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The Effect of Photoperiod on the Flight Activity and Biology of *Rhyzopertha dominica* (Coleoptera: Bostrichidae)

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ABSTRACT: Patterns of *Rhyzopertha dominica* (F.) biology were studied at photoperiods of 16:8, 14:10, 12:12, 10:14, 8:16, and 6:18 (L:D). Aspects of biology studied included flight activity of a lab and field strain, and oviposition, egg hatch, developmental time and larval-pupal survival for the lab strain. Egg hatch and larval-pupal survival were unaffected by photoperiod. The longest scotophase significantly delayed development, increased egg production and reduced flight. Oviposition was highest at 8:16. Young females at all photoperiods had a higher rate of oviposition than older females. Flight occurred primarily throughout the photophase, and the number of flights did not vary with sex. Flight activity of 3- and 6-day-old adults was significantly higher than that of 9-day-old adults. Adults from the field strain flew more frequently than those from the lab strain. Time of day did not affect the flight patterns of lab-strain adults, but field-strain adults flew more frequently in the first 2 hr of the photophase at all photoperiods. Based on photoperiod alone, this study suggests that young *R. dominica* should tend to fly more in the summer during wheat harvest and oviposit more in the late fall, winter and early spring.

Effects of photoperiod on the seasonality of stored-product insect biology rarely have been studied. This limited interest is perhaps because of the general conception that stored-product environments are constantly dark or artificially lighted. Stamopoulos (1989) studied the effects of photoperiods on several aspects of the biology of *Acanthoscelides obtectus* Say. A long scotophase increased fecundity, egg hatch, and the number and weight of emerging adults, and decreased larval mortality and developmental time. Cymborowski and Giebultowicz (1976) found that a 12 L:12 D photoperiod reduced developmental time of *Ephestia kuehniella* Zell. by three days compared with development under constant darkness. The time of year that several species of stored-product pyralid moth pests diapause can be determined by photoperiod (Cox and Bell, 1991). These studies indicate that seasonal variation in photoperiod can influence the biology of stored-product insects in situations of natural light exposure.

Rhyzopertha dominica (F.) is a major pest of stored grain that shows seasonal flight patterns (Fields et al., 1993) and is commonly trapped in the field away from masses of stored grain (Cogburn, 1988). For this species, photoperiod has been shown to affect daily flight patterns (Leos-Martinez et al., 1986) and response to an aggregation pheromone (Obeng-Ofori and Coaker, 1990). Pajni and Shobha (1979) showed that *R. dominica* tends to fly in the light and oviposit in the dark. They also suggested that this species may have a reproductive diapause. Therefore, the objective of our study was to examine the effect of photoperiod on flight

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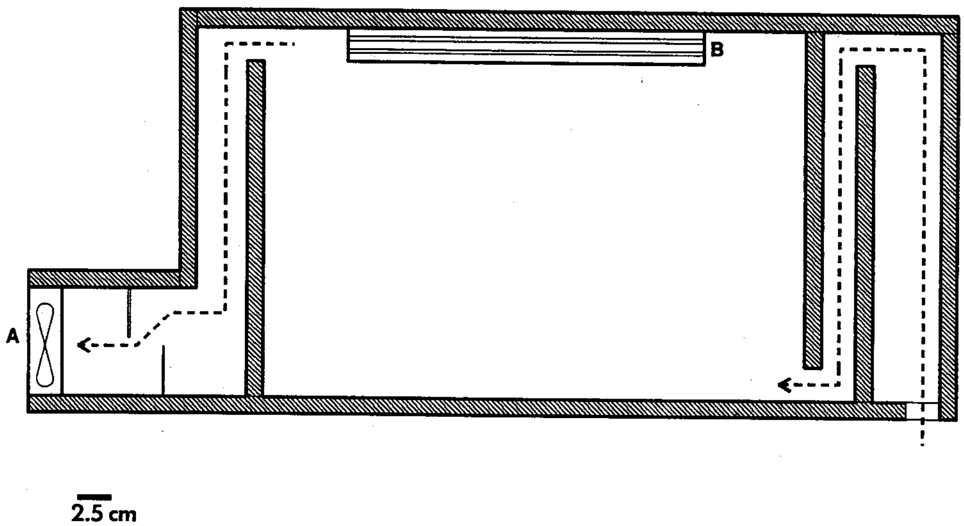

