Implementation and adoption of the stored grain advisor decision support system in the USA

Paul W. Flinn[1]

Abstract

Stored Grain Advisor (SGA) was one of the first decision support systems for stored grain insect management. SGA helps grain managers identify insects, predicts the likelihood of infestation, advises how to sample, and interprets insect trap catch SGA uses insect simulation models to predict the likelihood of insect infestation, and provides preventative advice. The software was originally distributed in 1995 by three University extension services. Since 1997, the software has been available for free over the Internet, which has greatly increased its usage With the decline in stored grain extension service in the USA, SGA, can help to supply some of the knowledge that is needed by farmers and stored grain managers. SGA has been most useful for training farmers and grain managers Many of these people continue to use SGA in their grain storage operations Over 1,500 copies of SGA have been distributed to farmers and grain managers in the USA Oklahoma State University has used SGA to train over 1,500 grain managers, Montana State Univ. has used SGA to train over 300 grain managers. Involvement of extension personnel early on in the development of SGA greatly contributed to the successful implementation of this decision support system. Because of the decline in stored grain expertise and the reduced tolerance for damaged grain and insecticide residues, the need for decision support systems should increase.

Introduction

Nearly one billion bushels of wheat are produced and stored in the U. S. annually, and each year stored grain insects continue to cause millions of dollars in losses There is much known about factors that contribute to infestation in stored grain, such as duration of storage time, grain temperature, moisture, and management practices However, integrated pest management (IPM) is not routinely used in grain storage. In general, stored grain is not optimally managed because the grain manager cannot reliably predict the need for treatments or the economic benefits. Management decisions can be very complicated because many factors affect insect infestation potential in stored grain. For example, storage conditions are very different in the southern and northern latitudes of the U. S. In the north, grain is harvested later, and can be cooled earlier with aeration than in the south (Flinn et al 1997). Grain temperature and moisture affects insect population growth and pesticide degradation (Flinn and Hagstrum 1990a). While a grain manager may understand some of these relationships, it is nearly impossible to quantify them without the use of computer models. Fortunately, computer models have been developed for most of the insect pests of stored wheat, and many of these models include various management options such as pesticides and aeration (Longstaff 1988, Kawamoto et al. 1989, Hagstrum and Throne 1989, Flinn and Hagstrum 1990a, Hagstrum and Flinn 1990, Thorpe et al. 1982, Flinn et al. 1997)

Mathematical models of agricultural systems can be made more accessible to farm managers by including the models in a decision support system. These systems offer an additional method of representing farm management knowledge. Often gaps in knowledge exist that prevent models from being implemented. Decision support systems can bridge this gap by supplying heuristic information to the models when necessary (Coulson and Saunders 1987) This hybrid system allows more rapid implementation For the farm manager, making decisions based on a qualitative understanding is still better than making decisions without any understanding (Plant and Stone 1991). Decision support systems are simply a practical approach for providing grain managers with better information to make pest management decisions. These systems can assist grain managers in making complicated decisions by integrating diverse types of information They can help grain managers predict what will happen to the quality of their grain over time and the economic consequences of different management actions (Flinn and Muir 1994). Several other countries have, or are in the process of developing decision support systems for stored grain. PestMan was developed in Australia (Longstaff and Cornish 1994), China has developed an expert system based on an early version of PestMan, Grain Pest Advisor was developed in the UK (Wilkin et al. 1990a). Other

[1] Grain Marketing and Production Research Center, USDA, Agricultural Research Service, 1515 College Ave , Manhattan, KS 66502, U S A

countries in the process of developing decision support systems include Canada, Croatia, and France. The fact that so many countries are working on decision support systems for stored grain indicates their global significance.

Development of stored grain advisor

Stored Grain Advisor (SGA) is a computerized decision support program that can help farmers make decisions about managing insect pests in stored wheat (Flinn and Hagstrum 1990b). Development on SGA was started in 1988 at the Grain Marketing and Production Research Center in Manhattan, Kansas. The first version was developed for Macintosh computers. The current version of SGA 3.03 runs under Microsoft Windows™ 95 and NT, and has many more features and capabilities than the original version (Flinn 1995). SGA is one of a growing number of decision support systems in agriculture that use mathematical models to predict insect problems.

