Effects of Moisture Content and Initial Insect Density on Ability of Rusty Grain Beetles (Coleoptera: Cucujidae) To Infest Whole Corn[1,2]

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ABSTRACT Rusty grain beetle (RGB), *Cryptolestes ferrugineus* (Stephens), progeny production on undamaged corn kernels (*Zea mays* L.) and on artificially damaged kernels was investigated at varying moisture contents and initial insect densities. Only three adult progeny were produced on undamaged kernels in both tests. The number of adult progeny produced on damaged kernels increased as moisture content increased from 11.3 to 14.8%, but was still low. Initial insect densities of 1, 2, 5, 10, 20, or 40 RGB on ten kernels of corn did not affect the low number of progeny produced on damaged kernels. These results indicate that even though a high proportion of stored corn contains breaks in the seed coat, growth of RGB populations would be slow if the corn is otherwise intact and is stored at or below 14.8% moisture content.

KEY WORDS Insecta, *Cryptolestes ferrugineus,* rusty grain beetle, stored products, *Zea mays,* progeny production, moisture content, population density.

The rusty grain beetle (RGB), *Cryptolestes ferrugineus* (Stephens), is a cosmopolitan pest of stored products, particularly stored grains (Throne 1987). RGB are frequently found in stored corn, *Zea mays* L. (Giles and Leon 1974; Horton 1982; Storey et al. 1983); however, there have been few studies investigating the biology of RGB on corn (Sheppard 1936; Throne and Culik 1989).

Sheppard (1936) reported that no larvae reared on whole corn kernels survived to the pupal stage. Throne and Culik (1989) investigated progeny production on undamaged corn kernels and on kernels that had been artificially damaged by slitting through the seed coat at the germ. Treatment conditions were 30°C, 43% and 75% RH, and initial insect densities of one female ovipositing on 20 ml (ca. 50 kernels) of corn for two weeks and ten females ovipositing on 20 ml of corn for three days. Few adult progeny were produced (means ranged from 0 to 3) at any of the treatment conditions on undamaged or damaged, whole kernels. As many as 43 progeny were produced on cracked corn.

Corn kernels are very susceptible to breakage during harvesting, drying, and handling (Christensen and Meronuck 1986). Although whole, damaged corn kernels were not conducive to RGB population growth in a previous study (Throne and Culik 1989), it is possible that such kernels may be susceptible to RGB infestation at conditions other than those tested. Throne and Culik (1989) suggested that

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[2] This article reports the results of research only. Mention of a proprietary product does not constitute an endorsement or a recommendation for its use by USDA.

RGB might be able to infest whole corn kernels if the infestation level was high enough. The objective of the present study was to determine whether initial infestation level or moisture content affect the ability of RGB to infest whole corn kernels.

Materials and Methods

The corn used in the study was 'Pioneer 3320', a dent variety commonly grown in the southeastern U.S. The corn was stored below 0°C for at least two weeks to kill insects that may have naturally infested the corn and was sieved on a U.S. standard no. 6 (3.35 mm) sieve to remove dockage. The insects used in the study were from a culture maintained on cracked corn at 30°C and 12:12 L:D. The culture was initiated with RGB collected on corn in Bamberg Co., SC, and second laboratory generation adults were used in the study.

Effects of moisture content. Three hundred kernels of corn with no obvious breaks in the seed coat were selected. Half of these were slit longitudinally through the germ with a razor blade (<1 mm deep) to simulate damaged kernels. Ten kernels of either damaged or undamaged corn were placed in cylindrical plastic cages. Each cage consisted of two cylinders. The top cylinder (45 mm i.d. by 13 mm high) was placed over the bottom cylinder (38 mm i.d. by 25 mm high), and the ends were covered with nylon screen (64 μ openings).

Five cages of each type of kernel (damaged or undamaged) were placed randomly on perforated false floors in each of three covered plastic boxes (40 by 27.5 by 16 cm high) containing humidity-controlling saturated salt solutions. The salt solutions used were K_2CO_3 for 43% RH, NaBr for 56% RH, and NaCl for 75% RH (Greenspan 1977). These relative humidities were chosen because the equilibrium moisture contents of 'Pioneer 3320' corn stored at these humidities correspond to the 11 to 15% range of moisture contents at which corn is normally stored in the southeastern U.S. A 300 g sample of whole corn was placed in each humidity box to check the moisture content weekly (with a Burroughs DMC-700 moisture computer). The humidity boxes were placed in an environmental chamber maintained at 30°C and 12:12 LD. This temperature was chosen because it is near the optimum for oviposition (Smith 1963, 1965), development (Rilett 1949; Smith 1965), and survival of RGB (Rilett 1949).

Ten 20- to 27-day old females were added to each cage after the corn had equilibrated for nine weeks. Females were removed from the cages after a one week oviposition period, and their species and sex confirmed (Banks 1979). Beginning three weeks after the females were first placed on the corn, adult progeny were removed from the corn weekly, using an aspirator, until a second generation of adult progeny began to emerge. The test was terminated 15 weeks after the females were first placed on the corn, at which time kernels were examined for presence of live adult progeny inside kernels.

The data were analyzed as a completely randomized design using the general linear models (GLM) procedure of SAS (SAS Institute 1987). Data for one cage were not included in the analyses because the initial females escaped. The data were transformed as log(progeny + 1) to stabilize the variances. Means and standard errors in the tables are for nontransformed data.

