and in paints as well [4].

The species is used in intercropping systems, grows on poor but also extremely wet soils, and contributes to soil conservation. While hardly improved, and suffering from low yields and susceptibility to insect herbivores, it contributes up to 50% of the Ethiopian oil-seed crop. Noug belongs to the Composite family and is closely related to sunflower. It differs from domesticated sunflower mainly due to its high level of branching, numerous flower heads and small seeds. The oil content of noug seed varies from 30 to 50%. The fatty acid composition is typical for seed oils of the Composite family with linoleic acid being the dominant component [4].

Major production area for Noug are Oromia Horogadum zone, East and west Wellega, Amhara Awi zone, East and west Gojam and north and west Tigray [4].

2.1.2. Gomenzer (Ethiopian mustard)

Ethiopian Mustard locally known as Gomenzer has been grown in Ethiopia and it is believed to have been evolved from the natural hybridization between black mustard and cabbage [4].

Ethiopian mustard has been grown well on well drained and organic matter rich soils close to homesteads in small quantity because of its poor oil (erucic acid) and meal (glucosinolate) qualities [4, 5].

However, recently Ethiopian Farmers have adopted to grow in it the field in larger plots because of its market demands [4].

In Ethiopia Gomenzer is used for many purposes. It is used for greasing the "Mitad" before local bread or "Enjera" is baked; the leaves are boiled as Gomen-Wet, the seeds are crushed and oil is extracted by stirring to be used as additional ingredient together with spices; it is used to make soap and soften leather. Ground seeds are also used to cure certain ailments or stomach upsets and to prepare beverage [4, 5].

2.1.3. Linseed (Telba)

Linseed is one of the oldest crops known to man and it has been cultivated for both fiber (flax) and seed oil. Its origin is unknown but the Mediterranean has been suggested as a possible center. Linseed is thought to have been an early introduction to Ethiopia [4].

Linseed Oil content is mainly in the range of 35-44% with drying oil properties which is highly important for the manufacture of paints and varnishes. Linseed oil in Ethiopia has been used for edible purpose in the past many years. The ground seed is of great value for, a number of purposes including gastric pain and the extracted mucilage is used in cosmetic and Pharmaceutical [4].

Major production areas for linseed are Arsi, bale, west shewa and west gojam [4].

As per the information obtained from discusstion and observation there is clear shortage of agricultural expert in Ethiopia. Therefore there is a need for knowledge base system which can help the farmers as a sourse of information when expert is not available.

2.2. Overview of KBS

“KBS is a software system that contains a significant amount of knowledge in an explicit, declarative form” [21].

KBS is computer program designed to simulate the problem solving behavior of an expert in a narrow domain or discipline [2, 3, 8, 9].

Speel [21] suggests that KBS is an old term for KBS and should not be used because it may give rise to wrong expectations. In general, a KBS is not intended to replace an expert but to support an expert. So KBS is used throughout the thesis.

While KBS technology originated in the United States, its development has become an international concern [2, 9, 15]. Since artificial intelligence (AI) was named and focused on at the Dartmouth Conference in the summer of 1956, a variety of intelligent techniques have been initiated to perform intelligent activity. Among them, the knowledge based technique is the most important and most successful branch [2, 3, 15]. The power of KBS is not derived from the particular formalism and inference mechanism they use, but from the knowledge they possess [15]. Knowledge is the information about a specific domain needed by a computer program to enable it to exhibit intelligent behavior with regard to a specific problem. Knowledge includes information about both real-world entities and the relationships between them. Furthermore, knowledge can also take the form of procedures for combining and operating on information [2, 9]. Computer programs that encapsulate such knowledge are called KBS. It performs at high levels of competence in cognitive tasks [2].

KBS is one of the major family members of the AI group. 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 expert’s decision making ability. Indeed, KBS can act as an expert on demand without wasting time, anytime and anywhere [8].

Knowledge is usually captured in some form of human logic and programmed through nondeterministic, declarative programming languages such as Prolog and OPS5. These languages allow the programmer to define, in a highly descriptive manner, the knowledge of a human expert about problems and their solutions. Furthermore, programs written in such languages can be extended easily because the data and program structures are more flexible and dynamic than the usual programs. Different approach has been used for designing KBS. According to [8] there are five different existing approaches for modeling KBS, which are Rule based approach, the frame based approach, object oriented approach, logic based approach, and Hybrid approach. Hybrid approach combines KBS with some other methodology [2].

Contemporary real-world computer applications try to model the complex and vast amount of modern society's knowledge that must be handled by knowledge-based systems. More "traditional" applications suffer similarly from the existence of large amounts of data, which are equivalent to facts in the context of knowledge-based systems. The traditional solution is to couple the programs that process data with special systems devoted to the efficient and reliable storage, retrieval, and handling of data, widely known as database management systems (DBMSs) [2, 15].

The same trend is followed for KBSs, where the management of knowledge has moved from the application to knowledge base management systems. Knowledge base management system is an integration of conventional DBMSs with artificial intelligence techniques. Knowledge base management system provides inference capabilities to the DBMS by allowing encapsulation of the knowledge of the application domain within the database system. Furthermore, KBS provide sharing, ease of maintenance, and reusability of knowledge, which is usually expressed in the form of high-level declarative rules, such as production and deductive rules [2].

KBS consists of sets of rules (called the rule base) and data or facts (called the database). The rule base and the database of a KBS are collectively called the knowledge base [2, 3, 10, 21].

2.2.1. Application Areas of KBS

KBS has been developed for a variety of reasons, including [8, 9, 16,17, 20].

- Diagnostic applications
- Make financial planning decisions
- Servicing people, plants and machinery
- Configure computers
- Monitor real time systems
- Underwrite insurance policies
- preserving the knowledge of retiring personnel
- They also play chess, and perform many other services which previously required human expertise.

The breadth of the major application areas of KBS technology is very impressive. These include the following, among other areas. Agriculture, Business, Law, Education Chemistry, Communications, Computer Systems, Management, Manufacturing, Mathematics, Medicine, Electronics, Engineering, Environment, Geology, Image Processing, Information, Military, Mining, Power Systems, Science, Space Technology and Transportation [2, 15, 16, 20].

It is difficult now to imagine an area that will not be touched by intelligent, KBS technology [2, 15, 16, 17]. The following are some examples of KBS, that are currently being used [2, 8, 9]:

- MYCIN. It encodes expert knowledge to identify kinds of bacterial infections. Contains 500 rules and use some form of uncertain reasoning
- DENDRAL. Identifies interpret mass spectra on organic chemical compounds
- MOLGEN. Plans gene-cloning experiments in laboratories.
- XCON. Used by DEC to configure, or set up, VAX computers. Contained 2500 rules and could handle computer system setups involving 100-200 modules.
- GASOIL is an KBS for designing gas/oil separation systems stationed of-shore
- "Thinking computer may copy doctor", a system which emulate doctors By Robin turner from welsh university.

2.2.2. KBS component

KBS have a number of major system components. In this section we will try to see some of the basic components of KBS.

The area of KBS development has matured over the past few decades. It started with first-generation KBS with a single flat knowledge base and a general reasoning engine, typically built in a rapid-prototyping fashion [21]. KBS has its own architecture that depicts its basic components as shown in Figure 2.1 below [2, 3].

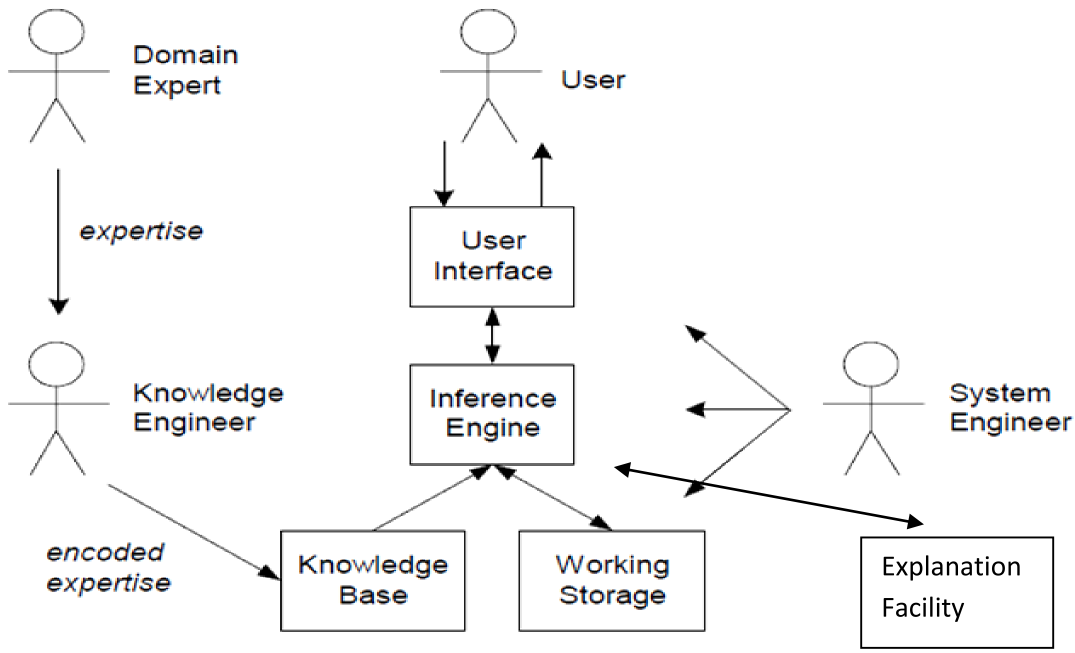

Fig 2.1 Knowledge base system component

2.2.2.1. Domain Expert

Domain expert is the individual who has currently the knowledge required for solving the problems the system is intended to solve. The person is responsible for defining the rules [2]. In the KBS development, the expertise has been captured in the KBS. Therefore, the expert must be able to communicate his or her knowledge, be willing to participate in the KBS development and commit a substantial amount of time to the program development. The domain expert is the most important player in the KBS development team [2, 3].

2.2.2.2. Knowledge Engineer

Knowledge engineer is the individual who encodes the expert's knowledge in a declarative form that can be used by the KBS.

The development of KBS requires knowledge about both human reasoning and computer techniques. Analysis of these aspects is known as knowledge engineering Knowledge engineer is a person who is capable of designing, building and testing KBS including [2, 3, 9]:

- Interviews the expert to elicit his or her knowledge;
- Encodes the elicited knowledge for the knowledge base;

- Interrogates the domain expert to find out how methods the expert uses to handle facts and rules and decides how to represent them in the KBS a particular problem is solved;
- Establishes what reasoning;
- Chooses some development software or KBS shell, or looks at programming languages for encoding the knowledge.

Knowledge engineering can be divided into two levels. The knowledge level deals with the conceptual models underlying human reasoning [2]. The computational level deals with the representation of this knowledge and reasoning in computer systems [2]. The knowledge level consists of conceptual models for representing the world, domain knowledge, and reasoning models, inferential knowledge [2, 18].

Knowledge Base: Simply knowledge base declarative representation of the expertise, often in IF THEN rules. The knowledge base represents the deposit of knowledge for specific and narrow domain. Usually in any knowledge base there are a collection of facts, rules, and Meta knowledge [2, 3, 9].

2.2.2.3. Working storage

Working storage is extracted from the knowledge base; it is the data that is specific to a problem being solved [3, 9].

2.2.2.4. Inference engine:

KBS applications problems typically require some form of reasoning to produce the required results. Inference engine is the code behind this or it's the code responsible for making reasoning [2, 9, 15, 20].

Inference engine is involved in drawing a conclusion or making logical decision from the knowledge base and problem-specific data in working storage [3, 9].

Prolog is a symbolic programming language based on declarative programming, not procedural programming. What we do when writing Prolog programs is to declare facts and rules. After that we ask questions to Prolog. Prolog tries to answer our questions by searching through possible ways of deducing satisfiability of our question based on given facts and rules (by doing so called backtracking search).

The engine searches the rules and the facts from left to right and from top to bottom. In its relentless search for solutions the inference engine uses something called backtracking [12].

The inference engine tries to solve the goal by matching facts. It takes the goal and sees that the predicate in the goal matches with the facts listed in the program. It is going to start with the first fact to see if it matches the goal. But before it does so, the engine puts a pointer at the second fact. This pointer is called a "backtrack point". It is the point where the engine should return when it has treated the first fact.

2.2.2.5. User interface

User interface is the code which handles the interactions between the system and the user or in other word is the piece of program that controls the dialog between the user and the system [3, 9].

2.2.2.6. System engineer

System engineer is the individual who builds the user interface, designs the declarative format of the knowledge base, and implements the inference engine [3, 9]. Depending on the size of the project system and knowledge engineer could be the same person (for small project) [9].

2.2.2.7. User

User is the individual who will be consulting with the system to get advice that would have been provided by the domain expert. In our case the DA and farmers [3, 9].

2.3. KBS Features

There are a number of features which are commonly used in KBS. The major features covered are [2, 3]

- Knowledge Acquisition
- Concept modeling
- Forward or backward chaining
- Dealing with uncertainty
- Knowledge representation
- Explanations

2.3.1. Knowledge Acquisition

Knowledge acquisition is a prerequisite phase of KBS development it consists of collecting (acquiring), structuring, organizing and studying knowledge. The knowledge is collected from some knowledge source (human experts, books, and internet) and will be represented in a way that the computer understands for constructing or expanding the KBSs [2, 3].

One of the major bottlenecks in building KBSs is the knowledge engineering process. The coding of the expertise into the declarative rule format can be a difficult and tedious task [3, 9].

There are different knowledge acquisition technique currently being used repertory grid, laddering, card sorting, 20 questions, and Protocol analysis. Detailed discussion can be found in [22].

Among these techniques Protocol analysis was chosen for the development of the prototype. In protocol analysis (also called think aloud), the specialist is given a description of a problem and is asked to verbalize or write all his/her thoughts while solving the problem (e.g. making a diagnosis). The protocol is then later analyzed by the knowledge engineer to identify the structure of the reasoning process [3, 22].

2.3.2. Inference Mechanism

As shown in figure 2.2 below, there are two basic types of inferencing, such as forward chaining and backward chaining.