SGA has four main modules: management, insect identification, sampling and, run model. The management module provides information on how long you can safely store your wheat under your storage conditions It predicts future insect population growth, the consequences of control actions, and customizes its recommendations specifically to a grain manager's storage conditions. If you have found insects in your grain, it will tell you if you need to fumigate, based on the number and species of insects The management module requires information about the grain stored in a bin, such as, length of storage, initial grain temperature and moisture (Fig. 1). After entering the information, SGA provides advice on how long you can safely store the grain under these conditions, and methods to suppress insect population growth (Fig. 2), and provides a graph of predicted insect population growth (Fig. 3). SGA also assists the grain manager in identifying insects or other problems. The user answers a series of questions about the appearance of the insect. After SGA has narrowed the possibilities down to a few insect species, it provides the user with a series of pictures of the most likely insect pests (Fig. 4) SGA provides a description of the insect and the types of damage it causes The user can print a picture of the insect along with its description using the printer icon in the toolbar. The sampling module shows the user how to sample grain for insects, identifies them, and helps the user decide if enough insects are present to warrant fumigation. The sampling module also helps the user interpret probe trap catch by using equations that adjust trap catch based on time and insect species The 'run model' module, teaches the user about factors that affect insect growth in stored grain. This module does not provide advice; its purpose is to let the user play with different management controls, such as time of aeration, bin size, time of fumigation, etc. SGA then graphically shows the user how changing these variables affects insect population growth. The input screen is similar to the management module except that you can also specify which insect species you want to simulate, and the timing of fumigation. The user can quickly run various 'experiments' (early vs. late aeration, use of protectant, etc.) and graphically see the outcome

SGA was validated during 1991 through 1993 in 16 to 20 bins of newly stored hard red winter wheat on 19 farms in Oklahoma and Kansas (Flinn and Hagstrum 1994). Wheat in the bins was sampled monthly using a grain trier from June through February (or until it was sold). Evaluation criteria consisted of comparing SGA's prediction of insect density (low, moderate or high) to insect density in each grain bin at the end of the storage period. Based on the 1991 – 1993 data, SGA was correct 80 percent of the time in predicting which bins would become infested with low, moderate or high insect densities by the end of the storage period (Table 1).

Table 1. Test results of Stored Grain Advisor (SGA) over a three-year period involving 50 bins in Oklahoma and Kansas. Comparisons were made at the end of the storage period (usually Oct. to Feb.). SGA was correct 80% of the time in predicting whether a bin of stored wheat would become infested with low, moderate or high densities of Rusty Grain Beetle, *Cryptolestes ferrugineus*.

	Predicted by SGA		
Actual Field Result	Low	Moderate	High
Low[a]	15	4	0
Moderate[b]	2	17	0
High[c]	0	4	8

[a] Less than 2 rusty grain beetles/kg wheat
[b] 2 and ≤ 30 rusty grain beetles/kg wheat
[c] Greater than 30 rusty grain beetles/kg wheat

Implementation of stored grain advisor

Implementing decision support systems is one of the most difficult steps because it often involves transfer of the system from a research to an extension mode. Although extension personnel are often involved in development, researchers have developed most decision support systems. For SGA, the developers of the system were deeply involved in the implementation stage. Over 10 extension personnel from several states were involved in the project early on. This helped to ease the transition. These extension personnel provided critical feedback on how SGA should be modified so that it would be accepted by grain managers.

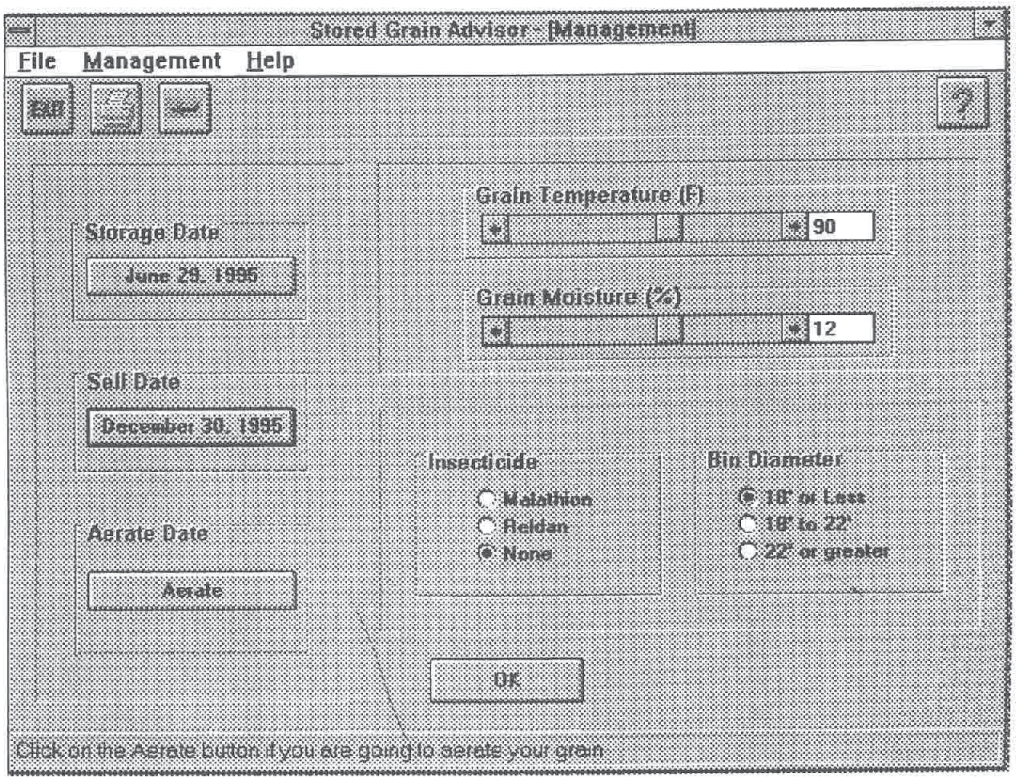
Stored Grain Advisor - [Management]
File Management Help
Grain Temperature (F)
90
Storage Date
June 29, 1995
Grain Moisture (%)
12
Sell Date
December 30, 1995
Insecticide
Malathion
Reldan
None
Bin Diameter
18' or Less
18' to 22'
22' or greater
Aerate Date
Aerate
OK
Click on the Aerate button if you are going to aerate your grain

