Survey of Insect Pests in Shelled Corn Stored On-Farm in Kentucky[1]

John D. Sedlacek, Paul A. Weston, Bryan D. Price and Patti L. Rattlingourd

Community Research Service, Kentucky State University, Frankfort, KY 40601 USA

J. Entomol. Sci. 33(2):171-179 (April 1998)

Abstract Shelled corn stored in metal bins was sampled for insects on farms in the three westernmost crop reporting districts of Kentucky during 1989 and 1990 to identify pest insects present, determine the relative abundance of insect pests, and determine their geographic distributions. Thirty-six species or species groups were found in this survey. The most abundant insects were maize weevil, *Sitophilus zeamais* Motschulsky; Angoumois grain moth, *Sitotroga cerealella* (Olivier); flat grain, rusty grain, and flour mill beetles, *Cryptolestes* spp.; sawtoothed grain beetle, *Oryzaephilus surinamensis* (L.); foreign grain beetle, *Ahasverus advena* (Waltl); red and confused flour beetles, *Tribolium* spp.; and hairy fungus beetle, *Typhaea stercorea* (L.). Greater densities and numbers of species were caught later during the storage season and greater numbers were captured from the center versus edges of bins. The unexpectedly high abundance and widespread distribution of maize weevil and Angoumois grain moth suggests that greater care needs to be taken to manage these pests because of direct feeding damage and the resulting increased susceptibility of grain to secondary insect pests (e.g., *Cryptolestes* spp., sawtoothed grain beetle, *Tribolium* spp., foreign grain beetle, and hairy fungus beetle, which were commonly found) and fungi.

Key Words Insecta, stored corn, survey.

Kentucky produces and stores a substantial quantity of corn, storing over 98 million m^3 on the farm in 1995 (Kentucky Agricultural Statistics 1996). However, little is known of the insect, mite, and fungal species complexes present in shelled corn in on-farm metal storage facilities in Kentucky (Barney et al. 1989, Sedlacek et al. 1992). According to a questionnaire survey conducted in Kentucky, stored-corn losses due to insects can be considerable because grain is typically stored for up to 3 yr, and farmers rarely follow a particular bin-filling strategy (Barney et al. 1989). Further, approximately 18, 36, and 28% of farmers never use aeration, sanitation, or insecticide treatments, respectively, to control insect problems in their storage facilities (Barney et al. 1989). Around 35% of the farmers storing corn 6 to 12 mo are not sure they have storage pests in their bins, and 40% are convinced they do not have pests in their bins. Incredibly, about 45% of the farmers storing corn up to 36 mo say they do not have any pest problems in their storage facilities. This is unlikely because increasing duration of storage increases the probability of grain infestation due to short- or long-range orientation or chance encounter by insect pests.

Four species of insects infesting stored-grain in Kentucky were anecdotally re-

[1]Received 04 March 1997; accepted for publication 02 September 1997.

ported to Barney et al. (1989). The lack of information concerning insect pests in on-farm stored corn prompted us to conduct a survey of insect pests in this commodity in the western half of Kentucky, where most of the corn is grown and stored in the state. The objectives of this study were to identify insect species present in on-farm stored corn, determine the relative abundance of insect pests in corn stored on-farm in galvanized bins, and determine the geographic distribution of these pests.

Materials and Methods

The three westernmost crop reporting districts in Kentucky were selected for sampling in this survey. During the 2-yr study, 249 samples in 134 bins were taken at 114 farms in 24 counties in the 3 districts (Fig. 1). As many farms as possible were sampled with no effort to standardize bin conditions (e.g., bin size, volume of grain per bin, duration of storage) in that the objective was to maximize detection of species and provide relative abundance and geographic distribution of species rather than to test associations between species and environmental factors or storage conditions. Thus, such variables as grain mass temperature, moisture content, and volume were not measured and varied among bins. Bin size ranged in capacity from 70.4 to 2,100 m^3, and corn was in storage from 6 to 30 mo.

