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OBSERVATIONS ON THE BIOLOGY OF HYPOASPIS ACULEIFER
(CANESTRINI, 1884), APPARENTLY NEW TO NORTH AMERICA
(ACARINA: MESOSTIGMATA: LAELAPTI DAE)

BY

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I. INTRODUCTION.

Hypoaspis aculeifer was first described by Canestrini (1884) in the genus
Laelaps, but he transferred the species to his new genus, Hypoaspis, shortly afterwards
(Canestrini, 1885). The original description was made from the female
only, one or more of which were obtained from the botanic garden at Padua in
Italy. Figures of the species have been published by Berlese (1892), Trägårdh
(1912), Bregetova (1956) and A. M. Hughes (1961), but the most detailed are
those of Oudemans (in Strandtmann, 1963) which also include the male. Oudemans
(1929) implied that H. aculeifer is a synonym of H. cadaverinus (Hermann,
1804), but no subsequent author has followed him (Strandtmann, 1963).

In Europe, the species is now known from Italy, the Netherlands, Germany,
U.S.S.R., Sweden, and England (see authors already cited; also Sellnick, 1958,
and Karg, 1961). A female was also intercepted on a rose plant imported into
the U.S.A. at New York, 16. III. 1959 (prepared slide received for study from
the Institute of Acarology, Wooster, Ohio). The only published records of the
species from North America of which we are aware are our own very recent refer-
ences from south-western Quebec (Kevan and Sharma, 1963 a; 1963 b), but the
species is probably widespread in North America and has merely escaped
notice.

The species is known from a variety of habitats: gardens (Canestrini, 1884),
small mammals (Bregetova, 1956), pastures (Sellnick, 1958), potato fields (Karg,

1. Strandtmann (1963) twice gives the date of the species as 1844, which is clearly an
error; other authors give the date variously as 1883 (the date of the volume, but not of the
relevant article), and 1885 (the date of the transfer to Hypoaspis).

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1961), and stored food products (A. M. Hughes, 1961). In eastern Canada it is known from soil and litter, collected in 1961 from under sugar-maple trees (Acer saccharum Marsh) — see Kevan and Sharma (1963 a; 1963 b) — and, more recently, from pot soil in the greenhouses and from cultivated garden soil at Macdonald College.

Little information regarding the biology of H. aculeifer is available. Karg (1961) makes reference to food and feeding habits and compares the structure of the chelicerae with those of other predatory mites. Strandmann (1963) reproduces Oudemans' previously unpublished illustrations of the nymphal and adult (but not larval) stages. Our own preliminary note (Kevan and Sharma, 1963 b) was only incidental to the study of Tyrophagus putrescentiae (Schrank) (Acarina), reared at different temperatures, and the present account incorporates what little information is given. A slight inaccuracy in the abstract of the present paper (Kevan and Sharma, 1963 a) is here corrected.

2. Materials and methods.

Living specimens of H. aculeifer were obtained from samples of soil and litter, taken with a corer 12.7 cm. in diameter to a depth of 6 cm., beneath sugar-maple trees (Acer saccharum Marsh) in the Morgan Arboretum, and from cultivated garden soil, at Macdonald College, Ste Anne de Bellevue, west Montreal Island, Quebec. They were extracted from the samples by means of modified Tullgren funnels (Haarlov, 1947). Mass cultures were reared at room temperature (about 26°C.) in small jars of the type described by Sharma and Kevan (1963) and Kevan and Sharma (1963 b). As food, pure colonies of either Tyrophagus putrescentiae (Acarina) or Isotoma notabilis Schäffer (Collembola) were provided in abundance. Commercial bakers' yeast was added to the jars to sustain these food species.

