Infestation by *Cryptolestes ferrugineus* (Coleoptera: Cucujidae) of Newly Harvested Wheat Stored on Three Kansas Farms

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ABSTRACT The vertical distributions of *Cryptolestes ferrugineus* (Stephens) in newly harvested wheat, *Triticum aestivum* L., on three Kansas farms during the first two months of storage were studied to characterize the process of infestation. In three bins, the number of adult *C. ferrugineus* tended to decrease from top to bottom layers of grain. In the fourth bin, the numbers decreased from top and bottom layers to middle layers. A regression model explained 82.2% of the variation between bins. These data suggest that most of the insect infestation occurred after the wheat was loaded into the bin instead of before or during loading and that insects then dispersed from the grain surfaces into the grain mass.

KEY WORDS Insecta, stored products, dispersal, rusty grain beetles

AN UNDERSTANDING of the manner in which insects initially infest grain, disperse within the grain mass, and increase in numbers is vital to sound insect pest management. The insects that initially infest grain represent the starting point from which insect populations increase in abundance at a rate determined by environmental factors. The rate at which insect populations increase in abundance and disperse within the grain mass determines how insect sampling and possibly control efforts should be distributed within a bin.

Most studies of insects in farm-stored grain emphasize either their distribution or abundance. Insect populations have been studied in stored corn (Barak & Harein 1981), sorghum (Meagher et al. 1986), oats (Ingemansen et al. 1986) and wheat (Smith 1978, 1983; Cuperus et al. 1986; Hagstrum 1987). Hagstrum (1987) provided a detailed study of the changes during the storage period in distribution and abundance of insects in the top meter of farm-stored wheat. Smith (1978, 1983) experimentally infested bins with laboratory-reared insects near the floor and sampled *Cryptolestes ferrugineus* (Stephens) (Coleoptera: Cucujidae) populations throughout the grain bin and over the full storage period, providing data on seasonal changes of insect distribution and abundance throughout the bin. In his studies, few of the insects dispersed upward. This is consistent with the positive geotaxis reported by Watters (1969) and Loschiavo (1983) using laboratory-reared insects.

My study characterizes the natural process of infestation of commercial farm-stored wheat by following the vertical distribution of adult *C. ferrugineus* in four bins of newly harvested wheat on three Kansas farms during the first 2 mo of storage.

Mention of a commercial or proprietary product in this paper does not constitute endorsement by the USDA.

Materials and Methods

Adult insect populations, temperatures, and moisture contents for hard red winter wheat, *Triticum aestivum* L., (mixture of 'Pioneer,' 'Mustang,' 'Newton,' and 'Arkan') were measured in two cylindrical metal bins (bin A was 5.5 m diameter with 82 t of wheat 4.6 m deep; bin B was 5.5 m diameter with 41 t of wheat 2.3 m deep) on two farms near Junction City, Kans. during 1987 and in two cylindrical metal bins (bins C and D were 6.4 m diameter with 82 t of wheat 3 m deep) on a farm near Enterprise, Kans. during 1986. Bins were sampled 7, 21, 35, 49, and 63 d after newly harvested wheat was placed in storage in 1987 and 3, 7, 14, 28, 42, and 56 d after storage in 1986. Bins had been swept clean of old wheat (Bin A, B, and C) or grain sorghum (Bin D) and treated with the insecticides malathion or methoxychlor before new harvested wheat was stored. The two bins in 1987 studies had only concrete floors, whereas the bins in 1986 studies had perforated metal drying floors above the concrete floors.

On each occasion, samples of wheat were taken with a commercial pneumatic grain sampler (Cargill Probe-A-Vac, Minneapolis, Minn.). The sampler pulls air carrying the grain up through a 3.2-cm inner tube, and replacement air passes down between this tube and an outer 5.1-cm tube. The air with the grain passes into a cyclone collector which allows particulates to drop out. Six 2.9-kg samples in each 0.75-m layer of wheat were taken at three points near the center of the bin and at three points two-thirds of the distance between the

