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Feeding and Mortality of *Sitophilus granarius* (L.) Adults During Simulated Winter Farm Bin Temperatures[1,2]

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ABSTRACT

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After gradual cold-temperature acclimation, granary weevils, *Sitophilus granarius* (L.) (Coleoptera: Curculionidae), fed on cut wheat kernels, but not on undamaged kernels, at 4.4°C. Mortality was greater for weevils confined with single, uncut kernels than for those confined with cut kernels, and males died sooner than females.

The granary weevil, *Sitophilus granarius* (L.), a pest of stored grain, normally completes its entire development inside a single cereal grain kernel. Adults feeding on grain may produce as much total damage as do their larval stages (Back and Cotton 1926). Feeding by both larvae and adults is less the cooler the temperature, and grain cooling is frequently used as a means of reducing damage by this and other stored-grain pests. Granary weevil adults will become motionless and perish in 38 days if maintained at 1.6°C (Robinson 1926); however, Back and Cotton (1924, 1926) reported faint movements and survival for 111 days at 1.7 to 4.4°C and up to 73 days at −1.1 to 1.7°C. Feeding activity at such low temperatures has not been reported. Richards (1947) reported weevils feeding and ovipositing in wheat at 9.5°C. Evans (1977) found that survival and fertility of granary weevils reared and evaluated at 15°C were considerably less than for weevils reared at 27°C and then evaluated at 15°C.

This research was to determine whether adults could feed and survive on whole or cut kernels of wheat at temperatures between 4.4 and 7.8°C, after they had been acclimated during 109 days by exposure to temperatures gradually lowered to 4.4°C in a thermal sequence that simulated temperature changes in a farm bin of wheat during fall, winter, and spring in Kansas.

Materials and Methods

Granary weevils had been reared continuously at 26.7 ± 1°C and 67 ± 3% relative humidity (RH), on hard red winter wheat of 13.5% moisture content (MC) for 10 or more years at Kansas State University. Adults from these cultures, 3.5 ± 3 days old, were placed in 1-pint (ca. 0.47-liter) jars with lids having brass screen and filter paper inserts: 250 insects per 250 g of 12.5 ± 0.5% MC hard red winter wheat in each jar with 2.5% of the kernels broken. Three such jars were placed in a walk-in growth chamber at 25.6°C and 68% RH. Temperatures were lowered 2.2°C or less weekly, based on the simulation sequence of Table 1. After 109 days, temperatures reached 4.4°C. On day 118, the weevils in the test jars still moved, though very slowly.

Wheat kernels without evidence of breakage or damage were selected from 12.5% MC grain with the aid of a magnifying-lens lamp. "Cut" kernels were prepared by cutting off a third (brush end) of each kernel. One hundred cut kernels and 100 uncut kernels were each placed, germ end down, in a no. 2 gelatin capsule (Eli Lilly and Co., Indianapolis, Ind.). The capsules were capped and placed upright into a pegboard holder and transferred directly to the 4.4°C of the simulation sequence. After capsules and kernels had been at 4.4°C for 5 h, weevils were screened from three test jars (removed from 4.4°C one jar at a time) at 26.7°C, and the live weevils (79% surviving) were returned to 4.4°C within 10 min. At 4.4°C, weevils from all three jars were combined in a metal pan. Weevils moved about continually during the next hour as they were randomly selected and each was placed individually in a gelatin capsule with a single cut or uncut kernel. On days

Table 1.—Temperature sequence used to simulate fall, winter, and spring temperatures in a bin of wheat,[a] Manhattan, Kans.

Days of sequence	Dates simulated	Temp (°C)
0–3	19–22 Nov.	25.6
4–6	23–25 Nov.	24.4
7–10	26–29 Nov.	23.3
11–13	30 Nov.–2 Dec.	22.2
14–20	3–9 Dec.	21.2
21–24	10–13 Dec.	20.0
25–27	14–16 Dec.	18.9
28–34	17–23 Dec.	17.8
35–38	24–27 Dec.	16.7
39–41	28–30 Dec.	15.6
42–45	31 Dec.–3 Jan.	14.4
46–52	4–10 Jan.	13.3
53–55	11–13 Jan.	12.2
56–62	14–20 Jan.	11.1
63–69	21–27 Jan.	10.0
70–76	28 Jan.–3 Feb.	8.9
77–83	4–10 Feb.	7.8
84–97	11–24 Feb.	6.7
98–108	25 Feb.–7 Mar.	5.6
109–132	8–31 Mar.	4.4
133–150	1–18 Apr.	5.6
151–160	19–28 Apr.	6.7
161–167	29 Apr.–5 May	7.8
168–174	6–12 May	8.9
175–182	13–20 May	10.0

[a] 1,250 bu (ca. 45 m^3) of wheat, 10 ft (ca. 3.05 m) deep, in a round, metal bin; temperatures simulated were in the center of the wheat mass, 6 ft (ca. 1.83 m) from floor. For days of observations, see text.

