AGRICULTURAL EXPERT SYSTEMS DEVELOPMENT IN EGYPT

Ahmed A. Rafea
Central Lab. for Agricultural Exper Systems
Agriculture Research Center
Dokki-Egypt
email: rafea@frcu.eun.eg

Abstract: This paper presents current efforts in developing expert systems for crop management in Egypt. It includes the description of five expert systems for Cucumber, Tomatoes, Orange, Lime, and Wheat. The development methodology and implementation tool are presented for each of these five expert systems. Early results of testing two of them are given and discussed. The paper concludes with some ideas for using expert system as a tool for decision making, for training, and for technology transfer in developing countries.

INTRODUCTION

A Central Laboratory for Agricultural Expert Systems (CLAES) was established in 1991 within the Agricultural Research Center (ARC) at Ministry of Agriculture and Land Reclamation (MOALR). The main objective of CLAES is transferring the technology of knowledge based systems in the field of production management of agricultural products to the Egyptian environment.

Production management of agricultural products is a complex problem that involves many parameters and requires very complicated modeling steps. Thus, decision making is difficult and depends very much on experiences of farmers and experts. Particularly, the dynamics of a decision in agriculture are such that the result of the decision may not show its effect except after a significant delay.

The paper will first present the expert systems developed at CLAES. Early results of testing expert systems for Cucumber and Citrus are then discussed.

EXPERT SYSTEMS DEVELOPED AT CLAES

In this section, an overview of expert systems developed at CLAES is given .The two expert systems developed so far are a result of the Expert System for Improved Crop Management Project (ESICM) which is funded by United Nation Development Program (UNDP), and executed by the Food and Agriculture Organization (FAO) in the Ministry of Agriculture and Land Reclamation (MOALR). These two systems have been developed for Cucumber and Citrus. The other three expert systems are being developed in three collaborative research projects with Michigan State University, Penn State University, and University of Florida. These three projects are funded by the National Agriculture Research Project (NARP) which is supported by USAID. Each of these five expert systems is a complex system. Therefore, each one is actually a set of expert systems.

Expert Systems for Cucumber

The first expert system has been developed for cucumber seedling production under plastic tunnels. In order to develop this prototype, a throw-away research prototype was produced to investigate the feasibility of the expert systems technology for the domain of crop production management (Rafea, Warkentin,Ruth,1991). A laboratory prototype was developed (El-Dessouki, et al,1991). This laboratory prototype was verified and validated (El-Dessouki, Rafea, Youssef,1992). The field prototype was the result of the verification and validation of the lab. prototype. This prototype has six functions: seeds cultivation, media preparation, control environmental growth factors, diagnosis, treatment, and protection. It was implemented in EXSYS Professional [EXSYS, 1988]. Although the design did include Frames, the implementation was completely in rules. This was because the frames support in the shell was limited. The implementation has used the Hypertext facility included in the shell. The overall control was implemented using the language provided by the tool and consequently, the rule base was divided into modules according to the system functions. The prototype consists of: 46 qualifiers, 89 choices, and 109 rules. This is in addition to the developed hypertext for explanation, image files for the same purpose, and the code of control. The experience gained was the need to have more powerful support for frames representation, and more flexible inference strategies.

Another expert system for Cucumber, Precultivation Management under Plastic Tunnel (CUPTEX/ precultivation), was developed (Rafea, et al,1992) using NEXPERT/OBJECT shell. CUPTEX/ precultivation has two main functions: Tunnel preparation, and soil preparation. The outputs of this expert system are a set of agricultural operations. Some of these operations are special to a specific situation, and the others are routine operations. User interfaces, and hypertext-like facilities were customized using the shell capabilities. It was found that there is a great deal of routine operations for which no preconditions are to be satisfied. However, the explanation on these operations may be very useful for novice growers.The prototype consists of : 33 objects, 23 hypotheses, 60 rules, and explanation files. The experience gained was the need to develop the interfaces externally using a programming language, in this case it is C as the shell provides a run-time library to communicate with Microsoft C. The hypertext support is limited in NEXPERT. The How-explanation had to be externally developed.

