

The Biology of *Pyemotes boylei* Krczal (Acarina: Pyemotidae)^{1,2}

PENSRI VAIVANJKUL AND FRANK H. HARAMOTO
DEPARTMENT OF ENTOMOLOGY, UNIVERSITY OF HAWAII
HONOLULU, HAWAII

Pyemotes boylei was described by Krczal in 1959 from specimens collected by W. W. Boyle from the dry-wood termite, *Cryptotermes brevis* (Walker), and the koa haole seed weevil, *Araecerus levipennis* Jordan, in Honolulu, Hawaii. This mite is known to parasitize various kinds of insects. Some of the common hosts are the coleopterous larvae which infest the seeds of such plants as koa haole (*Leucaena glauca* (L.) Benth.), kiawe (*Prosopis pallida* (Humb. and Bonpl. ex Wild) HBK), monkeypod (*Samanea saman* (Jacq.) Merr.), and the various species of *Cassia* (Arnold and Haramoto, 1962). Man is sometimes attacked by *P. boylei* and other species of *Pyemotes*; however, they are not known to reproduce on him. Man is bitten by these pyemotid mites when he comes in close contact with products infested by insects which are parasitized by them.

P. boylei may have been in Hawaii much earlier than 1959, but because it is morphologically very similar to other species of *Pyemotes*, it could have been misidentified as *Pediculoides* (= *Pyemotes*) *ventricosus* Newport, a name once applied to several species of *Pyemotes*. If so, then *P. boylei* could have been in Hawaii as early as 1913 for Erhorn reported the discovery of the mite which caused "kiawe itch" which he referred to as *P. ventricosus*.

The symptoms of dermatitis to man caused by *P. boylei* are similar to that caused by other species of *Pyemotes*. Pruritic skin lesion which is rosyrred and about 0.5 cm in diameter develops on the site of each bite. Because of the intense itching, the lesion is often excoriated by scratching and thus allowing secondary infection to set in (Goldberger and Schamberg, 1909; Schamberg, 1910; Webster, 1910; Swan, 1934; and Booth and Jones, 1952). When a person is extensively bitten, the itch condition is accompanied by fever, headache, backache, and asthma (Rokstad, 1943; Booth and Jones, 1952). "Kiawe itch", "grain itch", "hay itch", "barley itch", and "water itch" are some of the terms used to designate the dermatitis caused by the different species of *Pyemotes* (Illingworth, 1927; Rokstad, 1943; Booth and Jones, 1952; Booth, 1954; and Arnold and Haramoto, 1962). As a relief measure for the intense itching, kerosene (Illingworth, 1923), bathing in warm water containing soda (Askin, 1924), and calamine lotion containing

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1% precipitate of sulfur and 2% phenol (Arnold and Haramoto, 1962) have been recommended.

There are many cases of pyemotid-caused dermatitis to humans recorded in the literature from various countries. Studies of these cases have revealed that the victims have handled products such as cereals and beans infested by insects which in turn were parasitized by species of *Pyemotes* just prior to being afflicted with an itch condition (Tothill, *et al.*, 1930; Webster, 1910; Davis, 1950; and Booth and Jones, 1952). Such cases of dermatitis resulting from the handling of infested products still appear from time to time here in Hawaii for *P. boylei* is commonly present in beetle-infested pods of such plants as *L. glauca* and *P. pallida* which are frequently collected by people.

In Hawaii, during 1957 and 1960, there were several cases of dermatitis caused by *P. boylei* following circumstance other than from handling infested products. Occupants of several buildings in Honolulu which had undergone recent methyl bromide fumigation for the control of the dry-wood termite, *C. brevis*, have been severely bitten by *P. boylei* (Boyle, 1958; and Arnold and Haramoto, 1962). However, since 1960 when sulfuryl fluoride (Vikane) largely replaced methyl bromide for the treatment of buildings infested by *C. brevis*, no case of dermatitis due to this mite following fumigation has been reported.

