Indian Meal Moth[1] Infestation of Farm-Stored Wheat in Kansas[2]

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ABSTRACT

When 66 bins of farmed-stored wheat in central and southcentral Kansas were inspected 4 times during the 1975–76 storage season, 79% were found to be infested by *Plodia interpunctella* (Hübner) during the summer and fall after harvest. Wooden bins had a higher incidence of infestation, became infested earlier, and had more severe infestations than steel bins. Most of the infested bins had histories of frequent or severe infestations. Heavy infestations occurred in 24% of the bins, primarily in the southeastern portion of the study area where the avg precipitation was higher and where the more severe infestations in prior years were reported.

Biological control agents have been proposed to protect stored grain against almond moths, *Cadra cautella* (Walker), and Indian meal moths, *Plodia interpunctella* (Hübner) (McGaughey 1975, 1976), pests that have recently shown increasing levels of resistance to malathion and synergized pyrethrins (Zettler et al. 1973). The Indian meal moth is the species found more commonly in stored grain in the central and midwestern United States. In fact, it has been termed one of the most widespread and persistent pests of stored food products in the USA (Cotton 1961).

Unpublished reports[5,6] compiled at Kansas State University in 1952 and 1972 indicated that as many as 18% of farm bins of wheat in Kansas were infested with Indian meal moths when such storages were surveyed during Aug., Sept., or Oct. However, no recent data are available concerning the severity or frequency of infestations throughout the storage season. Therefore, before beginning large-scale control studies in wheat, we made a 1-yr study of the occurrence of Indian meal moth infestations in farm-stored wheat in central and southcentral Kansas. Our objectives were to determine whether infestations were present in a sizeable proportion of bins, when the infestations occurred, and the relationships between frequency of infestation and factors such as previous history, type of storage structure, susceptibility of the grain to infestation, and the presence of Indian meal moth granulosis virus.

METHODS AND MATERIALS.—A single bin of wheat at each of 58 farm bin sites and 2 bins each at 4 other sites in a 23-county area in central and southcentral Kansas (Fig. 1) were visited 4 times (3-mo intervals) beginning Aug. 1975. Only bins containing wheat harvested that year (June and July 1975) were examined. Most (48) were circular steel bins that ranged in capacity from 1000–3300 bu. These bins were filled from ¼ to full capacity. Sixteen of the bins were constructed of wood. They were either old wooden granaries or bins in barns or machinery sheds (8), wooden railway boxcars (3), or wooden bins in farm elevators (5) containing 150–2000 bu of wheat. The remaining 2 storages were a steel quonset building with wheat (ca. 1500 bu) piled on the floor (no cribs) and an old combine hopper (ca. 80 bu) under a shed. Evidence of Indian meal moth infestation was noted at each visit by visual examination of the grain surface and exposed areas of the bin walls and roof for webbing, larvae, pupae, and moths. Also, a 5 cm diam × 1.5 cm wide roll of corrugated paper was placed on the grain surface near the center of the bin at the 1st, 2nd, and 3rd visits to provide a site for larvae to pupate. These rolls of paper were removed at the next visit, returned to the laboratory, and examined for the presence of larvae, pupae, and exuviae. Because any level of infestation of Indian meal moth in stored grain can cause damage and thus warrant remedial action, we were interested in noting whether infestations, regardless of size, were present, and when they first appeared. However, infestations were so heavy in several bins that extensive webbing of the grain surface had occurred and damaged wheat kernels were obvious; in some others, populations were high enough that damage appeared imminent. The farmers were advised of the infestations, and several took action to control the insects.

At each visit, a sample of ca. 1000 g was drawn from the surface layer of wheat in the most accessible area of each bin. These samples were returned to the laboratory and held at −23°C for 14 days to eliminate any insect infestation that was present. Infestibility of the wheat was determined by placing three 150-g subsamples of each sample in 1-pt Mason jars, allowing the samples to equilibrate to 12–12.5% moisture content, infesting each jar with 33 Indian meal moth eggs from the laboratory colony, holding the jars at 25°C and 60% RH, and observing them for larval development and adult emergence. The remainder of each sample was held in a closed jar at 25°C and 60% RH until after the May 1976 sampling. Infested samples were examined weekly for the presence of frass, larvae (normal and granulosis-virus-infected), pupae, and adults. Adults that

