Pyemotes herfsi (Acari: Pyemotidae), a Mite New to North America as the Cause of Bite Outbreaks

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ABSTRACT High incidences of red, itching, and painful welts on people in the midwestern United States led to the discovery of a European species of mite, *Pyemotes herfsi* (Oudemans) (Acari: Pyemotidae), preying on gall-making midge larvae on oak leaves. The mites' great reproductive potential, small size, and high capacity for dispersal by wind make them difficult to control or avoid.

KEY WORDS *Pyemotes herfsi*, mite, itching bites

The first news report of an outbreak of itching and painful bites in the midwestern United States concerned football players from Western Colorado State College after attending a picnic at a park at Pittsburg State University (PSU), Pittsburg, KS, on 26 August 2004, where, on the same day, they played against the PSU team. The news (local and regional newspapers and TV) of the outbreaks resulted in 75–100 calls a day to the Crawford County Public Health Office from Pittsburg residents complaining of similar "insect bites." During that time, an unrecorded number of patients visited the city hospital and 50 students with "pruritic rashes" were seen 23–27 August by the PSU Student Health Center. Typical bites were red welts ≈2 cm in diameter with a central vesicle (Fig. 1A) and were itchy and painful when scratched, often resulting in secondary bacterial infection. Most puzzling was the lack of any insect being seen or felt during the act of biting. The Kansas Department of Health and Environment requested assistance from the Centers for Disease Control and Prevention (CDC), Atlanta, GA, and the Department of Entomology, Kansas State University (KSU), Manhattan, KS, in determining the cause of the mysterious bites. Entomologists from the University of Nebraska, Lincoln, NE, where similar bites were being reported, and from PSU joined in the search.

Materials and Methods

Five CDC traps (John W. Hock Co., Gainesville, FL) baited with 0.5 kg of dry ice were operated for two nights (8 and 14 September 2004) in Pittsburg, KS, where bite incidence was running high. Fluorescent light traps operated in the county by the Kansas Cooperative Extension Survey were inspected for biting insects. Three of us (A.B.B., R. B., and D. G.) spent three evenings (14–16 September) in the high bite incidence park at PSU collecting flying biting insects that alighted on our exposed necks and shoulders (the most common sites of bites). Leaf litter and lawn debris were collected at the PSU park and placed in Tullgren funnel extractors (Burkard Manufacturing Co. Ltd., Rickmansworth, England) overnight.

Results and Discussion

Mosquitoes (Diptera: Culicidae) and biting midges (Diptera: Ceratopogonidae) were collected with the CDC traps but in numbers too small to account for the high incidence of bites. Collections by fluorescent light traps yielded no unusual biting insects. Efforts by three of us (A.B.B., R. B. and D. G.) to collect flying biting insects alighting on our bodies yielded no insects, yet the next morning each of us displayed five to eight itching welts on our necks and upper torsos. Likewise, Tullgren funnel extractions of arthropods from leaf litter and lawn debris yielded no unusual biting arthropods. The distribution of bites on the neck and shoulders, and where clothing fit loosely, eliminated chiggers (Acari: Trombiculidae) as sus-

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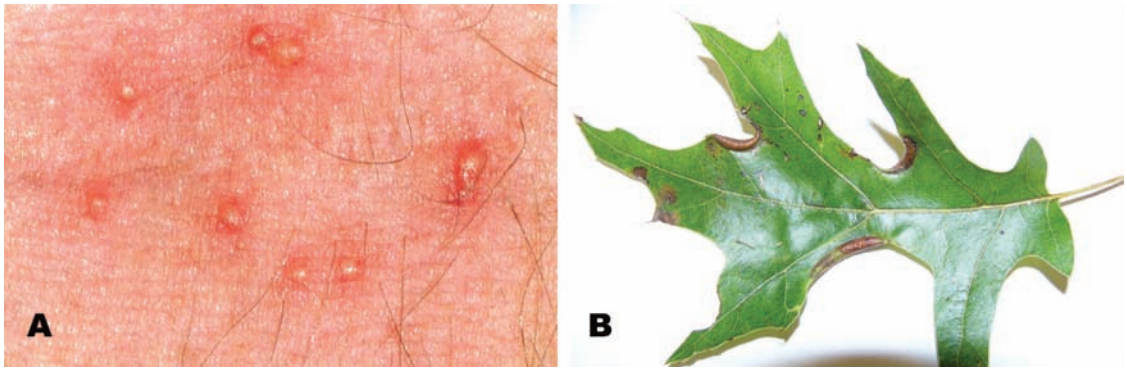