A deep bin cup probe sampler was used to remove 0.3 liter of corn from 3 depths (i.e., top, middle, and bottom) in the grain mass at the center and near the inside ladder of bins to detect and estimate insect density in representative samples (Hagstrum 1994). No other locations in bins were sampled because of instability of the

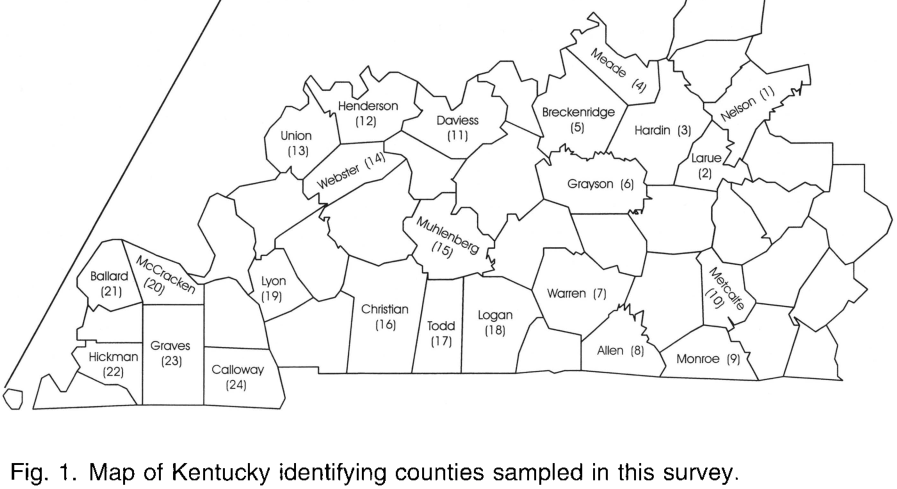

Fig. 1. Map of Kentucky identifying counties sampled in this survey.

grain mass in many of the bins visited. However, a small percentage of bins had grain mounded up only in the center or near the bin edge. Representative composite samples were taken in these situations as well using the cup sampler to sample top, middle, and bottom of each mound. The three samples taken from each location within a bin were combined and placed in a 0.9-liter jar with a ventilated lid. Thus, two composite samples (center and edge) were derived from most bins sampled. Sampling began in May in 1989 in the easternmost counties and progressed westward through July. We reasoned that following the opposite sampling progression and extending the sampling period might allow us to capture insects that would otherwise go undetected. Therefore, in 1990 sampling began in June in the westernmost counties and progressed eastward through September.

Samples were placed in a growth chamber at 15 ± 1°C until sifted. Each sample was sifted through 5-mm followed by 2-mm sieves within 1 wk after sampling to remove all living and dead insects. The samples were sifted again after incubating them at 27 ± 1°C and ⩾70% RH for 30 d to collect adult insects that had completed their larval and pupal development during the month-long period. Numbers presented are the sum of individuals from both siftings. Insects were preserved in 70% ethyl alcohol and subsequently identified to genus and species, when feasible, and enumerated.

Descriptive statistics as well as analysis of variance were used to analyze data (SAS 1988). Only bins for which both center and edge samples were taken had data analyzed for effect of location on number caught. These data were log-transformed (log (x + 1)) for analyses with untransformed values presented in tables.

Results and Discussion

Thirty-six species or species groups of stored-grain insect pests were identified in this survey (Table 1), as compared with 24 species or species groups found in a survey of 19 corn-producing states (Storey et al. 1983) and 29 species found in farm-stored corn in South Carolina (Horton 1982). The seven most abundant and widely distributed species or species groups in our survey were the maize weevil, *Sitophilus zeamais* Motschulsky; Angoumois grain moth, *Sitotroga cerealella* (Olivier); flat grain, rusty grain, and flour mill beetle,[2] *Cryptolestes* spp.; sawtoothed grain beetle, *Oryzaephilus surinamensis* (L.); foreign grain beetle, *Ahasverus advena* (Waltl); red and confused flour beetles, *Tribolium* spp.; and hairy fungus beetle, *Typhaea stercorea* (L.) (Table 2, Fig. 2). These species comprised 85.2 and 91.6% of the total number of insects captured during 1989 and 1990, respectively. Approximately 65 and 83% of the samples taken in 1989 and 1990, respectively, contained at least one insect. Twice as many species per bin were recovered in 1990 as in 1989 (3.7 ± 0.3 versus 1.8 ± 0.3, respectively).

The percentage of counties and bins infested, the average number of insects per sample, and the maximum number per sample were higher in 1990 than in 1989 for the seven most abundant species recovered (Table 2). This increase is probably explained because sampling began later and extended longer into the warm storage months in 1990 (June-September) than in 1989 (May-July). Another likely contributing

[2]Not an ESA approved common name.

