CHAPTER 2
LITERATURE REVIEW

2.1 Taxonomic History

The mites that are now called Cunaxidae were previously placed under the family Bdellidae. Until 1902, Thor (1902) proposed Cunaxidae to accommodate three genera, transferred from Bdellidae, namely *Cunaxa* Von Heyden, 1826, *Eupalus* Koch, 1838, and *Scirula* Berlese, 1887. He also conditionally placed the genus *Pseudocheylus* in this family (Den Heyer, 1981c).

Fourteen years later, Berlese (1916) proposed subgenus *Dactyloscirus* in the genus *Scirus* to accommodate his new species, *Scirus* (*Dactyloscirus*) *eupaloides*. He (Berlese, 1916) also erected the new genus *Coleoscirus* with *C. halacaroides* Berlese, 1961 as a type species.

Oudemans (1922) proposed the genus *Rosenhofia* [subsequently synonymized with the genus *Dactyloscirus* Berlese by Smiley (1975)] to accommodate *R. machairodus* Oudemans, 1922 [=*D. machairodus* (Oudemans) sensu Smiley (1975; 1992)]. Five years later, he (Oudemans, 1927) also erected the genus *Bonzia* for *B. halacaroides* Oudemans, 1927.

Since the family Cunaxidae was proposed, the work of Thor and Willmann (1941) was the first comprehensive study of the family recognizing seven genera and thirty species and varieties. They evaluated the subgenus *Dactyloscirus* to the generic status.

However, Baker and Hoffmann (1948) recognized only six genera, namely *Coleoscirus* Berlese, *Rosenhofia* Oudemans, *Bonzia* Oudemans, *Cunaxa* Von Heyden, *Scirula* Berlese, and *Cunaxoides* Baker and Hoffmann. They considered *Dactyloscirus* a junior synonym of the genus *Cunaxa* Von Heyden, 1826 and proposed the genus *Cunaxoides* to replace the genus *Eupalus* Koch, 1838, a junior homonym of *Eupalus* Gistl, 1834 (in the Coleoptera). This classification system was followed by Baker and Wharton (1952).

In his generic revision of the family Cunaxidae, Smiley (1975) retained the genus *Dactyloscirus* and considered *Rosenhofia* a junior synonym of *Dactyloscirus.* He also proposed four new genera, viz. *Parabonzia, Pseudobonzia, Neocunaxoides* and *Pseudocunaxa* (= *Coleoscirus*).

Although working mainly on the afrotropical fauna, Den Heyer (1975 and later papers), made most contribution to the taxonomy of the family Cunaxidae. He did not only describe/redescribe a number of cunaxid taxa but also made higher classification of the family (Den Heyer, 1980c). He erected four subfamilies, Bonziinae (Den Heyer, 1978a), Coleoscirinae (Den Heyer, 1978c), Cunaxoidinae (Den Heyer, 1979d), and Scirulinae (1980c). He provided numerous illustrations, both line drawing and SEM photographs, of both sexes and many nymphal stages. As Sepasgosarian (1984), in the compilation of cunaxid works, stated that "This work (a classification system for the family Cunaxidae) is so important that no taxonomist should described a new genus or a new species without consulting Den Heyer's work".

During the period of 1970-1990, a numbers of cunaxid species were added to the family from various parts of the world. The most remarkable paper was of Bu and Li (1987b) who proposed new genus and new subfamily, Orangescirulinae, to accommodate their new species, *Orangescirula youngchuanensis* from China.

In 1992, the world cunaxid fauna (166 species) was reviewed by Smiley (1992). Based on the number of palpal segments, the kinds of palpal setae, and the kinds of setae hg_1, he recognized 17 genera and proposed a new family classification that divides the Cunaxidae into nine subfamilies. Key to subfamilies, genera and species were provided. However, Smiley (1992) missed the paper of Inayatullah and Sahid (1989) describing two new species of the genus *Neocunaxoides* Smiley, 1975, from Pakistan.

