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Effect of photoperiod on flight activity in *Graphosoma lineatum* (Heteroptera: Pentatomidae)

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***Graphosoma lineatum*, Pentatomidae, adult diapause, hibernation, photoperiod, flight activity, host plant, breeding site, foraging**

Abstract. Flight activity in a pentatomid bug, *Graphosoma lineatum*, was measured under different photoperiodic conditions. Insects started flying 3 days after adult ecdysis and the percentage of flying adults became highest about 1 week after the ecdysis, regardless of the photoperiod. Under long day (18L : 6D), high flight activity was continued, whereas under short day (12L : 12D), most adults stopped flying when diapause was induced. In both photoperiods, a small number of adults showed flight of a long duration, longer than 30 minutes. Thus, no evidence was found relating the long flight to diapause. It is suggested that diapause adults of *G. lineatum* do not overwinter far from their breeding sites and thus there is no migration to hibernation sites. Also, the long flight is probably only a foraging flight, enabling the bugs to find their dispersed host plants.

Introduction

In insects hibernating or estivating far from their breeding sites, the early period of diapause (or prediapause) is characterised by migration (Johnson, 1969). Experimental analysis often reveals that a diapause-promoting photoperiod induces not only diapause but also long-distance flight that is linked to the diapause syndrome. One of the classic examples of this dependence was recorded in the coccinellid *Hippodamia convergens* undertaking long migrations (Rankin & Rankin, 1980). A high flight activity was also recorded in heteropterans when they were kept under a diapause-inducing short-day photoperiod or collected from the field before overwintering (e.g. *Cletus punctiger*, *Lygaeus equestris*, *L. kalmii*, *Neacoryphus bicrucis* and *Oncopeltus fasciatus*) (Solbreck, 1971, 1978; Dingle, 1972, 1974, 1978, 1996; Caldwell, 1978; Ito, 1980).

The hibernation diapause of *Graphosoma lineatum* (L.) adults is induced by a short-day photoperiod in populations of different geographical origin (Popov, 1971; Musolin & Saulich, 1995; Nakamura et al., 1996). Hibernation sites of *G. lineatum* have not yet been described; we do not know how far away they might be from the breeding sites. The aim of this experiment was to find out whether photoperiodically induced diapause is connected with long flight; this might indicate a long migration to dormancy sites.

Material and methods

Adults of *G. lineatum* were collected from meadows and fields along the river Vltava in České Budějovice (49°N, 15°E), Czech Republic, from late May to October in 1995. Insects were reared as male-female pairs in petri dishes (8 cm in diameter, 1.5 cm in depth). Long-day (18L : 6D) and short-day (12L : 12D) photoperiods at 26°C were used throughout the experiments. Eggs were placed to long-day or short-day conditions within 24 h after oviposition. When the last instar nymphs ecdysed to adults, the experimental animals were kept in petri dishes as male-female pairs. All insects received the same mixture of dried seeds of various Daucaceae and water ad libitum. Mortality and oviposition were recorded daily.

A tethered flight method was used for measurements of flight duration. A fine pin was attached to the pronotum with a low-melting-point wax and the insect was placed in front of a low-speed fan. The air speed was not measured; it was identical during all measurements, similarly to temperature (25 ± 3°C). If the insect started flying within 2 minutes from switching on the fan, duration of the longest flight was measured. Otherwise, "no-flight" was recorded. Measurement was started 2 days after adult ecdysis and continued every day until 10 days after the ecdysis, and then at intervals of 5 days until 45 and 50 days after ecdysis in short day and long day, respectively.

Results

Under long-day conditions, oviposition started 15 to 30 days after adult ecdysis (Fig. 1A), whereas under short days no eggs were laid and the insects entered diapause (Fig. 1C).

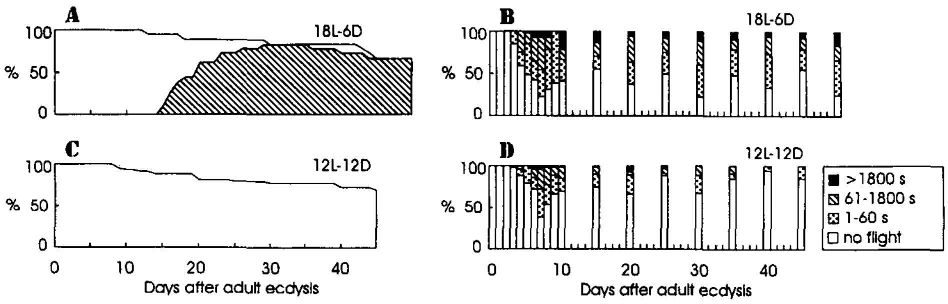

Fig. 1. Survival and oviposition (left) in females of *Graphosoma lineatum* reared in the laboratory from eggs at 26°C and the distribution of their flight activity (right). Open and shaded areas in A and C, survival and incidence of ovipositing females, respectively. n = 39–43.