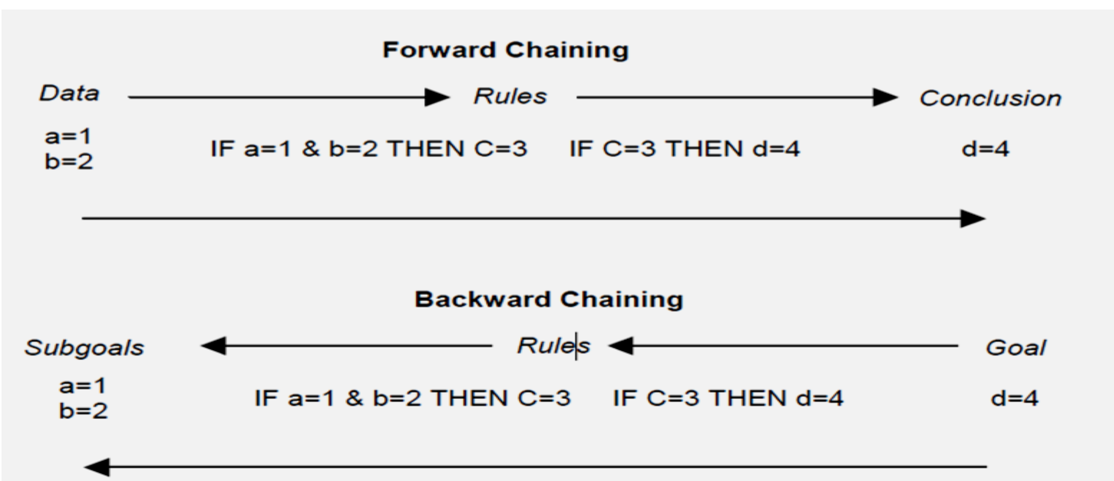

Fig 2.2 Backward chaining VS forward chaining

Forward chaining

Forward chaining or data driven reasoning is an inference technique that uses IF THEN rules to deduce a problem solution from initial data. It starts with the facts, and sees what rules to apply or what should be done next [9].

It is a reasoning strategy which starts from the evidence (symptom) and then to conclusion (diagnosis) [10, 12].

Forward chaining in rule based system begins by triggering all of the rules “if clause” which 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. In a forward chaining system, the initial facts are processed first, and the inference keeps using the rules to draw new conclusions given those facts [3, 9].

Backward chaining

Backward chaining inference technique, also called goal driven reasoning is reverse of forward chaining. It works from hypothesis to evidence [10]. It’s a technique which uses IF THEN rules to repetitively break a goal into smaller sub-goals, which are easier to prove. First a goal is specified and the inference engine tries to determine what conditions are needed to arrive at the specified goal. Backward chaining is good when all outcomes are known and the number of possible outcomes is not large [3, 9, 20].

That is, the aim of the system is to pick the best choice from many counted possibilities. For example, an identification problem falls in this category. Diagnostic systems also fit this model, since the aim of the system is to pick the correct diagnosis [2, 9].

Let us use this simple example to illustrate the difference of forward and backward chaining. The forward chaining system starts with the data of a=1 and b=2 and uses the rules to derive d=4. The backward chaining system starts with the goal of finding a value for d and uses the two rules to reduce that to the problem of finding values for a and b [9, 20].

2.3.3. Dealing with uncertainty

Often in structured selection problems the final answer is not known with complete certainty. The expert's rules might not be clearly understood or expressed, and the user might be unsure of answers to questions. Some KBSs incorporates probabilistic reasoning, particularly those doing predictions [2, 3].

This can be easily seen in medical diagnostic systems where the expert is not able to be definite about the relationship between symptoms and diseases. In fact, the doctor might offer multiple possible diagnoses (blood test, urine test etc.) [3, 9].

For KBSs to work in the real world they must also be able to deal with uncertainty. One of the simplest schemes is to associate a numeric value with each piece of information in the system. The numeric value represents the certainty with which the information is known (e.g. 50%, 80%). There are numerous ways in which these numbers can be defined, and how they are combined during the inference process [9].

2.3.4. Conceptual Knowledge Modeling

KBS construction methods typically provide tools for knowledge analysis in the form of so-called conceptual models of knowledge or simply knowledge models [21].

An important feature of knowledge engineering research is that it provides us with predefined, reusable models for certain knowledge-intensive tasks, also called problem-solving methods [21]. 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. Models are used in system development to draw the blueprint of the system, so that people could easily understand each particular area of the system [3].

Before building KBS, knowledge must somehow be identified, collected, and a model of domain knowledge must be constructed. Knowledge includes information about both real-world entities and the relationships between them [2].

Modeling domain knowledge implies capturing the static structure of information and knowledge types. Just like in regular data modeling, a schema is constructed containing the major types and relations occurring in the application domain. Conceptual modeling always needs to be proceeded by a careful business analysis, in which opportunities for KBS construction are identified [21].

We do not have a generic approach how to best classify rules in knowledge bases. This is part of the experience of a knowledge engineer. One heuristic is to organize rule sets according to reasoning steps [22].

Decision tree is one of modeling technique it classify instance by sorting them down the tree from the root to some leaf node, which provides the classification of the instance. Each node in the tree specifies a test of some attribute of the instance and each branch descending from the node corresponds to one of the possible values for this attribute. It's powerful and popular tool for classification and prediction [23].If the classification is "yes" or "no" then the tree is called a Boolean tree.

Decision trees are able to produce human readable descriptions of trends in the underlying relationships of a data set and can be used for analytic task such as diagnosis and classification it could also be used for prediction tasks [3, 10, 20, 21,23].

Decision tree learning is a method for approximating discrete-valued target functions, in which the learned function is represented by a decision tree. Learned trees can also be re-represented as set of if-then to improve human readability. These learning methods are among the most popular of inductive inference algorithms and have been successfully applied to a broad range of tasks from learning to diagnose medical cases to leering to assess credit risk of loan applications [23].

Algorithms for constructing decision trees usually work top-down, by choosing a variable at each step that best splits the set of items [23]. Different algorithms use different metrics for measuring "best".

Information gain is used by the ID3, C4.5 and C5.0 tree-generation algorithms. It's based on the concept of entropy from information theory [23].

Ejigu [3], Tsegaw [10], Mahaman [20] all used decision tree to model domain knowledge that is later converted to rule base (production rules).

Bethlehem [11] used semantic network for modeling domain knowledge that is later was converted to rule base.

2.3.5. Knowledge representation

Knowledge representation refers to the way in which the problem specific data in the system is stored and accessed. 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 [2, 3].

For all rule based systems, the rules refer to data. First generation KBS typically used a single representational paradigm such as production rules to meet all requirements. Although different knowledge representation exists, rule based Knowledge representation is the most commonly used methodology in agriculture [3, 11, 21].

The data representation can be simple or complex, depending on the problem. The models covered are [3, 9].

- Network model and Frame Model
- Production rule
- First-Order Logic

- Connectionist model (Neural network)
- Case-based reasoning

2.3.5.1 Network model and Frame model

Network model become popular in the 1960's. The idea is Knowledge is hierarchical and it's composed of nodes and the nodes have various relation and properties. It's a graphical method of representing real world concepts via nodes in a directed graph [2, 9]. Knowledge and meaning between concepts, is implied through the interconnection between each concept. By reading this directed graph, a language or semantic structure of the knowledge can be formed and hence can be abstracted through a computer language [9, 11].

Frame systems were introduced by Minsky (1975), as a means to structuralize a semantic network in order to describe specific instances of an occurrence. Here, a frame is a named piece of data, which exhibits particular attributes known as slots. Due to the fact that each frame has certain properties, more complex knowledge structures can be inferred by artificially replicating and inheriting semantic node attributes.

2.3.5.2. Production Rule (Rule based)

Production rule become popular in 1970's. In a rule base knowledge based system the knowledge of the domain is represented by production rules. The rule base is typically populated with rules of the following form [2, 11, 15].

If A then B,

This is interpreted as "if condition A is satisfied then do B". The "A" portion of the rule is called the antecedent or LHS (Left Hand Side) of the rule. The "B" portion of the rule is called the consequent or RHS (Right Hand Side) of the rule. If A is true and whatever actions specified in B are accomplished then the rule is said to have been "fired". The condition "A" may be a conjunction of conditions A_l, A_2 ...A_n. In this case all must be satisfied in order to trigger any actions stipulated by B. Any component of this conjunction may involve a negative. Likewise "B" may be a sequence of actions B_l, B_2...B_k all of which will be taken if the conditional part of the rule is satisfied and the rule is fired or executed [9, 11].

The relationship between the rule base and the fact base is quite straightforward. If there is a fact in the fact base like "V = n" and there is a rule in the rule base that states that "If V = n then B" then this rule is considered for execution [2, 11].

All researchers [3, 10, 11, 16, 17, 20] mentioned used rule based reasoning to represent the knowledge they acquired from agricultural expert and found good result. In this work I used this representation technique for the prototype development.

Tsegaw [10] in particular tried to integrate rule based reasoning technique with neural network. Even though he didn't show the results clearly he suggested that it improved the system.

2.3.5.3. First-Order Logic

First order logic (FOL), also known as predicate calculus or predicate logic is a well understood formalism for reasoning. Although the logic and knowledge representation communities are distinct, the expressivity of FOL nevertheless makes it a powerful knowledge representation language. From the perspective of FOL, the world consists of objects and the relations that hold between them. A FOL language consists of logical and non-logical symbols. The logical symbols represent quantification, implication, conjunction and disjunction; while the non-logical symbols are constants, predicates, functions, and variables. Constant, variable and function symbols are used to build terms, which can be combined with predicates to construct formulas [2, 11].

2.3.5.4. Connectionist model (neural network)

Connectionist model become popular in the 1980 and continue to be popular today specially for artificial intelligence [2, 10]. It models mental or behavioral phenomena as the emergent processes of interconnected networks of simple units. There are many forms of connectionism, but the most common forms use neural network models [2, 10].

The basic connectionist principle is that mental phenomena can be described by interconnected networks of simple and often uniform units [2, 10].

Neural networks are by far the most commonly used connectionist model today. Though there are a large variety of neural network models, they almost always follow two basic principles regarding the mind [2, 10]:

- Any mental state can be described as an (N)-dimensional vector of numeric activation values over neural units in a network.
- Memory is created by modifying the strength of the connections between neural units. The connection strengths, or "weights", are generally represented as an N×N m

The neural network branch of connectionism suggests that the study of mental activity is really the study of neural systems. This links connectionism to neuroscience, and models involve varying degrees of biological realism. When we see human brain we see a complicated network of cells and they communicate with each other with action potentials. Neural network tries to depict the brain of human mind [2, 10].

In neural network we have input node output node and hidden node this node basically has no meaning but they have various relationship patterns among the nodes and different activation patterns will yield different outcomes. In the figure below you can see the layers of neural network [2, 10].

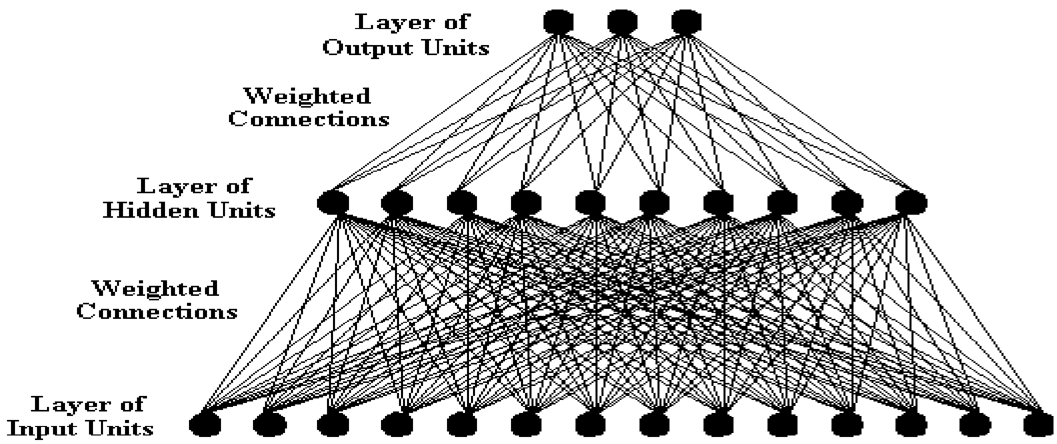

Fig 2.3 Neural network layers

2.3.5.5. Case based reasoning

In case-based reasoning, a reasoner remembers previous situations or cases similar to the current one and uses them to help solve the new problem [22].

"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 (much like labor mediators do)" [22].

If we observe peoples solve a problem we can see case-based reasoning, peoples usually makes decision based on past experience or cases [22].Doctors, mediators and arbitrators are taught study previous cases. For example a doctor sees a president's history to help him come up with a better conclusion [22].

Any programs we write to automatically do case-based reasoning will need to be seeded with a representative store of experiences. These experiences (cases) should include goals, sub goals and both failed and success cases [22].

Case based reasoning could be difficult to model where there are no or very few cases [3, 22]. The researcher opinion is it's difficult to design case-based reasoning KBS for Ethiopian agriculture at the time of writing because it would be almost impossible to find stored cases of infected crop or uses of fertilizer in Agricultural research center.

2.3.6. Explanation facilities

One of the more interesting features of KBSs is their ability to explain themselves. Given that the system knows which rules were used during the inference process, it is possible for the system to provide those rules to the user as a means for explaining the results [9].

However, in some case the explanations are relatively useless to the user. This is because the rules of KBS basically represent empirical knowledge, and not a deep understanding of the problem domain. For example a car diagnostic system has rules which relate symptoms to problems, but no rules which describe why those symptoms are related to those problems [9].

Explanation has high value for the knowledge engineer. By looking at the explanation the system engineer would be able to see how the system is doing. This is very useful for diagnosis tool during development [9, 15].

2.4 KBS Development tool

Over the past several years there have been many implementations of KBSs using various tools and various hardware platforms, from powerful LISP machine workstations to smaller personal computers [9].

There continues to be a debate as to whether or not it is best to write KBSs using a high-level shell, an AI language such as LISP or Prolog, general purpose programming languages like C++ or Java. An alternative is to buy a library or component that contains the required functionality. Nowadays professional libraries can be found on the market [9, 22].

The main benefits of using special tools for building KBSs are lower costs for development and maintenance compared to building the same things using general programming tools. The reason why these specialized tools can offer such advantages are their built-in knowledge representation and manipulation methods plus the integration of these methods with other parts of a program like the object model and the user interface elements. It gives a programmer the possibilities to focus on the essence of the job [15, 21].

Prolog is a logic-based language based on first-order predicate calculus. It has its roots in formal logic unlike many other programming languages. The program logic is expressed in terms of relations, and execution is triggered by running queries over these relations [3, 9].

