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Insect Infestations in Wheat and Corn Exported from the United States[1]

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ABSTRACT

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The incidence of insects in wheat and corn for export from the United States was determined in grain loaded at 79 port terminals in the United States and Canada (the St. Lawrence Seaway) during a 2-year period from January 1977 to December 1978. One or more live, stored-product insect species were found in 17.9% of the wheat samples and 22.4% of the corn samples. Insects of the Genus *Sitophilus* were the predominate ones in all samples, with 7.7% of the wheat samples containing an average of 4.2 weevils per 1,000 and 14.4% of the corn samples containing an average of 5.8 weevils per 1,000 g. *Cryptolestes* was the second most frequent genus of insect pests, with 7.5% of the wheat and 9.7% of the corn containing averages of 1.9 an 2.4 insects per 1,000 g, respectively. The lesser grain borer, *Rhyzopertha dominica* (F.), was third among species found in wheat, and the Indian meal moth, *Plodia interpunctella* (Hübner), was third among species in corn. Insects were detected most often in wheat from the Gulf and Great Lakes regions (23.8%) and in corn from the Great Lakes and Atlantic Regions (23.5 to 24%). Grain from the Pacific region contained the fewest insects. The highest incidence of insects generally occurred in September or October.

Problems concerning the quality of grain exported from the United States have been significantly magnified by the rapid expansion of export markets. One of the determinants of grain quality is the level of insect infestation associated with grain during its storage and transport in the marketing system. The Federal Grain Inspection Service (FGIS) of the USDA has reported that "...insect infestation is a major issue. It is a source of foreign complaints about the quality of U.S. grains and correction of the [grade] standards to better reflect insect infestation is of high priority" (Anonymous 1979a). Another report issued by the U.S. General Accounting Office stated that "...according to several major foreign buyers, the most significant and prevalent quality problem with U.S. grains involve infestation and lack of adequate fumigation" (Anonymous 1979b). The GAO report attributes the insect problem in exports from the United States to two principal factors involved in inspection of grain. First, insects detected during sampling and grading of grain are not disclosed on inspection certificates unless they exceed certain tolerance levels established by FGIS. Second, present inspection methods cannot determine the hidden or "latent" infestations of internally developing insect species, nor can they readily detect eggs or some larval stages of externally developing species that feed deep inside the germ portion of a grain kernel.

The studies presented here were developed to show a national overview of the incidence of insect infestation in wheat and corn for export from the United States. Procedures used for processing and examining the grain samples obtained in this survey were designed to maximize the survival and development of all stored-product species present in the grain at the time the samples were collected for export grade certification. Furthermore, insects detected on initial examination or after incubation of the samples did not necessarily exceed the insect tolerance guidelines under the Special Grade Weevily, and no inference should be made that all samples containing live insects were "weevily" by current definition.

Under U.S. grain standards, weevily grain is grain infested with "live weevils" or "other live insects injurious to stored grain" (Anonymous 1980). Live weevils include the *Sitophilus* spp. (rice, maize, and granary weevils), the cowpea weevil, *Callosobruchus maculatus* (F.), and the lesser grain borer, *Rhyzopertha dominica* (F.). Other live insects injurious to stored grain include grain beetles, grain moths, and vetch bruchids. Insects in this group are generally considered to be those species not previously characterized as live weevils, identified in the USDA Agricultural Handbook, No. 500, "Stored-Grain Insects" (Anonymous 1979c). A total of 14 possible combinations of live weevils and other live injurious insects are employed in determining whether a specific grain is assigned the Special Grade Weevily. In general, the tolerance for insects is more lenient when grading corn than wheat. For example, if one insect considered to be a "live weevil' is found in a single cut taken from a running stream, the presence of any other live insect injurious to stored grain in the same sample would be sufficient to cause wheat to be graded weevily. In corn, five other live insects injurious to stored grain in addition to the live weevil would have to be present to cause the corn to be designated weevily. Similarly, if no insects considered to be live weevils are present, the Special Grade Weevily would be applied to wheat if 5 or more live insects defined as injurious to stored grain were present, and in corn if 15 or more were found.