Fig. 1.

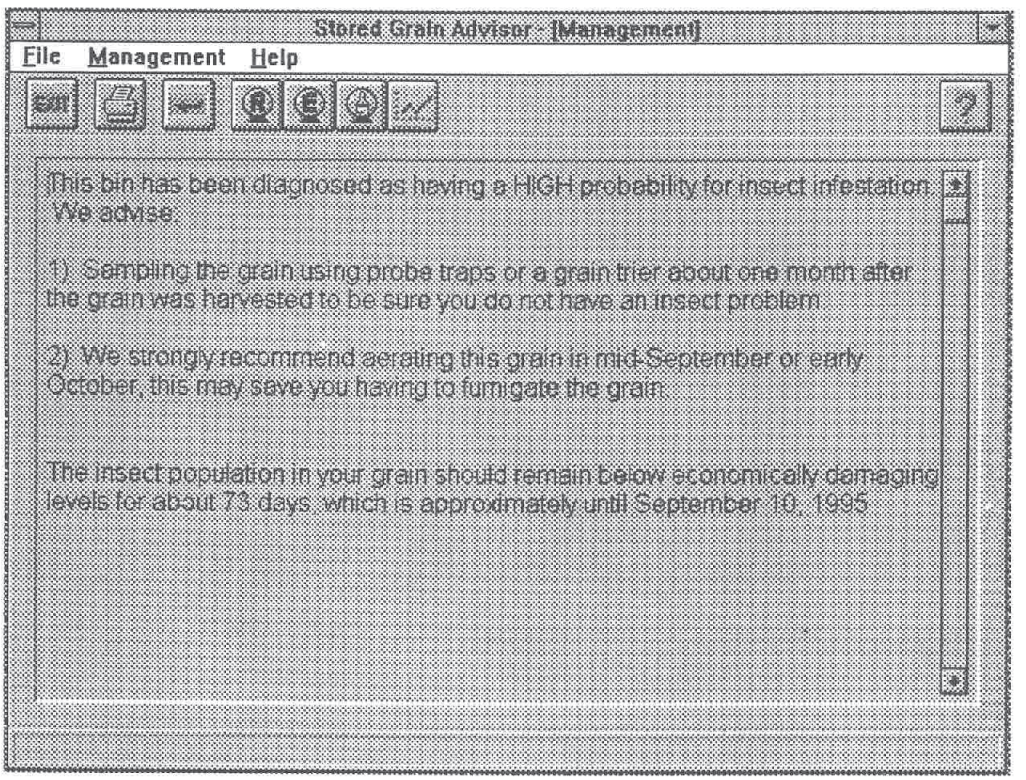
Stored Grain Advisor - [Management]
File Management Help
This bin has been diagnosed as having a HIGH probability for insect infestation. We advise:
1) Sampling the grain using probe traps or a grain trier about one month after the grain was harvested to be sure you do not have an insect problem.
2) We strongly recommend aerating this grain in mid-September or early October, this may save you having to fumigate the grain.
The insect population in your grain should remain below economically damaging levels for about 73 days, which is approximately until September 10, 1995

Fig. 2.