One of the common hosts of *P. boylei* in nature is the koa haole seed weevil, *A. levipennis*, an anthribid beetle that feeds on the seeds of koa haole, *L. glauca* (Sherman and Tamashiro, 1956). *P. boylei* occurs practically wherever this insect is present. It has been found in association with this insect on the islands of Hawaii, Kauai, Maui, Molokai, and Oahu. Although *P. boylei* is very common in nature and has attracted much attention because of its ability to cause dermatitis to man, very little is known of its biology. Therefore, this study was undertaken to obtain as much information as possible on the biology of this mite.

MATERIALS AND METHODS

Laboratory cultures of *P. boylei* were started from specimens collected from the larvae of *A. levipennis* in *L. glauca* pods on the University of Hawaii Campus, Honolulu, Hawaii, on August 13, 1967. The mites were mass reared on *C. brevis* and as required, individuals of a known age group were selected out randomly from the laboratory cultures and used to conduct the various experiments reported in this paper.

The life history study of *P. boylei* was conducted in an air-conditioned laboratory in which the temperature and humidity ranged between 24.2°C–27.2°C and 50%–54% respectively. Newly emerged females were used in determining the life cycle, reproductive capacity, longevity, and the other aspects of the biology. They were reared on freshly-killed *C. brevis* nymphs and on *A. levipennis* larvae. These *P. boylei* females together with their hosts

were held individually in 1.5 cm bottle caps or in lots in Syracuse Watch Glasses. The lips of the bottle caps and watch glasses were coated with "Stikem" to prevent the mites from escaping and intruders from coming in. The mites caged in these containers were then placed in Scheibler Desiccators which served as constant humidity chambers. The humidity in the chambers was maintained at about 52% with a saturated solution of magnesium nitrate. This level of relative humidity was selected because it best simulated the humidity condition under which *P. boylei* thrives in the field, and because optimum survival and reproduction of this mite were obtained in the laboratory. At relative humidity levels above 60% the food source, the insect host, became moldy, and at levels below 45% it desiccated too rapidly to allow completion of the life cycle of *P. boylei*. The mites were taken out from the humidity chambers only briefly at 6-hour-intervals for examination under a dissecting microscope to obtain the necessary life history data.

The hosts and distribution of *P. boylei* were determined from examinations made of insect-infested plants collected from the various islands of the State of Hawaii. During this period of study, June, 1967 to March, 1968, bean pods of *L. glauca* were collected monthly from Manoa, Oahu, and at least once from the different areas on Oahu and from the other islands. The other kinds of plants were collected only from Oahu and less intensively.

An attempt was made to resolve the factors that may have contributed to the outbreaks of *P. boylei* following fumigations of buildings with methyl

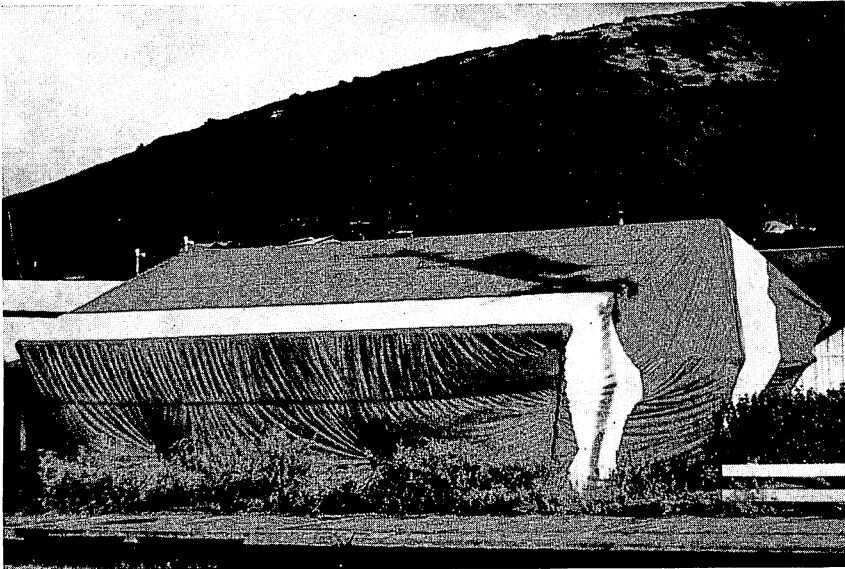


FIG. 1. A building wrapped with tarpaulin for fumigation with methyl bromide to control the dry-wood termite, *Cryptoterms brevis* (Walker).

