Acoustical monitoring of stored-grain insects: an automated system[1]

D.W. Hagstrum*, P.W. Flinn* and D.Shuman†

Abstract

An automated system for monitoring insect populations in stored grain with acoustical sensors was tested in six bins storing 65 to 110 t of newly-harvested wheat on four farms in Kansas during 1992 and 1993. During both years, sounds were detected more frequently as insect density increased during the storage period and the acoustical sensors detected insects 16 to 31 days earlier than grain trier samples.

The number of times that acoustical sensors detected insects was correlated with insect densities in grain samples over the range of 0.5 to 7.5 insects per kilogram of grain. Acoustical detection increased by one each time insect density increased by 0.305 insects per kilogram of grain. The correlation between acoustical detection and insect density will enable us to estimate insect density without taking grain samples.

Insects were detected at only 5 to 15 of the 56 sensor locations at which grain samples were taken. These locations were generally near the grain surface in the centre of the bin. Acoustical sensors at these locations should provide the most effective insect monitoring in farm bins.

Introduction

Research on the use of acoustical sensors to monitor stored-grain insect populations has been reviewed (Hagstrum 1991). Acoustical sensors were first used to detect insect larvae feeding inside kernels of grain. The most accurate system for detecting larvae inside kernels in large grain samples, as a method for grain grading, counts the number of locations in a kilogram of wheat at which insect sounds are detected (Shuman et al. 1993). Another approach has been to probe or install cables with acoustical sensors instead of taking grain samples. An automated system that uses acoustical sensors on cables to monitor stored-grain insect populations has been developed and shown to be effective in laboratory tests (Hagstrum et al. 1991).

We report here the results of the first two years of a three-year field study which compares the effectiveness of this automated system in monitoring insect populations with that of grain trier samples.

[1] This article reports the results of research only. Mention of a proprietary product or pesticide does not constitute an endorsement or a recommendation for its use by USDA.

* U.S. Grain Marketing Research Laboratory, Agricultural Research Service, United States Department of Agriculture, 1515 College Avenue, Manhattan, Kansas 66502, USA.

† Insect Attractants, Behaviour and Basic Biology Laboratory, Agricultural Research Service, United States Department of Agriculture, P.O. Box 14565, Gainesville, Florida 32604, USA.

Materials and Methods

Our automated insect detection system was field tested in six bins storing 65 to 110 t of newly-harvested wheat on four farms in Kansas during 1992 and 1993. Seven flexible cables were installed vertically in the grain mass along a transect across the diameter of the bin. The cables to either side of the centre cable were 30 cm from centre and the remaining cables were 60 cm from the nearest cable. The 3 m of each cable that were in the grain had 20 sensors (MuRata PKM28-2AO, Smyrna, Georgia) 15 cm apart. The cables were 21 m long and connected to electronic instrumentation located in a small trailer next to the bins. The instrumentation monitored sensors in two bins. The signal from sensors was amplified 10 000 times (Bruel and Kjaer Model 2610, Marlborough, Massachusetts), filtered (Krohn-Hite Model 3700 variable band-pass filter, Avon, Massachusetts), and the number of voltage spikes above a 0.22 volt trigger level during a 10-second interval were counted (Hewlett-Packard universal counter Model 5316A, Wichita, Kansas). An IBM-compatible computer stored the data, reset the counter after making the count for each sensor and controlled switching (Hewlett-Packard switch /test unit Model 3235) to the next sensor. The system reads each sensor for 10 seconds 27 times per day during the first three to four months of storage.

Grain samples were taken every two weeks from in front of each sensor in the top 1.2 m of grain with a compartmented grain trier. The insects in each grain sample were counted and these numbers were compared with the average number of 10 second intervals per day in which sounds were detected during the five-day period prior to sampling.

Results

Insect densities were highest near the top of the grain mass in the centre. In this region, the number of intervals in which insect sounds were detected began to increase on day 39, but the first insect was not detected in grain samples until day 70, 31 days later (Fig. 1). The insect species present in this bin included *Rhyzopertha dominica* (F.), *Tribolium castaneum* (Herbst) and *Sitophilus oryzae* (L.). On days 39, 44, 48, 54 and 57 and from day 67 to day 78, there were significantly fewer ($p < 0.05$) 10-second intervals without sounds at the sensor locations where grain trier samples confirmed the presence of insects than at the locations where they did not (Table 1). For the days in Figure 1 that are not shown in Table 1, differences were not significant between day 15 and day 34, and were significant between day 79 and day 125.