For observations on the life history of H. aculeifer, small individual plastic rearing cells of the type described by Marshall and Kevan (1962) and of the size referred to by Sharma and Kevan (1963) and Kevan and Sharma (1963 b) were used. Only T. putrescentiae was used as food in the cells. The relative humidity of the cells was about 98 per cent. Numerous H. aculeifer eggs, obtained from the culture jars (ca. 26°C.) were distributed singly in the rearing cells. Of these, 39 were incubated at 26°, 34 at 17° and 46 at 11°C, in order to determine the period required for incubation and the percentage mortality at these temperatures. Fourteen individual mites that emerged from these eggs and completed their development at 26°C., and 10 each at 17 and 11°C., were further considered for comparative studies. Ten eggs each were also incubated at 8, 4 and 0°C. and kept under observation. Young adult females (recently mated in the culture jars) were also transferred to individual cells and kept at the same six temperatures. Ten such individuals were kept at each temperature to observe their rates of oviposition and the numbers of eggs laid. All cells were kept under constant
observation for more than a month, but at 8, 4 and 0°C. eggs did not develop and females did not oviposit.

To provide food in the rearing cells, ten *Tyrophagus putrescentiae* adults were introduced daily over a period of a week for each adult female *H. aculeifer* kept at 26°C., after which, further mites were added as required. At lower temperatures, an initial supply of ten *Tyrophagus* adults was provided for each female on the first day, but thereafter, additional mites were only supplied as required. As the eggs of *H. aculeifer* hatched, two adult and five immature *T. putrescentiae* were introduced into each cell, but this food supply was only augmented at intervals, as and when required.

3. Food.

*Karg* (1961) indicates that *H. aculeifer* is a polyhagous predator that will feed upon Collembola (*Folsomia fimetaria* (Linnaeus) and *Tullbergia kraussbaueri* (Börner)), mites (*Tyrophagus* sp.), insect larvae, and to some extent on nematodes. He concludes that the abundance of *H. aculeifer* depends upon that of the Collembola and mites and not upon that of the nematodes. We have also indicated elsewhere (*Kevan* and *Sharma*, 1963 a; 1963 b) that *H. aculeifer* feeds upon *Tyrophagus putrescentiae*, particularly the larvae and nymphs.

*Ryke* (1959) states that none of the species of hypoaspids collected from soils, stored food products, the nests of insects’ or from the bodies of mammals or invertebrates appears to be parasitic, but species that occur on myriapods apparently show certain modifications suggesting a symbiotic mode of existence. *T. E. Hughes* (1959) states that most species of *Hypoaspis* are "general detritus feeders", but A. M. Hughes’ (1961) citation of J. U. *Lund* finding *H. aculeifer* on caked flour suggests to us that the species was in that case feeding on other mites present, rather than upon the caked flour. *Strandtmann* and *Crossley* (1962) are of the opinion that, on the basis of its distribution, their new species, *H. marksi*, is predatory and not a detritus feeder.

It has already been noted above that *H. aculeifer* is definitely a predatory species, but it should perhaps also be mentioned that it has never been observed by us to feed upon detritus or the dead bodies or faeces of mites and collembola, nor upon yeasts or fungi. In the absence of living prey, *H. aculeifer* apparently starves to death. We found that *Tyrophagus putrescentiae* was preferred to *Isotoma notabilis* as food, but it is interesting to note that *Karg* (1961) observed the reverse to be true in the case of *Tyrophagus* sp. and another collembolan, *Folsomia fimetaria*. We know that *F. candida* (Willem) is attacked, but have no information on preferences.

*Tyrophagus putrescentiae* was readily (and easily) caught and devoured in all stages by *H. aculeifer*, although immature forms were much preferred. *Isotoma notabilis* was less readily taken and then usually only in the immature stages; adults were sometimes attacked and killed, but almost invariably rejected as food.
Cultures of *H. aculeifer* have been reared on a constant diet of *T. putrescentiae* for over two years, but it has not been found possible to maintain the species on *I. notabilis* alone for much more than a month, even with constant replenishment of the food supply (see p. 654). Eggs of neither *Isotoma* nor *Tyrophagus* were attacked by *H. aculeifer*, which, further, exhibits little tendency towards cannibalism, although adults will feed upon protonymphs and larvae of their own kind if no other food is available.