Table 1. Species list and distribution of insect pests collected during a 1989 and 1990 survey of corn stored on-farm in metal bins in western Kentucky

Family	Species	Common name	Distribution by county*
Grain Weevils and Borers			
Curculionidae	*Sitophilus zeamais* Motschulsky	maize weevil	1-11, 13, 15-22
	Sitophilus oryzae (L.)	rice weevil	1-10, 15-19, 22
Anthribidae	*Araecerus fasciculatus* (DeGeer)	coffee bean weevil	1, 15, 16, 21, 22
Bostrichidae	*Rhyzopertha dominica* (F.)	lesser grain borer	18
Grain and Flour Moths			
Gelechiidae	*Sitotroga cerealella* (Olivier)	Angoumois grain moth	1-11, 13-22, 24
Pyralidae	*Plodia interpunctella* (Hübner)	Indianmeal moth	1-3, 8, 17, 19, 20
Grain and Flour Beetles			
Cucujidae	*Cryptolestes* spp.	flat & rusty grain, & flour mill beetles**	1-11, 13-24
	Oryzaephilus surinamensis (Fauvel)	sawtoothed grain beetle	1, 2, 5-11, 15, 17-22
	Ahasverus advena (Waltl)	foreign grain beetle	1-11, 13, 15-24
	Cathartus quadricolis (Guerin-Meneville)	squarenecked grain beetle	14, 19
Tenebrionidae	*Tribolium* spp.	red & confused flour beetles	1, 3-10, 15-17, 19, 22
	Palorus ratzeburgi (Wissman)	smalleyed flour beetle	1, 5, 7, 9, 10, 15, 18, 20, 22
	Palorus subdepressus (Wollaston)	depressed flour beetle	11, 13, 19
	Cynaeus angustus (LeConte)	larger black flour beetle	2, 5, 11, 15, 16, 19
	Gnatocerus maxillosus (F.)	slenderhorned flour beetle	4, 5, 8, 9, 19
	Alphitobius diaperinus (Panzer)	lesser meal worm	5, 6, 8, 9, 19
Trogositidae	*Tenebroides mauritanicus* (L.)	cadelle beetle	1, 18, 19

Table 1. Continued.

Family	Species	Common name	Distribution by county*
Miscellaneous Beetles			
Mycetophagidae	*Typhaea stercorea* (L.)	hairy fungus beetle	1-11, 13, 15-24
	Mycetophagus punctatus Say	a hairy fungus beetle†	17
Anobiidae	*Stegobium paniceum* (L.)	drugstore beetle	3, 17
Lathridiidae	*Cartodere constricta* (Gyllenhal)	plaster beetle	1-7, 15, 17, 18
	Corticaria pubescens (Gyllenhal)	a minute brown scavenger beetle†	1, 4, 6, 7, 17, 23
Cryptophagidae	*Cryptophagus varus* Woodroffe and Coombs	sigmoid fungus beetle	7-9, 19
Tenebrionidae	*Alphitophagus bifaciatus* (Say)	twobanded fungus beetle	1, 6, 15, 16, 21
Ptinidae	*Pseudeurostus hilleri* (Reitter)	a spider beetle†	9
Dermestidae	*Trogoderma variabile* Ballion	warehouse beetle	15
	Trogoderma inclusum LeConte	a dermestid beetle†	15
	Megotoma variegata (Horn)	a dermestid beetle†	15
Nitidulidae	*Carpophilus dimidiatus* (F.)	corn sap beetle	1, 4, 7, 9, 10, 15-23
	Carpophilus hemipterus (L.)	driedfruit beetle	15
	Nitidula bipunctata (L.)	a sap beetle†	17
Anthicidae	*Anthicus cervinus* La ferte-Senectere	an antlike flower beetle†	15
	Anthicus punctulatus LeConte	an antlike flower beetle†	6, 7
Rhizophagidae	*Monotoma picipes* Herbst	a rhizophagid beetle†	6
Cerylonidae	*Murmidius ovalis* (Beck)	a cerylonid beetle†	1, 5, 7, 9, 15, 18
Histeridae	*Gnathoncus nanus* (Scriba)	a hister beetle†	22

* County numbers correspond to county names as follows: 1-Nelson, 2-Larue, 3-Hardin, 4-Meade, 5-Breckinridge, 6-Grayson, 7-Warren, 8-Allen, 9-Monroe, 10-Metcalfe, 11-Daviess, 12-Henderson, 13-Union, 14-Webster, 15-Muhlenberg, 16-Christian, 17-Todd, 18-Logan, 19-Lyon, 20-McCracken, 21-Ballard, 22-Henderson, 23-Graves, and 24-Calloway. Numbers correspond to numbered counties on map (Figure 1).

