Journal of Zoo and Wildlife Medicine 44(3): 654–659, 2013

CHEYLETUS ERUDITUS (TAURRUS®): AN EFFECTIVE CANDIDATE FOR THE BIOLOGICAL CONTROL OF THE SNAKE MITE (*OPHIONYSSUS NATRICIS*)

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Abstract: The most commonly encountered ectoparasite in captive snakes is the hematophagous snake mite (*Ophionyssus natricis*). Infected snakes often exhibit lethargy, dysecdysis, pruritus, crusting dermatitis (sometimes progressing to abscesses), and behavioral changes (increased bathing time, rubbing against objects). Anemia and septicemia are occasional complications. Eliminating snake mites from a collection is frustrating. Insecticidal and acaricidal compounds used in mammals can be used against *O. natricis* infestation in reptiles, but they all are potentially neurotoxic to reptiles. The use of a biological agent to control the snake mite was first developed by using the predatory mites *Hypoaspis miles* and *Hypoaspis aculeifer*. However, no data are available regarding the potential of these mites to control *O. natricis*. Furthermore, the survival and predatory behavior of *H. aculeifer* and *H. miles* decreases above 28°C, which is the lower value of the optimal temperature zone range required for rearing snakes. The aim of this study is to identify the ability of the predatory mite *Cheyletus eruditus* to control *O. natricis*. In the first experiment, 125 *O. natricis* mites where placed in separate plastic tubes together with the same number of *C. eruditus* mites. After 48 hr, the survival rate of snake mites was 6% compared with 92% in the control group ($n = 125$, $P < 0{,}001$). In the second experiment, 11 infested (average of 13 *O. natricis* per snake) ball pythons, with an average of 13 *O. natricis* per individual, were placed in separate cages with 1,000 *C. eruditus* mites + vermiculite After 15 days, only an average of two mites per snake remained, compared with 48 per snake in the control group (t-test, $P < 0{,}01$).

Key words: Reptile, *Ophionyssus natricis*, *Cheyletus eruditus*, predatory mite, biological control.

INTRODUCTION

Both wild and captive reptiles are frequently affected by external parasites. Of these, acarids (ticks and mites) are the most commonly encountered in first opinion practice. They can affect their host through various mechanisms, including blood sucking resulting in anemia, mechanical or allergic irritation leading to stressful pruritus or as vectors for other pathogens (filariae, blood parasites, viruses, and bacteria).[8,11,14,17,25] In snakes, the most common ectoparasite (and most feared by snake keepers) is the hematophagous snake mite (*Ophionyssus natricis*) belonging to the Macronyssidae family of the suborder Mesostigmata.[9,10,14,17,20,29,30] Although snakes are the usual host, captive lizards may also become infested.[4,14,16,17,18,25] Some infestations may be spectacular with thousands of mites per host.[14,29] *O. natricis* has been shown to infest wild snakes although ecologic factors probably influence host-parasite relationships when compared with captive conditions.[30] In captivity, outbreaks of *O. natricis* can expose snakes to a much higher load of parasites when compared with wild conditions.[30]

The snake mite is a nest parasite and is thus well adapted to reptile collections, with cages and other enclosures providing an ideal nesting environment.[10,14,17,20,29,30] Its morphology and behavior suggest that it shares a common lineage with *Steatonyssus* spp. (a mammalian mite) and *Dermanyssus gallinae* (the red poultry mite).[14] *O. natricis* has a life span of about 40 days, irrespective of whether it has fed or not. The life cycle is relatively short, ranging from 7 to 16 days. The female (up to 1.5 mm in length) is larger than the male and takes two to three blood meals lasting between 4 and 8 days at an interval of 1 to 2 wk. At each meal, a female can ingest more than 1,500% of her body weight in blood. A clutch of about 20 eggs (0.5 mm each) is laid on the inner surfaces of the terrarium. When the humidity rises above 85% and the temperature ranges between 20°C to 30°C, larvae hatch in 1 to 4 days. The eggs die from desiccation if the humidity drops below 50% and/or the temperature rises above 40°C. The free-living larvae measure about

