Field validation of a decision support system for farm-stored grain[1]

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Abstract

The decision support system 'Stored Grain Advisor' (SGA) for farm-stored grain was validated using three years of field data from 50 grain bins. Each year, 16 to 20 bins of newly-stored wheat were sampled monthly from June to January for insects, grain temperature, moisture, test weight and insecticide residue. SGA was correct 80% of the time in predicting which bins would become infested with low, moderate or high insect densities by the end of the storage period. SGA uses rules based on model simulations to forecast population trends. It provides a quantitative interpretation of future population levels, the consequences of management tactics, and customises its recommendations specifically to a farmer's storage conditions. We believe that farmers using this system can make better management decisions, resulting in higher quality grain, reduced insecticide usage and less storage risk.

Introduction

Population growth of grain insects is a function of time, grain temperature, and grain moisture. Other management factors also affect insect population growth, such as sanitation, insecticide concentration in the grain, and aeration. These relationships are dynamic, and thus, it is very difficult for stored-grain managers to accurately forecast the quantitative effects that these variables will have on insects in stored grain.

Expert systems are computer programs that mimic a human expert's ability to solve problems. Expert systems have been touted as a mechanism to rapidly transfer integrated and interpreted information to the grower. They can incorporate 'rules of thumb' as well as technical information and they can explain their reasoning.

Stored Grain Advisor (SGA) is one of a growing number of expert systems in agriculture that either incorporate mathematical models or use them to develop rules. The details of SGA are fully described in Flinn and Hagstrum (1990a). Rules in the insect management module in SGA are based on model simulations (Flinn and Hagstrum 1990b; Hagstrum and Flinn 1990; Flinn et. al. 1992). Variables examined in the simulations included: bin sanitation, storage date, initial grain temperature, initial grain moisture, aeration, and insecticide. The results of these simulations were then translated into rules for the knowledge base. SGA also assists the grain manager in identifying insects or other problems, predicts the likelihood of insect infestation and helps select the most appropriate prophylactic or remedial actions. It also shows the user how to sample grain for insects, identify them, and helps the user decide if enough insects are present to warrant fumigation. It has equations that convert pitfall trap catch to insect density based on species and length of time the traps were left in the grain (Cuperus et al. 1990).

The objective of this study is to validate SGA under field conditions.

Methods

During 1991 to 1993, 16 to 20 bins of newly-stored hard red winter wheat were intensively sampled on 10 farms in Oklahoma and Kansas. Bin capacity ranged from 80 t (3000 bu) to 268 t (10000 bu), with most of the bins holding 80 t. We purposely selected farms in two different latitudes (North-central Kansas and South-central Oklahoma) to test SGA's ability to predict climatic effects on insect growth. Grain storage usually started three weeks earlier on the Oklahoma farms. Wheat in the bins was sampled monthly from June to February (or until it was sold). In 1991, seven, 0.5 kg grain samples were obtained from each bin using a 1.5 m grain trier (Seedburo Equip. Co., Chicago Illinois). Three samples were taken close to the centre of the bin (within 0.5 m) and four other samples were taken at each cardinal compass direction halfway between the centre and the bin wall. In 1992 and 1993, the sample weight was increased to 1 kg by taking two grain-trier samples in each of the seven sample locations. The grain samples were placed in plastic bags and brought back to the lab for analysis. Each grain sample was sieved to separate insects from the grain. Grain test weight and moisture was measured using a Dickey John GAC II (Dickey John Corp., Auburn, Illinois). Grain that was treated with an insecticide was sent to Peterson's Laboratory (Hutchinson Kansas) for residue analysis using gas chromatograph.

SGA is a rule-based expert system; the rules are based on model predictions of insect population growth. Information required by SGA to predict the probability of infestation consists of: storage date, expected sale date, whether aeration will be used, if a protectant was applied at binning, and the initial grain temperature and moisture. 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 interviews with extension specialists that were knowledgeable about stored wheat, we defined low levels as < 2 *Cryptolestes ferrugineus*/kg, moderate as ≥ 2 and ≤ 30 *C. ferrugineus/kg*, and high as > 30 *C. ferrugineus*/kg. Although it is difficult to predict which insect species will reach economic levels, we selected *C. ferrrugineus* because it is the dominant species in most cases.

Results

Based on the 1991, 1992 and 1993 data (50 bins), SGA was correct 80% of the time in predicting which bins would

[1] This paper reports the results of research only. Mention of a proprietary product does not constitute an endorsement by the USDA.

