Expert Systems in Agriculture: An Overview

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Abstract

Role of expert systems in agriculture and its applications in efficient crop production and protection technologies has been reviewed and discussed in this paper. Different domains of agriculture are highlighted where expert systems can play an important role for an expert in transferring expert-driven knowledge instantly at the level of farmer's field. This paper explores structure of an expert system, role of expert system in agriculture along with details of expert system developed in the different field of agriculture and also possibilities of designing, developing and implementation of an expert system for agriculture would motivate scientists and extension workers to investigate possible applications for the benefit of entire agricultural community.

Keywords: Expert System, Knowledge base, Inference engine, Crop Management, Crop Disease Diagnostic Domain.

I. Introduction

For around 80% Indian population, agriculture is one of the major source of livelihood. It has also always been India's most important economic sector. Although crop production is not up to the mark anywhere in the world but in developing countries like India it is even lower in comparison to other countries. The low production level has been very frequently attributed to the low yield potential. Crop production is a complex phenomenon that involves many activities and requires very complicated optimization and modeling steps. The overall crop production management problems involve, among many others, management of diseases and insect-pests, integrated water and fertilizer managements, crop economics etc. The management problems also include the lack of enough experts and availability of experts at the farmer's field to support the crop growers. Each crop requires entirely different management practices and cropping pattern. Farmers may not know about all the information on production technology, so they need rapid access to all the possible information and need to take fast decisions to manage their crops efficiently and effectively. In order to raise a successful pulse crop and remain competitive, the modern farmers often rely on crop production specialists to assist them in arriving at the timely decision. Unfortunately, crop specialists are not always available for consultation at the nick of the time. To solve this problem, an Expert System (ES) may become a powerful tool which is a dire need of the day for farmers,

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extension workers and Government officials. ES can provide on-line information on different crop management issues like diagnosing and controlling noxious and commonly found insect-pests and diseases, crop economics and designing schedule for irrigation and fertilization application etc. This paper explores the possibilities of designing, developing and implementation of an Expert System for different activities of agriculture in integrated approach.

II. Structure Of An Expert System

An Expert system can be viewed as having two environments[10,16]: the system **development** environment in which the ES is constructed and the **consultation** environment which describes how advice is rendered to the users (Fig. 1). The **development** environment starts with the knowledge engineer acquiring the knowledge from the expert. This acquired knowledge is then programmed in the knowledge base as facts about the subject and knowledge relationship. The **consultation** environment involves the user, who starts the process by acquiring advice from the ES. The ES provides a conclusion and explanation, using its inference engine. It is used by end-users (*i.e.* farmers/extension workers in agriculture domain) to obtain expert's knowledge and advice. The three major components that appear in virtually every expert system are the knowledge base, inference engine, and user interface [7,9].

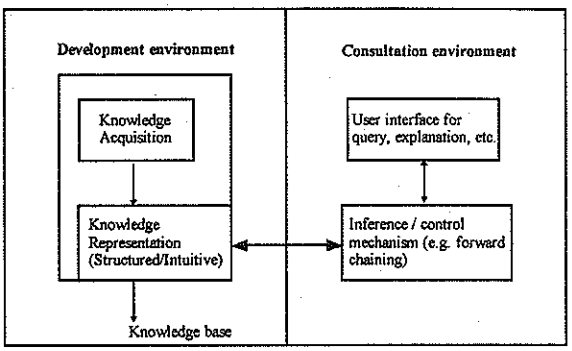

Figure 1 : Structure of an Expert System.

III. Role Of An Expert System In Agriculture

Traditionally, if a farmer is interested in crop cultivation, he encounters following problems related to information transfer.

Static Information: Information on pulse production technology stored and available in the problem domain reveals that the information is static and may not change according to the growers need. All extension literatures just give general recommendations without taking into consideration all the factors. Hence, generally the information is incomplete.

Integration of specialties: Most of the extension documents deal with problems related to certain specialties: plant pathology, entomology, nutrition, production, etc. In real situations the problem may be due to more than one cause, and may need the integration of the knowledge beyond the information included in different extension documents and books. Image may need, sometimes, an expert to combine other factors to reach an accurate diagnosis, and even if a diagnosis is reached, the treatment of the diagnosed disorder should be provided through extension document.