LISP is one of the oldest programming languages, and it is most useful for symbolic representation. However, using LISP to develop KBS requires the most development time because desirable characteristics such as the user interface, inheritance and method of reasoning need to be specifically coded. Recently, KBS development tools (e.g., shells) developed in LISP, C, or Prolog offer built-in functions that have significantly simplified the task of building KBS [3, 9].

C Language Integrated Production System (CLIPS) is KBS tool that provides a complete environment for the construction of rule and/or object based KBSs. The CLIPS is a fact driven environment where rules are fired depending upon the pattern matching [3, 9].

2.4.1. Visual Prolog

Visual prolog is selected as a development tool for this work. It is a strongly typed object oriented programming language based on the Prolog programming language [12].

Visual Prolog is a multi-paradigm programming language based on the logical language Prolog. The goal of Visual Prolog is to facilitate programmatic solutions of complex knowledge emphasized problems [12, 18 and 19].

Visual Prolog is a powerful and high level programming language combining the very best features of logical, functional and object-oriented programming paradigms in a consistent and elegant way [12, 18].

With Visual Prolog you can build applications for the Microsoft Windows 32/64 platforms. It supports advanced client-server and three-tier solutions. Visual Prolog is especially well suited for dealing with complex knowledge [12, 18].

By utilizing the powerful object system you are able to architect your application very rigidly and at the same time benefiting from very loose coupling. This will enable you to reduce development and even more maintenance cost [12, 18].

Visual Prolog is an OO programming language. That means that when you program, you will have to think in classes and objects. Every operation is performed by a method in an object [12].

2.4.2. Visual Prolog features: [12, 18, and 19]

- logical programming concepts (backtracking, pattern matching)
- algebraic data types
- a unique object system
- multi-threading
- parametric polymorphism
- Unicode support
- automatic memory management (garbage collection)

2.5. KBS Application in Agriculture

The need of KBSs for technical information transfer in agriculture can be identified by recognizing the problems in using the traditional system for technical information transfer, and by proving that KBSs can help to overcome the problems addressed, and are feasible to be developed [8].

Recent advances in computer technology have been made possible the development of KBS. KBS are special computer software applications that are capable of carrying out reasoning and analysis functions in narrowly defined subject areas (including agriculture) approaching that of a human expert [2, 8, 10].

KBS could be applied in these areas of agriculture:

- Disorder Diagnosis
- Disorder Treatment
- Irrigation Scheduling
- Fertilization Scheduling
- Plant care

In agriculture, KBSs can be applied to, e.g., plant pathology, entomology, horticulture and agricultural meteorology. KBSs 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 [8].

2.5.1. Characteristics of Agricultural KBS

As noted by Prasad [8] agricultural KBS, simulates human reasoning about a problem domain, rather than simulating the domain itself. It performs reasoning over representations of human knowledge. It solves problems by heuristic or approximate methods.

The application of KBS in Agriculture is 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 [2,10]. It could also be integrated with artificial neural network [9]. These rules and facts are used to solve problem by answering questions on such diversified topics as crop control, the need spray, selection of chemicals to spray, management practice, weather damage recovery such as freeze for drought etc. [8].

"In 1991, serious efforts have been started in Egypt to develop crop management KBSs for different crops. A prototype for an KBS for cucumber seedlings productions has been developed. This prototype has six functions: seeds cultivation, media preparation, control environmental growth factors, diagnosis, treatment, and protection. In Italy, a KBS for integrated pest management of apple orchards, POMI, has been developed" [8].

KBSs Implemented at CLAKBS:

The Central Laboratory for Agricultural KBSs (CLAKBS) is helping farmers throughout Egypt optimize the use of resources and maximize food production some of the KBSs developed at CLAKBS are [8]:

- Cuptex: An KBS for Cucumber Crop Production
- Citex: An KBS for Orange Production
- Neper Wheat: An KBS for Irrigated Wheat Management
- Tomatex: An KBS for Tomatoes
- Limex: A Multimedia KBS for Lime Production [8]

These KBS gives the farmer many services including, Disorder Diagnosis, Disorder Treatment, Irrigation Scheduling, Fertilization Scheduling, Plant care and other services as well [8].

2.6. Related works

Bethelehem [10] developed a KBS to diagnose common diseases occurring in pepper plant. The focus of the study was to address problems of common diseases occurring in pepper plant using network modeling and rule based reasoning approach for modeling and representation respectively. Rule based reasoning approach is also applicable for solving oilseed crops problems in which the experience and knowledge of human experts are captured in the form of if-then rules and facts.

Ejigu [2] tried to develop a KBS which was similar to Bethelehems's work that diagnoses cereal crop diseases and advises research experts and development agents in identification and treatment of cereal crop diseases. He used decision tree to model the knowledge and knowledge was represented using production rule as if-then rules and he develop prototype using SWI prolog programming tool.

Tsegaw [9] designed knowledge based reasoning system for agricultural crop management focusing on vegetable crops to develop an KBS model as an attempt to automate the reasoning strategy of human vegetable experts. His approach was different from other researchers mentioned above. He employed a hybrid of rule based and artificial neural network approach to implement the KBS for fertilizer recommendation and diseases identification for vegetable crops.

Tsegaw [9] employed a hybrid of rule based and artificial neural network approach to implement the KBS for fertilizer recommendation and diseases identification for vegetable crops. He explained that the neural network module would be used when facing with unseen situations or new problems.

Tsegaw [9] used fast artificial neural network (FANN) libraries written by Steffen Nissen. He stated that the system has improved but he didn't use any evaluation mechanism to show how the system improved.

The other contribution of this study is that it identifies the factors to make this knowledge base system accessible and applicable for the local farmers and DAs.

The main contribution of this study is that unlike other research that concentrate on paper

Unlike other researchers that concentrate on peeper plants, cereal crops and vegetable crops the main contribution of this study is developing a knowledge based system for oilseeds.

Chapter Three
Knowledge Acquisition and concept Modeling

The main goal of this chapter is to acquire knowledge from domain experts and secondary sources on oilseed crops diseases and diagnosis techniques as well as modeling acquired knowledge which will be used for representation.

One of the primary tasks of a knowledge engineer in the development of KBS is capturing the expert's knowledge for representation in the knowledge base. To this end knowledge capturing process is performed in three different ways [2, 3, 9]; by interviewing individual experts, by using questionnaire, and by reviewing related documents.

3.1. Knowledge acquisition

In this study both primary and secondary data source were used for acquiring suitable tacit and explicit knowledge.

3.1.1. Knowledge Acquisition from Domain Experts (Primary data source)

The main problem of KBSs is acquiring knowledge from human specialist. It is a difficult, cumbersome and long activity [2, 9]. To adequately develop KBSs, one must also learn techniques of knowledge acquisition [3, 10, 16]. This requires extracting information from the experts and representing it in a data base.

Most of the data for this work was collected from Holeta agricultural research center. Knowledge of the domain area was collected through interviewing and Mixed (structured and unstructured) questionnaire Experts from Ethiopia Institute of Agricultural Research **(EIAR),** specifically from Holeta Agricultural Research center.

3.1.1.1. Interviewing Domain Experts

Unstructured interviews were employed to elicit tacit knowledge from domain experts. Since the knowledge model is intended as bridge between domain specialists and knowledge engineers, the model can only be developed in a dialogue between the two [21].

One of the specific objectives of this research is extracting tacit knowledge which is not explicit, and that also cannot be made explicit easily. For this reason, three research experts from Holeta Agriculture Research Center were selected purposively for interview.

The researcher had several interview with Dr Bulcha Weyessa who works on breading of oilseed crop. The researcher has also interviewed other two experts Ato Misteru Tesfaye and Ato Yared Semahegn, all from Holeta Agricultural Research center, Highland oil crops Improvement project. These experts are all working on oilseed crops.

The researcher have tried to ask these experts whether KBS can be a help for oilseed crop production after explaining what KBS is. The researcher has also asked them about disease of KBS their symptom and treatment.

During face to face communication, the information obtained from experts has been recorded manually by using pen and paper sheet. The researcher has also tried to record the interview with sound recorder.

But interviews were not enough to collect the data that was needed to complete this work so anther technique was used which is questionnaire.

3.1.1.2. Questionnaire

The first plan was just to interview the experts and to review the documents collected from agricultural research center but the data collected was clearly not enough so the researcher decided to use another approach which is using questionnaire [3, 10].

Mixed Questionnaires were used to gather information about disease of oilseed and to see the views of the agricultural experts on the proposed system.

Most of the questions in the questionnaire were open questions (unstructured) because it allows the respondent to express their views and ideas openly and without any restriction. The questionnaires were distributed to the three experts mentioned above [3, 10]. The researcher simply writes the name of the disease and asked the experts to write the symptom and also the treatment for the specific disease.

3.1.1.3. Knowledge Acquisition from Relevant Document (Secondary Data source)

Document analysis has been carried out to acquire explicit knowledge. For the sake of getting deeper insight about the characteristics of oilseed crops and to strengthen the information obtained from experts through interview and questionnaire documents were reviewed.

Book and production manual from Holeta agricultural research center, were reviewed to get information about oilseed diseases and treatment. Different Articles from the internet on oilseed disease have been reviewed.

3.2. Oilseed Diseases

Oil crops producers need to know how to diagnose each and every disease of the crops. Especially Important disease of the crops needs to be diagnosed. Wilt in the case of linseed, blackleg in the case of Ethiopian mustard and leaf spot in case of noug are remarkably important. Dr Bulcha Woyessa said in one of our meetings.

After discussion with experts, collecting the questionnaires 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 oilseed crop diseases, the symptoms and the types of control measures undertaken for treatment. As indicated above, the oilseeds covered in this study are Noug, Linseed and Gomenzer. The discussion in this section is made by each of the oilseeds covered in this study.

Experts at Holeta made it clear that there hasn't been much done in terms of diseases protection in Ethiopia for oilseed crop. Pathogenic fungi are by far the most common and yield limiting causes of diseases which attack oilseed crops. And most of the time resistance variety is used as control measure.

3.2.1. Noug

As indicated above Pathogenic fungus is by far the most common and yield limiting causes of diseases and this applies for noug crop too. There are about 15 disease of noug caused by fungus;among them the researcher selected four disease based on the recommendation of experts. These four diseases include Shot hole, Leaf and steam Blight, Tar spot, and Powdery Mildew were selected because they were chosen by experts to be economically important.

Most of the information discussed below are copied from the interview questionnaire collected and very few from the production manual collected from Holeta Agricultural research center.

The experts in Holeta have made it clear that unless extrapolated from other similar crop diseases no control method was studied for noug diseases at the time of writing in Ethiopia.

3.2.1.1. Shot hole

Shot hole and noug blight are the most frequently observed and economically important diseases. Shot hole is among the 15 disease of noug caused by fungus Seprorea sp, and it is one of the most widely distributed diseases of noug.

Among noug disease shot hole causes low yield losses [4] about 10-15% and hence doesn't seems to be economically important.

These symptoms could be observed when the crop is affected by shot hole disease. As the name indicates first formation of circular leaf spot of various size and then Pycnidium are formed on the central part of the infected leaf tissues. At advanced infection stage the central part of the leaf spots fall off or plunge forming a peculiar circular hole becoming distinguishing character for the disease shot hole.

Control method includes

- To use clean seed,
- To use crop rotation
- Field sanitation
- Using Paliram 1.8 kg/hectare, Mistral 1 liter/hectare and Tilt 0.5 litter/hectare

3.2.1.2. Leaf and steam Blight

Noug blight is caused by fungus Alternaria sp or Cercospara Guizotia. Alternaria causes symptoms like brown to black circular spot on the leaves while Cercospara Guizotia causes symptom like small and straw to brown colored spots mainly on leaves. In the latter case spots may coalesce to cause defoliation and thus seems to be more damaging than that of Alternaria.

In severe case spots coalesce and will result killing larger area leading to blighting on leaves. The symptoms progressively decrease from lower to upper direction of the plant canopy confusing with senescence.

At the latter stage all plant parts could be affected and severe damage and losses could occur.

Control method includes

- To use clean seed,
- To use crop rotation
- Field sanitation

- To use of tolerant (resistant) varieties of noug blight are recommended

3.2.1.3. Tar spot

Tar spot is caused by fungus Phylosticta sp. Phylosticta is Pycnidium fungi similar to Phoma except that the former infects only leaf tissue causing spots with dark Pycnidium fruiting bodies formed in the middle of the spots. Hence phylosticta does not deposit a tar like sign (tar spot) on diseased parts of noug plant.

Control method includes

- To use clean seed,
- To use crop rotation
- Field sanitation
- To use of tolerant (resistant) varieties of tar spot are recommended

3.2.1.4. Powdery Mildew

Powdery Mildew mostly occurs in humid temperature. The mildew symptoms on noug are very simple to recognize as in other crops. It appears on young steams and then on leaves.

Affected areas on the steams develop a purplish tinge while on the leaves it shows white sign. The grayish white mycelium that develop on plant tissues appears a mildew mark on the plant and disappears when the black cleisthecia develop at the latter stage.

Control method includes

- To use clean seed,
- To use crop rotation
- Field sanitation
- To use of tolerant (resistant) varieties of powdery mildew are recommended

3.2.2. Linseed

As indicated above linseed diseases are caused by fungi. There are ten diseases of linseed caused by fungi and among them the researcher selected four of them namely wilt, root rot, pasmo, and powdery mildew which are suggested to be economically important by the experts at the Holeta Agricultural research center.

3.2.2.1. Wilt

Wilt is caused by soil and borne fungus Fusaium Oxysporium. It is reported to be one among ten disease of linseed caused by fungi. Wilt is also one of the most widely distributed diseases of linseed known.

Wilt is more pervasive disease from major linseed producing areas of the country particularly in central parts. It occurs when the soil's moisture and temperature increase. Wilt can cause yield losses from 9.2 to 58.6 %.

Symptom can be at early stage the seedling shows drooping and shriveling ant at the later stage it shows necrotic lesion.

Control method is to use resistant varieties or tolerant varieties of wilt.

3.2.2.2. Root Rot

Root rot is caused by Rhizoctonia sp. It's among the major disease of linseed. It occurs mainly in cooler and highland area. The symptoms are damping off leaves, seedling bight, or root rot.

Control method is to use Resistant varieties or tolerant varieties of root rot.

3.2.2.3. Pasmo

Pasmo is caused by the sole and seed-born fungus Septoria Lunicola. The disease is promoted by warm and humid weather.

The disease usually causes lesions on stem and leaves resulting in severe causes of defoliation.