Effects of initial insect density. The methodology used was the same as described in the previous section, except as noted here. Cages were two cylinders (32 mm i.d. by 13 mm high) taped together with the ends covered with nylon screen. Either 1, 2, 5, 10, 20, or 40 21- to 28-day old RGB were added to each cage after the corn had equilibrated for eight weeks. In cages containing only one RGB, females were used. In cages containing two RGB, one male and one female were used. At higher densities, the RGB were not sexed until after completion of the experiment. Data for any cage in which the initial percentge of RGB that were females was not at least 40% were not included in analyses. Data for three cages were not included because of too few females. Data for an additional cage were not included because the initial adults escaped. There were four replications of each density, and the test was conducted at 75% RH. The test was terminated 16 weeks after RGB were first placed on corn.

Results

Effects of moisture content. Moisture content of the 300 g samples of whole corn in the humidity boxes was between 11.1 and 11.6% in the box containing K_2CO_3 (the mean of the 16 weekly observations=11.3%; SD=0.1%); 12.1 and 12.5% in the box containing NaBr (the mean of the 16 weekly observations=12.4%; SD=0.2%); and 14.6 and 15.0% in the box containing NaCl (the mean of the 16 weekly observations=14.8%; SD=0.1%). No adult progeny were produced on undamaged kernels at any moisture content (Table 1). Significantly more adult progeny (20) were produced on damaged kernels ($F=8.98$; df=1,23; $P(F>8.98)=0.0065$). The number of adult progeny produced on damaged kernels (Table 1) increased linearly with increasing moisture content ($F=8.58$; df=1,13; $P(F>8.58)=0.0117$), but was still low.

Table 1. Number of *Cryptolestes ferrugineus* adult progeny produced on damaged and undamaged corn at varying moisture contents*.

Grain condition	Moisture content (%)	Number of adult progeny X̄	SEM†	n‡
Undamaged	11.3	0.0	0.0	5
	12.4	0.0	0.0	4
	14.8	0.0	0.0	5
Damaged	11.3	0.4	0.2	5
	12.4	0.8	0.6	5
	14.8	2.8	1.1	5

* Ten females oviposited for one week on ten kernels.
† SEM=standard error of the mean.
‡ n=number of replications.

Effects of initial insect density. Moisture content of the 300 g sample of whole corn in the humidity box (75%) was between 14.6 and 15.1% (the mean of the 17 weekly observations=14.9%; SD=0.2%). As the initial insect density increased, the percentage of parent RGB dying during the one week oviposition period (Table 2) increased quadratically on undamaged kernels ($F=45.5$; df=2,19; $P(F>45.5)=0.0001$)

and linearly on damaged kernels (F=40.3; df=1,20; P(F>40.3)=0.0001). Most of the parent adults that died were males (172 of 202 that died were males, or 85.2%).

Only two adult progeny were found on undamaged kernels during the weekly examinations (Table 2) - both from the same cage that was set up at an initial insect density of five adults. During the final examination of kernels, an additional adult was found inside one of the kernels that was set up at an initial insect density of 40 adults.

Table 2. Initial number of females, parental mortality (males and females) during the one week oviposition period, and progeny production of *Cryptolestes ferrugineus* on undamaged and damaged corn at varying initial insect densities*.

Grain condition	Density†	Initial females		Parental mortality (%)		No. adult progeny		n§
		$\bar{X}$	SEM‡	$\bar{X}$	SEM‡	$\bar{X}$	SEM‡	
Undamaged	1	1.0	0.0	0.0	0.0	0.0	0.0	4
	2	1.0	0.0	0.0	0.0	0.0	0.0	4
	5	3.3	0.6	0.0	0.0	0.7	0.7	3
	10	5.3	1.5	26.7	6.7	0.0	0.0	3
	20	13.0	1.2	33.8	5.9	0.0	0.0	4
	40	23.0	4.2	35.6	2.8	0.3	0.3	4
Damaged	1	1.0	0.0	0.0	0.0	2.5	1.2	4
	2	1.0	0.0	0.0	0.0	2.0	0.7	4
	5	3.7	1.5	6.7	6.7	1.7	0.9	3
	10	5.3	0.6	30.0	10.0	2.0	0.6	3
	20	12.8	3.2	20.0	10.2	4.0	1.5	4
	40	20.0	2.9	51.9	5.1	3.0	0.4	4

* Parent RGB were removed after a one-week oviposition period.
† Number of RGB (males and females) per ten kernels.
‡ SEM = standard error of the mean.
§ n = number of replications.

More adult progeny (63) were produced on damaged kernels than on undamaged kernels, where only three progeny were produced (F=31.9; df=1,32; P(F>31.9)= 0.0001). However, progeny production was still low. Differences in the number of adult progeny produced at the different initial insect densities were not statistically significant (F=0.72; df=5,18; P(F>0.72)=0.62).

Discussion

Only three adult progeny were produced on undamaged kernels in the study, demonstrating that neither increased moisture content nor increased initial insect density increased the ability of RGB to infest undamaged kernels. Undamaged corn placed into storage should be safe from rusty grain beetle infestation; however, there is usually a high percentage of damaged kernels when corn is placed into storage (Christensen and Meronuck 1986).

Few progeny developed on whole kernels that were artificially damaged by slitting the seed coat. Mean number of adult progeny produced per ten kernels was always four or less following a one week oviposition period by one to twenty females (7 to 140 female-days). Throne and Culik (1989) reported that a mean of 43 progeny were produced when one female oviposited for two weeks (14 female-days) on 50 kernel equivalents of cracked corn. Therefore, even when the seed coat is broken, there are still relatively few progeny produced on whole kernels. This agrees with results from previous studies on whole wheat kernels (Rilett 1949; Mathlein 1971). These results indicate that even though a high proportion of stored corn contains breaks in the seed coat, growth of RGB populations should be slow if the corn is otherwise intact and is stored at or below 14.8% moisture content.

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