Efficacy of Malathion Against Coleopteran Populations in Newly-Harvested Versus Year-Old Stored Corn[1,2]

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J. Entomol. Sci. 33(3): 282-291 (July 1998)

Abstract The impact of malathion treatment and duration of storage prior to treatment on species composition and relative abundance of beetle pests was investigated in shelled corn in newly-constructed galvanized steel bins. Corn was sampled monthly for insects with plastic probe traps from January through September 1989. Red and confused flour beetles, *Tribolium* spp., hairy fungus beetle, *Typhaea stercorea* (L.), flat and rusty grain and flour mill beetles, *Cryptolestes* spp., and foreign grain beetle, *Ahasverus advena* (Waltl), were most abundant in traps, but plaster beetle, *Cartodere constricta* (Gyllenhal), minute brown fungus beetle, *Corticaria pubescens* (Gyllenhal), antlike flower beetle, *Anthicus* spp., and larger black flour beetle, *Cynaeus angustus* (LeConte), also were trapped. Greater numbers of the four major beetle species were trapped in older corn and in corn that was not treated with malathion and, depending on species, trap catch peaked in August or September. Information gathered during this investigation adds to our knowledge of insect infestation and insecticide application to on-farm stored corn and confirmed earlier reports that *T. stercorea* and *A. advena* potentially are pests of stored shelled corn. Thorough inspection and sampling should be conducted throughout the storage period, but especially after grain temperatures warm above 20°C.

Key Words Coleoptera, stored corn, malathion, trapping

Malathion has been labeled as a protectant for all major grains for over 35 years. It has proven effective against a wide variety of insect pests in stored corn (LaHue and Dicke 1976, Lahue 1977, Quinlan 1980) for varying lengths of storage (LaHue 1975, LaHue and Dicke 1976, Storey et al. 1982, Wintersteen and Foster 1992) and under a variety of storage conditions (Kadoum and LaHue 1979, Wintersteen and Foster 1992).

Insect populations were sampled in Georgia from a flat aluminum storage containing shelled corn during an 8-yr period to determine seasonal abundance and succession (Arbogast and Mullen 1988). While providing much useful information, their study was conducted in an atypical and unreplicated storage structure. Surveys to determine presence and relative abundance of insects in grain bins during one sampling period in a storage season were conducted in Kentucky (JDS, in press), South Carolina (Horton 1982), and Minnesota (Barak and Harein 1981). Storey et al. (1983) surveyed insects in stored corn in 19 states, predominantly in the north central

[1]Received 15 April 1997; accepted for publication 25 March 1998.

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

[3]Not an ESA approved common name

region of the United States. These studies, while beneficial for determining species composition and abundance, provide a frame of reference for presence or absence and abundance of insects during one sampling. Different probe trap designs were used to examine insects infesting stored corn in Minnesota (Subramanyam et al. 1988) and detection and mean trap catch (Subramanyam et al. 1993). To date, only Arbogast and Throne (1997) have examined seasonal distribution and abundance of insects in replicated typical on-farm grain bins containing stored corn in southwestern South Carolina. Seasonal trap catch of stored grain insects and efficacy of malathion as a grain protectant in uninfested versus previously infested shelled corn has not been investigated.

Thus, the objectives of this study were to (1) determine species composition and seasonal abundance of beetle pests in newly harvested and 1-year-old naturally-infested shelled corn stored on-farm, and (2) examine the effect of malathion treatment on insect populations in the newly-harvested and 1-year-old corn in Kentucky.

Materials and Methods

This research was conducted at the Kentucky State University Agricultural Research Farm, Franklin Co., KY, from November 1988 through September 1989. Insects were monitored in 12 previously unused 300-bu corrugated galvanized steel grain bins, each containing 150 bu of a locally-grown corn hybrid (DeKalb 689), varying in age (i.e., year of harvest) and malathion treatment. Newly-harvested corn was treated and binned on 11 November 1988, whereas year-old corn was harvested in November 1987, stored untreated for 1 yr in two 1,000-bu metal bins adjacent to the experimental bins, and treated and binned on 12 November 1988.

