# Flight Initiation of Lesser Grain Borer (Coleoptera: Bostrichidae) as Influenced by Temperature, Humidity, and Light

ALAN K. DOWDY

U.S. Grain Marketing Research Laboratory, USDA–ARS, 1515 College Avenue, Manhattan, KS 66502

J. Econ. Entomol. 87(6): 1714–1717 (1994)

**ABSTRACT** The rate that stored-product insects migrate by flight into a grain storage facility is influenced by environmental conditions that mediate flight activity. The influence that temperature, humidity, and light intensity have on the initiation of flight by the lesser grain borer, *Rhyzopertha dominica* (F.), was examined in the laboratory. Flight initiation by male and female beetles up to 8 wk old was examined. Lower and upper temperature thresholds for flight were calculated to be 19.9 and 41.6°C, respectively. Humidity did not influence flight initiation within this temperature range. The optimal temperature resulting in the highest percentage of flights was 30.7°C. Male and female *R. dominica* flight activity was similar. Greatest flight activity occurred in beetles up to 1 wk old, whereas older adults exhibited little flight activity. This suggests that, once *R. dominica* infest a bulk of grain, they tend to stay and reproduce rather than leave. Migration by flight is possible during the summer when wheat is harvested and stored, but temperatures may limit migration in fall when corn and sorghum are harvested or wheat is aerated. Early fall aeration when temperatures are >20°C could cause *R. dominica* to be attracted to volatiles emanating from the bin.

**KEY WORDS** lesser grain borer, stored-products, flight

THE LESSER GRAIN BORDER, *Rhyzopertha dominica* (F.), is a strong flyer (Winterbottom 1922, Leos-Martinez et al. 1986) with greatest flight activity occurring in late afternoon and evening, when temperature and light levels begin to decline (Sinclair & Haddrell 1985). Because *R. dominica* is a small poikilothermic organism, body temperature tends to be similar to that of the environment. For flight to occur, environmental temperature must be above a minimum threshold to allow the physiological processes necessary for flight to occur. Additionally, temperature must be below a maximum temperature at which the insect is unable to dissipate additional heat generated by flight activity (Mordue et al. 1980). Heat generated by flight can be lost by evaporative cooling, but this may result in desiccation in environments with low humidities (Mordue et al. 1980).

The migration of adults into a bin containing new wheat can result in economically important populations within a few weeks of storage (unpublished data). Aerating grain to reduce temperature to ≤17°C will reduce effectively the growth rate of insect populations and minimize grain damage (Burges & Burrell 1964). However, natural convection currents cause warm air to leave the storage structure, which creates a plume that contains grain and insect odors that are attractive to insects outside the structure (Barrer 1983, Dowdy et al. 1993). If outside air temperature and humidity are within the limits necessary for flight, *R. dominica* may be attracted to the odor plume originating from a grain bin, which results in increased migration. This possible increase in migration may reduce the benefits of aeration if grain is not cooled quickly to reduce insect population growth. By knowing how *R. dominica* flight initiation is affected by environmental conditions, we can estimate better when beetles are most likely to be attracted to a storage facility and can increase sampling efforts to detect beetles migrating into the grain mass. The objectives of my study were to examine the effects of temperature, humidity, and low light intensity on flight initiation of *R. dominica*.

## Materials and Methods

A flight bioassay chamber that has a 90-mm diameter glass filtering funnel (Kimax no. 28950, Kimble Glass, Vineland, NJ) with the inner surface coated with sticky material (Stiky Stuff, Olson Products, Medina, OH) inverted over a petri dish (9-cm diameter) containing beetles was developed by Aslam et al. (1994). The funnel stem was not sealed shut, and the petri dish sides were coated with Teflon PTFE 30 flurocarbon

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 the USDA.

resin (DuPont, Wilmington, DE) to stop beetles from walking onto the funnel edge. Flying beetles were trapped on the sticky inner surface of the funnel.

Before conducting the bioassays, all beetles were reared and maintained in a walk-in environmental chamber at a temperature of 28°C (±1°C), 65% RH (±5%), and a photoperiod of 14:10 (L:D) h. In each bioassay, beetles were placed in the petri dish and covered with the dish lid. One replication consisted of eight dishes containing 20 beetles each ($n$ = 160) at each environmental combination. The covered dishes were placed on a metal tray and put in an environmental chamber set at the desired temperature, humidity, and light levels. The beetles were left for 30 min to adjust to environmental conditions. The lids then were replaced with the inverted funnels. The number of beetles adhering to the funnels indicated the number that initiated flight and were recorded after 24 h.