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400 μm, are whitish in color. and possess three pairs of legs. When the temperature reaches between 25°C and 30°C with a humidity above 75%, the larvae molt into protonymphs within 24 hr. The protonymphs, which possess four pairs of legs, take a single blood meal that enables them to survive between 3 and 7 days at 25°C. In 12 to 48 hr following their meal, 90% molt into deutonymphs. Like larvae, the deutonymph stage is a free-living nonparasitic stage. At 25°C, the deutonymphs molt into adults, a process that takes 24 to 26 hr. Adults are highly mobile, and following mating, females lay eggs that hatch into females only. If the eggs are not fertilized, they hatch into males only by arrhenotokous parthenogenesis. Both the adult and protonymph stages are parasitic and feed on reptile blood. In contrast, the larval and deutonymph stages are nonparasitic free-living stages. All stages are killed if the temperature in the terrarium rises above 50°C–55°C, and development is arrested if the humidity remains below 50%.[10,14,17,29,30]

Infected snakes often exhibit lethargy, dysecdysis, pruritus, crusting dermatitis (sometimes progressing to abscesses), and behavioral changes (increased bathing time and rubbing against objects). Anemia and septicemia are occasional complications. The presence of small black granules between scales or on the hand following handling should lead to a scrupulous examination of the entire tegument of the snake. The snake mite can most commonly be found around the eyes, where they cause a characteristic annular swelling on the rims of the spectacle. They can also be found on the thin part of the skin between the mandibles.[14,29]

The diagnosis of snake mite infestation is usually straightforward: the parasites are easily identifiable with the naked eye or with a magnifying glass. Water bowls can be examined for drowned parasites. The definitive diagnosis is made by microscopic identification.[14,29]

Eliminating snake mites from a collection is notoriously frustrating, as they are expensive and time consuming to kill and have a high rate of recurrence. Total elimination is only successful if coupled with rigorous environmental treatment. Many insecticidal and acaricidal compounds used in dogs, cats, and other mammals can be used against *O. natricis* infestation in reptiles.[5,6,7,14,17,26,29] These include pyrethrins and pyrethroids, organophosphates, ivermectin (as a prepared diluted topical spray or injected subcutaneously), fipronil, and dichlorvos. These molecules are, however, to varying degrees potentially neurotoxic to reptiles. Environmental treatment involves removal of all objects in the terrarium. The terrarium should be washed and scrubbed with hot water (>50°C) and then thoroughly sprayed with an acaricide. Decorations such as stones and bowls can be treated in the same manner; however, bark and soil should be thrown away. Prevention relies on a strict quarantine of at least 3 mo for any newly acquired specimen prior to its introduction into the collection.[5,6,7,14,17,26,29]

A novel treatment method developed in the past decade in the United States involved biological control agents using the predatory mites *Stratiolaelaps miles* and *Stratiolaelaps aculeifer* (syn.: *Hypoaspis*).[3] Unfortunately, no data are available regarding the potential of these mites to control snake mites.

The predatory mite *Hypoaspis miles* is currently used to control *Dermanyssus gallinae* in poultry farms and has been used for several years as a biological control agent of sciarid flies in horticultural and mushroom-rearing facilities.[23]

Predator mites of the genus *Hypoaspis* are mainly ground dwelling, although they have occasionally been reported to live in bird nests in very low numbers.[13,19,21] The activity of *Hypoaspis aculeifer* is temperature dependent as it cannot survive for extended periods at 32°C–34°C.[23] Furthermore, predation capacity of *H. aculeifer* and *H. miles* decreases above 28°C.[1]

Information is lacking about the use of *Cheyletus eruditus* as a biological control agent of the snake mite. *C. eruditus* is another species of predatory mite that seems to be better suited for the control of snake mites. Unlike the *Hypoaspis* species, *C. eruditus* is present in large numbers in bird nests and mammal burrows,[23,28] feeding on different astigmatic and blood-sucking mite species.[1,15,23,28] *C. eruditus* is well adapted to feed on *D.* gallinae,[1,15] is able to survive in warm environments, and reproduces well at 28°C.[28]

The life cycle of *C. eruditus* takes 2 wk at 28°C and around 52 days at 18°C.[2] The mite remains active as a predator against dust mites between 20°C to 30°C and 70–90% humidity.[27] Snake breeding units are usually warmed between 28°C–30°C and 70–90% humidity, which are good conditions for *C. eruditus* introduction and survival. That the predator mites have the same environmental requirements as snakes is advantageous.