Half the corn from each year was treated with malathion 57 EC at the rate of 0.4 liters per 1000 bu (nominally 9.5 ppm). Insecticide was sprayed onto the corn as a water emulsion spray with a tee-jet nozzle at 30 psi as it flowed from a grain wagon into the hopper of a loading auger. The nozzle delivered approximately 28.7 liters of finished spray per 1000 bu. The remaining corn was sprayed with an equivalent amount of water to control for moisture effects. All corn in bins was then dried with aeration fans until moisture content near the bottom of the grain was approximately 9 to 10%.

The combination of harvest year (newly harvested vs. 1-yr-old corn) and malathion treatment (no malathion vs. malathion treatment) formed a 2 × 2 factorial. Three replicates were used for each treatment combination and were assigned in a completely randomized design to the 12 bins.

Grain masses were sampled for insects with probe traps made of Lexan® (Grain Guard, Verona, WI) in January, March, and monthly from May through September 1989. A representative sampling protocol was used (Hagstrum 1994). Traps were placed at three depths (0.3, 0.8, and 1.6 m) at two points along a north-south transect in each bin; each point was halfway between the center and the wall of the bin. On each sampling date, traps were withdrawn from the grain mass, the contents were emptied into glass vials that were then filled with 70% ethyl alcohol, and the traps were reinserted into the same location. This resulted in a trapping duration of 1 month. Insects from each sample were counted and identified to species or species group. *Tribolium* spp. and *Cryptolestes* spp. were identified only to genus due to the great number trapped and the need for rapid and accurate sight identifications. Since that time, red flour beetle, *Tribolium castaneum* (Herbst), the primary tenebrionid species

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present in bulk stored grain, and flour mill beetle[3], *Cryptolestes turcicus* (Grouvelle), were confirmed as the predominant species of these two genera in these grain bins. Grain temperature was measured during each sampling period at the center of each grain mass (0.8 m deep at bin center) using an aluminum temperature probe connected to a TM-2B temperature meter (Delmhorst Instrument Comp., Towaco, NJ). Grain moisture content was determined with a farm grain moisture tester (Insto Inc., Auburn, IL) using 1-liter of corn collected just beneath the grain surface at the center of each bin.

Data were analyzed with repeated measures analysis of variance (ANOVA) and least significance differences (LSD) in the GLM procedure of SAS (SAS Institute 1988). Main and interactive effects were age of grain, malathion treatment, and age of grain × malathion treatment, respectively. Linear regression was used to test the correlation between insects trapped and either temperature or moisture content. Data were transformed using $\log(x + 1)$ prior to analysis, but untransformed means are presented.

Results and Discussion

The predominant species or species groups trapped were red and confused flour beetles, *Tribolium* spp., and hairy fungus beetle, *Typhaea stercorea* (L.), followed by flat/rusty grain and flour mill beetles, *Cryptolestes* spp., and foreign grain beetle, *Ahasverus advena* (Waltl) (Table 1). Antlike flower beetles, *Anthicus* spp., plaster beetle, *Cartodere constricta* (Gyllenhal), minute brown scavenger beetle, *Corticaria pubescens* (Gyllenhal), and larger black flour beetle, *Cynaeus angustus* (LeConte), also were recovered, but in numbers so low that they are unlikely to be important in the overall infestation process. Therefore, the results presented focus on the four most abundant pests identified above.

The relative abundance of stored-grain beetle pests trapped varied with respect to

Table 1. Beetle pests found in on-farm stored corn totaled over grain age and malathion treatment in Franklin Co., KY

Family	Species	Common name	Total no. trapped
Tenebrionidae	*Tribolium* spp.	Red and confused flour beetles	14,682
Mycetophagidae	*Typhaea stercorea*	Hairy fungus beetle	9,632
Cucujidae	*Cryptolestes* spp.	Flat/rusty/flour mill beetles	1,754
Lathridiidae	*Ahasverus advena*	Foreign grain beetle	489
	Cartodere constricta	Plaster beetle	82
	Corticaria pubescens	Minute brown scavenger beetle	39
Anthicidae	*Anthicus* spp.	Antlike flower beetle	4
Tenebrionidae	*Cynaeus angustus*	Larger black flour beetle	4

