364

Reprinted from the
JOURNAL OF ECONOMIC ENTOMOLOGY, VOL. 76, NO. 6, DECEMBER 1983

Insect Populations in Wheat, Corn, and Oats Stored on the Farm[1]

C. L. STOREY, D. B. SAUER, AND D. WALKER

U.S. Grain Marketing Research Laboratory, Agricultural Research Service, U.S. Department of Agriculture, Manhattan, Kansas 66502

J. Econ. Entomol. 76: 1323–1330 (1983)

ABSTRACT One or more live, stored-product insect species were found in 25.1% of the wheat, 56.4% of the oats, and 79.7% of the corn samples obtained from over 8,000 farm storages across 27 states. The average number of insects per 1,000 g in the infested samples was 26 for corn, 39 for oats, and 105 for wheat. Insects of the genus *Cryptolestes* were the predominant pests in wheat and corn, and *Oryzaephilus surinamenis* (L.) was the principal insect in oats. *Rhyzopertha dominica* (F.) was found throughout much of the grain-producing areas, including the northern states, but *Sitotroga cerealella* (Olivier) was only rarely detected in farm-stored grain. *Plodia interpunctella* (Hübner) occurred in 27.6% of the corn, but was only an infrequent pest in wheat and was not detected in oats. Insect species that prefer high moisture or feed on molds were found in 28.8% of the corn samples. The incidence of insects generally increased with increased grain moisture, and average test weights per bushel were lower in infested grain than in uninfested grain. The incidence of insects and the composition of insect populations within each commodity did not vary significantly with the length of time the grain had been in storage.

During the 1950s and 1960s, large inventories of grain were maintained in government-owned storage facilities, and the growth rate of on-farm storage declined. After phase-out of these structures in the early 1970s, the USDA offered low-interest loans for the purchase of grain storages to encourage producers to store their own grain. Producer storage programs authorized by the Food and Agriculture Act of 1977 (Public Law 9S-113, 91 STAT. 913 et seq.) permitted producers to store their grain under loan during periods of abundant supply, thus allowing them to retain control of their crops until it was to their economic advantage to release them into the market system. As a result of these programs, the on-farm capacity for grain storage has increased steadily during the past decade, from 4.6 billion bu (ca. 125.2 million metric tons) in 1970 to an estimated 11 billion bu (ca. 300 million metric tons) in 1979 (Anonymous 1979). Record amounts of grain are now being stored on farms during at least part of the marketing year. Grain stock position reports for 1 January 1982 show nearly two-thirds of the U.S. grain supply stored on the farm.[2]

The biological consequence of expanded farm storage of grain was discussed over 40 years ago by Cotton (1938) in connection with a farm storage program established under the Agricultural Adjustment Act of 1938, called the "Ever-Normal Granary Plan." Cotton noted that farm storage of grain often "results in infestation and serious losses from insect attack" which are "likely to be greater in periods of overproduction, since such years are correlated with periods of abundant moisture when the heavy (grain) carryover and high moisture content of the grain are always conducive to heavy insect damage." Surveys of farm storage conducted during the years after establishment of the storage plan characterized insect populations in wheat stored in the north-central states as consisting primarily of six species, flat grain beetle, *Cryptolestes pusillus* (Schönherr); lesser grain borer, *Rhyzopertha dominica* (F.); sawtoothed grain beetle, *Oryzaephilus surinamensis* (L.); red flour beetle, *Tribolium castaneum* (Herbst); rice weevil, *Sitophilus oryzae* (L.); and long-headed flour beetle, *Latheticus oryzae* Waterhouse (Cotton 1963). Insect pests found in shelled corn stored on farms consisted primarily of the flat grain beetle, sawtoothed grain beetle, red flour beetle, foreign grain beetle, *Ahasverus advena* (Waltl), hairy fungus beetle, *Typhaea stercorea* (L.), and the larger black flour beetle, *Cynaeus angustus* (Le conte), (Cotton 1963). Reports of heavy infestations were common. Winburn (1940) noted that 33% of the railcars of wheat passing through inspection points in the Kansas City market during the latter part of 1939 were graded weevily. He also reported heavy infestations in farm-stored wheat with numbers of insects ranging up to 205 per quart (ca. 1,000 g).