Fig. 1. Cross-section of light-tight box constructed from plywood. Dotted line shows the path of air movement through the box. A series of baffles makes the box light-tight. A = fan, B = fluorescent light on 24 hr timer.

activity, reproduction, development, and survival of *R. dominica* and determine if photoperiod regulates the behavior and biology of *R. dominica.*

Material and Methods

All rearing and experiments were carried out in light-tight plywood boxes (Fig. 1) kept in a rearing chamber maintained at 27°C, 65% RH. Light sources were Philips F8T5/CW fluorescent lights (425–470 lux). Each box contained baffles to keep them light tight and to allow electric fans to circulate air through the boxes. Photoperiods used in these studies were 16 hr light : 8 hr dark (16L : 8D), 14L : 10D, 12L : 12D, 10L : 14D, 8L : 16D, and 6L : 18D. Adults used in experiments were reared from eggs in half pint jars on wheat held at appropriate experimental photoperiods.

Experiments on flight activity, reproduction, development and survival were done with *R. dominica* from a long-term laboratory colony (=lab strain) maintained at the U.S. Grain Marketing Research Lab in Manhattan, Kansas. In addition, parallel studies on photoperiod effects on flight activity were done with field-collected *R. dominica* (=field strain). Adults were trapped in Keats, KS in October 1991 using Lindgren funnel traps (Lindgren, 1983) containing wheat and baited with aggregation pheromone (Trece, Inc.). At least 50 of these adults were placed in each of the six photoperiods and allowed to oviposit. The first generation of adults produced from these cultures were used in flight studies. All adults used in flight studies were starved for 18 hr prior to the experiment.

Flight activity was assayed by placing 50 adults without food into the bottom half of petri dishes (10 × 85 mm) with tefloned sides at 2:30 P.M. on the day prior to test. Just prior to lights going on at 8:30 A.M. on the morning of the test, petri dish covers were replaced with inverted 95-mm diameter glass funnels coated with glue (Stiky Stuff, Olsen Products, Inc.). After 24 hr, the glass funnels were removed and the number of *R. dominica* caught in the glue were recorded. Eight replicates of lab-strain adults were run at a 12L : 12D photoperiod to determine the effect of age and sex on flight activity. Adults were sexed by the method of Stemley and Wilbur (1966). In addition, numbers of adults trapped were determined during the light phase and the dark phase. An additional 10 replicates each of lab and field strains were run to determine variation in flight activity versus time of day at 6 photoperiods. Numbers of adults trapped were recorded at 2 hr intervals during the light phase. All data were analyzed using analysis of variance and mean separation was done by Tukey's procedure at $P = 0.05$ (SAS Institute, 1985).

Oviposition rates at different photoperiods were determined by placing a female : male pair of newly-emerged *R. dominica* adults in 25 ml vials with 10 ml of wheat. Adults were transferred to a vial with fresh wheat every 3–4 days. The old vials (with wheat) were filled with 70% ethanol, shaken, and the contents sieved through a #20 sieve into a glass petri dish (15 × 100 mm). Numbers of eggs collected from each vial were recorded. The test was replicated with 30 male : female pairs.

Egg to adult developmental times were determined at different photoperiods by placing an individual egg onto a single, punctured wheat kernel. Kernels were kept in individual cells of 24-well culture plates (Corning). Percent egg hatch, percent larval-pupal survival, and total developmental time (oviposition to adult emergence) were recorded. The test was replicated 40 times.

