Developments in Expert Systems for Pest Management at Imperial College, U.K.

Geoff Norton*

Introduction

Expert systems are now being developed for a range of pest management problems (see for instance, Coulson and Saunders 1987). In the U.K., the most advanced expert system in pest management has been developed by ICI's Plant Protection Division. "Counsellor", an Expert System for cereal diseases in winter wheat, is now commercially available to farmers on a videotex system (Jones *et al* 1984). It can help farmers to plan their fungicide strategy for the year ahead, based on specific field information and past history, and offers in-season recommendations as more information becomes available and the risk of disease loss can be better assessed. Counsellor also provides information on the reasoning behind the evaluation, including a cost benefit analysis, if required.

At the Silwood Centre for Pest Management (SCPM), Imperial College, there are four projects that currently utilise the Expert System approach. Each illustrates a different way in which Expert Systems can be developed and used. The final example, concerning stored grain pest control, is used to describe in more detail how Expert Systems can be applied to pest management.

Cotton Pest Management in Southern Africa

To obtain the information necessary for developing an Expert System for cotton insect pest management, John Mumford (SCPM) first interviewed public and private sector advisers individually and then brought them together to produce a single, agreed set of rule-based recommendations for each crop stage through the season. This has now been developed into an Expert System that runs on IBM compatible machines. It is currently being utilised in some farmer cooperative depots. When growers come into the depot to purchase pesticide, they can use the Expert System to check that pesticide is necessary and, if it is, what type and how much they should purchase. Where more than one pesticide can be used, their prices are shown. The Expert System also warns which insect pests *may* become a problem in subsequent weeks.

Forecasting Armyworm Outbreaks in East Africa

A joint project with scientists from the U.K. Tropical Development and Research Institute and the Kenyan Government is intended to improve the data storage and retrieval system used for forecasting outbreaks of Armyworm *(Spodoptera)* in East Africa. Initially, we need to understand how current and past insect trap, meteorological and outbreak information is used to derive a forecast. In this case, an Expert System is currently being developed by Roger Day (SCPM) to mimic the way an expert (with 20 years' experience) makes forecasts. This explicit form of the forecasting process can then be used, along with economic models, to determine how Armyworm control can be improved through changes in data collection, storage, and retrieval, which improve the forecasting of outbreaks.

The Control of Brown Planthopper on Rice in China and the Philippines

Simulation models of the Rice Brown Planthopper *(Nilaparvata lugens)* have been constructed for very different climatic conditions: for the Philippines (Holt *et. al* 1987) and for temperate China. The Chinese model has also been used to search for "robust" control strategies, which perform acceptably across a wide range of biological and management conditions. Using this information, together with expert experience, an Expert System has been constructed that aims to help field extension officers in Zhejiang Province, China give more specific advice to farmers. This Expert System, with over two hundred rules, is to be field tested in 1987, alongside the existing forecasting advisory system.

In the tropics, the Brown Planthopper problem is far more complex. The greater importance of natural enemies, for instance,

* Silwood Centre for Pest Management, Imperial College, Silwood Park, Ascot SL5 7PY, U.K.

means that insecticide use can cause Brown Planthopper resurgence. Therefore, although an Expert System is being developed for conditions in the Philippines by Johnson Holt (SCPM), together with John Perfect from the Tropical Development and Research Institute, we see its main use, at least initially, as a training tool and a means of helping to identify applied research priorities.

Stored Grain Pest Control in the U.K.

