Effects of Temperature and Humidity on Oviposition, Molting, and Longevity of *Dermanyssus gallinae* (Acari: Dermanyssidae)

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ABSTRACT The juvenile development and survival of *Dermanyssus gallinae* (De Geer) kept in vitro at different temperatures and humidity were investigated to obtain biological baseline data for a Swedish population. Individual females, eggs, larvae, and protonymphs were observed with regard to egg-production, duration of various stages, and longevity when kept at different temperatures and relative humidities. Female mites laid eggs at temperatures between 5 and 45 °C with the highest numbers laid at 20 °C and 70% RH, but development to larvae and protonymphs was only observed at temperatures ranging from 20 to 25 °C. The average duration of oviposition varied from 1.0 to 3.2 d within the temperature range 20–45 °C but was gradually increased to 28 d at 5 °C. Specimens survived for up to 9 mo without access to food when kept in the temperature range of 5–25 °C. Temperatures >45 °C and at ~20 °C were found to be lethal. Longevity was similar for females and protonymphs kept at 30 and 45% RH, but it was enhanced at 70 and 90% RH for protonymphs. This study showed that *D. gallinae* can survive for a long time without feeding if the microclimate is suitable, but it does not thrive at low relative humidities and at temperature extremes. This indicates that changing of the abiotic conditions in infested poultry houses could be a possible measure to reduce mite populations.

KEY WORDS *Dermanyssus gallinae*, temperature, humidity, longevity, oviposition

The chicken mite or poultry red mite, *Dermanyssus gallinae* (De Geer), and the northern fowl mite, *Ornithonyssus sylviarum* (Canestrini & Fanzago), are 2 of the more economically important ectoparasites of domestic fowl (Kettle 1993). A recent prevalence study (Högglund et al. 1995) showed that *D. gallinae* was the only hematophagous mite species found in Swedish poultry premises, and that this parasite constituted a well recognized problem for the poultry production in the country.

The chicken mite is a cosmopolitan ectoparasite of both wild and domestic birds (Evans and Till 1966). Birds are attacked mainly at night when nymphs and adults feed (Kirkwood 1968). Hence, most of its life cycle is spent off the host in cracks and crevices in roosting and nesting sites (Hearle 1938). Development is rapid and under favorable conditions the life cycle can be completed in 1 wk (Kirkwood 1963).

*Dermanyssus gallinae* causes anemia, decreased egg production, and in some cases even the death of its host (Kirkwood 1967). It is also a possible vector of bacterial and viral disease agents such as *Salmonella* spp, avian spirochetes, as well as disease agents of other livestock species (e.g., eastern equine encephalomyelitis virus) (Zeman et al. 1982, Lancaster and Meisch 1986, Durden et al. 1993). Furthermore, the mite may attack humans and is thereby a nuisance for personnel working in affected poultry premises (Hoffman 1987).

To outline rational control measures generally requires knowledge of the development and survival of the pest organism. Several studies have been made of the effect of temperature and relative humidity on *O. sylviarum* (Kirkwood 1963, Abasa 1969), but there are few such data available for *D. gallinae*. Because *O. sylviarum* usually remains on the host whereas *D. gallinae* hides off the host most of the day, it can be assumed that the 2 species respond differently to environmental factors such as temperature and relative humidity.

The aim of the current study was to investigate the influence of temperature and humidity on reproduction, juvenile development, and survival of *D. gallinae* isolated from a Swedish poultry house. Data were obtained by incubating adult females at different temperatures and relative humidities and by regularly assessing the viability of females, eggs, larvae, and protonymphs.

Materials and Methods

*Dermanyssus gallinae* were obtained from an egg producing poultry farm in the vicinity of Uppsala in central Sweden. To collect specimens, specially designed traps were placed in the housing facilities for 24 h. The traps were rectangular pieces (100 by 140 mm) of corrugated cardboard (3 mm thick) (Fig. 1). Inside the cardboard traps were transverse funnels (~4 mm in diameter) where nites were allowed to...
The following saturated solutions, with measured relative humidities of 0.8-liter plastic containers (17.5 by 11.7 by 6.8 cm). (Winston and Bates 1960) were placed in the bottom of the plastic containers. All containers for each relative humidity were kept in the same incubator at 20°C throughout the trial. The mites were observed every 24 h for the first 8 d, once weekly for the next 6 wk, and every 2 wk until all the adult mites were dead after 23 wk.

**Statistical Analysis.** Egg data were analyzed and group means were compared with 1-way analysis of variance (ANOVA) using the software package SuperANOVA (Abacus Concepts 1989). The 50% mortality period was calculated by maximum likelihood estimation (Finney 1971). The method was implemented in Matlab (Mathworks, 1996).

**Results**

**Temperature Study.** Number of Eggs Laid. Eighty percent of the 96 mites at both 5 and 25°C produced eggs. The mean number of eggs laid by females maintained at 5°C was significantly lower than those held at 25°C (ANOVA, \( F = 68.4, \text{df} = 2.175, P < 0.001 \)) (Fig. 2A).