In a second bin, the number of intervals with insect sounds began to increase by day 44 and insects were first detected in grain samples on day 60, 16 days later. The shorter time between first acoustical detection and first detection with grain samples in the second bin may be due to only *R. dominica* being found in this bin. This species is more difficult to detect with acoustical sensors (Hagstrum and Flinn 1993). In the second bin after day 44, the numbers of intervals with insect sounds were consistently significantly different

Table 1. Statistical comparison of detection of sounds at locations where insects were found in grain samples to that at other locations.

Day of storage	Number of intervals without sounds				t	Probability
	Insects present in grain samples		Insects absent from grain samples			
	Mean	SD	Mean	SD		
35	22.0	5.6	23.5	1.0	0.70	0.51463
36	23.0	2.0	23.9	0.9	1.09	0.32503
37	24.0	2.0	24.6	2.3	0.52	0.62305
38	22.2	1.5	23.0	0.9	1.23	0.27214
39	22.6	1.7	25.2	0.7	3.81	0.01249
40	20.8	1.8	22.0	1.7	1.25	0.26501
41	22.5	2.5	25.3	0.5	2.96	0.03143
42	22.8	2.4	23.9	1.5	1.05	0.34096
43	23.3	3.5	25.5	0.5	1.50	0.19428
44	18.6	5.4	25.7	0.0	3.22	0.02345
45	21.3	4.3	23.3	3.7	0.70	0.51290
46	23.4	1.3	23.8	1.5	0.37	0.72532
47	24.0	1.7	23.9	2.2	–0.05	0.96446
48	22.0	1.7	24.7	1.1	3.26	0.02251
49	20.4	5.7	22.2	1.4	0.71	0.50887
53	18.8	8.8	25.6	0.6	1.88	0.11891
54	17.9	6.3	25.6	0.5	3.24	0.02300
55	18.8	6.8	24.7	1.0	2.23	0.07574
56	15.7	6.8	20.7	1.7	1.88	0.11890
57	16.0	9.0	25.1	1.7	2.57	0.04982
58	15.8	6.0	22.9	5.1	2.07	0.09275
59	15.4	7.9	24.2	3.3	2.54	0.05203
60	15.6	6.9	22.5	4.5	2.06	0.09412
61	11.9	7.6	19.1	6.4	1.71	0.14811
62	12.9	8.4	20.8	7.2	1.69	0.15097
63	11.7	5.4	19.6	6.5	1.72	0.14570
66	12.2	8.7	20.6	5.7	1.87	0.12060
67	10.7	8.0	20.3	3.8	2.66	0.04497
68	9.3	6.0	21.8	3.6	4.36	0.00732
69	8.0	5.9	19.7	3.7	4.10	0.00936
70	8.7	5.2	21.8	3.1	4.93	0.00435
71	6.7	4.8	20.4	4.2	4.62	0.00572
72	3.6	3.3	17.5	5.2	5.36	0.00305
73	1.9	1.3	17.2	2.7	12.36	0.00006
74	2.7	1.6	19.6	4.4	8.61	0.00035
75	2.2	1.4	19.0	3.5	10.40	0.00014
76	1.7	0.5	18.9	5.0	8.37	0.00040
77	3.9	1.7	18.6	6.1	5.55	0.00262
78	4.3	3.4	18.8	4.2	4.88	0.00454

between the sensor locations with and those without insects in grain samples.

The number of times that acoustical sensors detected insects was correlated with the number of insects in grain samples over the range of 0.5–7.5 insects/kg grain (Fig. 2). Acoustical detection increased by one each time insect density increased by 0.305 insects/kg grain and the intercept of the regression equation was not significantly different from zero (p=0.96). The correlation (r^2=0.53) between acoustical detection and insect density will enable us to estimate insect density with the automated insect monitoring system. The confidence intervals indicate that insect density can generally be estimated within plus or minus one or two insects.