Recent surveys of farm stored grain have been limited to localized examinations within individual states. Farm-stored corn and wheat in Minnesota were sampled for insects during 1977, 1978, and 1980 (Barak and Harein 1981a,b). The most common species observed were *Cryptolestes spp.*; Indianmeal moth, *Plodia interpunctella* (Hübner); larger black flour beetle, red flour beetle, hairy fungus beetle, and sawtoothed grain beetle. Between 41.5 and 90% of the storages sampled during various time periods of the storage year contained live insects. Insects were identified as a major problem, and 17 different species were recorded in a 1979 survey of 23 farm bins in one county of Nebraska (Spitze 1980). Two-thirds of the bins examined in this survey were reported to have a "high enough insect population to warrant control." Eighty-six percent of the grain drawn from 196 bins of farm-stored grain in South Carolina in 1979 and 1980 was found infested with stored-grain insects (Horton 1982).

To obtain a broader national overview of insect infestation in grain stored on the farm, a cooperative study was developed with the USDA, Agricultural Stabiliza-

[1]Received for publication 8 June 1983; accepted 15 August 1983.
[2]Grain Market News, USDA, Agricultural Marketing Service, monthly issues.

Table 1. Incidence and density (number) of insects in wheat, corn, and oats stored from 1 to 4 years (1976–1979) on farms across 27 states examined during summer and fall 1980

Commodity and crop year	No. of samples	% Infested[a]	Density/ 1,000 g[b]
Wheat			
1976	1,320	24.2	157
1977	1,119	26.6	98
1978	785	24.5	63
1979	864	26.5	64
1980[c]	57	20.3	14
Corn			
1976	330	81.8	42
1977	745	79.6	11
1978	1,075	80.5	15
1979	766	77.9	14
Oats			
1976	32	65.6	73
1977	683	55.9	36
1978	178	55.6	81
1979	154	57.1	39

[a]Percentage of samples with one or more live insects.
[b]Average number for all species combined.
[c]Samples from grain placed under storage loan in 1980.

storages of wheat and corn does indicate that the risk of developing damaging insect populations may increase with longer storage periods.

The composition of insect populations detected within each of the three commodities did not vary significantly from one crop year to another. The insect species or groups of species that comprised over 90% of the total insect incidence in each commodity were detected in samples from each successive crop year. Furthermore, the comparatively minor variations in the frequency of occurrence of most individual species between each crop year did not indicate a consistent relationship between invasion of grain by a specific insect species and the length of time the grain had been in storage. Some fungus-feeding species did occur more frequently in newer corn from crop year 1979 than in older 1976 corn, but this relationship was due primarily to higher moisture levels in the newer corn. Older corn tended to dry somewhat with age, thereby repressing mold development and limiting the food source for these species.

Because the incidence, species composition, and density of insects varied significantly among the wheat, corn, and oat samples, results for each commodity are discussed separately.

Wheat

Wheat samples were obtained from 299 counties in 17 states, with most of the samples from 7 states (North Dakota, Montana, Minnesota, South Dakota, Nebraska, Kansas, and Colorado) (Table 2). Among these states, Minnesota wheat had the highest incidence of insects (42.9%), and Montana wheat the lowest (11.6%).

Cryptolestes spp. (flat and rusty grain beetles) were the predominant insects in wheat (Table 3), occurring in 13.8% of all samples at an average density of 45/1,000 g. They were found in 82% of the states and in 51% of the counties sampled. No consistent geographical pattern of distribution was evident between *Cryptolestes* spp. identified as *C. ferrugineus* (Stephens), rusty grain beetle, and those identified as *C. pusillus* (Schönherr), flat grain beetle.

O. surinamensis (L.) was the second most frequent insect found in wheat, occurring in 7.9% of all samples at an average density of 30 per 1,000 g. This species occurred in 76.5% of the states and in 40% of the counties sampled.

Only four other species or groups of species occurred in >1% of the total wheat samples: *Liposcellis* spp. (psocids), lesser grain borer, dermestid beetles, and *Tribolium* spp. (red and confused flour beetles). Of these species, lesser grain borers were the most widely distributed; they occurred in 65% of the states and in 17.1% of the counties sampled. Lesser grain borers were found in wheat samples from several states along the Canadian border and were particularly well distributed in Minnesota where they were detected in 27.6% of the counties sampled.