Flight activity began on the 4th day after ecdysis in both long-day and short-day conditions (Fig. 1B, 1D). The proportion of flying adults gradually increased and became highest the 7th day after ecdysis. While many insects continued flying under long day (Fig. 1B), under short day, the incidence of flying females was very low after day 25 (Fig. 1D). Results in male adults were similar to those in females (Fig. 2).

The Chi-square test for the % flying did not show any significant difference ($p > 0.05$) at any day in both sexes. The U-test for the flight duration detected a difference between the two photoperiods only in

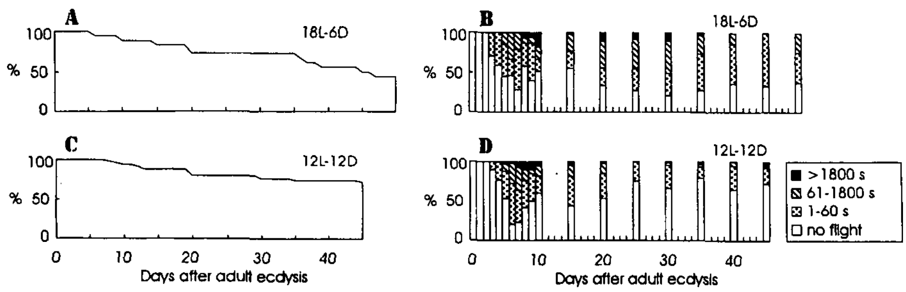

Fig. 2. Survival (left) in males of *Graphosoma lineatum* reared in the laboratory from eggs at 26°C and the distribution of their flight activity (right). n = 34–50.

males at day 45 ($p < 0.05$). When the difference among the photoperiods was analysed by Chi-square test, there was a significant difference in the % flying on days 25, 30, 35 and 40 in males and days 6, 10, 15, 20, 25, 30, 35, 40 and 45 in females. When the Kruskal-Wallis test was made for the flight duration, there was a significant difference on days 4, 20 and 30 in females, and there was no difference in males.

Discussion

Our results give only fragmentary information on the induction of long flight, as only the photoperiodic effect was studied, while the impacts of starvation and other factors were not analysed. Presence or absence of food has been recorded as an essential cue for some seed bugs. The females of a facultative migrant, the lygaeid *Neacoryphus bicrucis*, exhibited very little flight when given abundant food, but they flew when starved (both cases at a long day of 16L : 8D). They retained the flight capacity during several weeks of total starvation (Solbreck, 1978). The males flew both when starved and given abundant food. Crowding and a lack of mates were recorded as further cues for stimulation of migration in seed bugs, eg. in *Oncopeltus fasciatus* (Dingle, 1974). Also, in *Graphosoma lineatum*, continuing flight activity under long-day conditions may play an important role for males, enabling them to find mates throughout their adult life.

Flight activity in reproductive, well fed females decreases in many bugs (Dingle, 1965, 1966; Dingle & Arora, 1973; Kehat & Wyndham, 1973; Solbreck & Pehrson, 1979). The results in *G. lineatum* show quite an opposite picture. There is a certain similarity with *Dysdercus nigrofasciatus*. In contrast to *D. fasciatus*, in which fed females do not fly, *D. nigrofasciatus* keeps flight activity for the first several days of adult life, even under good food conditions. According to Dingle & Arora (1973), the different behaviour is related to the host plants of the two *Dysdercus* species: while *D. fasciatus* feeds on the constantly-abundant seeds of baobab (*Adansonia*), *D. nigrofasciatus* feeds on herbaceous plants which are scattered over the habitat and do not fruit continuously. Thus, this species retains some flight capacity, even when fed, to locate the scattered host plants. Several species of Daucaceae, the host plants of *G. lineatum*, successively produce seeds throughout the reproductive period of the insects. However, the seeds dry up quickly, fall off the plants and decay. Thus, females must move to find food in other places. Another bug, *Riptortus clavatus*, also keeps flight activity during reproduction (Natuhara, 1983), because this species lives long and lays eggs in many places to avoid great competition for food among nymphs (Ito, 1984; Natuhara, 1983). Present results for *G. lineatum* may indicate similarity to *R. clavatus*.

Diapause induces long-distance flight in some insects that show seasonal migration (Kennedy, 1961; Johnson, 1963). Such a flight related to diapause persists for a long time, while under a diapause-averting photoperiod the flight disappears in most bugs as soon as oviposition occurs (Dingle 1968; Solbreck & Pehrson, 1979). In short-day adults of *G. lineatum*, the incidence of flying individuals became highest 7 days after adult ecdysis, as in long days, but then decreased (Fig. 1D), probably due to the induction of diapause. It appears that *G. lineatum* does not perform migration flight related to diapause. The insects make short-distance flights to search for seeds several days after adult ecdysis. When they accumulate enough nutrients for hibernation, they probably overwinter on the place of the latest feeding, without moving further.

As correctly mentioned, it is very difficult to measure how food resources vary (Solbreck, 1978). The daucaceous plants preferred by *G. lineatum* are not rare, but they usually do not form large clusters and do not develop simultaneously on various localities. Thus, a steady movement may be advantageous for both searching for host-plants in a suitable developmental phase and to prevent larval crowding.

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