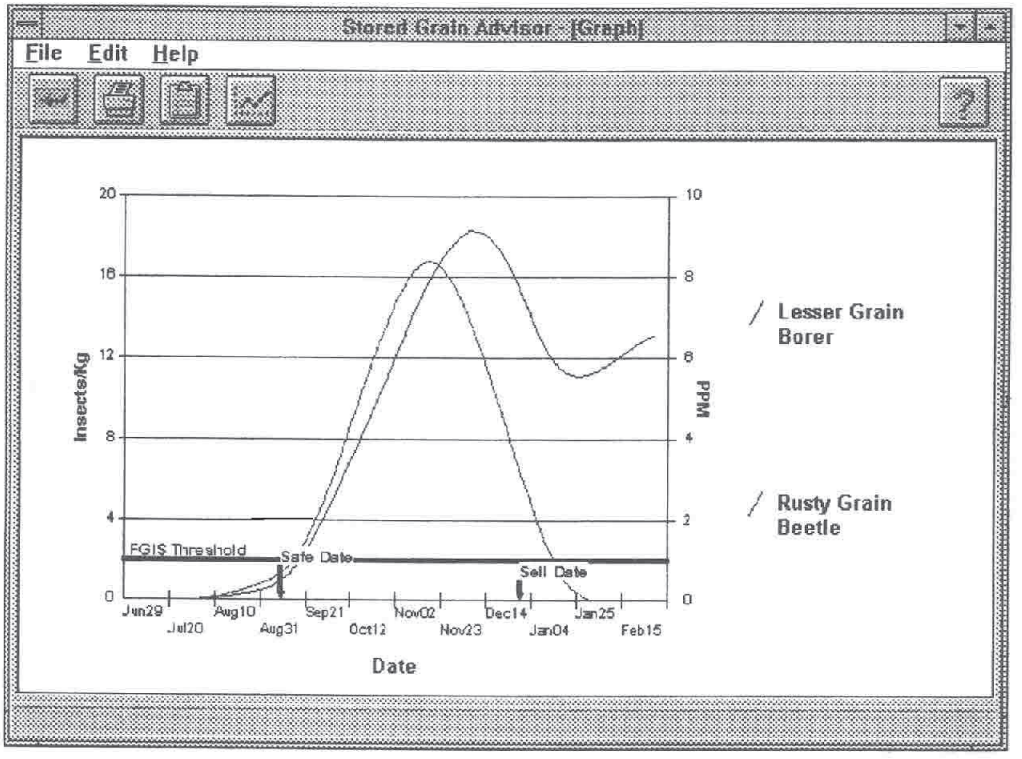
Stored Grain Advisor - [Graph]
File Edit Help
Insects/Kg
ppm
Lesser Grain Borer
Rusty Grain Beetle
FGIS Threshold
Safe Date
Sell Date
Jun29
Jul20
Aug10
Aug31
Sep21
Oct12
Nov02
Nov23
Dec14
Jan04
Jan25
Feb15
Date

Fig. 3.

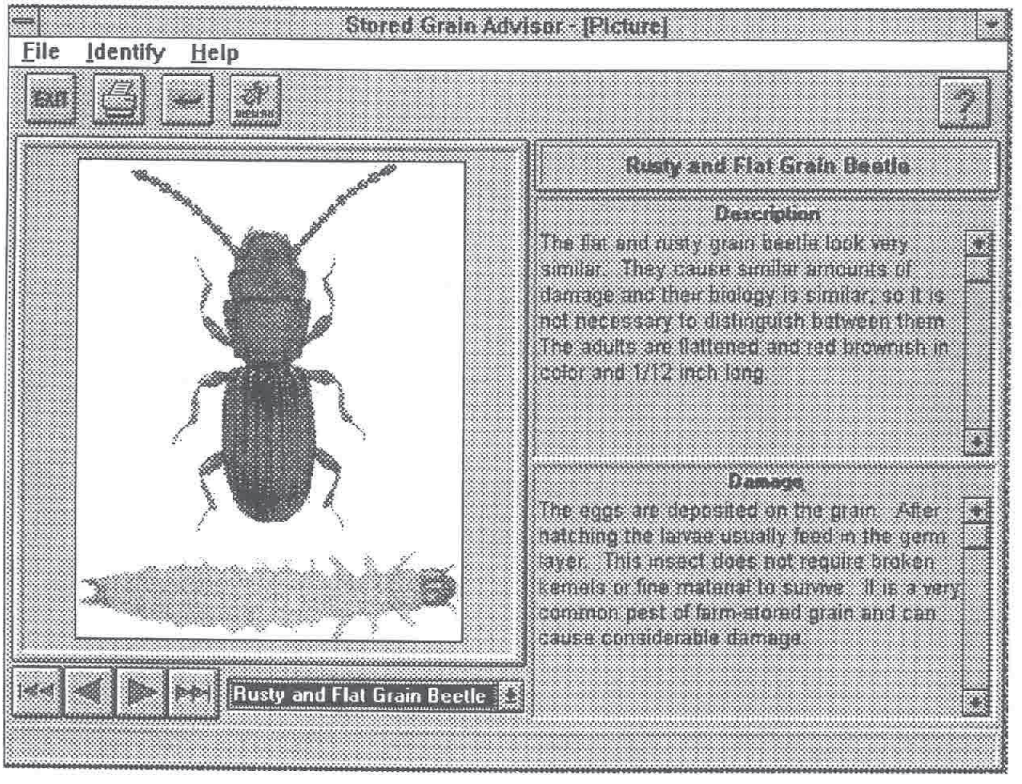
Stored Grain Advisor - [Picture]
File Identify Help
Rusty and Flat Grain Beetle
Description
The flat and rusty grain beetle look very similar. They cause similar amounts of damage and their biology is similar, so it is not necessary to distinguish between them. The adults are flattened and red brownish in color and 1/12 inch long.
Damage
The eggs are deposited on the grain. After hatching the larvae usually feed in the germ layer. This insect does not require broken kernels or fine material to survive. It is a very common pest of farm-stored grain and can cause considerable damage.
Rusty and Flat Grain Beetle