In four bins, the number of sensor locations at which insects were found ranged from 5 to 15 of the 56 sensor locations at which grain samples were taken. Acoustical sensors at these locations should provide the most effective insect monitoring in farm bins.

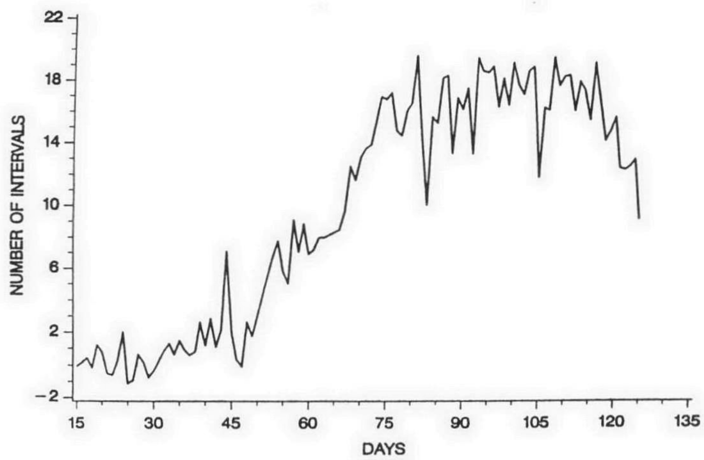

Fig. 1. Increase during the wheat storage period in the number of time intervals in which insects sounds are detected. The number of intervals with insect sounds is calculated by subtracting the number of intervals without sounds at locations where insects are present in grain samples from the number of intervals without sounds at locations where insects are absent from grain samples.

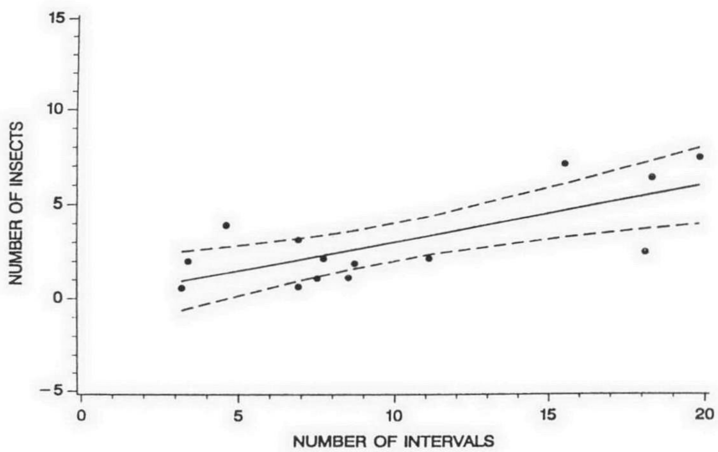

Fig. 2. Correlation between the number of insects (y) and the number of time intervals (x) in which insect sounds are detected where $y=0.305x-0.048$ with $r^2=0.53$. The dashed lines show the 95% confidence limits.

Discussion

The automatic monitoring system for stored-grain insects which estimates insect densities from the number of times that insect sounds are detected will reduce the labour required for insect monitoring and will improve pest management by providing more accurate and up-to-date information about insect infestations. Automation is needed because large numbers of samples are generally needed to detect stored-grain insects (Hagstrum and Flinn 1992). The lower the insect density the larger the number of samples needed to be 95% confident of detection. With standard sampling procedure, only one sample per 27 t of grain is needed with a mean insect density of 6 insects/kg grain but >100 samples are needed with a density of 0.02 insects/kg grain. Because insects have a high population growth rate, in addition to sampling thoroughly, it is also necessary to sample frequently to be sure that infestations are discovered before insect populations reach unacceptable levels (Hagstrum and Flinn 1990).

Although the automated system was tested on farms to make scaling up from laboratory studies with 0.135 t lots of wheat more practical, it is more likely to be used at elevators. With the automated system, a computer in the main office could provide a list of bins that will need insect control. Insect population growth models can be used to forecast which bins will need insect control in one, two or three months (Hagstrum and Flinn 1990). This information could be useful in deciding which grain to sell first or in making sure that grain with different insect infestation levels is not combined to fill an order. By networking computers, we could follow a lot of grain as it moved through the marketing system and control insects at the most appropriate time.

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