Control method includes:

- To burn the crop that are affected by the disease and
- To use Resistant varieties of pasmo
- Crop rotation or alternation sowing technique

3.2.2.4. Powdery Mildew

Powdery Mildew is caused by Erysiphe Polygoni fungus. It occurs in the area where the temperature is humid. The main symptom of powdery mildew is white powdery growth on both sides of the leaf.

Control method includes:

- To use seeds covered with medicine
- To use Resistant varieties of powdery mildew

- Crop Rotation or alternation sowing technique

3.2.3. Gomenzer (Ethiopian Mastard)

3.2.3.1. White Rust

White rust is caused by fungus namely Albungo Condida. It's one of the most spread diseases in Ethiopia. It's known by affecting the flowers and the lower parts of the leaves. The infected crop shows swelling and deformation of the terminal parts of flower stalks and spiny stag heads.
There is no control method is studied for this disease in Ethiopia but the trend is

- To remove the infected crop and
- To use 1% of Bordeaux mixture.

3.2.3.2. lackleg (dry rot)

Black leg is caused by fungus namely Leptosphaeria Maclons. It affects the steam and leaf of the crop. This disease is very spread on the country and can cause 100% production loss.
The symptom is more conspicuous on lower stem. A lesion will appear on leaves steams and roots. The disease has a tendency to spread to the root of the crop, thus making the root rot.
Control method for this disease includes

- Using clean seeds or disease free seeds,
- To aply benomyl and thiabendazole suspension for 24 hours

3.2.3.3. Powdery Mildew

Powdery Mildew is caused by fungus namely Oidium sp. It mostly occurs in humid temperature. It affects photosynthesis of the crop. The symptom is white powdery like structure on the leaves or pods.
Control method includes:

- To use seeds covered with medicine
- To use Resistant varieties of powdery mildew
- Crop Rotation or alternation sowing technique

3.2.3.4. Leaf and pod spot

Leaf and pod spot is caused by Alternaria Bressiacae fungus. When the disease occur it show light brown, grayish or dark spot on the leaf stem and pods of the crop. Studies show that this disease can cause up to 14% loses of production.

Control method includes,

- To use seed free of disease
- To use anti fungus medicines like Bordeaux, bayleton and mistral
- To remove the crop infected with the disease
- To use nitrogen fertilizers

3.2.3.5. Downy Mildew

Downy Mildew is caused by Fungus Peronospora ParaSitica. In most case it appears on the latter part of rainy season. The symptom for the disease includes angular spots on the leaves and Veins and yellow spot on upper surface of the leaf.

Control method includes:

- To use Resistant varieties of downy mildew
- Crop rotation or alternation sowing technique

3.3. Concept Modeling using Decision Tree

Knowledge modeling is widely recognized as the critical phase of knowledge engineering. Before KBS can be built, knowledge must somehow be identified and collected and a model of domain knowledge must be constructed [3, 7, 10, 21].

Diagnosis system is concerned with finding the fault that causes a device or biological system to malfunction [3, 10, 22]. These faults are identified by looking at the behaviors of the system.

Decision trees are one of a modeling technique that is 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 [3, 7, 10].

Decision tree is a tree where the leaves are labeled with classifications. If the classification is “yes” or “no” then the tree is called a Boolean tree [7, 10].

The researcher has selected Decision tree to model knowledge that were collected. The reason of choosing this modeling technique is that decision trees decision trees is good at representing rules or more formally logical sentences [3, 10]. Decision tree can also be easily converted to the form of if-then rules which are suitable and understandable by computer programs [3, 7, 10, 22].
The researcher has used smart draw trial version to draw the decision tree. In the figures below you can see the decision tree of Noug, Linseed and Gomenzer oilseed crop.

3.3.1. Decision Tree for Noug disease diagnosis

Disease diagnosis involves identifying which disease, if any, a particular crop has on the basis of observable symptoms [3, 10, 11, 20]. The diagnostic process should include looking at the entire plant as well as its separate parts (leaf, steam), and carefully analyzing the observations, and attempting to understand why a disorder has occurred.
The researcher used Boolean decision tree with classification “yes” or “no”. The diagnosis activities are performed by applying observation of the symptoms appeared on the parts of the crops.
The decision tree starts with a hypothesis. For example if we take the decision tree for noug disease diagnosis, it first assumes the disease is shot hole and asks the user one of the symptoms of shot hole disease, if the answer is “yes” then it will go on and ask the user the other symptoms of shot hole if the user answer “yes” to all the symptom then finally the decision tree decides that the disease is shot hole. But if the user answers “no” to one of the symptoms of shot hole then the decision tree will go on and ask other symptoms of noug diseases.

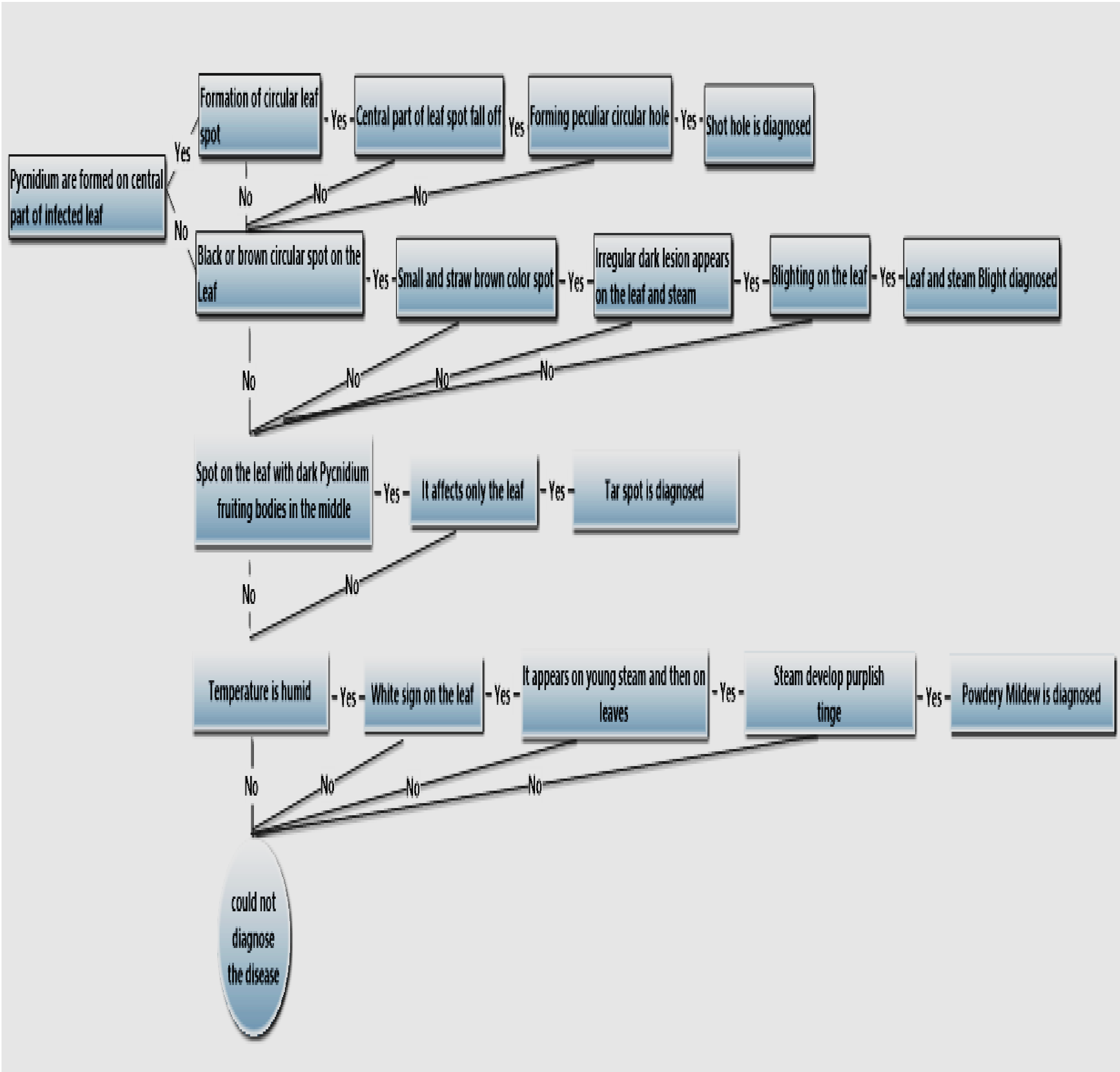

Fig 3.1 Decision Tree for Noug disease diagnosis

3.3.2. Decision Tree for Linseed disease diagnosis

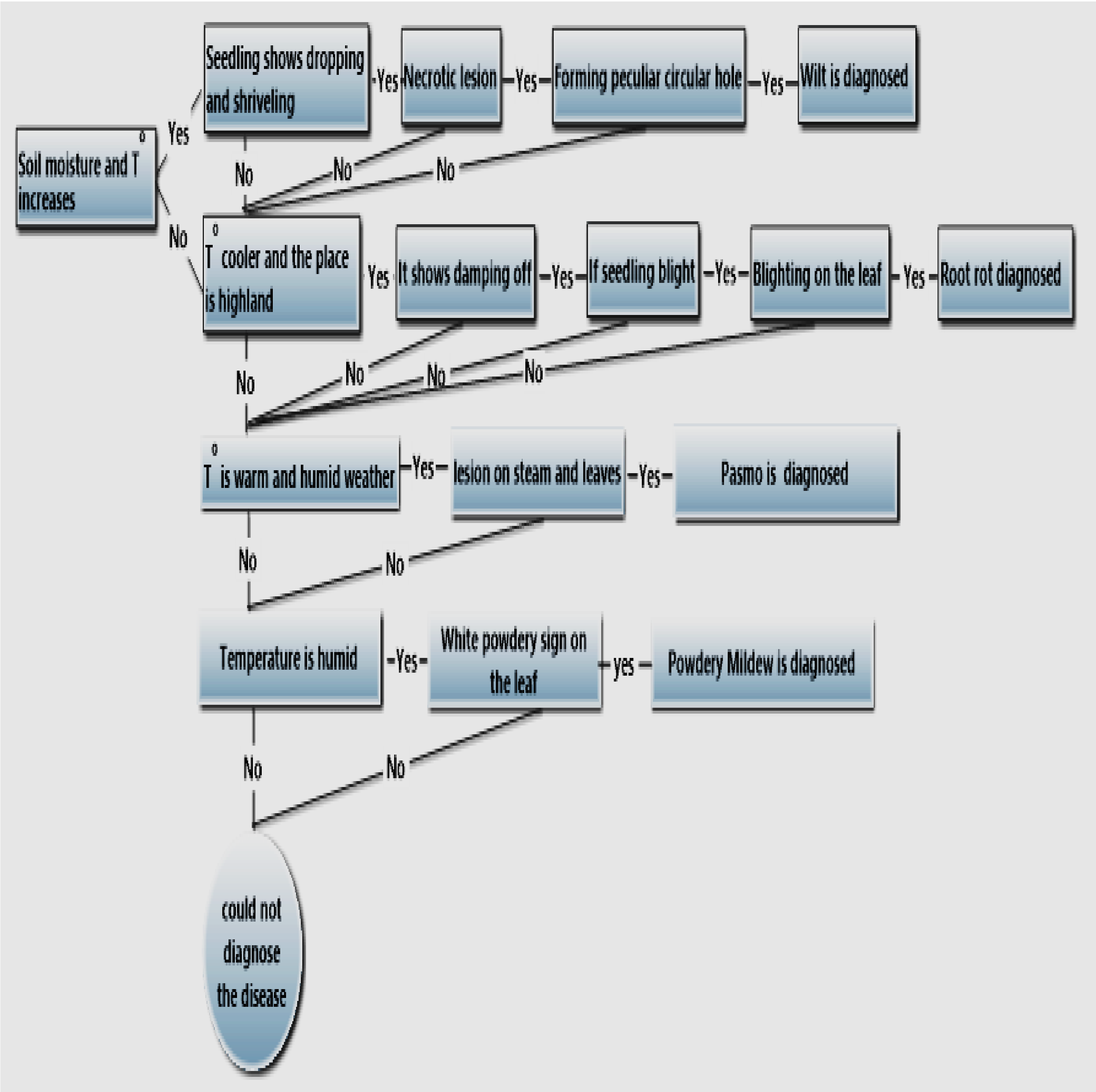

Fig 3.2 Decision tree for Linseed disease diagnosis

3.3.3. Decision Tree for Gomenzer disease diagnosis

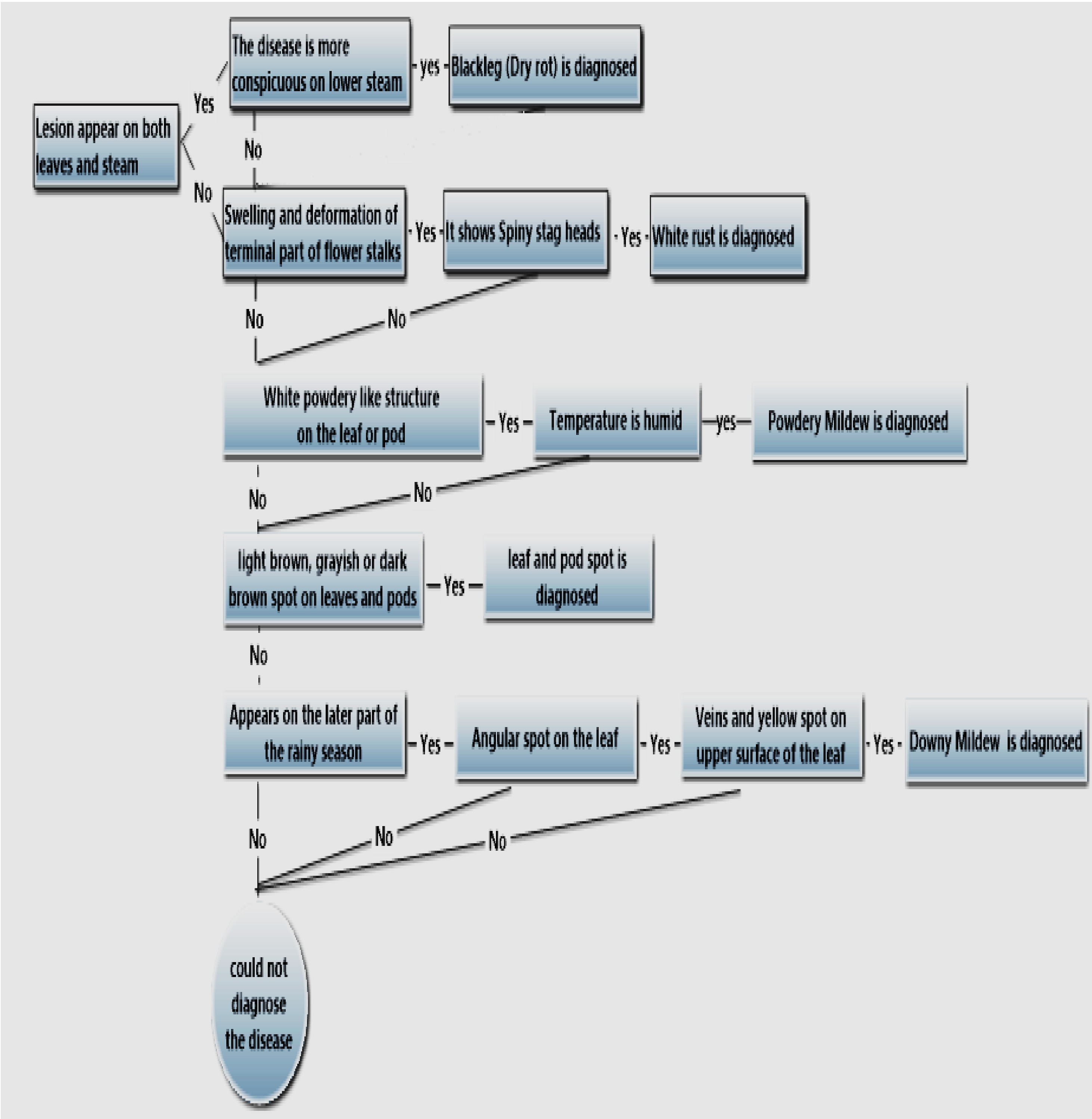

Fig 3.3 Decision Tree for Gomenzer Diseases diagnosis

Chapter Four
KBS Development

Once knowledge acquisition and concept modeling are done the next step is KBS development that encompasses the structure and content of the oilseeds diagnosis knowledge based system.