Up to ten adult *T. putrescentiae* may be consumed per day by adults of *H. aculeifer*, but this rate of consumption was not maintained in our observations. Even in the confines of the small rearing cells, some of the *Tyrophagus* females provided were able to lay eggs before being devoured, and, owing to their much greater fecundity, populations of *T. putrescentiae* in excess of the food requirements of *H. aculeifer*, and of the initial numbers introduced, were built up.

4. Eggs.

According to Oudemans (1915), *Hypoaspis spirostrepti* Oudemans is ovoviviparous or viviparous, and Evans (1955) states that *H. polydesmoides* Evans is also ovoviviparous. *H. aculeifer*, however, is oviparous, laying its eggs singly in small crevices, or amongst organic matter. In the laboratory, this occurred in the plaster of Paris of the culture jars and rearing cells or amongst yeast masses and fungal hyphae in the former. The eggs were white in colour, oval, and smooth. At oviposition they measured about 0.34 to 0.35 mm. in length. No apparent change in size or gross chorion structure was observed during their development.

The numbers of eggs laid per female, and the period over which oviposition occurred, at 26, 17 and 11°C., are indicated in Table I. No oviposition occurred at 8°C. or less. It will be seen that oviposition continued longest at 17°C., but that the maximum number of eggs was laid at 26°C. The oviposition period was shortest at 11°C., at which temperature only a very few eggs were laid. Never more than one egg was laid by any one female in a day, except for three kept at 26°C., each of which, on one occasion, laid two eggs within 24 hours. At 26°C. also, females laid their first eggs within about a week of mating and continued daily oviposition for seven to ten days (except for two individuals, each of which missed one day); thereafter oviposition occurred at irregular intervals until it ceased altogether about a month after egg-laying had begun. The largest gap between ovipositions for any one female was four days. An average of 17 eggs per female was laid.

At 17°C., oviposition was more erratic with gaps in laying of up to a week (in one case). An average of only 15.5 eggs per female was laid at this temperature. At 11°C., the egg-laying period was much shorter, oviposition was very erratic, and the average egg-production was only four eggs per female.

1. These were not the same females that had laid two eggs on one day.
TABLE I. — Oviposition period and number of eggs laid after first mating for ten females of *Hypoaspis aculeifer* (Canestrini).

<table>
<thead>
<tr>
<th>Temperature (°C.)</th>
<th>26</th>
<th>17</th>
<th>11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oviposition period (days)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min.</td>
<td>26</td>
<td>35</td>
<td>17</td>
</tr>
<tr>
<td>Max.</td>
<td>32</td>
<td>41</td>
<td>23</td>
</tr>
<tr>
<td>Mean</td>
<td>28.8</td>
<td>38.3</td>
<td>21.6</td>
</tr>
<tr>
<td>No. of eggs laid per female</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min.</td>
<td>15</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Max.</td>
<td>20</td>
<td>17</td>
<td>7</td>
</tr>
<tr>
<td>Mean</td>
<td>17.0</td>
<td>11.5</td>
<td>4.0</td>
</tr>
</tbody>
</table>

The incubation periods required, and the percentages of eggs hatching at the three temperatures, are indicated in Table II, from which it will be seen that a progressively longer time was required for development, and a progressively smaller percentage of hatching occurred as the temperature was lowered. An average of about two to three days was required before hatching occurred at 26 and 17°C., but this time was greatly prolonged (to over 11 days average) at 11°C. Mortality rose from 7.7 per cent. at 26°C. to 54.4 per cent. at 11°C. At 26°C., 19 (52.8 %) of the 39 eggs observed hatched within 24 hours and, of those hatching, only two eggs delayed this until the fourth day. At 17°C., over 80 per cent. of the 34 eggs hatched between the second and third days. At 11°C. hatching was more erratic, but of the 46 eggs observed, over 70 per cent. did so on the tenth or eleventh days of incubation. Eggs that failed to hatch became brown in colour.

