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Some observations on the biology and behavior of *Acarapis woodi* and *Acarapis dorsalis* in Oregon

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INTRODUCTION

The discovery of the honey-bee tracheal mite, *Acarapis woodi*, in the United States in 1984 and Canada in 1986 has resulted in a dramatic enhancement of North American research efforts aimed at clarification of this endoparasite's pest status. The rapid, anthropogenic spread of this parasite throughout major beekeeping regions in the US has already brought serious economic hardship to the American and Canadian beekeeping industry. With the near perfect clarity of hindsight, the research and regulatory communities now agree that we were unprepared for the consequence of the presence of this honey-bee acarine pest even though its discovery in Mexico in 1980 (Wilson & Nunamaker 1982) presaged its arrival in the US. The development of the research base necessary to understand the bionomics of *A. woodi* under the various environmental conditions of North America will take several more years, at the very least.

Curiously, the long established presence in North America of the two external species of *Acarapis* has been almost completely overlooked. There is little debate concerning the lack of pathogenicity of *A. dorsalis* and *A. externus*, although both ectoparasites are known to be hemolymph feeders.

The external *Acarapis* species, described by Morgenthaler in 1934, are cosmopolitan. By 1936 they had been recorded from 21 countries including the US and Canada (Eckert 1961). Recently, Clark (1985) revealed the widespread distribution of external *Acarapis* in British Columbia. This provided the stimulus for our search for these ectoparasites in Oregon. An examination of bee samples taken by the Oregon Department of Agriculture (ODA) in an *A. woodi* survey in the spring of 1986 revealed the widespread occurrence of the two external *Acarapis* species

throughout the state. These records support the suggestion by Eckert (1961) that in North America their distribution approaches ubiquity.

A major impetus for the *Acarapis* research program at Oregon State University was the discovery of an *A. woodi* infestation in Jackson County, Oregon, in November 1985. With the elimination of 1500 verified and suspected host colonies in January 1986, the Oregon Department of Agriculture declared the state to be once again free of *A. woodi* (ODA personal comm.).

MATERIALS AND METHODS

In the late summer of 1986 we began a series of studies on the life history of two *Acarapis* species: *A. woodi* and *A. dorsalis*. *A. externus* was not included owing to its near absence from colonies in the University apiary. While occasionally detected, *A. externus* was always at low levels in but a few colonies.

Because Oregon is an *A. woodi*-free state, our research material of this species has, of regulatory necessity, been maintained under quarantine conditions. An experimental colony was established with a 1.5 kg package of *A. woodi* infested bees in a 4.32 × 2.16 m growth chamber. Temperature was maintained at a constant 20°C, and lighting was with fluorescent illumination. Full light was maintained 24 h a day. The colony was confined in a 3.70 × 1.85 m screened cage within the chamber and provided *ad lib* with water, sugar syrup, and pollen. *A. dorsalis* material was readily available from free-flying *A. mellifera* colonies in the University apiary.

In order to study the life cycle of the two mite species, worker bees <24 h old were introduced into colonies with known mite infestation rates. Callow workers were marked on the abdomen with acrylic paint. Samples of 100 marked bees were placed in the *A. woodi* infested hive, and 30 bees of each sample were recovered after each of various exposure periods. A preliminary study was done with *A. woodi* using sampling periods of 19, 22, 48, and 72 h to document movement of these mites from source hosts to new hosts. Larger samples of 300 bees were used in the *A. dorsalis* studies as the outdoor hives were larger and had higher infestation rates of *A. dorsalis* than the hive infested with *A. woodi*. A flask containing CO_2 was used to collect the bee samples; this anesthetized both the bees and the mites, ensuring no further transfer between the times of collection and examination. It was also easier to collect the bees by this method. Comparison with methods used earlier showed that there was no loss of mites off the bees due to anesthetization.

The abundance of *A. woodi* and *A. dorsalis* was monitored weekly using 30 bee samples, to establish a record of mite population changes over time. We used two hives with a high infestation and two hives with a low infestation of *A. dorsalis*, and the quarantined hive infested with *A. woodi*.

In studies of both the life cycle and population changes over time, the relative proportions of the life stages were recorded for each mite. Bees were examined live for the *A. woodi* study. Larvae were differentiated from nymphochrysalides by the movement evident in the former but not the latter. Males were differentiated from females on the basis of body size and the number of setae on the fourth pair of legs (male smaller than female and with one long seta, versus two in female). Samples of *A. dorsalis* were frozen because of time constraints, and no distinction was made between larvae and nymphochrysalides.