Updating: Over a period of time the extension documents become obsolete which need to be updated time to time. Changes in chemicals, their doses, and their effect on the environment should be considered while adopting the production and protection technology. Updating this information in the documents and dissemination of the same takes a long time.

Information unavailability: Certain information may not be available in any form of media. It is available only from human experts, extensionists, and/or experienced farmers. In addition, the information transfer from specialists and scientists to extensionists and farmers represents a bottleneck for the development of crop production technology on the national level.

The problems identified can be solved easily using Expert Systems technology in agriculture by using its knowledge base and reasoning mechanism through information acquired from human experts and other sources. Apart from these, the Expert System helps farmers and extension workers to generate all the relevant information and assists them in making environmental friendly and economically viable crop management decisions. Expert system in agriculture, therefore, offers to provide a necessary link between both research information and human expertise and the practical implementation of the knowledge.

IV. Expert Systems In Agriculture : An Overview

Expert system evolved as the first commercial product of Artificial Intelligence and is now available in the large number of areas. The potency, scope and appropriateness of expert system in the area of agriculture have been well realized two decades back in developed countries [1,11] and several successful systems have been developed in the field of agriculture. In the recent years, main focus of agricultural expert system applications research is on crop management and plant disease and insect-pests diagnosis [2,3,12,14]. These areas are followed by irrigation management, fertilization management, varietal selection, farm management, crop economics etc. Based on our literature survey, overview of some of the expert systems developed in agriculture fields especially in domain of crop management and crop disease/insect-pest diagnosis and control are presented here.

4.1 Crop Management Expert Systems

This category of ES includes advisory systems that emphasize the management of specific crops. These systems generally attempt to provide a complete and integrated decision support approach that includes most aspects of growing the crop. There are also crop management advisory systems that focus on specific management issues common to most cropping systems and can therefore be used on a wide range of crops within specific geographic regions[6]. The following ES deals with the growing of a specific crop:

GRAPE is an *ES for viticulture in Pennsylvania.* This ES was developed at Pennsylvania State University in association with Texas A&M University to address the advisory needs of grape growers. This system provides grape growers with recommendations regarding pest management (insect, disease and weed control), fertilization, pruning and site selection. The development environment included the rule based shell called Rule master on the Macintosh microcomputer.

ESIM an Expert System for Irrigation Management was developed for making decisions on water management in an irrigation project. The system was applied to an irrigation management problem of the Mae-Taeng Irrigation Project located in Northern Thailand. The system developed was interactive and made user friendly.

CROPLOT is a rule-based expert system for determining the suitability of crops to given plots. Its use was in the process of plot allocation when planning the production of field crops on the individual farm, usually under severe uncertainties. The system's performance was found satisfactory and a comparison between recommendations of human experts and CROPLOT showed 90% agreement.

COMAX provides information on integrated crop management in cotton. It is designed for use by farmers, farm managers, and county and oil conservation agents. The system uses a combination of expert-derived rules and result generated by the cotton – crop simulation model GOSSYM. This was the first integration of an expert system with simulation model for daily use in farm management.

CUPTEX is an Expert System for cucumber production management under plastic tunnel. System currently provides services on disorder diagnosis, disorder treatment, irrigation scheduling, fertilization scheduling, and plant care subsystems used by agricultural extension of agriculture, and by the private sector. It was developed in KADS. KADS is a methodology for building knowledge-based systems (reference). KADS was used for representation of the interface and task knowledge. Finally, LEVEL 5 object was object for the implementation. It was also the first deployed Expert System in developing countries not only in agriculture but in other fields as well.

CITEX is an Expert System for orange production. It provides services on assessment of farm, irrigation and fertilization scheduling, disorder diagnosis and disorder treatment. System was developed by the Central Laboratory of Agricultural Expert Systems(CLAES), Egypt.

NEPER WHEAT is an Expert System for irrigated wheat management developed at the Central Laboratory of Agricultural Expert System (CLAES) is Egypt. It performs various functions *viz.*, Advice the farmers on field preparation, control pests and weeds, manage harvests, prevent malnutrition, design schedule for irrigation and fertilization, select the appropriate variety for a specific field, diagnose disorder, suggest treatments etc. It is an easy-to-use in Microsoft Windows based application with an English and Arabic interface.