Knowledge representation is one phase of KBS development. It is the processes of formalizing the identified, structured concepts and facts that are acquired or collected from the domain experts and different secondary sources.

As mentioned in the methodology part of the first chapter horn clause (if - then) logic method is implemented to represent expert knowledge concerning oilseed crops diseases and diagnosis techniques.

Goal driven reasoning or backward chaining was used as an inference technique. It works from hypothesis to evidence. As discussed in the second chapter diagnostic systems fit this model [9]. The rule representation in this study involves selection of the types of oilseed 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.

The goal of the system is to find the correct diagnosis result and treatment for oilseed disease. To reach this goal the system would take the symptom of one of the disease as a sub goal and if that symptom is conformed to be true by the user, the system will go on and ask the other symptoms of the disease until all the symptoms are found to be true. If all the symptoms are true the system will finally conclude the disease.

4.1. Architecture of the proposed system

System architecture is the blueprint of the system that defines the structure and guidelines of the system. In figure 4.1 you can see the architecture of the proposed system.

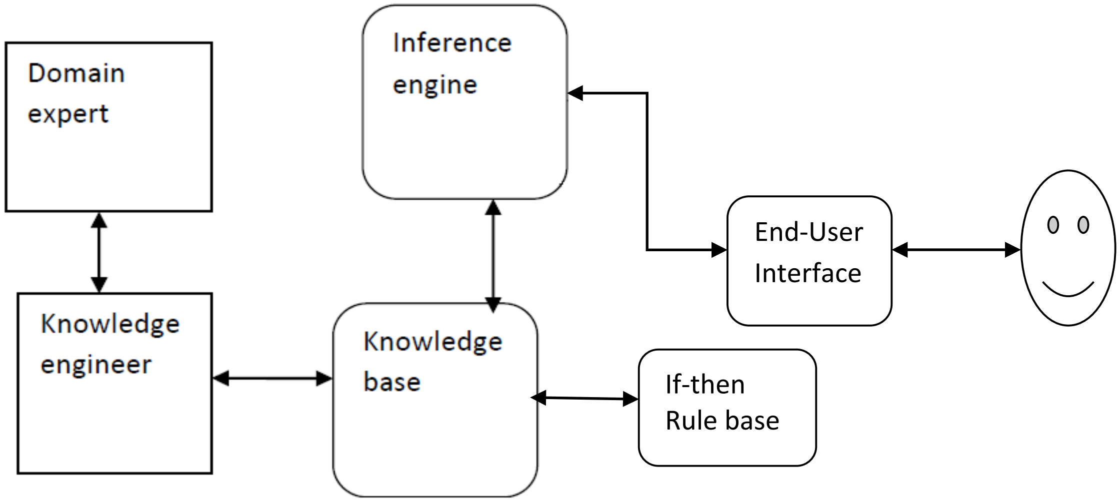

Fig 4.1. Architecture of the proposed system

4.2. Representation of the knowledge in the rule base

The diagnostic method and reasoning strategy collected from oilseed experts and other sources has been converted to rules that can be activated to provide a solution to a given problem. The rules are generated from the decision tree presented in section 3.3.

Production rule (if - then) was used to represent the knowledge. Most diagnoses work always asks a symptom to rich at conclusion. If human or crop shows some symptoms that are previously known to be related to a disease the doctor or the expert would come to a conclusion; or advice some lab test to confirm their conclusion.

In this study facts were not used because if-then was enough to represent the knowledge. If the crop shows certain symptom then we can conclude the disease.

4.2.1. Noug

As mentioned in the previous chapter only those disease which are economically important were selected and modeled. The selection was made by the experts; the researcher simply lists all the disease that was found on document and internet and asks the experts to selects those which are economically important.

As you can see in the tables below the symptoms are placed at the "if" section and the diagnosis result is placed at then "then" section. If those symptoms are true then we can conclude the result.

The comma in the “if” section represents “And”. The symptoms are connected with and which means that it only reaches a conclusion if all the symptoms are true (met). But some condition might be true and some condition might be false that’s way similar work should consider probabilistic technique.

The researcher converted the model (decision tree) to rules, and put them in table, so that it would be easier to see for the reader. In the tables below you will find all the rules that were used for diagnosis.

Case	If condition	Decision
1. Shot hole	If Pycnidium are formed on the central part of infected leaf, If formation of circular leaf spot of various size, If the central part of the leaf spots falls off, If forming peculiar circular hole,	Then the disease is shot hole Treatment for shot hole (refer to chapter 3)

Case	If condition	Decision
2. Leaf and steam Blight	If black or brown circular spot on the leaves, If small and straw brown colored spot, If there is irregular dark lesion appears on leaf and steam, If the leaves blighting,	Then the disease is Noug Blight Treatment for steam blight (refer to chapter 3)

Case	If condition	Decision
3. Tar spot	If there is a spot on the leaf with dark Pycnidium fruiting bodies in the middle, If it affect only leaf tissues, If forming peculiar circular hole,	Then the disease is Tar spot Treatment for tar spot (refer to chapter 3)

Case	If condition	Decision
4. Powdery Mildew	If temperature is humid, If there is white sign on the leaf, If it appears on young steams and then on the leaves, If steam develop a purplish tinge,	Then the disease is powdery mildew Treatment for powdery mildew (refer to chapter 3)

4.2.2. Linseed

In the tables below is the rules used for diagnosing linseed crop.

Case	If condition	Decision
1. Wilt	If the soil's moisture and temperature increase, If seedling shows drooping and shriveling, If necrotic lesion,	Then the disease is wilt Treatment for Wilt (refer to chapter 3)

Case	If condition	Decision
2. Root Rot	If temperature is cooler and the place is highland area, If it shows damping off, If Seedling blight,	Then the disease is root rot Treatment for root rot (refer to chapter 3)

Case	If condition	Decision
3. Pasmo	If the temperature is warm and humid weather, If lesions on steam and leaves,	Then the disease is Pasmo Treatment for Pasmo (refer to chapter 3)

Case	If condition	Decision
4. Powdery Mildew	If temperature is humid, If there is a white powdery growth on both side of the leaf, size, If the central part of the leaf spots falls off, If forming peculiar circular hole,	Then the disease is Powdery Mildew Treatment for Powdery mildew (refer to chapter 3)

4.2.3. Gomenzer (Ethiopian Mastard)

In the tables below is the rules used for diagnosing Ethiopian Mastard crop.

Case	If condition	Decision
1. White Rust	If it affects the flowers and the lower parts of the leaves, If you observe swelling and deformation of the terminal parts of flower stalks, If spiny stag heads,	Then the disease is White rust Treatment for white rust (refer to chapter 3)

Case	If condition	Decision
2. Blackleg (dry rot)	If lesion appears on leaves steams and roots, If the disease is more conspicuous on lower stem,	Then the disease is Blackleg (dry rot) Treatment for blackleg (refer to chapter 3)

Case	If condition	Decision
3. Powdery Mildew	If white powdery like structure on the leaves or pods, If temperature is humid,	Then the disease is Powdery mildew Treatment for Powdery mildew (refer to chapter 3)

Case	If condition	Decision
4. Leaf and pod spot	If light brown, grayish or dark brown spots appears on the leaves and pods. If temperature is humid,	Then the diseases is leaf and pod spot

Case	If condition	Decision
5. Downy Mildew	If its appears on the later part of rainy season, If angular spots on the leaves, If Veins and yellow spot on upper surface of the leaf,	Then the disease is downy Mildew Treatment for downy mildew (refer to chapter 3)

4.3. The Inference Engine

As discussed in chapter two the inference engine is the one that is going to do the reasoning. Simply it's a part of the program that is going to decide which disease is going to be diagnosis.

Backward chaining has been used because it's suitable for diagnostic system. It works from hypothesis to evidence [3, 9]. The aim of the system is to pick the best choice from many enumerated possibilities which are symptoms. So what it basically does is to take one of the disease symptoms as its sub goal and if its proven true by the user, then it asks the other sub goals then finally prove the goal which is the disease. If the user answer otherwise (no) then it goes on and ask other diseases symptom.

For example if we take the inference engine for noug disease diagnosis, it first assumes the disease is shot hole and asks the user one of the symptoms of shot hole disease, if the user reply "yes" then it will go on and ask the user the other symptoms of shot hole if the user answer "yes" to all the symptom then finally the inference engine decides that the disease is shot hole. But if the user answers "no" to one of the symptoms of shot hole then the inference engine will call the next predicate which is in this case noug blight. Predicates are functions whose domain is the set of {true, false} [12].

Like discussed in chapter two, the inference engine searches the rules and the facts from left to right and from top to bottom. And this technique is called backtracking [12].

Code used to diagnose oilseed crop diseases; the researcher tried to make the predicates and variables name meaningful so that the reader could easily understand how the inference engine works.

As indicated above backward chaining was used. For example Noug's disease diagnosis starts with hypothesis that the disease is shot hole.

```
shot_hole():-symptom_shot_hole1(),!.
```

If the first symptom "symptom_shot_hole1()" proved to be true by the user, then this predicate would call the next symptom of shot hole "symptom_shot_hole2()". The inference engine will carry on doing the same thing until the goal is proven. However if the user answer no to one of the symptom of shot hole then another goal would be considered in this case "noug_blight()"

Object oriented feature; Visual prolog like indicated in chapter two, is object oriented programming language [12, 18, 19].This means that there are built in classes and procedures inside the classes, and we can use these pieces of already written code in our program. Reusing existing code is an efficient way of writing programs [12, 18].

The researcher used a class called “vpiCommonDialogs”. It contains over 30 procedures like note (), messageBox(), ask(), and error() to access these procedure we have to refer the class like this,“vpiCommonDialogs::note(“this is note”)”. Or we can include the class name “vpiCommonDialogs” in the header file. The researcher includes “vpiCommonDialogs” in the header files so that there is no need to write “vpiCommonDialogs” every time the procedures are used.

```
Ans = messageBox("Noug Disease Diagnosis", "Do you observe Pycnidium  formed on the central part of
 infected leaf",
   mesbox_iconquestion,
   mesbox_buttonsyesnocancel,
   mesbox_defaultSecond,
   mesbox_suspendApplication)
```

For example in the code above the researcher used “messageBox()” procedure to get “yes” or “no” response from the user. When we call the procedure “messagebox”, it not only puts a message on the screen, it also accepts the button that the user clicks and returns tithe buttons are numbered from left to right starting with the number one. That means if the user clicks “yes” then the procedure returns one and if the user clicks “no” the procedure returns two and the result will be stored on “Ans” variable.

Below you can find a sample code taken from noug disease diagnosis. You can find the whole code used to develop the prototype in the Appendix I.

```
clauses
   shot_hole():-symptom_shot_hole1(),!.

   symptom_shot_hole1():-
   Ans = messageBox("Noug Disease Diagnosis", "Do you observe Pycnidium  ``formed on the central
part of infected leaf",
   mesbox_iconquestion,
   mesbox_buttonsyesnocancel,
   mesbox_defaultSecond,
   mesbox_suspendApplication),
   if Ans = 1 then
```

```
symptom_shot_hole2()
elseif Ans = 2 then
noug_blight()
end if.
```

```
symptom_shot_hole2():-
 Ans = messageBox("Noug Disease Diagnosis", "Do you observe formation of circular leaf spot of various size",
mesbox_iconquestion,
mesbox_buttonsyesnocancel,
mesbox_defaultSecond,
mesbox_suspendApplication),
if Ans = 1 then
symptom_shot_hole3()
elseif Ans = 2 then
noug_blight(),!
end if.
```

As mentioned above, user's response would be stored on "Ans" variable. If the user responds yes, then "Ans" variable would be one, and if the user responds no, then "Ans" variable would be two. These is where backtracking mechanism is used

```
        if Ans = 1 then
symptom_shot_hole2()
elseif Ans = 2 then
noug_blight()
```

If the user responds yes the inference engine will go on and check whether the next symptom is also true in this case "symptom_shot_hole2()" but if the user responds no then the inference engine would check the symptom of the next disease in this case "noug_blight().

So to put it short to reach at conclusion that the disease is shot hole the inference engine must get yes response to these predicates listed below. Otherwise the inference engine would check the next diseases.

```
symptom_shot_hole1()
symptom_shot_hole2()
symptom_shot_hole3()
```

symptom_shot_hole4()

In the same way to reach at conclusion that the disease is noug blight the inference engine must get yes response to these predicates listed below. Otherwise the inference engine would call on the next disease predicate in this case “tar_spot()”

symptom_noug_blight1()
symptom_noug_blight2()
symptom_noug_blight3()
symptom_noug_blight4()

4.4. Prototype User interface

The researcher has tried to make the user interface simple and easier to use. As mentioned in the earlier chapters the researcher has chosen visual prolog for its user interface features. The researcher also considered using SWI-prolog, but its command based; the user has to type to communicate with the system.

