Early Detection of Insects in Stored Wheat Using Sticky Traps in Bin Headspace and Prediction of Infestation Level

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ABSTRACT Insect populations in 14 bins of newly harvested wheat on eight farms in Kansas were monitored with sticky traps in the bin headspace and with grain samples. Sticky trap catches during the first 3 wk of storage were used to provide an estimate of the species and densities of insects that were present in the headspace. Grain samples were taken every 2 wk during the first 3 mo of storage to provide an estimate of population growth under the grain temperature and moisture conditions in the bins. The sticky traps correctly predicted whether lesser grain borer, *Rhyzopertha dominica* (F.), and rusty grain beetle, *Cryptolestes ferrugineus* (Stephens), would be found in the grain samples in 85.8 and 78.6% of the bins, respectively. Traps were less reliable for foreign grain beetle, *Ahasverus advena* (Waltl), and hairy fungus beetle, *Typhaea stercorea* (L.), with correct predictions in 57.1 and 42.9% of bins, respectively. Indianmeal moth, *Plodia interpunctella* (Hübner), was found in both traps and grain samples in only one bin and red flour beetle, *Tribolium castaneum* (Herbst), and sawtoothed grain beetle, *Oryzaephilus surinamensis* (L.), were not found in both traps and grain samples in any of the bins. The traps in the center of the bin caught 4.7–14.2 times more beetles than those on the bin walls, but only 1.3 times more *P. interpunctella* adults. The total numbers of *C. ferrugineus* adults in the grain samples could be predicted better from the product of mean grain temperature times maximum grain moisture than from sticky trap catch.

KEY WORDS stored-product, trapping, sampling

MONITORING TRAPS HAVE been used extensively in insect pest management programs. Ideally, insects are detected early and predictive models are used to forecast when pest control will be needed. Insects that infest stored wheat have been shown to come from a number of sources. Insects that are commonly found in grain residues left in harvesting equipment (Sinclair & White 1980) or empty grain storage bins (Barker & Smith 1987) can infest newly harvested wheat. However, these insects are generally removed by cleaning the equipment, and other infested grain is probably the most significant source of insects. Large numbers of insects have been trapped in the vicinity of farm bins (Schwitzgebel & Walkden 1944, Dowdy & McGaughey 1994) and near elevators (Fields et al. 1993), and small numbers have been trapped at some distance from farms in farming regions (Sinclair & Alder 1984). Insects enter farm bins (Schwitzgebel & Walkden 1944) and flat storages (Barrer 1983) and move down into the grain mass to various depths resulting in a logarithmic decrease in insect density from the top to bottom (Hagstrum 1989). However, it may be possible to use headspace trap catches of insects before they enter the grain as an indicator of the species and numbers of insects that are present.

We determined whether sticky trap catches in the bin headspace during the first 3 wk of storage can be used to predict if stored wheat will become infested during the first 3 mo of storage. For the most common species, rusty grain beetle, *Cryptolestes ferrugineus* (Stephens), we also determined whether the severity of infestation could be predicted.

Materials and Methods

Insect populations in 14 grain bins containing newly harvested wheat on eight farms in Kansas were monitored using sticky traps and grain samples. Seven, two, and five bins were sampled during 1986, 1987, and 1992, respectively. Wing-type sticky traps (Scentry, Billings, MT) were used to provide an estimate of the species and densities of insects that were present in the headspace. Grain samples were taken to provide an estimate of population growth under the grain temperature and moisture conditions in a bin.

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Table 1. Percentage of each species captured with both, neither, or one type of sample

Species	Location	% Trap only	% Grain only	% Both samples	% Neither sample	% Correct[a]
P. interpunctella	All	92.9	0	7.1	0	7.1
C. ferrugineus	All	21.4	0	78.6	0	78.6
A. advena	All	42.9	0	57.1	0	57.1
T. stercorea	All	42.9	14.3	42.9	0	42.9
R. dominica	Center	7.1	7.1	42.9	42.9	85.8
	Wall	14.3	35.7	0	50.0	50.0
T. castaneum	Center	14.3	35.7	0	50.0	50.0
	Wall	7.1	35.7	0	57.1	57.1
O. surinamensis	Center	28.6	28.6	0	42.9	42.9
	Wall	7.1	28.6	0	64.3	64.3

[a] Percentage of correct predictions equals the percentages of bins with insects in both samples and traps plus percentages of bins with insects in neither samples nor traps.

The cylindrical metal bins ranged from 41- to 82-t capacity. The roof of bins peaked in the center where there was a 60-cm diameter entry hole covered by a removable cap. There were spaces between the roof and side walls, and the roof and cap were large enough for insect entry. The traps hung inside the bins by placing the wire provided for hanging traps through these spaces. During each of the first 3 wk of storage, fresh sticky traps were placed at eight locations (i.e., in each of the four cardinal directions against the bin wall and under the center cap). The top cover of the traps was not used so that the sticky surface was fully open. The grain surface was leveled, and traps against the bin wall were 0.3–0.6 m from the grain surface and those in the center were 1.2–1.5 m from the grain surface.