RESULTS

Acarapis dorsalis

Figs 1a, b show two levels of *A. dorsalis* populations in the experimental colonies. Two colonies were found to have consistently high populations and two consistently low populations.

The infestation rate fluctuated throughout the experimental period, with its peak during early Fall. It is interesting to note that all stages of the mite were seen at every sampling period of the study; however, the fecundity of females decreased in November and increased in February. These trends in *A. dorsalis* populations correspond with those found by Eckert (1961).

An estimate based on Figs 2a, b presents a total developmental period of *A. dorsalis* of *c.* 11 days, and this corroborates the findings of Eckert (1961). The first eggs were noticed 24–48 h (1–2 days) following the introduction of bees to the host colonies. Eggs began hatching at 120–144 h (4–5 days). After 240 h (10 days), the first males were observed and females appeared at 264 h (11 days).

In bees of known age and known exposure time to *A. dorsalis*-infested bees, adult *A. dorsalis* populations decreased with increased bee exposure time up to 216 h (9 days). The proportion of eggs remained stable over this period (24–216 h). However, fewer eggs were observed at 240 h of exposure. This clearly suggests that young bees between 24 and 216 h old are most susceptible to mite infestation.

Acarapis woodi

The duration of the developmental cycle of *A. woodi* was estimated from the marked-bee experiment (Fig. 3). The first eggs appeared in the tracheae after 72 h of exposure (3 days), larvae after 168 h (7 days), nymphs after 264 h (11 days), and males after 336 h (14 days). An increase in the number of females occurred after 504 h (21 days). The total development (not including transfer time), is estimated to be a minimum of 11 days. The data indicate that male eggs are laid first or that males have a shorter developmental time. These alternative conclusions have also been suggested by Bailey (1963).

Our data show that movement from the source host to a new host requires at least 72 h (Table 1), and that the mites move into the wing axillaries of the new bee, and then into the vestibule of the prothoracic spiracle before entering the tracheae. It appears that mating takes place before transfer, because males are rarely seen outside the tracheae of older bees.

Weekly sampling demonstrates some of the changes occurring in the mite population (Fig. 4). We are cognizant that an environmental chamber imperfectly mimics the ambient environment and thus may prejudice our observations in some undetermined manner. This colony was established at the end of July 1986 with a mite infestation of *c.* 15–20%. The infestation rate began to increase slightly near the end of October and then leveled off. The colony ceased brood production at the end of October, and no newly emerged workers were present until the end of February. Mite reproduction decreased during the broodless period and was maintained at a low level (Fig. 4). During November a change in the sex ratio occurred, and males became more numerous than females. This trend is suggestive of parthenogenesis (arrhenotoky): the high proportion of older females in the population may use up