4.4.1. User interface of the main window

When KBS oilseed disease diagnosis (KBSODD) starts, the user would find a form as shown in the figure 4.1. The form comprises text explanation, and six buttons. The text explains the purpose of the system. The three buttons are used for diagnosing the selected oilseeds crop diseases, and the other three are for viewing general information about noug, linseed and Gomenzer.

The user could also use the task window (see figure 4.2) menu that has option of File, Edit, Diagnosis, General Expert advice, and help. If the user selects the “Diagnosis” from the task menu option, then a sub menu will appear which contains the list of the oilseed crops which are Noug, Gomenzer and Linseed. If the user selects the “General Experts’ Advice” option, similar sub-menu with the “Diagnosis” will appear which contains general information about oilseed crops.

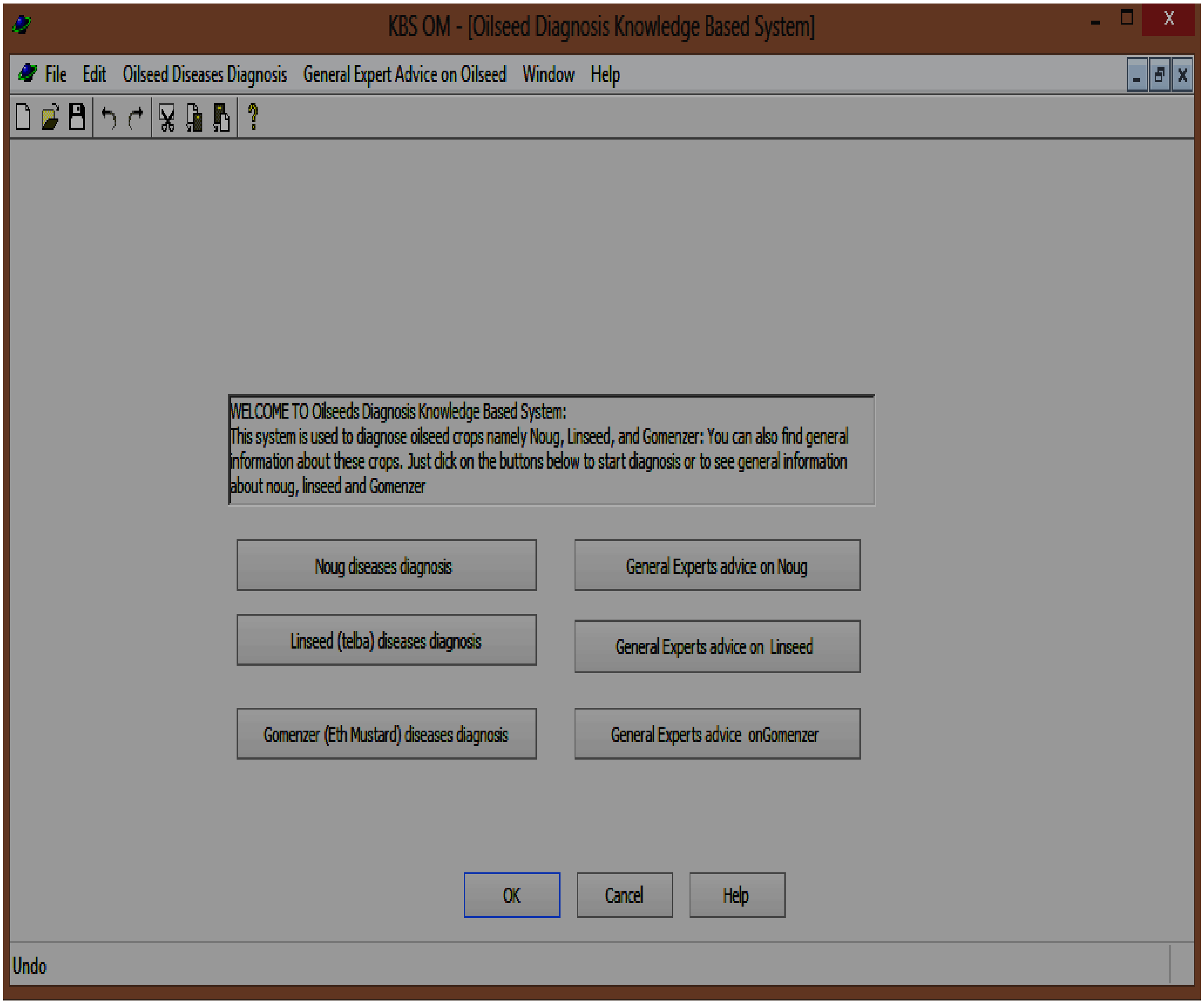

Figure 4.1 Main window of KBSODD

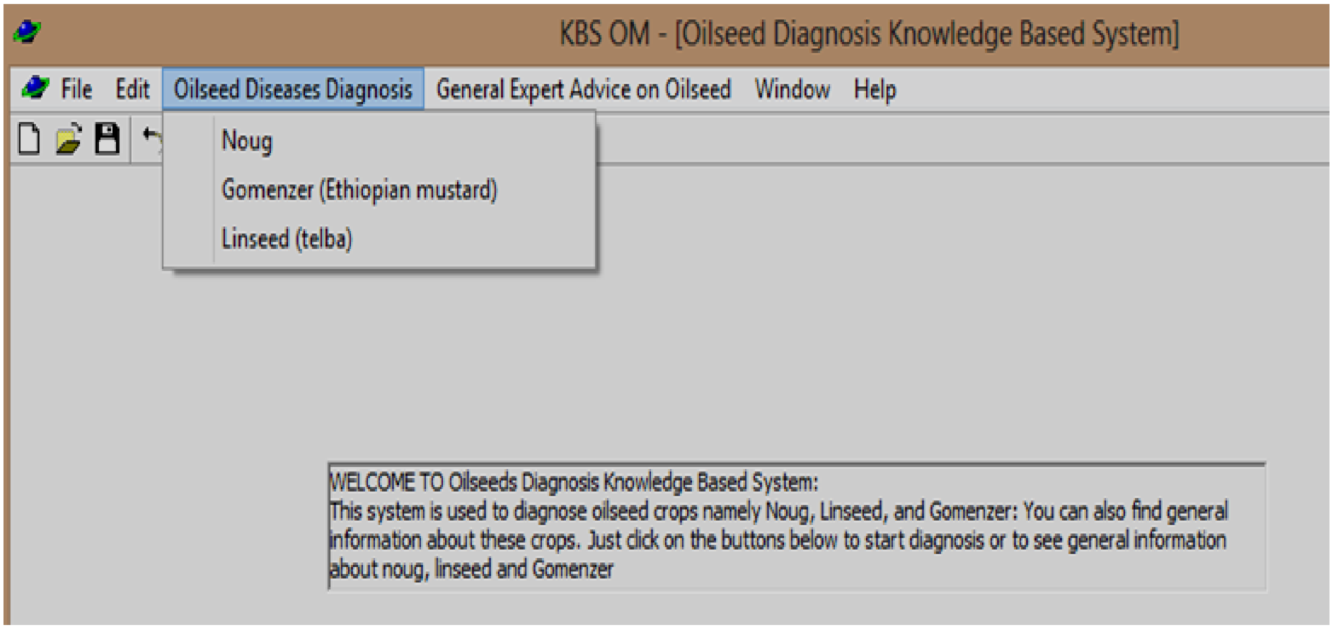

Figure 4.2 Main window of KBSODD

If the user clicks on general expert advice for noug a form will appear as shown in the figure 4.3. It contains information about suitable condition for the crop like, aptitude, rainfall, temperature, soil, and fertilizer. It also has information about major production area in the county.

This knowledge was gathered through interview and questionnaire. And the researcher believes that it would increase the importance of the prototype.

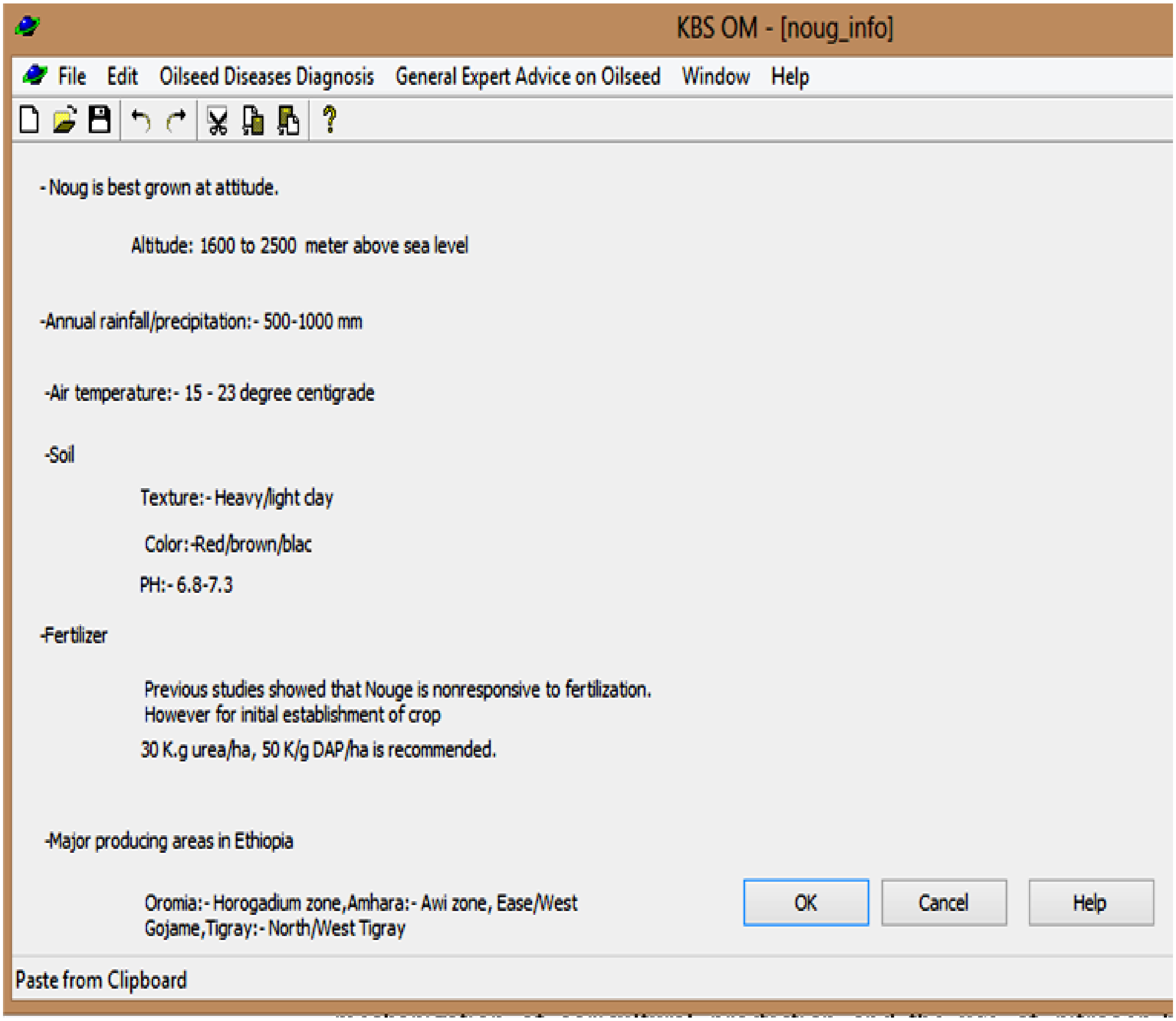

Figure 4.3 General Information for Noug crop

4.2.1. Oilseed Disease diagnosis

As indicated earlier the researcher used simple dialog box form the class "vpiCommonDialogs" which is found in library of visual prolog, to construct the user interface or the dialog between the user and the system.

Let's say the user clicks on linseed disease diagnosis buttons from the main screen, or chooses the diagnosis part from the task window and chooses "linseed" from the submenu, then a series of question will appear to figure out which disease affect the crop.

For example the system start by asking one of the symptoms of **wilt** disease if the answer is “yes” then it goes asking the other symptoms of wilt. If the answer to all series of symptom of wilt is “yes” then finally it can conclude that the disease is wilt, but if the answer is “no” then it asks one of the symptoms of other disease.

The following snapshots are dialog cases taken from one possible situation. Let’s assume the user clicks linseed disease diagnosis form the main window. And the prototype starts by asking one of the symptoms of linseed diseases as shown in the snapshot below.

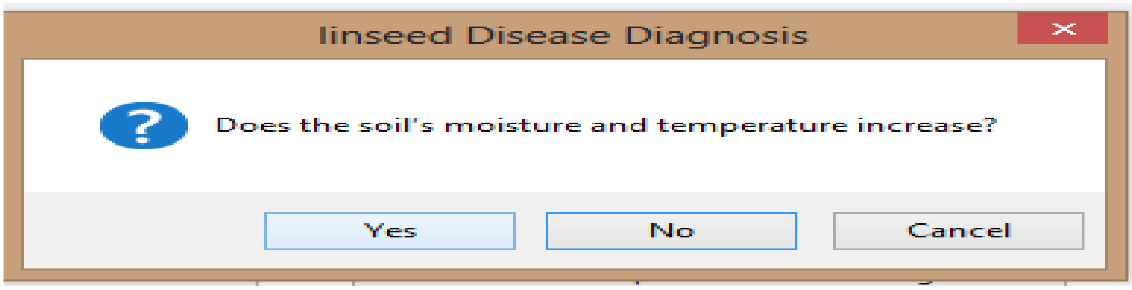

Figure 4.4 Dialog interface

If the user clicks “no”, another dialog window will appear as shown in the snapshot below.

