The life cycle of *Trhypochtoniellus crassus* (Warburton et Pearce, 1905)

(Acari: Oribatida)

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**Abstract** Ontogenetic development, reproductive method and faecal pellet deposition of *Trhypochtoniellus crassus* (Warburton et Pearce, 1905) in a *Sphagnum* mire at Akaiyachi in a mountainous district of Northeast Japan, were investigated using laboratory cultures and field surveys. During ontogenetic development, the number of pair of dorsal setae and genital setae changed in the sequence 10-14-14-14 and 0-2-4-6-7, respectively. This species is oviparous, and laid a maximum of 117 eggs (mean 41.6) per life cycle at 25°C. The parity mode and fertility were quite different from that of *Trhypochtoniella brevisetus*, living in *Sphagnum* mires in the subalpine zone. The adult deposited many faecal pellets under pieces of decayed tissues of *Phragmites australis*, the largest number at 25°C, with a maximum of 2,483 faecal pellets (mean 1341 pellets) per animal within a life span of 168 days (mean 70.7 days).

**Key words:** faecal pellet, fertility, Oribatida, oviparous, *Sphagnum* mire

**Introduction**

*Trhypochtoniellus crassus* (Warburton et Pearce, 1905) is an aquatic species (Behan-Pellletier and Eamer, 2007) recorded from some quite different habitats in Japan: high-mounted drinking water tanks (Asanuma et al., 1988), swimming pools (Tagami et al., 1992), *Sphagnum* mire (Kuriki & Yoshida, 1999) and moss cushions growing on city constructions (Aoki, 2000). The ecology of this species, however, has yet to be investigated in depth (Behan-Pellletier and Eamer, 2007).

Kuriki (1993, 1995, 1996, 2008) reported the life cycles of two dominant species (*Trhypochtoniellus brevisetus* Kuriki, 2005, and *Limnozetes ciliatus* (Schrank, 1803)) in a *Sphagnum* mire at Yachidaira, located in the subalpine zone (1,510 m above sea level) in Northeast Japan. These studies showed that *T. brevisetus* is thelytokous and ovoviviparous; deposits a small number of larvae one by one between July and early September in the field; takes one year for each developmental stage; and deposits many faecal pellets (1.15 mm² in volume) during its life span. It was also shown that *L. ciliatus* is oviparous and laid a mean of 3.4 eggs one by one at 25°C; and the adults deposited many faecal pellets, with a maximum of 1,528 per animal within a life span of 150 days.

The present study on the life cycle of a third species of oribatid mite in a humid habitat investigated some aspects of the life cycle of *Trhypochtoniellus crassus* living in a mire at Akaiyachi in a mountainous district (530 m above sea level), using laboratory cultures and field surveys. The reproductive process and faecal pellet deposition were compared with those of *T. brevisetus*.

**Study site and methods**

**Study site**

The *Sphagnum* mire at Akaiyachi is in the mountainous district (530 m above sea level, 37° 30' 41" N, 140° 00' 20" E) situated near the northeast shore of Lake Inawashiro in Fukushima Prefecture, northeastern Honshu, Japan. The mire is very moist and covered with *Phragmites australis* and *Sphagnum palustre*, forming a 10 cm layer of plant detritus. The ground is covered with deep snow from December to March and is inundated with water in April and early May. In the town of Inawashiro, about 10 km to the north-west of the mire and at the same altitude, the mean annual temperature is about 10°C. The surface temperature of the mire at 10 a.m. on the days of surveying was 4.5°C on April 14, 25.7°C on...
August 26 and 7.2°C on November 16.

**Population dynamics in the field**

One study plot for investigating population dynamics was set out in the mire 5 m away from the margin. Samplings of soil (including *Sphagnum* moss) were carried out at one-month intervals in 2007 in order to analyze the seasonal change of gravid rate and body size of each developmental stage, except for a period from December to March when the mire was covered with snow. The surveyed days were April 14, May 13, June 19, July 22, August 26, September 30 and November 16, 2007. On each survey day, about 500 ml of top soil (5 cm in depth including *Sphagnum* moss) were sampled by the gleaning method (Aoki, 1978). Mites were extracted with Tullgren apparatus over seven days.

**Laboratory cultures**

A few days after extraction from the soil samples, the adults taken on April 14 were reared individually in plastic vessels of 34 mm in diameter and 10 mm in height. The vessels were replenished weekly with distilled water and decaying tissues of *Phragmites australis*, and maintained at 15°C, 20°C or 25°C. On each occasion, 10 mites were reared. The number of faecal pellets and larvae released were counted every one or two days (because eggs deposited in or on decayed *P. australis* were invisible), following which they were removed from the vessels.

**Results**

**Morphological features of each developmental stage**

The morphological features of each developmental stage are shown in Fig.1.

**Adults.** Body length 460-590 μm, the largest in May and the smallest in July. Notogaster with 14 pairs of long smooth setae and a pair of *f₁* vestiges.