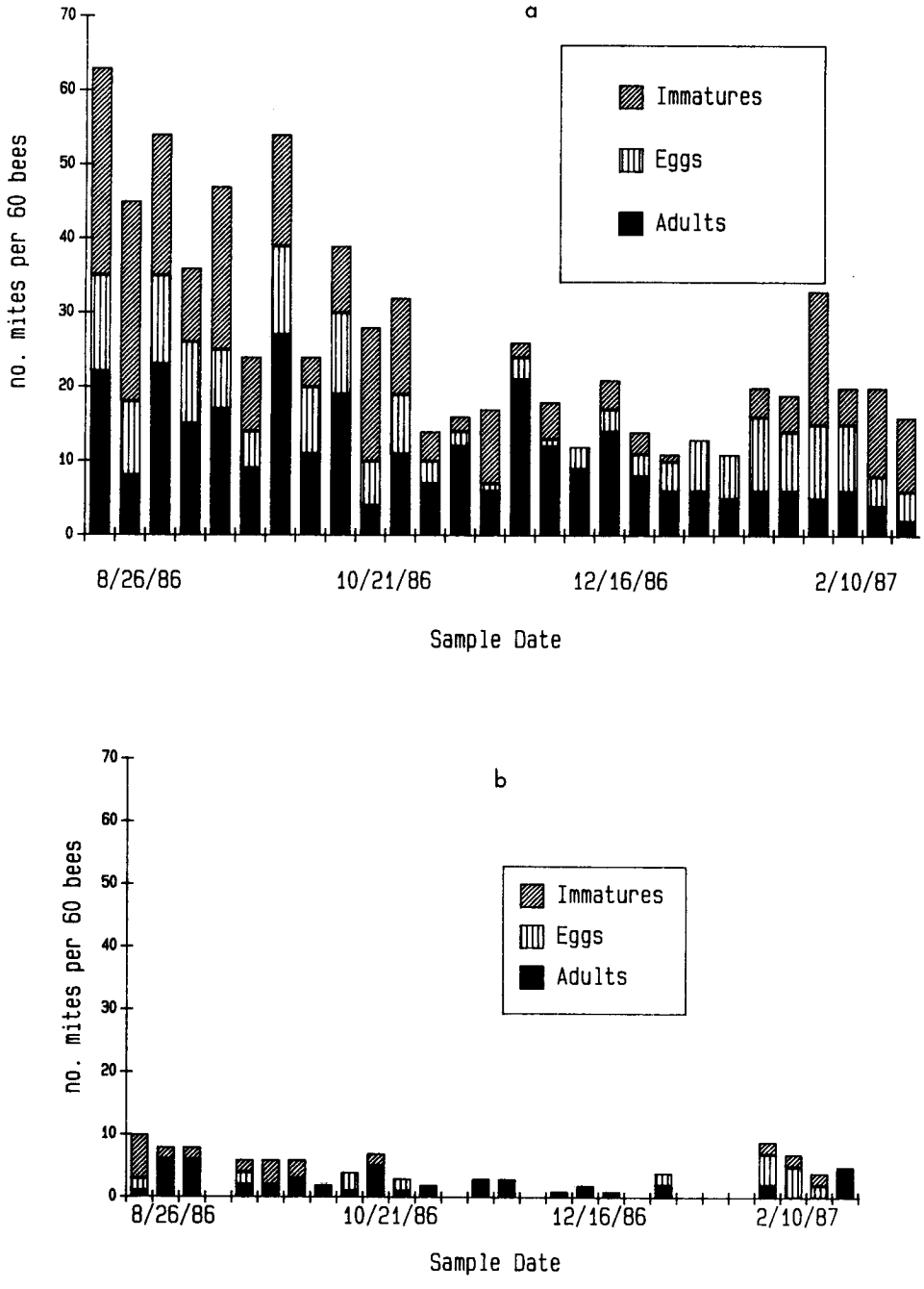

Fig. 1 — Life stage distribution of *A. dorsalis* showing the number of mites at weekly intervals: (a) two hives with high infestation rates, (b) two hives with low infestations rates. NB: US style dating.