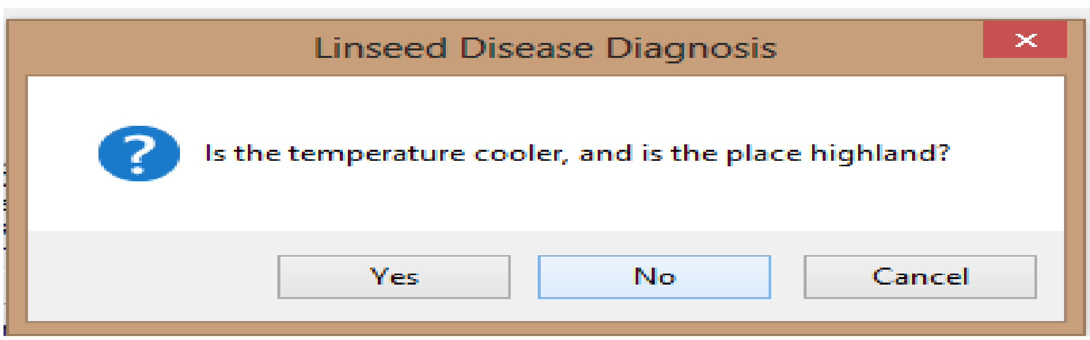

Figure 4.5 Dialog interface

If the user clicks “no”, again another dialog window will appear as shown in the snapshot below**.**

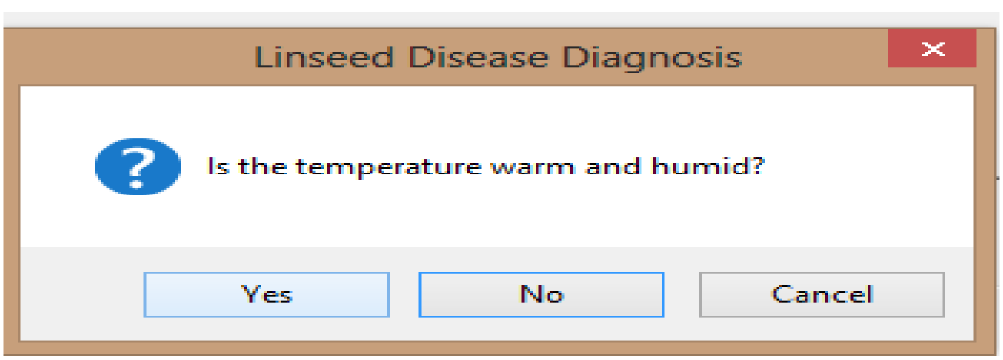

Figure 4.6 Dialog interface

If the user clicks “Yes”, another dialog window will appear as shown in the snapshot below.

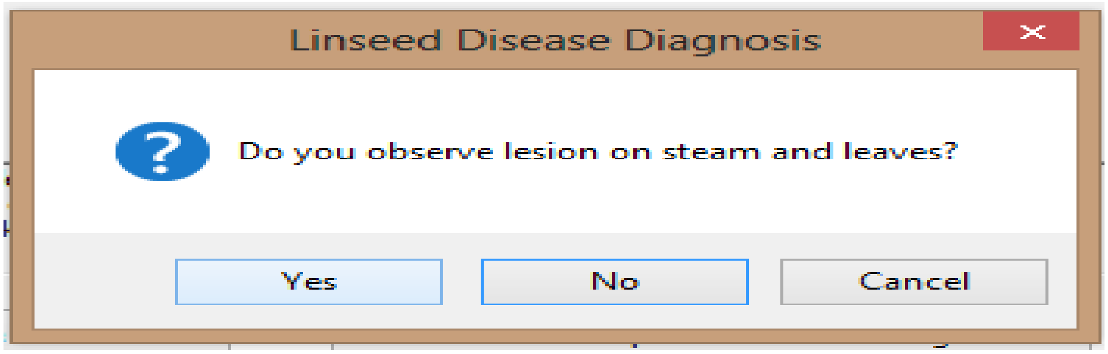

Figure 4.7 Dialog interface

If the user clicks “Yes”, another dialog window will appear like shown in the snapshot below.

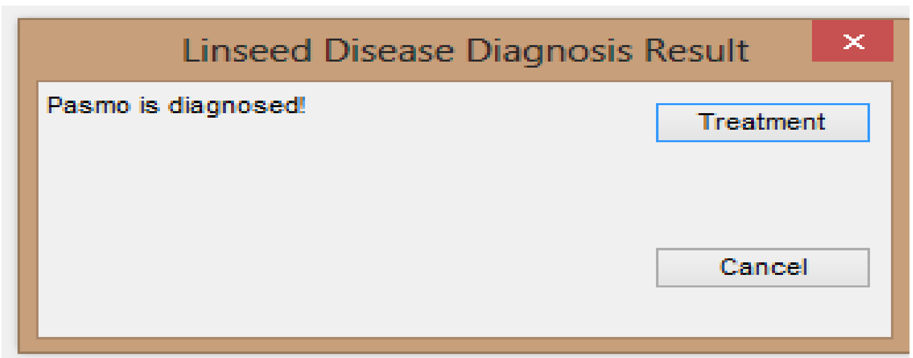

Figure 4.8 Diagnosis result

KBSODD has finally reached a conclusion and the result as shown in the snapshot above is pasmo. If the user clicks treatment; then another dialog window will appear as shown in the snapshot below with the recommended treatment. However if the user clicks “cancel” it would exit the program.

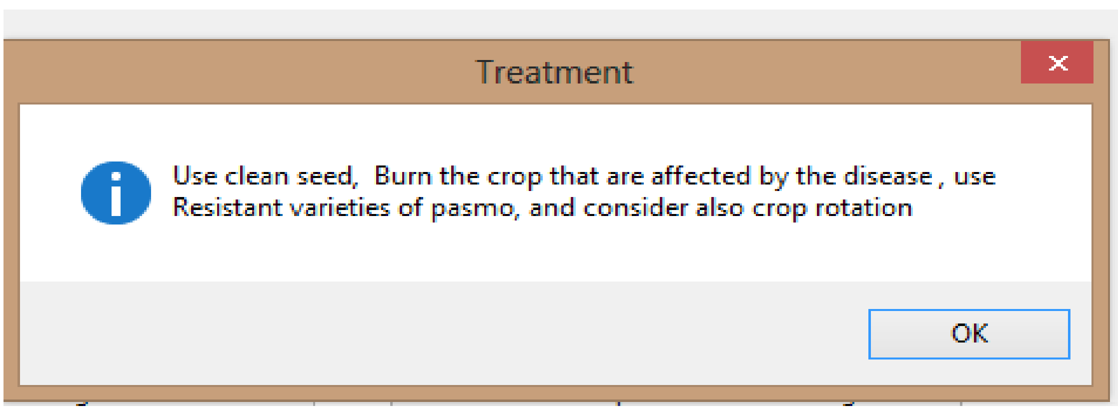

Figure 4.9treatments for pasmo

Once the knowledge based system for oilseeds diagnosis and treatment is designed and implemented, we tried to evaluate its performance and tested for user acceptance. The result is presented in the next chapter.

Chapter five
Evaluation and prospect of the prototype

5.1. Evaluation of the prototype

As indicated in chapter two one of the interesting features of KBSs is their ability to explain themselves. Given that the system knows which rules were used during the inference process, it is possible for the system to provide those rules to the user as a means for explaining the results [3, 9].However, in this case the explanations are relatively useless to the user. This is because the rules basically represent empirical knowledge, and not a deep understanding of the problem domain.

To evaluate the prototype, five domain experts and two DAs were selected as the system evaluators. The evaluation was done through questionnaire. The evaluators were allowed to rate the options as excellent, very good, good, fair, and poor. You can see the questions in table 5.1.

One of the best features of visual prolog is that, it will produce the executable (.exe) file of the project [12]. So the researcher gave the executable file of the prototype to the selected evaluators. After the evaluators were allowed to interact with the system by running number of cases; the researcher gave them the questionnaire that was prepared to evaluate the prototype. Using this questionnaire, domain experts and DAs feedback towards this developed system was gathered for analysis.

The format of the questionnaire was adapted from Ejigu [3]. And the questionnaire has five close ended questions, and one open ended question. The open ended question asks the expert if they have any comment or suggestion on the proposed prototype.

Table 5.1below shows the feedback from the domain experts and DAs. To make analyzing easier, the researcher assigned numeric value for each of the options given in words. The values are given as Excellent = 5 (100%), Very good = 4(80%), Good = 3(60%), Fair = 2(40%), and Poor = 1(20%). For example if we take the first question, “How do you rate the prototype? “In this case four of the evaluators rated the prototype as “Excellent”, two of the evaluators rated that the prototype as very good, and one evaluator rated the prototype as good. As a result, the average is (5+5+5+5+4+4+3)/7 = 4.4which is 88 %.

No	Questions	Excellent	Very good	Goo d	Fair	Poor	Aver age (5)	%age
1	How do you rate the overall performance of the prototype?	4	2	1	0	0	4.4	88%
2	Is the prototype easy to use and interact with?	3	3	1	0	0	4.3	86%
3	Does the system give the correct diagnosis result?	3	3	1	0	0	4.3	86%
4	Does the system give the right treatment?	2	4	1	0	0	4.1	82%
5	How do you rate the significance of the system in your domain area?	5	2	0	0	0	4.7	94.3%
		Total Average					4.36	87.2%

Table 5.1 Evaluation Result

As Table 5.1 indicates, the performance of the prototype was rated 88% by the experts and DAs. The easiness of the prototype was rated 86%.The correctness' of diagnosis result was rated 86%.The correctness of the treatment was rated 82%. The significance of the prototype in the domain area was rated 94.3%. The overall average performance of the prototype according to the evaluators is 87.2 %.

The prototype is good but it should be exhaustive by including detailed description of the diseases to be diagnosed, one of the experts wrote on the comment area.

The result was very encouraging, however the researcher noticed that expert's rules might not be clearly understood or expressed, and the user might be unsure of answers to questions. So the researcher recommends for those who plan to do similar work has to deal with uncertainty.

5.2. Prospect of the proposed prototype

The researcher had several interview with the experts from Holeta agricultural research center, highland oil crops Improvement project, concerning the prospect of the proposed prototype or generally applicability of KBS for agricultural purpose.

After showing the prototype the researcher asks the experts if it could be of any help for farmers or DAs in the near future. After discussing in depth with the experts we have come to conclusion that for the prototype to have a positive prospect it should be deployed with local language like Amharic, Afan Oromo, Tigragna.

The other factor that we agreed on was that since most of the farmers or DAs don't have personal computer, and might not have in the future, the prototype would be very applicable if the system could be deployed on smart phones.

The researcher has used an additional close ended questionnaire to assess the prospect of the system. Table 5.2 below shows the question asked and the feedback of the three experts from Holeta. The result was calculated as explained in evaluation section.

No	Your view on Knowledge based system for oilseed management.	Excellent	Very good	good	Fair	poor	%age
1	Do you think that knowledge based system has a potential of helping the farmers or development agents in the future?	2	0	1	0	0	80%
2	How much do you think would the system improve if we use local languages? (Amharic and Afan Oromo etc...)	3	0	0	0	0	100 %
3	How much do you think would the system improve if we deploy the program in mobile phone (smart phone)?	3	0	0	0	0	100 %

Table 5.2 questionnaire used to assess the prospect of KBSODD

As indicated in the table 5.2 the experts think that KBS could be a help for farmers or DAs when experts are not available in the future. And they very much agree that for the prototype to be effective or used by farmers it should be done using local language and it should be deployed on smart phones.

KBS could help farmers and DAs very much; as noted by one of the expert during the interview session. It's like putting your knowledge in different cabinet so that if you couldn't find it in first cabinet you would find it in other cabinet.

One of the expert suggested that picture would be more descriptive than words. There is a common saying that says picture is worth a thousand words. If we can gather picture of infected crop and shows it to the farmer, he/she can easily identify the symptom. So the researcher believes similar work should incorporate pictures, to make the system more effective.

Ethiopia is one of the fastest growing economies in the world [1, 4]. The Ethiopian electric power corporation has a rural electrification program in its five year development plan [1] and the price of computer and electronics equipment is decreasing every year. These factors make the prospect of KBS for agriculture in Ethiopia very positive.

Chapter Six
Conclusion and Recommendation

6.1. Conclusion

KBS is currently attracting a great deal of interest in the business community including agriculture. Almost all the business contemporary depends on knowledge. So it's always a good idea to find a way to keep and preserve knowledge.

In Ethiopia most of the peoples are farmers, it's believed that more than 80% of the population depends on agriculture; therefore it's logical to assume that there exists shortage of agricultural experts in the country. KBS can be used as an additional or source of information when experts are not available.

In this work the researcher has tried to develop a KBS prototype for diagnosis and treatment of oilseed crop. The main phases were knowledge acquisition, knowledge representation, developing and testing the prototype.

Most of the knowledge was gathered from three domain experts, from Holeta Agricultural research center, Highland oil crops Improvement project. The knowledge was gathered through interview, questionnaire, and document analysis.

Then the knowledge was modeled using Boolean decision tree which then was converted to if - then rule base. To diagnose and recommend the treatments of possible oilseed crop disease, the system uses goal driven or backward chaining inference mechanism. And rule based backward chaining is found to be suitable for oilseed crop diagnosis.

Finally the proposed system KBSODD was developed using visual prolog 7.5. The results of KBSODD were evaluated by the experts (from whom the knowledge was gathered) and 85.2% system performance result was obtained.

The researcher has also tried to find a way to make KBS system applicable in Ethiopia agriculture by discussing with the experts.

The researcher believes the prototype has some weaknesses and that it could be improved if it's integrated with probabilistic and machine learning technique.

Based on the result obtained after implementing the proposed prototype, the researcher strongly believes that KBS could be a help in the area of agriculture in the future, for farmers or DAs when experts are not available.

6.2. Recommendation

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

- During the discussion with domain experts, domain experts noted that KBS system has promising prospect for Ethiopian agriculture, especially if it's developed using local languages like Amharic, Afan Oromo and Tigrigna. So future work on this area should consider using local languages.
- In this study an attempt is made to develop text based KBS. To clear the advice provided by the system there is a need to incorporate picture that describe oilseed deseases.
- The domain Experts and the researcher also suggests that KBS would be more applicable if the system is deployed on smart phones since its handy and most of the farmers will eventually use one.
- The rule based knowledge base system in this study is not self-learning; so future work should improve the system performance by integrating it with learning component.
- The expert's rules might not be clearly understood or expressed, and the user might be unsure of the answers to the questions. So the researcher recommend for the future works on this area to use some probabilistic technique to deal with uncertainty.
- The knowledge was modeled using Boolean decision tree with only yes or no classification. The researcher believes that it would improve the model if probabilistic techniques are incorporated.
- The knowledge was collected from three experts and might not be enough so future work should consider adding to the knowledge to make it complete and could also work on fertilizers for oilseed.
- Visual prolog 7.5 came with a new feature like web based KBS so future work should consider web based KBS.

