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Using Expert Systems as a Training Tool in the Agriculture Sector in Egypt

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Abstract—*This paper describes the Egyptian experience in using Expert Systems (ES) as a training tool in the agriculture sector. The work described here is part of an ongoing research to study the use of ES in human resources development. In particular, we present the use of such a tool as an instructional device for increasing the efficiency of extension workers through improving their general decision-making skills in their jobs. To clarify this process, we conducted an experiment and analyzed its results. Copyright © 1996 Elsevier Science Ltd*

1. INTRODUCTION

Knowledge-based systems (KBS) are computer programs that incorporate heuristic knowledge and emphasize declarative knowledge over procedural problem solving. KBS can be used as a powerful training tool. In general, the goal of training is to produce a motivated user who has the basic skills needed to apply what has been learned and then to continue to learn on the job (Compeau et al., 1995). Two features make KBS an excellent training tool for personnel whose mission is providing advice. The first feature is that KBS incorporate experienced-based knowledge derived from different sources of a certain domain, e.g. human experts, and is now structured and provided in a very portable and easily accessible medium. For example, by using an expert system for crop management, the crop consultant is forced to go through the entire reasoning process in a systematic manner ensuring consideration of all factors affecting the decision. Another feature of the KBS is the explanation facility which is inherently an educational tool. Explanation facilities provide for reasoning which is important as a training tool for new personnel, e.g. new extension personnel that are new to certain crop.

Literature that sheds light on using KBS in training programs is beginning to emerge. An empirical study of the use of ES in U.S.A. business schools and its implications for industry is present ed in (Teer et al., 1994). Several cases and benefits of using KBS as an instructional device in MBA programs is surveyed in (Dologite, 1991). An interesting study by Mockler (1990) is the use of KBS for teaching and performing KBS development. This development is to guide both technical and non-technical managers in finding, defining, selecting, evaluating an area, decision or task for potential KBS development. Moreover, an expert system can be used to advise managers on selecting employees for training, as in Ntuen et al. (1995), which is time consuming and belongs to a special class of multiattribute decision making.

The study described in this article addresses the use of ES as a training tool for increasing the efficiency of extension workers through improving their general decision-making skills in their jobs. The next section briefly presents the needs for ES's technology in the agriculture sector. Then the focus turns to a description of the agriculture extension service environment. The expert systems involved in this training are then described briefly. It is followed by a description of the experiment conducted during the training of extension workers that is the concern of this study. Next, we discuss the outcome of applying the experiment and present its results. In a concluding section, we present some final remarks.

2. THE NEEDS FOR EXPERT SYSTEMS TECHNOLOGY IN THE AGRICULTURE SECTOR

Agriculture production has evolved into a complex process requiring the accumulation and integration of knowledge and information from many diverse sources including marketing, horticulture, insect management, disease management, weed management, accounting and tax laws. Expert systems are tools for agriculture management since they can provide the site-specific integrated and interpreted advice that farmers and consultants need to more efficiently handle management concerns (Rafea, 1995). This section decribes the need for ES as a tool for decision support and as a tool for training.

2.1. The Need for Expert Systems in Decision Support

The development of an agriculture expert system requires the combined efforts of specialists from many fields of agriculture, and must be developed with the cooperation of the farmers and extension officers who will use them (Broner et al., 1992). A recent study of the needs assessment for expert systems in the agriculture sector in Egypt (ESICM, 1994) suggested that the sector needs to use the ES technology to improve the quality of the products and increase the efficiency of the agricultural system.

Expert systems are recognized as an appropriate technology because they address the problem of transferring knowledge and expertise from highly qualified specialists to less knowledgeable personnel. In agricuture, this transfer is always taking place from research to extension, from extension to farmers, and even from farmer to farmer. Expert systems present excellent tools for relieving the increasing pressure on the limited expertise available in developing nations. It must be recognized that knowledge, the very foundation of expertise, is a scarce resource in developing nations. Expert systems can help expand this vital resource by making available, in specific situations, vital knowledge that increases the effectiveness of less experienced personnel.

Expert Systems can be used by decision makers at different levels: operation level and planning level. On the operation level, the extension worker in the village, district, and/or governorate can use the system to support him in making his decision in giving the appropriate advice to growers. On the planning level, the decision makers can use the expert system for predictions, such as on the needs for water, fertilizers and pesticides for a particular crop in the region given the area cultivated with such a crop. This generated information is very important for different users: the traders, the exporters, the importers of these materials. Another type of application is the estimation of the yield given a simulation model linked with the expert system. The prediction of yield can serve the decision makers in deciding the amount to be imported in advance, if any, and hence take necessary actions.

