Evolution of a decision support system with changing market

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Abstract

Falling grain prices and local surpluses have led to increasing competition and demands for higher quality, especially for export markets The market has been able to impose demands at substantial cost to the farmer but with no apparent price benefits In response to this, the UK Combinable Crops Quality Assurance scheme has evolved emphasising traceability and quality control Crucial to this scheme, is the accurate monitoring of quality, physical conditions, pest populations and any control measures undertaken, for instance pesticide application

The original Grain Pest Adviser, the first grain storage decision support system, was written in Prolog and combined encyclopaedic information with predictions about storability, such as pest outbreaks. The increased availability of ever more powerful personal computers and the development of easy to use programming tools has resulted in the new Integrated Grain Storage Manager (IGSM) The program now includes a database facility and is compatible with all versions of Microsoft Windows.

The design process of IGSM included the requirements of the Combinable Crops Quality Assurance scheme and involved canvassing farmers' opinions of what information should be recorded by the program A prototype was used to test the usability at selected storage businesses, which resulted in modification of the programme after which the final version was demonstrated at agricultural shows for fine-tuning. Future developments are likely to permit direct inputs of existing temperature and moisture monitoring systems into the IGSM Quality Analysis report system

Introduction

The task of managing grain in storage is a complex one, requiring managers to make a number of decisions and take various actions. The longer the period of storage the greater the risk of a problem developing, leading to the reduction in the quality and value of the grain. Current trends suggest that there will be continued upward pressure on quality with a customer-lead requirement to produce grain to closely defined specifications. At the same time, sources of independent advice are becoming more restricted and more expensive.

Over the past years, in most of the main producing countries, there have been major changes in the level of support offered to primary producers or storekeepers This has taken the form of a reduction in research funding and, more importantly, a move away from government supported advisory services

The UK, which had an extremely effective system of passing new research information from scientists to farmers and storekeepers, can be used as an example of these changes. The Agricultural Development and Advisory Service (ADAS) of the Ministry of Agriculture, Fisheries and Food acted as a conduit between scientists and end users. They offered a free advisory service and in the 1970s employed more than 80 advisors with specialist training in post harvest problems. ADAS provided the key channel for a flow of information between researchers and particularly farmers and played an important role in assisting the industry to adapt to the new requirements for pest-free grain However, this service was first reduced, then charges were made for advice and, by now, ADAS employs only one or two advisors with specialist knowledge in grain storage

The lack of an effective extension and advisory service has been a handicap in promoting the values of new approaches such as integrated pest management and other advances is storage technology. A few of the larger farming groups obtain information from the agricultural press and demonstrations at shows They then employ consultants to adapt these new ideas into their farming systems but this represents a minority Within the UK and elsewhere the problem has been compounded by falling grain prices and profit margins coupled with increasing demands from producers and end users for high quality raw materials and food. For example, grain prices have fallen by more than 25% but during the same period, input costs have risen by 15% Assurance schemes for quality have been introduced which put pressure on the farmer to achieve very high standards of store management but give no financial return for compliance

In order to address the problem of information transfer,

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the Home-Grown Cereals Authority (HGCA) and MAFF provided funding to support the development of a computerised decision support system for grain storage

Initial development programme

When the idea of a computerised support system was first considered, the aim was to develop a simple aid for extension workers, rather than a decision support system for the farmer and storekeeper. This was just as well because limitations in computers and operating systems constrained the scope for complex programmes First examples had to be programmed line-by-line in a computer language; a time-consuming, tedious and error prone approach. For the first versions, the main programme was written in Prolog with sub-programmes in basic being used for some specific functions such as calculations. The compiled programme ran under DOS, as Windows was, at that time neither widely accepted nor entirely satisfactory In practice, Grain Pest Advisor, as the first version was titled, worked well within the limitations imposed by the computers of the day

The aims of the system were to provide information in support of decision making and to make management both easier and more effective First development was done as part of a project funded by the HGCA (Denne, Unpublished PhD thesis, University of London). This project resulted in the development of the decision support system for grain pest management (Grain Pest Advisor, GPA) mentioned above. The system included some encyclopaedic information on the pests and management practices and simple models to predict the growth of pest species under the prevailing storage conditions. Advice on control methods was then presented to the user together with an estimate of the costs of the actions. Development continued over the next 7 years in collaboration with Central Science Laboratory. Improvements were added such as more sophisticated models for insects, a model for mite development; improved encyclopaedic information about the pests with colour pictures for easy identification; improved information on the control options and a prototype cooling model to predict the insect population growth under reducing temperatures. The system also had an improved graphical output enabling users to see a graph of pest population over time, allowing strategic decisions to be made as to the most appropriate time to sell. This programme showed the potential value of such systems but its development also illustrated the complexity of the task and the limitations of the software used.