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age of corn and malathion treatment (Table 2). In untreated grain (Fig. 1a and c), the most abundant species trapped was *Tribolium* spp., except in newly-harvested grain in August, which was predominated by *Typhaea stercorea* (Fig. 1a). Numbers of *T. stercorea* in traps declined in September in all treatments, but numbers of *Tribolium* spp. continued to increase (Fig. 1a-d). Numbers of *Tribolium* spp. collected during January in the 1-yr-old corn were relatively high. Because the number of insects caught in probe traps is dependent on insect activity as well as insect abundance, one might argue that lower trap catches were due to decreased activity during cooler winter temperatures and not to smaller population size. That this decline is attributable to a decline in population size and not merely reduced activity resulting from cooler grain temperatures is supported by the fact that numbers of all species trapped remained low until August, well after grain warming occurred; temperature increased from an overall average of 14.7° to 29.1°C during storage (Fig. 2a). During September, temperature was significantly higher in corn treated with malathion ($F = 21.87$; dF = 1,7; MS = 102.08, $P = 0.0023$), but temperature was not significantly correlated with trap catch of *Tribolium* spp. ($r^2 = 0.0196$, $P = 0.3705$), *Typhaea stercorea* ($r^2 = 0.1127$, $P = 0.2501$), *Cryptolestes* spp. ($r^2 = 0.0263$, $P = 0.9340$) or *A. advena* ($r^2 = 0.0947$, $P = 0.1690$). Thus, differences in trap catch among treatments cannot be attributed to differences in temperature.

Patterns of trap catch for *Cryptolestes* spp. were similar to those of *Tribolium* spp. More *Cryptolestes* spp. were trapped in 1-yr-old corn than in newly-harvested corn, and the numbers continued to increase up to the last sampling date (Fig. 1a-d). The abundance of *Cryptolestes* spp. in traps was lower during cooler months than that of *Tribolium* spp., but their numbers increased earlier in the storage season as grain temperature increased; more *Cryptolestes* were trapped in 1-yr-old untreated corn than *Tribolium* spp. in June and July (Fig. 1c). Although *A. advena* comprised a relatively minor fraction of the beetle population trapped, they exhibited population trends similar to those of *Typhaea stercorea,* reaching higher numbers in traps in newly-harvested corn than in 1-yr-old corn, and declining by September. The significant sampling date × age interaction for each of the four most abundant insect species (Table 2) was due to low numbers of individuals being trapped through July in all treatments and large differences in peak numbers trapped occurring in either August or September in grain differing with respect to age (Fig. 1).

It is widely believed that the most pronounced effect of increasing moisture content is on the composition and abundance of fungus feeding insects. *Ahasverus advena* and *T. stercorea* are generally thought to be grain pests of minor importance associated with other grain pests and found predominantly in moldy grain (Sinha 1961, Woodroffe 1962). However, these insects have been reported to feed on grain endosperm and germ (Kasolapova 1970, Popova 1971 [cited in Thomas and Clasper 1986, Tigar and Pinninger 1996]) and have been found in high numbers in grain with moisture content too low to support active fungal growth, including this study (Fig. 2b) (Chapman 1960). Moisture content increased from an overall average of 9.0 to 10.9% during the storage period (Fig. 2b). Interestingly, in August, moisture content was significantly higher in malathion-treated ($F = 6.98$; dF = 1,7; MS = 1.2033; $P = 0.0333$) and 1-yr-old corn ($F = 6.98$; dF = 1,7; MS = 1.2033; $P = 0.0333$) and during September in malathion-treated corn ($F = 24.82$; dF = 1,7; MS = 3.7408; $P = 0.0016$). However, moisture content was not significantly correlated with trap catch of *Tribolium* spp. ($r^2 = 0.0193$, $P = 0.3694$), *Typhaea stercorea* ($r^2 = 0.1127$, $P = 0.4862$), *Cryptolestes* spp. ($r^2 = 0.0263$, $P = 0.9380$), or *A. advena* ($r^2 = 0.0947$, $P = 0.3266$).