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[5] Wilbur, D. A. 1952. Extent of insect infestation and moisture of wheat in farm storage: report of the survey for August 1952 (unpublished mimeographed report, 5 pp.); report of the survey for September 1952 (unpublished mimeographed report, 5 pp.).
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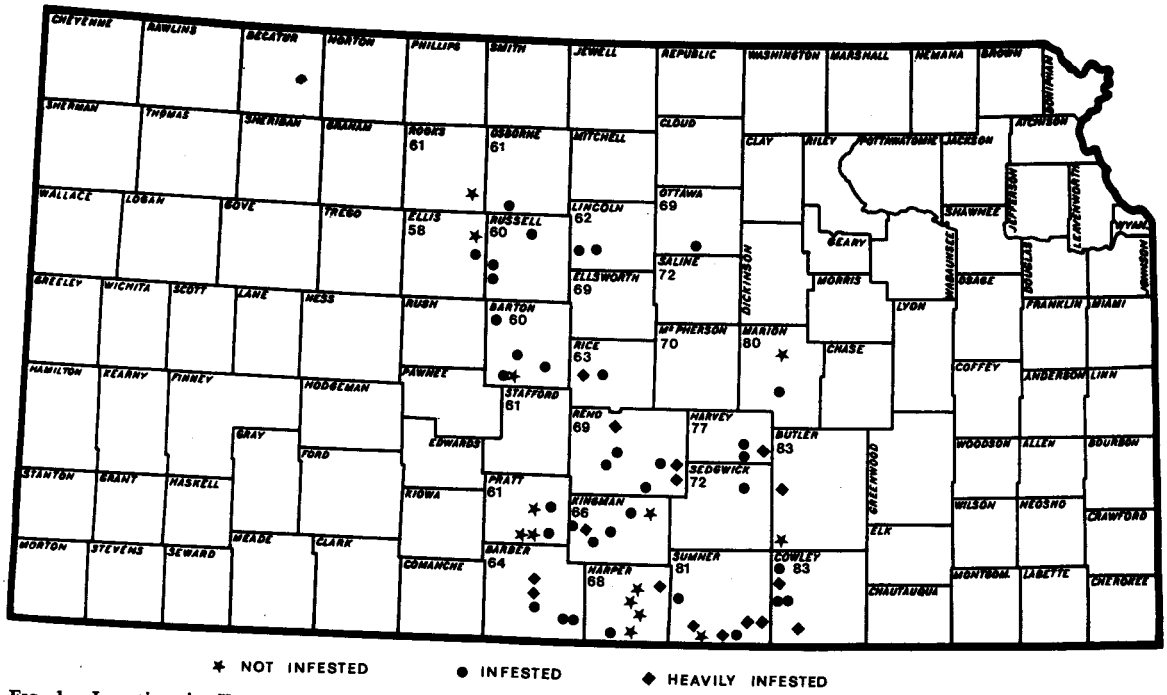

FIG. 1.—Location in Kansas of the infested and uninfested bins, and avg annual precipitation (cm) in each county.

emerged were counted. Samples in which insects failed to develop were evaluated a 2nd time in the same manner. Larvae infected with granulosis virus were identified by their chalky-white and flaccid appearance. These symptoms are characteristic of advanced stages of infection by this virus (Arnott and Smith 1968, Hunter 1970).

During the 4 visits to each farm, the incidence and severity of Indian meal moth infestations in prior years were established by interviewing the farmers. Then each bin was rated as follows: 0 = infestations never observed or considered to be of no consequence; 1 = infestations observed almost every year but almost never or only occasionally (once every 3–5 yr) present in damaging proportions; and 2 = infestations observed in damaging proportions almost every year. Also, bins were inspected for evidence of prior infestation such as webbing, larval and pupal exuviae, and dead larvae in cracks and crevices. This information was useful in many cases in confirming the assigned rating.

RESULTS AND DISCUSSION.—Table 1 summarizes the duration of the storage period and the incidence of infestations of the Indian meal moth. Of the 66 bins inspected initially (Aug. 1975), 50 still contained wheat 3 mo later (Nov. 1975), 40 after 6 mo (Feb. 1976), and 26 after 9 mo (May 1976). Through the 9-mo period, 52 (79%) of the bins became infested, ⅔ prior to the 1st inspection date. Of the 32 uninfested bins observed in Aug., 27 still contained wheat in Nov., and ⅔ of these (18) had become infested between Aug. and Nov. No new infestations were found during the Feb. and May visits, but evidence that larval activity had occurred during the winter months was noted in several infested bins. The amount of webbing increased in some bins and larvae, pupae, and exuviae were present in the rolls

Table 1.—Length of storage period and incidence of Indian meal moth infestation of 66 bins of farm-stored wheat in Kansas in 1975–76.