At the same time as this development process was taking place, the changes in the availability of agricultural advice began to take effect and it became apparent that there was a need for a decision support system at a farmer level. Field testing was done with Grain Pest Advisor and, whilst user feed back was encouraging, it also showed that a much more sophisticated system was needed if the topic of pest management in stored grain was to be effectively covered Fortunately, the advent of computerised farm management software meant that most arable farmers storing grain were likely to have access to and be familiar with computers

Development of integrated grain storage manager

Integrated Grain storage Manager (IGSM) was developed jointly by Imperial College and the Central Science Laboratory However, the development process had to be supported by external funds that were provided by MAFF and the HGCA. One condition attached to these funds was that the end product of the project should be a fully working system that could be offered for sale to farmers and storekeepers at a modest cost

The earlier GPA system provided a concept from which to start and the comments collected during field testing of this system were used to draw up the design parameters of a new computerised decision support programme. Included within these parameters was the need for a new system to act an information transfer conduit for passing new R & D data to farmers in an easy-to-use form This was because the HGCA and MAFF who between them fund most agricultural research in the UK, were becoming concerned about the lack of channels for information transfer. Several important projects had been completed successfully offering improved and more cost-effective storage Other work had been done on developing Total Quality Management systems. However, the implementation of the research results arising from such projects was reliant, in part, on growers and store managers interpreting research reports or holding impromptu discussions with research workers at promotional events IGSM was expected to incorporate research findings from several HGCA and MAFF-funded projects in an easy-to-use format to encourage growers and store managers to evaluate their current practices and implement improved storage practices as appropriate

Design and development approach to IGSM

As a first step to ensure that the proposed software was as relevant as possible to the intended end users, demonstration copies of Grain Store Manager were placed with several farmers and storekeepers for assessment during 1994. This continued in a more targeted way during 1995 Copies were assessed by groups of storekeepers, a company providing pest control services and a major agrochemical supplier.

Comments were generally favourable but a number of specific points were made regarding potential improvements. These included: making the system more user-friendly; adding more information on topics such as bulk drying, cleaning, pesticides, mites, moulds and grain sampling; inclusion of a key for identification of insects; and incorporating a quality management package. The testing also showed that the package needed to be easier to install on a wide range of computer systems.

Software

The starting point for the new system, IGSM, was a DOS-based program written in Borland Turbo Pascal In order to make the program as accessible and easy to use it was decided to develop IGSM to work under Microsoft Windows. To reduce the development time a visual programming language, Borland Delphi, was adopted which has a number of advantages. Firstly, it is based on Pascal and was therefore immediately familiar to the developer. Secondly, it includes a database component that can be used for the record keeping aspect of the new system Thirdly, it is a visual programming language so the new interface could be developed relatively quickly and, finally, a number of libraries were available that could be used to speed the development of the system. Whilst many other languages would have been suitable, Borland Delphi seemed to be the most appropriate for the job.

Pest models

The pest models used in IGSM are derived from those developed in GPA with the exception of the model for the mites. A new mite model was developed from data published by Solomon (1969) and Cunnington (1984) which allowed the construction of a response surface for mite growth rate with respect to temperature and relative humidity. The relationship was derived using a line fitting procedure in CSS Statistica. This provided a quadratic equation for the relationship between growth rate, temperature and relative humidity and was used to ascertain the growth rate of mites under a range of conditions in the stored grain. The output of the model was compared with expert opinion to confirm that it was a reasonable representation of the population dynamics of mites under different conditions.

