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# The effects of temperature on flight initiation in a range of moths, beetles and parasitoids associated with stored products

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**Abstract**

The effects of temperature on flight initiation in a range of stored-product pests and their parasitoids have been studied in laboratory flight chambers. Tests were conducted between 10 and 32.5 °C at intervals of 2.5 °C. The minimum temperatures for flight initiation in the stored-product moths *Ephestia kuehniella, E. elutella* and *Plodia interpunctella* were in the range 12.5–15 °C. For the stored-grain beetles, minimum temperatures for flight initiation varied from 17.5 °C for *Ahasverus advena* and *Typhaea stercorea,* 20 °C for *Rhyzopertha dominica*, 25 °C for *Tribolium castaneum*, to 27.5 °C for *Sitophilus oryzae*. The minimum temperature for flight initiation in the hymenopteran parasitoids, *Anisopteromalus calandrae* and *Lariophagus distinguendus*, was 17.5 °C. Flight is discussed as a factor in sustainable pest management strategies for storage insects; its importance in the spread of infestation and the likely success of physical and biological control methods is highlighted.


*Keywords:* Flight; Stored-product insects; Parasitoids; Flight chamber; Temperature

## 1. Introduction

Flight in insect pests and their parasitoids is important for the spread and control of infestation in stored-grain products (Giles, 1969; Sinclair and Haddrell, 1985; Barrer et al., 1993; Throne and Cline, 1994; White et al., 1996). Low temperature is likely to be the most important limiting factor for flight in countries such as the UK, with a temperate climate and where cooling of stored grain is becoming an increasingly important part of pest management strategy (Cox and Dolder, 1995; Cox and Collins, 2002). There is only a limited amount of information available on the effects of temperature on flight initiation for most storage pests, with detailed studies published for *Rhyzopertha dominica* (F.), *Ahasverus advena* (Waltl) and *Cryptolestes ferrugineus* (Stephens) (Dowdy, 1994; Cox and Dolder, 1995). The present study aims to fill the gaps in our knowledge for the more important pest and parasitoid species associated with stored-grain products.

Laboratory tests were conducted on six stored-grain beetles, the foreign grain beetle *A. advena*, saw-toothed grain beetle *Oryzaephilus surinamensis* (L.), lesser grain borer *R. dominica*, rice weevil *Sitophilus oryzae* (L.), rust-red flour beetle *Tribolium castaneum* (Herbst) and hairy fungus beetle *Typhaea stercorea* (L.), and three stored-product moths, the warehouse moth *Ephestia elutella* (Hübner), Mediterranean flour moth *E. kuehniella* Zeller, and Indian meal moth *Plodia interpunctella* (Hübner). These are all important pests of stored grain and grain products, although *T. stercorea* is a mould feeder usually associated with damp storage conditions (Jacob, 1988; Arbogast, 1991; Cox and Bell, 1991; Halstead, 1993). Two hymenopteran parasitoids of a number of different storage beetles including *Sitophilus* spp. and *R. dominica*, were also tested (Ghani and Sweetman, 1955; Steidle and Schöller, 1997). These parasitoids, *Anisopteromalus calandrae* (Howard) and *Lariophagus distinguendus* (Foerster), have been the subject of much interest as biocontrol agents (Cline et al., 1985; Flinn et al., 1996; Steidle and Schöller, 2002). The minimum temperature for flight initiation was determined for all species. In addition, the propensity to fly

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at a wider range of temperatures was examined for the beetles and their parasitoids.

## 2. Materials and methods

### 2.1. Insect strains and rearing conditions

The country of origin of each strain of insect tested and the number of years each had spent in laboratory culture at time of testing was as follows: *Oryzaephilus surinamensis* (UK, 1 year), *A. advena* (UK, 1 year), *T. stercorea* (UK, >10 years), *T. castaneum* (UK, 1 year), *R. dominica* (UK, >10 years), four strains of *S. oryzae* (UK, >10 years; Taiwan, >10 years; Nepal, >10 years; UK, 1 year), *E. elutella* (Switzerland, 2 years), *E. kuehniella* (UK, >10 years), *P. interpunctella* (Iran, 1 year), *A. calandrae* (UK, 8 years) and *L. distinguendus* (UK, 8 years).