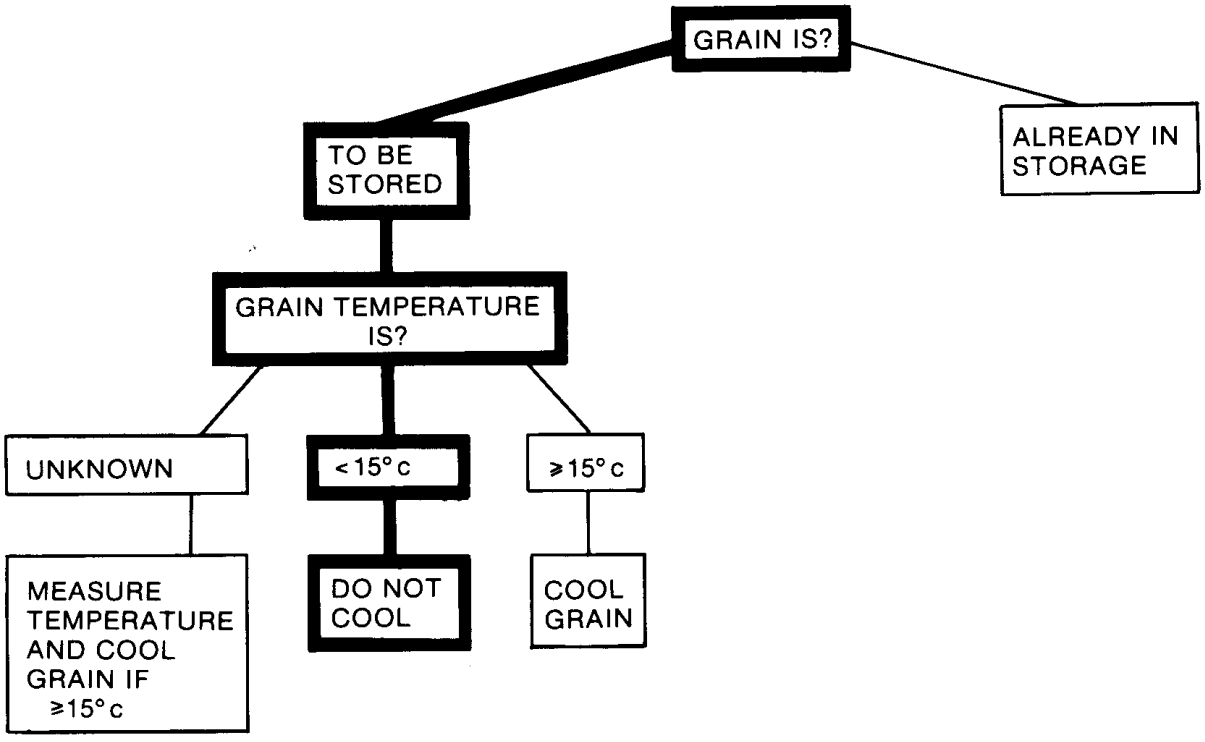
A collaborative project with entomologists of the Ministry of Agriculture, Fisheries and Food's Stored Products laboratory at Slough, U.K., has been funded by the Home Grown Cereals Authority, to develop an Expert System for the management of pests in stored grain. Again, the short-term aim is to provide a training device and to contribute to the identification of relevant applied research priorities. Subsequently, we hope to develop a commercial package for sale to store managers.

For the initial development of this Expert System, Tim Denne (SCPM) used two "software shells" called *EXSYS* and *CRYSTAL*. These shells are very simple to use, require no programming expertise as such, and

Figure 1: Part of a Decision Tree

To illustrate how—

(a) a branch of a decision chart—



Can be expressed as—

(b) an IF-THEN rule in an expert system format.

IF GRAIN IS TO BE STORED
AND GRAIN TEMPERATURE IS <15°c

THEN DO NOT COOL

Figure 2: An IF-THEN Rule for Stored Grain Pest Control

IF GRAIN IS ALREADY IN STORE
AND GRAIN NEEDS TREATMENT
AND LEVELS OF CHEMICAL RESIDUE ARE LOW

THEN FUMIGATE OR ADMIX INSECTICIDE

provide excellent working tools for quickly constructing particular branches of the system. As the project develops, a more comprehensive and flexible shell called *APES* (Augmented Prolog for Expert Systems), developed by staff at Imperial College Computer Department, is being used to construct the final system.

To illustrate the rule-based principle of Expert Systems, Figure 1a shows a very small section of a possible decision tree for grain storage managers. Figure 1b shows how a particular branch, shown outlined in bold in Figure 1a, can be expressed as *"IF-THEN"* rules in *EXSYS*. A more comprehensive rule, with three qualifiers (or conditions) is shown in Figure 2.

