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A NEW COCCIDIAN FROM *ACOMYS CAHIRINUS* DESMAREST, 1819, FROM EVOLUTION CANYON, LOWER NAHAL OREN, MOUNT CARMEL, ISRAEL

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ABSTRACT: In 1994, fresh fecal samples were collected and examined for coccidian parasites from 43 spiny mice (*Acomys cahirinus*) and from 60 wood mice (*Apodemus mystacinus*). The 2 genera of rodents inhabit an area in Lower Nahal Oren, Mount Carmel, Israel, known as Evolution Canyon, which consists of opposite-facing slopes that are geologically identical, but microclimatically very different. *Acomys cahirinus* is found primarily on the warmer and drier south-facing slope (SFS), whereas *A. mystacinus* primarily inhabits the cooler and wetter north-facing slope (NFS). None of the samples from the *A. mystacinus* contained coccidia, but 6 of 43 (14%) *A. cahirinus* individuals were discharging eimerian oocysts that we describe herein as a new species. Five of the 6 positive samples were from the SFS. Sporulated oocysts are ovoidal to subspheroidal, 26.5×22.9 ($21\text{--}29 \times 19\text{--}26$) μm , without a micropyle, but with an oocyst residuum of 1 to several large clear globules and a medium-sized refractile polar body; they contain lemon-shaped sporocysts, 10.4×8.1 ($10\text{--}11 \times 7\text{--}10$) μm , with a sporocyst residuum and Stieda body, but no sub-/or parastieda body. Sporozoites lie side by side, completely filling oocysts; each contains a large posterior refractile body.

A unique canyon in Lower Nahal Oren, Mount Carmel, Israel, recently referred to as Evolution Canyon (Nevo, 1995), provides a convenient site to study the evolution of rodents that are ecologically segregated in relation to microclimatic factors. The north-facing slope (NFS) and the south-facing slope (SFS) share the same geology, but are separated by a valley floor approximately 100 m wide. Despite such close proximity, these opposing slopes have remarkably different biological communities (Nevo, 1995), due to considerably different inputs of solar radiation (up to 300% greater on the SFS than on the NFS) (H. Kutiel and L. Sher, unpubl. obs.). The SFS is basically a savannahlike, open park forest, consisting largely of perennial and annual grasses, patches of shrubs (mainly *Pistacia lentiscus*), an occasional carob tree (*Ceratonia siliqua*), and considerable open rock surfaces. By contrast, the NFS is a dense maquis of live oak (*Quercus calliprinos*) and shrubs. Overall, the macroclimate of both slopes is Mediterranean, with an average rainfall of about 600 mm that falls almost exclusively from November through April. The rest of the year is relatively dry. The dramatic interslope microclimate divergence is caused by the substantially higher solar radiation on the SFS, resulting in a xeric, stressful savannah.

The rodent community on the SFS is dominated by the spiny mouse, *Acomys cahirinus* Desmarest, 1819, with a much smaller proportion of the wood mouse *Apodemus mystacinus* Danford and Alston, 1877 (see Results). The NFS is dominated numerically by *A. mystacinus*, with a smaller population of *A. cahirinus* (Blaustein et al., 1996; L. Blaustein, G. Shenbrot, and E. Nevo, unpubl. obs.).

Acomys spp. typically inhabit arid regions that consist of rocky areas or dry woodlands/savannahs, such as that of the SFS. They shelter in rocky crevices, cracked soil, or sometimes other rodent burrows. Their diet consists primarily of plant material such as grains and grasses, although they are occasionally omnivorous (Nowak and Paradiso, 1983).

In contrast, *Apodemus* spp. primarily inhabit the woodlands

and forests of the NFS (Blaustein et al., 1996). They live in burrows, usually with many chambers, under tree roots. Their diet consists of roots, grains, seeds, berries, and insects. Additionally, they tend not to travel beyond a radius of 180 m from their burrows (Crawley, 1969).

To date, no studies have been done on the parasites that may infect rodents from this locality. Also, because the opposite slopes represent dramatically different biotic environments due to differences in solar radiation and other climatic factors such as rainfall and temperature, we were interested in determining if these factors affect parasite (coccidian) prevalence in the rodents inhabiting Evolution Canyon.

MATERIALS AND METHODS

From July through December 1994 (primarily the dry season), 43 spiny mice and 60 wood mice were live-trapped from Evolution Canyon. Fresh fecal samples were collected from each animal upon capture and placed in separate vials containing 2% (w/v) aqueous potassium dichromate ($\text{K}_2\text{Cr}_2\text{O}_7$), mixed thoroughly, and stored for approximately 2–4 wk at ambient temperature (ca. 21 °C). Animals were released after collection of feces. Samples were returned to Albuquerque, New Mexico, and processed as detailed by Duszynski et al. (1982), and stored at 4 °C. Oocysts were measured and photographed within 30 days after arrival. All measurements are given in μm with size ranges in parentheses following the means.