Moreover, it has been observed that *C. eruditus* sometimes attacks and kills preys without feeding on them and leaves them partially eaten.[12,22] This nonconsuming prey behavior may have an impor-

tant benefit as to the use of controlling parasite populations because the number of preys killed is not entirely dependent on feeding status.

Another interesting aspect is the capacity of *C. eruditus* to survive in poor environmental conditions. *C. eruditus* can be kept alive for several months in cold conditions (0°C ±1°C and 84–85% relative humidity [RH]) without feeding.[24] Cannibalism and the ability to endure periods of starvation enable the mite to withstand periods of prey absence.[27] The mites persevere at very low population densities and multiply once prey numbers begin to increase.

The aim of this study was to identify the potential of *C. eruditus* in controlling the snake mite. To achieve this, an experiment was devised to study the predation rate of *C. eruditus* on *O. natricis* and its capacity for eradicating the parasite from a snake breeding unit in similar conditions those found in amateur collections.

MATERIALS AND METHODS

The snake mites (*O. natricis*) and snakes (*Python regius*) described in this paper were taken from a heavily infested amateur breeding unit. The collection comprised 43 snakes, mostly *P. regius* and a few Colubridae species. The snake mites were collected from snake cages (plastic boxes) and infested substrate using a mouth vacuum. Mite manipulation and transfer were done using a thin paintbrush. Identification of the mite was done under stereomicroscopy from a sample of 10 mites cleared with a Hoyer's solution (20 g of glycerine, 30 g of gum Arabic, 40 g of distilled water, and 150 g of chloral hydrate).

The predatory mites *C. eruditus* used were obtained from the product TAURRUS®, containing living *C. eruditus* mixed in vermiculite (APPI-group Koppert, 36 Boulevard Joliot Curie 44200 Nantes, France) and commercially available in France.

An in vivo predation test was first undertaken in transparent plastic tubes (6 mm long × 2.5-mm diameter) that contained neither water nor food. Each plastic tube contained one isolate individual nymphs of each species (groups 1 and 2) or one nymph of both species together: the predator *C. erudilus* and the parasite *O. natricis* (group 3).

Nymph stages of both species were preferred to adult ones, and nymphs were selected randomly from an initial population without any consideration for sex, size, color, or age. Nymphs were transferred to tubes with the help of a thin paintbrush, and survival rate of the different groups was assessed after 48 hr by counting the number of live and dead mites inside each tube.

The first control group (group 1, M1) was composed of 125 pill tubes, each containing an isolated *O. natricis* nymph. The second control group (group 2, M2) was composed of 125 pill tubes, each containing an isolated *C. eruditus* nymph. The test group (group 3, M3) was composed of 125 pill tubes, each containing one *O. natricis* nymph and one *C. eruditus* nymph. All tubes were then transferred into a dark climatic room at 26°C and 75% RH.

The second experiment performed was an in situ biological control test. Twenty-two ball pythons (*P. regius*) with visible snake mite infestation were selected from a breeding unit (La Ferme Tropicale, 54 rue Jenner, 75013 Paris, France) independently of their age, sex, or size. Selected snakes were isolated in separate plastic boxes measuring 60 × 60 × 35 cm (L × W × H) containing 300 g of clean coco bark substrate and one plastic pot with water. The number of parasites on the snake's skin was counted visually before transferring each snake into a new box. An average of 13 *O. natricis* was counted per snake at the beginning of the experiment, with a range of 4 to 22 mites per snake. Snakes were then divided equally into a test group and a control group (11 snakes in separate boxes per group). Both groups were kept in two different ventilated rack cupboards equipped with warming cables. At the beginning of the experiment (T0), the environmental conditions approximated 26°C (±3°C) and 80% RH (±15%) in each box, measured with HOBO® U10-003 (Onset Company, Bourne, Massachusetts 02532, USA).

At T0, 15 g of the product TAURRUS (containing 1,000 mobile stages of the predatory mite *C. eruditus* mixed in vermiculite) was deposited on the substrate of the 11 boxes in the test group. The control group received only 15 g of pure vermiculite.

Ten days (T0 + 10) and 15 days (T0 + 15) after the start of the experiment, the snake mite population was assessed by visually counting the number of mites present on the skin of each snake in both control and test groups. Counting was done after transferring each snake from their box to an examination table. Mites that had dropped off the snake during examination were counted; however, mites found in the substrate or drowned in water bowls were not counted.