bromide for the control of *C. brevis* and the cessation of such outbreaks following the replacement of this fumigant with sulfuryl fluoride. Living individuals of both *C. brevis* and *P. boylei* were exposed to either methyl bromide and sulfuryl fluoride. In addition, individuals of *C. brevis* killed by one of these two fumigants were fed to *P. boylei*. Fumigation of *C. brevis* and *P. boylei* with methyl bromide for this study was done by enclosing them for 2 hours in a chest, 27.5 × 50.0 × 35.0 cm, in which a 20 cc ampul of this fumigant was discharged. Fumigation with sulfuryl fluoride was done by placing living *C. brevis* and *P. boylei* in buildings undergoing commercial treatment for the control of the dry-wood termite. In this type of fumigation, the building is wrapped with tarpaulin (Fig. 1) and sulfuryl fluoride released usually during the evening into the gas-tight enclosure at a rate of about 340 g per 28.1 m³ and left overnight for the fumigant to dissipate (Steward, 1957; and Bess and Ota, 1960).

LIFE HISTORY

P. boylei was found to reproduce ovoviviparously. The eggs hatched within the ovaries and the immature stages retained there until they reached sexual maturity. These eggs and immature stages occupied the bulk of the inside of the enormously enlarged opisthosoma of the gravid females (Fig. 2). When ready for birth, the offspring emerged in succession, anterior end first, through the mother's genital opening. In the case of mated females, the first 2 to 4 offspring were males and subsequent ones all females, whereas in the case of unmated females, all of the offspring were males. Upon emergence, the males congregated around the mother's genital opening and waited for the birth of the female offspring. They obtained their nourishment from their mothers and seldom wandered afar. As soon as the females were ready to emerge, the males vigorously vibrated their front pair of legs up and down. As the females emerged, the males grasped them with their well-developed hind legs and copulated. The females were released after a brief mating period of 10 to 30 seconds. One of the males mated with as many as 8 females during a period of 3 minutes and most of them mated with as many as 100 females during their normal life span of about 25 days. Also, some males mated with females that have been mated previously by them or by other males. Despite the habit of *P. boylei* males standing watch around the mother's genital opening, some females escaped mating. These females gave rise to all male offspring. Under field condition, however, only a few females must escape mating for out of the several hundreds of gravid females collected from various localities on Oahu, only 1 of them produced all male offspring.

Most of the female offspring left their mothers soon after emergence to seek new hosts. As soon as a host was encountered, they paralyzed it. For most hosts, a ratio of 1 *P. boylei* female to 1 host was adequate to cause paralysis, but a ratio greatly in favor of *P. boylei* was needed to paralyze

