Aerial dispersal behavior and positive phototropism of hatched larvae of bagworm moth, *Eumeta minuscula* (Lepidoptera, Psychidae)

Shintaro Funakoshi and Hiroyuki Tanaka
Ohgakikita High School, Nakagawa-cho 4-110-1, Gifu Pref., 503-0017 Japan

**Abstract** Experiments were carried out to examine whether the ballooning of hatched larvae was effected by larval phototropism and velocity of air. The orifice of the case was directed downwards and lit from beneath by an electric torch in a dark room. Many hatched larvae of the bagworm moth, *Eumeta minuscula* Butler, crawled down into the orifice of the case and dispersed on spinning cobwebs. The velocity of air had no effect on dispersal rates.

**Key words** Bagworm moth, aerial dispersal behavior, hatched larva, positive phototropism.

**Introduction**

Male imagoes of the bagworm moth have wings and can fly like other moths. On the other hand, female imagoes, whose forms are larval types, have no wings. They cannot fly and are in bags throughout their life. The later instar larvae of bagworms have excellent abilities in movement, and are often crossing streets and under the eaves of buildings. They have been located in isolated areas where it seemed impossible to crawl, for there were wide streets or city waterways hindering the route (Wakazono & Funakoshi, 2002). As the bags were found at the place where they had never been seen in the previous year, it was suggested that aerial dispersion, or ballooning by the hatched larvae occurred. Previously, there have been some investigations on the ballooning of bagworms (Marc & Gerhard, 1977; David et al., 1986). However, little is known about the ballooning and dispersal behavior of the hatched bagworm larvae in Japan. The objective of our study was to investigate the effect on ballooning of larval phototropism and velocity of air.

**Materials and methods**

About fifty hatched larvae of *Eumeta minuscula* were put in a semitransparent plastic case (8.0 cm high, 24.2 cm² diam.). This case was put in front of an electric fan under three conditions, i.e. (1) the orifice of the case was directed upwards in a lit room, (2) the orifice was directed downwards in the same room, and (3) the orifice was directed downwards and lit from beneath by an electric torch in a dark room. Pieces of white paper, measuring 1 × 5 m², were spread in front of the electric fan and a white curtain measuring 2 × 1.9 m² hung at a point 5 m from the fan. Air was blown against the plastic case for seven minutes on each of the fan's three settings, and the number of dispersed and stationary individuals was recorded. The hatched larvae, which had been carried off by the air, were searched for on the white paper and curtain. The flying distance, which the individuals had traveled, was measured from the case to the paper and curtain.

The filter paper, on which approximately fifty hatched larvae of *E. minuscula* were placed, was set up vertically and lit by an electric torch from 3 directions of left, right and down in...
a dark room (Fig. 1). To measure larval crawling ability downwards, the crawling velocity of larvae was measured from the center to the edge of the paper and recorded by a video camera. Also hatched larvae were put in the same conditions in the dark room. The experiments were carried out in July, 2001.

**Results**

Table 1 shows the rates of dispersed larvae of *E. minuscula* under the three conditions.

<table>
<thead>
<tr>
<th>orifice</th>
<th>upwards</th>
<th>downwards</th>
<th>downwards*</th>
</tr>
</thead>
<tbody>
<tr>
<td>stage 1</td>
<td>0 (50)</td>
<td>0 (50)</td>
<td>66.0 (50)</td>
</tr>
<tr>
<td>stage 2</td>
<td>3.7 (40)</td>
<td>0 (38)</td>
<td>61.9 (42)</td>
</tr>
<tr>
<td>stage 3</td>
<td>0 (52)</td>
<td>0 (52)</td>
<td>66.1 (59)</td>
</tr>
</tbody>
</table>

*Lighting from beneath by an electric torch in the darkroom.
( ): number of larvae used.
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Almost none of the hatched larvae flew from the case in the lit room. When the orifice of the case was directed upwards, hatched larvae crawled on the circumference of the case (Fig. 2). When the orifice of the case was directed downwards, hatched larvae crawled up the semitransparent case and wandered around on the bottom. On the other hand, when the orifice of the case was directed downwards and lit from beneath by an electric torch in the dark room, almost all of the hatched larvae crawled down into the orifice of the case and about 60% of all hatched larvae spun cobwebs and flew (Figs 3, 4). The velocity of air had no effect on dispersal rates.

The air velocity was measured at six point intervals from just in front of the fan during the three stages. The air velocities were different in each of the three stages. In the third stage, it was 2.3 times as large as it was at the first stage in front of the fan, whereas 5 m from the fan, it was 11.5 times as large (Fig. 5). The flying distances of hatched larvae of *Eumeta minuscula* are shown in Fig. 6. Though hatched larvae dispersed to a greater distance on the strong air of stage 3, the numbers of dispersed larvae were almost the same for the three velocities of air.