Fig. 1. (A) Bites on a person 38 h after exposure to *P. herfsi* mites in Lincoln, NE. (B) Pin oak leaf with three marginal leaf roll galls caused by *Contarinia* sp. larvae in Manhattan, KS.

pected culprits, despite that the bites resembled those of chiggers.

Clues about the probable cause of these bites were found in 1994 reports by Dr. Donald Mock (retired, Kansas Cooperative Extension Service) indicating that similar bites occurred in 1994 in Kansas City, KS. Straw itch mites, *Pyemotes tritici* (LaGrèze-Fossot & Montagné) (Acari: Pyemotidae), were suspected, but no specimens were collected. The reports indicated that the bites occurred on people after being outdoors in or near wooded areas. Based on this information, a search for itch mites was initiated and resulted in the discovery of *Pyemotes herfsi* (Oudemans) (Acari: Pyemotidae), preying on midge larvae, *Contarinia* sp. (Diptera: Cecidomyiidae), in leaf galls on pin oak, *Quercus palustris* Muenchh, in Lincoln, NE. Soon after, a similar picture of mites and midge larvae in oak leaf galls and associated incidence of bites on humans was documented in Pittsburg and Manhattan. The *Contarinia* sp. larvae induce leaf marginal roll galls (Fig. 1B) and smooth vein pocket galls (Gagné 1989), mainly on pin oaks but also on red, *Quercus rubra* L., and black, *Quercus velutina* Lam., oak.

The midge galls were either empty or contained dead (not responding to the touch) or living midge larvae. Among the larvae, one to several gravid (physogastric) female mites (Fig. 2) were discovered feeding on the *Contarinia* sp. larvae. *P. herfsi*, a European species, was identified on morphological characters. The only other report of this mite presence in the Americas is from Chile where it was found preying upon larvae of the pine tip moth, *Rhyacionia buoliana* Schiffermüller (J.M., unpublished). Surprisingly, a reinspection by J.M. (unpublished) of *Pyemotes* mites collected in Colorado in 1956 from hackberry nipple-galls has turned out to also be *P. herfsi*.

P. herfsi are 0.2 mm in length and barely visible to the naked eye. Species of *Pyemotes* mites generally have similar life habits (Smith 1973, Bruce and Wrensch 1990), as follows: newly emerged and mated females inject a neurotoxin-containing saliva into their hosts, which paralyzes the host and enables the gravid female mites to feed on the host' hemolymph. The toxin in the saliva of these itch mites is so potent that a single mite can paralyze and kill an insect larva 166,000 times its own weight (Tomalski et al. 1988). The posterior portion (opisthosoma) of the female enlarges (physogastry; Fig. 2) as its progeny develops inside, and, within a few days, up to 250 adult mites emerge from the gravid female. Bruce and Wrensch (1990) found that progeny of the straw itch mite averaged 254 offspring of which 92% were females. Males emerge before the females, position themselves around the mother's genital opening, and mate with emerging females. Then, mated females disperse to find new hosts. These mites often are dispersed by wind, and when they land on vertebrate hosts, they attempt to feed, resulting in the bites. A life cycle can be completed within 7 d, and progeny emergence can be extended to 15 d.