RESULTS

Acomys cahirinus dominated the SFS whereas *A. mystacinus* dominated the NFS. During the period of study, 152 *Acomys* and 52 *Apodemus* were collected on the SFS. In contrast, 34 *Acomys* and 93 *Apodemus* were collected on the NFS. Density of *Acomys* on the SFS (152 of 204, 75%) was significantly higher than that of *Apodemus* (52 of 204, 25%; Fisher's Exact Test, $P < 0.0001$), whereas the reverse was true for the NFS, with a higher density of *Apodemus* (93 of 127, 73%) vs. *Acomys* (34 of 127, 27%) (L. Blaustein, unpubl. observ.). Fecal samples were obtained from 43 *A. cahirinus* and from 60 *A. mystacinus*. None of the samples from *Apodemus* contained coccidian oocysts, but 6 of the 43 (14%) *A. cahirinus* samples were positive for oocysts, representing a species of eimerian that we describe here as new. Five of the 6 positive samples were from the SFS.

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FIGURES 1–3. Photomicrographs of sporulated oocysts obtained from the feces of *Acomys cahirinus* in Lower Nahal Oren, Mount Carmel, Israel. Scale bar = 10 μ m for all figures. Abbreviations: or, oocyst residuum; s, Stieda body; sr, sporocyst residuum.

DESCRIPTION

Eimeria cahirinensis n. sp. (Figs. 1–4)

Oocyst ovoidal to subspheroidal (Figs. 1–3), wall ~ 1.5 , composed of 2 layers: outer layer slightly striated and pitted, $\sim 3/4$ of total thickness; inner layer smooth, transparent; oocyst residuum consists of either 1 large clear globule or several large granules (Figs. 1, 2); micropyle absent, but medium sized, refractile polar body present; sporulated oocysts ($n = 20$) 26.5×22.9 ($21\text{--}29 \times 19\text{--}26$) with length:width ratio (=shape index, SI) 1.2 (1.0–1.3); sporocysts ($n = 20$) lemon-shaped, 10.4×8.1 ($10\text{--}11 \times 7\text{--}10$) with SI 1.3 (1.1–1.4); somewhat wide, thick

Stieda body present (Fig. 3), sub-/and parastieda body absent; sporocyst residuum of medium-sized granules that appear in clusters across center of sporocyst between sporozoites (Fig. 2); 2 sporozoites present, each with posterior refractile body, lying head to tail, and filling entire sporocyst.

Taxonomic summary

Type host: *Acomys cahirinus* Desmarest, 1819 (Muridae: Murinae), spiny mouse.

Type locality: Israel, Mount Carmel, Nahal Oren, south-facing slope, Evolution Canyon, $32^{\circ}43'N$, $34^{\circ}58'E$.

Prevalence: Found in 6 of 43 (14%) *A. cahirinus*; 2 samples from the SFS and 1 sample from the NFS had unsporulated oocysts, but these were identical in size and general oocyst structure to the sporulated oocysts.

Site of infection: Unknown, oocysts collected from feces.

Material deposited: Phototype (see Bandoni and Duszynski, 1988) of sporulated oocysts in the U.S. National Parasite Collection, Beltsville, Maryland, USNPC no. 86844.

Etymology: The nomen triviale is derived from the species name of the host and *-ensis* (L., belonging to).

Remarks

Within the subfamily Murinae, to which *Acomys* belongs, there are 119 genera (Wilson and Reeder, 1993). Only 14 of the 119 (12%) genera have coccidian species described from them (82 *Eimeria* spp. and 10 *Isospora* spp.), but none has been described from *Acomys* until now. Only 2 of these previously described *Eimeria* spp. from genera of this subfamily are similar to the 1 that we describe here as new (see Levine and Ivens, 1990). Oocysts of this new species most closely resemble those of *Eimeria nesokia* Mirza, 1975, described from the short-tailed bandicoot rat, *Nesokia indica* Gray and Hardwicke, 1830, in Egypt and Iraq, in size and shape of their oocysts, in wall structure, and in shape of their sporocysts. Oocysts of the proposed species differ, however, by being slightly larger (26.5×22.9 vs. 24×20), and by having sporocysts with a Stieda body, which those of *E. nesokia* lack. Oocysts of the new species also resemble those of *Eimeria pretoriensis* De Vos and Dobson, 1970, described from the 4-striped grass mouse, *Rhabdomys pumilio* Sparrman, 1784, from South Africa, in size and shape of their oocysts, in wall structure, and in size (but not shape) of their sporocysts. Oocysts of the proposed species differ by being slightly larger (26.5×22.9 vs. 24×19), and by having sporocysts that are lemon-shaped with a wide, thick Stieda body vs. an elliptical shape with a small Stieda body. In addition, the sporocysts of *E. pretoriensis* have a sporocyst residuum composed of large granules that almost completely obscure the sporozoites, whereas those of this species are medium-sized granules clustered along the center of the sporocyst.