At the end of the experiment, five boxes in each group were randomly chosen. From each one, 150 g of substrate was sampled. Mites were extracted

Table 1. Mean survival rates (%) of *O. natricis* and *C. eruditus* in groups M1, M2, and M3. Group M1 = nymphs of *O. natricis* isolated individually in pill tubes. Group M2 = nymphs of *C. eruditus* isolated individually in pill tubes. Group M3 = nymphs of *O. natricis* and *C. eruditus* placed together in pill tubes. n = number of pill tubes in each group. Survival rate of the snake mite *O. natricis* was significantly higher when isolated individually (Fisher's exact test, $n = 125$, $P < 0.001$).

	n	*O. natricis*	*C. eruditus*
M1 = *O. natricis*	125	92	NP[a]
M2 = *C. eruditus*	125	NP[a]	96
M3 = *O. natricis* + *C. eruditus*	125	5.83	99

[a] NP, not present.

with a Berlese funnel using a 100-W bulb placed 12 cm above a funnel (covered with a mesh of 0.5-mm diameter) that contained the substrate sample. Animals dropping from the funnel were collected in a glass receptacle containing alcohol. The lamp was turned on for 15 min, and the contents of the receptacle were analyzed under stereomicroscopy.

RESULTS

Mite survival rate in the control group M1 was high (10 dead, 92% survival). Similar observation was made for the survival of the predatory mite from the control group M2 (96% survival rate). Thus, experimental conditions were not overly deleterious, neither for parasitic nor predatory mites when isolated in such conditions.

The survival rate of *O. natricis*, when enclosed with the predator *C. eruditus* (test group, M3), fell to fewer than 6%, significantly lower than survival observed when snake mites (M1) are enclosed individually (Fisher's exact test, $P < 0{,}01$; Table 1).

Figure 1. Predatory mite *C. eruditus* attacking a snake mite (*O. natricis* female).

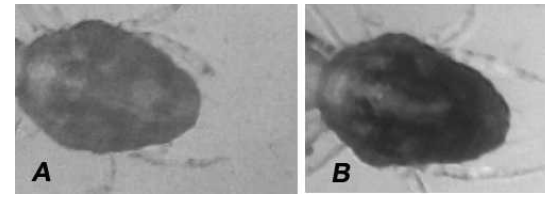

Figure 2. **A.** *C. eruditus* before feeding (with a light brown idiosoma). **B.** *C. eruditus* after feeding on an *O. natricis* mite (with a dark red idiosoma).

Visual observations were made throughout the experiment, showing the predatory mite attacking the parasite *O. natricis* (Fig. 1). As the idiosoma (body) of *C. eruditus* changed color following ingestion of *Ophionyssus* mites (Figs. 2A, B) and because no dead mites were present in the tubes at the end of the experiment, it was possible to conclude that *C. eruditus* shows a predatory behavior against *O. natricis* and that the unaccounted for *Ophionyssus* mites in each tube had been eaten by the predatory mites.

In the second experiment (the in situ biological control test), at T0 + 10, snakes in the control group were the most infected with an average of 25 *O. natricis* per animal (range = 4 to 55 per snake). Snakes in the test group carried an average of 13 parasites (range = 2 to 18 per snake). Snakes from the control group were significantly more infected than snakes from the test group (T. test, $P < 0{,}05$).

At the end of the experiment (T0 + 15), snakes in the control group were still the most infested (T. test, $P < 0{,}01$), with an average of 42 mites per snake (range = 18–55). Snakes in the test group were the less infested with an average of two mites per snake, (range = 0–4; Fig. 3). Average parasitic mite population of snakes from both groups differs with Δ of -1; $+13$, and $+40$.

Parasites (*O. natricis*) in the substrate were not accurately counted, but it was possible to observe more snake mites in the samples from the control group compared with the test group. These observations were corroborated with the results of substrate extraction using the Berlese funnel: in total, five mobiles stages of *O. natricis* were extracted from the substrate samples of the test group, and 179 were extracted from the substrate samples of the control group. This system does not count eggs, freshly hatched larvae, and weak individuals that dry out before reaching the end of the funnel.