Materials and Methods

Grain Samples

Grain samples for analysis were obtained from sublots of wheat and corn loaded on ships at 79 port elevators

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Table 1.—Summary of grain sublots designated weevily and survey samples that contained live insects in 1977–1978 corn and wheat exports

Grain	Region	No. of sublots sublots loaded	% Designated "weevily"	No. of survey samples	% With one or more live insects
Corn	Atlantic	19,028	0.27	625	23.5
	Great Lakes	18,074	0.02	580	24.0
	Gulf	18,615	1.34	1,034	21.7
	Pacific	3,539	0.42	144	16.0
	All regions	59,256	0.54	2,383	22.4
Wheat	Atlantic	1,334	4.72	83	16.9
	Great Lakes	6,277	0.25	592	23.8
	Gulf	8,936	0.86	777	23.8
	Pacific	8,990	0.91	606	4.6
	All regions	25,537	0.93	2,058	17.9

Table 2.—Insect species and population densities found in 1977–1978 corn and wheat reports

Insect species	Corn samples		Wheat samples	
	% Infested	Density/1,000 g	% Infested	Density/1,000 g
Sitophilus spp. (maize and rice weevils)	14.4	5.8	7.7	4.2
Cryptolestes spp. (flat and rusty grain beetles)	9.7	2.4	7.5	1.9
Rhyzopertha dominica (F.) (lesser grain borer)	0.3	0.7	5.6	4.3
Plodia interpunctella (Hübner) (Indian meal moth)	1.6	39.9	1.2	21.5
Anagasta kuehniella (Zeller)	0.2	4.3	0	—
Tribolium spp. (red and confused flour beetles)	0.3	1.1	0.4	1.1
Ephestia cautella Walker) (almond moth)	0.2	55.5	0.1	2.1
Sitrotroga cerealella (Olivier) (Angoumois grain moth)	0.2	1.0	0	—
Tenebroides mauritanicus (L.) (cadelle)	0.2	1.0	0	—
Oryzaephilus surinamensis (L.) (sawtoothed grain beetle)	0.1	0.2	0.3	4.0
Dermestids (*Trogoderma* spp.)	0	—	0.1	0.1
Miscellaneous beetles	0.1	13.7	0	—
Typhaea stercorea (L.) (hairy fungus beetle)				
Ahasverus advena (Waltl) (foreign grain beetle)				
Liposcelis spp. (psocids)	0.5	—[b]	0.1	—[b]
Acarus siro L.[a] (grain mites)	30.0	—[b]	0	—

[a]1977 samples only.
[b]Density not calculated.

in the United States and certain Canadian ports on the St. Lawrence Seaway during the period from January 1977 to December 1978. During most of 1977, sample frequency was based on selecting from every 50th corn and every 100th wheat sublot shipped from each elevator. A sublot of grain may contain a maximum of 1633.2 metric tons (60,000 bushels), from which one or more component samples are drawn to determine if the grain is uniform in grade to that required for the shiplot. The combined sublots loaded onto a particular ship are considered a shiplot. Beginning in the late fall of 1977 and throughout 1978, sample frequency was substantially increased by selecting one sample from a randomly selected sublot from every shiplot of wheat and corn loaded at each terminal. All samples were obtained by diverter-type mechanical grain samplers and consisted of ca. 1 kg of the orignial sample taken for official grade analysis.

That portion of the grade sample we examined for insects was not graded or inspected by FGIS but was sent directly to the U.S. Grain Marketing Research Laboratory (GMRL) for processing. When received, each

Table 3.—Percentage of 1977-1978 corn and wheat export samples from each region infested with identified insect species