TABLE II. — Incubation periods and percentages of eggs of *Hypoaspis aculeifer* (Canestrini) hatching at three temperatures.

<table>
<thead>
<tr>
<th>Temperature (°C.)</th>
<th>26</th>
<th>17</th>
<th>11</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of eggs observed</td>
<td>39</td>
<td>34</td>
<td>46</td>
</tr>
<tr>
<td>Incubation period (days)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min.</td>
<td>1</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Max.</td>
<td>4</td>
<td>6</td>
<td>14</td>
</tr>
<tr>
<td>Mean</td>
<td>1.8</td>
<td>2.9</td>
<td>11.2</td>
</tr>
<tr>
<td>Percentage of eggs hatching</td>
<td>92.3</td>
<td>70.6</td>
<td>45.6</td>
</tr>
</tbody>
</table>
The larva of *H. aculeifer* (fig. 1) has not previously been described. It was found to be white in colour and on emergence from the egg, measured about 0.37 mm. in length. It soon increased in size to about 0.42 to 0.45 mm., however. The larval chelicerae, in contrast to those of the later instars are comparatively simple.
with the fixed and movable digits each bearing only one or two denticles instead of many (see fig. 1 a). The dorsal shield is undeveloped.

The larvae were rather sluggish in comparison with the later instars and were never observed to feed, or even to attack prey. This has not previously been recorded for *Hypoaspis*, but Rivard (1960) observed that the larvae of another predacious mesostigmatid mite, *Melichares dentriticus* (Berlese) (Aceosejidae) are also inactive and do not feed. The simple chelicerae of larval *H. aculeifer* (fig. 1 a) are doubtless significant in this respect since they would be much less suitable for seizing prey than those of the actively feeding nymphal and adult stages — see protonymphal chelicerae indicated in fig. 1 and those of the adult female illustrated by Karg (1961) and of the adult male shown by Oudemans (in Strandtmann, 1963).

The larval stage is of short duration, usually lasting less than 24 hours at 26°C. (Table III). In only two of the 14 individuals kept under observation at this temperature was the larval stadium as much as 48 hours. Progressively longer periods were passed as larvae as the temperature was lowered, and as many as six (av. 4.4) days were thus passed at 11°C. (Table III) before the first moult occurred. No development was observed at lower temperatures.

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>26</th>
<th>17</th>
<th>II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Larva</td>
<td>1-2 (1.1)</td>
<td>1-3 (2.3)</td>
<td>3-6 (4.4)</td>
</tr>
<tr>
<td>Protonymph</td>
<td>5-7 (6.3)</td>
<td>5-8 (6.5)</td>
<td>10-15 (11.4)</td>
</tr>
<tr>
<td>Deutonymph</td>
<td>2-5 (2.3)</td>
<td>6-7 (6.5)</td>
<td>15-22 (16.6)</td>
</tr>
<tr>
<td>Egg-laying to Adult *</td>
<td>10-13 (11.7)</td>
<td>17-23 ** (18.4)</td>
<td>40-48 (43.6)</td>
</tr>
</tbody>
</table>

* Note: these are figures for individual mites and not sums of the figures in the preceding rows and in Table II.

** All but one took 17 to 19 days.

Prior to moulting, the larva was observed to enter a resting stage of from one to four hours duration. During this period the newly formed protonymphal structures became visible within the integument, notably the chelicerae with their fixed and movable digits, each with numerous teeth, and the fourth pair of legs directed
— 654 —

forwards between the coxae of the third pair (fig. 1). During this phase, also, the anal plate with three setae made its appearance.