Results

Flight activity was strongly affected by the age of the adult. Three-day-old adults (7.4 ± 2.4 flights/50 adults) and six-day-old adults (8.0 ± 1.4 flights/50 adults) tended to fly significantly more than 9-day old adults (2.4 ± 1.0 flights/50 adults) ($F_{3,148} = 4.22$, $P = 0.02$). Given the effect of age on flight activity, other flight studies were done with 6-day old adults. Sex of the adults had no significant effect on flight frequency (4.1 ± 1.5 vs. 5.0 ± 1.3 flights/50 adults for male and female, respectively) ($F_{1,24} = 0.48$, $P = 0.49$). However, the phase of the photoperiod significantly affected the frequency of flight, with nearly all flight activity occurring during light (7.4 ± 1.3 vs. 0.6 ± 0.2 flights/50 adults during light and dark periods, respectively) ($F_{1,48} = 39.3$, $P < 0.0001$). Length of the photoperiod had some effect on flight frequency of the lab strain (Fig. 2), with more adults flying during long photoperiods. Adults from the field strain flew significantly more frequently at all photoperiods than adults from the lab strain ($F_{1,638} = 136.5$, $P = 0.0001$) (Fig. 2), but the length of photoperiod did not significantly affect the number of flights in 24 hr. The time of day had no effect on flight frequency of the lab strain ($F_{7,297} = 0.84$, $P = 0.84$), but significantly affected flight frequency of the field strain ($F_{7,308} = 10.41$, $P = 0.0001$) with a significantly larger number of adults flying in the first 2 hr ALO (Figs. 3, 4).

Photoperiod affected immature developmental time. *R. dominica* development was significantly delayed by the short (6:18) versus the long photoperiods (16:8, 12:12, and 10:14) ($F_{5,192} = 3.25$, $P = 0.0076$) (Table 1). In contrast, photoperiod had no significant effect on percent egg hatch ($F_{5,84} = 0.86$, $P = 0.51$) or larval survival ($F_{5,36} = 1.44$, $P = 0.23$) (Table 1). Female adults laid significantly more eggs per day during short photoperiods versus long photoperiods ($F_{5,1767} = 8.32$,

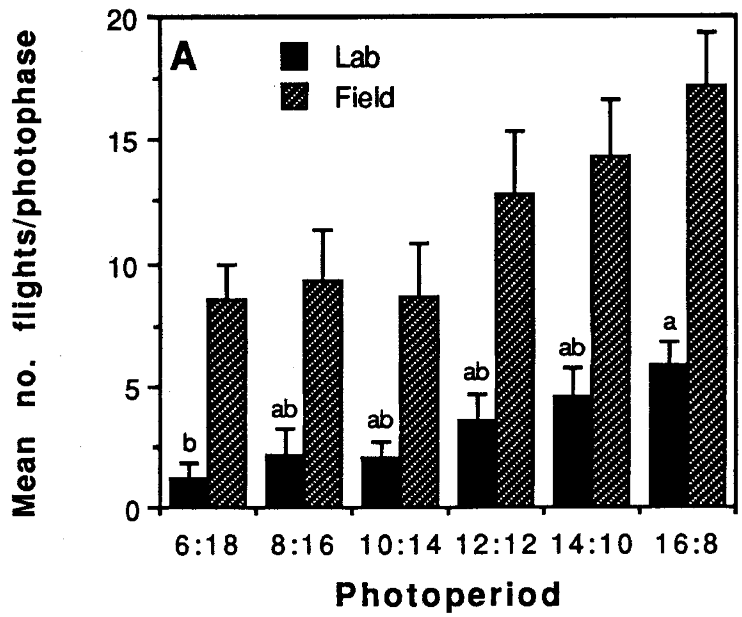

Fig. 2. Effect of photoperiod on flight frequency of a lab strain and field strain of *Rhyzopertha dominica*. Number of flights are expressed as the mean of number of insects out of 50 individuals in each replicate flying during the entire photophase of each photoperiod. Means followed by the same letter are not significantly different by Tukey's procedure at the 0.05 probability level.