2.2. The Need for Expert Systems in Training

Although the goal for developing agricultural expert systems in Egypt has to be used as a decision support tool for the extension workers, practical training of extensionists on the developed ES has revealed that ES can be used for expediting the training of extension workers. In the near future, it is not expected to install computers in the 4000 villages in Egypt. Installing computers in the 200 district offices, however, is an attainable goal. Therefore, if these 200 centers could be used to train the extension workers at the village level using the ESs installed at these centers, there will be a tremendous impact. Traditional ways of training are not sufficient to cope with the fast growing technologies in the different agriculture specialties for the different crops. Using ESs will reduce training time and enhance its quality.

3. AGRICULTURE EXTENSION SERVICES ENVIRONMENT

Agriculture development in Egypt depends on the connection between the three sides of the extension process (CLAES, 1993): (1) research, (2) extension and (3) farmers. The reporting of problems, and finding solutions to them are the main concern of the cooperative extension programs.

Through the different stages of technology development and information transfer to farmers, the extension sector works with the research component to narrow the gap between research results and this application in the field.

Extension engineers help in studying the production situation as they can identify farmers' problems through watching the farmers and working with them to diagnose problems and attempt to find the solutions.

The Ministry of Agriculture and Land Reclamation in Egypt is concerned with all activities in agriculture development, and gives special attention to the cooperation of research and extension in order to facilitate continuous training for all people concerned. This is done to spread appropriate agriculture technology all over the country.

4. A BRIEF DESCRIPTION OF THE EXPERT SYSTEMS USED IN TRAINING

The expert systems being used are mainly for crop management which are developed by the Central Laboratory for Agriculture Expert System (CLAES) at the Agriculture Research Center of Ministry of Agriculture and Land Reclamation in Egypt. They are the Cucumber Expert System (CUPTEX) and the Citrus Expert System (CITEX). CUPTEX (El-Dessouki et al., 1993; Rafea et al., 1995) is an expert system for cucumber production management in a plastic tunnel. CITEX (Salah et al., 1993) is an expert system for citrus production in open fields. Both the two expert systems were modeled using the KADS methodology (Schreiber et al., 1993; Wielinga et al., 1991). A laboratory prototype was implemented using the NEXPERT Object shell (Neuron Data Inc., 1991). Currently, they have been transferred to a knowledge representation language based on object-oriented and logic programming paradigms (ESICM, 1992). These expert systems are intended to be used by the agricultural extension service within the Egyptian Ministry of Agriculture and by the private sector. The following are components or subsystems of the two expert systems: irrigation, fertilization, verification and treatment.

The main objective of the irrigation and fertilization subsystems is to generate schedules, that include the water quantity, irrigation interval, nutrient quantity and application interval. These outputs are based on quantitative reasoning rather than heuristic reasoning. The objective of the verification subsystem is to confirm the user suggestion of particular disorder according to the symptoms provided by the user. The objective of the treatment subsystem is to recommend treatment operation according to a case description.

5. EXPERIMENT DESCRIPTION

This section describes the experiment conducted during the training of extension workers at the project premises for CUPTEX and CITEX at CLAES. CLAES provided an excellent research site for this study. To date, 749 man/days training were realized. This experience provides a useful vehicle for evaluating the effect of using ES as a training tool to increase the decision-making skills of extension workers. Concerning this study, 11 extension workers who specialized in protected cultivation were involved in the evaluation using CUPTEX and 8 extension workers who specialized in horticulture were involved in the evaluation using CITEX. The objective of conducting this experiment 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-making 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, its application is given in the second subsection.

5.1. The Methodology

The proposed methodology is based on tests conducted during one training cycle of competent extension workers to measure the effect of using expert systems on their performance, and to assess their decision-making skills compared to decisions generated by the expert systems. It can be summarized in the following steps:

(1) Design forms to document the cases and their results.
(2) Prepare cases which are described by a set of input data.
(3) Distribute these cases to the trainees to give their decisions before using the expert system.
(4) Train the extension workers on the expert system.
(5) Distribute again the same cases without their previous decisions and ask them to give their decisions again.
(6) Evaluate the cases before and after training

TABLE 1
Irrigation Results

	Average score before (%)	Average score after (%)	Enhancement	Percentage of enhancement
Water qty	38.1	73.6	35.5	93.18
Interval	41.9	71.2	29.3	69.93
Average	40.0	72.4	32.4	81.00