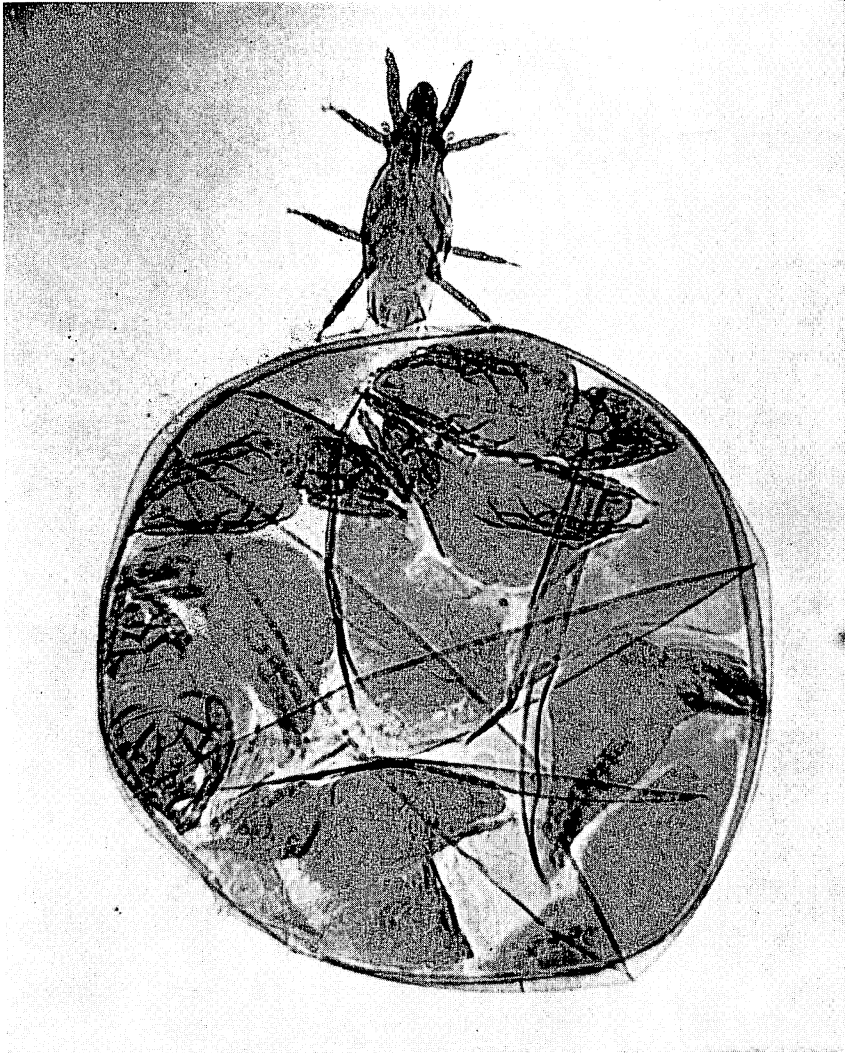


FIG. 2. A gravid female of *Pyemotes boylei* Krczal.

the nymphs of *C. brevis*. When *C. brevis* was outnumbered by *P. boylei* as much as 5 to 1, 98% of the test termites were paralyzed, but none of them was paralyzed when the ratio was 1 : 1. In addition to the increase in the percentage of paralysis, the rapidity of paralysis also increased progressively with increase in the ratio of *P. boylei* to *C. brevis*. The time required for paralysis decreased from an average of 99.6 ± 8.1 minutes to less than 17.7 ± 3.1 minutes when the ratio of *P. boylei* females to *C. brevis* nymphs was increased from 5 : 1 to 25 : 1. The nymphs of *C. brevis* died 2 to 4

hours after being bitten by *P. boylei*; however, some of the larger hosts such as the larvae of *Galleria melonella* L. lived for several days after being immobilized and when *P. boylei* was detached from their bodies soon after paralyzation, they became active again. Those newly emerged females that failed to find a host either returned to the original site of birth and started to compete with their mothers for the same food or died from starvation unless nourishment was obtained within 24 hours after emergence.

As soon as a source of food was found, the newly emerged females inserted their needle-like chelicerae through the membraneous parts of the host's body and started to feed on its body fluids. Simultaneous to commencement of feeding, the posterior one-half of the opisthosoma of the females started to swell. After 2 days of continuous feeding, the opisthosoma was so swollen that the females were unable to crawl, and after 4 to 5 days, it became fully swollen. The size of the fully swollen opisthosoma of the females which fed on *C. brevis* was much larger than those that fed on *A. levipennis*. Despite this greater size, the females on the former host produced only one-half as many offspring as the females on the latter host. However, on host of the same species, *P. boylei* females with greater opisthosomal enlargement tended to produce more offspring than those with opisthosoma of lesser size.