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become infested with low, moderate or high insect densities by the end of the storage period (Table 1). SGA was not biased in over-predicting or under-predicting the level of infestation. It also never made a major error by predicting a low infestation when the field result was high, or predicting a high infestation when the field result was low.

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 October to February). 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*.

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

[a] < 2 *C. ferrugineus*/kg wheat.
[b] ≥2 and ≤ 30 *C. ferrugineus*/kg wheat.
[c] > 30 *C. ferrugineus*/kg wheat.

Because of the large number of bins that were sampled in this study, we will show representative figures depicting typical insect population growth for high, moderate and low levels of insect infestation. The rusty grain beetle *Cryptolestes ferrugineus* was the dominant insect pest in most of the grain bins that we sampled, followed by the lesser grain borer, *Rhyzopertha dominica,* and the red flour beetle *Tribolium castaneum.* Although the sawtoothed grain beetle, *Oryzaephilus surinamensis* infrequently infested grain bins, it did reach high levels in two of the bins.

High insect densities (>30 *C. ferrugineus*/kg) usually developed in grain that was stored at moistures greater than 11%, was not aerated, and was stored for more than 100 days (Figure 1). These represent ideal growing conditions for most stored grain insects. In this study, eight bins had high insect densities. Several other bins would have reached high densities if the farmers had not sold or fumigated their grain. The bins in which SGA underestimated insect density tended to be located on farms with livestock. Feeding operations made good sanitation more difficult to maintain. This probably resulted in higher insect immigration rates into new grain.

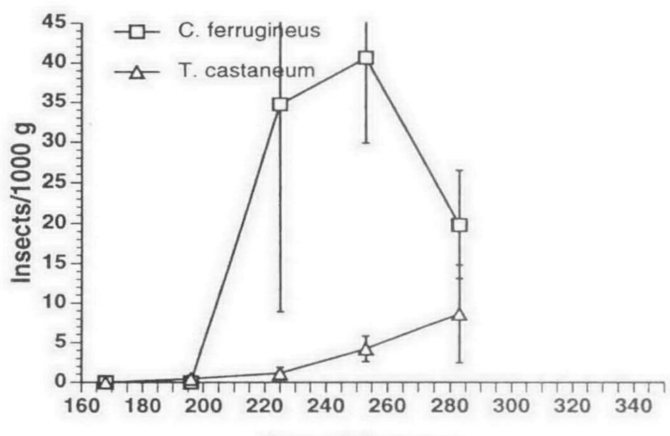

Fig. 1. Insect density in 84.2 t (3200 bu) of stored wheat in Oklahoma during 1991. No protectant was used, initial grain temperature was 32.9°C, and grain moisture was 11.6%. The grain was not aerated. SGA correctly predicted a high level of infestation in this bin

Figure 2 shows a moderate insect density (≥ 2 and ≤ 30 *C. ferrugineus*/kg). SGA correctly predicted that moderate densities of insects would develop in this bin by the end of the storage period. The lower grain temperature at the time of storage probably caused the lower insect growth rate in this bin compared to the previous example.

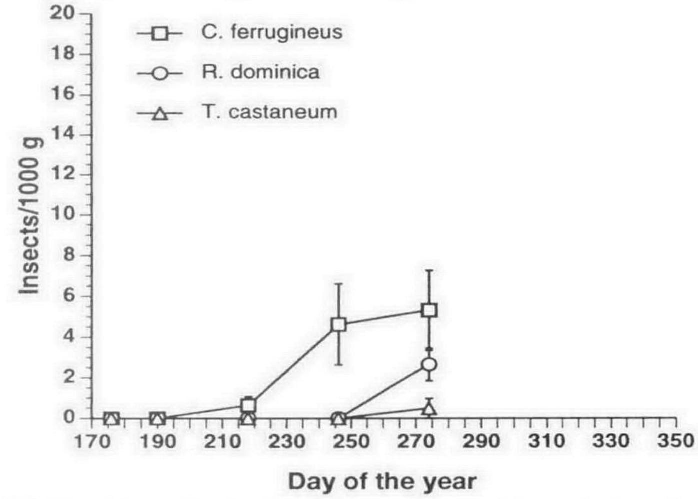

Fig. 2. Insect density in 86.8 t (3300 bu) of stored wheat in Kansas during 1992. No protectant was used, initial grain temperature and moisture were 27.8°C, and 11.4%. The grain was not aerated. SGA correctly predicted a moderate level of infestation in this bin.