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Appendix I

Code used to diagnose noug crop. The structure of the code that was used to diagnose linseed and Gomenzer is basically the same.

```
predicates
   onNougClick : button::clickResponder.
   shot_hole:().
   noug_blight:().
   tar_spot:().
   powdery_mildew:().

   symptom_shot_hole1:().
   symptom_shot_hole2:().
   symptom_shot_hole3:().
   symptom_shot_hole4:().

   symptom_noug_blight1:().
   symptom_noug_blight2:().
   symptom_noug_blight3:().
   symptom_noug_blight4:().

   symptom_tar_spot1:().
   symptom_tar_spot2:().

    symptom_powdery_mildew1:().
    symptom_powdery_mildew2:().
    symptom_powdery_mildew3:().
    symptom_powdery_mildew4:().

   result_shot_hole:().
   result_noug_blight:().
   result_tar_spot:().
   result_powdery_mildew:().

   errorMessage:().
  clauses
   onNougClick(_Source) = button::defaultAction:-shot_hole().
```

```
clauses
    shot_hole():-symptom_shot_hole1(),!.

    symptom_shot_hole1():-
    Ans = messageBox("Noug Disease Diagnosis", "Do you observe Pycnidium  formed on the central part of infecte
d leaf?",
    mesbox_iconquestion,
    mesbox_buttonsyesnocancel,
    mesbox_defaultSecond,
    mesbox_suspendApplication),
    if Ans = 1 then
    symptom_shot_hole2()
    elseif Ans = 2 then
    noug_blight()
    end if.

symptom_shot_hole2():-
 Ans = messageBox("Noug Disease Diagnosis", "Do you observe formation of circular leaf spot of various size?",
mesbox_iconquestion,
mesbox_buttonsyesnocancel,
mesbox_defaultSecond,
mesbox_suspendApplication),
if Ans = 1 then
symptom_shot_hole3()
elseif Ans = 2 then
noug_blight(),!
end if.

symptom_shot_hole3():-
 Ans = messageBox("Noug Disease Diagnosis", "Does the central part of the leaf spots falls off?",
mesbox_iconquestion,
mesbox_buttonsyesnocancel,
mesbox_defaultSecond,
mesbox_suspendApplication),
if Ans = 1 then
symptom_shot_hole4()
elseif Ans = 2 then
```

```
noug_blight(),!
end if.

symptom_shot_hole4():-
 Ans = messageBox("Noug Disease Diagnosis", "Do you observe formation of peculiar circular hole?",
mesbox_iconquestion,
mesbox_buttonsyesnocancel,
mesbox_defaultSecond,
mesbox_suspendApplication),
if Ans = 1 then
result_shot_hole()
elseif Ans = 2 then
noug_blight(),!
end if.

result_shot_hole():-
Ans = ask("Noug Disease Diagnosis Result", "shot hole is diagnosed! " , ["Treatment", "Cancel"]),
if Ans = 0 then
   note("Treatment", "Use clean seed,
use crop rotation Field sanitation, Use Paliram 1.8 kg/hectare, Mistral 1 liter/hectare  and Tilt 0.5 litter/hectare ")
   end if.

clauses noug_blight():- symptom_noug_blight1().

   symptom_noug_blight1():-
   Ans = messageBox("Noug Disease Diagnosis", "Do you observe black or brown circular spot on the leaves?",
   mesbox_iconquestion,
   mesbox_buttonsyesnocancel,
   mesbox_defaultSecond,
   mesbox_suspendApplication),
   if Ans = 1 then
   symptom_noug_blight2()
   elseif Ans = 2 then
   tar_spot()
   end if.

   symptom_noug_blight2():-
```

```
Ans = messageBox("Noug Disease Diagnosis", "Do you observe small and straw brown color spot ? ",
    mesbox_iconquestion,
    mesbox_buttonsyesnocancel,
    mesbox_defaultSecond,
    mesbox_suspendApplication),
    if Ans = 1 then
    symptom_noug_blight3()
    elseif Ans = 2 then
    tar_spot()
    end if.

    symptom_noug_blight3():-
Ans = messageBox("Noug Disease Diagnosis", "Do you observe irregular dark lesion appears on the on the leaves a
nd steams ?",
    mesbox_iconquestion,
    mesbox_buttonsyesnocancel,
    mesbox_defaultSecond,
    mesbox_suspendApplication),
    if Ans = 1 then
    symptom_noug_blight4()
    elseif Ans = 2 then
    tar_spot()
    end if.

    symptom_noug_blight4():-
Ans = messageBox("Noug Disease Diagnosis", "Do you observe blighting on the leaf  ? ",
    mesbox_iconquestion,
    mesbox_buttonsyesnocancel,
    mesbox_defaultSecond,
    mesbox_suspendApplication),
    if Ans = 1 then
    result_noug_blight()
    elseif Ans = 2 then
    tar_spot()
    end if.

    result_noug_blight():-
```

```
Ans = ask("Noug Disease Diagnosis Result", "Noug blight is diagnosed! " , ["Treatment", "Cancel"]),
    if Ans = 0 then
    note("Treatment", "Use clean seed, Use crop rotation, field sanitation, Use of tolerant (resistant) varieties of noug
blight ")
    end if.

    tar_spot():-symptom_tar_spot1().

    symptom_tar_spot1():-
Ans = messageBox("Noug Disease Diagnosis", "Do you observe spot on the leaf with dark pycnidum fruting bodies
in the middle  ?",
    mesbox_iconquestion,
    mesbox_buttonsyesnocancel,
    mesbox_defaultSecond,
    mesbox_suspendApplication),
    if Ans = 1 then
    symptom_tar_spot2()
    elseif Ans = 2 then
    powdery_mildew()
    end if.

    symptom_tar_spot2():-Ans = messageBox("Noug Disease Diagnosis", "Does it affect only the leaf  ?",
    mesbox_iconquestion,
    mesbox_buttonsyesnocancel,
    mesbox_defaultSecond,
    mesbox_suspendApplication),
    if Ans = 1 then
    result_tar_spot()
    elseif Ans = 2 then
    powdery_mildew()
    end if.

    result_tar_spot():-
    Ans = ask("Noug Disease Diagnosis Result", "Tar spot is diagnosed! " , ["Treatment", "Cancel"]),
    if Ans = 0 then
    note("Treatment", "Use clean seed, use crop rotation, Use of tolerant (resistant) varieties of tar spot ")
```

```
   end if.

clauses    powdery_mildew():-  symptom_powdery_mildew1().

    symptom_powdery_mildew1():-
   Ans = messageBox("Noug Disease Diagnosis", "Is the temperature humid ? ",
   mesbox_iconquestion,
   mesbox_buttonsyesnocancel,
   mesbox_defaultSecond,
   mesbox_suspendApplication),
   if Ans = 1 then
  symptom_powdery_mildew2()
   elseif Ans = 2 then
   errorMessage()
   end if.

   symptom_powdery_mildew2():-
   Ans = messageBox("Noug Disease Diagnosis", "Do you observe white sign on the leaves ? ",
   mesbox_iconquestion,
   mesbox_buttonsyesnocancel,
   mesbox_defaultSecond,
   mesbox_suspendApplication),
   if Ans = 1 then
  symptom_powdery_mildew3()
   elseif Ans = 2 then
   errorMessage()
   end if.

   symptom_powdery_mildew3():-
   Ans = messageBox("Noug Disease Diagnosis", "Does it appears on young steam and then on leaves ? ",
   mesbox_iconquestion,
   mesbox_buttonsyesnocancel,
   mesbox_defaultSecond,
   mesbox_suspendApplication),
   if Ans = 1 then
  symptom_powdery_mildew4()
   elseif Ans = 2 then
```

```
  errorMessage()
  end if.

  symptom_powdery_mildew4():-
  Ans = messageBox("Noug Disease Diagnosis", "Does the steam develop purplish tinge ? ",
  mesbox_iconquestion,
  mesbox_buttonsyesnocancel,
  mesbox_defaultSecond,
  mesbox_suspendApplication),
  if Ans = 1 then
 result_powdery_mildew()
  elseif Ans = 2 then

  errorMessage()
  end if.



  result_powdery_mildew():-
Ans = ask("Noug Disease Diagnosis Result", "Powdery mildew is diagnosed! " , ["Treatment", "Cancel"]),
  if Ans = 0 then
  note("Treatment", "Use clean seed,
Use crop rotation, Field sanitation, use of tolerant (resistant) varieties of powdery mildew ")

  end if.
 errorMessage():-error("Sorry could not diagnose the disease! ").
```

Appendix II

4.2.2. Sample Questionnaire Presented to domain experts

This questionnaire is prepared by Biruk Ambachew, a student from Addis Ababa University, School of Information Sciences Graduate Program.

This questionnaire is prepared, to collect some important data, for the completion of the knowledge based system that the researcher is developing.

Knowledge based system is simply a computer program that emulates the decision-making ability of a human expert. The program uses human knowledge to solve problem that normally would require human knowledge.

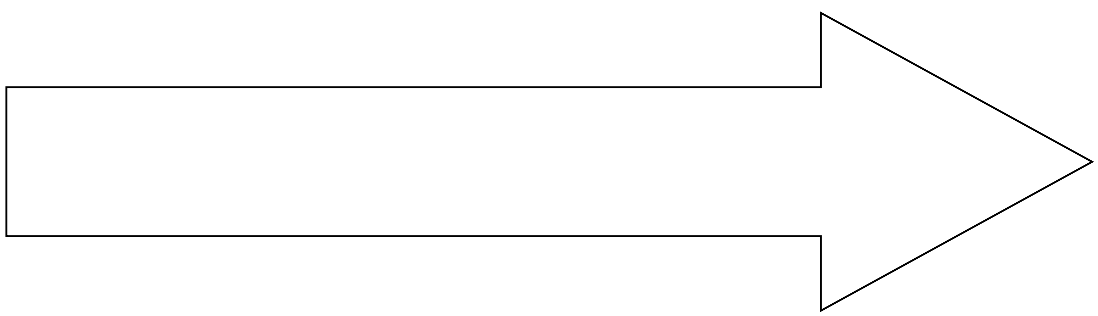
The researcher is currently trying to develop oilseed crop diagnosis system, for this purpose I need a slice of your precious time in filing this questionnaire with the appropriate answer. I thank you very much in advance.

Name:____

See the attached papers that were filled by the experts when they are asked to write the symptoms and treatment of oilseed disease.

The researcher simply listed the name of the disease and the agricultural experts select those which are economically important.

The places left empty are the diseases that were not selected by the experts.



2. Nouge

2.1. Shot hole

Shot hole is among the 15 diseases of Noug caused by fungi & it is one of the most widely distributed diseases of noug. As the name indicate this disease is characterized by first formation of circular leaf spot of various sizes and then pycnidia are formed on the centeral part of the infected leaf tissues. At advanced infection stage, the centeral part of the leaf spots falloff or plunge forming a peculiar circular hole becoming distinguishing character for the disease "Shot hole" and hence is the name. Among noug diseases, shot hole casuses low yield losses (Dereje 2011) about 10 % and hence doesn't seem to be economically important.

2.2. ~~Leg~~ Noug blight

Alternaria porri causes |symptoms| brown to black circular spots on the leaves while Cercospora guizotiae causes symptoms like smalland straw to brown colored spots mainly on leaves. In the latter case, spots may coalesce to cause defoliation and thus seem to be more damaging than that of Alternaria porri. In severe cases spots coalesce and killing larger area leading to blighting on leaves. The symptoms progressively decrease from lower to upper direction of the plant canopy confusing with senescence. At the latter stages all plant parts could be affected and severe damage & losses could occur.

2.3. Tar spot

As reported by Getnet Alemaw and Sharma (1996)

Phylosticta sp. can cause tar spot. Phylosticta is a Pycnidial fungus similar to Phoma except that the former infects only leaf tissues causing spots with dark pycnidial fruiting bodyes found in the middle of the spots. Hence phylosticta does not deposit a tar like sign (tar spot) on diseased parts of noug plant. Teklemariam et al (1985) has correctly recorded this disease in that tar spot on noug was caused by Phyllachora sp rather than Phylosticta sp. The fungal genus phyllachora causes tar spot sign in many plants species in Ethiopia (Stewart & Dagnachew, 1967).

2.4. Powdery mildew

The mildew symptoms in noug are very simple to recognize as in other crops. It appears on young stems and then on leaves. Affected areas on stems develop a purplish tinge while on the leaves it shows white sign. The grayish white mycelium that developed on plant tissue appears a mildew mark on the plant and disappears when the black cleistothecia develops at the latter stages.

2.5. Noug blight

Shot-hole, stem and leaf blight are the most frequently observed and economically important diseases Dereje et al reported that currently, noug blight is a serious disease in most places of the country where noug is widely grown. Dereje and his group have also made clear that, unless extrapolated from other similar crops and diseases, no controll method was studied for noug disease until now in Ethiopia. Hence disease managment methods like use of clean seed, crop rotation, field sanitation and good crop management and use of tolerant varieties are recommended.

3. Linseed

3.1. ~~Whlt~~ Wilt (*Fusarium oxysporium*) is reported to be one among (10) ten diseases of linseed caused by fungi. Wilt is also one of the most widely distributed diseases of linseed known. Hence, wilt is one among more pervasive diseases found in major linseed producing areas of the country; particularly in Centeral parts. Both wilt & root rot occured mainly in the cooler highland areas. Wilt can couse yield loss from 9.2 to 58.6 %

3.2. Root Rot Wilt/root rot disease is caused by (Fusarium sp.) and/Rhizoctonia solani) among the (10) ten diseases caused by fungi. Are among the major diseases of linseed. As mentioned here above both root rot and wilt are found mainly in the coler highland areas.

3.3. Seedling blight

3.4. Rust

Rust (Melampsora lini) was considered one of the problems during the early periods of linseed research Yitbarek (1991)

4.2. Blackleg

It was observed for the first time in the early 1970s in some experiment stations became one of the production limiting factors in rapeseed. The disease level reached epidemic in some production areas associated with the increased acreage of rapeseed coupled with poor crop rotation schemes followed by other cultural practices.

4.4. Powdery Mildew

4.5. Downy Mildew

Gomenzer often suffers from a downy mildew disease during the latter part of the rainy season. The disease is fairly common. Symptoms of the disease can de described as spots on the leaves are angular, often restricted by the veins and yellow in colour on the upper surface of the leaf. On the lower side of these spots, the purplish downy growth appears during periods of high humidity. However, this growth is not as conspicuous as in other downy mildews. The affected leaves may die and injury to the plant as a whole may be enough to cause a weak and stunted growth.

4.6. Stem Rot

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.

____

Biruk Ambachew, 2015

This thesis has been submitted for the examination with my approval as the university advisor

____

Dr Gashaw Kebede