Donahaye, E.J., Navarro, S. and Leesch J.G. [Eds.] (2001) Proc. Int. Conf. Controlled Atmosphere and Fumigation in Stored Products, Fresno, CA. 29 Oct. - 3 Nov. 2000, Executive Printing Services, Clovis, CA, U.S.A pp. 699-705

USE OF SAMPLING INFORMATION FOR TIMING FUMIGATIONS AT GRAIN ELEVATORS

C. REED,[1]* D. HAGSTRUM,[2] P. FLINN,[2] AND T. PHILLIPS[3]

[1]*Dept. of Grain Science and Industry, Kansas State University, Manhattan, KS, 66506, USA*
*[*e-mail: carlgs@ksu.edu]*
[2]*Grain Marketing and Production Research Center, USDA-ARS, Manhattan, KS, 66502 USA*
[3]*Dept. of Entomology, Oklahoma State University, Stillwater, OK, 74078, USA*

ABSTRACT

Fumigation with phosphine fumigants is the primary method of controlling insects in wheat at many commercial grain storage facilities in the hard red winter wheat production area of North America. To evaluate the approach taken by managers when deciding which grain to fumigate, wheat was sampled when being moved and fumigated at various times during the storage year. The insect density was determined and compared to that in wheat moved but not fumigated at the same time of year in similar elevators. The results indicated that managers did not apply a consistent density threshold in their decision-making process. Wheat fumigated in the fall and early winter was not more densely infested on the average than wheat moved but not fumigated at the same time of year.

Researchers interested in developing an IPM strategy for stored grain desire to accurately predict early in the storage season the level of insect density and grain damage likely to be found later in the types of grain samples typically taken at commercial grain stores. This would allow grain managers to make more cost-effective decisions related to timing of grain fumigations. To sample the insect populations shortly after wheat harvest, pitfall probe traps were placed in the surface of wheat in elevator bins. These traps did not prove useful for predicting which lots would require fumigation.

Grain samples were taken periodically with a vacuum probe from wheat stored in upright concrete bins. The usefulness of this data when deciding which lots to fumigate and when to fumigate was evaluated. Many factors affected population trends, and sophisticated models and thresholds will be required to consistently identify high-risk grain and predict the optimum timing of grain fumigation.

INTRODUCTION

Data-based decision-making about when to apply pest control chemicals is an essential, defining component of any IPM strategy. Its successful use requires timely and accurate information on densities of pest and beneficial species. Grain stored in commercial elevators presents a formidable challenge to information-based decision-making because the large size and inaccessibility of the masses of stored grain complicate the estimation of pest population densities.

Surveys of elevator managers' insect-control practices have been reported by Reed and Worman (1993), Kenkel *et al.* (1994), and Martin *et al.* (1997), but no objective evaluation of the efficacy of those practices have been published. About half of Kansas elevator managers reported that they normally fumigate only if infestation is noted, but more than half indicated that some grain would be fumigated on a pre-planned schedule, depending on the intended length of storage and the type of structure (Reed and Worman, 1993). A multi-year research project currently underway in Kansas and Oklahoma provides the opportunity to objectively evaluate various fumigation strategies and to evaluate the usefulness of various sampling methods for IPM strategies.

MATERIALS AND METHODS

Three distinct sampling methods were employed in elevator-stored wheat in a network of thirteen country and terminal elevators in central Kansas, USA. Shortly after harvest, a pitfall probe trap was placed 1-2 cm beneath the grain surface. The trap consists of a plastic cylinder 36 cm long, 2.5 cm diameter with 3.5-mm, downward-slanting perforations through which beetles enter. Traps remained in the grain 4-5 days before insects were collected and identified. Counts are reported as number captured per day.

The second sampling method used a vacuum probe. This apparatus consisted of a vacuum pump powered by a 5.3-Kw gasoline engine, connected by flexible plastic tubing to rigid metal tubes 3.5-cm diameter. Sections of the rigid tubes 1.2 m long were connected to form a probe that was inserted into the grain mass. The grain collected as each section was inserted into the grain mass was measured by volume to units of 3.9 L (ca. 3 kg) and twice passed over an inclined sieve (Hagstrum, 1989) to remove fine material including insects. The fine material was sealed in plastic bags and transported to the laboratory where live adult beetles were identified to genus. Insect density was reported as number of live adults per kg of grain. Species included in total insect counts were *Cryptolestes* spp., *Oryzaephilus* spp., *Sitophilus* spp., *Tribolium* spp., and *Rhyzopertha dominica* (F.).