After 4 to 5 days of continuous feeding, the gravid females started reproducing. On the first day, 1 or 2 offspring were produced and thereafter during the first half of the reproductive period the number of offspring produced per day per female gradually increased and then gradually decreased during the second half (Fig. 3). Death of the parent females usually followed soon after emergence of the last offspring, but in a few cases, some offspring continued to emerge for 3 to 4 days after death of their parent females. These offspring emerged not through the genital opening but by piercing through the thin, translucent opisthosomal wall of the dead females.

The longevity and the reproductive capacity of the gravid *P. boylei* females were influenced by such factors as host differences, amount of food consumed, and on whether they were mated or not. When reared singly on *A. levipennis* larvae, mated females lived for 19.9 ± 1.6 days after emergence and produced on an average of 207.7 ± 9.7 offspring per female, but on *C. brevis* nymphs, mated females lived for 23.4 ± 2.7 days and produced 106.7 ± 6.6 offspring while unmated ones lived for no more than 17.7 ± 2.1 days and produced less than 49.3 ± 6.7 offspring. When more than 1 female, whether mated or unmated, were allowed to develop on an individual host, both longevity and reproductive capacity progressively decreased with increased competition for food. *P. boylei* females lived for less than 8.2 ± 1.1 days and produced no more than 4.1 ± 2.9 offspring per female when 40 individuals were allowed to compete for the same *C. brevis* nymph. Under such an overcrowded condition, the *C. brevis* nymph was completely covered with the partially swollen *P. boylei* females. Since food was not

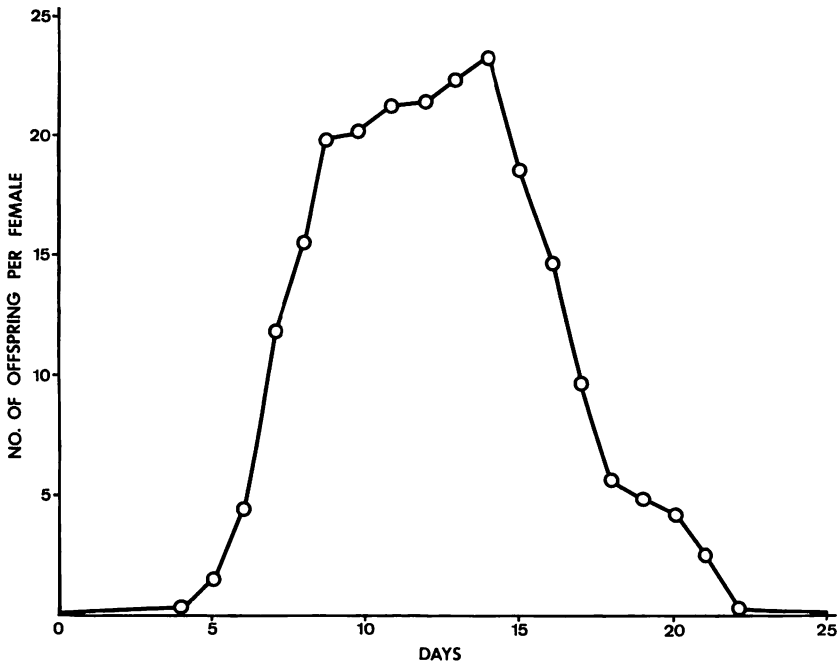


FIG. 3. Reproductive cycle of *Pyemotes boylei* Krczal.

available to support all of them to gravidity, only a few reproduced. Some of them parasitized their own kind but never obtained sufficient nourishment for reproduction. The majority of them died *in situ* for their opisthosoma was swollen beyond the point of being able to crawl to another host.

Both sexes were always present among the offspring of the mated *P. boylei* females, but the sex ratio was greatly in favor of the females. The sex ratio of the 11,943 specimens of *P. boylei* collected from the field between June, 1967 and February, 1968 was 1 : 62.1 in favor of the females. A similar sex ratio, 1 : 61.6, was obtained in the laboratory when mated females were reared on *A. levipennis* larvae, but on *C. brevis* nymphs, the number of females decreased while the number of males remained the same for a sex ratio of 1 : 40.3. Furthermore, when the reproductive capacity of the females was reduced due to increased competition for food, the number of female offspring decreased while the number of males remained the same, 3 to 5 per mother, as when reared singly on *A. levipennis* larvae or on *C. brevis* nymphs. Unmated females not only produced fewer offspring than mated ones but they produced only male offspring whether reared singly or in mass on *A. levipennis* or on *C. brevis*.

