Survival of Immature Rusty Grain Beetles (Coleoptera: Cucujidae) on Various Particle Sizes of Cracked Corn[1,2]

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J. Entomol. Sci. 27(1): 65-70 (January 1992)

ABSTRACT Survival of individually-reared immature rusty grain beetles (RGB), *Cryptolestes ferrugineus* (Stephens), was determined on finely cracked, medium cracked, and coarsely cracked corn maintained at 30°C and 75% RH. The study was conducted to determine whether differences in progeny production on the various particle sizes of corn (as shown in an earlier study) could be attributed to inherent differences among the various particle sizes of cracked corn in their ability to support egg to adult development of RGB. The proportion of the test population surviving (number of live adults/number of eggs hatched) was 0.76 (214/280) for finely cracked corn, 0.79 (222/280) for medium cracked corn, and 0.72 (194/269) for coarsely cracked corn. These differences in survival were not statistically significant. Thus, the hypothesis that there are differences in inherent suitability of the various particle sizes of cracked corn for supporting egg to adult development of RGB is not supported.

KEY WORDS Insecta, *Cryptolestes ferrugineus*, rusty grain beetle, bionomics, survival, stored products, *Zea mays*.

The rusty grain beetle (RGB), *Cryptolestes ferrugineus* (Stephens), is a cosmopolitan pest of stored products, particularly of stored grains (Throne 1987). Although RGB infest corn, *Zea mays* L. (e.g., Horton 1982), few studies have reported on the biology of RGB on corn.

Throne and Culik (1989) reported on studies designed to optimize rearing conditions and elucidate the ecology of RGB on corn. Few RGB progeny were produced on whole corn and the developmental period was extended. The number of RGB progeny increased and the duration of development decreased as the particle size of cracked corn was increased. These authors suggested that the direct correlation between progeny production and particle size may have been related to an increase in moisture content as particle size increased. A second explanation suggested a direct correlation between particle size and oviposition rate and/or survival rate.

Examining the first of these hypotheses, Throne (1991a) demonstrated that equilibrium moisture contents of the various particle sizes of cracked corn were not statistically different. This indicated that differences in progeny development on the various particle sizes of corn could not be attributed to differences in

[1] Accepted for publication 2 December 1991.

[2] Names of products are included for the benefit of the reader and do not imply endorsement or preferential treatment by USDA.

moisture contents. Throne (1991b) subsequently reported that RGB laid more eggs in finely cracked corn (11.2 eggs/female/72h) than in medium cracked (9.6) or coarsely cracked corn (3.9). This indicated that the increase in the number of progeny associated with an increase in particle size was negatively correlated with the number of eggs deposited on the various particle sizes.

Thus, the increase in the number of progeny that were produced as the particle size of corn was increased (Throne and Culik 1989) probably was due to an increased rate of survival of immature RGB on more coarsely cracked corn. Such increased survival may have been due to the inherent superiority (e.g., high nutrient availability) of coarsely cracked corn for RGB growth. Alternatively, large numbers of eggs deposited on finely cracked corn relative to other particle sizes may have led to overcrowding of the immature stages and subsequent reduced survivorship. The present study was designed to confirm or refute one of the alternative explanations. RGB were reared individually on various particle sizes of cracked corn, eliminating the potential effects of overcrowding. Any differences detected in the rates of survival of immature RGB on the various particle sizes of cracked corn should thus be due to inherent differences in the suitability of the substrate.

Materials and Methods

RGB were obtained from cultures reared on coarsely cracked corn and maintained at 30°C, 60 to 65% RH, and 12:12 h photophase:scotophase (L:D). Coarsely cracked corn was defined as corn that passes a U.S. standard ¼″ sieve (6.3-mm openings) and is retained on a U.S. standard number 6 seive (3.35-mm openings). The cultures originated with RGB obtained in or around bins of corn on farms in Bamberg and Barnwell Counties, SC. RGB used in the experiment were from the second through fourth laboratory generations.

The variety of corn used for rearing and experimentation was 'Pioneer 3320,' the cultivar most commonly grown in the southeastern United States. For this study, corn was obtained from southern South Carolina in 1987. In the laboratory, corn was sieved over a number 6 sieve to remove dockage, and then frozen at ca. -1°C for at least two weeks to kill insects that may have infested the corn naturally.