Insects rarely reached high densities in bins that were cooled by aeration to 20°C or less by the end of October. Figure 3 shows a *C. ferrugineus* population that peaked in September then declined due to falling grain temperatures. SGA correctly predicted that insects would reach moderate levels in this bin by the end of the storage period.

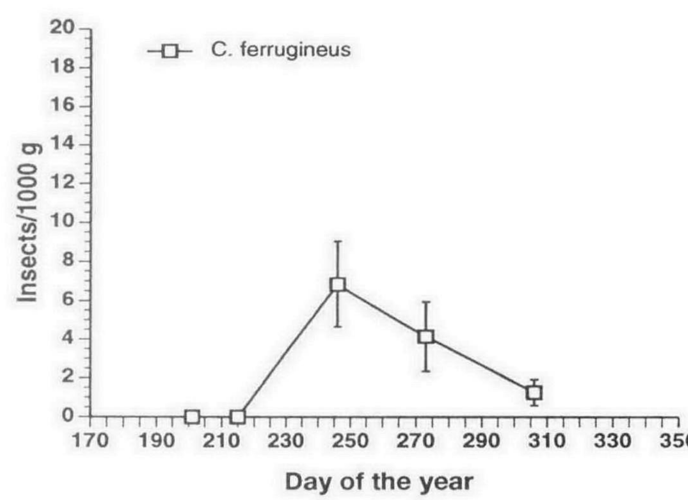

Fig. 3. Insect density in 84.4 t (3100 bu) of stored wheat in Kansas during 1993. No protectant was used, initial grain temperature and moisture were 31.7°C, and 11.9%. The grain was cooled by aeration to 21°C and then to 17.8°C on the last two sample dates, respectively. SGA correctly predicted a moderate level of infestation in this bin.

SGA correctly predicted that insects would remain at low levels in grain that was stored at low grain moisture (<10%) and was aerated to a temperature below 20°C by the middle of October (Fig. 4). SGA correctly predicted that insect levels would remain at low levels through the winter.

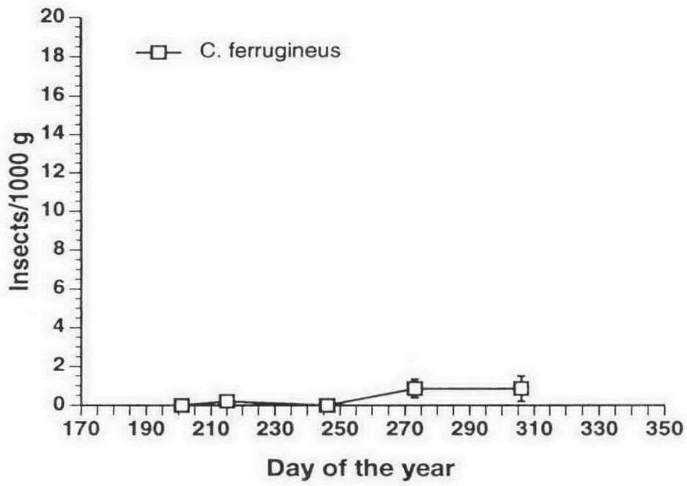

Fig. 4. Insect in 81.3 t (3200 bu) of stored wheat in Kansas during 1993. No protectant was used, initial grain temperature was 29.1°C, and grain moisture was 9.9%. The grain was cooled by aeration to 20°C and then to 15.3°C on the last two sample dates, respectively. SGA correctly predicted a low level of infestation in this bin.

Cryptolestes ferrugineus populations usually remained at low levels when the protectant chlorpyrifos-methyl was applied to the grain at binning. However, *R. dominica* sometimes reached damaging levels even though this protectant was used (Fig. 5). For this bin, SGA incorrectly predicted a low probability of infestation by the end of the storage period.

The bin in Figure 6 was located next to the bin in Figure 5, each had grain with similar temperature and moisture, both had chlorpyrifos-methyl applied at binning, but only the bin in Figure 6 was aerated. SGA correctly predicted that the grain in this bin would remain safe from infestation through the winter. The combination of early fall aeration plus the use of chlorpyrifos-methyl as a grain protectant usually resulted in low insect densities.