At ecdysis a marginal split developed in the integument of the posterior part of the larva, as far forward as the third pair of legs. Through this split the protonymph was seen to withdraw backwards from the larval exuviae.

6. PROTONYMPH AND DEUTONYMPH.

These stages are illustrated by Oudemans (in Strandtmann, 1963). In our material, the protonymph measured from 0.45 to 0.62 mm. in length. Like the larva it was white in colour. The dorsal shield of this stage is clearly developed, but consists of two distinct parts, the podosomal and pygidial plates, between which lie three pairs of minute interscutal platelets. The anal plate with its three setae and the peritremes are now clearly defined.

The deutonymphs in our material measured between 0.60 and 0.80 mm. in length and the dorsal shield was pale yellow to light brown in older specimens. The form of the deutonymph is rather similar to that of the adult (especially the male), but is clearly distinguishable on account of the dorsal shield, the podosomal and pygidial plates of which are fused only in the centre, indicating the bipartite origin of the shield (see protonymph, above), which is not discernable in the adult. We have been unable to detect any morphological difference between those deutonymphs that will produce males and those that will produce females — although the latter are presumably the larger ones.

At 26°C, most of the 14 individuals kept under observation passed a greater part of their pre-adult lives as protonymphs than in any other stage, averaging 6.3 days (Table III). At 17°C, the duration of the protonymphal stadium was almost the same as at 26°C., and as the deutonymphal stadium at 17°C., but, at 11°C., the protonymphal stage lasted almost twice as long, although for a considerably shorter time than the deutonymph at the same temperature. The deutonymphal stage averaged only 2.3 days at 26°C., but this period was almost tripled at 17°C., and at 11°C. it was very considerably prolonged — to about two to three weeks — 30 per cent. of the individuals becoming adult on the 16th day.

7. ADULT.

The chief morphological features of female *H. aculeifer* have been given by various authors from Canestrini (1884) to A. M. Hughes (1961) and both sexes are well illustrated by Oudemans (in Strandtmann, 1963). However, as compared with Oudemans’ figures, our material shows certain differences in the setal arrangement of the legs as indicated in fig. 2 and Table IV. Variation in setal arrangement of other laboratory-reared mites (*Trombicula akamushi* (Brumpt), *Trombiculidae*) has also been observed by other authors (Gorsu, Wharton and Yunker,
We have also observed variations in the shape of the tritosternal and anal plates and in the setal arrangement on the ventral plate of the adults, but these, together with the number and arrangement of setae on various parts of the body during postembryonic development, will be discussed elsewhere.

TABLE IV. — Number and nature of setae on the legs of adult ♀ Hypoaspis aculeifer (Canestrini) reared in the laboratory. Notation: l = long; s = short; t = thick; f = fine.

<table>
<thead>
<tr>
<th>Leg</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coxa</td>
<td>2 l, f</td>
<td>2 l, f</td>
<td>2 l, f</td>
<td>1 l, f</td>
</tr>
<tr>
<td>Trochanter I</td>
<td>5 l, f</td>
<td>5 l, f</td>
<td>4 l, f</td>
<td>4 l, f</td>
</tr>
<tr>
<td>Trochanter II</td>
<td>Nil</td>
<td>Nil</td>
<td>Nil</td>
<td>Nil</td>
</tr>
<tr>
<td>Femur</td>
<td>2 s, t</td>
<td>1 s, t</td>
<td>3 s, t</td>
<td>3 s, t</td>
</tr>
<tr>
<td>Genu</td>
<td>10 l, f</td>
<td>8 l, f</td>
<td>6 l, f</td>
<td>7 l, f</td>
</tr>
<tr>
<td>Tibia</td>
<td>11 l, f</td>
<td>8 l, f</td>
<td>6 l, f</td>
<td>7 l, f</td>
</tr>
<tr>
<td>Pretarsus</td>
<td>Nil</td>
<td>2 l, t</td>
<td>2 l, t</td>
<td>2 l, t</td>
</tr>
<tr>
<td>Body of tarsus</td>
<td>20 l, f</td>
<td>5 l, t</td>
<td>6 l, t</td>
<td>7 l, t</td>
</tr>
<tr>
<td>Tip of tarsus</td>
<td>10 l, t*</td>
<td>4 s, t</td>
<td>4 l, t</td>
<td>4 l, t</td>
</tr>
</tbody>
</table>

* One curved.