Attempts to feed on humans result in pruritic skin eruption, a condition that became widespread and serious in the United States for ≈10 yr at the beginning of the twentieth century and was attributed to *P. tritici*-infested straw used for manufacturing straw mattresses (Booth and Jones 1952). Booth and Jones (1952) gave a detailed description of the clinical manifestations and pathology of *P. tritici* bites: "The characteristic, cutaneous lesion is a rosy-red wheal sur-

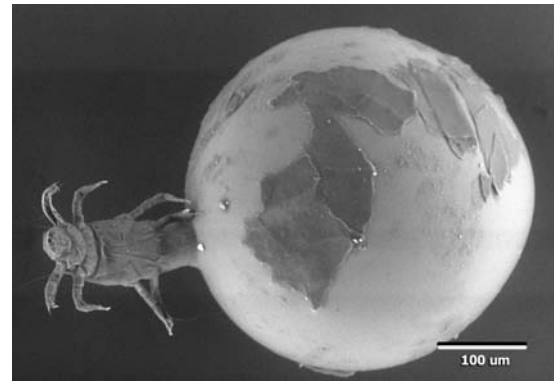

Fig. 2. Image of a physogastric *P. herfsi* female, taken as a fresh, nonfixed specimen on a frozen stage of a Hitachi S3500N scanning electron microscope.

mounted by a vesicle that rapidly becomes a pustule"; the pustules occur 10–16 h after mite exposure, with a wheal diameter of 0.5 cm (but might vary considerably). "Intense pruritus often leads to secondary bacterial infection." This description of bites is identical to that of *P. herfsi.* Although no record exists of a human death caused by the bites of these mites, many reports document the hospitalization of victims (Moser 1975). Bites on people visiting their physicians in the recent outbreaks have most commonly been misdiagnosed as spider bites.

A characteristic of most *Pyemotes* species is that their insect hosts are found in protected habitats, such as within kernels of stored grain, within the straw stem of grasses, inflorescences, and pine beetle galleries. This is a reflection of the precarious condition of the gravid female with a distended abdomen, and with no means of effective attachment to the host, except the minute, 15-μm-long stylets (measurement of scanning electron micrographs). The list of reported hosts of *P. herfsi* includes the furniture beetle, *Anobium punctatum* (De Geer), and various pests of stored grain, such as *Sitophilus granarius* (L.), *Sitophilus oryzae* (L.), and *Grapholita molesta* (Busck) (Cross and Moser 1975). Other hosts reported from Europe include *Tineola bisselliella* (Hummel) and *Pectinophora gossypiella* (Saunders). No reference was found in the literature on *Pyemotes* mites preying upon gall-making insects as is the case with the recent outbreaks. Weatherby et al. (1989) reported that *Contarinia acuta* Gagné, a pine needle sheath midge attacking loblolly pine, *Pinus taeda* L., is preyed upon by *Pyemotes emarginatus* Cross, Moser & Rack. Predation of the gall-making midges on oak leaves by *P. herfsi* is a new record for habitat and host expansion by *Pyemotes.* Numerous reports from Europe implicate *P. herfsi* as the causative agent of cases of dermatitis on workers in the stored grain industries (Samsinak et al. 1979, Liguori et al. 1989).

The severity of the infestation of oak galls with *P. herfsi* mites was demonstrated by values obtained from trees sampled in 30 different areas in Pittsburg and surrounding communities as ancillary activity to a community-based survey to assess the extent of the bite outbreak in that area (epidemiological survey conducted by personnel from CDC, Kansas Department of Health and Environment, and Crawford County Health Department; Hansen et al. 2005). Five leaves were collected at random from each of up to seven trees in each area and placed in plastic bags. Leaves were frozen at −5°C to kill the mites. Two leaves from each tree sampled were inspected for galls, gravid female mites and midge larvae. Leaves from 17 of the 30 areas were infested with *P. herfsi* mites, with an average of 48.11 ± 0.06 (SE)% of the leaves positive for gravid female mites. The leaves averaged 4.69 galls; with an average of 4.48 ± 1.00 gravid female mites per leaf and 0.89 ± 0.20 gravid mites per gall. The host midge larvae averaged 1.01 ± 0.11 per gall, of which 51.13 ± 0.06% were dead. Results of the epidemiological survey (Hansen et al. 2005) indicated that ≈54% of the population in Crawford County was affected by the bites and that the odds of having these bites were 3.9 times greater for residents who had at least one pin oak on their lot compared with those with no pin oak on their lot.