Other species found in wheat occurred in less than 1% of the samples. Among these insects, the *Sitophilus* spp. (rice, maize, and granary weevils) and *Plodia interpunctella* (Hübner) (Indianmeal moth) were the most widely distributed. *Sitophilus* spp. were found in 47% of the states and 7.7% of the counties, and Indianmeal moths were recorded in 35% of the states and 6% of the counties. No Indianmeal moths were found in wheat samples from the western states. Other species occurring in <1% of the samples were generally limited to only one to four samples from three or fewer states.

Corn

Corn samples were obtained from 391 counties in 19 states. Over 90% of the samples were obtained from 6

Table 3. Species, percent incidence, and average density (number) of insects in wheat, corn, and oats stored on the farm, examined during summer and fall 1980

Insect species	Wheat		Corn		Oats	
	% Infested	Density/ 1,000 g	% Infested	Density/ 1,000 g	% Infested	Density/ 1,000 g
Cryptolestes spp. (flat and rusty grain beetles)	13.8	45	57.7	18	16.7	34
Oryzaephilus surinamenis (L.) (sawtoothed grain beetle)	7.9	30	9.3	17	39.9	206
Plodia interpunctella (Hübner) (Indianmeal moth)	0.8	450	27.6	107	0	—
Tribolium spp. (red and confused flour beetles)	1.7	76	19.4	12	4.3	112
Liposcelis spp. (psocids)	4.2	—	1.4	—	11.3	—
Ahasverus advena (Waltl) (foreign grain beetle)	0.02	4	16.0	21	0	—
Sitophilus spp. (rice, maize, and granary weevils)	0.8	146	9.4	50	2.6	59
Dermestids *(Trogoderma, Attagenus, Dermestes spp.)*	1.7	24	3.7	13	3.7	31
Rhyzopertha dominica (F.) (lesser grain borer)	2.6	160	0.4	7	0.5	23
Cynaeus angustus (Leconte) (larger black flour beetle)	0.1	3	6.9	9	1.2	6
Tenebroides mauritanicus (L.) (cadelle)	0.1	2	3.3	9	0.8	10
Typhaea stercorea (L.) (hairy fungus beetle)	0	—	3.2	6	0.1	4
Tribolium audax Halstead (American black flour beetle)	0.04	3	1.0	5	0.8	16
Ptinus spp. (spider beetles)	0.02	3	0.3	7	0.2	2
Murmidius ovalis (Beck) (minute beetle)	0	—	0.6	62	0	—
Platydema ruficorne (Sturm) (redhorned grain beetle)	0	—	0.3	5	0	—
Tenebrio molitor (L.) (yellow mealworm)	0.04	6	0.2	4	0	—
Nemapogon granella (L.) (European grain moth)	0	—	0.2	10	0	—
Sitotroga cerealella (Olivier) (Angoumois grain moth)	0	—	0.1	289	0	—
Alphitophagus bifasciatus (Say) (twobanded fungus beetle)	0	—	0.1	7	0	—
Cathartus quadricollis (Guérin-Méneville) (squarenecked grain beetle)	0	—	0.1	7	0	—
Latheticus oryzae Waterhouse (longheaded flour beetle)	0.02	831	—	—	0	—
Carpophilus dimidiatus (F.) (corn sap beetle)	0	—	0.1	2	0	—
Lophocateres pusillus (Klug) (Siamese grain beetle)	0.02	2	0.1	1	0	—
Gnatocerus maxillosus (F.) (slenderheaded flour beetle)	—	—	0.1	6	0	—
All species	25.1	105	79.7	26	56.4	39

the samples came from ears of corn stored in a wooden crib, and the third from bulk corn stored in a circular steel bin. Another moth species, *Nemapogon granella* (L.), the European grain moth, was observed in only two samples from Minnesota and in two samples from Wisconsin.

One live field pest, *Blissus* spp., chinch bug, was occasionally detected in stored corn. Its presence was considered accidental and probably due to entrapment in grain bins adjacent to infested fields.