Bin type	Inspection date[a]	No. bins in test[b]	No. and (%) of bins infested[c]	No. of newly infested bins
All	Aug.	66	34 (52)	34
	Nov.	50	41 (82)	18
	Feb.	40	33 (83)	0
	May	26	22 (85)	0
Steel	Aug.	48	22 (46)	22
	Nov.	34	27 (79)	14
	Feb.	27	22 (81)	0
	May	19	15 (79)	0
Wood	Aug.	16	11 (69)	11
	Nov.	15	13 (87)	3
	Feb.	12	10 (83)	0
	May	7	7 (100)	0
Other[d]	Aug.	2	1 (50)	1
	Nov.	1	1 (100)	1
	Feb.	1	1 (100)	0
	May	0	—	—

[a] The wheat was harvested and placed in storage in June and July preceding the Aug. 1975 visit.
[b] The number of bins decreased through the year as grain was sold.
[c] Based upon bins remaining at indicated visit (not cumulative).
[d] Includes 1 steel quonset building and 1 converted combine hopper under a shed.

of corrugated paper exposed in the bins during that period.

The incidence of infestation in bins constructed of wood was slightly higher (14 of 16 bins) than that in cylindrical steel bins (36 of 48 bins). Additionally, the infestations in the wooden bins occurred earlier, 11 at the initial inspection and 3 at the 2nd inspection vs. 22 initially and 14 at the 2nd inspection in the steel bins. These differences between wood and steel bins were not entirely unexpected because the wood bins now in use are old. Many are multipurpose structures and their construction and condition make effective sanitation difficult. Harborage of reservoirs of infestation in such structures is almost inevitable.

The sale or other disposition of the stored wheat occurred at a uniform rate throughout the study period. A few farmers told us that they sold their wheat because of problems with Indian meal moth and other insect infestations, but the proportion of infested bins neither increased nor decreased after the 2nd inspection, and it remained at 82–85% for those bins that remained through the 3rd and 4th visits. Thus, despite the farmers' comments, the presence of Indian meal moths was not a widespread or consistent factor in the decision to dispose of the wheat. (The increase to 100% infestation among the wood bins at the 4th inspection (May) is probably a reflection of the small number of wood bins at that time and the slightly higher incidence of infestation in wood bins than in steel bins).

Table 2 summarizes the relationship between history of Indian meal moth infestations at the bin sites and type of storage structure, length of storage period, and infestation during the storage period. Of the 66 bins, 79% had a history of ca. yearly infestations, but they were almost never or only occasionally (every 3–5 yr) damaging. None of the wood bins had been completely free of infestation (rating of 0), while 6% of the steel bins were purported to have had no significant infestations. The percentages of wood and steel bins having histories of severe infestations (rating of 2) were the same.

When infestation history was compared with infestation during the study, the results were similar (Table 2). The majority of both the infested and not infested bins had experienced only occasional problems in previous years (79%). However, 21% of the uninfested bins had had no previous problems, and none had had severe problems. In contrast, 15% of the infested bins had a history of severe infestation, and only 1 bin (2%) had a history of no infestation. This tendency toward a history of more severe infestation for infested bins was consistent regardless of bin construction.

Heavy infestations were observed in 16 bins (24%) during the study (Table 2). These infestations were severe enough that extensive webbing had occurred and damaged kernels were obvious, or the insect population was high enough that severe damage appeared imminent. Of these 16 heavily infested bins, 6 were noted in Aug., 9 in Nov., and 1 in Feb. The one observed in Feb. had been previously noted as a light infestation in Nov. Heavy infestations developed in 10 of the 48 steel bins (21%), in 4 of the 16 wood bins (25%), and in both (100%) of the bins categorized as "other". Each of the heavily infested bins had a history of moderate to severe Indian meal moth infestation. None had a history free of troublesome infestation.

Table 2.—Relationship between history of previous Indian meal moth infestation in the test bins and type of bin, occurrence of infestation during the study, and length of storage period.