HOSTS

In the field, *P. boylei* was found feeding on at least 10 different kinds of

insects (Table 1). Of these, it was most frequently encountered on the larvae of *A. levipennis*. Parasitization of this insect by this mite in *L. glauca* pods which were collected monthly from Manoa, Oahu between June, 1967 and March, 1968 ranged between 4.9% and 9.7%. *P. boylei* was found in association with *A. levipennis* in almost every locality where *L. glauca* was found growing and was collected on this host from the islands of Oahu, Maui, Molokai, Kauai, and Hawaii.

TABLE 1. *Hosts of Pyemotes boylei* Krczal in Hawaii.

Order	Family	Species
Coleoptera	Anthribidae	<i>Araecerus levipennis</i> Jordan
Coleoptera	Bruchidae	<i>Algarobius prosopis</i> (Le Conte)
Coleoptera	Bruchidae	<i>Mimosestes sallaei</i> (Sharp)
Coleoptera	Scolytidae	<i>Xylosandrus compactus</i> (Eichhoff)
Diptera	Tephritidae	<i>Procecidochares utilis</i> Stone
Diptera	Tephritidae	<i>Dacus cucurbitae</i> Coquillet
Diptera	Tephritidae	<i>Dacus dorsalis</i> Hendel
Homoptera	Coccidae	<i>Ceroplastes rubens</i> Maskell
Homoptera	Diaspididae	<i>Diaspis echinocacti</i> (Bouché)
Lepidoptera	Pyralidae	<i>Galleria melonella</i> Linnaeus

In the field, *P. boylei* females were seen on several occasions feeding on the eggs of *Dacus dorsalis* Hendel and *D. cucurbitae* Coquillet, but none of them had their opisthosoma enlarged enough so that reproduction was possible. Laboratory studies have revealed that although *P. boylei* females feed readily on the eggs of these fruit flies, the contents of 1 egg are not sufficient for development to gravidity. One egg only caused the opisthosoma to enlarge to a point where it became impossible for the female to crawl to another food source. These partially swollen females died *in situ* after about 5 days on the first eggs they consumed.

EFFECT OF METHYL BROMIDE AND SULFURYL FLUORIDE
FUMIGATION ON *P. BOYLEI*

Prior to 1960, methyl bromide was most commonly used to fumigate *C. brevis* infested houses in Hawaii. Outbreaks of *P. boylei* which caused severe dermatitis to the occupants of these fumigated houses became a serious problem. However, since sulfuryl fluoride came into common use in about 1960, no *P. boylei* outbreak following fumigations with this material has occurred. Therefore, a laboratory study was undertaken to determine whether or not these two fumigants are toxic to *P. boylei* and to see what influence methyl bromide- and sulfuryl fluoride-killed termites have on *P. boylei*.

The toxicity of methyl bromide and sulfuryl fluoride to *P. boylei* was studied by exposing colonies of this mite to these fumigants at dosages used in commercial fumigation for the control of *C. brevis*. All of the *P. boylei*

treated with these 2 fumigants were killed immediately, thus indicating that any individuals of this mite which were present in the houses prior to fumigation could not have survived but that the outbreaks of *P. boylei* following the use of methyl bromide were most likely due to the entrance of a few individuals of this mite into the houses and the multiplication of them on the dead termites after the fumigant had dissipated. The sources of *P. boylei* were probably the parasitized coleopterous larvae in the pods of such trees as monkey pod, kiawe, shower, and koa haole which occur commonly in the residential areas of Hawaii.