*Rhyzopertha dominica* and *S. oryzae* were cultured on whole wheat grains. The other beetles and moths were cultured on standard cereal-based diets, mixes of flour and yeast for the beetles (Hole et al., 1976; Jacob, 1988) and a wheatfeed, glycerol yeast mix for the moths (Bell, 1975). The hymenopteran parasitoids were cultured on the grain weevil, *S. granarius* (L.) as hosts. All the insects were reared under standard laboratory conditions at 25±1 °C and 70±5% r.h.

### 2.2. Flight chamber

The flight chambers and methodology developed previously at CSL for studying flight activity in small insects have been used for the current tests on beetles (Cox and Dolder, 1995). Each flight chamber was constructed from a glass cylinder 25 cm tall with an internal diameter of 10 cm. Fifty insects were placed in a 7-cm diameter 'Fluon®' coated flight take-off dish containing a central cone projecting through a hole in the dish lid. Insects could only escape from the dish by climbing the central cone and flying out. For the tests, the flight dish containing the insects was placed in the bottom of the flight chamber and the chamber closed.

The suitability of the same methodology was assessed for studying flight in storage moths and parasitoids. Moths were able to escape from the take-off dish without actually flying, by jumping across from the central take-off cone to the edge of the dish. So, the system was modified by using a taller flight take-off dish with a longer and thinner central cone to ensure the moths could only leave the dish by flying out.

The parasitoids were able to walk over the Fluon bands, so again a different system was required. Methods using sticky surfaces suspended above the take-off dishes were considered and the use of time-lapse video recording was assessed but none was found to be practical. Finally, the flight take-off dish itself was modified further by inserting a thin plastic collar in the opening of the lid, projecting down into the dish. The collar was coated with a thin layer of white paraffin grease over which the parasitoids were unable to climb.

### 2.3. Test methodology

For each species and strain 100–300 adults, 0–3 weeks old, were used at each temperature tested. The number of adults flying out of the take-off dishes over a 24-h period was counted. After the tests, samples of adults were examined to confirm that males and females were present in approximately equal numbers (Corbet and Tams, 1943; Halstead, 1963; Boucek, 1988).

### 2.4. Test conditions

Tests were conducted at 70±5% r.h. and at temperatures in the range 10–32.5±1 °C at intervals of 2.5 °C. A light regime of 16 h light and 8 h dark (LD 16:8), incorporating a simulated dawn and dusk, was provided by a control unit, constructed by L.G. Collins at CSL from a 'Smiths' 7-day timer switch, a low speed electric motor and a 'Velleman K2657' electronic dimmer circuit, similar to that described by Bell and Walker (1973), which controlled a 'daylight blue' 60 W bulb and diffuser suspended above the insects. Tests were conducted at the same time each day and were synchronised with the light regime to enable handling of the insects to occur during the light phase. Test conditions were maintained in constant environment rooms. Adults were left in the test conditions for a minimum of 5 h prior to commencing each test.

## 3. Results

### 3.1. Beetles

The minimum temperatures for flight initiation ranged from 17.5 °C for *A. advena* and *T. stercorea,* to 20 °C for *R. dominica,* and 25 °C for *T. castaneum* (Table 1). The optimum temperature for flight initiation was in the region of 25–27.5 °C for *A. advena* and *T. stercorea* with a maximum of 82% and 70% flying, respectively. For *R. dominica* the optimum temperature was around 27.5–30 °C with just under 20% flying, while the highest number (15%) of *T. castaneum* flew at 30 °C.

Four strains of *S. oryzae* were tested but flight was observed in only one UK laboratory strain where the minimum temperature for flight was 27.5 °C (Table 2). No flight was observed in *O. surinamensis,* even at the highest temperature tested of 32.5 °C.

### 3.2. Moths

The minimum temperature for flight initiation in the moths was considerably lower than for the beetles, 12.5 °C in *E. kuehniella* rising to 15 °C for *E. elutella* and *P. interpunctella* (Table 3). Over 30% of the *Ephestia* spp. and around 10% of *Plodia* moths flew even at 17.5 °C.