	Bins	% of bins with indicated history[a]			
		0	1	2	X[b]
Construction					
steel	48	6	79	13	2
wood	16	0	81	13	6
other[c]	2	0	100	0	0
all	66	6	79	12	3
Not infested	14	21	79	0	0
steel	12	25	75	0	0
wood	2	0	100	0	0
other[c]	0	—	—	—	—
Infested	52	2	79	15	4
steel	36	0	80	17	3
wood	14	0	79	14	7
other[c]	2	0	100	0	0
Heavy infestation	16	0	75	25	0
steel	10	0	80	20	0
wood	4	0	50	50	0
other[c]	2	0	100	0	0
Storage period[d]					
1–4 mo	16	6	76	6	12
4–7 mo	10	10	70	20	0
7–10 mo	14	0	93	7	0
>10 mo	26	4	81	15	0

[a] 0 = infestation never observed or considered to be of no consequence; 1 = infestations observed almost every year but almost never or only occasionally (once every 3–5 yr) in damaging proportions; 2 = infestations observed in damaging proportions almost every year.
[b] Infestation in prior years unknown.
[c] Includes 1 steel quonset building and 1 converted combine hopper under a shed.
[d] Bins were inspected in Aug., Nov., Feb., and May following harvest in June and July. Bins inspected in Aug., but from which the grain had been removed when visited in Nov., were presumed to have storage periods of 1–4 mo, etc.

The length of the storage period (as determined by early disposition of the wheat) did not appear to be related to prior experience with Indian meal moth infestations (Table 2).

Although the study area comprised less than 1/4 of the state (Fig. 1), avg annual precipitation (Anon. 1975) across that area ranged from 83 cm in the southeast to 58 cm in the northwest. All heavy infestations occurred in the southeastern 2/3 of the study area, and bin sites with histories of severe infestations also were concentrated there. These climatic differences may be responsible partially for differences in severity of infestations, but the incidence of infestation (regardless of severity) did not vary across the study area.

Treatment of the walls and floor of the grain bins

with residual chemical insecticides prior to filling or treatment of the grain as it was placed in the bin did not reduce the incidence of Indian meal moth infestation (80%) below the level that occurred when insecticide was not used (78%). Nevertheless, the treatments may have reduced the severity of some infestations since they were more often used in bins that were reported by the farmers to have had histories of rather severe and frequent infestations (75%) than in the less frequently infested bins (32%). Chemical insecticides used specifically for Indian meal moth control were usually applied after infestations were apparent, and when they were used conscientiously, seemed to be effective in reducing the insect populations. Additional conclusions regarding the efficacy of the treatments could not be drawn because the number of bins that received each treatment was small; several different insecticides, formulations, and combinations of treatments were used; there was wide variation in infestation levels at the time of application; and our inspections were too infrequent to allow us to differentiate between seasonal fluctuations in population and the results of insecticidal treatments.

Fourteen bins remained uninfested throughout the study. The samples of wheat from only 3 of these bins did not support an infestation introduced in the laboratory (confirmed by reevaluating the samples at the conclusion of the study). The farmers told us that the wheat in these 3 bins had been treated with a grain protectant. Thus, only 11 bins of laboratory-infestible and untreated (according to the farmers) wheat in this study of 66 bins remained free of infestation.

During laboratory evaluation of the wheat samples, symptoms of granulosis virus infection were observed among larvae in samples from 7 bins taken during the 2nd and subsequent visits. Once the virus was detected in a sample, it was observed in all subsequent samples from that bin (with one exception). All virus-infected bins were noted to be infested with Indian meal moth during the initial visit. The presence of granulosis virus in the samples was not related to severity of infestations in the bins before or during the study.

We conclude that Indian meal moth infestations are more frequent in stored wheat than has been generally assumed and that extensive damage may result in some years if remedial treatments are not used. Also, infestations begin during the warm months immediately following harvest and through the fall months in Kansas. The frequency and severity of infestations can be predicted by evaluating prior experiences at the bin site. Within the limited area of this study, rainfall could be related to the severity of infestations but not their frequency. Thus, effective preventive and control measures for the Indian meal moth are needed. The granulosis virus appeared too late to suppress early moth infestations, but it may provide benefits if storage is extended into a 2nd yr. The infrequent occurrence of the virus in this study, however, casts doubt upon the value of natural viral infection as an effective biological control for Indian meal moth infestations in stored grain.

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