# Flight Activity of *Rhyzopertha dominica* (Coleoptera: Bostrichidae) in Response to Feeding Damage and Accumulation of Waste

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**ABSTRACT** The effects of insect-damaged wheat (*Triticum aestivum* L.) kernels, frass, and uric acid on flight initiation by the lesser grain borer, *Rhyzopertha dominica* (F.), reared in crowded and uncrowded cultures were determined. In all 3 treatments, beetles reared in uncrowded cultures had a significantly lower flight initiation rate than beetles reared in crowded cultures. Beetles reared in crowded cultures and exposed to insect-damaged wheat kernels had a significantly higher flight initiation rate than beetles exposed to whole or mechanically damaged wheat kernels. Although beetles in uncrowded cultures had a low flight response, the number of beetles initiating flight increased with exposure to increased concentrations of frass or uric acid. These results indicate that the high flight initiation rate of *R. dominica* reared in crowded cultures can be explained partially by greater insect-feeding damage and accumulation of waste in crowded compared with uncrowded cultures.

**KEY WORDS** *Rhyzopertha dominica*, flight initiation, crowding, damaged wheat kernels, frass, uric acid

THE LESSER GRAIN borer, *Rhyzopertha dominica* (F.), is an important primary pest of whole cereal grains, especially small grains such as wheat (*Triticum aestivum* L.), sorghum (*Sorghum vulgare* Pers.), millet [*Pennisetum typhoides* (L.) Leeke], and rice (*Oryza sativa* L.) throughout the world (Rees 1995). Both larvae and adults are able to attack whole, sound grain (Elek 1994). *R. dominica* adults are strong fliers and often are detected flying outside and inside grain-handling facilities during the warmest months of the year (Sinclair and Haddrell 1985, Fields et al. 1993, Dowdy and McGaughey 1994, Throne and Cline 1994, Hagstrum et al. 1994). The daily flight patterns of *R. dominica* have been described by Leos-Martinez et al. (1986) and Wright and Morton (1995).

High flight initiation rates have been observed in *R. dominica* adults reared in very crowded cultures compared with those reared in uncrowded cultures (Barrer et al. 1993, Aslam et al. 1994, Perez-Mendoza 1997). This suggests that rates of flight initiation increase in response to habitat deterioration. The effects of crowding on flight initiation in insects are usually associated with a reduction in the quantity and quality of food available, an increased accumulation of metabolic waste, or both (Tauber et al. 1984, Barrer et al. 1993, Fadamiro et al. 1996). However, the contribution of various factors present in crowded cultures such as insect-damaged kernels, frass, and uric acid in stimulating flight by *R. dominica* has not been studied. Frass produced by *R. dominica* consists of flour particles and excretory material (Rao 1969). Frass contains 67% fecal material composed mainly of starch (42.5%), uric acid (17%), protein nitrogen (13%), other nitrogenous compounds (7%), and glucose (3%). Therefore, high concentrations of frass lead to high concentrations of uric acid as population density increases (Jood and Kapoor 1993). The objective of the current study was to determine which components of a crowded culture were responsible for increasing flight activity. A field strain of *R. dominica* was exposed to insect-damaged wheat kernels, frass, or the uric acid component of frass to determine the contribution of each of these components of a crowded culture in increasing the rate of flight initiation.

## Materials and Methods

**Rearing Methods and Flight Initiation Assay.** Adults of *R. dominica* were collected in July 1996 in Manhattan, KS, by using Lindgren funnel traps (Lindgren 1983) baited with wheat and commercial aggregation pheromone (Trece, Salinas, CA). Adults used in flight tests were obtained from crowded or uncrowded cultures. Crowded cultures were started by introducing 350 adults on 400 g of hard red winter wheat in jars (1,000 ml). Uncrowded cultures were started by placing 1 newly hatched larva on a single kernel of wheat in each cell of multiple-well tissue culture plates (Corning, Corning, NY). Cultures of both rearing densities were maintained in light-tight plywood boxes developed by Aslam et al. (1994) at a photoperiod of 14:10 (L:D) h, 27 ± 2°C, and 65 ± 5% RH. Flight initiation by *R. dominica* was measured using the flight

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assay developed by Aslam et al. (1994). Batches of 50 adults were placed in a petri dish that had tefloned sides (Teflon PTFE 30 fluorocarbon resin, DuPont, Wilmington, DE) covered with an inverted funnel. The Teflon coating prevented insects from walking onto the funnel. The inner surface of the funnel was coated with glue (Sticky Stuff, Olsen Products, Medina, OH) and the number of insects trapped was recorded after 24 h.