TABLE 2
Fertilization Subsystem Results

	Average score before (%)	Average score after (%)	Enhancement	Percentage of enhancement
Nitrogen	44.8	64.4	19.6	43.75
Phosphorus	36.3	50.9	14.6	40.22
Potassium	40.1	60.6	20.5	51.12
Magnesium	7.0	62.3	55.3	790
Manure	0.0	91.8	91.8	infinity
Average	25.64	66.0	40.36	157.41

TABLE 3
Verification Subsystem Results

	Average score before (%)	Average score after (%)	Enhancement	Percentage of enhancement
Symptoms on leaves	16.5	38.9	22.4	135.76
Symptoms on stem	28.8	46.5	17.7	61.46
Symptoms on root	40.3	87.5	47.2	117.12
Symptoms on fruits	34.0	36.0	2.0	5.88
Average	29.9	52.23	22.33	80.06

taking the expert system results as a reference (the result of the expert system for these cases had been verified with domain experts before conducting the experiment). The following formula is used to compute the percentage (%) of the enhancements:

$$\frac{\text{Enhancement}}{\text{Average Score before using the ES}} \times 100$$

where the *Enhancement* is the difference between the average score before and after using the ES.

5.2. The Application of the Methodology

The methodology was applied as follows:

(1) Forms were designed for the different subsystems of CUPTEX and CITEX, namely, irrigation, fertilization, verification and treatment. In effect, the irrigation and fertilization were grouped in one form whereas the verification and treatment were grouped in another form.
(2) Sets of cases covering the different aspects of the developed expert systems were prepared in forms. Each set consisted of approximately 20 cases.
(3) 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 treatment schedule. It should be noted that some of the trainees have the same cases while some others may have different cases.
(4) The training was conducted by letting the trainees run the expert system, providing the inputs in the cases and observing the outputs of the expert system. During training, each trainee was given all the cases, and other cases he/she created were also run on the system.
(5) The same cases (cases before training) were given to each trainee after conducting the training. He/she was not told that they were the same cases nor had he/she access to the forms completed before training.
(6) The cases were evaluated in the following way:
   - The irrigation subsystem was evaluated taking into account the water quantity and irrigation interval.
   - The fertilization subsystem was evaluated taking into account the quantities of nitrogen, phosphorus, potassium, magnesium and manure.
   - The verification subsystem was evaluated taking into account symptoms on root, stem, leaves and fruits.
   - The treatment subsystem was evaluated taking into account the treatment materials and their corresponding doses.

In all cases the forms before and after training were analyzed taking results produced by the expert system as a reference. If the decision given by the trainee matches the expert system result, the trainee is given full marks. If the decision given by the trainee mismatches the

TABLE 4
Treatment Subsystem Result

	Average score before (%)	Average score after (%)	Enhancement	Percentage of enhancement
Material (1)	41.8	72.4	30.6	73.21
Dose (1)	25.8	64.8	39.0	151.16
Material (2)	24.7	36.5	11.8	47.77
Dose (2)	10.5	20.0	9.5	90.48
Average	25.7	48.43	22.73	90.66

TABLE 5
Irrigation Results

	Average score before (%)	Average score after (%)	Enhancement	Percentage of enhancement
Water qty	31.3	67.5	36.2	115.65
Interval	39.7	60.6	20.9	52.64
Average	35.5	64.05	28.55	84.15

expert system result, the trainee is given zero. In cases where the decision is a quantity or a dose, the trainee is given a score relative to the quantity or dose produced by the expert system. In other cases, a score was estimated by a domain expert who was responsible for this evaluation.

6. RESULTS OF APPLYING OUR TRAINING METHODOLOGY TO THE AGRICULTURE SECTOR IN EGYPT

Evaluators have used all the components of the above-mentioned methodology in their effort to measure the effect of using expert systems on extension personnel performance. The outcome of applying all components of the methodology to CUPTEX and CITEX is discussed below.

6.1. CUPTEX Results and Discussion

The irrigation results are summarized in Table 1. As can be seen, an average increase of 81% has been achieved in the decision taken by the trainees after using the expert system. The enhancement in deciding the water quality is much better than the enhancement in deciding the irrigation interval.

The fertilization results are summarized in Table 2. It is worth noting that manure was not included by any of the trainees although it is well known that manure should be added before cultivation. They might have assumed that this is a well-known fact. So, they did not put it. The second important remark is that they did not know much about magnesium; the percentage of enhancement regarding magnesium was 790%. Eliminating these two odd cases, an average enhancement of 45.12% can be observed in three fertilizers, namely, nitrogen, phosphorus and potassium.