Insect species	Atlantic		Great Lakes		Gulf		Pacific		All regions	
	Corn	Wheat	Corn	Wheat	Corn	Wheat	Corn	Wheat	Corn	Wheat
Sitophilus spp. (maize and rice weevils)	16.8	10.7	9.8	7.9	15.9	12.9	11.1	0.5	14.4	7.7
Cryptolestes spp. (flat and rusty grain beetles)	6.9	4.8	16.9	16.6	7.8	5.8	6.9	1.3	9.7	7.5
Rhyzopertha dominica (F.) (lesser grain borer)	0.3	0	0.2	2.7	0.3	11.1	0	2.3	0.3	5.6
Plodia interpunctella (Hübner) (Indian meal moth)	2.7	2.4	0.3	0	1.7	2.4	0.7	0.5	1.6	1.2
Anagasta kuehniella (Zeller) (Mediterranean flour moth)	0.3	0	0	0	0.2	0	0	0	0.2	0
Tribolium spp. (red and confused flour beetles)	0.2	2.4	0.7	0.3	0.1	0.5	0	0	0.3	0.4
Ephestia cautella (Walker) (almond moth)	0.3	0	0	0	0	0.3	0	0.2	0.2	0.1
Sitotroga cerealella (Olivier) (Angoumois grain moth)	0.3	0	0	0	0.2	0	0.7	0	0.2	0
Tenebroides mauritanicus (L.) (Cadelle)	0	0	0	0	0.2	0	0	0	0.2	0
Oryzaephilus surinamensis (L.) (sawtoothed grain beetle)	0.2	0	0	0.3	0	0.5	0	0	<0.1	0
Dermestids (*Trogoderma* spp.)	0	0	0	0.2	0	0	0	0	0	<0.1
Miscellaneous beetles										
Typhaea stercorea (L.) (hairy fungus beetle)	0	0	0.3	0	0	0	0	0	0.1	0
Ahasverus advena (Waltl) (foreign grain beetle)										
Liposcelis spp. (psocids)	1.0	0	0	2.0	1.0	0	0	0	0.5	0.06
Acarus siro L. (grain mites)	25.0	0	48.0	0	22.0	0	18.0	0	30.0	0
No. of samples	625	83	580	592	1,034	777	144	606	2,383	2,058
Avg % infested[b]	23.5	16.9	24.0	23.8	21.7	23.8	16.0	4.6	22.4	17.9

[a]1977 samples only.
[b]Psocids and mites omitted.

sample was catalogued and weighed, and its moisture content was measured on a Motomco electronic moisture meter.

Insect Analysis

Corn samples were hand-sieved over a screen with 0.476-cm (12/64-in.) round openings, and wheat samples were sieved over a no. 10-mesh screen with 10 openings per 2.54 cm (1 in.). The screenings were weighed and examined for live insects. Insects found in the screenings and in the screened grain were identified, counted, and removed. The screenings and screened grain were recombined in 0.95-liter jars and stored at 27 ± 1°C and 60 ± 5% relative humidity (RH). The storage (incubation) period ranged from 3 to 6 weeks, depending on the species and stages of development detected in the initial examination and the number of days between the date the sample was taken and the date the sample was received for examination. Interim examinations during the incubation period were made to insure that only those insects present in the grain at the time the grain was sampled were counted and no additional generations of insects were produced.

Most insects species found in the samples were identified by personnel of the Biological Research Unit, GMRL. To facilitate rapid characterization of insect found in the samples, species belonging to the genera *Sitophilus*, *Cryptolestes*, and *Tribolium* were identified to genus only. Selected insects were sent to the Insect Identification and Beneficial Insect Introduction Institute, ARS, USDA, Beltsville, Md. for identification or confirmation.

Supplemental Data

A summary of the monthly corn and wheat shipping activity was obtained from each elevator location which identified each ship loaded, grain loaded, number of sublots designated Weevily by FGIS, date grain was loaded, and survey sample number applicable to each sublot.

Data Processing

Information associated with the grain samples examined during the 2-year period was summarized by computer to provide a listing of insect activity by commodity, by port region (Atlantic, Great Lakes, Gulf, and Pacific), by insect species, and by month. Insect activity was also correlated with the supplemental data, including shipping information (dates and sublots loaded) and the number of sublots designated weevily by FGIS.

Total wheat and corn exports during the 2-year period (1977–1978) were ca. 57.1 × 10^6 metric tons of wheat (2.1 × 10^9 bushels) and 95.3 × 10^6 metric tons of corn (3.5 × 10^9 bushels).[5] The wheat exports were divided among the four export regions as follows: 51% from Gulf ports; 30% Pacific; 15% Great Lakes; and 4% Atlantic. The corn exports were divided as follows: 65%

[5]Grain Market News, USDA, Agricultural Marketing Service, monthly issues.

Gulf; 21% Atlantic; 11% Great Lakes; and 3% Pacific. A total of 4,441 grain samples (2,058 wheat and 2,383 corn) was examined during the 2-year period. Distribution of the survey samples among the four export regions followed the same general pattern as the actual shipping activity, with the highest number of both wheat and corn samples obtained from the Gulf region.

Results and Discussion

There were no significant differences between the 1977 and 1978 samples; therefore, data presented here, unless identified otherwise, are means of the combined 2-year sampling period.

One or more live, stored-product insect species were found in 17.9% of the wheat samples and 22.4% of the corn samples examined from all regions during the 2-year survey (Table 1). Although not shown in Table 1, the average percentage of samples in which insects was detected was 3.9 for wheat and 4.3 for corn on initial examination and 15.9 for wheat and 20.2 for corn after incubation. When adult insects were found on initial examination, additional insects were generally observed after the sample was incubated. However, most of the insects obtained after incubation occurred in samples in which no adult insects were observed on initial examination.