Finally, samples of grain were collected as certain lots of wheat, some of which had been sampled with a vacuum probe, or were taken from grain moved on belts. Samples of moving grain were collected from the belt with an Ellis cup at the rate of 3.9 L per 27.2 tonnes. Insects were removed with the inclined sieve and identified as described above.

RESULTS AND DISCUSSION

Characterization of the decision to fumigate

To determine whether a manager's decision to fumigate wheat was related to the insect density in the grain, the insect density in samples of moving grain that received a fumigant application after sampling was compared to that in samples taken from moving grain that was not fumigated. Managers apparently did not apply a consistent insect density threshold when deciding which bins or when to fumigate, as mean densities ranged from 0.01 insect/kg to 1.6 insect/kg in grain that was fumigated, depending on time of year (Table 1). Also, mean insect densities in grain that was fumigated were not significantly higher than those in grain that was not fumigated. Rather, managers reported fumigating based on how long they intended to hold the grain or the schedule of activities at the elevator.

TABLE 1
Density of insects, all species combined, in elevator-stored wheat moved for fumigation or for another purpose July through October, 1998. Samples were taken with an Ellis cup as the grain was moved

	Fumigated			Not fumigated		
	Number	Mean (No./kg)	SD (No./kg)	Number	Mean (No./kg)	SD (No./kg)
July	192	0.01	0.06	174	0.01	0.06
August	26	0.3	0.7	94	0.1	0.4
September	902	0.5	1.1	141	0.5	1.1
October	412	1.6	6.0	693	0.9	2.1

In the U.S. grain handling system, the adoption of data-based decision-making with regards to fumigation application and timing will require a substitution of the IPM approach for the current, familiar approach (Hagstrum *et al.,* 1999). This, in turn, implies that the sampling procedure must be able to supply very accurate insect density information on a timely basis, and this information must be used to predict, early in the storage season, which grain is at higher risk of insect-related deterioration.

Use of trap catch data to identify high-risk grain

Pitfall probe traps are known to be sensitive indicators of insect activity, but did not provide data useful to predicting which lots of grain are likely to develop dense insect populations faster than others. Within two weeks of harvest, traps detect insects in one-quarter to one-half of all elevator-stored wheat (Fig. 1), but the relationship between trap catch and insect density later in the year was tenuous (Fig. 2). Even when probe-trap and vacuum-probe data were collected within a month of one another from several bins, we observed no significant correlation.

Using samples from grain at rest to identify high-risk grain

In commercial practice, buyers evaluate the quality of grain based on samples taken as the grain is moved in the grain conveying system. For purposes of insect control, an accurate estimation of the insect density must be obtained long before this occurs, that is, before the grain is sold or moved to the processing plant to export. Vacuum-probe sampling was used to estimate insect densities in the grain at rest. Despite the known inaccuracies of sampling grain at rest, the insect density means from vacuum samples correlated well ($r^2 = 0.79$) with the means of samples taken as the grain was moved on grain belts in cases when the two types of samples were taken within two weeks of one another and when only one bin was discharged at a time (Fig. 3). The