** Flour mill beetle is not an ESA approved common name.

† Not an ESA approved common name.

Table 2. Incidence and mean (±SE) density per sample of the most widely distributed and abundant insects collected in on-farm stored corn in Western Kentucky during 1989 and 1990

	1989			1990		
Insect species	% counties infested	% bins infested	no./sample, (range)	% counties infested	% bins infested	no./sample, (range)
Sitophilus zeamais	53.3	31.3	4.9 ± 2.5 (0-187)	75.0	45.3	10.7 ± 3.3 (0-346)
Sitotroga cerealella	73.3	31.3	3.7 ± 2.1 (0-163)	83.3	47.7	6.4 ± 2.3 (0-321)
Cryptolestes spp.	73.3	43.8	5.8 ± 1.5 (0-68)	91.7	68.6	9.3 ± 3.2 (0-504)
Oryzaephilus surinamensis	46.7	22.9	2.8 ± 1.2 (0-82)	58.3	29.1	4.2 ± 1.2 (0-148)
Ahasverus advena	53.3	25.0	1.6 ± 0.6 (0-35)	91.7	66.3	11.5 ± 2.8 (0-342)
Tribolium spp.	53.3	20.8	0.7 ± 0.4 (0-29)	54.2	29.1	1.7 ± 0.9 (0-147)
Typhaea stercorea	60.0	29.2	1.1 ± 0.5 (0-36)	87.5	64.0	4.0 ± 0.9 (0-119)

factor is that sampling in 1990 began in the westernmost counties and moved eastward, opposite the sampling progression for 1989. The western counties in the state warm earlier than those in the eastern portion of the sampling area; thus, bins in the eastern counties may have revealed lower numbers of insects in 1989 because the grain was not yet warm enough to allow for appreciable insect movement or population growth when they were sampled (May-June).

Our findings differ somewhat from earlier surveys conducted in different states, although some similarities do exist. Horton (1982) reported maize weevil, *Tribolium* spp., *Cryptolestes* spp., sawtoothed grain beetle, and hairy fungus beetle to be the most abundant species in on-farm stored corn in South Carolina. Foreign grain beetle was found but was not considered as widely distributed or abundant. Ruppel (1977) surveyed extension personnel and grain industry specialists in Michigan and determined that there were 35 species of grain insects in that state. Maize weevil was not among those listed. Overall, maize weevil and Angoumois grain moth were detected in 40.3% and 41.8% of the bins we sampled, respectively. Interestingly, 66.3% of the farmers, responding to a questionnaire survey, who store grain on-farm in Kentucky thought they had a weevil problem and 16.3% thought they had an Angoumois grain moth problem (Barney et al. 1989). It must be emphasized that these were perceived pest problems which were not necessarily supported by inspection or accurate identifications. Therefore, it is likely that a substantial number of misidentifications of

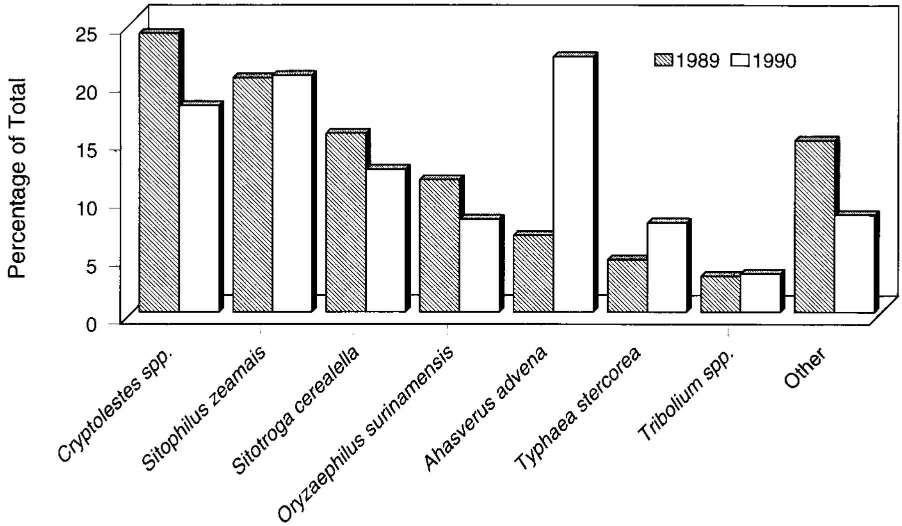

Fig. 2. Relative abundance of insects caught in on-farm stored corn during 1989 and 1990.