Oats

Nearly all of the samples of oats were obtained from three states (South Dakota, Minnesota, and North Dakota). The percentages of infested samples were nearly identical from Minnesota and South Dakota, but the average density of insects in infested samples was much higher in Minnesota oats (61/1,000 g) than in South Dakota oats (34/1,000 g).

Sawtoothed grain beetle dominated all other species

in oats, occurring in 39.9% of the samples at an average density of 206/1,000 g (Table 3). They occurred in 60% of the states sampled and in 61.3% of the 142 counties within those states. *Cryptolestes* spp. at 16.7% was the second most frequent pest in oats and psocids at 11.3% was third. Each pest was found in about half of the states, but *Cryptolestes* spp. occurred in 52% of the counties, and psocids in 31%. *Tribolium* spp. and dermestids were present in about 4% of the oats at densities higher than for either pest in wheat or corn. *Sitophilus* spp., particularly *S. granarius* (L.), occurred more frequently in oats than in wheat, but at lower densities. The large black flour beetle, the cadelle (*Tenebroides mauritanicus* L.), and the American black flour beetle (*Tribolium audax* Halstead) also occurred more often in oats than in wheat, and at higher densities.

Supplemental Data

The volume of grain in the storages sampled in the survey was ca. 980,000 metric tons of wheat (36 million bu) 1,451,000 metric tons of corn (57.5 million bu) and 130,600 metric tons of oats (9 million bu).

About 85% of the wheat and 79% of the corn was stored in circular metal bins, with oats more evenly divided between metal bins (56%) and wooden bins (36%). Less than 10% of the grain was stored in bins identified as flat storage or concrete storage. Correlations between the various types of bins and the incidence of insects were mostly obscured by the low percentages of grain in storages other than circular steel; however, the incidence of insects was about 10% higher in oats stored in wooden bins than in oats stored in metal bins. Furthermore, the cadelle beetle, an occasional pest of stored oats, was found almost exclusively in wooden bins.

Grain Moisture vs. Insect Infestation

The average moisture content ± SD and range of moisture for all grain samples were 11.3 ± 1.05% (6.9–16.0) for wheat, 11.9% ± 1.13% (8.0–18.4) for corn, and 10.9% ± 1.14% (7.4–15.3) for oats. Oats had the highest percentage of samples, with moistures under 10% (19.7%), and corn had the highest percentage, with moistures above 13% (15.8%). Similarly, corn had the lowest percentage of samples below 10% (3.2%), and oats had the lowest percentage above 13% (4.2%). Moisture levels in wheat were nearly the same for each crop year from 1976 to 1979, but moisture in corn and oats averaged about 0.5% lower in older grain (crop year 1976) than in newer grain (crop year 1979).

The range of moistures and the average moistures were consistently higher in grain containing insects than in uninfested grain, and the incidence of insects in each commodity generally increased with increased moisture levels in the grain (Table 4). In the wheat samples, the percent incidence of insects increased progressively through each higher moisture range with incidence in samples above 13% moisture more than four times higher than in samples below 10% moisture. The density of insect populations in the wheat samples also increased with higher moistures up to the range from 11.0 to 11.9%, but declined significantly at levels above 12 and 13%. The incidence of insects in corn increased about 15% between samples with less than 10% moisture and those in the range from 11.0 to 11.9%. There was little additional change in the incidence of insects in corn above 12% moisture. Insect densities in corn were variable between infested samples in the lower moisture ranges, but showed little change at levels above 11%. Insect infestations in oats increased with higher moistures up to the 11% range, remained nearly the same through the 12% range, and declined at moistures above 13%.

Among the principal insect species or groups of species found in wheat, the incidence of *Cryptolestes* spp., sawtoothed grain beetle, and psocids increased consistently between each moisture range. For example, *Cryptolestes* spp. occurred in 3.5, 6.5, 12.8, 23.6, and 34.1% of the samples at 10% moisture, 10.0–10.9%, 11.0–11.9%, 12.0–12.9%, and 13.0%, respectively.

Lesser grain borer and *Tribolium* spp. occurred most frequently in wheat samples with moisture levels above 13%, but incidence of those species did not increase consistently between lower moisture ranges. The lowest incidence of dermestids in wheat occurred in samples with the highest moisture. Densities of insects in wheat were variable throughout the moisture range, but the highest density of each species generally occurred between 10 and 12% moisture, and the lowest density at either moisture extreme (<10 or >13%).