**Immatures.** Body length 200-280 μm in larvae, 240-300 μm in protonymphs, 310-400 μm in deutonymphs and 380-490 μm in tritonymphs. Prodorsum without sensillus on small pocket-like bothridium. Dorsal setae 10 pairs in larvae and 14 pairs in nymphs. Vestige *f₁* present in every stage. Number of genital setae (pairs) increased from 1 in protonymphs, through 4 in deutonymphs, to 7 in tritonymphs.

**Seasonal change of gravid rate and body size**

Most of the adults in April and May had several eggs in their body with a mean of 5.0 (maximum 8). The percentage of gravid females decreased to 57-65% in the summer season, and was almost zero after the end of September (Fig. 2). The immature stage was largest in body length in April or May, smallest in August (Fig.3).

**Reproductive process in the laboratory**

Fig. 4 shows the survival curves for adults at 15°C, 20°C and 25°C, obtained in spring (April 14, 2007), the inferred start of the reproductive season. All mites at 20°C and 25°C had died after only 36 and 24 weeks, respectively. On the other hand, 50% of the mites at 15°C were still surviving after 36 weeks, and one mite survived for 600 days. Table 1 shows the basic reproductive characters under different temperatures in these laboratory cultures. Life span was very long at 15°C, with a mean of 207.7 days, but only about a third of this at 20°C and 25°C. At all of these temperature, all mites laid many eggs, a mean of 25.1 at 15°C, 20.4 at 20°C, and 41.6 at 25°C. One mite at 25°C laid a maximum of 117 eggs, often at a rate of once day, within 168 days.

Fig. 5 shows two examples of egg deposition times at 25°C, along with the number of faecal pellets released each day. These mites were at the first or the second rank of fertility under this condition. In the upper example (animal No.7), the first larva was observed 12 days after the start of the culture. After that, the mite laid 75 eggs, one to six per day at intervals of 1-8 days, and died after 89 days. The second example (No.3) laid 117 eggs in total at intervals of 1-8 days, and died after 168 days. During their life, the total number of faecal pellets was 1797 for No.7 and 2483 for No. 3.

**Faecal pellet deposition**

Table 2 shows two aspects of faecal pellet deposition in laboratory cultures. The total number of faecal pellets during a life span at 20°C was the smallest among the three conditions because of the shortness of their life span. The maximum number of faecal pellets per individual and per day, however, increased with temperature. For two samples in fig. 5, the first mite deposited many faecal pellets, with a maximum of 56 per day and a total of 1797 pellets. The second mite deposited many more faecal pellets, with a maximum of 68 per day and a total of 2484. The faecal pellets are spherical or cylindrical in form, with a mean volume of 320 × 103 μm³ and a range of 220-460 × 103 μm³.
Fig. 1. *Trhypochtoniellus crassus* (Warburton et Pearce, 1905) from Akaiyachi.

Fig. 2. Seasonal changes in percentage of females gravid and frequency distribution of egg number carried by adults.

Fig. 3. Seasonal change of size distribution of *T. crassus* in the field.
The life cycle of *Trithochthoniellus crassus*

Fig. 4. Survival curves for adults collected on April 14, 2007, and maintained at different temperatures.

Table 1. Reproductive characters of adults collected in the spring season (April 14) in laboratory cultures.

<table>
<thead>
<tr>
<th>Character</th>
<th>15°C</th>
<th>20°C</th>
<th>25°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean life span (days ± SE)</td>
<td>207.7 ± 153.6</td>
<td>58.2 ± 33.9</td>
<td>70.7 ± 42.3</td>
</tr>
<tr>
<td>Oviposition rate of adults (%)</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Number of eggs released (minimum-mean-maximum)</td>
<td>6-25.1-41</td>
<td>6-20.4-36</td>
<td>5-41.6-117</td>
</tr>
</tbody>
</table>

Fig. 5. Faecal pellet deposition and newly released larvae and nymphs of *T. crassus* in culture condition (25°C) for two individuals: No. 3 and No. 7. ○, larvae; ●, nymphs.
Discussion

Morphological features of each developmental stage

Adults and immatures collected from the mire well agree with the description of specimens from the USA (Seniczak et al., 1998). Some setations of this species during ontogenetic development are as follows: 1) notogastral setae is 10 pairs in the larva and 14 pairs in nymphs and adult, 2) two pairs of adanal setae and one pair of anal setae appear in deutonymph and tritonymph, respectively, 3) the formula of genital setae is 1-4-7-9 (protonymph to adult), and 4) the epimeral setal formula is 2-1-2 in the larva, 3-1-3-1 in the protonymph, and 3-1-3-2 in the deutonymph, tritonymph and adult.

Population dynamics in the field

Some aspects of the life cycle of oribatid mites were ascertained by the gleaning method in field and laboratory cultures. In particular, the following data from the field survey provided more information for analysis of the life cycle: gravid rate, embryonic stage of the eggs in the adult body, and composition of body size of each developmental stage.