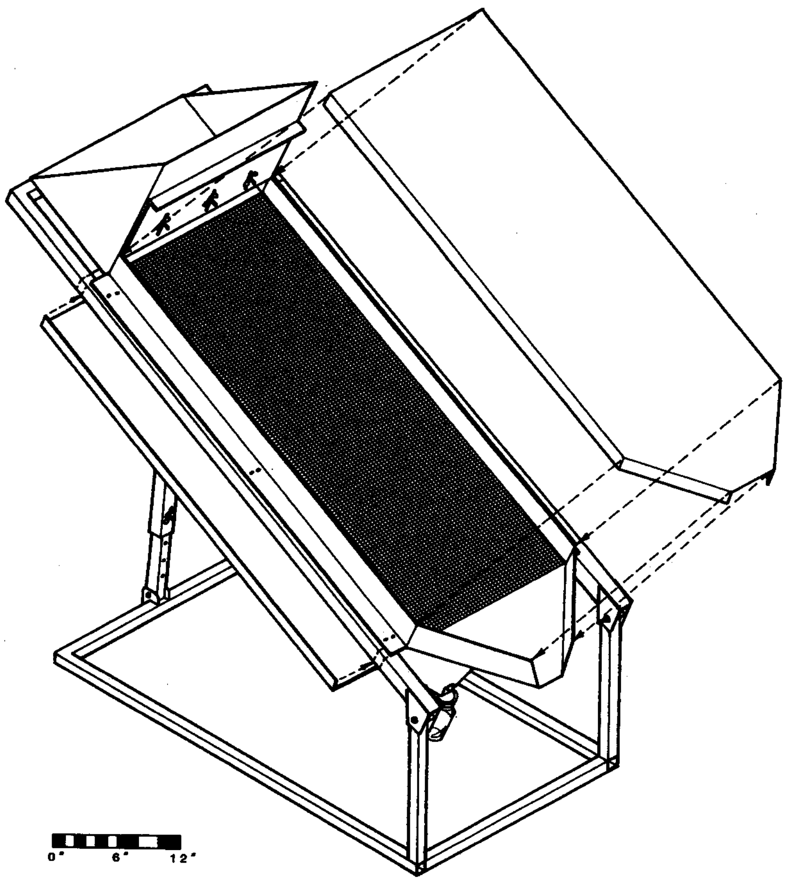

Fig. 1. Sieve used to separate insects from the grain.

center and the outer wall. Sampling points were selected randomly on each date. Three to six layers of grain were sampled depending upon the depth of grain in the bin. The layers were numbered from top (1) to bottom (3–6, depending upon the depth of wheat in the bin). Because the grain sampler continuously removed grain while the sampling tube was pushed through each layer, the full depth of each layer was sampled.

To extract the insects from the wheat samples, the wheat was passed over an inclined sieve (Fig. 1) similar to the one described by White (1983). The grain dumped into the hopper flows over the screen and is collected at the bottom. The depth of grain on the screen can be adjusted by changing the width of the slit through which grain leaves the hopper. Insects falling through the stainless steel wire mesh screen (1.6-mm aperture, 0.45-mm wire diameter) slide along a stainless steel tray beneath the screen and are collected in a jar at the lower end of the sieve. In 1986, the three center or the three peripheral samples for each layer were combined into a single 8.7-kg sample which was passed three times over the inclined sieve. In 1987, each of 36 samples from bin A and 18 samples from bin B were sieved separately. The combined sievings from the three passes were taken to the laboratory to be examined for insects, and the wheat was put back into the bins near the walls so the areas being sampled were not disturbed.

Environmental conditions also were monitored in each bin. To determine moisture content, an additional 4–7 center and 4–7 peripheral 0.125-kg samples of wheat were taken at the surface, between the 0.75-m layers of wheat, and at the bottom. The grain was transported to the laboratory in sealed jars, and the moisture content of the wheat samples was checked with a grain analysis computer (Model GAC II, Dickey-John Corporation, Auburn, Ill.). Temperatures were measured using two thermocouple cables located at the bin center and at two-thirds of the distance between the center and the outer wall with thermocouple junctions spaced on cables at depth intervals of 0.30 m in bins A and B, 0.45 m in bin C, and 0.90 m in bin D.

The Statistical Analysis System (SAS Institute 1985) was used to plot trends and fit two linear regression equations.