To obtain 3 different particle sizes of corn, a combination of grinding and sieving procedures was employed. Finely cracked corn was prepared by grinding 75 g of corn in a Wiley mill (Thomas Scientific, Swedesboro, NJ) over a U.S. standard number 20 seive (0.85-mm openings). The ground corn was then seived over a U.S. standard number 40 seive (0.425-mm openings). Approximately 41 g of finely cracked corn were retained on the number 40 sieve. Medium cracked corn was prepared by grinding 42 g of corn in a blender (Waring 31B92, New Hartford, CT) until all corn passed through a number 6 sieve. Approximately 32 g of medium cracked corn were retained on a number 20 sieve. Coarsely cracked corn was prepared by grinding 40 g of corn in the blender until all corn passed through a ¼″ seive. Approximately 32 g of coarsely cracked corn were retained on a number 6 sieve.

Rearing containers were constructed by drilling 50 holes (9-mm diameter) into each of two plexiglass panels (22 × 12.5 × 1.3-cm thick). A sheet of 64-μ mesh nylon screen covered the holes on the bottom and rubber stoppers closed the holes from the top. There were four 1.2-cm long legs on each panel.

Nineteen replications were conducted. In the first replication, 25 samples of each particle size of corn were randomly placed in 75 of the 100 holes (50 holes per panel). In all other replications, 48 of the 50 holes in a panel were used, resulting in 16 samples of each particle size of corn per replication.

The amount of corn placed in each rearing hole was 0.32 g, a kernel equivalent. This value was obtained by averaging the weights of seven 100-kernel samples of 1987 crop 'Pioneer 3320' corn equilibrated to 10.7, 12.6, and 14.6% moisture contents (7 samples at each of the 3 moisture contents). The resulting weights were 32.04 g ± 0.86 (SD), 32.09 ± 0.94, and 33.12 ± 1.03, respectively, for an overall mean of 32.4 g. One kernel eqivalent of one of three particle sizes of corn was randomly placed in a hole and the hole was closed with the rubber stopper. After the holes were filled with corn, one or two panels were placed in covered plastic boxes (40 by 27.5 by 16 cm high) containing a perforated false floor below which was a saturated sodium chloride (NaCl) solution. This salt solution maintained the relative humidity at 75% (Greenspan 1977). A 300-g sample of whole corn was placed in each humidity box. The moisture content of this sample was monitored weekly using a Motomco® model 919® automatic grain moisture tester (Dickey-John Corp., Auburn, IL). Boxes were placed in an environmental chamber maintained at 30° ± 1°C and 12:12 L:D. Corn was maintained at these conditions for at least six weeks before insects were added. These temperature and relative humidity conditions were used in the study because they are close to optimal for RGB development (Smith 1965).

RGB eggs were obtained by placing 200 2-3 week old adult RGB in each of two 0.24-L jars half-filled with coarsely cracked corn and maintained at 30°C and 60 to 65% RH. Adults were removed after 24 h using a U.S. standard number 20 sieve. Eggs for the first seven replications were collected by examining the corn containing eggs under a dissecting microscope, and transferring eggs from the corn to the test cages with a flattened pin. Eggs for the last twelve replications were collected by placing ca. 15 ml of the corn containing eggs in a 75 ml flask, adding ca. 35 ml of water, shaking vigorously for ca. 5 sec., pouring the supernatant over a funnel lined with nylon screen (64-μ openings) and collecting the water in a beaker below the funnel, repeating the rinse twice more, rinsing the sieve with water and then discarding the corn, rinsing the material retained on the nylon screen onto a black cloth, and examining the material on the black cloth for eggs (Throne 1991b). The egg collection technique was changed during the experiment because the washing technique was more convenient. One egg was placed in each test cage using a flattened pin.

Corn in the test cages was examined for adult RGB eight weeks after the eggs were added. If no adult was found, the corn was inspected for immature RGB. If the immature RGB was alive, it was placed back into the cage and examined again after an additional four weeks.

The data were transformed to stabilize the variances by taking the arcsin (in radians) of the square-root of the proportion of RGB that survived to the adult stage on each particle size of corn in each replication. The data were then analyzed using the general linear models procedure (GLM; SAS Institute 1987) and weighting by n. Mortality occurring during the egg stage was presumed to be caused by handling. Therefore, data for RGB that died during the egg stage were not included in the analysis.

Results and Discussion

Moisture content of the 300-g samples ranged between 14.3 and 15.1%, a range that is close to optimal for RGB development (Smith 1965). There was some fungal growth on the corn in many of the cages, especially in cages in which the insects died. This appeared to be the same fungus that grows on the corn kernels when placed at high humidity, and is not assumed to be associated with the dead insects. Cages in which the RGB survived to the adult stage generally had less fungal growth, perhaps because the insect ate the fungus (Sinha 1965).