Grain samples were taken every 2 wk during the first 3 mo of storage. Insect populations generally grow rapidly during this period before cooler fall temperatures reduce the rate of population growth. During 1986 and 1987, 2.9-kg samples were taken at three locations near the center and at three locations halfway between the center, and the bin wall as a vacuum probe (Cargill Probe-A-Vac, Minneapolis, MN) was pushed down 1 m into the grain. During 1992, 0.5-kg samples were taken at three locations near the center, and at four locations halfway between the center and the bin wall with a grain trier (Model 20-OH, Seedburo Equipment, Chicago, IL). The moisture content of wheat was determined for each grain sample (Model GAC II, Dickey–John, Auburn, IL), and grain temperature was determined at depths of 15, 45, and 75 cm below the surface in the center of bin and halfway between the center and the bin wall.

Means and standard deviations were calculated and *t*-tests were done using the statistical analysis system (SAS Institute 1985). The STEPWISE procedure was used to fit a regression equation that predicts the total numbers of insects found in grain samples as a function of total sticky trap catch, average grain temperature, maximum grain moisture, and the interactions among these variables. Before doing regression, the total number of insects found in grain samples during 1992 was multiplied by five to adjust for the difference in sampling rate between this year and the previous years.

Results

Headspace trap catches correctly predicted whether a beetle species would be found in grain samples in 42.9–85.8% of bins (Table 1). The results for traps in the center of the bin were the same as those for the traps against the bin wall for Indianmeal moth, *Plodia interpunctella* Hübner, *C. ferrugineus*, foreign grain beetle, *Ahasverus advena* (Waltl), and hairy fungus beetle, *Typhaea stercorea* (L.), but not for the other species. Adult *P. interpunctella* were often caught in traps but neither larvae nor adults of this species were generally found in grain samples because they remain on the grain surface and are not readily detected by sampling vertically with a grain trier.

The traps in the center of a bin caught 4.7–14.2 times more beetles than those on the bin wall (Table 2). Significantly more *C. ferrugineus*, *A.*

Table 2. Species differences in the average number of insects (mean ± SD) captured by traps in the bin center compared with those on the bin wall

Species	*n*	Center trap	Wall trap	*t*	*P*	Ratio
P. interpunctella	31	49.6 ± 80.7	37.1 ± 61.5	0.69	0.4951	1.3
C. ferrugineus	24	130.9 ± 151.1	27.9 ± 44.9	3.20	0.0035	4.7
A. advena	23	88.8 ± 87.7	6.3 ± 7.1	4.50	0.0002	14.2
T. stercorea	24	355.6 ± 425.0	37.4 ± 69.0	3.62	0.0014	9.5
R. dominica	4	200.3 ± 120.9	24.5 ± 17.6	2.88	0.0614	8.2

Table 3. Numbers of *Cryptolestes ferrugineus* adults in traps or grain samples and wheat conditions for 14 bins

Bin[a]	Mean % moisture	Maximum % moisture	Mean temp, °C	Total insects trapped	Total insects in grain samples	
					Observed	Predicted
A2	8.3	9.6	37.5	517	0	14
A3	9.5	11.1	34.0	175	7	22
A5	10.4	11.2	34.4	132	63	26
C1	10.8	11.4	28.7	8	0	−1
A1	10.0	11.5	38.1	127	62	51
G1	11.7	12.0	29.9	1,009	5	13
C2	11.4	12.1	32.0	25	110	27
B1	10.6	12.1	38.3	23	0	63
H1	12.1	12.5	27.4	439	0	6
D1	13.2	13.8	27.5	26	0	23
E1	12.8	13.5	28.9	1,061	5	28
F1	13.1	13.6	26.6	280	10	15
A4	11.2	14.8	34.3	121	102	84
B2	12.6	14.8	34.1	9	91	83

[a] Letters designate the eight farms and the numbers the one to five bins sampled on each farm. Bins A1, A2, A3, B1, B2, C1, and C2 were sampled during 1986. Bins A4 and A5 were sampled during 1987 and the remainder of the bins were sampled during 1992.

advena, and *T. stercorea* were captured in the center. This ratio could not be calculated for *T. castaneum* or *O. surinamensis*, because neither species was found in both the center traps and those against the bin wall in any of the bins. Only 1.3 times more *P. interpunctella* adults were caught in the center compared with the bin wall.

The total numbers of *C. ferrugineus* adults (y) in the grain samples could be predicted better from the product of average grain temperature times maximum grain moisture (x) ($r^2 = 0.40$, $P = 0.015$) than from trap catch ($r^2 = 0.17$, $P = 0.14$) (Table 3). The equation $y = 0.47x - 156.47$ provided the best fit for the data from 14 bins. The regression of observed number of adults against the predictions of this equation had a slope of one ($t < 0.001$, $P = 1.0$) and an intercept of zero ($t < 0.001$, $P = 1.0$). The product of average grain temperature times average grain moisture ($r^2 = 0.29$, $P = 0.045$) did not predict the total numbers of insects in grain samples as well as product of average grain temperature times maximum grain moisture.