Insects were detected most often in wheat samples from the Gulf and Great Lakes regions (ca. 24%) and least often (4.6%) in samples from the Pacific export terminals. Corn samples from the Great Lakes and Atlantic regions had the highest incidence of infestation (23.5 to 24%) and the Pacific Region the lowest (16.0%).

Of the sublots loaded during the sampling period, 0.93% of the wheat sublots and 0.54% of the corn sublots were designated weevily by FGIS (Table 1). No consistent relationship was evident between the number of sublots graded weevily, the incidence of live insects in survey samples, or the volume of grain shipped from each region. The Atlantic region had the highest percentage of wheat sublots designated weevily (4.72%), but exported the least amount of wheat (4%). In contrast, the Gulf region exported most of the corn (65%) and also had the highest percentage of sublots designated weevily (1.34%).

Insects of the Genus *Sitophilus* were the predominant insects in all grain samples: 7.7% of the wheat samples contained an average of 4.2 weevils per 1,000 g, and 14.4% of the corn samples contained an average of 5.8 weevils per 1,000 g (Table 2). Most of the selected *Sitophilus* spp. submitted to the USDA Insect Identification Institute were identified as the maize weevil, *S. zeamais* Motschulsky. Others were identified as the rice weevil, *S. oryzae* (L.). No granary weevils, *S. granarius* (L.), were detected in the survey. *Cryptolestes* spp., which included the flat grain beetle, *C. pusillus* (Schoenherr), and the rusty grain beetle, *C. ferrugineus* (Stephens), were the second most frequent genus of insect pests found in the export samples; 7.5% of the wheat samples contained an average of 1.9 insects per 1,000 g, and 9.7% of the corn samples contained an average of 2.4 insects per 1,000 g. The lesser grain borer, *Rhyzopertha dominica* (F.), ranked third among species found in wheat and was present in 5.6% of the samples at an average density of 4.3 borers per 1,000 g. The Indian meal moth, *Plodia interpunctella* (Hübner), ranked a distant third among the genera found in corn samples (1.6%) and occurred in only 1.2% of the wheat samples. The number of these moths present in infested samples was high, averaging 39.9 moths per 1,000 g of corn and 21.5 moths per 1,000 g of wheat. Other insect species were detected in generally less than 0.5% of the export samples (Table 2)

Flour or grain mites (Acari: Acaridae) were found in ca. 30% of the corn samples received during the 1977 sampling period and in none of the 1978 corn samples. No mites were detected in the wheat samples examined during the 2-year period. Reasons for the inconsistency are unclear; however, the 1978 corn samples averaged ca. 0.3% lower in moisture (14.3 vs. 14.6%) content than the 1977 samples, and nearly 65% of the 1977 corn samples had moisture levels at or above 15%. Only 45% of the 1978 corn samples had similar moisture levels.

Table 4.—Percentage of monthly samples of 1977–1978 wheat exports from each region containing live insects

Month	No. of samples	% Of samples infested				
		Atlantic	Lakes	Gulf	Pacific	All regions
Jan.	87	0[a]	—	12.5	0[a]	7.8
Feb.	89	0[a]	—	14.0	2.8	7.9
Mar.	121	16.7[a]	0[a]	4.8	2.2	5.0
Apr.	134	0[a]	2.5	14.5	6.3	9.0
May	207	8.3[a]	2.5	13.3	12.5	8.7
June	193	40.0[a]	13.0	20.3	4.4	14.5
July	149	33.0[a]	25.5	21.1	2.6	18.1
Aug.	191	33.0[a]	33.7	28.6	0	23.6
Sept.	211	55.6[a]	31.6	36.1	0	26.5
Oct.	216	0[a]	37.8	46.8	4.8	31.5
Nov.	191	0[a]	30.3	38.0	7.1	27.7
Dec.	269	11.1[a]	20.0	20.4	6.9	14.9

[a]Less than 20 samples.