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Table 2. Repeated measures ANOVA for effect of age of grain and spray treatment

		Tribolium spp.		*Typhaea stercorea*		*Cryptolestes* spp.		*Ahasverus advena*	
Source	df	MS	*F*	MS	*F*	MS	*F*	MS	*F*
(A)ge	1	35.85	14.24†	10.87	9.19**	27.85	17.96‡	1.02	2.08
(S)pray	1	108.43	43.08‡	31.33	26.49‡	53.40	34.17‡	1.33	2.70
A × S	1	11.27	4.48*	0.73	0.62	22.20	14.31	0.83	1.68
Rep	1	29.92	11.90†	1.49	1.26	10.73	6.92*	0.05	1.10
Error 1	67	2.52		1.18		1.55		0.49	
(S)ample (D)ate	6	2.42	4.38‡	12.49	23.26‡	0.69	3.02**	0.48	2.01
SD × A	6	3.94	7.14‡	4.33	8.06‡	1.55	6.73‡	1.78	7.38‡
SD × S	6	21.87	39.63‡	8.79	16.38‡	6.26	27.28‡	0.76	3.14**
SD × A × S	6	2.39	4.32†	0.34	0.62	2.03	8.85‡	0.26	1.09
SD × Rep	6	1.84	3.34**	1.18	2.20*	0.76	3.32**	0.57	2.35*
Error 2	402	0.55		0.54		0.23		0.24	

* $P < 0.05$; ** $P < 0.01$; † $P < 0.001$; ‡ $P < 0.0001$.

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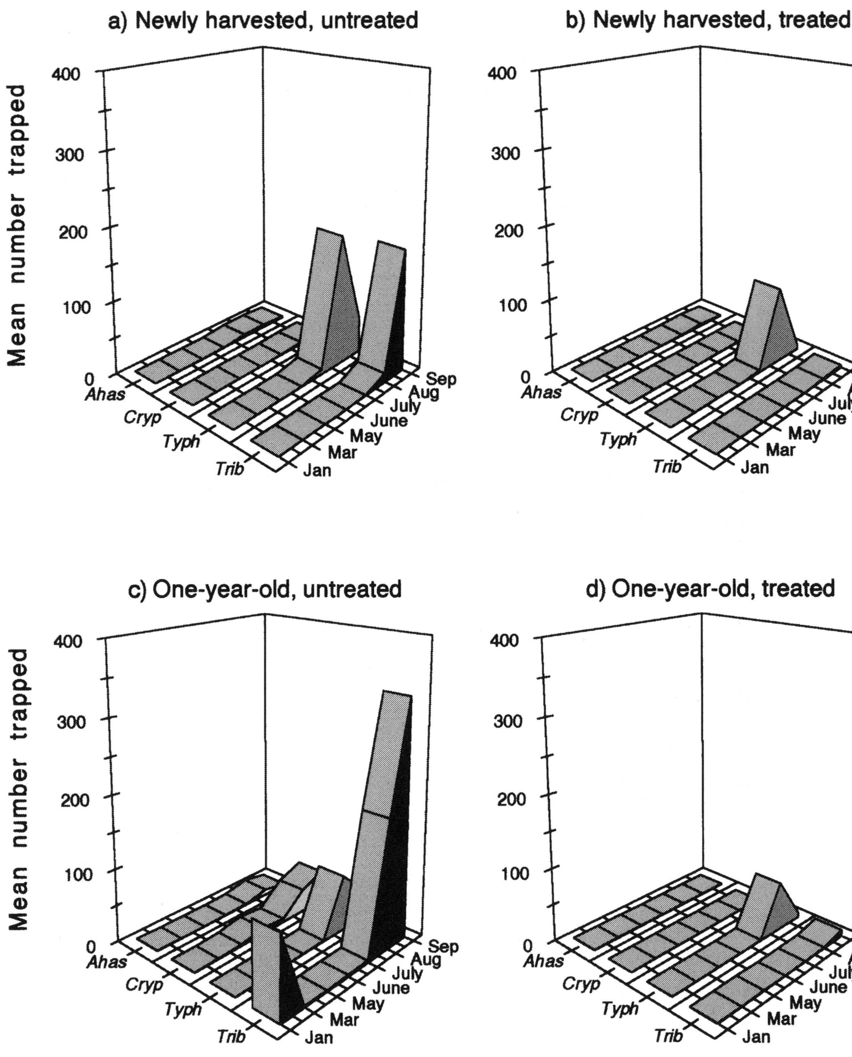