$P = 0.0001$) (Table 1). In addition, young females at all photoperiods laid more eggs per day than old adults ($F_{11,1767} = 6.32$, $P = 0.0001$) (Fig. 5). Interaction between photoperiod and age were not observed ($F_{55,1767} = 0.91$, $P = 0.66$).

Discussion

While *R. dominica* normally infests masses of stored grain where there is limited amounts of light, they are often trapped in the field away from such masses (Cogburn, 1988). Adult behavior, therefore, may be affected by photoperiod or the availability of light. In lab-strains, the flight activity of *R. dominica* was strongly affected by both the age of the adult and the phase of the photoperiod. Reduced frequency of flight by adults 9-days old versus 3- or 6-day-old adults suggests that newly emerged adults may tend to fly for approximately one week before settling in a habitat such as stored grain, and that they tend to remain in the grain because of reduced flight activity. Reduced flight activity of older adults was also noted by Barrer et al. (1993) who found that starvation increased flights of *R. dominica.* In contrast with our results, Barrer et al. (1993) found that flight activity increased during the last 6 h of the photophase. Additionally, our observations of low flight activity in the dark is consistent with the results of Pajni and Shoba (1979). In our experiments, insects were deprived of food for 18 hr prior to tests. Although the presence of food or the use of sated adults might reduce the number of flights observed in our assays, the focus of this study was on the regulation of adult behavior away from grain masses.