species by farmers occurs, undoubtedly affecting management decisions. Storey et al. (1983) reported that *Cryptolestes* spp., *Tribolium* spp., and foreign grain beetle were the most abundant and widely distributed insects present in a 19-state survey of stored corn and other grains. Of lesser importance were maize weevil, sawtoothed grain beetle, hairy fungus beetle, and Angoumois grain moth. Barak and Harein (1981) found *Cryptolestes* spp., foreign grain beetle, *Tribolium* spp., hairy fungus beetle, and sawtoothed grain beetle to be most common in Minnesota.

In 1989, we found significantly more *Cryptolestes* spp. ($F = 15.68$; df = 1, 73; $P = 0.0003$), *Tribolium* spp. ($F = 4.25$; df = 1, 73; $P = 0.0466$), hairy fungus beetles ($F = 5.22$; df = 1, 73; $P = 0.0283$), and total insects ($F = 12.11$; df = 1, 73; $P = 0.0013$) in the centers of grain masses than at the edges (Table 3). In 1990, we found significantly more maize weevils ($F = 20.97$; df = 1, 155; $P = 0.0001$), foreign grain beetles ($F = 9.49$, df = 1, 155; $P = 0.0029$), hairy fungus beetles ($F = 18.47$; df = 1, 155; $P = 0.0001$), and total insects ($F = 17.25$; df = 1, 155; $P = 0.0001$) in the center than at the edges of the grain masses (Table 3). Hagstrum et al. (1985) similarly found the densities for the five most abundant species and total insects to be higher in the center zone than edge zone in on-farm stored wheat. This was thought to be due to a higher concentration of fines located in the center of the grain mass.

Relative abundance and distribution of stored-corn insects within Kentucky provide an indication of importance of insect pests in the on-farm storage environment of this state. Data obtained in this survey indicate that corn stored in on-farm grain storage bins contains a broad spectrum of storage pest insects that frequently occur in large numbers. Several of these pests (e.g., maize weevil, Angoumois grain moth, *Cryptolestes* spp., sawtoothed grain beetle, foreign grain beetle, *Tribolium* spp., and hairy fungus beetle) occur throughout the sampling area (Table 1, Fig. 1). Conversely,

Table 3. Abundance of insects in center and edge of bins of corn

	1989			1990		
Species	Location	n	Mean ± SE	Location	n	Mean ± SE
Sitophilus zeamais	Center	37	6.3 ± 5.1a	Center	78	14.5 ± 5.3a
	Edge	37	0.9 ± 0.6a	Edge	78	7.4 ± 4.4b
Sitotroga cerealella	Center	37	7.1 ± 4.8a	Center	78	8.9 ± 4.6a
	Edge	37	0.8 ± 0.4a	Edge	78	4.7 ± 1.7a
Cryptolestes spp.	Center	37	9.4 ± 3.1a	Center	78	12.9 ± 6.5a
	Edge	37	2.5 ± 1.2b	Edge	78	6.6 ± 1.6a
Oryzaephilus surinamensis	Center	37	3.8 ± 2.6a	Center	78	5.0 ± 2.1a
	Edge	37	2.2 ± 1.1a	Edge	78	3.6 ± 1.3a
Ahasverus advena	Center	37	2.8 ± 1.3a	Center	78	16.8 ± 5.4a
	Edge	37	0.8 ± 0.4a	Edge	78	7.2 ± 2.2b
Tribolium spp.	Center	37	1.3 ± 0.8a	Center	78	3.2 ± 2.0a
	Edge	37	0.2 ± 0.1b	Edge	78	0.4 ± 0.1a
Typhaea stercorea	Center	37	2.0 ± 1.0a	Center	78	6.7 ± 1.8a
	Edge	37	0.3 ± 0.1b	Edge	78	1.6 ± 0.3b
Total Insects	Center	37	33.5 ± 9.6a	Center	78	74.9 ± 22.3a
	Edge	37	8.6 ± 2.3b	Edge	78	33.6 ± 8.3b

Means followed by different letters within a species and column are significantly different ($P \leq 0.05$; ANOVA [SAS 1988]).

