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Integrating the Stored Grain Advisor Pro expert system with an automated electronic grain probe trapping system

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Abstract

Automation of grain sampling should help to increase the adoption of stored-grain integrated pest management. A new commercial electronic grain probe trap (OPI Insector™) has recently been marketed. To make accurate insect management decisions, managers need to know both the insect species and numbers found in their grain. To make good management decisions, trap catch needs to be interpreted for the user. Insect species and grain temperature are two important factors that influence trap catch. Thus, an electronic trap needs to be able to estimate the species caught and grain temperature. We field tested OPI Insector™ electronic grain probes in two bins, each containing 32.6 Tonne of wheat, for a 10-month period. We compared estimates of insect density (insects/kg wheat) to the Insector counts. A statistical model was used to convert Insector™ catch into insects per kg. The average Insector™ manual tip counts and electronic counts were similar for most trapping dates. Stored Grain Advisor Pro (SGA Pro) was modified to automatically read the Insector database and to use a statistical model to estimate *Cryptolestes ferrugineus* density from trap catch counts and grain temperature. Management decisions using Insector™ trap-catch estimates for *C. ferrugineus* density were similar to those made using actual insect density for 11 out of 12

sampling dates for the first grain bin, and 11 out of 12 sampling dates for the second grain bin. The statistical model used to predict insect density from Insector trap catch tended to underestimate *C. ferrugineus* density when the grain was warmer than 23 °C.

Key words: Probe trap, *Cryptolestes*, decision support system, integrated pest management, OPIGMAC™, Insector™.

Introduction

Pitfall probe traps have been used to estimate insect populations in stored grain for many years (Loschiavo and Atkinson, 1967; Loschiavo and Smith, 1986; Lippert and Hagstrum, 1987; Vela-Coffier et al., 1997; Wakefield and Cogan, 1999). These traps are composed of cylindrical tubes with perforations through which insects drop into a collecting tip in the bottom of the trap. Many versions of the trap have been designed (Burkholder, 1984; Madrid et al., 1990; White and Loschiavo, 1986). Shuman et al. (1996) developed an electronic version of the trap that automatically counts insects as they fall into the tip.

Pitfall probe traps are very good at detecting insects in stored grain, and often can detect insects as much as 37 days earlier in grain compared to

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samples taken with a grain trier (Hagstrum et al., 1998). However, one of the problems with probe traps is that insect catch is strongly influenced by both grain temperature and insect species (Fargo et al., 1989). To use probe traps correctly to make insect management control decisions, trap catch needs to be converted to an absolute density estimate (insects/kg grain). Several researchers have developed statistical equations to do this based on insect species caught per day and grain temperature (Hagstrum et al., 1998; Toews et al., 2005).

An electronic probe trap with infrared-beam sensors (EGPIC) was developed to alleviate the need to enter the bin (Shuman et al., 1996). EGPIC has gone through many design iterations during the last 10 years. The EGPIC design was licensed by OPI Systems, Inc. (Calgary, Alberta, Canada) and is commercially available as Insector™. The Insector™ is controlled by a computer program running on a PC (OPIGIMAC™). The newest design uses a dual infrared-beam to better estimate the size of the insect. The ability of the Insector™ to detect the size of the insect falling into the trap allows it to roughly identify two of the common insect pests of stored wheat, mainly (*Cryptolestes ferrugineus* (Stephens) and *Sitophilus* species. As noted above, in order to predict insect density from probe trap catch, it is necessary to know the counts for each species that were caught by the trap, as well as the grain temperature. In addition, knowing the species that are in the grain improves IPM decision-making, because internal-feeding insect species cause much more damage to the grain than external-feeding insects.

Stored Grain Advisor Pro (SGA Pro) is an expert system for managing insect pests in stored grain that makes recommendations based on estimates of insect density in the grain using vacuum probe or grain-trier samples (Flinn et al., 2003). To automate the sampling process, we wanted to modify an existing version of SGA Pro to use Insector™ data to make insect management decisions. To do this, we needed to convert probe trap catch into insect density (insects/kg grain). The statistical model (Hagstrum

et al., 1998) was based on studies that used the WBII™ trap. Because the Insector is quite different than the WBII™ trap (the WBII™ holes are larger, and the Insector™ has upward sloping holes) we wanted to determine if the model by Hagstrum et al. (1998) could be used for the Insector™ trap.

The purpose of this study was to modify a version of SGA Pro so that it could automatically access the OPIGIMAC™ database, convert trap catch into insect density, and make management recommendations. We also wanted to determine if SGA Pro's management recommendations were similar using either grain samples or Insector™ estimates of insect density (using the model by Hagstrum et al. (1998)).