Fig. 4.

Stored Grain Advisor was first made available to the public in 1995 through a joint venture with the Agricultural Research Service (ARS) and the Extension Services of Kansas State and Oklahoma State Universities. The Extension service at Kansas State University agreed to print copies of the user manual, duplicate SGA installation disks, and to make the software available to users. Over 1,500 copies of SGA have been distributed to farmers, grain managers, consultants, and extension specialists The majority of the software has been distributed in the States of Oklahoma, Montana and Kansas

In Montana, SGA has been distributed to over 310 participants in MSU's Crop Pest Management School. The participants spend 45 minutes in a pest recommendation training session in which they use SGA as a 'hands on' introduction to the variables that affect insect population growth in stored wheat. For example, SGA can be used to demonstrate the importance of proper grain storage techniques and monitoring. The instructor can use SGA to show the value of properly timed aeration compared to last minute fumigation. With SGA it is easy to compare situations a farmer has experienced; it can show how, with a little planning, it is possible to avoid storage losses caused by insects. Most farmers found SGA easy to use After a brief introduction, workshop participants quickly begin using the program to look at different grain storage scenarios

Each year, MSU Extension presents workshops in the 6 grain-growing counties across the state. During each 2-hour meeting, approximately 15 participants are presented with a 30 minute demonstration of SGA. Participants are also made aware that SGA can now be downloaded for free at the GMPRC web site. MSU's surveys of participants showed that growers, consultants, and county agents found SGA easy to use and informative. Post session surveys indicate a high proportion of participants continue to use SGA six months after a training session. County agents and elevator managers frequently use the insect identification module

A network of 12 county extension agents in Montana has formed a SGA users group The county agents use SGA as a quick reference and a source of stored grain pest recommendations. They use SGA to provide information to their clients on how to prevent insects in stored grain, and what to do if they find insects in their grain Decision support tools, such as SGA, are helpful because they are like an electronic book. The user can obtain as much or as little information that they need. The user learns information by using the program, and obtains information that is most relevant to their storage situation.

Oklahoma State University has used SGA from 1995 to the present as an educational tool in their elevator workshops to train over 1,500 grain managers. They use it to demonstrate the importance of grain temperature and moisture on insect population growth, and how aeration suppresses insect growth in stored grain. They also use SGA to show how to reduce the number of times grain is fumigated in elevator storage. Post session surveys indicated that close to 100% felt the software would have an immediate impact in their elevators and would be used in training their personnel.

We first started distributing SGA on the Internet in August 1997. In the eight months since SGA has been available on our web site (http://bru. usgmrl. ksu edu/sga), over 200 copies of SGA have been downloaded from over 25 countries. Based on people downloading SGA from our web site, over 50% were university faculty (primarily extension service), 15% farmers, 12% grain managers, 9% consultants, and 10% other (mostly agricultural companies) (Fig. 5). This probably gives a rather biased estimate of SGA users because it only accounts for those users that have access to the Internet If one takes into account copies of SGA that have been distributed to farmers and grain managers by extension personnel, then the percentages in these two categories would be considerably higher.