In our material the size ranges for males and females of *H. aculeifer* were 0.65 to 0.68 and 0.82 to 0.94 mm. in length respectively. From field samples, collected four times a month from June to September, 1961, at depths down to 6 cm., the percentage of females in the population was 43.7%. In the laboratory cultures 52.7% per cent. were females.

At 26°C., *H. aculeifer* took 10 to 13 (av. 11.7) days to reach maturity from the time the eggs were deposited, about a week longer at 17°C., and over a month longer at 11°C (Table III). Although no development occurred at temperatures below 11°C., adult *H. aculeifer* survived temperatures of 8, 4 and 0°C. for considerable periods — even at 0°C. they remained alive after more than a month of observation, although they were not active.
8. RELATIONSHIP BETWEEN THE LIFE-HISTORIES
OF H. ACULEIFER AND ITS LABORATORY PREY.

Details regarding oviposition, rates of development, etc., at different temperatures in the laboratory are given by SHARMA and KEVAN (1963 a) and KEVAN and SHARMA (1963 b) for the two species used as food for H. aculeifer. At all temperatures concerned (26, 17, 11°C.), the eggs of H. aculeifer hatched sooner than those of the prey laid at the same time, although many fewer eggs were laid. Thus by the time that Isotoma notabilis or Tyrophagus putrescentiae hatched, H. aculeifer was already in the protonymphal stage and ready to devour first-instar prey. The interval between successive ovipositions in I. notabilis was longer than for H. aculeifer (about 6 days at 17°C.), and, except at lower temperatures, the life-cycle was a little longer, so that successively hatched mites were often ready to feed before the collembolan food supply was naturally replenished. This is presumably one of the reasons why it was found difficult to rear H. aculeifer on pure cultures of I. notabilis (although this collembolan, even in adequate supply, does not seem to give good results — see p. 649). Tyrophagus putrescentiae, on the other hand, although its eggs usually take a little longer to hatch, is much more
prolific and completes its life cycle rather more rapidly at any given temperature. Thus an adequate food supply is always likely to be present naturally, making it much easier to maintain *H. aculeifer* on this species.

The partiality of *H. aculeifer* for *Tyrophagus* spp. would explain the presence of the former in stored food products, where the latter are often pests. Although *H. aculeifer* may have some effect on naturally occurring populations of *Tyrophagus*, its reproductive potential is so much lower that it would seem very improbable that, by itself, it could exercise any appreciable degree of control.

9. Acknowledgements.

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10. Summary.

1. *Hypoaspis aculeifer* (Canestrini) is a predatory mesostigmatid mite widely known from Europe, where it occurs in various habitats, but it has only recently been noted from North America. It occurs in soil and litter in south-west Quebec. It has probably been overlooked elsewhere.

2. *H. aculeifer* has been reared in the laboratory on *Isotoma notabilis* (Collembola) and *Tyrophagus putrescentiae* (Acarina), the latter of which it prefers. It is known to feed only on living prey.

3. The various stages of the life cycle are described and their rates of development and reproduction at 26, 17 and 11°C are given. The larva is figured for the first time and the changes that it undergoes on entering the protonymphal stage are noted. The larva does not appear to feed.

4. The setal arrangement on the legs of the adult is noted and illustrated.

5. The relationship between the life histories of *H. aculeifer* and the species used as food in the laboratory are briefly discussed.

6. *H. aculeifer* probably does not control naturally occurring populations of *Tyrophagus*.

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