A total of 152 eggs was laid by the females maintained at 5°C; the last egg was laid by day 91 of the trial. No further egg development occurred at 5°C, but the eggs appeared shiny and springy and thus considered viable. At 25°C, a total of 295 eggs was laid; whereas at 45°C a total of 19 and at 65 and −20°C none. After 2 d the eggs held at 45°C were shrunken and dried and had no further development.

Oviposition period started at day 1 at 5, 25, and 45°C (Fig. 2B), but the duration were significantly different (ANOVA, \( F = 60.2, \text{df} = 2.175, P < 0.001 \)).

**Developmental Times of Eggs and Larvae.** Ninety-eight percent of the eggs kept at 25°C hatched into larvae and 92% of these subsequently molted into protonymphs. The minimum duration of embryonic development from eggs was 2 d and minimum metamorphosis period from larvae only 1 d. The duration of the development from egg to protonymph is illustrated in Fig. 3.

**Longevity of Females and Protanymphs.** All mites kept at −20, 45, and 65°C were dead after 24 h. Mites kept at −20°C survived for 10 min, but after 20 min, all were dead. Twenty percent of the mites kept at 45°C died within 90 min and the remaining ones within 120 min. LT50 values for mites at 5°C (58 d) were significantly higher than for the mites at the other temperatures (Fig. 4A). Longevity of protonymphs is shown in Fig. 4B.

**Humidity Study.** There were differences between expected and measured percent relative humidities (see Materials and Methods), probably because lids of the containers were not completely airtight.

**Number of Eggs Laid.** Seventy-eight, 87, and 89%, respectively, of the females at the 3 lower humidities produced eggs, but only 66% at 90% RH. The number of eggs laid by oviparous females varied between 1 and 8 (Fig. 2C). The females kept at 70% RH laid significantly more eggs than those at 30 and 45% RH. Fe-
males kept at 20°C also laid significantly more eggs than those kept at 25°C and 23% RH (ANOVA, \( F = 26.1, \text{df} = 4.388, P < 0.001 \)). The numbers of eggs laid were 343, 409, 493, and 354, respectively, from the lowest to highest humidity. The oviposition periods (Fig. 2D) were not significantly different (ANOVA, \( F = 1.8, \text{df} = 3.305 \), not significant).

Developmental Times of Eggs and Larvae. Eggs hatched in a minimum of 4 d at each humidity level. Minimum metamorphosis period from larva to protonymph was 2 d at 30% RH and 1 d at the other humidities. The hatching rates were 98% at 30 and 45% RH, and 99% at 70 and 90% RH. Molting success increased from 91% at 30% RH to 95% at 45% RH, and to 98% at both 70 and 90% RH.

Longevity of Females and Protonymphs. Table 1 shows 50% mortality period and maximum survival time of females and protonymphs. \( LT_{50} \) values for the female mites were significantly different (\( P < 0.05 \)) at all humidities (Fig. 4C) and highest at 90% RH on all occasions. The protonymphs lived somewhat longer than the parental generation except at the lowest humidity (Fig. 4D). \( LT_{50} \) values for protonymphs were significantly higher (\( P < 0.05 \)) at 70 and 90% RH than at the lower humidities, and \( LT_{50} \) values for all the protonymphs at 20°C and different humidities were significantly higher (\( P < 0.05 \)) than for protonymphs at 25°C (Fig. 4B and D).

At the end of the test period, several of the wells of the ELISA plate held at 90% RH developed considerable mold growth, which was likely responsible for the relatively rapid decline of mites at the highest humidity (Fig. 4C and D).

Discussion

We found that \( D. \) gallinae produced eggs within a relatively broad temperature interval. Mites kept at 5°C laid on average \(~2\) eggs each per oviposition- or test period. This contradicts previous results that \( D. \) gallinae do not deposit eggs at temperatures \(<10°C \) (Steinegger and Berger 1956). Moreover, in our study more eggs were laid by mites kept at 5°C than was observed in a previous study, where only a small number of females laid 1 egg each per oviposition period (Maurer and Baumgärtner 1992). However, in that study oviposition was determined for only 1 d after each meal, whereas we found that the average oviposition period was \( 28.2 \) d at 5°C.

Developmental rates of eggs and larvae in this study were relatively high and constant at 20 and 25°C. Previously, it has been shown that the most favorable temperatures for juvenile development of \( D. \) gallinae ranges between 25 and 37°C (Maurer and Baumgärtner 1992). Our study also showed that molting success
of larvae and juvenile developmental rates were enhanced with increased relative humidity.