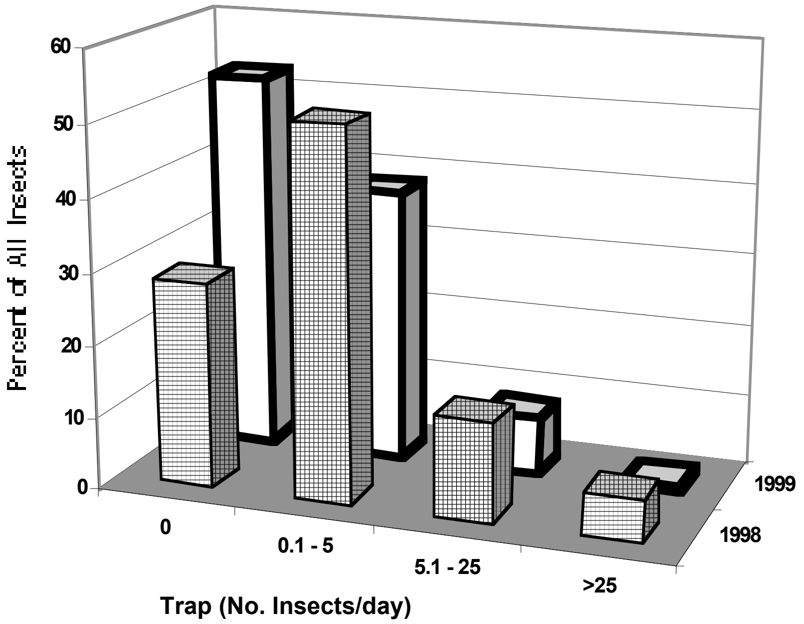

Fig. 1. Ranges of capture rates in pitfall probe traps placed within two weeks after harvest in the surface of wheat stored in Kansas elevators.

regression equation was MV = 1.2*VP – 0.4, where MV is the insect density (No./kg) in samples of moving grain and VP is the mean insect density in the vacuum-probe samples. The strength of this relationship is greater than expected, given the uneven distribution of various species of insects in the bins (Fig. 4), the flow patterns of grain from an upright silo, and the limited accessibility for sampling.

Although the high level of correlation between insect density estimates supplied by vacuum-probe samples and those observed as grain is moved is encouraging, the ultimate objective of the sampling is to predict the insect density that will be observed as the grain is moved after several months of storage. This allows the manager to make economically sound insect-control decisions before the insect density reaches the point at which price discounts or other penalties exceed the cost of insect control. When insect density means from vacuum-probe samples from 32 bins were correlated with those from samples taken after the same grain had been stored 2-3 months, the relationship was not significant ($r < 0.3$, $p>0.05$). To better

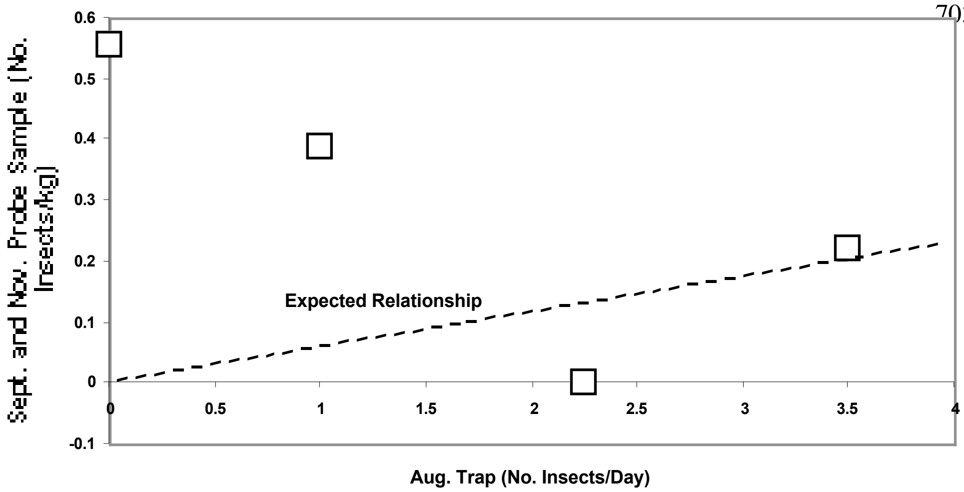

Fig. 2. Relationship between pitfall probe trap catch in August and insect density as estimated by vacuum-probe data in the same bins in September or October.

predict insect density after 2-3 months, the influence of grain temperature and moisture on insect population growth must be considered.

Grain temperature and moisture would be expected to greatly affect the rate of change in insect density during storage. Models of insect density changes over time, given the initial density, species composition, grain moisture and temperature, have been developed from laboratory data. They have been shown to account for about 90% of the variability in insect growth over time (Hagstrum and Flinn, 1990; Hagstrum and Throne, 1989). A promising strategy for estimating the insect density after several months of storage, based on samples of grain at rest, is to use the sampling data from early in the storage season and the models to project the density that would be observed at a future date.