To study the influence of methyl bromide- and sulfuryl fluoride-killed *C. brevis* on *P. boylei*, nymphs of this dry-wood termite first killed by these fumigants were fed to *P. boylei* females at 5-day-intervals. One lot of termites killed by methyl bromide and another killed by sulfuryl fluoride were fed to them immediately after having being fumigated. The other lots of fumigated termites were held in a 52% humidity chamber until the day of the next feeding.

P. boylei females readily fed on the termites killed by methyl bromide (Fig. 4). The number of females that became established and gravid on the methyl bromide-killed termites which were fed to them soon after fumigation was quite high, but fewer and fewer of them became established and gravid when fed termites which were kept for a longer period of time in the

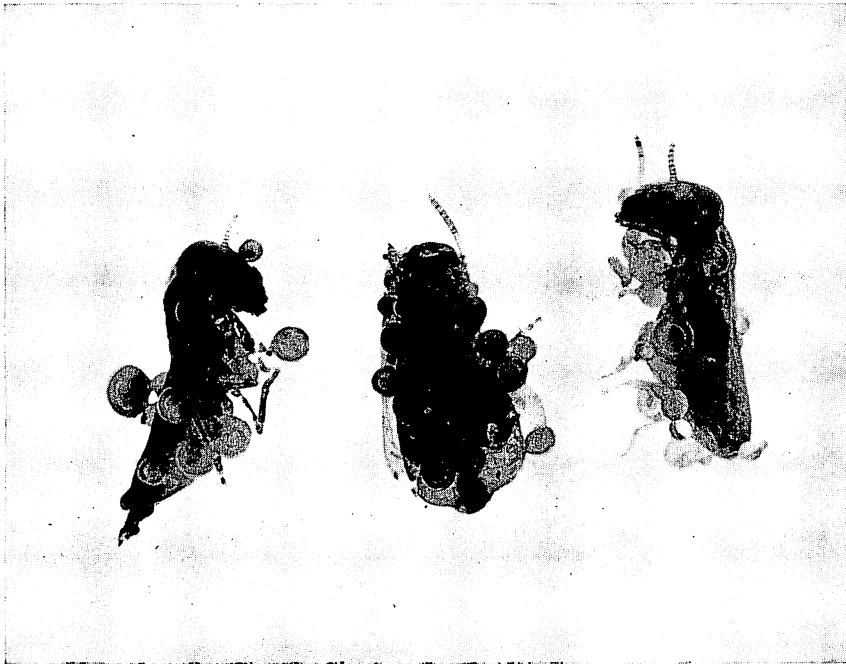


FIG. 4. *Cryptotermes brevis* (Walker) being fed on by *Pyemotes boylei* Krczal.

humidity chamber (Table 2). In addition, greater numbers of offspring were produced after feeding on the more freshly dead termites than on those that have undergone longer decomposition. The average number of offspring produced per female after feeding on the methyl bromide-killed termites soon after fumigation equalled that produced by the gravid females after feeding on termites which they themselves had paralyzed and killed. The methyl bromide-killed termites fed upon 10 days and earlier after fumigation supported 2 generations of *P. boylei*, whereas, those 15- and 20-day-old dead termites supported only 1 generation (Table 2). Inasmuch as the second generation females had to feed on the same termites which had been already partially consumed by the first generation females, the percentage of establishment, amount of opisthosomal enlargement, longevity, and the reproductive capacity of the second generation females were considerably less than those of the first generation females.

TABLE 2. *Effect of Methyl Bromide-Killed Cryptotermes brevis* (Walker) on *Pyemotes boylei* Krczal in Hawaii.

Days after Fumigation	Per cent Gravid Females	
	First Generation	Second Generation
0	95.0 ± 4.1	32.5 ± 3.1
5	54.2 ± 3.2	18.8 ± 4.8
10	30.3 ± 2.5	6.0 ± 3.3
15	15.8 ± 3.6	0
20	4.8 ± 2.5	0
25	0	0

None of the *P. boylei* females became established and gravid on *C. brevis* nymphs killed by sulfuryl fluoride. Termites subjected to this fumigant defecated and vomited out their body contents so within 2 to 3 days after fumigation, the dead termites were completely shrivelled and dried. Many *P. boylei* females fed and their opisthosoma enlarged slightly when given freshly-killed termites, but all of them died within 24 hours after commencement of feeding as though poisoned by some toxic residue.