FIGURE 4. Composite line drawing of sporulated oocyst of the eimerian collected from the feces of *Acomys cahirinus* from Lower Nahal Oren, Mount Carmel, Israel. Scale bar = 10 μ m.

Finally, these oocysts also closely resemble those of *Eimeria arizonensis* Levine, Ivens and Kruidenier, 1957, described from the piñon mouse, *Peromyscus truei* Shufeldt, 1885 (subfamily Sigmodontinae), from Arizona, which are similar in shape of oocyst and sporocysts. The oocysts from *A. cahirinus* differ by being slightly larger overall (26.5×22.9 vs. 23.6×20.8), by having less elongate sporocysts (10.4×8.1 vs. 12.1×7.7), and by having a slightly wider and flatter Stieda body. In addition, *E. arizonensis* has only been described from North American hosts.

DISCUSSION

The period of time that coccidian oocysts survive in the natural environment of their hosts is dependent on such factors as temperature, vegetation, shade, and moisture. Some coccidian oocysts can remain viable in their external environment for 52–86 wk (Farr and Wehr, 1949; Koutz, 1950; Frenkel et al., 1975), but the length of survival is apparently species dependent and, thus, unknown for most coccidia. Oocysts would probably survive longer in mesic environments with little direct solar (ultraviolet) radiation and with substantive vegetation to provide shade and retain moisture. The SFS is an area that is climatically unpredictable and, seemingly, less conducive to oocyst survival because it is warmer and more xeric, has more solar radiation, and has less vegetation than does the NFS. In addition, our collections were made during the dry season. Surprisingly, 5 of the 6 infected *Acomys* in this study were taken from the SFS.

In another rodent species from Israel, *Spalax ehrenbergi*, prevalence also was higher in rodents that inhabited the more xeric regions (Couch et al., 1993). In *S. ehrenbergi*, host genetic diversity (chromosomal and genic) increases as habitats become more climatically unpredictable (Nevo and Cleve, 1978; Nevo, 1985, 1995), which is positively correlated with parasite prevalence and parasite success in these hosts (Couch et al., 1993). A similar observation was made by Gardner and Duszynski (1990) on the rodent tuco-tuco (genus *Ctenomys*) in Bolivia, a species that exhibits the highest known chromosomal variation of all mammals. *Acomys* spp. also are known to show considerable genetic variation with $2n$ ranging from 36 to 38 to 66 in different species (Nevo, 1985). The *A. cahirinus* examined in this study had a $2n = 38$. Perhaps this species also exhibits more genetic diversity, is more recently derived in response to the harsher environment, or both. The SFS habitats are more physiologically stressful for species living there than those that inhabit the NFS. Thus, if increased genetic diversity is a result of environmental stress on the host, then this response to stress may further contribute to the higher incidence of infection in *Acomys* spp. when coccidia are present in its xeric natural environment.

Although the habitat and habits of *Apodemus* spp. are more conducive to oocyst survival, (i.e., temperate and moist, use of burrow systems), the *A. mystacinus* we examined were uninfected with coccidia. In contrast, other *Apodemus* spp. studied in Japan, Russia, and the British Isles all have had substantial infections with several species of coccidia (Musaev and Veisov, 1963; Glebezdin, 1973; Lewis and Ball, 1983; Wash et al., 1985). *Apodemus* spp. do not exhibit high genetic diversity (Filippucci et al., 1989; Nevo et al., 1997), and if genetic diversity is indeed a response to harsher environments, then one would not expect to see such diversity in an environment such as that of the more mesic and less climatically unpredictable NFS.

Wasser et al. (1995) described a large number of species of antibiotic fungi found in Evolution Canyon; we speculate that this may contribute in part to the low prevalence, particularly in the *Apodemus*. For example, 15 species of *Penicillium* (of 100 known species worldwide) were isolated among soil micromycetes in the canyon. Perhaps the abundance of fungal spores lends itself to providing some medicinal value that may inhibit coccidial infections in these rodent species. In particular, *A. mystacinus* may be better protected due to an increased growth of the fungi on the more mesic NFS (12 species vs. 6 species on the SFS).

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