Cooling model

Meteorological data for a number of sites around the UK were used to develop the cooling model. Initially it was thought necessary to develop individual models for different parts of the geographic regions according to the local average temperatures. However, differences between regions were relatively small in terms of their effects on grain cooling and the increased complexity of including site information was felt to be unnecessary This model was integrated with the existing pest models so that the potential of using ambient aeration to limit or control pests could be assessed

The cooling model is date sensitive so that the time of year and likely number of hours when the ambient temperature would be below the current grain temperature is calculated to assess the potential value of cooling. Results from several new research projects on affects of grain cooling on pest development were used to assist in the risk assessment/decision support process.

Interpretation of pest detection data

Pest detection data can be input in the form of results from the collection and assessment of samples or as numbers caught in traps. These represent very different approaches to population measurement and IGSM had to be able to weight different types of data in an appropriate manner.

Information gathered from other experimental work and from the literature was used to develop better relationships of trap catches of insects in grain stores with the number detected by sampling. This was explained in the encyclopaedic section of the program but was also incorporated in the system for calculating pest population development. In the UK, where grain temperatures may be very low, trap catch data must use a temperature related correction factor.

In addition, a module to assist farmers and storekeepers produce a sampling/ monitoring regime to suit specific stores was developed and included. This had links to the encyclopaedic section offering advice about equipment, methods and safety.

Quality management

The quality management section was developed using information from millers, maltsters, grain merchants and other end users of grain. This information included quality standards required for the various categories of grain and the important data about the grain to be included in any quality report. The data collected were also assembled into tables that were added to the encyclopaedic section of the program. A system to advise users on standards and approaches to storage was added.

In order to meet the criteria set down for a national scheme to regulate quality of on-farm grain (The Assured Combinable crops Scheme), a new section was added to the programme. This firstly set out the requirements and then used a database function to store data input by the user to assemble a quality report. These data were summarised in the form of a printed quality report at the end of storage.

The database component was designed to allow the user to produce record sheets that encouraged compliance with good management practices. Therefore, suitable storage and monitoring regimes were suggested at the start of storage. The user could tune these suggestions to suit individual requirements but, once a regime was chosen, it would require the user to input data on a regular basis. The database was also made interactive with the problem solving function so that the constant risk assessments were carried out and potential problems were flagged

The database has the facility for the user to store information on temperature, moisture content and any management actions taken. The stored information is summarised so that weekly maximum and minimum data are used in the output to provide the purchaser of the grain with a clear indication of the storage practices. The process of entering data into the quality assessment part of the package was set up so that it was not readily possible to change any data once it had been placed in the database. Similarly, it is not possible to retrospectively fill any gaps

Encyclopaedic section

The encyclopaedic information section on pests, management and equipment contains approximately 200 entries including information on pest identification, sampling, available technology management strategies, control options etc. This information can either be accessed through the Integrated Grain Storage Manager or can be loaded as a Windows help file and browsed in this way.

Pest identification

Identification of pests is often at the heart of any decision-making process during grain storage. The lack of advisory aid to farmers and storekeepers means that it is not always possible to check the identity of mites and insects found in grain and it is almost always impossible to get a quick confirmation of anything found in incoming loads of grain at commercial stores. Therefore, it is important to offer support in this area. IGSM now offers a simple key to assist in identification and this is coupled with the colour pictures of the pests and detailed descriptions

Customer assessment

Once a working prototype version of IGSM was available, it was shown to a range of farmers and storekeepers and some end users of grain. This process threw up some 'bugs' and omissions and was, therefore, an essential step towards the final version. Surprisingly, few major changes were needed although the programme system did require attention in order to prevent conflicts within the computer operating systems. The final version had also to be made compatible with Windows 95.

Ultimately, the final system had to be demonstrated to the Board of the HGCA to confirm that the terms of grant had been fully met.

The final product

The final product made available to UK farmers and storekeepers consists of a set of three disks for installing the program and a user manual. Telephone support is provided for technical computer problems and for grain storage problems for a period of one year. The manual contains detailed information about installing and using the program.

Once installed, IGSM offers a detailed description of all the fundamental aspects of grain storage This is made up of text, graphs, figures and photographs, and contains many links between related topics. It also provides a calculator to work out moisture content relative humidity relationships and weight changes caused by drying or cleaning. The problem solving feature will predict changes in pest population, offer a range of option to ovoid or minimise damage and allow the user to play 'what if' games by adding pesticides or using other control options The data base facility has been made fully compliant with the UK Assured Combinable Crops Scheme and allows farmer to produce standardised QA statements at the end of storage.