LIMEX is an integrated Expert System with multimedia that has been developed to assist lime growers and extension agents in the cultivation of time for the purpose of improving their yield. The scope of LIMEX expert system includes: assessment, irrigation, fertilization and pest control. This system was augmented with multimedia capabilities as enhancing an expert system by the integration an expert image, sound, video and data, allows for a good feedback from users, assists in better understanding of the system, and allows for more flexibility in the interactive use of the system. It was developed using an adapted KADS methodology for the

knowledge part. CLIPS TM Ver. 6.0 shell on Windows and CLIPS object – oriented language (COOL) was used for development of Expert System.

4.2 Crop Disease/Insect-pest Diagnostic Expert Systems

Expert System is not new for crop disease diagnostic domain. The weather-based computerized disease forecasters initially developed in the 1970's. Blitecast and the Apple Scab predictive system are examples of forecasters that are currently used to help farmers make decisions about the management of potato late blight and apple scab, respectively [8]. They are similar to expert systems in that the rationale behind their development and application is to aid in the implementation of economically and environmentally sound control practices for particular disease [5]. Of all the systems reviewed, disease/insect-pest management ES were by far the most common, numerous, and widespread. These systems provide farmers, researchers and extension workers with integrated disease and pest management strategies which include all relevant factors in order to adequately and cost effectively control diseases and insect-pests [13]. This requires that many factors such as population dynamics, weather, cost, fungicide and pesticide susceptibility, and the environment be considered in order to reach optimal decisions. Based on our literature survey, we have to mention here some of the expert systems developed for diagnosing diseases of many crops [4, 15] The following Expert Systems are the examples of such crop disease/insect-pest diagnostic systems.

POMME is an Expert system for Apple Pest Orchard Management. It was developed in Virginia to help in managing diseases and insect-pests on apples. This system provides growers with knowledge about fungicides, insecticides, freeze, frost and drought damage, non-chemical care options as well as information from a disease model. External information such as weather data including forecasts and crop symptoms are utilized by the system to generate management decision recommendations. POMME was one of the first expert systems to incorporate the decision making process of the expert to advice producers in making disease management decisions. The system contains more than 550 rules. PROLOG language was used to build POMME.

VEGES is a multilingual expert system for the diagnosis of pests, disease and nutritional disorder of six green house vegetable viz., pepper, lettuce, cucumber, bean, tomato, and aborigine. It provides the user with a diagnosis on the basis of a brief description of the external appearance of the affected plant. It then suggests method to remedy the problem (e.g., fertilizer, adjustment, fungicides or pesticide applications). The system is accompanied by a new language translation module which allows a non specialist user (e.g. extension officer) to translate the knowledge base to the native language or dialect of the local farmers.

CPEST is an expert system for managing pests and diseases of coffee in a developing country. Graphical user interface incorporated in CPEST that not only help the farmer in inputting information but also give them visual clues, such as pictures of a pest at different stages of

development. System consisted rule-set of 150 production rules. CPEST was built in wxCLIPS, a high-level programming language for constructing expert systems. CPEST uses forward chaining reasoning mechanism. CPEST's graphical user interface consists of about 40 screens.

AMRAPALIKA is an Expert System for the diagnosis of pests, diseases, and disorders in Indian Mango. The system makes diagnosis on the basis of response/ responses of the user made against queries related to particular disease symptoms. A rule-based expert system is developed using Expert System Shell for Text Animation (ESTA). The knowledge base of the system contains knowledge about symptoms and remedies of 14 diseases of Indian mango tree appearing during fruiting season and non-fruiting season.

POMI is an Expert System for integrated pest management of apple orchards. This system was developed cooperatively at the Istituto per la Ricerca Scientifica e Technologica and the Istituto Agrario S. Michele in Italy. The system provides the apple producer with help on first classifying observations and then providing recommendations on appropriate actions. The KEE development environment was used to construct this system. The system consists of two parts: classification of user findings, and explanation of these findings using abductive reasoning.

CALEX is an Expert System for the diagnosis of peach and nectarine disorders. System diagnoses 120 disorders of peaches in California, including insects, diseases, and cultural problems. The user begins a session by identifying a area on the plant where the problem occurs. The Expert System uses "Certainty Factor" to arrive at conclusions. At the end of a session the Expert System displays all conclusions reached with corresponding levels of certainty.