Materials and methods

Two steel bins (4.72 m in diameter by 3.35 m in height at the eaves) were each filled with 32.6 tonne (1,200 bushel) newly-harvested hard red winter wheat on 21 July 2005 (2.44 m depth). The grain temperature and moisture at the time of storage were approximately 33 °C and 12 %, respectively. Five Insectors™ were inserted (Insector™ top was 0.30 m below the grain surface) into the wheat in the bin center and N, S, E, and W directions (approximately 0.5 m from the bin wall). Solid collection tips filled with 1 cm of ethylene glycol (to preserve the insects) were used with the Insectors™ for 1 week, after which the Insectors™ were pulled out of the grain, and the solid tips were replaced with tips that had a hole in the bottom (for insects to escape). The insects in the tips were carefully identified and counted. Four grain-trier samples were taken 30 cm distance from each Insector™ every 2 weeks (1 m depth, 0.5 kg each). Because grain samples taken in July and August showed very low densities for *Rhyzopertha dominica* (F.) in the grain, we added 400 *R. dominica* adults to each bin on September 2005. This was done to ensure that the three most common insect pests of stored wheat in Kansas (*C. ferrugineus*, *R. dominica*, and *Tribolium castaneum* (Herbst))

were present in the grain. Grain temperatures were monitored using the OPI temperature sensor cables. One cable was inserted next to each Insector and recorded grain temperatures every 30 cm, from the bottom to the top of the grain mass.

Regression equations (Hagstrum et al., 1998) were used to convert trap catch into insect density for *C. ferrugineus* and *R. dominica*. Because there was no model for estimating insect density from trap catch for *T. castaneum*, we used the *R. dominica* model. SGA Pro was programmed to automatically access the OPIGMACTM database and convert trap catch into insect density. We compared SGA Pro's management recommendations using both trier samples and InsectorTM catch.

Results and discussion

Because *C. ferrugineus* was the most numerous insect pest in the study, we will discuss only the results for the *C. ferrugineus* data. The density of *C. ferrugineus* reached a maximum value on 18 January (Figure 1). In contrast, the *C. ferrugineus* Insector trap catch reached a maximum value on 27 September, after which it slowly declined, due to cooler grain temperatures. Trap catch decreased with grain temperature, even though the actual insect density in the grain was continuing to increase. Other researchers have reported similar temperature effects (Hagstrum et al., 1998; Toews et al., 2005). This is why it is necessary to convert trap catch into insect density, otherwise erroneous management decisions may be made.

We adapted a version of SGA Pro to automatically access the OPIGMACTM database, and used the model from Hagstrum et al. (1998) to convert electronic counts into insect density. To do this, we first had to estimate the insect species (for each count), based on the adjusted target peak amplitude recorded by the InsectorTM. Based on data from Shuman et al. (2005), we used an amplitude range of greater than 10, but less than 25, to classify *C. ferrugineus*. The

correlation between electronic counts and manual tip counts was fairly good ($r^2 = 0.65$, $N = 93$, $P=0.001$), although the electronic counts of *C. ferrugineus* tended to be higher than the manual counts (Fig. 2). The higher counts occurred when the psocid counts were also very high. Because of the size overlap between large psocids and small *C. ferrugineus*, some of the larger psocids may have been misclassified as *C. ferrugineus* by the InsectorTM.

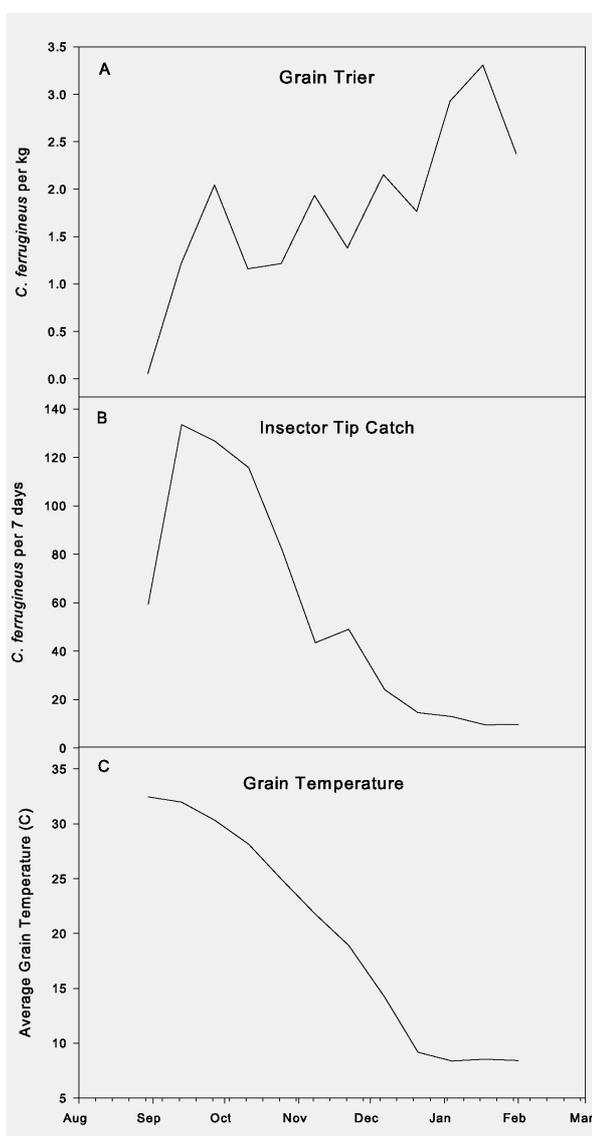


Figure 1. Seasonal changes in average (a) *C. ferrugineus* density (grain trier samples); (b) Insector tip counts (7-day catch); (c) grain temperature (data is for two bins, each containing 32.6 tonne of hard red winter wheat).