The system went on sale in November 1997 and several 100 copies have been sold to date. Users have reported no serious problems

Conclusions

The development of the computerised decision support system Integrated Grain Storage Manager proved to be a long and complex process To some extent the evolution of the current successful system proved to be depended on concurrent developments in computer and software design Therefore, it has to be accepted that future hardware and software developments are likely to render IGSM redundant because, if it is to remain in use, the programme must be compatible with other pieces of software.

In the present political climate in which public spending is being reduced in favour of direct support from industry, the development of systems such as IGSM is not possible without finding some funding from external sources. However, this same climate is reducing all forms of centralised advisory service so that it is becoming increasing difficult to promote and support new research findings Perhaps the onus is now on the research worker to think in terms of either developing a decision support system to carry research results to the end user or to integrate his results into systems that are already in use.

Much of the basic biological data used in IGSM and its predecessor has been available for many years However, as the models were constructed, it became apparent that there were still gaps in the knowledge about insect life history that limited the ability of the system to predict some events. For example, there are little data on the rates of development of some pest species at sub-optimal temperatures and there is almost no reliable data on the survival of pests at low temperatures. If the affects of low doses of pesticide and pesticide resistant strains are added to this equation, there are large event sectors that become extremely difficult to model To this end computerised decision support systems can perform an extremely valuable but frequently overlooked function of identifying and providing cost benefit analysis of topics needing further research.

The identification of further research topics is, in its self, not simple. When modelling to assess risk, there can be some debate about the level of precision necessary In many cases, it may be acceptable to define pest numbers in terms of being static, increasing or decreasing Within the much of European Union, the discovery of a single insect in a load of grain at time of sale will produce a financial penalty for the seller Given this constraint, a risk assessment must react by recommending control action to any upward trend in pest numbers and defining the population as being 22/kg in 3 weeks time has no added value over knowing that some increase is likely However, given long-term storage and the ability to use sophisticated pest management techniques, comparisons between measured and predicted population has real value.

Setting a commercial end point for a decision support system is extremely challenging End users of a free system are likely to be much less critical than those who have paid for the privilege. It also puts constraint on the development process because it must be possible to have a distribution arrangement to cover any commercial software used to make the system. Finally, selling a system means that the suppliers are legally responsible for the quality and accuracy of the information contained and advice given by the program

Some funds are being generated by the sale of copies of IGSM Whilst much of this may go towards the provision of telephone support, some money can be put aside to fund further developments The commercialisation of the system also offers opportunities to incorporate appropriate advertising material and to set up links with companies wishing to use features of IGSM to enhance their own products. For example, it is relatively simple to set up an interface to down-load temperature and moisture data directly from a meter into the QA database

What about the future?

The authors of this paper are convinced that computerised decision support systems will become an integral part of agricultural extension work in all field and all parts of the world. Once the development bullet has been bitten, the ensuing software can be used by thousands of end users. This means that every extension worker can be provided with an instant aid memoir containing up-to-date information and providing the most effect solutions to specific problems. In developed counties were extension workers are become scarce, every farmer and storekeeper will become his own expert

New development in computer and grain storage technology offer the potential of using decision support systems to run grain stores on an automatic basis Trapping or acoustic pest detection methods have the potential for automatic, electronic recording of results which, together with temperature, moisture and perhaps oxygen levels, could be fed back to the system for analysis, action and storage. It would be relatively simple to set up feedback loops to control ventilation fans or adjust gas concentrations during fumigation or controlled atmosphere storage Once a store was filled, the storekeeper would become largely irrelevant in terms if making decisions or taking action.

Perhaps a more likely development will be some form of interactive system, in which a storekeeper can remotely oversee the events at several stores situated at different locations Another useful addition would be an automated pest identification system. This might work by scanning in the image of the unknown pest and the system would use image analysis techniques to arrive at an identification. The above possibilities are currently feasible using existing, albeit, expensive technology Given more computer/communications development, they are likely to become standard features of any system designed to assist with the storage of grain

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