A third expert system was developed for handling Cucumber disorders CUPTEX/disorder-handling (El-Dessouki,Edrees,El-Azhari, 1993). The main objective of this expert system is to identify the cause of an observed disorder, its severity, and then propose the appropriate remediation. The user can consult directly the remediation part if the cause of the disorder is known for him. However the remediation part, in this case, verifies the cause given by the user before giving the remediation advise. The subsystem for Cucumber was implemented using KROL (ESICM,1992). This expert system consists of approximately 400 rules, and 100 objects which includes the disorders and materials used for remediaiton. The experience gained was how to transform the design made in KADS methodology (Wielinga, Schreiber, Breuker, 1992) into KROL, and how to build the user interface, and database interface in the C language and linked to KROL which was built on top of Prolog.

Expert Systems for Citrus

An expert system for the technical feasibility of Citrus cultivation (CITEX/feasibility) was developed (Salah, Rafea, Mohamed,1992) using NEXPERT/OBJECT shell . CITEX/feasibility) for the time being handles only Oranges which represent approximately 75% of Citrus Production in Egypt. The function of CITEX/feasibility is to generate one of these decisions : the site is perfect for cultivation, a set of treatment operations has to be applied before cultivation, it is feasible to cultivate but you have to follow a set of recommendations, or the site is not suitable for cultivation. The implementation strategy was the same as CUPTEX. This expert system consists of: 22 objects, 12 hypotheses, 44 rules, and explanation files. This expert system was being developed concurrently with CUPTEX/precultivation. Therefore, the experience gained from CUPTEX/preculdvation was actually a result of implementing this expert system as well.

The CITEX/agromanagement expert system was later developed (Salah,et al,1993). The main objective of this system is to generate an irrigation, fertilization, and preventive operations schedules. The irrigation and fertilization schedule includes the water quantity, irrigation interval, nutrient quantity, and application interval. These outputs are based on quantitative reasoning rather than heurestic reasoning. The preventive operations schedule includes the preventive operations such as agriculture practices operations, and preventive chemical spraying. This expert system was developed using Nexpert/Object shell (Nexpert,1988), and was transferred to KROL as well. The number of rules of this expert system is approximately 700 rules, and 100 objects which are the disorders and materials used. This expert system was concurrently developed with CUPTEX/disorder-handling. Therefore, the experience gained from CUPTEX/disorder-handling was actually a result of implementing this expert system as well.

Expert System for Wheat

This expert system is being developed in collaboration with Michigan State University (Kamel,et al,1993). In this system, the integration of a simulation model with the expert system is being investigated using the well known CERES simulation model.

The expert system is suggested to include: Varietal Selection, Planting Date Calculation, Irrigation and Fertilization Requirement, Insect and Disease Identification, Insect and Disease Remediation, and Harvest Management.

The methodology adopted for this project is the generic task methodology. The implementation tool is the object oriented package Small Talk.

Expert System For Lime

This expert system is currently being developed in cooperation with University of Florida in a project supported by NARP. The Lime was selected in this project as it is the second crop in production in the Citrus group in Egypt.

A technical feasibility study was conducted to identify the scope of the expert system to be developed for Lime (LIMEX) (LIMEX,1993). The result of that study identified the expert system scope to cover: Services, Irrigation, Fertilization, Pest Control, Flowering control system, and Fruit Life Control System. Actually, the Fruit Control System is a new component that we are trying to develop an expert system for in this project. The report mentioned hereabove recognized that there is a lack of knowledge of how to control the fruit life either on the tree or during storage after harvesting. This is very important for marketing which is a great problem the growers are facing now in fruit production. The production of fruits now exceeds the demand of local market and consequently, growing fruits does not pay off. If the producers could control the fruit life until the market is in need of the product and/or control the quality of the fruit to meet the requirement for exportation, then the fruit growing will pay off.

It is intended to use the CLIPS shell in the development of this expert system. The reasons for using CLIPS is to be able to integrate easily the developed expert system with software developed in University of Florida for Images and databases. The knowledge for the two identified modules are being acquired, and the software for creating Arabic textual database is being developed.

Expert System for Tomatos

The development of this expert system lies in a wider project aiming at studying the introduction of expert system technology in the extension system in Egypt. This project is being implemented in cooperation with Penn-State University. Tomato is selected as an example to assess the needs of end users, who are the growers, and consequently assess the needs for introducing the expert systems technology.

A survey has been conducted and its results showed that there is a lack of knowledge in different aspects of crop management, especially in pest management. Therefore, it was decided to concentrate on the identification and remediation of insects and diseases.