The first experiment examined the effect of temperatures from 20 to 40°C (±1°C) in 5°C increments (five levels), and levels of 50% and 70% (±5%) RH on flight initiation of beetles ≤1 wk after eclosion. Beetles also were tested at 15 and 45°C in preliminary work, but no flight occurred and, thus, they were not included in this analysis. Light intensity was measured with a model LX-101 digital lux meter (Lutron, Taiwan) and measured 4,600 lux. This light level is comparable to the intensity ≈2 h before dark on a cloudless summer day. Beetles were separated by sex, and each temperature-by-humidity combination was replicated four times with four observations of each treatment combination per replicate for a total of 640 beetles tested for each combination. The experimental design was a split-plot with beetle sex and humidity levels arranged in a 2-by-2 factorial configuration as the main plot and with temperature at the subplot level.

The effect of insect age on flight initiation was examined in the second experiment. Newly emerged adults were collected from laboratory cultures at weekly intervals, and flight activity was tested for beetles at 1, 2, 4, and 8 wk of age. All beetles were categorized by sex, and bioassays were conducted at the same temperatures as experiment 1, 70% (±5%) RH and 4,600 lux light intensity. The experiment was conducted in a 5-by-2 factorial arrangement, and data were analyzed using a split-plot design, with temperature as main plot and age as subplot, and replicated twice, with one observation of each temperature by age level per replicate for a total of 1,600 beetles with 80 tested for each temperature-by-age combination.

A final experiment examined the initiation of flight by beetles ≤1 wk after eclosion exposed to three light intensities at optimal temperature determined in the first experiment. Low level light consisted of indirect illumination in the flight chambers by one pair of fluorescent lights (General Electric, 20-W, cool white) placed below the bioassay chambers. Light intensity measured 149 lux beside the bioassay chambers. A medium and high light level were obtained with direct lighting above the bioassay chambers using one or two pairs of fluorescent lights, respectively. Light intensity was 2,335 lux for the medium level, and high intensity measured 4,600 lux. Although the highest light intensity did not approach the brightness outside on a sunny day (about 100,000 lux), the range of light levels gives insight into how low light intensity, typical of conditions within 2 h of sunset on a clear day, affects flight initiation of the lesser grain borer. This experiment was conducted at 30°C (±1°C) and 70% (±5%) RH. Data were analyzed using a randomized complete-block design with four replications and eight observations per light level per replicate, for a total of 640 beetles tested at each light level.

In all experiments, the percentage of beetles that initiated flight after 24 h in each bioassay chamber was calculated. All data were subjected to analysis of variance (ANOVA) (SAS Institute 1985), and means separations were done using least significant differences (LSD) (Steel & Torrie 1980). Using data from the first experiment, a quadratic model was constructed to predict the percentage of beetles that would fly at a particular temperature, and a lack of fit $F$-test was used to determine how well the model fit the data (Neter et al. 1983). The lower and upper temperature thresholds at which flight ceases were predicted from this model, as was the optimal temperature for flight.

**Table 1. Effect of temperature and humidity on the flight activity of female and male *R. dominica* (mean ± SEM) ($n$ = 32 for each mean)**

| Temp, °C | Female | | Male | |
|---|---|---|---|---|
| | 50% RH | 70% RH | 50% RH | 70% RH |
| 20 | 2.5 ± 0.8a | 0.3 ± 0.3a | 0.9 ± 0.5a | 1.6 ± 0.8a |
| 25 | 26.9 ± 3.5b | 21.6 ± 3.1b | 25.3 ± 2.4b | 24.7 ± 2.9b |
| 30 | 35.9 ± 4.1c | 35.9 ± 3.9c | 35.3 ± 3.9c | 38.1 ± 3.9c |
| 35 | 28.1 ± 1.5b | 35.3 ± 3.4c | 24.7 ± 3.5b | 30.6 ± 3.9d |
| 40 | 10.9 ± 1.9d | 15.3 ± 2.5d | 6.3 ± 1.2d | 14.1 ± 1.6e |

Within a column, means followed by the same letter are not significantly different ($\alpha$ = 0.05, least significant difference (LSD) = 3.4).