Table 5.—Percentage of monthly samples of 1977–1978 corn exports from each region containing live insects

Month	No. of samples	% Of samples infested				
		Atlantic	Lakes	Gulf	Pacific	All regions
Jan.	195	9.8	0[a]	9.5	20.0[a]	10.0
Feb.	121	10.9	—	12.0	6.3[a]	10.7
Mar.	1544	16.7	—	2.3	5.6[a]	7.1
Apr.	212	3.1	13.2	3.2	0[a]	4.7
May	234	16.0	11.1	13.0	0[a]	12.4
June	233	28.3	16.7	16.0	6.3[a]	18.0
July	201	40.5	24.7	28.2	22.2[a]	28.9
Aug.	214	36.6	34.7	43.0	62.5[a]	39.7
Sept.	205	40.9	52.5	48.4	72.7[a]	49.3
Oct.	1544	52.6	36.2	47.0	33.3[a]	44.8
Nov.	221	39.2	15.8	28.9	9.1[a]	25.8
Dec.	239	16.4	15.8	16.2	0[a]	15.1

[a]Less than 20 samples.

Table 3 shows the percentage of wheat and corn samples from each region infested with each of the identified species. *Sitophilus* spp. and *Cryptolestes* spp. were found in both wheat and corn samples from all regions. Corn samples from the Atlantic region had the highest incidence of *Sitophilus* spp. (16.8%), and wheat samples from the Pacific region had the lowest (0.5%). *Cryptolestes* spp. occurred most often in the wheat and corn samples from the Great Lakes region (16.9 and 16.6%) and least often in the Pacific wheat samples (1.3%). None of the other insect pests found in the survey occurred universally throughout all regions in both wheat and corn.

The number of monthly samples and the percent containing one or more live insects in each region are shown in Table 4 for the wheat samples and Table 5 for the corn samples. The number of samples received each monthly generally reflect the shipping activity for that month. The lowest number of samples was obtained during January and February, and the highest number of samples during December. In most regions there was a general trend for insect infestations to increase beginning in late May and reach a peak during the September and October shipments. Thereafter, the frequency of insects in the grain samples declined to a low point in the March and April shipments. The monthly incidence of insects in wheat from the Pacific was different, in that the peak incidence occurred in May and no insects were detected in the August and September samples.

Among the four principal insect species detected in the survey (*Sitophilus* spp., *Cryptolestes* spp., lesser grain borer, and Indianmeal moth), all except the lesser grain borer occurred more frequently in corn than in wheat throughout most of the calendar year. *Sitophilus* spp. were detected in corn and wheat samples during every month of the year, and *Cryptolestes* spp. were detected in all months except the January and May wheat samples. Lesser grain borers were found in all months except March in the wheat samples, and Indianmeal moths were found throughout the entire year in the corn samples. *Sitophilus* spp. and *Cryptolestes* spp. occurred most often in the corn samples during the month of October. During these periods, *Sitophilus* spp. occurred most often in samples from Gulf ports, and *Cryptolestes* spp. occurred most often in samples from the Great Lakes region. Infestations of lesser grain borer in wheat occurred most often in the late-fall months and were found principally in the Gulf Region. Indianmeal moth infestations in corn began to increase in March and remained about the same during the summer months. From March to August, the highest incidence of Indianmeal moths occurred in the Atlantic corn samples. During early fall, the Indianmeal moth was detected somewhat more frequently in samples of corn from the Gulf Region.

The highest incidence that we found of those species considered "live weevils" occurred in Gulf region wheat (24.1%) and Atlantic region corn (17.5%). The lowest incidence of live weevils was found in Pacific region wheat (2.5%). Among species considered as other insects injurious to be stored grain, excluding psocids and mites, corn (18.7%) and wheat 17.6%) from the Great Lakes region contained the most frequent infestations and wheat from the Pacific region (2.2%) the least. No relationship is evident between either of these groupings of insect frequency and the incidence of sublots designated weevily. The major areas for weevily designated sublots as shown in Table 1 were Atlantic wheat (4.72%), followed by Gulf corn (1.34%), Pacific wheat (0.91%), and Gulf wheat (0.86%). Weevily sublots were virtually absent (0.016%) from all sublots of corn shipped out of Great Lakes ports during the 2-year period. Among the corn samples from the Great Lakes region that contained live insects, ca. 40% contained insect species considered to be live weevils and nearly 78% contained species considered as other insects injurious to be stored grain.

Data obtained in this study show that wheat and corn exported from the United States contain a significant incidence of undetected or undeclared insect infestation. The extent and frequency of insects found in the grain suggest that insect tolerances permitted under current

guidelines may be excessive and that present inspection methods may not provide an accurate evaluation of insect contamination in U.S. grain.

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