The KADS methodology is being used for the development of this expert system with an extesion of using the Dependency Network to represent the domain layer in a pictorial form. Dependency Network was used successfully in Penn-State as an intermediate knowledge representation scheme, and the project has decided to investigate using this intermediate representation to code the domain layer.

TESTING EXPERT SYSTEMS

The expert systems developed were thoroughly tested by the knowledge engineers, domain experts participated in knowledge acquisition, and by external domain experts. The comments observed at each level of testing were handled.

Another type of testing was conducted during the training cycles of extension workers. The objective of this testing was two fold: first, to measure the effect of using expert systems on the performance of the extension workers, and second to assess the decision taking skills of the extension workers compared with decisions generated by the expert systems. The methodology followed to achieve this objective is presented in the first subsection. Whereas, the results of applying this methodology is given in the second subsection.

Methodolgy for Testing during Training

This type of testing was done as follows:

1- Sets of cases covering the different aspects of the developed expert systems, were prepared in forms. Each set was approximately 20 cases.

2- Each trainee was given around 10 cases before conducting the training and was asked to give his decisions for these cases. The decision is either irrigation schedule, fertilization schedule, symptoms to be observed if a disorder is suspected, or a treatement schedule.

3- The training was conducted by letting the trainees run the expert system, providing the inputs in the cases and observing what the outputs of the expert system are. During training, each trainee was given all the cases, and other cases, he created, were also run on the system.

4- The same cases (cases before training) were given to each trainee after conducting the training . He was not told that they are the same cases nor had he access to the forms he filled before training.

5- The forms filled before and after training were analysed taking the results produced by the expert system as a reference. A score was given to the decision taken by each trainee based on the decision generated by the expert system, i.e. if the trainee's decision is compatible with the expert system, this trainee gets the full mark and if it is far beyond this decision, he gets zero. If the decision is not completely comptible, and is not completely wrong either, a score was estimated by a domain expert who was responsible for this evaluation.

Testing Results

Applying the methodology on 11 extension officers specialized in protected cultivation using the expert system for Cucumber (CUPTEX), and on 8 extension workers specialized in Horticulture using the expert system for Orange (CITEX),the results of the analysis are summarized as shown in Table-1. The entries of this table represnts the average score of the trainees before and after conducting the training on using the expert system. It can easily be noticed that an improvement in the performance has occured, and the performance of the developed expert system is much more better than the extension workers even after using the system.

Table-1 Testing Results

	CUPTEX		CITEX	
	Before	After	Before	After
Disorder Verification	29.9%	52.2%	9.4%	55.0%
Treatment	25.7%	48.4%	7.5%	44.7%
Irrigation	40.0%	72.4%	35.5%	64.1%
Fertilization	25.6%	66.0%	51.4%	67.8%
Average	30.3%	59.8%	26.0%	57.9%

Discussion

First of all, it should be noticed that the percentages presented in Table-1 are not absolute i.e. one cannot say that these percentages reflect their actual capabilities. But the increase in these percentages means that they were convinced by the system that the solution it provides is good and that is why their decisions were more comptible with the system after training. We must also not forget that an early assumption was made that the expert systems decisions are the right ones because they were thouroughly tested in the laboratory by domain experts. For sure these numbers may be changed after testing the expert systems in the field. However, what is important here is the trend rather than the absolute values.

As can be seen in the table, the average enhancemet in extension worker performance for both CUPTEX and CITEX was approximately doubled after using the system. Another important remark taking the score percentages after training, and neglecting small differences is coincidence of the subsystems score order of the two systems to be: Irrigation , Fertilization, Disorder Verification, and Treatment in descending order. This indicates the needs priority to devlop expert systems in crop management domain.

CONCLUSION

The work presnted in this paper, when completed, will be the basis for detailed comparative studies of methodologies and implemetation tools.

Early results of using two of the five systems described proved the effectiveness of expert system technology as a training tool. More work should be done to measure the performance of the extension workers on regular basis while using the expert systems.

Measuring the effect of using the expert systems on maximizing the production, and minimizing the cost, will also be done once the expert systems start to be in the production environment and are used as a decision support tool.

The developed expert systems can be used to transfer the technology from one country to another. Adapting the expert system to run in another environment could also be done by establishing a mechanism for exchanging knowledge and information among developing countries.

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