Mite infestation of galls in Lincoln, NE, might have been higher than that in southeastern Kansas given that of 44 gall-infested red oak leaves collected from flower beds on 27 February 2005, 229 galls in total were inspected and 193 (84%) were infested with mites.

Failure to recover with the Tullgren funnels any itch mite from leaf litter and lawn debris from the PSU park cannot be explained, given that three of us (A.B.B., R. B., and D. G.) had spent time searching for biting insects on the park, and instead had received bites consistent with the general description of bites caused by this mite. However, failure to recover mites with these extracting funnels may indicate that these mites respond differently than other arthropods to the mechanism of Tullgren funnels; for example, mites exposed to the funnels' conditions may remain inside the galls and other available microhabitats and perish in the process.

With the arrival of fall (2004), the frequency of bite reports shifted from persons engaged in summer activities to homeowners engaged in fall gardening activities (especially leaf raking) or just sitting on infested surfaces. We regularly found live mites in galls in fallen leaves. Galls collected in September 2004 that were placed in a freezer (kept at −5°C) in Manhattan resulted in 100% mite mortality; however, we found live mites in both Manhattan and Lincoln as late as 27 February 2005 in galls on leaves still on the trees or on the ground, which had been exposed to temperatures lower than −18°C. Three of the galls had a total of seven live gravid mites. These observations suggest that, most likely, these mites survive the winter in some form of diapause.

We also received reports of bites on dogs and cats. Of interest was the occurrence of bites on humans and pets that rarely ventured outdoors, thus, raising the possibility that the mites entered human dwellings through opened screened doors and windows, aided by the wind. The idea that mites might disperse by air was strengthened by the capture of mites on 15.2- by 30.5-cm yellow sticky trap cards placed either horizontally or vertically beneath pin oak trees in backyards of Lincoln, NE, homes where a high incidence of bites had been reported. Two cards placed vertically and one horizontally on 19 September 2004 and exposed for 24 h at home A trapped eight and 79 and 371 mites, respectively. One horizontal card each placed at homes B and C on 9 October 2004 yielded 23 and 29 mites, respectively. These observations at least give a sense of the risk of being bitten by these mites under mite-infested oak trees.

Bite outbreaks and associated *P. herfsi* specimens have been confirmed (finding mite-infested oak leaf galls) from Pittsburg and other areas of Kansas (Manhattan and surrounding communities), Missouri (St. Louis and Joplin), and Nebraska (Lincoln, Omaha, Norfolk, and Grand Island).

Many important questions remain as to the biology of this mite, including wind dispersal, overwintering strategy, how it reinfests galls on trees, the strategy used by this multivoltine species as it preys upon (putatively) univoltine midge species, and its current and potential distribution in the United States. Furthermore, the vertebrate–host relationship, such as the time needed for the host to be exposed to the mite for a bite to be manifested, and the value of repellents as protectants against these mites' bites would be valuable information in recommending human and pet protection.

We do not present direct evidence proving that this introduced species of mite is responsible for the bite outbreaks; direct proof would require finding nongravid female mites in the act of biting humans and then observing the manifestation of bites some 16 h later. Because of the mite's small size and the lack of pain associated with the biting process, documenting this event would be difficult. However, the number of patients with bites of similar characteristics and associated with the presence of oak trees and gall midge larvae is compelling evidence to support the conclusion that these mites are responsible for these bite outbreaks. Additional support for a cause-and-effect relationship stems from the numerous bites several of us received early in the study while working with mite-infested oak leaf galls. Experience and the itching bites taught us to exercise extreme care in handling oak leaf samples. Finally, the similarity of the bites recorded in 2004 with those caused by other *Pyemotes* and the patent differences with those caused by other arthropods (e.g., mosquitoes, chiggers, and fleas) add to the body of indirect evidence emphasizing the consistent connection between these mites and bites. Although we have no definite evidence, we present here a strong case that leads us to conclude that *P. herfsi* is responsible for the outbreaks of bites in the midwestern United States.

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