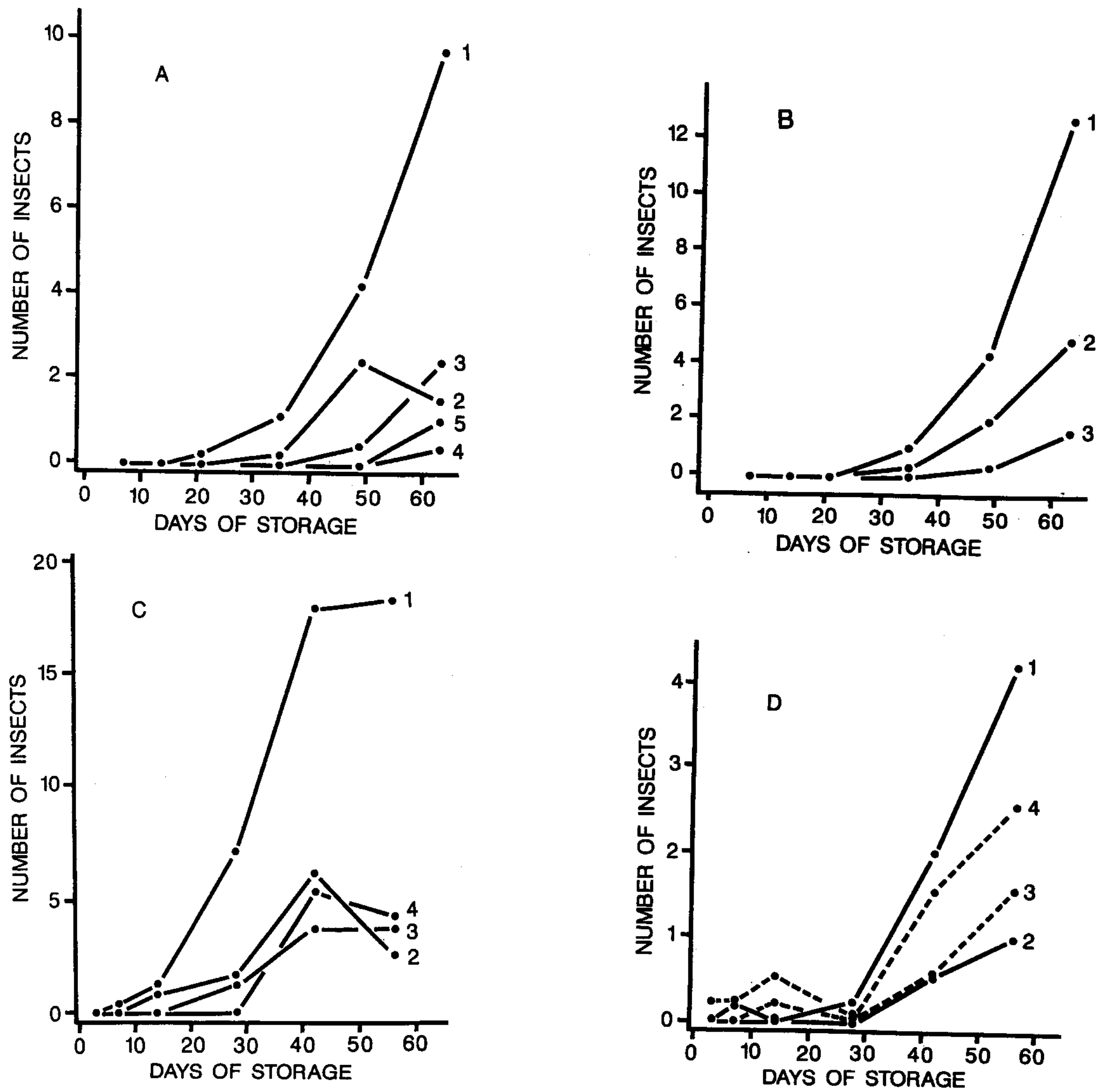

Fig. 2. Changes during the storage period in mean numbers of *C. ferrugineus* per 2.9-kg sample of wheat taken from 0.75-m layers in four farm bins (A–D). Numbers 1–5 represent layers of wheat from top to bottom.

Results

The vertical distribution patterns of *C. ferrugineus* adults in four bins of newly harvested wheat on three Kansas farms were generally similar during the first 2 mo of storage (Fig. 2). Adult *C. ferrugineus* populations were found only in the top or bottom 0.75-m layers of wheat during the first week of storage. In bins A, B, and C, the numbers of adults tended to decrease logarithmically from the top to bottom layers of wheat (Fig. 3). However, in bin D, adult numbers decreased from the top and bottom layers to middle layers. The percentages of the *C. ferrugineus* population (y) in each layer (x) are described by the equation $\log y = -1.79 \log x - 0.16$ ($r^2 = 0.9229$ and df = 18). In fitting the equation, insects dispersing up from the bottom layer 4 in bin D to layer 3 (shown as dashed line in Fig. 2) were treated as if they were dispersing down from the top.