lesser grain borer, squarenecked grain beetle, *Mycetophagus punctatus* Say, drugstore beetle, warehouse beetle, and several other species have very limited distributions in on-farm stored shelled corn. The greater number and variety of insects captured in 1990 was anticipated because sampling occurred for a greater portion of the storage year (i.e., through September) and approximately 80% more bins and 60% more counties were sampled than in 1989. Adults of the dominant insect species were widespread and much more abundant than anticipated. Large differences between our survey and previous surveys conducted in other states in terms of numbers of species detected (i.e., as with maize weevil and Angoumois grain moth) could be due to geographic differences in abundance or distribution of these species or possibly due to phenological differences in terms of emergence and/or abundance versus time of year sampled. Of particular interest was the distribution and abundance of the Angoumois grain moth, which was thought to have virtually disappeared in Kentucky and other corn-producing states as a result of increased use of combine harvest and picker sheller machinery and bulk storage technology (Storey et al. 1983). Based upon our survey, it is apparent that maize weevil and Angoumois grain moth can be major pests and should be treated as such along with the other dominant beetle species captured, particularly because of their ability to colonize intact grain. In addition, the widespread distribution, frequency of occurrence, and abundance of species preferring high-moisture conditions or that feed on fungi (e.g., hairy fungus beetle and foreign grain beetle) indicate that excessive moisture content of corn is a pervasive problem in Kentucky. Hairy fungus beetle appears to be a significant insect pest that warrants further investigation because it was relatively abundant and widespread in this survey and in several central Kentucky investigations examining short- and long-term on-farm corn storage (J.D.S., unpubl. data).

Results of our survey, as compared with previous surveys of stored grains in other states, suggest that major insect pests of stored corn found in other geographic areas, particularly the southeastern United States, are major pests in corn stored in Kentucky. Managers of on-farm stored corn and other grains should be cognizant that the time of year and geographic location in the state can determine whether or not insects will be detected and their relative abundance. For example, infestations of maize weevil may not be detected if corn stored in more central locations of the state is sampled in May through early July. Results of this investigation also suggest that the center of the shelled corn grain masses should be examined for insect infestation rather than the edges near bin doors. On-farm managers of stored corn should follow proper sanitation, aeration, and other integrated pest management recommendations to minimize losses or adverse effects resulting from the presence of high numbers of primary, secondary, and fungivorous insects. This is particularly important if the grain is going to remain in storage beyond the spring following binning, when warming of the grain can result in exponential growth of insect populations.

Acknowledgments

We thank the County Agriculture Agents and cooperating growers in Ballard, Calloway, Hickman, McCracken, Graves, Daviess, Lyon, Muhlenberg, Todd, Webster, Christian, Henderson, Logan, Union, Allen, Grayson, Hardin, Larue, Monroe, Nelson, Breckinridge, Meade, Metcalfe, and Warren counties. This research was supported by a USDA/CSRS grant to Kentucky State University under agreement No. KYX-10-87-06P.

References Cited

Barak, A. V. and P. K. Harein. 1981. Insect infestation of farm-stored shelled corn and wheat. J. Econ. Entomol. 74: 197-202.

Barney, R. J., D. E. Legg and J. D. Sedlacek. 1989. On-farm grain storage facilities and management practices. Bull. Entomol. Soc. Am. 35: 26-33.

Hagstrum, D. W. 1994. Field monitoring and prediction of stored-grain insect populations. Postharv. Pest News Inf. 5: 39-45.

Hagstrum, D. W., G. A. Milliken and M. S. Waddell. 1985. Insect distribution in bulk-stored wheat in relation to detection or estimation of abundance. Environ. Entomol. 14: 655-661.

Horton, P. M. 1982. Stored product insects collected from on-farm storage in South Carolina. J. Georgia Entomol. Soc. 17: 485-491.

Kentucky Agricultural Statistics, 1995-1996. Kentucky Agricultural Statistics Service, Louisville, KY. 144 pp.

Ruppel, R. F. 1977. An inventory of stored grain insects in Michigan. Great Lakes Entomol. 10: 243-244.

SAS Institute, Inc. 1988. SAS/STAT user's guide, release 6.04. SAS Institute, Cary, NC.

Sedlacek, J. D., P. A. Weston, B. D. Price and P. L. Rattlingourd. 1992. Insect fauna associated with on-farm stored corn in Kentucky. Intern. Symp. on Stored-Grain Ecosystems Extended Abstr. pp. 41-42.

Storey, C. L., D. B. Sauer and D. Walker. 1983. Insect populations in wheat, corn, and oats stored on the farm. J. Econ. Entomol. 76: 1323-1330.