Parasitoids Found in On-Farm Shelled Corn in Kentucky[1]

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ABSTRACT Shelled corn (*Zea mays* L.) in metal grain storage bins was sampled between June and September 1990 for insects on farms in the three westernmost crop reporting districts in Kentucky to identify, enumerate, and determine geographic distributions of pest and beneficial insects. A deep bin cup probe sampler was used to remove 0.3 liters of corn from three different depths in the center and at the edge of grain masses to detect and estimate insect density in representative composite samples. Each composite sample was sifted 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 development during the month-long period. Seven species or species complexes of pest insects were found representing 92% of the total number of pests captured. Eight species or species complexes of parasitoids were identified from the samples. *Anisopteromalus calandrae* (Howard) (Hymenoptera: Pteromalidae) was dominant. Other species present were *Pteromalus* sp. (Hymenotpera: Pteromalidae), *Cephalonomia waterstoni* Gahan (Hymenoptera: Bethylidae), *Cephalonomia tarsalis* (Ashmead) (Hymenoptera: Bethylidae), *Cephalonomia* spp. (Hymenoptera: Bethylidae), *Habrobracon hebetor* Say (Hymenoptera: Braconidae), *Theocolax elegans* (Westwood) (Hymenoptera: Pteromalidae), and a member of the family Eurytomidae. *Anisopteromalus calandrae* and *Pteromalus* sp. were found in greater numbers in the center versus the edge of grain masses. Results are discussed in the context of parasitoid importance in stored-grain ecosystems.

KEY WORDS *Anisopteromalus calandrae, Pteromalus* sp., *Cephalonomia tarsalis, Cephalonomia waterstoni*, Hymenoptera, Pteromalidae, Bethylidae, Braconidae, stored corn

On-farm storage of corn (maize, *Zea mays* L.) in Kentucky ranged from 60 to 85 million bu from 1993 to 1997 (Kentucky Agricultural Statistics 1996–1997). Despite the enormous value of this commodity and decreasing efficacy and availability of synthetic pesticides, little is known of the parasitic insect species present in shelled corn in on-farm metal storage facilities in Kentucky (Barney et al. 1989, Sedlacek et al. 1998).

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During a 1990 survey of pest species present in on-farm stored corn, 34 species or species complexes of insect pests were found in shelled corn (Sedlacek et al. 1998). Frequently, swarms of small wasps, 1–3 mm in length, were observed on the surface of the grain or flying in the headspace of the grain bins. These insects attack and kill several of the insect pest species that infest grain. However, information about the species of beneficials present in on-farm stored corn in Kentucky is not available. Thus, the objective of the research reported herein was to identify parasitoid species present in on-farm stored corn, determine their relative abundance in storage, and determine their geographic distributions in Kentucky.

Materials and Methods

Grain bins containing shelled corn in the three westernmost crop reporting districts of Kentucky, where most of the corn is grown and stored in the state, were selected for sampling insects. One hundred sixty-four samples in 85 bins were taken at 75 farms in 24 counties. The objective was to maximize detection of species and determine relative abundance and geographic distribution; therefore, as many farms as possible were sampled and no effort was made to standardize bin conditions (e.g., bin size, volume of grain per bin, duration of storage). Bin volume ranged from 1,000 to 60,000 bu; corn was in storage from 6 mo to 2.5 yr; and grain mass temperature, moisture content, and volume varied among bins.

A deep bin cup probe sampler was used to remove 0.3 liter of corn from three different depths (top, middle, and bottom) in the grain mass at the center and near the edge of bins to estimate insect density in representative samples (Hagstrum 1994). A small number 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 by using the cup sampler to sample from the top, middle, and bottom of each mound. The three samples taken from each location within a bin were combined to form a composite sample and placed in a 0.9-liter Mason jar with a ventilated lid. Thus, two composite samples (center and edge) were derived from most bins sampled. Sampling began in June in the westernmost counties and progressed eastward through September.

Samples were stored in an environmental growth chamber at $15 \pm 1^{o}C$ until sifted. Each sample was sifted through 5-mm followed by 2-mm sieves within 1 wk after sampling to remove living and dead parasitoids. The samples were sifted again after incubating them at $27 \pm 1^{o}C$ and $\geq 70\%$ RH for 30 d to collect adult parasitoids that had completed their development during the month-long period. Values presented represent the sum of individuals from both siftings. Insects were initially preserved in 70% EtOH. However, a reference collection was established by point mounting individual parasitoids and subsequently identifying them to genus, and species when feasible, by using the taxonomic key by Gordh (1991). Identification and enumeration of all species were based on individuals in the reference collection.