**Effect of Insect-Feeding Damage on Flight Initiation.** In the laboratory, the rates of flight initiation were observed for *R. dominica* exposed for 6 h to hard red winter wheat with different types and levels of damage: clean whole kernels, insect-damaged kernels, mechanically damaged kernels, and wheat flour. Mechanically damaged wheat kernels were produced by milling whole fresh wheat kernels in a grinder (Hobart, Troy, OH) and sieving through a standard testing sieve (U.S. No. 12) with a mesh aperature of 1.68 mm. The wheat passing through this sieve was used. Wheat flour and whole-kernel wheat were provided by the milling laboratory of the Department of Grain Science and Industry at Kansas State University. Two levels of insect-damaged kernels were produced by allowing 100 and 350 adults (2–3 wk old) to oviposit for 8 d in 400 g of 13.6% moisture content hard red winter wheat at 27 ± 2°C and 65 ± 5% RH in glass jars (800 ml). Fifty days later, after the progeny emerged from the grain, whole and insect-damaged kernels were separated from the insects, grain debris, and frass that could be removed by sieving the cultures with a U.S. No. 12 sieve. The percentages of insect-damaged kernels in each culture were determined from 20 random samples of 100 kernels. A mean of 13 ± 3% (±SE) of the kernels were damaged by the progeny from 100 adults, whereas 68 ± 8% of the kernels was damaged by the progeny from 350 adults.

Groups of 100 newly emerged adults (4–6 d old) were removed from crowded and uncrowded cultures and placed randomly in glass jars (250 ml) containing 25 g of 1 of the 5 types of damaged wheat. These jars were placed in the culture room at 27 ± 2°C and 65 ± 5% RH. After 6 h, beetles were removed and placed in groups of 50, without food, in the flight assay chamber. The number of beetles that flew was recorded after 24 h. The experiment was a 5 × 2 factorial. Each treatment combination was replicated 10 times. Data from this experiment were analyzed with analysis of variance (ANOVA) (SAS Institute 1985). Mean numbers of insects flying were compared using least significant differences (LSD) (Steel and Torrie 1980).

**Effect of Frass Concentration on Flight Initiation.** This experiment examined the effect of frass concentration on flight initiation by *R. dominica* from uncrowded cultures. Frass was separated from cultures using a U.S. No. 30 sieve with a mesh aperture of 0.6 mm. Because crowded cultures of *R. dominica* contained 20% frass (unpublished data), a range of frass concentrations above and below this concentration (0, 9, 16, 28, and 50% wt:wt) was mixed with clean wheat. Beetles (3–6 d old) from uncrowded 5th-generation cultures were used. Batches of 100 beetles were transferred into glass jars (250 ml) containing 20 g of wheat with one of the frass concentrations. After 6 h of exposure, beetles were transferred in groups of 50 to the flight assay chambers without food. Ten replicates of 50 insects were tested. The experiment was conducted in a completely randomized design. Parameters for an equation to describe the relationship between frass concentration and percentage of insects initiating flight were obtained using linear regression (SAS Institute 1985).

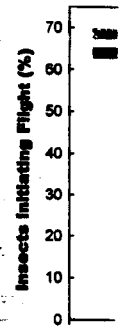
**Effect of Uric Acid on Flight Initiation.** The effect of uric acid on flight initiation by *R. dominica* from uncrowded cultures was assayed by mixing uric acid (Aldrich, Milwaukee, WI) with clean wheat + 5 g of flour to produce the following concentrations of uric acid: 0, 7.5, 12.5, 20, and 31.5% (wt:wt). Beetles (3–5 d old) from the 5th-generation uncrowded cultures were used. Batches of 100 were transferred into glass jars (25 ml) containing 20 g of wheat with one of the uric acid concentrations. The jars were placed in the culture room at 27 ± 2°C and 65 ± 5% RH. After 6 h, the beetles were removed and placed into groups of 50 in the flight assay chambers without food. After 24 h, the number of beetles that flew was recorded. Ten replicates of 50 insects were tested at each concentration. Parameters for an equation to describe the relationship between uric acid concentration and percentage of insects initiating flight were obtained using linear regression (SAS Institute 1985).

## Results

Flight initiation of *R. dominica* was affected significantly by insect rearing density ($F = 759.4$; df = 1, 90; $P < 0.01$). Beetles reared in crowded cultures tended to initiate flight more frequently than beetles reared in uncrowded cultures. Flight initiation was significantly different for beetles exposed to wheat with different kinds and levels of damage ($F = 23.6$; df = 4, 90; $P < 0.01$). The interaction of wheat damage and rearing density was also highly significant ($F = 10.6$; df = 4, 90; $P < 0.01$). Therefore, the data were analyzed by rearing density. Exposure of adults to insect-damaged kernels had a significant effect on flight initiation of the field strain of *R. dominica* reared in both crowded ($F = 27.7$; df = 4, 45; $P < 0.01$) and uncrowded cultures ($F = 3.6$; df = 4, 45; $P < 0.01$). Beetles reared in crowded cultures and exposed to 13 and 68% insect-damaged kernels tended to initiate flight more often than those exposed to clean, whole, wheat kernels; mechanically damaged wheat; and wheat flour (Fig. 1). The rate of flight initiation by beetles reared in uncrowded cultures and exposed to wheat with different kinds and levels of damage was higher than that of beetles exposed to clean, whole wheat.