The present study showed that *Trhypochthioniellus crassus* is oviparous and is able to lay many eggs over a long period; and deposit numerous faecal pellets during its life span. In the adult stage, however, the gravid rate in the field showed a clear seasonal pattern with a peak in spring and a marked decrease after autumn. This seasonal pattern showed that the reproductive period of this mite is restricted to the period between spring and summer. This pattern is identical to that for *Trhypochthioniellus brevisetus*, the dominant species at Yachidaira mire in the subalpine zone (1,510 m above sea level) (Kuriki, 1995), and is probably applicable to most oribatid species in both mires because the soil temperature drops markedly outside this period. This reproductive period is also the developmental period for immatures: new small immatures appeared in August. The present study could not, however, ascertain the volitism in a year.

Kuriki (1995) showed that *T. brevisetus* has a development threshold of 8.5°C, and took five years per generation in the field. This study, however, could not determine the full life span of *T. crassus* because not all developmental stages of immatures were studied.

Reproductive process

Norton (1994) suggested that oribatid mites have one of three parity modes in relation to offspring development: oviposition, prelarviposition and larviposition. He also showed that most species exhibit oviposition while prelarviposition is present in the Superfamily Phthiracaroidae, some of the Eupthiracaroidae and the Desmonomata; and larviposition dominates in the aquatic genera *Trimalaconothrus* and *Maerkelotritia*. Kuriki (1993) reported that *T. brevisetus* is ovoviviparous and lays a small number of larvae, a mean of 10.5 at 25°C. It is obvious from the present study that *T. crassus*, from a mountainous district, shows a different reproductive pattern compared with *T. brevisetus*, despite both species belonging to the same genus.

Adaptive explanations for prelarviposition or larviposition for oribatid mites are possible in terms of reduction of the time during which eggs are exposed to predators or preclusion eggs are washed away by tidal action. However, such adaptive explanations are confounded by the existence of exceptions (Norton, 1994).

Norton (1994) suggested that the fecundity of oribatid mites is low relative to many other mite groups (usually only several dozen eggs or fewer per lifetime), but no taxonomic or ecological patterns are retrievable from the sparse data available. It is obvious that there is a great difference in fecundity between *T. brevisetus* and *T. crassus*, since the number of eggs or larvae laid per individual at 25°C was a mean of 10.5 and a maximum of 17 in *T. brevisetus* (Kuriki, 1993), 41.6 and a maximum of 117 in *T. crassus*, which laid many eggs almost every day. At 25°C, one female *T. crassus* laid an average of 27 eggs a week, which is markedly larger than the instantaneous clutch size of eight. Therefore, it is obvious that the mite produced new eggs after deposition,

### Table 2. Faecal pellets deposition by ten adults collected in the spring season (April 14) in laboratory culture.

<table>
<thead>
<tr>
<th>Temperature</th>
<th>15°C</th>
<th>20°C</th>
<th>25°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of faecal pellets during laboratory culture (mean ± SE)</td>
<td>1242.7 ± 642.0</td>
<td>730.2 ± 454.2</td>
<td>1341.3 ± 940.5</td>
</tr>
<tr>
<td>Maximum number of pellets per day (mean ± SE)</td>
<td>21.2 ± 5.2</td>
<td>28.2 ± 4.4</td>
<td>44.5 ± 11.2</td>
</tr>
</tbody>
</table>
and had a higher reproductive ability than *T. brevisetus*, which laid a maximum of three larvae a week at 25 °C. The main habitat for *T. brevisetus* is *Sphagnum* mires in the subalpine zone, where environmental conditions are cool, acid, and with few predators. On the other hand, the habitat for *T. crassus* varies, but is mainly humid mires at low altitude. Several factors influencing the fecundity of oribatid mites have been investigated, such as the spectrum of food quality, microclimatic factors and population density, but unfortunately these studies were seldom comparable. Norton (1994) suggested that future comparative studies will be needed to assess adaptation, especially those linked to studies of energetics. Also, a comparative study of the fecundity of *T. crassus* from different habitats is necessary in relation to predators.

**Deposition of faecal pellets**

It is expected that studying the faecal pellet deposition of oribatid mites will provide valuable information concerning the feeding habits and reproductive ability of the mite. Regarding feeding habits, Fain and Lambrechts (1983) considered *T. crassus* to be an external parasites of young *Discus* fish in aquariums. The present study, however, showed that *T. brevisetus* is as great a saprophagous mite as *T. brevisetus*.

Though the size of the faecal pellet of *T. crassus* is smaller than that of *T. brevisetus* (810 × 10^3 μm^3 in mean volume) (Kuriki, 1996), the number of faecal pellets deposited per day was very large. Therefore, the total volume of faecal pellets at 25°C in the adult stage of *T. crassus* (only during the culture period) was only slightly smaller than that of *T. brevisetus* (0.72 ml) (Kuriki, 1996).

Concerning reproductive ability, a great difference was discovered between *T. crassus* and *T. brevisetus*. It is considered that the assimilation efficiency of *T. crassus* may be higher than *T. brevisetus* in relation to food quality.

This study has provided information about reproduction and faecal pellet deposition in the adults of *T. crassus*. Because the morphological features of each developmental stage have now been elucidated, the following subjects of research can proceed in the future: determination of the full life history, relationship between fertility and some habitat factors such as food quality, population density and predators.

**Acknowledgement**

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**References**


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