DDIS is a distance diagnostic and identification system developed at the University of Florida. The system allows users to submit digital samples obtained in the field for rapid diagnosis and identification of plants, diseases, insects, and animals. DDIS provides an environment for agricultural extension agents and specialists to share information on plants, insects and diseases. DDIS is a Java-based three-tier application using Java Remote Method Invocation (RMI) and object database technologies. The system creates a digital image library with associated site, crop, and pest or disorder data that could be used in educational program, assisted diagnosis, and data mining.

D-CAS is an expert system for aid in the appraisal and treatment of diseases of sugarcane. This multimedia computer program was designed and used with Windows as an expert system for identification and control of 59 sugarcane diseases. The program comprises 3 modules: diagnosis, data sheets with pathogen characteristics (including geographical distribution, symptoms, strains, transmission, host range, conditions favorable for disease development, economic importance and control) and data on diseases recorded in 19 parts of the world.

COUNSELLOR was developed in England by ICI Agrochemicals to manage insect and diseases on wheat. It was developed on a DOS computer using the expert

system shell Savoir. This shell is unique in that it uses evidence nets to predict risk of disease and to optimize treatment recommendations. COUNSELLOR displays a cost benefit analysis for the treatment recommendation.

PREDICT is an expert system for diagnosing pest damage of red pine stands in Wisconsin, runs on IBM or compatible microcomputers and is designed useful for field foresters with no advanced training in forest pathology or entomology. PREDICT recognizes 28 damaging agents including species of mammals, insects, and pathogens, as well as two types of abiotic damage. Two separate development tools (EXSYS and INSIGHT 2 +) were used.

PCEST is a pest control expert system for tomato. The system involves two main subtasks, namely: 'diagnose' and 'teat'. The 'diagnose' subtask finds out the causes of the growers' complains, while the 'treat' subtask finds out a treatment plan for these causes. Common KADS methodology has been used to develop the system. Dependency network is used as one of our knowledge representation schemes in both subtasks. A model-driven knowledge acquisition approach was used. Around 30 sessions of knowledge acquisition were held with seven domain experts from different specialties to acquire the domain knowledge of this application.

e-Sagu is a tool for IT–based personalized Agro-Advisory system. ("Sagu" means cultivation in Telgu language). It aims to improve farm productivity by delivering high quality personalized (farm–specific) agro-expert advice in a timely manner to each farm at the farmer's door–steps without farmer asking a question. In e-Sagu, the development of IT such as (Database, Internet, and Digital Photography) is extended to improve the performance of agricultural extension services. The e-Sagu system was implemented during 2004 by delivering advisory to 1051 cotton farms for the farmer of three villages in Warangal district in Andhra Pradesh.

PulsExpert is an operational automatic diagnostic tool that helps farmers/extension workers to identify diseases of major pulse crops and suggests the appropriate control measures. Automatic knowledge acquisition system of PulsExpert provides user-friendly interface to the domain experts for entering, storing and structuring the domain specific knowledge. The knowledge base of PulsExpert contains up-to-date knowledge about 19 major diseases of pulses. The system provides user-friendly interface to farmers and asks the textual as well as pictorial questions. On the basis of answers, PulsExpert diagnosis the pulse crop diseases along with its confidence factor and suggests most appropriate control measures which are composed of cultural practices as well as chemical controls.

V. Conclusion

The theory of Expert System is well developed & matured and can be applied to a wide spectrum of business problem. Perhaps one of the greatest hindrances in increasing crop production today is that of transferring new agriculture technologies developed at laboratories to the farmer's field. Expert System technology is an ideal approach for transferring the crop production technologies to the farmer's level, the ultimate consumer of agriculture research. Expert systems are not static but dynamic devices as there is always scope for improvement and up gradation.

The approach for the development of Expert System is not difficult to understand and tools for developing expert system are readily available, even some are freely available on internet. The careful development and logical use of Expert System in agriculture can help bridge the gap between research worker and extension worker.

This view of the future is the result of studies and experience gained through the Expert System currently being developed and implemented. Therefore, 'Expert System in Agriculture' aims to train extension workers and distribute the Expert System to all extension sites nation-wide. Taking the reducing prices of computers/ mobiles into consideration, internet connectivity at village level or punchayat level for the said purpose can be achieved.

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