Discussion

The sticky traps in the bin headspace correctly predicted whether *R. dominica* and *C. ferrugineus* would be found in the grain samples in 85.8 and 78.6% of the bins, respectively. Traps were less reliable as an indicator of the presence of other species in grain samples. All bins contained newly harvested wheat that should have been insect free (Hagstrum 1989), and trapping was discontinued before offspring from any insects infesting the newly harvested grain could become adults. The trapped insects were probably either present in the empty bins or entered the bins from the outside.

The possibility of using traps to predict the level of infestation in a bin was analyzed only for *C. ferrugineus* because lesser grain borer, *Rhyzopertha dominica* (F.), was present in only seven bins and the other species were not found in both traps and grain samples often enough to fit a seven-parameter model that initially included three parameters (trap catch, temperature, and grain moisture) and the three two-way and one three-way interactions among these parameters. The numbers of insects in grain samples are a measure of population growth rates. Insect population growth rates are influenced by grain temperature and moisture conditions (Hagstrum & Flinn 1990) and the total numbers of insects in grain samples can be predicted better from the product of average grain temperature and maximum grain moisture conditions in a bin than from trap catch. If the traps provide a reliable measure of the numbers of insects initiating an infestation, this may indicate that grain temperature and moisture are more important in determining infestation level in a bin than the number of insects initiating the infestation. The tendency for maximum grain moisture to provide a better prediction of insect numbers in grain samples than average grain moisture probably indicates that insects can take advantage of the regions of the bin with highest moistures. Adult *C. ferrugineus* are more likely to leave low moisture grain than high moisture grain and are, thus, likely to concentrate in grain with higher moisture content (Watters 1969).

Trap catches indicated that beetle activity tended to be 4.7–14.2 times higher in the center of the bin than near the bin wall. These differences in trap catch between locations might also indicate that more insects entered the bin at the peak than at the eaves or that insects entering at the eaves walked or flew up the roof to the center. Attraction of insects to wheat odor could explain these differences if the rising of warm air in the headspace carries wheat odor out of the bin

at the peak. The similarity in the numbers of *P. interpunctella* adults caught in the center traps to the numbers caught in the traps on the bin wall suggests that moths may be more uniformly distributed than beetles. A more uniform distribution could result from moths diapausing in the bin as larvae (Bell 1982) and being carried over in a bin from year to year rather than entering from outside.

Headspace trapping during the first 3 wk of storage can provide farmers with a fairly reliable indication of whether *C. ferrugineus* or *R. dominica* are present but cannot forecast whether insect populations will reach damaging levels. This can probably be explained by populations reaching damaging levels when small numbers of insects enter a bin if conditions are right for rapid population growth but not reaching damaging levels when large numbers of insects enter a bin if conditions are not right for rapid population growth. Because of the severity of the damage caused by *R. dominica*, the use of headspace traps to determine whether this species is present may be worthwhile. If *R. dominica* is present, farmers will need to monitor grain more closely and they may want to sell grain sooner than they would if this species was not present.

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References Cited

Barker, P. S. & L. B. Smith. 1987. Spatial distribution of insect species in granary residues in the prairie provinces. Can. Entomol. 119: 1123–1130.

Barrer, P. M. 1983. A field demonstration of odour-based, host-food finding behaviour in several species of stored grain insects. J. Stored Prod. Res. 19: 105–110.

Bell, C. H. 1982. Observations on the intensity of diapause and cold tolerance in larvae from twelve populations and two reciprocal crosses of the Indian meal moth, *Plodia interpunctella*. Physiol. Entomol. 7: 371–377.

Dowdy, A. K. & W. H. McGaughey. 1994. Seasonal activity of stored-product insects in and around farm-stored wheat. J. Econ. Entomol. (in press).

Fields, P. G., J. Van Loon, M. G. Dolinski, J. L. Harris, & W. E. Burkholder. 1993. The distribution of *Rhyzopertha dominica* (F.) in Western Canada. Can. Entomol. 125: 317–328.

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. & P. W. Flinn. 1990. Simulations comparing insect species differences in response to wheat storage conditions and management practices. J. Econ. Entomol. 83: 2469–2475.

SAS Institute. 1985. SAS user's guide: statistics. SAS Institute, Cary, NC.

Schwitzgebel, R. B. & H. H. Walkden. 1944. Summer infestation of farm-stored grain by migrating insects. J. Econ. Entomol. 37: 21–24.

Sinclair, E. R. & J. Alder. 1984. Migration of stored-grain insect pests from a small wheat bulk. Aust. J. Exp. Agric. Anim. Husb. 24: 260–266.

Sinclair, E. R. & G. G. White. 1980. Stored products insect pests in combine harvesters on the Darling Downs. Queensl. J. Agric. Anim. Sci. 37: 93–99.

Watters, F. L. 1969. The locomotor activity of *Cryptolestes ferrugineus* (Stephens) (Coleoptera: Cucujidae) in wheat. Can. J. Zool. 47: 1177–1182.

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