Flight frequency of lab-reared adults were primarily affected by age and phase

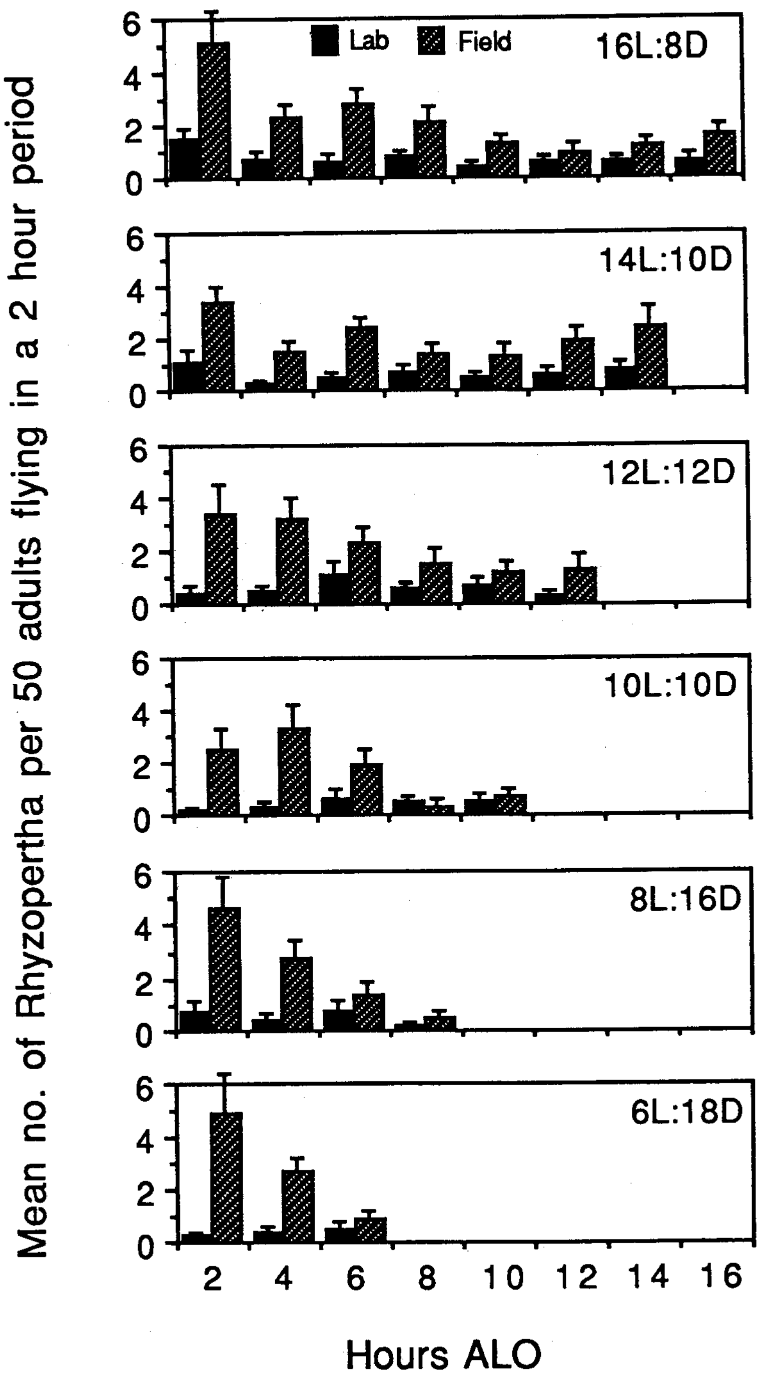

Fig. 3. Effect of time of day on flight frequency of a lab strain and field strain of *Rhyzopertha dominica* at different photoperiods. Number of flights are expressed as the mean of number of insects out of 50 individuals in each replicate flying during each 2 hour period of the photophase. Time is measured as the number of hours after lights on (ALO).

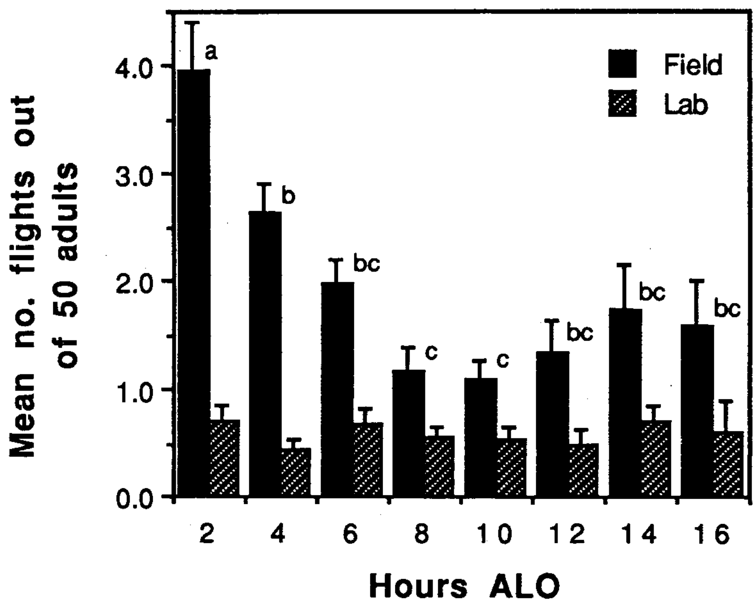

Fig. 4. Effect of time of day on flight frequency of a lab strain and field strain of *Rhyzopertha dominica.* Number of flights are expressed as the mean of number of insects out of 50 individuals in each replicated unit flying during each 2 hour period of the photophase. Time is measured as the number of hours after lights on (ALO). Means for the field strain followed by the same letter are not significantly different by Tukey's procedure at the 0.05 probability level. No significant differences were found between means for the lab strain.

of photoperiod. Although more adults from the lab strain flew in longer versus shorter photoperiods (Fig. 2), their flight was distributed relatively evenly throughout the day regardless of photoperiod (Figs. 3, 4), indicating that more flight occurred at longer photoperiods due to the greater amount of time available for flight (i.e., more "daylight"). In contrast, the number of field-strain adults flying during photophase was the same at all photoperiods (Fig. 2). This result seems due to the high variation between replicates and the fact that over one-third of the flights (37.4%) by field-strain adults occurred during the initial 2–4 hr of the