## Results and Discussion

The number of flights initiated was similar for male and female *R. dominica* across all temperature by humidity combinations ($F$ = 1.40; df = 1, 3; $P$ = 0.32) (Table 1). Aslam et al. (1994) also showed that sex of the beetle had no significant effect on *R. dominica* flight activity. Temperature exhibited a great impact on flight activity. Fewest beetles initiated flight at the lowest and

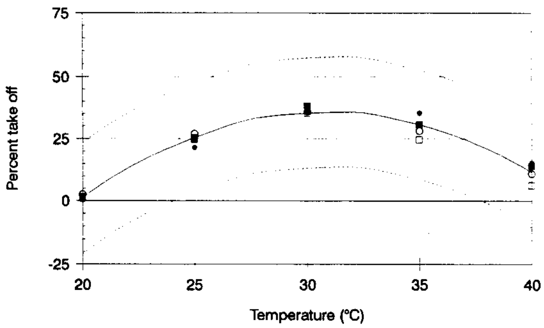


**Fig. 1.** Percentage of *R. dominica* adults predicted to initiate flight at temperatures from 20 to 40°C (±95% CLM). At 50% RH, ○ = female, □ = male; at 70% RH, ● = female, ■ = male.

highest temperatures tested, whereas most activity occurred around 30°C ($F = 47.18$; df = 4, 48; $P = 0.0001$). In the field, Sinclair & Haddrell (1985) documented that a temperature of at least 26°C was required before beetles were collected in a flight trap. My data show that few flights were initiated at lower temperatures (20°C). Thus, the likelihood of detecting flying beetles in the field probably increases as temperatures increase to an optimal level for flight. Humidity did not significantly affect flight activity ($F = 3.04$; df = 1, 3; $P = 0.18$). This agrees with the field data of Sinclair & Haddrell (1985). Interaction was not significant for humidity-by-temperature ($F = 1.04$; df= 4, 48; $P = 0.40$), temperature-by-sex ($F = 0.33$; df = 4, 48; $P = 0.88$), or for the three-factor interaction ($F = 0.07$; df = 4, 48; $P = 0.99$) (Table 1).

The following quadratic model was developed using data from the first experiment (Table 1):

$$y = -240.03(\pm 25.40) + 17.83(\pm 1.76)x - 0.29(\pm 0.03)x^2$$

where $y$ = the percent of beetles initiating flight and $x$ = temperature (°C) ($r^2 = 0.72$; $n = 20$) (Fig. 1). The lack-of-fit test was not significant, indicating that the model fits the data ($F = 0.07$; df = 2, 15; $P > 0.05$). According to this model, the minimum temperature that *R. dominica* initiates flight is 19.9°C, and the maximum temperature is 41.6°C. The temperature at which the highest percentage of beetles would fly is 30.7°C.

At temperatures >20°C, 1-wk-old *R. dominica* initiated significantly more flights than did older beetles ($F = 93.51$; df = 3, 34; $P = 0.0001$) (Table 2). Aslam et al. (1994) and Barrer et al. (1993) report similar results at 27°C and 65% RH and at 32°C and 65% RH, respectively. The effect of temperature on each age class was not significant ($F = 4.48$; df = 4, 4; $P = 0.09$). But, interaction between temperature and age was highly significant ($F = 8.66$; df = 12, 34; $P = 0.0001$) (Table 2). The flight activity for beetles ≤1 wk old was

**Table 2. Effect of insect age on the flight activity of *R. dominica* at five temperatures (mean ± SEM) ($n$ = 4 for each mean)**

| Temp, °C | Age (wk) post eclosion | | | |
|---|---|---|---|---|
| | 1 | 2 | 4 | 8 |
| 20 | 0a | 0a | 0a | 1.3 ± 1.3a |
| 25 | 27.5 ± 3.2a | 0b | 1.3 ± 1.3b | 0b |
| 30 | 21.3 ± 3.8a | 7.5 ± 3.2b | 2.5 ± 2.5b | 0b |
| 35 | 26.3 ± 3.1a | 6.3 ± 2.4b | 1.3 ± 1.3b | 2.5 ± 1.4b |
| 40 | 13.8 ± 3.8a | 1.3 ± 1.3b | 0b | 0b |

Within a row, means followed by the same letter are not significantly different ($\alpha = 0.05$, LSD for age = 2.4, LSD for temperature = 6.6).

similar to that of the other studies but was minimal for the three older age classes at all temperatures. The data from all three studies suggests that the initial colonizing beetles flying into a grain storage are young and, thus, likely to stay in the grain mass once they arrive.