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Table 2.—Death rates[a] for the acclimated granary weevils, *S. granarius* (L.), confined individually with cut or whole kernels of wheat during a low-temperature segment (days 118 to 168, temperature 4.4 to 7.8° C) of a simulated sequence of farm bin temperatures

Day of sequence	Temp (°C)	On whole kernels[b]		On cut kernels		Significant difference[c] (no. alive)
		No. alive	Deaths/day	No. alive	Deaths/day	
118	Day 9 of 4.4	100		100		ns
			0.3077		0.2308	
133	End of 4.4	96		97		ns
			2.6111		1.7777	
151	End of 5.6	49		65		*
			3.9000		4.1000	
161	End of 6.7	10		24		**
			1.2857		3.0000	
168	End of 7.8	1		3		ns

[a] For the time interval between observation days.
[b] Each weevil was confined on one kernel of grain in a no. 2 gelatin capsule.
[c] Based on chi-square analysis of differences on number of weevils alive, with expected numbers being those on the cut kernels; ns = no significant difference, * = significant difference at the 5% level, ** = significant difference at the 1% level.

113, 151, 161, and 168 of the simulation sequence (Table 1), when temperatures had reached 4.4, 5.6, 6.7, and 7.8°C, respectively, weevils still alive were individually transferred to a new similar kernel that had been held under the same simulation sequence since day 110. Removed kernels were examined for evidence of feeding. Scanning electron photomicrographs were made of a few kernels exhibiting feeding damage (Granovsky 1978). Death rate and percentage of male and female survival on whole or cut kernels were determined.

Results and Discussion

Granary weevils fed on cut kernels at all test temperatures, 4.4 to 7.8°C. Death rates (Table 2) during 50 days of the simulation sequence, days 118 to 168, indicated significantly fewer (chi-square analysis) weevils alive on the uncut than on the cut kernels after exposure to temperatures of 5.6°C on day 151 (5% level) and to 6.7°C on day 161 (1% level). Also, death rates for 10-day intervals, based on chi-square analysis of the areas under each 10-day portion of the death rate curves, were significantly different at the 1% level. The difference in death rates was greatest between days 138 and 158, when temperatures were increasing from 5.6 to 6.7°C. On both whole and cut kernels, males died at a significantly faster rate than did females. Percentages of male and female weevils alive at the end of the 5.6°C exposure (day 151) on whole kernels were significantly different, as were survivals on cut kernels after 6.7°C exposure (day 161) (Table 3).

Mortality as a function of age was not directly studied, since grahary weevils can live up to 432 days and have at LT_{50} of 157 days (Back and Cotton 1926, Richards 1947). The survival of only four granary weevils to 182 days in the experiment indicates the influence of cold on mortality, with females having more cold tolerance.

Quantities eaten were not measured, but none of the 100 weevils maintained on uncut kernels were able to penetrate the pericarp and had a greater mortality rate. Therefore, regardless of the quantities eaten, the consumption of food by adult granary weevils at temperatures between 4.4 and 7.8°C was important to their survival. Food consumption and survival by granary weevils below optimum temperatures is of interest, since these weevils are flightless and therefore are likely to be subjected to winter farm bin conditions.

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Table 3.—Percentage[a] of acclimated male and female granary weevils, *S. granarius* (L.), surviving after being confined individually[b] on cut or whole kernels of wheat during a low-temperature segment (days 118 to 168, temperature 4.4 to 7.8°C) of a simulated sequence of farm bin temperatures

Day of sequence	Temp (°C)	On whole kernels			On cut kernels		
		% Males	% Females	Significant difference[c]	% Males	% Females	Significant difference[c]
118	Day 9 of 4.4	41.0	59.0	ns	47.0	53.0	ns
133	End of 4.4	41.7	58.3	ns	47.0	53.0	ns
151	End of 5.6	38.8	61.2	*	47.7	52.3	ns
161	End of 6.7	40.0	60.0	*	29.2	70.8	**
168	End of 7.8	0	100.0	**	0	100.0	**

[a] Based on total number alive on each observation date.
[b] Each weevil was confined on 1 kernel of grain in a no. 2 gelatin capsule.
[c] Based on chi-square analysis of differences, with expected sex ratio 1:1 (Richards 1947); ns = no significant difference, * = significant difference at the 5% level, ** = significant difference at the 1% level.

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