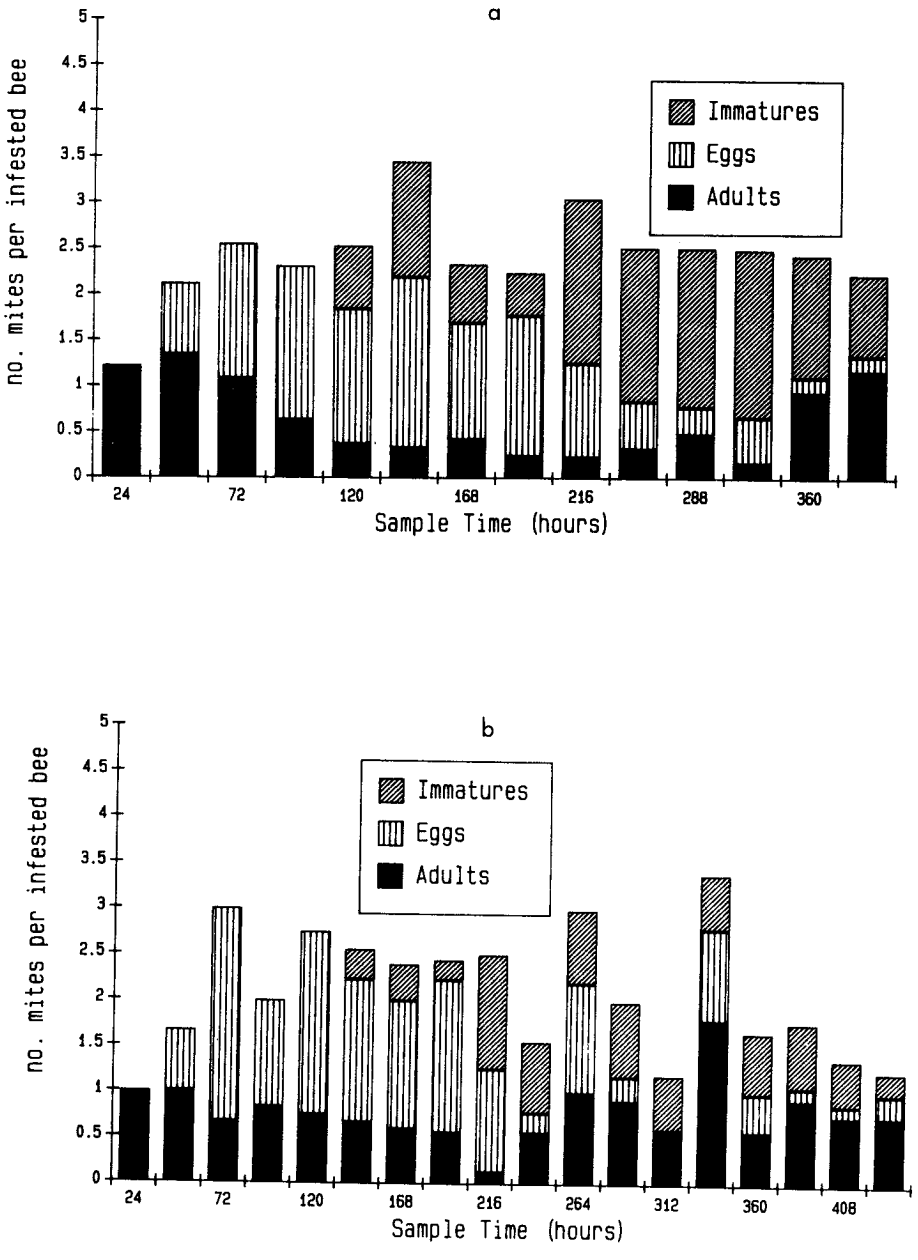

Fig. 2 — Life stage distribution of *A. dorsalis* showing number of mites per infested bee from samples of marked bees taken at 24 h intervals after the introduction of marked callow bees to an infested hive: (a) fall 1986; (b) spring 1987.

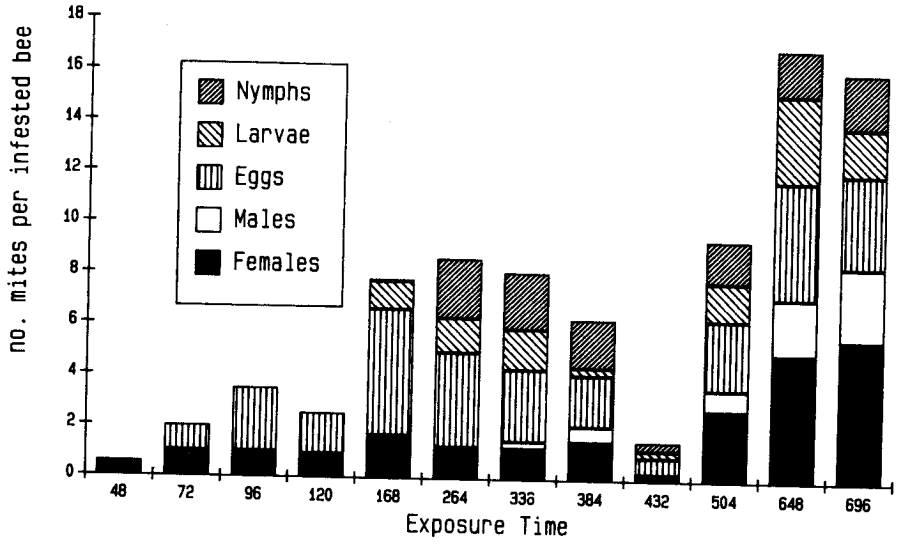

Fig. 3 — Life stage distribution of *A. woodi* showing the number of mites per infested bee from samples of marked bees that had been exposed to infested bees for various periods.