Fig. 1. Effect of grain age and malathion treatment on seasonal abundance of *Tribolium* spp. (Trib); *Typhaea stercorea* (Typh); *Cryptolestes* spp., (Cryp); and *Ahasverus advena,* (Ahas).

Malathion was extremely effective in suppressing populations of *Tribolium* spp., *Cryptolestes* spp., and *A. advena,* but was much less effective against *Typhaea stercorea* (Fig. 1b and d). The trends observed for *Tribolium* spp. and *Typhaea stercorea* in untreated corn were repeated here; numbers of *Tribolium* spp. trapped were higher on 1-yr-old, malathion treated corn; whereas, those of *Typhaea stercorea* were higher on newly-harvested, malathion-treated corn. In addition, the number of *Tribolium* spp. in traps increased through September, while those of *Typhaea ster-*

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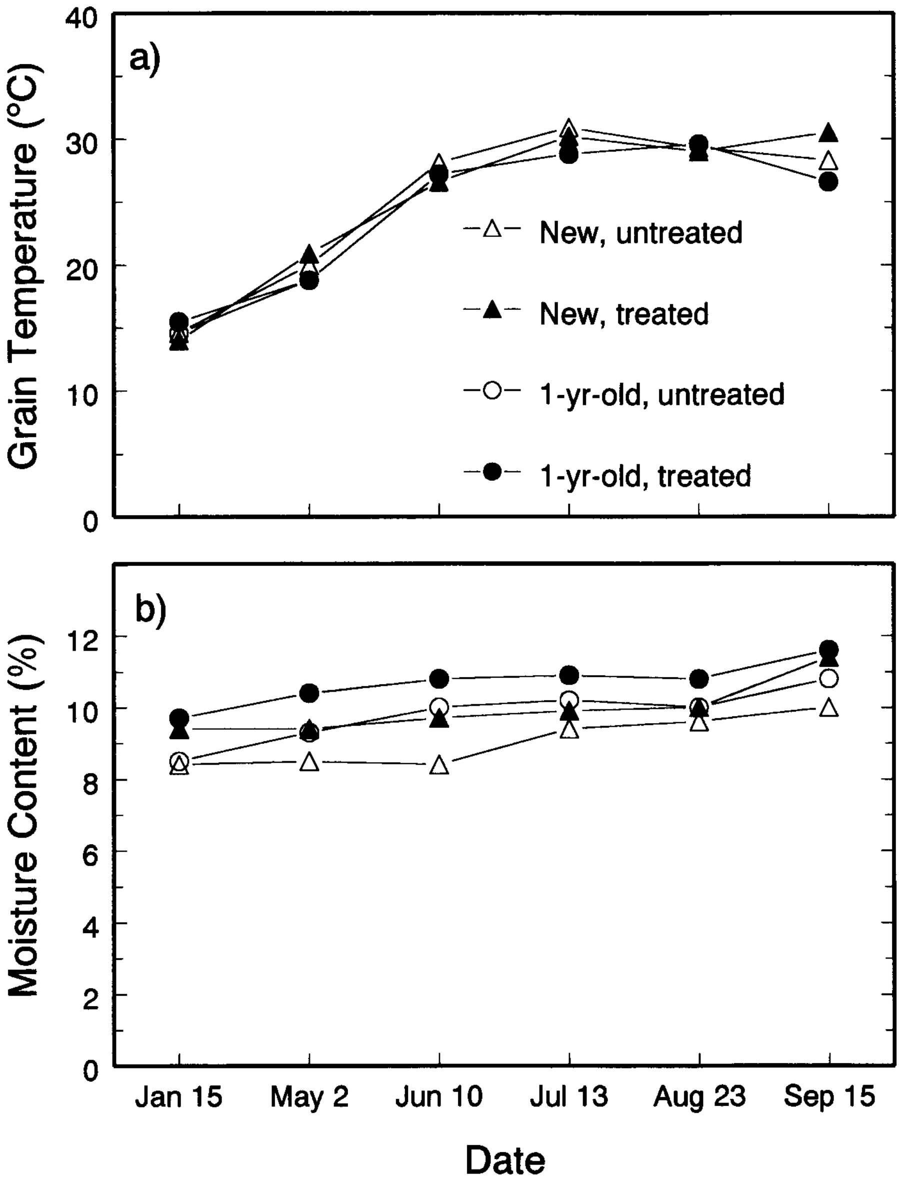