Predatory mites (*C. eruditus*) were not found in the substrate of the control group. However, a total of 103 mobile stages, including larvae,

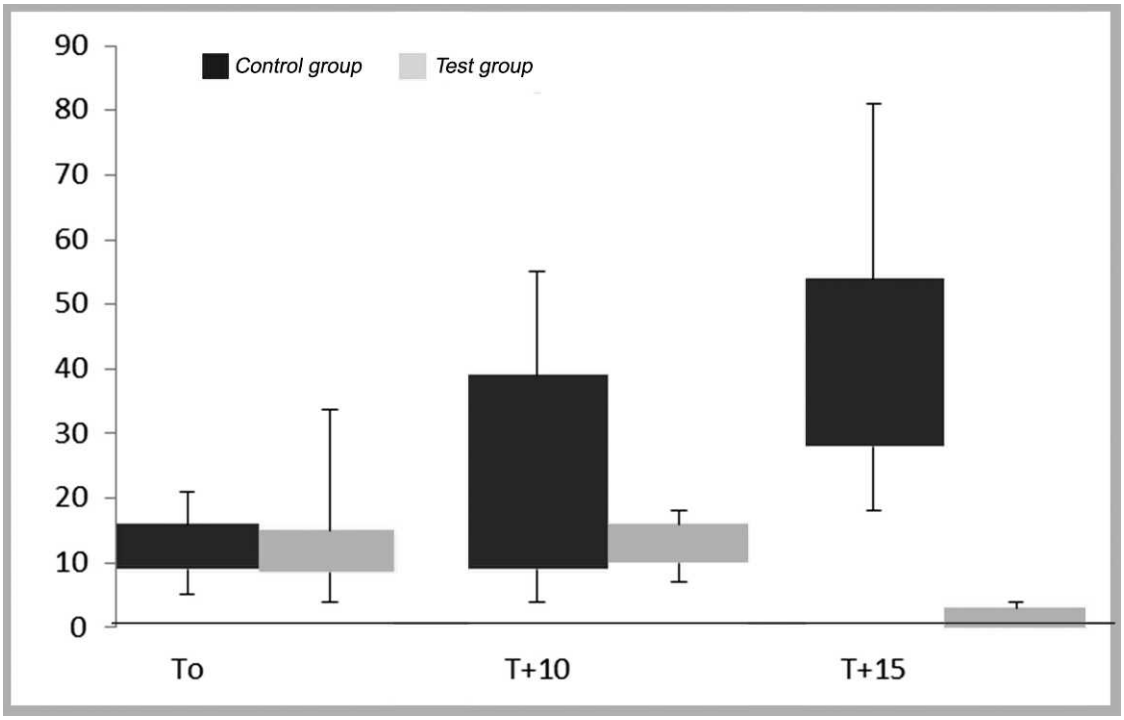

Figure 3. Quartiles distribution of numbers of snake mites in treated (test group) and untreated (control group) infested snakes at T0, T0 + 10, and T0 + 15. Quartiles are displayed with ± extreme numbers of snake mites counted per snake. $n = 11$ for each group at T0, T0 + 10, and T0 + 15. No significant differences in number of snake mites at T0 (T. test, $P < 0{,}01$) when significantly more snake mites were counted in the control group than in the test group at T0 + 10 and T0 + 15 (T. test, $P < 0{,}01$).

nymphs, and adults were collected from the substrates of the test group.

At the end of the experiment (T0 + 15), snake mite infestation seemed to be under control in the test group when compared with the control group because most of the snakes no longer had parasites, and those parasites were barely present in the substrate samples.

CONCLUSIONS

This is the first study that investigates the suitability of the predatory mite *C. eruditus* as a control agent for *O. natricis* in ball pythons (*P. regius*). This current study's approach was not only to test the predatory potential of *C. eruditus* under laboratory conditions but also as a control agent in a typical snake breeding unit. Strong evidence was found for *C. eruditus* attacking and feeding on *O. natricis*. Both in vivo and in situ experiments demonstrated a significant mortality of *O. natricis* in presence of predator mites.

The present study demonstrates *C. eruditus* as a good candidate for the biological control of *O. natricis*. The unusual biology of *C. eruditus* makes it particularly attractive as a biological control agent. This includes strong predatory potential, good environmental survival, and a temperature range adapted to captive snake conditions.

C. eruditus (or other species) probably also play a role in controlling the population of *O. natricis* in wild animals. Further field investigations into the possible correlation between the occurrence of *O. natricis* and *C. eruditus* outside the controlled atmosphere of a laboratory or a breeding unit may confirm this hypothesis.

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Received for publication 6 October 2012