In practice, many factors may reduce the ability to provide accurate information to the models, thereby compromising the ability to accurately predict population growth rates. When making fumigation decisions, it is precisely those bins wherein insect populations increase faster than normal that one must identify based on sampling and model predictions. Figure 5 shows the pattern of insect density change in six lots of wheat in the same elevator, as estimated from vacuum-probe samples. These bins were filled at about the same time with wheat of about the same temperature and moisture content. Samples taken in November provided reasonably good estimates of trends in population increase, but those taken in September did not. Obviously, a high level of sophistication and accuracy will be required of prediction methods in order to enable consistent identification of high-risk grain.

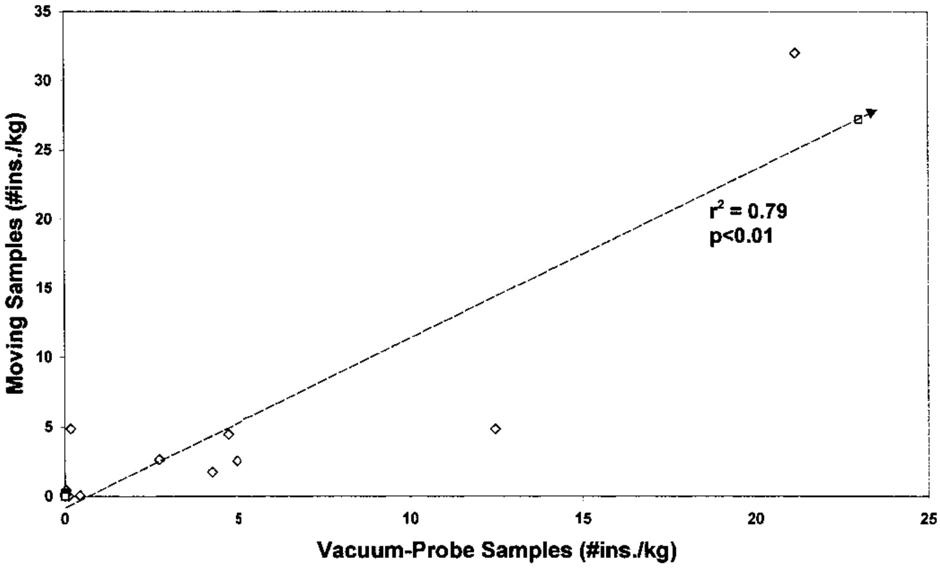

Fig. 3. Relationship between estimates of insect density provided by vacuum samples and those provided by samples of moving grain taken within three weeks of the vacuum samples.