Fig. 2. Seasonal changes in a) grain temperature and b) grain moisture content.

corea peaked in August. Although malathion did not have as large an effect on the peak number of *T. stercorea* trapped, it did reduce the number of individuals trapped after the populations entered their seasonal decline in September (Fig. 1b and d versus 1a and c). There was a significant sampling date × spray interaction for each

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of the four most abundant species (Table 2), attributable to low numbers of each through July and peak trap catch in August (*T. stercorea* and *A. advena*) or September (*Tribolium* spp. and *Cryptolestes* spp.) and trap catch uniformly peaking in untreated corn.

Even though malathion effectively reduced beetle numbers in this study, there is abundant evidence indicating increased insect resistance to this insecticide (Beeman et al. 1982, Zettler 1982, Haliscak and Beeman 1983, Arthur et al. 1988, Halliday et al. 1988, Sumner et al. 1988, Subramanyam et al. 1989, Subramanyam and Harein 1990, Beeman and Wright 1990, Weinzierl and Porter 1990). Several species of resistant insects have supplanted susceptible wild-types in some areas due to overuse and perhaps inaccurate dosing and application of malathion (Zettler 1982, Haliscak and Beeman 1983, Arthur et al. 1988). Because of resistance issues, high cost of reregistration, and the relatively small stored-product market size, manufacturers have voluntarily withdrawn the label for use of malathion 57 EC on stored grains. However, the U.S. Environmental Protection Agency has not yet published a final cancellation for this insecticide, so current stocks may be used until depleted.

This investigation has yielded information on insect infestation and insecticide application that will be helpful in development of management practices for insect pests of on-farm stored corn. First, the temporal patterns of insect abundance reported here lead us to recommend more intensive sampling in on-farm stored corn after grain temperatures have reached at least 25°C (mid- to late June in Kentucky) but before insect populations reach high levels. Sampling grain before this time may lead a grain manager to think that an insect problem does not exist, when in fact grain temperatures might be too low for appreciable insect activity or because densities are too low for easy detection. Early detection and continued monitoring, however, are important components of pest management in stored grain. Sampling should continue after treatment, if any, in order to gauge success of the control treatment.

We propose including *Typhaea stercorea* in lists of pests of stored grains because this species was very abundant in our and subsequent (unpublished) investigations in these grain bins. The large numbers trapped are even more remarkable because the bins used for this study were newly constructed, and the only grain that had been stored in this vicinity was the corn harvested in 1987 and stored in the two 1,000-bu bins adjacent to the experimental bins. Although the pest potential of *T. stercorea* has not been fully evaluated, the mere presence of sufficient numbers of this insect in grain samples may result in grain devaluation. Thus, management practices for this species need to be developed as well.

In conclusion, there is a continuing need for investigations characterizing regional stored-grain (especially corn) ecosystems. Future studies should include detailed interactions of biotic and abiotic variables affecting the stored grain ecosystem, in particular pesticide impact on the storage ecosystem over longer storage periods.

Acknowledgment

This research was supported by a USDA-CSRS grant awarded to Kentucky State University under agreement KY.X-10-86-05P.

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