The verification results are summarized in Table 3. As can be seen, the average enhancement of 80.06% was noticed after using the expert system for one-day training. The most remarkable enhancement was related to the symptoms on leaves, whereas the symptoms on fruits has slightly increased.

The treatment subsystem results are summarized in Table 4. As can be seen from the table, an average enhancement of 90.66% was noticed after using the expert system. A remarkable enhancement was noticed in determining the dose for material (1). It is also worth noting that the trainees were not aware of the second material application nor its dose (the lowest score before and after the training).

6.2. CITEX Results and Discussion

The irrigation results are summarized in Table 5. As can be seen, an average increase of 84.15% has been achieved in the decision taken by the trainees after using the expert system. The enhancement in deciding the water quantity is much better than the enhancement in deciding the irrigation interval.

The fertilization results are summarized in Table 6. An average enhancement of 35.89% can be observed after using the expert system. It is worth noting that the least enhancement was in adding manure, only 11.65%. This may be due to the fact that manure application is done once a year during preparation.

The verification results are summarized in Table 7. As can be seen, the average enhancement of 1464.08% was noticed after using the expert system for one-day training. However, the scores of zeros, before using the expert system, in recognizing the symptoms are very odd. But as can be seen, this recognition reached 90% in the case of symptoms on roots after using the expert

TABLE 6
Fertilization Subsystem Results

	Average score before (%)	Average score after (%)	Enhancement	Percentage of enhancement
Nitrogen	43.1	63.6	20.5	47.56
Phosphorus	46.4	66.9	20.5	44.18
Potassium	38.1	53.4	15.3	40.16
Manure	78.1	87.2	9.1	11.65
Average	51.43	67.78	16.35	35.89

TABLE 7
Verification Subsystem Results

	Average score before (%)	Average score after (%)	Enhancement	Percentage of enhancement
Symptoms on leaves	14.2	65.5	51.3	361.27
Symptoms on stem	0.0	33.3	33.3	infinity
Symptoms on root	0.0	90.0	90.0	infinity
Symptoms on fruits	0.0	33.3	33.3	infinity
Average	3.55	55.53	51.96	1464.08

system. So, even if the first row of Table 7 which relates to symptoms on leaves is considered, the enhancement is 361.27% which is still very high.

The treatment subsystem results are summarized in Table 8. As can be seen from the table, an average enhancement of 732.61% was noticed after using the expert system. A remarkable enhancement was noticed in determining the dose. The improvement in determining the material is also very high.

7. CONCLUSIONS

The results of this study suggest that the expert system can be an effective training tool in agriculture extension programs. The experiment showed that there is enhancement in the performance of the extension workers after the usage of the expert systems which developed after a very short time. Although the expert systems developed are thoroughly verified with domain experts, there is always room for further improvement. Regardless of the quantitative measures which may be arguable regarding how these values are calculated, the trend of the trainees was to accept the advice given by the system, which is why their measured performances were increasingly taking the decision of the expert system as a reference.

Table 9 presents a summary of the results for both CUPTEX and CITEX. As can be seen from Table 9 , the average score percentages for trainees on the four subsystems of CUPTEX and CITEX were approximately in the same range (30.31 and 27.13). But if we look at each individual subsystem, we can find a tangible difference between the verification and treatment subsystems in the favor of the CUPTEX trainees, while there is a tangible difference in the fertilization subsystem in the favor of CITEX trainees. This remark is related to the percentage of enhancement, we can see that the best enhancement for CUPTEX was in the fertilization subsystem, whereas the best enhancements for CITEX were in the verification and treatment subsystems. The average enhancement for CITEX was approximately six times the average enhancement for CUPTEX. This is because the performance of the CITEX trainees in the

TABLE 8
Treatment Subsystem Result

	Average score before (%)	Average score after (%)	Enhancement	Percentage of enhancement
Material	11.0	63.9	52.9	480.91
Dose	5.1	55.3	50.2	984.31
Average	8.05	59.6	51.55	732.61

TABLE 9
Results Summary

	CUPTEX (average score %)		CITEX (average score %)		CUPTEX (% of enhancement)	CITEX (% of enhancement)
	Before	After	Before	After		
Irrigation	40.0	72.4	35.5	64.05	81.0	84.15
Fertilization	25.64	66.0	51.43	67.78	157.41	35.89
Verifiction	29.9	52.23	3.55	55.53	80.06	1464.08
Treatment	25.7	48.43	8.05	59.60	90.66	734.61
Average	30.31	59.77	27.13	61.74	102.28	579.18

verification and treatment subsystems was very low (3.55 and 8.05), and consequently their performance has increased dramatically after using the system (percentages of enhancement are 1464.08 and 732.61).

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