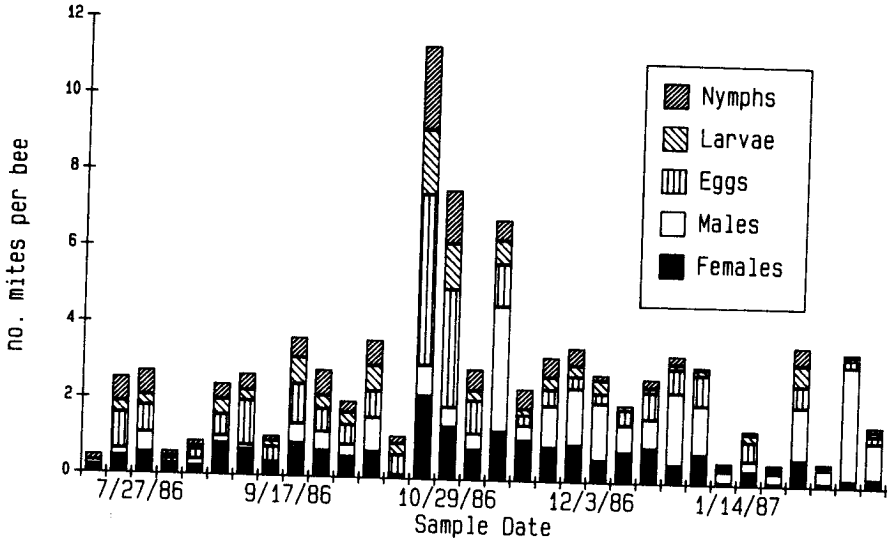

Fig. 4 — Life stage distribution of *A. woodi* showing the number of mites per bee at weekly intervals. NB: US style dating.

their viable sperm stores, or the sperm may become nonviable after a certain storage time in the seminal receptacle. Thus the eggs that are laid may be unfertilized.

An interesting observation was made during the months of October through February. The mites seen in the wing axillaries of bees from weekly samples increased through December and then decreased. This suggests that there is mite transfer during the broodless period.

A. dorsalis and *A. woodi* comparisons

The life cycles of both mite species are similar (Table 2), and our estimates of the duration of developmental stages support the observations made by Bailey (1963) and Eckert (1961). Our data suggest that the development of *A. dorsalis* is 24–48 hours shorter than that of *A. woodi*. Both mite populations are in synchrony with their host colony population fluctuations. During broodless periods reproduction decreased to low levels in both mite species.

There are differences between the two species in the use of wing axillaries. *A. woodi* uses the wing axillaries only during migration, so far as we can tell. *A. dorsalis* may sometimes use this area for reproduction, specifically in spring.

A. dorsalis appears to have adopted a reproductive strategy that incorporates multiple host individuals for individual female mites. *A. dorsalis* begins egg laying 24–48 h sooner than *A. woodi* after transfer to a new host, and appears to lay fewer eggs per host than *A. woodi*. In both species only gravid females move between hosts.

SUMMARY

All three species of *Acarapis* (family Tarsonemidae), parasites of the western honey bee, *Apis mellifera*, occur in North America. There are two ectoparasitic species, *A. dorsalis* and *A. externus*, and the endoparasitic *A. woodi*. *A. woodi* is a recent introduction to North America, and experimental and field evidence indicates that its presence is of economic consequence to the American beekeeping industry.

This paper is a preliminary report on continuing investigations that are focused on the population dynamics of *A. woodi* and *A. dorsalis*, both present in Oregon where *A. dorsalis* is the more common of the two external parasites.

The life cycles of *A. dorsalis* and *A. woodi* are similar. Newly mated females of both mite species preferentially parasitize young bees (<48 h old). The axillary wing areas are sought by *A. woodi* and *A. dorsalis* when they first transfer to an adult bee host. The mites are protected in the axillaries from host grooming and can move safely from there to their specific reproductive sites on the host: the dorsal scutoscutellar groove for *A. dorsalis*, and the prothoracic tracheae for *A. woodi*.

Females *A. dorsalis* do not remain on their first host, but move to other young bees after laying two or three eggs. *A. woodi* females remain in the tracheae of their first host, and deposit an average of 6 eggs during the first 12 days. After invasion of the trachea, they continue to oviposit throughout their adult life. The highest number of *A. woodi* per bee is attained in bees 11–12 days old, and the mite population declines in bees over 21 days old.

Table 1 — Migration pattern of female *A. woodi* on new hosts

Exposure of bees (h)	Proportion of females in:		
		prothoracic	
	wing axillaries	vestibule	trachea
19	0.63	0.38	0.00
22	0.22	0.67	0.11
48	0.21	0.11	0.58
72	0.00	0.00	1.00

Table 2 — Life cycle comparison of *A. dorsalis* and *A. woodi*

Life stage	*A. dorsalis* duration (h)	*A. woodi* duration (h)
egg	96	96
immature	120–144	168†
oviposition to adult	216–240	264

†*A. woodi*: larva, 96 h; nymphochrysalis, 72 h. This information not available for *A. dorsalis*.

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