Whether qualifier 1 is true will depend on the answer given by the user when asked:

"Grain is —
1. to be stored?
2. already in store?".

Similarly, the user would be asked questions regarding qualifier 3. Qualifier 2 — whether grain needs treatment — will depend on other rules that set the conditions for treatment; for instance, if infestation is detected, if grain temperature is increasing, or if the intended market is for export.

Initially, for the sake of simplicity, we have developed rules on the basis of the expert opinion of Robin Wilkin and his colleagues in the Ministry. Subsequently, we aim to develop a more objective means of evaluation that will include cost-benefit analysis and risk assessment.

The means by which knowledge and information is put into a computerised Expert System is called knowledge engineering. Before this can be done, however, the knowledge to be included first needs to be acquired. To identify the decision problems that store managers have most difficulty in

Figure 3: Knowledge Structuring Technique for Stored Grain Insects

		SITUATIONS					
QUALIFIERS	1.	2.	3.	4.	5.	6.	....
LEVEL OF PEST ATTACK	LOW						
AVAILABLE MARKETS FOR GRAIN	FEED						
MOISTURE CONTENT OF GRAIN	BELOW 10%						
CURRENT GRAIN TEMPERATURE AND LIKELY TREND	11°c DOWNWARD						
RISK TO NEARBY GRAIN	NONE						
AVAILABLE EQUIPMENT	NONE						
.....							

DO NOTHING	SELL IMMEDIATELY	DRY GRAIN	TURN AND CLEAN	AERATE	ADMIX INSECTICIDE	FUMIGATE
OPTIONS						

resolving, and therefore for which an Expert System would be most useful, we are conducting user surveys. We have also used a number of descriptive techniques, such as interaction matrices, to help identify and pull together relevant information that will need to be included in the Expert System.

Figure 3 illustrates a technique we used to think about the factors that need to be considered when faced with the problem of a large bulk of wheat infested with grain weevil *(Sitophilus granarius).* Initially all the options were identified, only some of which are shown in Figure 3. Then we attempted to determine under what circumstances each option would be recommended. This enabled us to identify the relevant qualifiers, some of which are shown in Figure 3. It should be clear from this how IF-THEN rules can be derived and included in the Expert System.

Conclusion.

Within our research programme at Silwood Park, Expert Systems are regarded as an additional tool for helping to analyse and resolve pest problems. While Expert Systems undoubtedly have a role to play in improving pest management, at this early stage in their application, it is not clear where their greatest contribution will lie: in giving advice to pest managers, in training field advisers, or in helping to identify applied research priorities.

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SIRATAC: a decision support system for cotton management

A. B. Hearn*

Introduction

SIRATAC is an acronym for CSIRO and N.S.W. Department of Agriculture tactics for growing cotton. Chemical control of pests is essential for commercially successful cotton production in Australia. Apart from costing from $100 to $300 per ha, chemical control carries risks of pests developing resistance to insecticides and environmental pollution. The SIRATAC system is a computer-based dial-up crop management system that has been developed to assist cotton growers make good tactical decisions in the use of insecticides.

In the early 1970s, commercial cotton production ceased in the Ord River area and was threatened elsewhere because a major pest, *Heliothis armigera,* had become resistant to DDT. Cotton research was intensified with the aim of developing economically viable and ecologically stable systems of cotton production. Room (1979) constructed a prototype computer-based pest management system to synthesise the research results that began to accumulate into a practical integrated management system that made the best use of currently available information. The system has been progressively updated as further research results became available not only from Narrabri but also more recently the University of Queensland and the Queensland Department of Primary Industries.

The SIRATAC Pest Management System

The SIRATAC pest management program consists of several simulation models and a decision model. The HELIOTHIS model simulates the development of eggs and larvae using Room's (1983) temperature driven

* CSIRO Cotton Research Unit, Narrabri. It is a pleasure to pay tribute to the people, too numerous to mention in this brief article, from many organizations who have contributed to the development and application of SIRATAC.