However, some papers published in a year before 1992 were not included in Smiley' s (1992) work. These are of Gupta (1991), describing one and two new species of *Neocunaxoides* and *Cunaxa* respectively, from Northeast India; Bu and Li

(1991), describing one new species of *Pulaeus*, from China, and Barilo (1991), describing one new species of *Pulaeus* and *Neoscirula* each, from Uzbekistan.

After Smiley' s (1992) publication, The Cunaxidae received considerable attention from many acarologists and were reported from many parts of the world such as India (Gupta, 1992; Chinniah and Mohanasundaram, 2001), Pakistan (Muhammad and Chaudhri, 1992; Inayatullah and Sahid, 1993, 1996), Hawaii (Swift, 1996), Crimea (Khaustov and Kuznetsov, 1998), the Philippines (Corpuz-Raros and Garcia, 1995; Corpuz-Raros, 1995; Corpuz-Raros, 1996a; Corpuz-Raros and Garcia, 1996; Corpuz-Raros, 1996b; Corpuz-Raros, 1996c; Corpuz-Raros, 1996d), China (Lin, 1997; Lin and Zhang, 1998; Lin, 2001; Lin, *et al.*, 2001; Lin and Zhang, 2002; and Lin, *et al.*, 2003), and Greece (Sionti and Papadoulis, 2003a; 2003b).

2.2 Morphology

Den Heyer (1981c) and Smiley (1992) provided excellent descriptions of and discussions on the morphology of Cunaxidae. In general, the body is divided into three regions, the gnathosoma, propodosoma, and hysterosoma (Fig. 1). The gnathosoma consists of two chelate chelicerae, a hypostome, and two palpi. The chelicerae and hypostome form a conelike structure projecting in between the palpal bases as in Bdellidae. The propodosoma, delimited dorsoposteriorly by a conspicuous constriction, bears two pairs of legs and two pairs of sensillum. The hysterosoma bears the two posterior pairs of legs, anus, and genitalia.

Gnathosoma consists of chelicerae, hypostome, and palpi. The number of palp segments vary from three, in Cunaxoidinae (Figs. 2B, 71C, 74E, 79E, 84C), to five segments, in Cunaxiinae and Coleoscirinae (Figs 2A, 4D, 9E, 34E, 39E). The five-segmented palp (Fig. 2A) is considered to be a primitive form, consisting of trochanter, basifemur, telofemur, genu, tibiotarsus (Smiley, 1992). The three-segmented palp (Fig. 2B) is considered that the femur (basifemur and telofemur) have fused with the genu segment, producing a segment called "femurogenu". The configuration of setae, spinelike setae and/or apophyses, on palp segments is usually constant within a species, providing useful taxonomic characters for separating subfamilies, genera and species. Hypostome possesses two pairs of adoral setae and four pairs of setae, hg_1, hg_2, hg_3, and hg_4 on the ventral side (Fig. 2A). These setae

are usually simple and slender, except hg_1, found only in the subfamily Bonziinae, are geniculate (Fig. 3B). The chelicerae (Figs. 1 and 2C) of Cunaxidae lack of immovable digit; a distal membranous projection of segment II may over the movable digit dorsally (Den Heyer, 1981c).

Propodosoma is the anterior portion of the mite behind the gnathosoma. Dorsal propodosoma usually possesses a single shield or plate. The shield may be smooth or reticulated, bearing four pairs of setae, *vi*, *ve*, *sci*, and *sce* (Fig. 1). Setae *vi* and *sci* are sensillus while *ve* and *sce* are usually simple. Ventral propodosoma consists of coxae I and II, they usually fuse to form coxae I+II on each side. In some species, coxae I+II coalesce to form a sternal shield (Figs. 4B, 9B, 71B)

The remainder of the body is the hysterosoma (Fig. 1). There may be one to three main shields or without any shields on dorsal hysterosoma (Smiley, 1992). These shields may be reticulate or non-reticulated, and sometimes lack setae. The integument that is outside shield is usually striation. Hysterosoma may be processes six to eight pairs of dorsal setae (see Table 2-1 for setae designation) but they are constant in numbers within the genus (Smiley, 1992). The numbers of these setae, therefore, are used for separating the genera while the types of these setae are used in separating cunaxid species within the genus. However, different authors used different setae designations. Kethley (1990), based on the topology of these setae, first homologized setae designations within the acarine suborder Prostigmata, which the Cunaxidae belong to. Although Smiley (1992) did not use this system, many acarologists (Swift, 1996; Lin and Zhang, 2002; Lin *et al.*, 2003; Sionti and Papadoulis, 2003a; 2003b) applied Kethley' s (1990) system to their works on the Cunaxidae. Swift (1996) equated the setal notation of Atyeo (1960) for Bdellidae and Den Heyer (1979c) and Smiley (1992) for Cunaxidae as in Table 2-1.