Table 1. Effect of photoperiod on oviposition, egg hatch, larval survival, and developmental time of *Rhyzopertha dominica.*

Photoperiod (hours L:D)	Eggs per female per day*	Percent hatch**	Percent survival**	Developmental time (days)*
16:8	1.56 ± 0.21 b	86.0 ± 4.0	28.6 ± 3.7	45.4 ± 0.8 b
14:10	1.93 ± 0.22 b	88.7 ± 2.2	25.4 ± 3.9	46.6 ± 0.8 ab
12:12	1.57 ± 0.19 b	84.0 ± 3.2	17.4 ± 4.3	45.3 ± 1.1 b
10:14	3.04 ± 0.31 a	90.0 ± 2.4	15.5 ± 5.0	44.6 ± 0.9 b
8:16	3.17 ± 0.31 a	83.3 ± 4.0	32.2 ± 9.0	46.7 ± 0.7 ab
6:18	2.37 ± 0.23 ab	89.3 ± 2.0	23.7 ± 4.4	49.3 ± 1.0 a

* Means followed by the same letter are not significantly different by Tukey's procedure at the 0.05 level.

** No significant difference by ANOVA *F*-test at the 0.05 level.

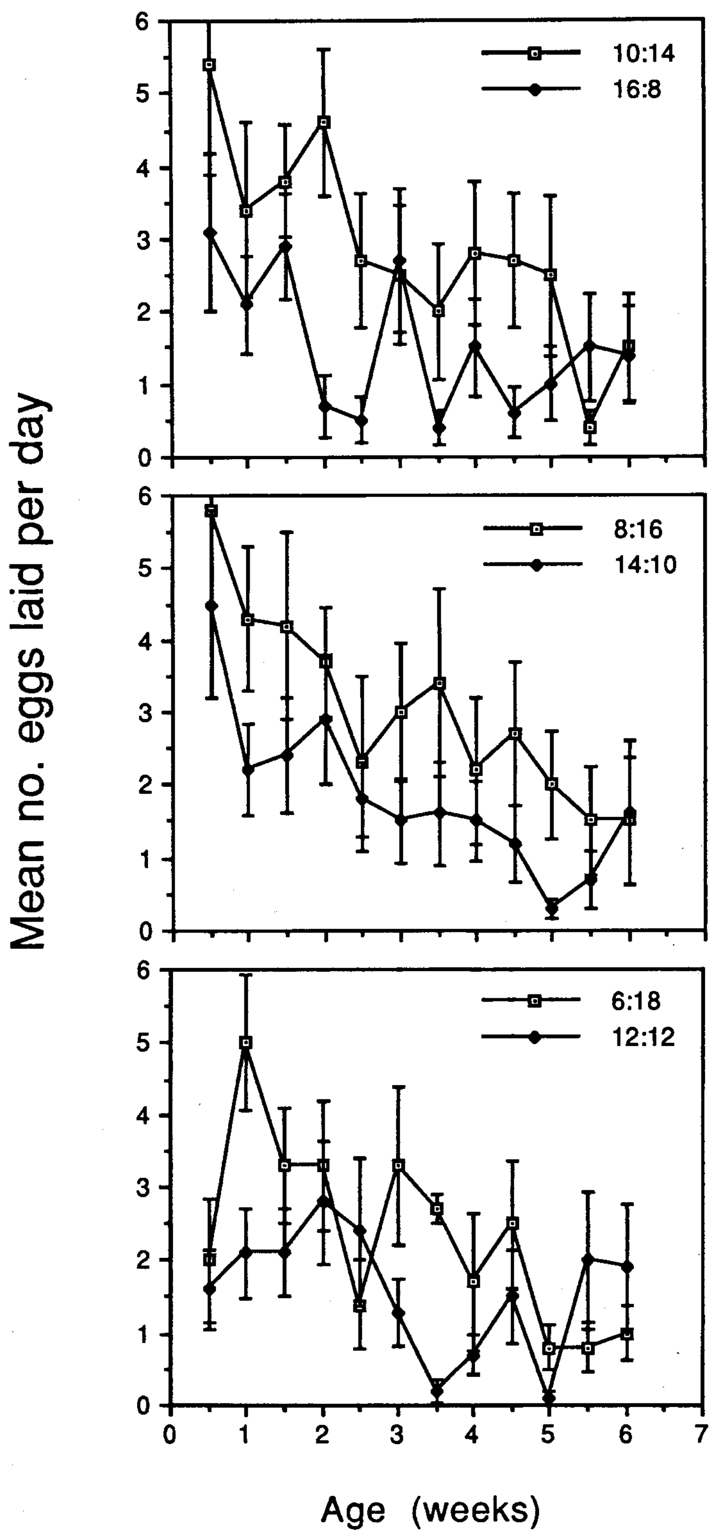

Fig. 5. Effect of age on egg-laying by female *Rhyzopertha dominica* at different photoperiods. Means are expressed as number of eggs laid per female per day in a half-week period.

photophase (Figs. 3, 4). In addition to showing a "morning" peak, adults from the field strain tended to fly more frequently than those from the lab-strain at all photoperiods and times of day. This difference would suggest that studies on the behavior of insects using lab strains should be interpreted with caution.

Diel patterns of flight activity and pheromone response of *R. dominica* have been previously reported (Leos-Martinez et al., 1986; Obeng-Ofori and Coaker, 1990). Although we observed a "morning" peak in flight activity, we did not see the equivalent of an "evening" peak. This observation is in contrast to previous field observations (Leos-Martinez et al., 1986). In our study, however, temperature was constant throughout the photophase. In the field, temperatures fluctuate throughout the day and these thermoperiods may regulate flight in the field in addition to photoperiod.

R. dominica lay eggs in grain masses and larval development occurs within the kernel where light does not reach. Given the dark environment, photoperiodic effects on immatures might be expected to be minimal. Our results support this hypothesis for egg hatch and larval survival. However, larval development was extended at the shortest photoperiod. This result is in contrast to other studies of stored grain insects in which immature developmental time is reduced at shorter