Distribution of SGA on our web site has many advantages over more conventional alternatives. One of the most important advantages is the software and manual can be distributed for free because there is no cost for duplicating disks, manuals, and mailing Because the software is free, more users are likely to try it Another advantage is that the most current version of SGA is easily available to the public Users can be notified by their email address of future upgrades. The web site also has a form that users can fill out. This form provides us with direct feedback from users, so we can continue to improve SGA. Extension specialists like the ability to download SGA from our web site. They can make the most recent version of SGA available to their clients by copying the program to floppy disks; or, if their clients have access to the Internet, they can provide them with the address of our web site

Future enhancements to stored grain advisor

We are currently working on SGA Pro This version will be targeted more for large commercial grain storage than for on-farm storage Enhancements will include a spatial bin model that can predict seasonal changes in grain temperature, moisture, and insect density for any region in a bin (Flinn et al 1997) It will also allow the user to customize the inputs for bin size, bin wall material, type of grain, aeration fan size, type of aeration controller, initial grain temperature and moisture, and many other variables (Fig 6). It will also allow the user to select historical weather data files for their location The simulation models in SGA Pro will predict insect densities for five species of

stored grain insects, as well as the number of insect infested kernels (IDK) and insect fragment counts in flour. It will also predict the effects of various control methods on insect populations, such as, phosphine fumigation, controlled atmospheres (Flinn and Hagstrum 1998), aeration, contact insecticides, and inert dusts. SGA Pro will provide the user with graphs showing predicted temperatures (Fig. 7) and insect densities (Fig. 8). The graphs will be interpreted by a knowledge base that will provide the user with remedial and preventative advice. The economic consequences of various management options will also be presented to the user. For example, the user could be presented with costs involved with turning and fumigating his grain compared with aeration.

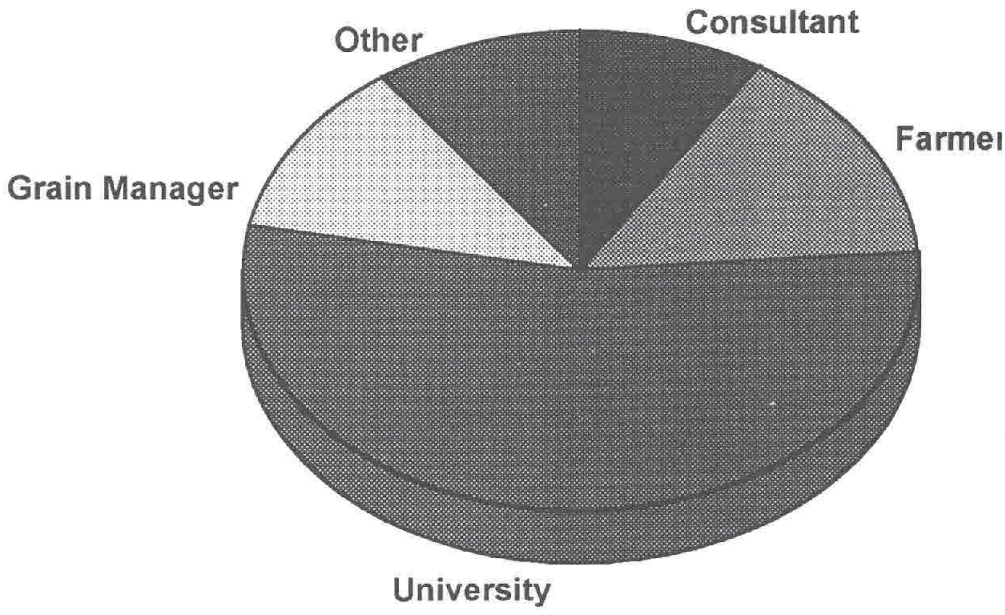

Fig. 5.