Descriptive statistics, Wilcoxon's sign rank test, and correlation and regression analyses were used to analyze data (SAS Institute 1988). Only bins for which both center and edge samples were taken had data analyzed for effect of location on number caught. Wilcoxon's sign rank test was used to determine differences in numbers of parasitoids caught between center and edge samples when transforming the data failed to homogenize variances. Correlation analysis was used to ascertain the relationship between number of parasitoids and pests caught among the three crop reporting districts and to test associations between pest and parasitoid species. Regression analysis was used to test associations between number of parasitoids and number of pests within bins.

Results and Discussion

Eight species or species complexes of parasitoids were found in this survey (Table 1). Five species were found in this commodity in a long-term study conducted by Arbogast & Mullen (1988) in southeastern Georgia and only one species by Horton (1982) in an extensive survey of stored corn in South Carolina. Finding fewer species could have been due to Arbogast & Mullen (1988) sampling a single, nontraditional storage structure (an aluminum shed lined with plywood and styrofoam) for the entire duration of their study. Similarly, Horton (1982) primarily sampled corn that had been in storage for a short period or that may have been treated with insecticides. In the current study, the most abundant and widely distributed species or species complexes of parasitoids were *Anisopteromalus calandrae* (Howard), *Pteromalus* sp., *Cephalonomia tarsalis* (Ashmead), and *Cephalonomia waterstoni* Gahan (Table 1; Fig. 1). Maize weevil, *Sitophilus zeamais* Motschulsky; Angoumois grain moth, *Sitotroga cerealella* (Olivier); flat, rusty, and flour mill beetles, *Cryptolestes* spp.; saw-toothed 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.), were the most abundant and widely distributed pest species encountered. They accounted for 92% of the total number of pest insects captured (Sedlacek et al. 1998).

Of those farmers providing information on duration of storage, corn was in storage from 6 mo to 2.5 yr. Interestingly, one of the most abundant and widely distributed pests was the maize weevil, and the majority of parasitoids found was *Anisopteromalus calandrae* (Table 1), the primary parasitoid of the maize weevil. Horton (1982) found the maize weevil to be the most abundant pest found in a survey of stored corn, yet *C. tarsalis* was the only parasitoid species reported. A survey of farmers in that study revealed that the sampled corn was in storage an average of 7.3 mo. Interestingly, *C. tarsalis* was usually found in empty grain bins containing corn residues that were in poor condition (Horton 1982). Arbogast & Mullen (1988) sampled one bulk of shelled corn for 8 yr and found maize weevil to be a dominant pest and *A. calandrae* to be a dominant parasitoid after 16 and 32 mo, respectively. In addition, abundance and frequency of occurrence of parasitoids were low in 9-mo-old corn stored on farm in western South Carolina (Arbogast & Throne 1997). Thus, it appears likely that duration of storage may be an important factor accounting for the abundance and even presence of beneficials.

Significantly more maize weevils, *Cryptolestes* spp., *Tribolium* spp., hairy fungus beetles, foreign grain beetles, and total beetles were found in the center than at the edges of grain masses in the bins sampled (Sedlacek et al. 1998).

Table 1. Incidence and average density per sample (± SE) of parasitoids caught in on-farm stored corn in western Kentucky during 1990.

Species	Counties present (%)	Bins present (%)	Avg. no./sample District 1 (range)	Avg. no./sample District 2 (range)	Avg. no./sample District 3 (range)
Anisopteromalus calandrae	41.7	17.2	0.28 ± 0.23 (0–7)	5.96 ± 4.50 (0–218)	11.28 ± 4.20 (0–205)
Pteromalus sp.	25	9.2	0.00 ± 0.00 (0)	1.40 ± 1.40 (0–73)	2.21 ± 1.34 (0–76)
Cephalonomia tarsalis	29.2	11.5	0.00 ± 0.00 (0)	0.21 ± 0.15 (0–7)	6.65 ± 0.22 (0–11)
Cephalonomia waterstoni	41.7	17.2	0.00 ± 0.00 (0)	0.08 ± 0.06 (0–3)	0.69 ±·0.19 (0–7)
Cephalonomia spp.	12.5	3.4	0.00 ± 0.00 (0)	0.04 ± 0.04 (0–2)	0.13 ± 0.09 (0–6)
Theocolax elegans	4.2	1.1	0.00 ± 0.00 (0)	0.00 ± 0 .00 (0)	0.47 ± 0.44 (0–32)
Habrobracon hebetor	8.3	2.3	0.00 ± 0.00 (0)	0.04 ± 0.03 (0–1)	0.01 ± 0.01 (0–1)
Eurytomidae	4.2	5.3	0.00 ± 0.00 (0)	0.00 ± 0.00 (0)	0.01 ± 0.01 (0–1)
unidentifiable [a]	45.8	5.8	0.09 ± 0.05 (0–1)	0.23 ± 0.16 (0–7)	1.17 ± 0.29 (0–12)

[a]Defined as broken pieces, body parts, or individuals damaged so as to make identification impossible.