Development of the eggs was not observed at 5°C, which is in accordance with previous findings where eggs did not hatch at temperatures below 12°C (Steinegger and Berger 1956). However, according to Maurer and Baumgartner (1992), the minimum time required for *D. gallinae* to reach the larval stage at 10°C is 12 d, and it is prolonged to >50 d at 5°C. Consequently, if observations of developing eggs are terminated too early, results are likely to be misinterpreted. That was probably not the case in our study because the experiment lasted for 286 d. However, the persistence of developmental capacity of *D. gallinae* eggs at low temperatures remains to be investigated.

Eggs that were laid at 45°C remained unhatched, as in a previous experiment performed at 40°C (Maurer and Baumgartner 1992). The inhibited development of the eggs in both of these experiments was probably related to low relative humidity (measured to 11% RH in our study). This indicates that eggs are susceptible to dehydration.

The juvenile development ceased at the protonymphal stage in the current study. This suggests the need of a blood meal for the protonymph to develop further, which is consistent with previous findings (Lancaster and Meisch 1986, Axtell and Arends 1990).

In our study *D. gallinae* survived for 9 mo at 5°C. Such a long survival has not been recorded for the chicken mite at this low temperature in vitro. However, they lived for only 6 wk at 25°C. This result contrasts with previous studies where the longevity of unfed female *D. gallinae* was 9 mo at 25°C (Harrison 1962). The observed dissimilarity in mite survival at 25°C was probably related to a difference in the relative humidity. In the experiment conducted by Harrison (1962) the relative humidity was 80%, whereas it was measured to only 23% in our study. This indicates that not only eggs, but also larvae, protonymphs, and adult *D. gallinae* are susceptible to dehydration.

When mite survival caused by differences in relative humidity at 20°C was elucidated, it was found that LT_{50} values for female *D. gallinae* were highest at 90% RH, but the longest survival period, 5 mo, was observed at 70% RH. This is of interest because it approximately equals the prevailing conditions in Swedish premises for egg layers (unpublished data). Although a previous study showed that the optimum relative humidity for survival of the related *O. sylvicu- rum* ranged between 76 and 80% at 25°C (Abasa 1969), similar data have not previously been presented for *D. gallinae*.

It was noted that several of the wells of the ELISA plate kept at 90% RH developed mold. This was likely

<table>
<thead>
<tr>
<th>Stage</th>
<th>Relative humidity at 20°C</th>
<th>30%</th>
<th>45%</th>
<th>70%</th>
<th>90%</th>
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<tr>
<td>Female</td>
<td></td>
<td>16</td>
<td>121</td>
<td>20</td>
<td>63</td>
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<td></td>
<td></td>
<td>34</td>
<td>163</td>
<td>111</td>
<td>147</td>
</tr>
<tr>
<td>Protonymph</td>
<td></td>
<td>30</td>
<td>70</td>
<td>48</td>
<td>70</td>
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<td></td>
<td></td>
<td>118</td>
<td>177</td>
<td>119</td>
<td>160</td>
</tr>
</tbody>
</table>

**Fig. 4.** Longevity of females and protonymphs of *D. gallinae* after continuous incubation at different temperature (A and B) and relative humidity (C and D).
to be responsible for inhibiting mite survival at this humidity, especially at the end of the test period. The mechanism for this inhibition is not known. Toxins produced by the fungi or the physical presence of hyphae, or both, may inhibit mite survival, reproduction, and population growth.

In the current study mites that were incubated at -20°C were all dead within 20 min, which supports the findings of a previous study where no indication of a seasonal adaptation of D. gallinae toward cold temperatures was found (Maurer and Baumgärtner 1992). However, mites could survive for a long time (8 mo) in an empty chicken hut during natural conditions, with temperatures ranging from -10 to +27°C (Kirkwood 1963). However, it remains to be investigated how temperatures below zero are tolerated by D. gallinae, especially when mites are gradually adapted.

Knowledge of mite development and survival during specific abiotic conditions provides useful information for the understanding of their population dynamics. Because of the health problem associated with mites, particularly for egg-producing hens (Höglund et al. 1995), these data also provide a basis for the establishment of guidelines for nonchemical control measures against chicken mites.

Our results imply that it is possible to interfere both with juvenile development and survival of D. gallinae by reducing the atmospheric humidity in afflicted poultry houses. Moreover, because -20°C and temperatures >45°C were found to be lethal for D. gallinae, freezing, heating, or both could be advocated as alternatives to chemical sanitation (e.g., by exposing egg flats, nest boxes, perches, and other detachable facilities to temperatures adverse for mite survival). The same has also been suggested for controlling O. sylvicarum, which can withstand temperatures of -20°C for 5 d but temperatures >49°C for only 2 h, off the host (DeVaney 1980).

In conclusion, the results of this study basically confirm previous observations on the survival characteristics of D. gallinae in relation to temperature. Additional knowledge was obtained on the influence of different relative humidities. It was also clearly demonstrated that eggs were laid during several days, and that hatching of the eggs was not synchronized. Finally, the results of our study also indicate the possible use of either high or low temperature extremes in the sanitation for D. gallinae in empty poultry premises.

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