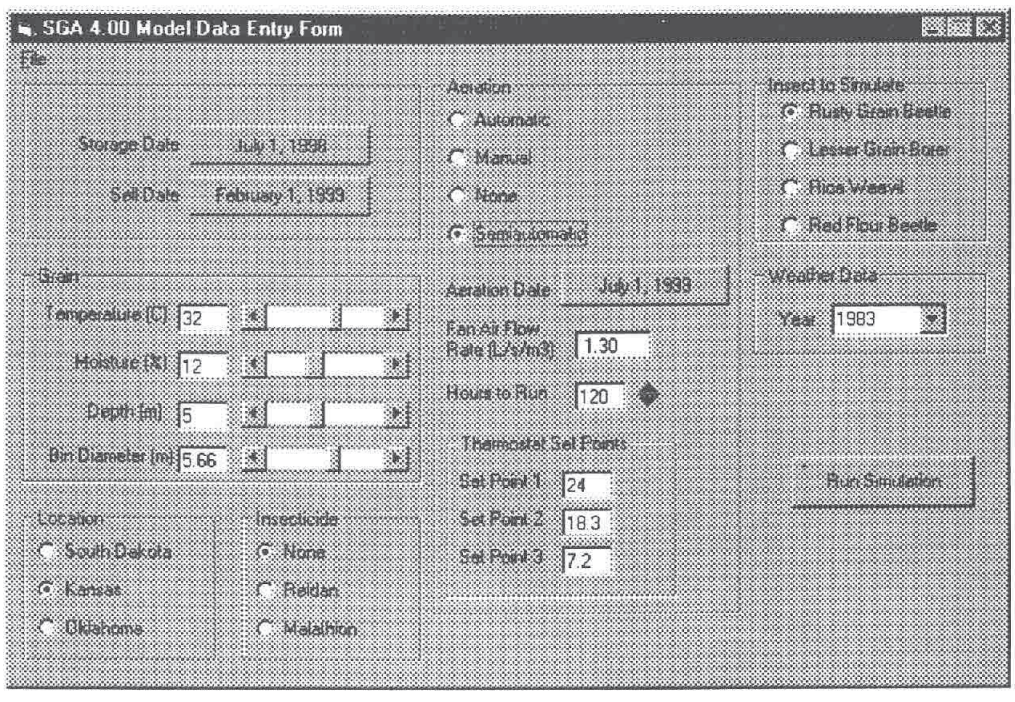

Fig. 6.

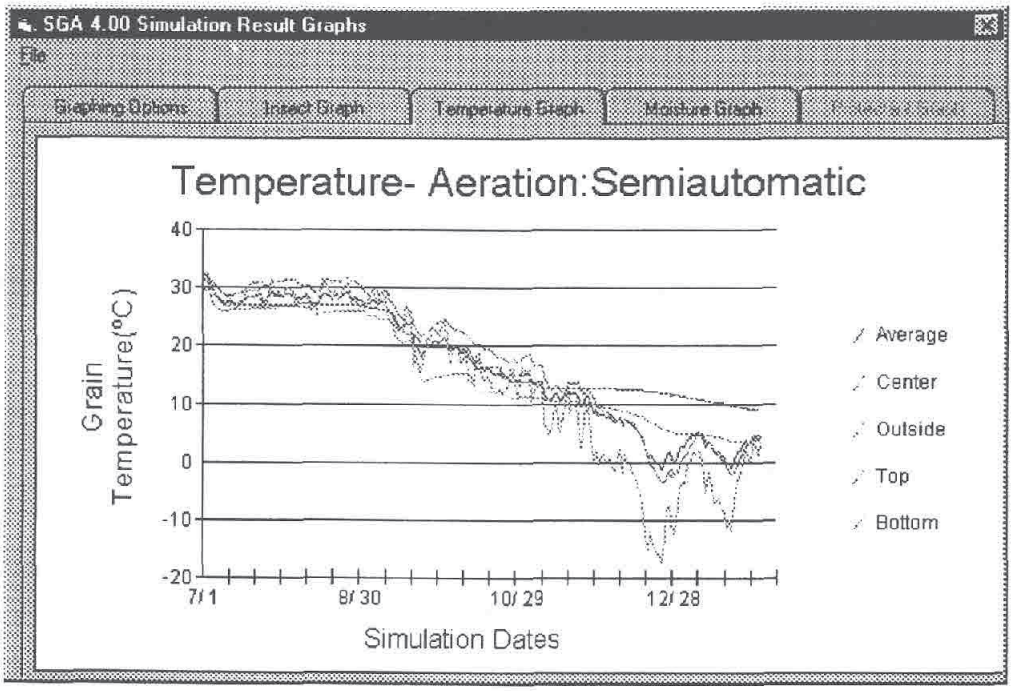
SGA 4.00 Simulation Result Graphs
File
Graphing Options
Insect Graph
Temperature Graph
Moisture Graph
Temperature- Aeration:Semiautomatic
Grain Temperature(°C)
40
30
20
10
0
-10
-20
7/1
8/30
10/29
12/28
Simulation Dates
Average
Center
Outside
Top
Bottom

Fig. 7.