Table 2-1. Dorsal setal designation used by various authors for Bdellidae and Cunaxidae.

Atyeo, 1960	Smiley, 1992	Den Heyer, 1979	Swift, 1996
Anterior sensillum	Anterior sensillum	PS1	*vi*
Lateral propodosomal	P1	dl1	*ve*
Posterior sensillum	Posterior sensillum	PS2	*sci*
median propodosomal	P2	dc1	*sce*
Internal humeral	D1	dc2	c_1
External humeral	L1	dl2	c_2
Internal dorsal	D2	dc3	*d*
Internal lumbral	D3	dc4	*e*
Internal sacral	D4	dc5	*f*
External clunal	D5	dc6	h_1
External sacral	*	dl6	h_2
Posterio anal	*	*	ps_1
Anal seta	*	*	ps_2

*No designation

The ventral region of the hysterosoma includes the coxal plates, coxae, genital plates, accessory plate(s) (Figs. 31B, 82B), and anal region (Smiley, 1992). The genital plate has a constant number of setae (4 pairs) in all genera except *Parabonzia* which has 9 pairs (Smiley, 1992). The integument that is outside the ventral shields is usually striate, bearing varied numbers of setae. The anus is on terminal end of hysterosoma with one to three pairs of anal setae.

The leg of cunaxid mites has six segments in larval stage, and seven segments in nymphal and adult stage (Smiley, 1992). Each leg (Fig. 1) consists of, proximal to distal end, coxa, trochanter, basifemur, telofemur, genu, tibia, and tarsus. The chaetotaxy on these segments is usually unique and can be used for identification to species level. Each leg terminates with two claws and an empodium with four raylets (Fig. 2D).