Fig. 7 shows the crawling velocity of hatched larvae on the vertical filter paper when lit from three directions. Every hatched larva crawled at almost the same velocity towards the lighting direction. The differences of velocity between right (1.139±0.175 mm/sec., *n* = 50) and left (1.152±0.152 mm/sec., *n* = 50) were not evident statistically. On the other hand, the downwards velocity was slower (0.939±1.183 mm/sec., *n* = 50). The differences of crawling velocity between down and right/left were significant statistically (*t*-test, *P* < 0.001).
The crawling velocity of hatched larvae on the vertical filter paper in the darkroom was slower than in the case towards the lit direction. The crawling velocity of hatched larvae in the darkroom changed from 0.17 mm/sec. to 0.46 mm/sec. The directions of crawling were different and changed rapidly in dark conditions (Fig. 8). It was not recognized to be negative geotropism.

**Discussion**

Spiders stand facing the wind and squeeze out a drop of silk which is expanded further by the wind. When the pull on the threads from the air currents is strong enough, the spider will float off into the air. As spiders have no wings, aerial dispersal in these animals is commonly known as “ballooning” (Decae, 1978; Yoshikura, 1987). The larvae of bagworms, the female of which cannot fly, might also disperse on the wind by spinning like a spider. But few hatched larvae flew on the air and it did not seem that they were able to fly actively. Fortunately, we found that right after eclosion, larvae have a strong positive phototropic inclination. Then, in the darkroom, a case containing the larvae was turned over and illuminated from below, then put in front of a fan. As a result, about 60 percent of the larvae...
were on the air for seven minutes. The force of the air did not have much effect on flying. Even on gentle air, in the first stage, hatched bagworm larvae can spin cobwebs and disperse on them.

Air velocity falls as the distance from the fan in the room increases, whereas wind velocity does not fall in the field. Wind speed stays regular at certain hours. It was thought that the wind brought hatched bagworm larvae to their respective distances. It was estimated that hatched bagworm larvae dispersed without having to wait for strong winds, because air moving slowly seemed to be enough for flying.

Nishida (1983) mentioned that probably positive phototropism allows the larvae to move in the light direction from the dark interior of the pupal case and the bag. Through this experiment, it is evident that hatched larvae have a stronger positive phototropic inclination than the negative geotropism which characterizes many insects' behavior. Females lay eggs on the top of the bag which are then closed inside the bag as a place for hatching. Hatched larvae crawl down the orifice towards the light and spin cobwebs for their flight from the bag. However, when lit from three directions we cannot understand why the crawling velocity of hatched larvae downwards is slower than towards right and left.

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References


摘要

チャミノガ孵化幼虫の空中分散と正の走光性（船越進太郎・田中浩之）

雌が翅をもたない幼虫型で、一生をミノの中で過ごすミノムシは、幼虫の空中分散が知られる。チャミノガ Eumeta minuscula Butler の孵化幼虫を使って幼虫分散を観察した。半透明のプラスチック容器にミノを作る前の孵化幼虫を入れ、扇風機の風を送って分散数や飛翔距離を測定した。暗室内で容器の口を下にし、下から懐中電灯の光を当てた場合、7分間で約 60% の幼虫が分散した。それに対し、明るい部屋で容器を上に向けた場合、幼虫は容器の口の周りを回るだけであり、下に向けた場合は上になった底に集まって、ほとんど分散は見られなかった。孵化幼虫にとって負の走地性よりも正の走
光性が優先した。約50匹の孵化幼虫を垂直に敷いたろ紙の上に置き、暗室内で光を一方から当てると、光の方向に向かう走光性を示したが、下に向かう幼虫の移動速度（0.939±0.183 mm/sec.）は左右に向かうもの（1.139±0.175 mm/sec., 1.152±0.152 mm/sec.）より劣っていた。光源をなくした場合は個体によってまちまちで、移動の方向は定まらず、負の走地性はみられなかった。また、移動速度も0.17 mm/sec.から0.46 mm/sec.の間で、光源に向かう速度に比べて遅いものであった。孵化幼虫の走光性の強さは、ミノの口は下に開口しており、ミノ上部で孵化した幼虫が開口部に向かうことを考えれば当然といえる。また、扇風機の風を3段階に切り替え実験を行ったが、孵化幼虫の分散数にはほとんど差がなく、ミノガ孵化幼虫は強風を待たずに分散していると推測された。飛翔距離は強風の下で長かったが、自然界では室内の扇風機のように風源から離れると風速が弱まることはなく、弱風でも風に乗って遠くまで分散するものと考えられた。しかし、それぞれの方向から光を当てた場合、孵化幼虫が左右に向かうより、下に向かう方が遅い理由は理解できなかった。

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