High light intensity resulted in significantly more *R. dominica* initiating flight than did the medium and low intensities ($F = 13.28$; df = 2, 88; $P = 0.0001$) (Table 3). Leos-Martinez et al. (1986), Sinclair & Haddrell (1985), and Winterbottom (1922) reported that most flight activity occurs during late afternoon and evening and that little flight activity occurs under normal dark conditions (Leos-Martinez et al. 1986). Unfortunately, no light intensities were reported by these authors, but we would expect levels to be declining through afternoon and evening. In the laboratory, Barrer et al. (1993) reported higher flight activity 135 to 85 min before dark than between 70 and 20 min before dark. The light intensities I tested correspond to approximately the last 2 h before dark on a summer day with no cloud cover (personal observation). The highest light level tested probably coincides with the time of the greatest flight activity reported by Barrer et al. (1993). Initiation of flight was again similar for both sexes at each light level ($F = 0.01$; df = 1, 88; $P = 0.92$), and the light level-by-sex interaction was not significant ($F = 0.52$; df = 2, 88; $P = 0.59$) (Table 3).

From a practical standpoint, the migration rate of *R. dominica* into a storage facility should be correlated with environmental temperature. Highest rates of migration would be expected at temperatures ≈31°C and would decrease as the

**Table 3. Effect of light intensity on the flight activity of female and male *R. dominica* (mean ± SEM) ($n$ = 16 for each mean)**

| Light level | Female | Male |
|---|---|---|
| High | 32.8 ± 3.2a | 35.6 ± 2.6a |
| Medium | 26.3 ± 2.6b | 23.8 ± 3.1b |
| Low | 21.3 ± 2.4b | 20.3 ± 2.2b |

Within a column, means followed by the same letter are not significantly different ($\alpha = 0.05$, LSD = 5.3).

temperature moves toward the upper and lower flight thresholds. Migration by flight is possible during the summer when wheat is harvested and stored. Temperatures may limit migration in fall when corn and sorghum are harvested or wheat is aerated. However, some early-fall aeration of wheat could occur when temperatures are >20°C, and it is possible that additional beetles would be attracted to grain volatiles emanating from the bin. Additionally, many insects sun themselves to warm up on cold days; therefore, some flight may still occur when the temperature is <20°C. If grain is aerated when temperatures are below the flight threshold, then no insects would be expected to fly to bins. Fall-harvested crops might be harvested late enough to escape infestation until the following spring and summer.

## Acknowledgments

I thank W. E. Blodgett for assistance in the laboratory and D. W. Hagstrum for assistance with the flight chamber.

## References Cited

**Aslam, M., D. W. Hagstrum & B. A. Dover. 1994.** The effect of photoperiod on the flight activity and biology of *Rhyzopertha dominica* (Coleoptera: Bostrichidae). J. Kans. Entomol. Soc. 67: 107–115.

**Barrer, P. M. 1983.** A field demonstration of odour-based, host-food finding behaviour in several species of stored grain insects. J. Stored Prod. Res. 19: 105–110.

**Barrer, P. M., N. T. Starick, R. Morton & E. J. Wright. 1993.** Factors influencing initiation of flight by *Rhyzopertha dominica* (F.) (Coleoptera: Bostrichidae). J. Stored Prod. Res. 29: 1–5.

**Burges, H. D. & N. J. Burrell. 1964.** Cooling bulk grain in the British climate to control insects and improve keeping quality. J. Sci. Food. Agric. 15: 32–50.

**Dowdy, A. K., R. W. Howard, L. M. Seitz & W. H. McGaughey. 1993.** Response of *Rhyzopertha dominica* (Coleoptera: Bostrichidae) to its aggregation pheromone and wheat volatiles. Environ. Entomol. 22: 965–970.

**Leos-Martinez, J., T. A. Granovsky, H. J. Williams, S. B. Vinson & W. E. Burkholder. 1986.** Estimation of aerial density of the lesser grain borer (Coleoptera: Bostrichidae) in a warehouse using dominicalure traps. J. Econ. Entomol. 79: 1134–1138.

**Mordue, W., G. J. Goldsworthy, J. Brady & W. M. Blaney. 1980.** Insect physiology. Wiley, New York.

**Neter, J., W. Wasserman & M. H. Kutner. 1983.** Applied linear regression models. R. D. Irwin, Homewood, IL.

**SAS Institute. 1985.** User's guide: statistics, version 5th ed. SAS Institute, Cary, NC.

**Sinclair, E. R. & R. L. Haddrell. 1985.** Flight of stored products beetles over a grain farming area in southern Queensland. J. Aust. Entomol. Soc. 24: 9–15.

**Steel, R.G.D. & J. H. Torrie. 1980.** Principles and procedures of statistics: a biometrical approach, 2nd ed. McGraw-Hill, New York.

**Winterbottom, D. C. 1922.** Weevil in wheat and storage of grain in bags. A record of Australian experience during the war period (1915 to 1919). South Australian Government Printer, Adelaide.

*Received for publication 21 December 1993; accepted 12 May 1994.*