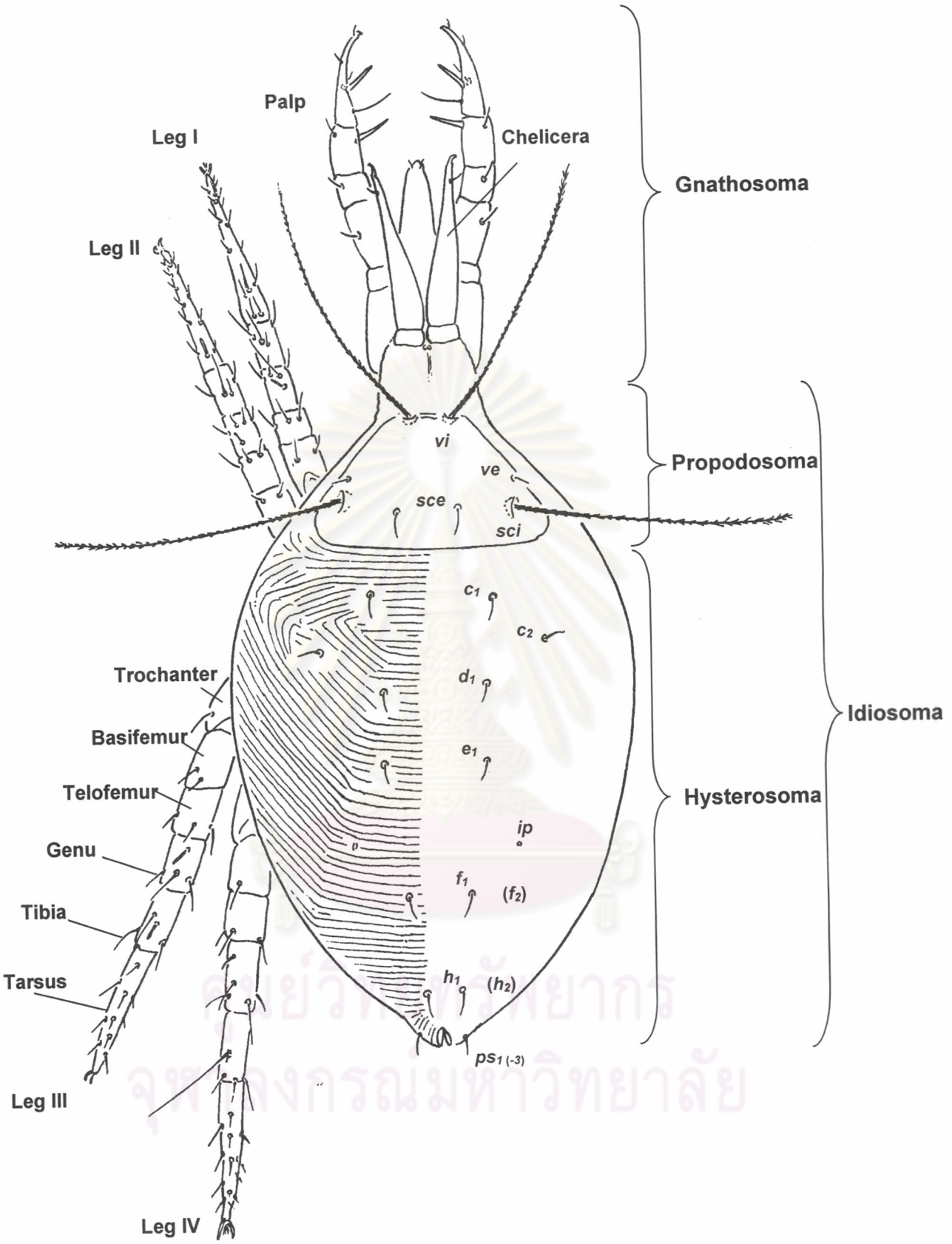

Figure 1. Dorsum of female Cunaxidae, *Cunaxa setirostris* (Hermann). (modified from Shiba, 1976)