photoperiods (Cymborowski and Giebultowicz, 1976; Stamopoulos, 1989). While immature *R. dominica* are confined to a "dark" environment, a photoperiodic effect on adult *R. dominica* might be expected based on their common occurrence in environments away from masses of stored grain and the possibility that *R. dominica* may have non-grain habitats (Wright et al., 1990).

Reproduction of female *R. dominica* was affected to some degree by photoperiod, as indicated by increased egg production at longer scotophases. At all photoperiods, we found that young females had higher rates of oviposition than old females (Fig. 4). The tendency for *R. dominica* flight to occur in the light and for oviposition to occur in the dark has been previously reported by Pajni and Shobha (1979) and is supported by our current studies. The increased oviposition at longer scotophases, therefore, is probably due to increased amounts of non-flight time. Pajni and Shoba, however, also reported the occurrence of reproductive diapause in *R. dominica.* They reported that *R. dominica* does not lay eggs from September to April and that eggs are absent from the ovaries during this period. Based on photoperiod alone, our results did not substantiate their observation as our insects laid eggs at all photoperiods.

In conclusion, we found some effect of photoperiod on oviposition, development and flight activity of *R. dominica.* Because the number of flights per 2 hr period was the same throughout the day, longer photophases resulted in more frequent flight. Similarly, higher rates of oviposition associated with longer scotophases also may be explained by length of non-flight time available for oviposition. In general, oviposition and flight studies suggested that, based solely on photoperiod, flight activity of *R. dominica* is extended during the summer while wheat is being harvested and stored, while oviposition occurs more frequently during late fall, winter, and early spring. *R. dominica* has a tropical origin (Potter, 1935), where seasonal phenomena (like rains) might require one part of the year to be preferred for oviposition. In addition, the interaction of temperature with photoperiod might enhance these phenomena, producing patterns more similar to those observed in the field.

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