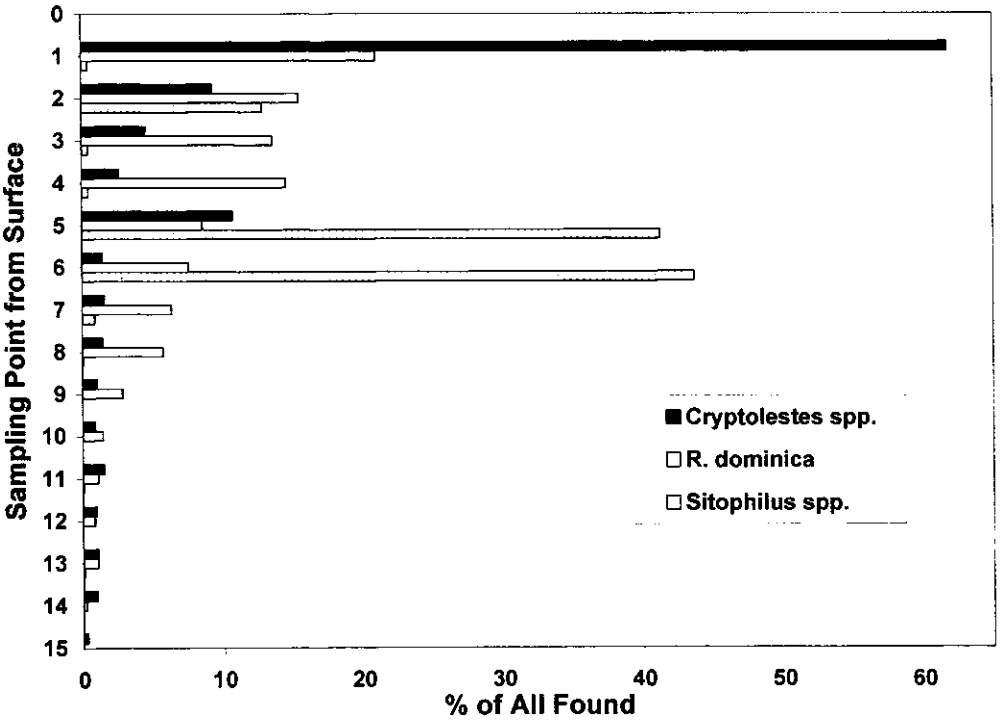

Fig. 4. Vertical distribution of three species of insects in vacuum-probe samples of 73 bins in Kansas elevators in November, 1999.

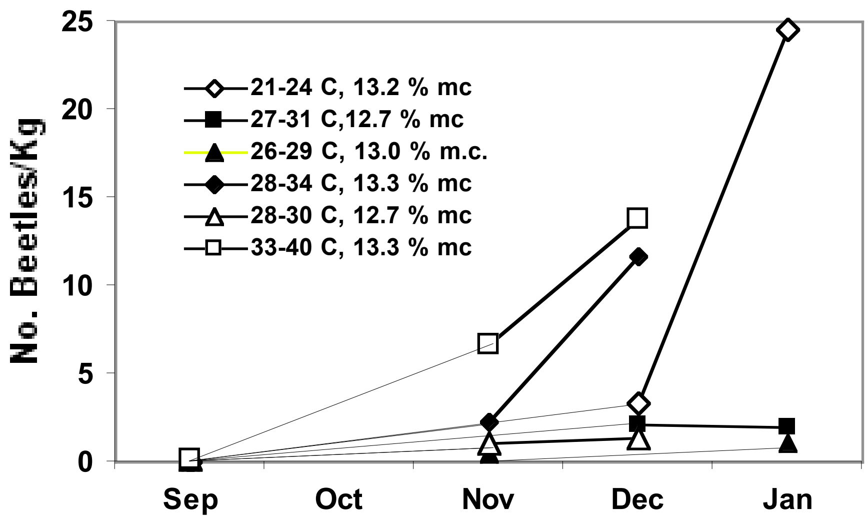

Fig. 5. Insect density changes over time as indicated by vacuum-probe samples in six lots of wheat stored in the same Kansas elevator in 1999/2000.

REFERENCES

Hagstrum, D.W. (1989) Infestation by *Cryptolestes ferrugineus* (Coleoptera: Cucujidae) of newly-harvested wheat stored on three Kansas farms. *J. Econ Entomol.*, **82,** 655-659.

Hagstrum, D.W. and Throne, J.E. (1989) Predictability of stored-wheat insect population trends from life history traits. *Environ. Entomol.,* **18,** 660-664.

Hagstrum, D.W. and Flinn, P.W. (1990) Simulations comparing insect species differences in response to wheat storage conditions and management practices. *J. Econ. Entomol.,* **83,** 2469-2475.

Hagstrum, D., Reed, C. and Kenkel. P. (1999) Management of stored wheat insect pests in the USA. *Integrated Pest Management Reviews,* **4,** 127-142.

Kenkel, P., Noyes, R.T., Cuperus, G.W., Criswell, J., Fargo, S. and Anderson, K. (1994) U.S. stored-wheat pest management practices: producers, elevator operators, and mills. In: *Proc. 6th Int. Working Conf. on Stored-Product Protection* (Edited by Highley, E., Wright, E.J., Banks, H.J. and Champ, B.R.) Canberra, Australia, 17-23 April 1994, CAB International, Wallingford, Oxon, UK, **2,** 935-939.

Martin, M.A., Edwards, C.R., Mason, L.J. and Maier, D.E. (1997). Stored wheat IPM practices and pesticide use in key regions of the United States and Canada. Publ. B752. Purdue University. W. Lafayette, IN.

Reed, C. and Worman, F. (1993) Quality maintenance and marketing of wheat stored on farms and in elevators in Kansas: Description, techniques, and innovations. Bulletin 660, Kansas Agricultural Experiment Station, Manhattan, 55 pp.