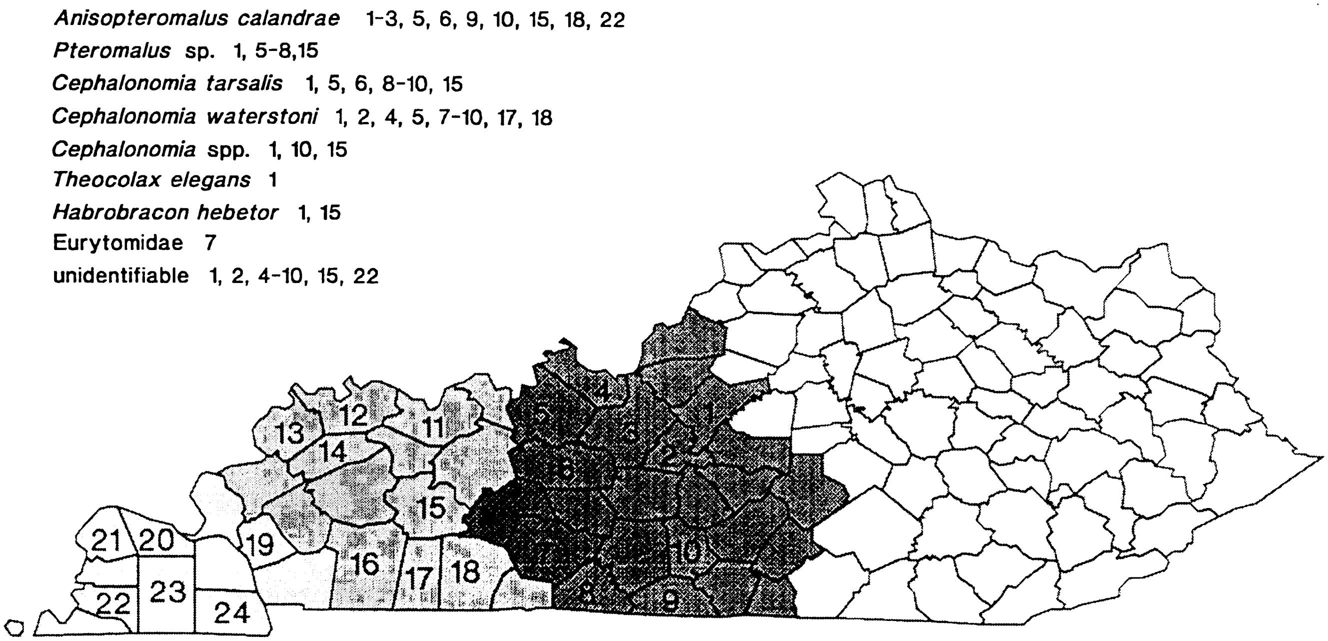

Fig 1. Map of Kentucky identifying counties in which shelled corn was sampled and showing distribution of parasitoids. County numbers correspond to county names as follows: 1-Nelson, 2-Larue, 3-Hardin, 4-Meade, 5-Breckinridge, 6-Grayson, 7-Warren, 8-Allen, 9-Monroe, 10-Metcalfe, 11-Daviess, 12-Henderson, 13-Union, 14-Webster, 15-Muhlenberg, 16-Christian, 17-Todd, 18-Logan, 19-Lyon, 20-McCracken, 21-Ballard, 22-Henderson, 23-Graves, 24-Calloway. Crop reporting districts 1–3 are denoted by progressively darker shading.

Hagstrum et al. (1985) also found higher densities of the most abundant insects in the center zone than edge zone in on-farm wheat. This was thought to be due to higher concentrations of fines located in the mass center. Similarly, more *A. calandrae* and *Pteromalus* sp. were recovered from centers than edges of shelled corn grain masses (Table 2). The reverse was found for *C. tarsalis* and *C. waterstoni,* but the magnitude of these differences was so small that realistically they have little biological significance. The spatial differences in number of parasitoids were largely explained by the differences in pest density; the regression between total pest insects and total parasitoids recovered from each sample was highly significant ($r^2 = 0.5972$, df = 154, $P < 0.0001$).

Table 2. Effect of sample location on number of parasitoids caught in center versus edge samples of corn stored on farm in grain bins.