The incidence of foreign grain beetle and larger black flour beetle, species that feed on molds or prefer high moisture conditions, increased more than five times between corn samples with <10% moisture and those with >13% moisture. The incidence of *Cryptolestes* spp. and *Sitophilus* spp. in corn also increased progressively through each higher moisture range, but *Cryptolestes*

Table 4. Incidence and density (number) of insect infestation vs. moisture content of wheat, corn, and oats stored on the farm

% Moisture range	Wheat		Corn		Oats	
	% Of samples infested	Avg density/ 1,000 g	% Of samples infested	Avg density/ 1,000 g	% Of samples infested	Avg density/ 1,000 g
<10	11.8	30	64.9	10	44.0	34
10.0–10.9	14.9	93	72.7	29	57.8	38
11.0–11.9	24.3	130	80.5	16	61.9	57
12.0–12.9	38.2	76	83.5	12	62.6	49
>13	51.4	49	81.7	16	45.5	100

spp. declined slightly in samples with >13% moisture. The incidence of Indianmeal moth and *Tribolium* spp., the second and third most frequent pests, respectively, in corn was relatively unaffected by moisture. Insect densities of the principal species in corn followed a similar relationship to that in wheat, with the highest densities of most species found in the middle moisture range (10–12%), and the lowest densities at either extreme.

Sawtoothed grain beetle, a species that dominated insect populations in oats, increased in incidence and density between each moisture range <12%, but decreased at higher moisture levels. *Cryptolestes* spp. and psocids increased progressively through each higher moisture levels in oats, except *Cryptolestes* spp. declined in incidence and decreased in density in samples with >13% moisture. The incidence and density of *Sitophilus* spp. were highest in oats with >13% moisture, but high densities of these insects were also found in dry oats with <10% moisture. *Tribolium* spp. occurred most often in the moisture range from 10 to 10.9%, and dermestids were detected most frequently in samples with <10% moisture.

These data document the close relationship between the occurrence and successful development of specific insect populations in farm-stored grain and the moisture at which the grain is stored. The risk of grain becoming infested with damaging populations of grain pests clearly increases when grain is stored at higher moisture levels. Storing grain at lower moisture levels would help reduce the probability and severity of insect attack, but would not eliminate infestations since many species were found to be readily adaptable to dry grain. Comparatively high populations of lesser grain borer and *Tribolium* spp. were found in dry wheat, Indianmeal moth in dry corn, and sawtoothed grain beetle, *Tribolium* spp. and *Sitophilus* spp. in low-moisture oats.

Test Weight vs. Insect Infestation

The average test weight ± SD for all grain samples was 59.8 ± 2.3 lb/bu for wheat, 57.6 ± 2.27 for corn, and 37.1 ± 3.13 for oats. Average test weights varied less than 0.5 lb between each crop year of wheat and oats, but varied by 1.1 lb between the 4 crop years of corn. Average test weights were lower in infested grain than in uninfested grain (Table 5). Differences between the average test weights of uninfested and infested grain were 0.8 lb for wheat, 0.7 lb for corn, and 0.5 lb for oats. Differences between infested and uninfested grain remained fairly constant even in states with widely varying test weights. For example, the average test weights ± SD for Montana wheat were 61.5 ± 3.09 lb for uninfested wheat, and 60.6 ± 2.51 lb for infested wheat. In states with lower average test weights such as Minnesota, the amount of the differences varied (59.1 ± 2.49 lb uninfested and 58.7 ± 2.44 lb infested), but infested grain was consistently lighter.

Although weight differences between uninfested and infested grain were somewhat less in newer grain (crop year 1979) than in grain stored for longer periods, the differences between other crop years were variable and showed no consistent trend toward increased weight loss with longer storage periods. Furthermore, the observed test weight differences were not related to moisture content in either the infested or uninfested samples.

Discussion

Data obtained in the survey indicate that grain stored on the farm contains a broad spectrum of storage insects that are often present in damaging numbers. The frequency and the overall distribution of grain pests were similar to conditions found in previous surveys of farm storage 40 years ago under the Ever-Normal Granary Plan. *Cryptolestes* spp., sawtoothed grain beetles, *Tribolium* spp., foreign grain beetle, *Sitophilus* spp., and lesser grain borer still comprise much of the insect populations found in farm-stored grain. However, relationships observed among some of the pests detected in farm-stored grain suggest the following changes in their pattern of distribution.