Discussion

During the three years of testing, SGA's predictions were accurate for a wide range of conditions: climate, grain moisture, grain temperature, aeration, insecticide, and length of storage. Many factors affect insect population growth in stored grain, but grain moisture, early aeration and length of storage were the most important factors in this study. SGA accurately predicted that grain that was stored at moistures less than 10%, or was aerated to less than 20°C as early as possible in the fall, rarely developed damaging insect populations. SGA correctly predicted that high densities of insects would develop in grain that was stored for more than 70 days at grain moistures greater than 11%, and was unaerated. Protectants did not guarantee low insect levels. Chorpyrifos-methyl suppressed most insects except for *R. dominica*.

SGA should be of great interest to grain managers, extension specialists, and stored grain consultants, both as a decision support tool, and as an educational tool to demonstrate stored-grain IPM principles. The Microsoft Windows® version of SGA has the ability to run the model and plot the results. A user can quickly run various 'experiments' (early vs. late aeration, use of protectant, etc.) and graphically see the outcome. SGA was used to demonstrate important principles of stored grain management in two extension short courses (Oklahoma State University and Montana State University).

Future enhancements to SGA will include the addition of other grains besides wheat, and economic evaluation of management strategies. A version of SGA for commercial elevators is also planned. Kansas State University, Oklahoma State University, and Montana State University plan to use this software in their extension programs beginning summer 1994.

Acknowledgments

I thank B. Dover (Department of Entomology, Kansas State University), G. Cuperus (Department of Entomology, Oklahoma State University), and L. Smith (SPIRDL, USDA-ARS, Savannah) for critically reviewing the manuscript.

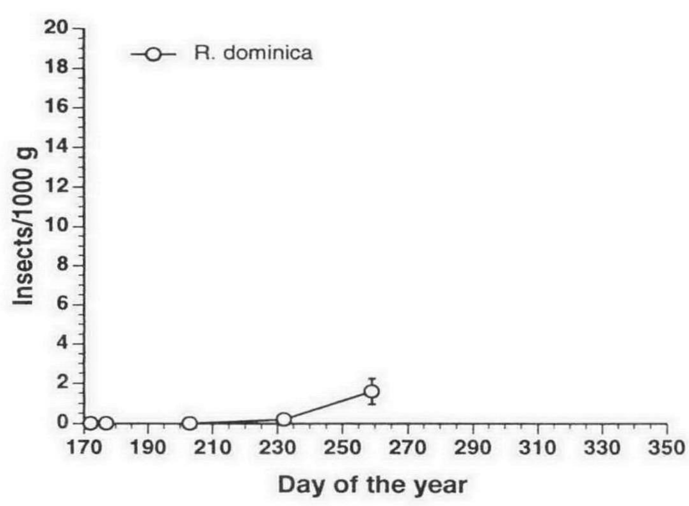

Fig. 5. Insect density in 93.6 t (3500 bu) of stored wheat in Oklahoma during 1992. Chlorpyrifos-methyl was applied as a protectant, initial grain temperature was 31.5°C, and grain moisture was 11.5%. The grain was not aerated. SGA incorrectly predicted a low level of infestation in this bin.

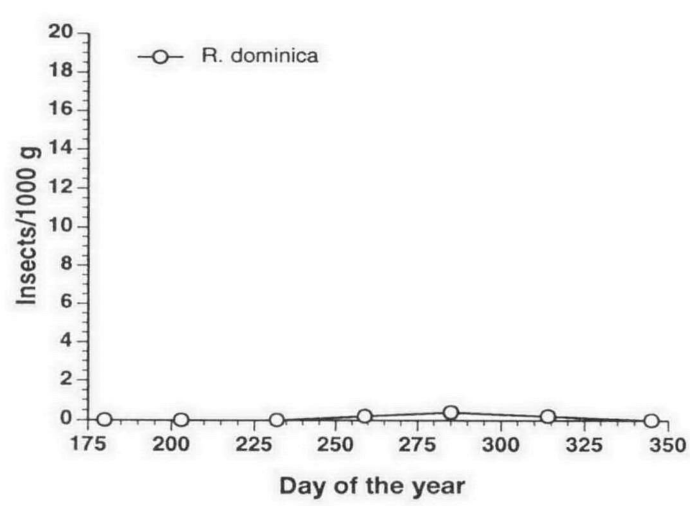

Fig. 6. Insect density in 96.3 t (3600 bu) of stored wheat in Oklahoma during 1992. Chlorpyrifos-methyl was applied as a protectant, initial grain temperature and moisture were 31.4°C, and 11.3%. The grain was cooled by aeration to a temperature of 22°C by late August. SGA correctly predicted a low level of infestation in this bin.

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