Species	*n*	Mean ± SE Center	Mean ± SE Edge	Pr > |*S*|
Anisopteromalus calandrae	78	9.15 ± 4.19a	5.35 ± 2.60b	0.0001
Pteromalus sp.	78	2.06 ± 1.35a	0.91 ± 0.76b	0.0078
Cephalonomia tarsalis	78	0.35 ± 0.17b	0.40 ± 0.15a	0.0020
Cephalonomia waterstoni	78	0.28 ± 0.12b	0.41 ± 0.15a	0.0001
Cephalonomia spp.	78	0.03 ± 0.03a	0.11 ± 0.08a	0.1250
Theocolax elegans	78	0.03 ± 0.03a	0.41 ± 0.41a	1.0000
Habrobracon hebetor	78	0.03 ± 0.02a	0.01 ± 0.01a	1.0000
Eurytomidae	78	0.01 ± 0.01a	0.00 ± 0.00a	1.0000
unidentifiable	78	0.63 ± 0.24a	0.55 ± 0.15a	—

Means followed by different letters within a row are significantly different ($P < 0.05$; Wilcoxon's sign rank test [SAS Insitute1988]).

Importance of insect pests and parasitoids in on-farm shelled corn storage can be determined by examining relative abundance and distribution. Data obtained from this survey indicate a relatively broad spectrum of parasitoids associated with on-farm stored shelled corn. Two species of parasitoids were found in large numbers and four species were distributed widely (i.e., in crop reporting district 3) (Table 1). Parasitoids found in higher densities that were associated with pest species were *A. calandrae* with maize weevil ($r = 0.8493$, df = 155, $P < 0.0001$), *Pteromalus* sp. [probably *cerealellae* (Ashmead)] with Angoumois grain moth ($r = 0.8215$, df = 155, $P < 0.0001$), and *C. tarsalis* with sawtoothed grain beetle ($r = 0.6718$, df = 155, $P < 0.0001$). These findings correspond well with known host associations (Pederson 1992).

Dominant parasitoids were not as widely distributed in the three crop reporting districts of the western half of Kentucky as were their primary hosts. However, the density of parasitoids was higher than we anticipated. For example, *A. calandrae*, *Pteromalus* sp., *C. tarsalis*, and *C. waterstoni* were found in 41.7, 25.0, 29.2, and 41.7% of the counties sampled, respectively. Their primary hosts, maize weevil, Angoumois grain moth, sawtoothed grain beetle, and *Cryptolestes* spp., were found in 75, 83.3, 58.3, and 91.7% of the counties sampled, respectively. The overall average number of pest insects and associated parasitoids caught per sample was as follows: maize weevil (10.7 per 0.9 liter), *A. calandrae* (6.9 per 0.9 liter), Angoumois grain moth (6.4 per 0.9 liter), *Pteromalus* sp. (1.4 per 0.9 liter), sawtoothed grain beetle (4.2 per 0.9 liter), *C. tarsalis* (0.4 per 0.9 liter), *Cryptolestes* spp. (9.3 per 0.9 liter), and *C. waterstoni* (0.3 per 0.9 liter). A greater number of parasitoid species and number of each species were caught in crop district 3 than in the other districts (Table 1). Differences among the crop districts could be due to presence or absence or abundance of prey, time of year sampled, or geographic differences in grain storage conditions. For example, infestations of maize weevil or parasitoids may not be detected if corn is sampled too early in the storage year because the grain has not yet warmed enough to permit significant insect development, movement, or population growth when sampled (Sedlacek et al. 1998). The greater number of parasitoids present in the eastern counties sampled is probably explained by thermal accumulation when sampling was initiated (June) in the westernmost counties and when it was terminated (September) in the easternmost counties. In Paducah (representing the westernmost counties sampled), 1,082 degree-days ($DD_{10°C}$) had accumulated by 1 June 1990 whereas in Bardstown (representing the easternmost counties sampled), 3,033 DD had accumulated by 1 September 1990. Geographic differences in grain storage practices and end use may be other contributing factors to parasitoid distribution and abundance. Crop reporting district 3 has a greater percentage of small farms, smaller or low-storage-capacity farms, corn cribs, farms maintaining livestock and, thus, farms feeding corn to livestock (Barney et al. 1989). Based on our observations, the condition of corn stored in crop district 3, especially on farms with livestock operations, was poorer than that in districts 1 and 2, where corn was more likely destined for sale at a country elevator or kept in federal grain reserve programs.

The relatively narrow host specificity of the parasitoid species caught, combined with the relatively high percentage of counties and bins in which they were found and the high average number per sample, suggests that controlled field-scale experiments should be conducted on the potential of parasitoids for limiting pest population growth in bulk grain. Augmentation and inundation of the commodity with multiple, frequent releases of parasitoids would be appropriate for use in these farm ecosystems because rapid response by parasitoids to growing populations of pests is necessary to preserve the value of the commodity (Brower 1996). However, this would require stringent quality control for mass rearing and development of economical techniques for mass rearing, storage, transportation, and application of live natural enemies.

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