In general, insect infestations appear to be increasing in grain stored in the northern states where low winter temperature was previously considered a primary factor in limiting insect development. This may be due, in part, to larger storages providing microenvironments that are less affected by changes in outside temperature. Also, the widespread distribution and frequent occurrence in corn of insect species that prefer high-moisture conditions or that feed on molds or decaying vegetable matter indicate that excessive moisture is a universal storage problem throughout the corn-producing area.

Among specific insect species, the distribution of lesser grain borer has expanded throughout the grain-producing area to include even the northernmost counties along the Canadian border. Indianmeal moth has become a major pest of stored corn, but only a relatively infrequent pest of stored wheat. Furthermore, the absence of Indianmeal moth in grain samples from the western states indicates that its distribution may be limited.

Table 5. Average test weight (lb/bu) of uninfested and infested wheat, corn, and oats stored on the farm

Commodity	Uninfested		Infested	
	Avg ± SD	Range	Avg ± SD	Range
Wheat	60.0 ± 3.30	37.8–66.1	59.2 ± 2.28	49.1–67.0
Corn	58.1 ± 2.18	47.8–63.7	57.4 ± 2.28	40.0–64.1
Oats	37.4 ± 3.65	21.8–47.0	36.9 ± 3.06	23.2–46.6

In contrast to the apparent expansion of some species, the virtual disappearance of Angoumois grain moth from farm-stored grain suggests that use of the combine harvester and the picker-sheller along with the resulting bulk storage of grain has downgraded the importance of this storage pest.

Some major differences were observed between insect species and population densities found in farm stored grain and insects detected in wheat and corn exported from the United States during 1977–1978 (Storey et al. 1982). In general, most insect species occurred more frequently and were present in higher numbers in farm-stored grain than in export grain. Two partial exceptions were *Sitophilus* spp., which occurred more frequently in wheat and corn exports than in farm-stored grain, and *R. dominica* (lesser grain borer), which also were present more often in export wheat than in farm-stored wheat. Secondary grain pests that develop outside the grain kernel and those species that feed on molds or prefer high moisture conditions disappeared or were significantly lower in average density between grain samples taken from farm storage and those obtained at export. Possibly, these species may be more adversely affected by changes in the storage environment.

Acknowledgment

We thank W. E. Blodgett and J. Wilson, USGMRL, for helping to organize and process the grain samples, and personnel of the Agricultural Stabilization and Conservation Service for their efforts in obtaining the grain samples.

REFERENCES CITED

Anonymous. 1979. Survey of on-farm grain storage capacity by Agricultural Stabilization and Conservation Service, U.S. Dep. Agric. Feedstuffs 50. Feb. 25, 1980.

Barak, A., and P. Harein. 1981a. Insect infestation of farm stored shelled corn and wheat in Minnesota. J. Econ. Entomol. 74: 197–202.

1981b. Losses associated with insect infestation of farm stored shelled corn and wheat in Minnesota. Univ. Minn. Agric. Exp. Stn. Misc. Publ. 12-1981. 94 pp.

Cotton, R. T. 1938. Development of insect infestation in wheat stored on farms in the United States. U.S. Dep. Agric. Bur. Entomol. Plant Quarantine. E-429. 17 pp.

1963. Insect pests of stored grain and their importance. The Northwestern Miller, August 5, 1963: 20–23.

Horton, P. M. 1982. Stored product insects collected from on-farm storage in South Carolina. J. Ga. Entomol. Soc. (in press).

Spitze, D. C. 1980. Farm-stored grain survey. Wade County Farm, Research, and Home Quarterly, University of Nebraska, Fall 1980: 16–17.

Storey, C. L., D. B. Sauer, O. Ecker, and D. W. Fulk. 1982. Insect infestations in wheat and corn exported from the United States. J. Econ. Entomol. 75: 827–832.

Winburn, T. F. 1940. Insect infestation in farm-stored grain in Kansas. Trans. Kans. Acad. Sci. 43: 289–290.