SUMMARY

Pyemotes boylei, a species described from Hawaii, is widely distributed on all of the major islands of this State. It parasitizes many different kinds of insects in nature, but also is necrophagous on *Cryptotermes brevis* killed by methyl bromide. One of the most common host of this mite is the koa haole seed weevil, *Araecerus levipennis*, which infests the seeds of the koa haole, *Leucaena glauca*. On this host, mated *P. boylei* females start to reproduce after 4 to 5 days of feeding and during their life span of 19.9 ± 1.6 days produce an average of 207 ± 9.7 offspring per female. Although *A. levipennis* is a favorite host of *P. boylei*, this mite is not an important control agent of this anthribid beetle. The infestation of *L. glauca* by this weevil is still high

today and the parasitization of it by *P. boylei* is less than 10%.

Mated *P. boylei* females give birth to offspring of both sexes, but the sex ratio is greatly in favor of the females. A few males, no more than 4 per mother, are among the first offspring to emerge. They cluster around the mother's genital opening, seldom wander afar, and wait for the female offspring to emerge. The males live about 25 days after emergence and during that time, each may mate with as many as 100 females. On rare occasions, some females escape mating. These unmated females produce all male offspring and the total number of offspring produced is less than one-half that produced by a mated female.

The longevity, reproductive capacity, and sex ratio of *P. boylei* are readily affected by host differences and by the number of females feeding on a single host. On *C. brevis* nymphs, *P. boylei* females live longer but produce fewer offspring than on *A. levipennis* larvae. When the reproductive capacity of this mite changes due to host differences and intraspecific competition for a host, only the number of female offspring fluctuates while the number of males produced by each mated female remains the same. Therefore, when the mated *P. boylei* females are reared 1 per host, the sex ratio of their offspring is about 1 : 62 on *A. levipennis* larvae and 1 : 40 on *C. brevis* nymphs in favor of the females. However, when several mated females feed on an individual host, the number of female offspring can be greatly reduced so that a ratio in favor of the males is possible.

Although frequently parasitized in the field, such hosts as the eggs of *Dacus dorsalis* Hendel and *Dacus cucurbitae* Coquillett do not support *P. boylei* females to gravidity. After consuming an egg of these fruit flies, the opisthosoma of the female enlarges to a point where she is unable to crawl to another egg to feed. Such partially swollen females die *in situ* of the first egg they had consumed after about 5 days without producing offspring. *P. boylei* females die within 24 hours after emergence when not fed.

In Hawaii, pyemotid-caused dermatitis following fumigation of buildings for the control of the dry-wood termite, *C. brevis*, is no longer a problem since methyl bromide was replaced by sulfuryl fluoride as the fumigant. Both *P. boylei* and *C. brevis* are readily killed by either of these fumigants however, *P. boylei* can feed and reproduce on the dead termites fumigated with methyl bromide but not on those fumigated with sulfuryl fluoride. At least 2 generations of *P. boylei* are produced on the methyl bromide-killed termites if established soon after fumigation. Therefore, the outbreaks of *P. boylei* following methyl bromide fumigations of houses during 1957 to 1960 resulted not because *P. boylei* survived the fumigations but because it gained entrance into the houses from nearby sources soon after the fumigant had dissipated, multiplied in large numbers on the dead termites, and then started to bite the occupants after the dead termites no longer served as food.

P. boylei is able to parasitize *C. brevis* only when the individuals of the

former greatly outnumber the latter. Inasmuch as *P. boylei* females do not migrate in mass, a situation where they outnumber the termites of a healthy colony is never created. The few females that may gain access into a colony are undoubtedly accosted and killed by the soldiers and nymphs for termites are known to clean each other of all foreign matters.

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