Differences among particle sizes in the proportion of RGB surviving to the adult stage were not statistically significant [Table 1; $F = 1.05$; $df = 2, 36$; $P (F > 1.05) = 0.36$]. The number of eggs tested at each treatment level was 313. Proportion survival was based on less than 313 eggs because eggs that did not hatch were not included in the analyses. Proportion survival (number of live adults/number of eggs that hatched) was 0.76 (214/280) for finely cracked corn, 0.79 (222/280) for medium cracked corn, and 0.72 (194/269) for coarsely cracked corn. The power of the test to detect a difference of 0.10 in proportion survival at the 90% confidence level was 0.90 (Cohen 1969).

Selvarajah (1987) also reared RGB individually from egg to adult on wheat flour (fine) and crushed wheat (coarse). Differences in rates of survival on crushed wheat and flour varied with temperature and relative humidity, but rates of survival on crushed wheat were always as high or higher than rates of survival on wheat flour. The sample size (15 to 30 eggs per treatment) for the experiment, however, was too small (Cohen 1969) to make meaningful comparisons of the effects of particle size on survival.

Table 1. Survival of immature rusty grain beetles on various particle sizes of cracked corn.

	Proportion survival			
	arcsin transformation		transformed back to proportions	
Particle size	$\bar{X}$*	SE*	$\bar{X}$	95% confidence interval
Finely cracked	1.12	0.23	0.81	0.61 - 0.95
Medium cracked	1.16	0.23	0.84	0.66 - 0.97
Coarsely cracked	1.08	0.28	0.78	0.58 - 0.93

* Mean ($\bar{X}$) and standard error (SE) of proportion survival in 19 replications (*n*) after arcsin square-root transformation (in radians) and weighting by numbers of eggs hatched in each replication. Differences among means were not statistically significant ($F = 1.05$; $df = 2, 36$; $\alpha = 0.05$; $P (F > 1.05) = 0.36$).

A greater proportion of the corn was discarded during preparation (grinding and sieving) as the desired particle size of the corn decreased. Most of the material discarded was probably endosperm, because endosperm is relatively dry and prone to cracking. The germ is oily and does not crack easily. Rate of survival of immature RGB reared on wheat containing germ is higher than for RGB reared on wheat not containing germ (Rilett 1949). Therefore, the loss of some endosperm, which constitutes 80 to 85% of a corn kernel (Zuber and Darrah 1987), should not have decreased the rate of survival of immature RGB in the study.

Most mortality occurred during the larval stage, as expected (Rilett 1949, Bishop 1959, Smith 1965). During the larval stage, on finely cracked corn 66 of 280 (24%) RGB died; on medium cracked corn, 58 of 280 (21%) RGB died; and on coarsely cracked corn, 74 of 269 (28%) RGB died (percentage larval mortality reported here differs from that in Table 1 because for Table 1 the data were transformed to stabilize variances and then the means were transformed back to the original scale.) The only mortality during the pupal stage was one RGB that died on coarsely cracked corn.

Combining data for all particle sizes, 24% of larvae and 0.1% of pupae died. Mortality on wheat has been reported as 9% for the larval stage and no pupal mortality at 90°F (ca. 32°C) and 75% RH on half of a wheat kernel (Rilett 1949); 31% for the larval stage and no pupal mortality at 90°F and 70% RH on half of a wheat kernel (Bishop 1959); and no larval or pupal mortality at 90°F and 80% RH on half of a wheat kernel (Bishop 1959). The percentage of larval mortality observed on corn in the present study falls within the range of larval mortality observed on wheat (0 to 31%) in previous studies.

In larger particles of grain, larvae generally burrow into the grain to complete development (Rilett 1949). This may provide protection from potential mechanical damage (e.g., adults walking on and damaging eggs) and cannibalism. If so, higher densities of RGB may be able to develop to the adult stage on larger particle sizes of corn. The results of the present study, however, indicate that there are no inherent differences in the suitability of the three particle sizes of corn for supporting survival of immature RGB to the adult stage when reared individually. Density effects still remain as a possible explanation for the differences observed by Throne and Culik (1989) in the number of progeny produced on the various particle sizes of corn.

Optimum densities for rearing RGB on various particle sizes of corn remain to be determined. Elucidating the interaction of RGB with their environment will enable researchers to optimize rearing conditions for mass culture and experimentation on RGB, and may also help improve management of this grain pest.

Acknowledgements

I thank M. Culik and P. Lang for technical assistance; V. Chew for advice on the statistical analysis; and J. Baker, H. Kawamoto, and J. Sedlacek for helpful comments on an earlier draft of the manuscript.

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