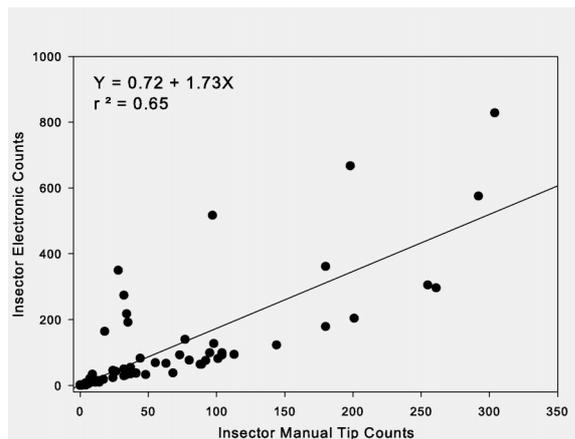


Figure 2. Electronic Insector™ counts vs. manual Insector tip counts for 10 Insectors™ (5 in each bin). Counts are based on a 7-day collection period.

For bin 21, the calculated values for *C. ferrugineus* density using the manual Insector™ tip counts were very similar to the average electronic tip count estimates (Figure 3a). The electronic Insector™ estimates of *C. ferrugineus* density were less than actual insect density (grain trier samples) at all sampling dates except for 25 October. However, management decisions regarding treatment (= 2 insects per kg threshold) would be the same for all sampling dates except 11 October; on this date, SGA Pro would have recommended fumigation based on grain sample data. Using the Insector™ data, SGA Pro would have recommended no fumigation for 11 October. For bin 22, the estimates for average density per bin for *C. ferrugineus* using the manual Insector™ tip counts were also very similar to the electronic Insector™ counts (Figure 3b). The electronic Insector™ estimates of average *C. ferrugineus* density per bin were very close to the actual insect density (grain trier samples) during December through February. SGA Pro's decisions regarding treatment (= 2 insects per kg threshold) would have been the same using trier samples or Insector™ for all sampling dates except 8 November. On 8 November, SGA Pro would have recommended fumigation based on the grain trier data.

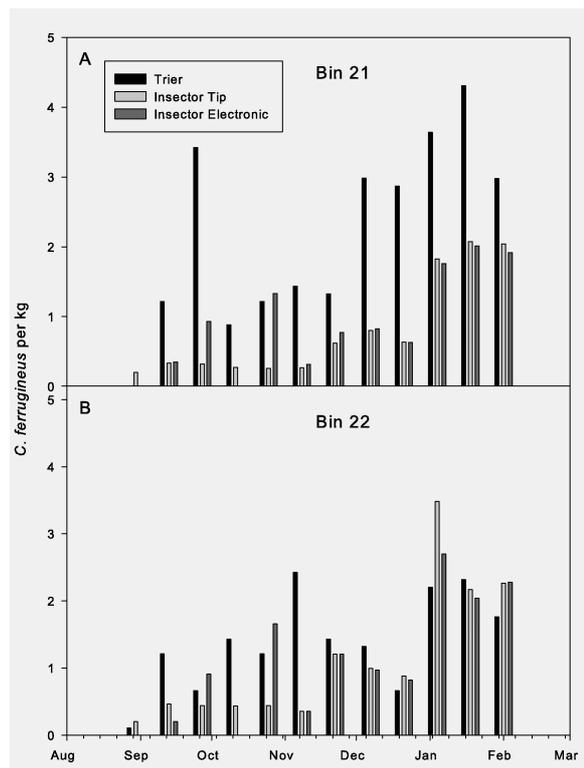


Figure 3. Mean insect density per bin estimated using grain trier samples, Insector tip count estimates (insects per kg), and Insector electronic count estimates (insects per kg) for (a) bin 21; (b) bin 22. Conversions of trap catch into insect density were estimated using equations from Hagstrum et al. (1998).

The statistical model that was used to estimate insect density from probe trap catch (Hagstrum et al., 1998) may need to be re-evaluated. The model tended to underestimate *C. ferrugineus* density when the grain was warm (August through November). For the most part, the model did accurately predict insect density when the grain was cool (December through February). There are physical differences between the WBII™ traps that were used to develop the Hagstrum et al. (1998) model and the Insector™. The holes in the WBII™ trap are larger and do not have the upward-sloping holes that the Insector™ trap has. This difference in trap design may result in fewer insects being caught in the Insector™ compared to the WBII™ trap. However, the

upward-sloping holes in the Insector™ are a very important feature because they reduce the amount of grain fragments falling into the trap (these could be misinterpreted by the LED sensors as insects).

Additional research is needed to develop a statistical model for the Insector™ trap that is able to make better predictions of insect density under warm grain storage conditions. We plan to develop a new statistical model to predict *C. ferrugineus* density for the Insector™ from the 2005 data, and evaluate the new model using data we will collect during the 2006-2007 year.

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