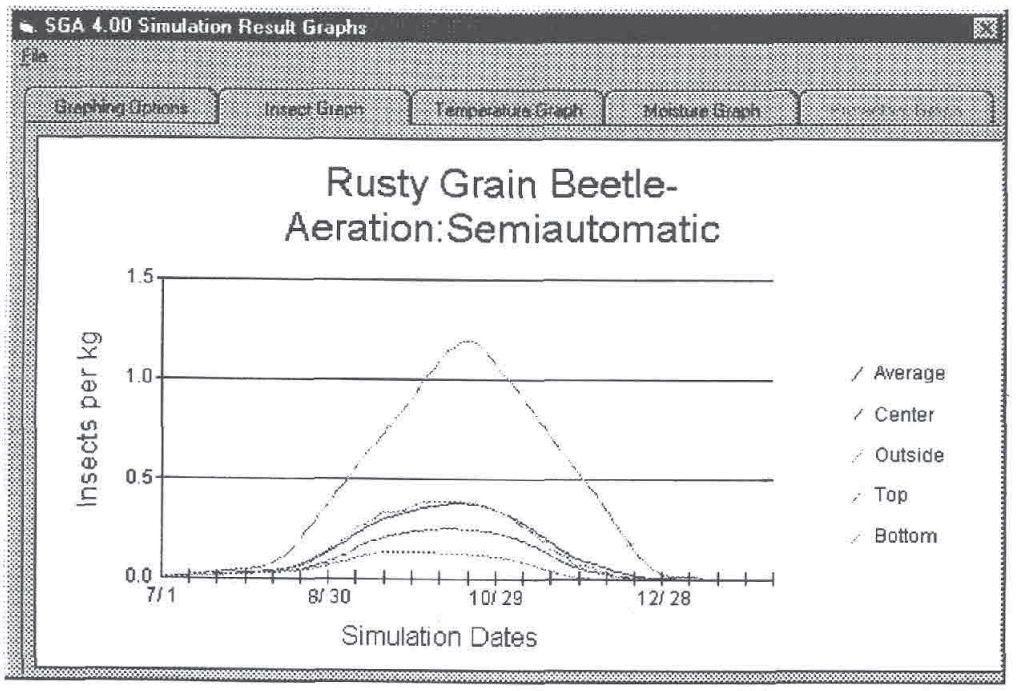
SGA 4.00 Simulation Result Graphs
File
Graphing Options
Insect Graph
Temperature Graph
Moisture Graph
Rusty Grain Beetle-
Aeration:Semiautomatic
Insects per kg
1.5
1.0
0.5
0.0
7/1
8/30
10/29
12/28
Simulation Dates
Average
Center
Outside
Top
Bottom

Fig. 8.

SGA Pro is a key component of the areawide IPM project that is just starting in the USA. This area wide IPM program is funded by the Agricultural Research Service, and is a combined research effort by the Grain Marketing and Production Research Center, Kansas State University, and Oklahoma State University. This project is based on the idea that grain can be better managed using a systems approach that allows for optimal management of grain as it moves from farm, to local elevator, to terminal elevator (Hagstrum and Flinn 1995). By managing insects in the grain as it moves through the marketing channels, insect problems are not passed along to the next marketing channel SGA Pro will allow grain mangers to predict bins that insect problems are likely to occur, and to either use this grain first, or to initiate control measures to prevent insects from developing in these bins

Importance of decision support systems in stored products

Decision support systems are a practical approach for providing grain managers with better information to make pest management decisions. Their importance will probably increase in the future as we lose traditional insecticides, such as malathion, phosphine and methyl bromide, due to environmental concerns. Improvements in the decision making process will lead to more efficient use of insecticides and reductions in storage losses (Longstaff 1997). In the future, we will be forced to rely more on biological and physical control methods to manage insect pests of stored grain, and less on traditional chemical controls Because these methods will require more knowledge about the grain storage system to be used effectively, grain managers will benefit from decision support systems. These systems will probably include models that predict the effects of physical and biological controls on the pest organisms, and will help the manager to use these nonchemical control methods

Extension specialists with responsibilities in stored grain management have continuously declined in the USA over the last five years. Similar trends have also been reported in the UK (Wilkin et al. 1990b; Wilkin and Mumford 1994). Stored Grain Advisor has helped to make up for the declining number of stored grain extension specialists. Hundreds of farmers and grain managers obtained SGA from our web site. They are able to use SGA to answer questions about insect infestation in grain storage. Many extension specialists that have only partial responsibilities in stored grain have also used SGA to help them better understand the principles of stored grain integrated pest management. Extension specialists have also used SGA in extension programs to train grain managers and farmers. Because of the decline in stored grain expertise and the reduced tolerance for damaged grain and insecticide residues, the need for decision support systems has never been greater.

Conclusions

SGA has proven to be a useful decision support tool for farmers, grain managers, and university extension. It has also shown to be useful as a teaching aid for demonstrating the principles of stored grain IPM. Involvement of extension personnel early on in the development of SGA greatly contributed to the successful implementation of this decision support system. Since 1997, the software has been available for free over the Internet, which has also increased its usage. The original version of SGA was targeted primarily towards farm stored wheat. We are now developing a much larger and complex decision support system for commercial grain storage. With the declining support in extension services in the USA for stored product insect management, the role of decision support systems should increase SGA can help to supply some of the knowledge that is needed by farmers and stored grain managers. The current emphasis on integrated pest management demands that grain managers need to have a much better understanding of the ecology of stored grain insect pests In addition, some of the environmentally friendly control methods, such as early aeration with automatic controllers, require more information than traditional chemically based insect control. Decision support systems can help provide some of this knowledge to the grain manager.

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