Another way of comparing the vertical distribution patterns of adult *C. ferrugineus* in four bins during the first 2 mo of storage is to fit a single regression equation to all of the data. The numbers of insects were adjusted before fitting the equation so that, over the storage period, the total number of insects in each bin equalled 25. Insects dispersing up from the bottom layer 4 to layer 3 were again treated as if they were dispersing down from the top. The regression equation $y = 0.0042x^2 + 0.00021x^2z^2 - 0.0019x^2z - 0.18$ predicted the

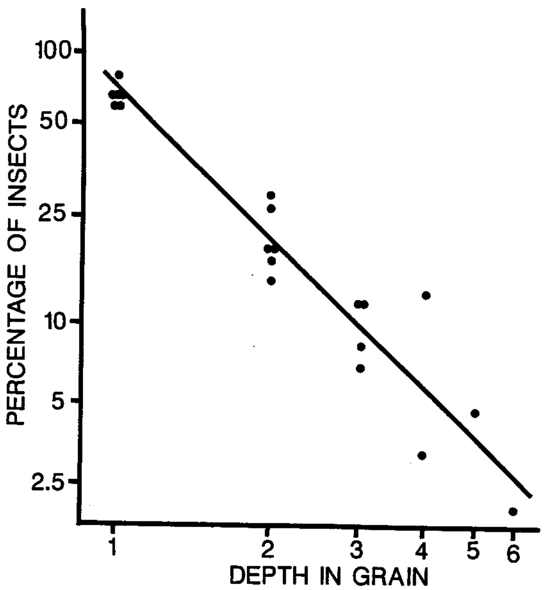

Fig. 3. Regression of logarithm of percentage of *C. ferrugineus* recovered during the 2-mo storage period in each 0.75-m layer of wheat against the logarithm of the depth of wheat given as the number assigned to layer.

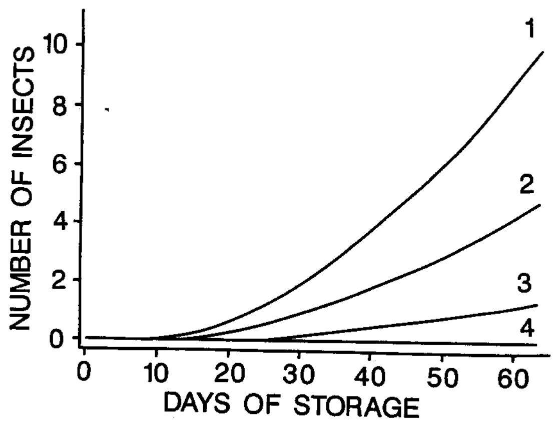

Fig. 4. The predicted numbers of adult *C. ferrugineus* at each depth during the first 63 d that wheat is stored in four grain bins. Numbers 1–4 above the lines represent layers of wheat from top to bottom.

numbers of adult *C. ferrugineus* (y) in each layer (z) during the first 63 d (x) of storage period and explained 82.2% of the variation among the four bins ($r^2 = 0.8224$; df = 98). The equation is represented graphically in Fig. 4.

During the first 2 mo of storage, temperature and grain moisture content were generally favorable for insect survival, development, and reproduction throughout all bins. Initial average temperatures were 35.0, 36.2, 33.0, and 36.3°C, and the average grain temperature dropped 0, 0.5, 0.7, and 0.8°C per week in bins A, B, C, and D, respectively. The average initial moistures in bin A were 14.7% in layer 2 and 12.9% elsewhere in the bin. The average initial moisture in bin B was 11.5%, and in bins C and D it was 10.4%. Moistures did not change during the storage period except for a 0.1% decrease per week in layer 2 of bin A and a 0.1% increase per week in the top and bottom layers of bins C and D.

Discussion

Although different patterns of infestation may be discovered with additional studies, the results of my study suggest that the observed infestation pattern was consistent over a broad range of conditions. These four bins represent data collected in two different years, on three farms, and with a diversity of bin sizes, type of bin floors, grain moisture (10.4–14.7%), and temperature (33.0–36.3°C), yet a single regression model explained 82.2% of the variation among four bins.

Such a consistent vertical distribution pattern of *C. ferrugineus* during the first 2 mo of storage would seem unlikely if insects infested wheat before or during loading of a bin. Perhaps the simplest explanation for the observed vertical distribution is that insects infest wheat after it is stored, then disperse from the grain surfaces into the grain mass. The population increase earlier in the top layer than in the middle layers, and the logarithmic decrease in insect numbers with distance from the top grain surface, suggest that the top layer was infested first.

These studies of the initial infestation of farm-stored wheat will provide guidelines for designing more detailed laboratory studies on the infestation process. The model predicting the vertical distribution can provide insights into how we should distribute sampling aimed at early detection in commercial bins. For example, with 68% of the *C. ferrugineus* adults generally found in the top 0.75 m of wheat, grain trier samples from that layer will be more likely to detect an infestation than samples taken elsewhere, but samples from only the top 0.75 m will overestimate the severity of the infestation.

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