Flight initiation increased linearly with frass concentration (Fig. 2) as described by the linear equation $Y = 1.4\ (\pm 0.3) + 0.05\ (\pm 0.1)\ x$, with $r^2 = 0.27$, $n = 50$, and $P < 0.01$, where $Y$ = percent of insects initiating flight and $x$ = frass concentration (%). Flight initiation also increased linearly with uric acid concentration (Fig. 3) as described by the linear equation, $Y = -18.3$



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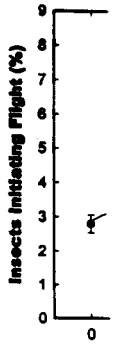


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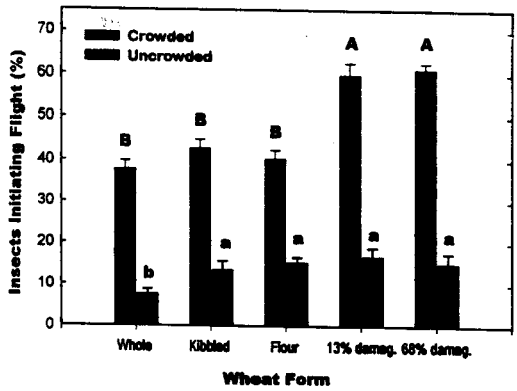


Fig. 1. Flight initiation by a field strain of *R. dominica*, reared in crowded and uncrowded cultures and exposed to wheat with different types and levels of damage. Mean ± SEM of 10 replicates per treatment, 50 insects per replicate. Means within a rearing density with different letters are significantly different ($P < 0.01$).

(±4.0) + 7.3 (±0.9) $x$ with $r^2 = 0.84$, $n = 15$ and $P < 0.01$, where $Y$ = percent of insects initiating flight and $x$ = uric acid concentration (%).

## Discussion

The presence of insect damage to kernels but not other types of kernel damage has a significant effect on the rate of flight initiation by *R. dominica*. Our results suggest that adult beetles are perhaps more likely to fly away from grain in which other beetles had fed in response to high levels of insect-damaged kernels or to waste products. A closely related bostrichid, *Prostephanus truncatus* (Horn), also responds to food depletion or unfavorable food quality by dispersing (Fadamiro et al. 1996). Reduced food quality or severe shortage of food also increased flight activity in certain locust species and some heteropteran species (Rankin and Singer 1984).

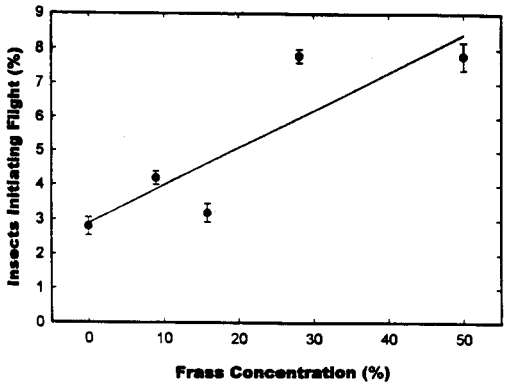


Fig. 2. Flight initiation by a field strain of *R. dominica*, reared in uncrowded cultures and exposed to different concentrations of frass. Mean ± SEM of 10 replicates per frass concentration, 50 insects per replicate.

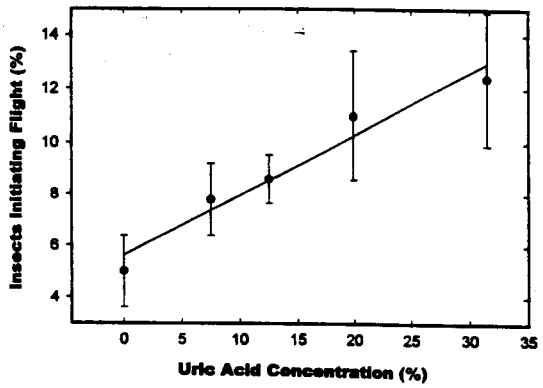


Fig. 3. Flight initiation by a field strain of *R. dominica*, reared in uncrowded cultures and exposed to different concentrations of uric acid. Mean ± SEM of 10 replicates per uric acid concentration, 50 insects per replicate.

*Rhyzopertha dominica* reared in uncrowded cultures had low flight initiation rates (Perez-Mendoza 1997). However, when these beetles with good nutritional history were exposed to high frass concentrations, the rate of flight initiation was high. Conversely, Rao (1969) found that *R. dominica* was not attracted to a food medium with 25% frass.

High concentrations of frass and insect-damaged kernels in crowded cultures of *R. dominica* and *P. truncatus* were correlated with high flight activity (Barrer et al. 1993, Fadamiro et al. 1996, Perez-Mendoza 1997). Our data also suggest that the increased flight activity by *R. dominica* from crowded cultures can be explained partially by an increase in insect-damaged kernels, frass, and uric acid in infested wheat. These data suggest that the number of lesser grain borer adults dispersing from a grain storage facility might depend on population size and the extent of food deterioration. The dispersing adults are likely to be <6 d old (Aslam et al. 1994). Young adult beetles may respond to poor resource quality, which is characteristic at the end of the storage season, by flying to another storage facility containing newly harvested grain.

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