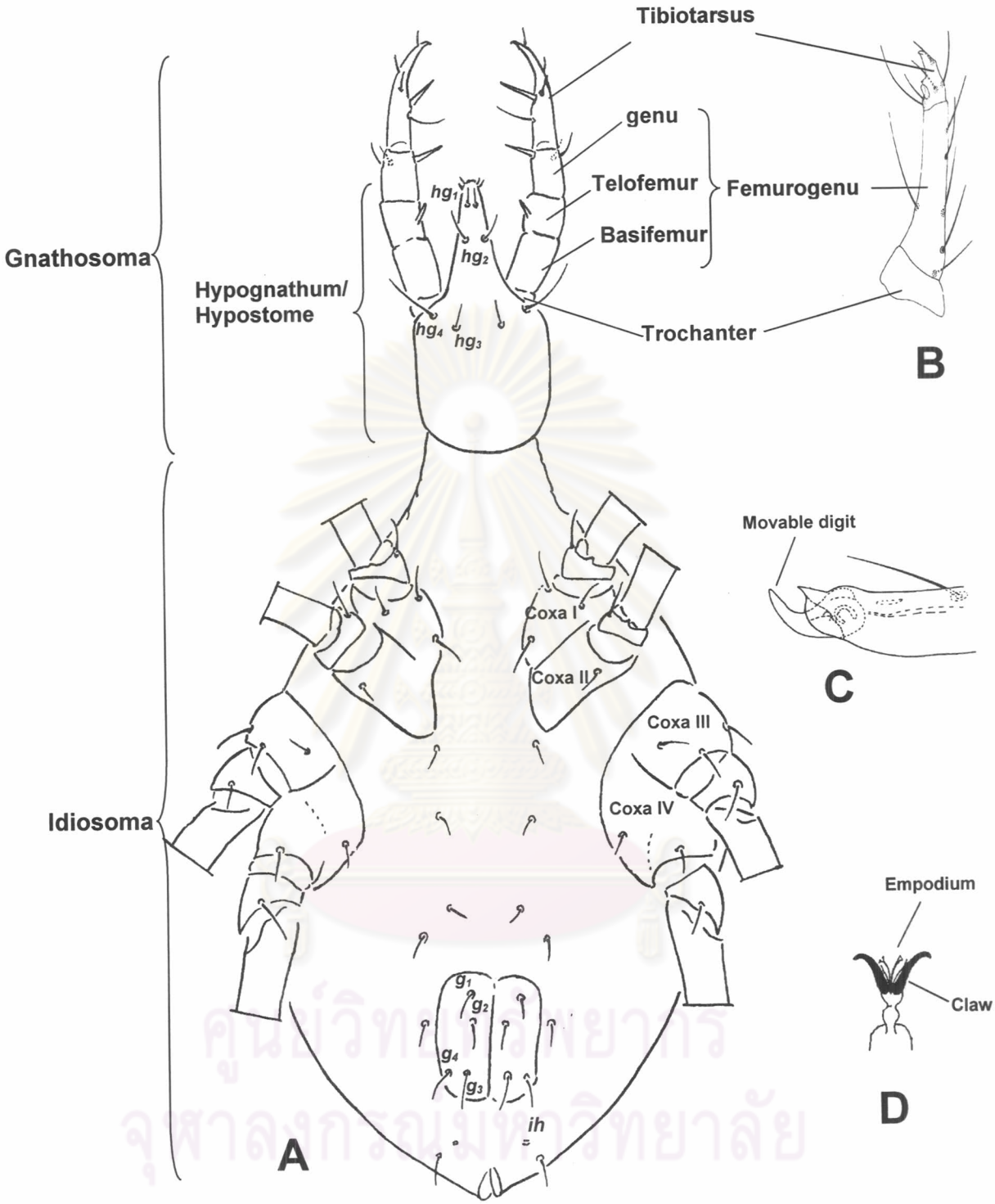

Figure 2. Female Cunaxidae – A, venter of five-segmented palp Cunaxidae, *Cunaxa setirostris* (Hermann); B, three segmented palp; C, tip of chelicera; D, tip of tarsus. (A, modified from Shiba ,1976; B, C, and D, modified from Den Heyer, 1981).

2.3 Biology

Because of their small size, biology and behavior of mites can only be observed in laboratory. Zaher *et al.* (1975) reared *Cunaxa capreolus* (Berlese) at 30 °C on three types of diet, plant materials, booklice, and spider mites, *Eutetranychus orientalis* (Klein). They found that the mite completed a generation in about 4 weeks and each female deposited about 45 eggs. Average prey consumption during development was 230 booklices or 472 spider mites/cunaxid. The mites fed neither on prey eggs nor on several plant diets.

Walter and Kaplan (1991) reported the feeding behavior and live history of a cunaxid mite, *Coleoscirus simplex* (Ewing), that colonized rootknot nematode culture in Florida and reviewed feeding behavior in cunaxid mites. They found, at 28 °C , that females took 10 – 16 days to develop from eggs to adults while males took 10 – 12 days. Mean generation time was 14.3 days. About 4 eggs were laid per day when excess nematode prey. The mite can build a silken web over the entrance to a crevice to protect itself during molting. Egg devolopment to female and male averaged 4.2 $\pm$ 0.2 and 3.6 $\pm$ 0.3 days, repectively, from oviposition to hatch.

In feeding behavioral study, Walter and Kaplan (1991) found that *Coleoscirus simplex* fed on nematodes, lightly sclerotized arthropods, such as juvenile and tenneral adult Oribatida, juvenile Mesostigmata, Eupodidae, and collembola (*Proisotoma* sp. and *Tullbergia* sp.). *Coleoscirus simplex* did not feed on the eggs of either rootknot nematodes or arthropods. *Neoscirula* sp. (Coleoscirinae) and *Pulaeus* sp. (Cunaxoidinae) also fed on both nematodes and arthropods, but three species in the Cunaxinae, *Dactyloscirus inermis* (Tragardh), *Dactyloscirus* sp., and *Cunaxa* sp., fed only on arthropods.

2.4 Cunaxidae in Thailand

The Cunaxidae of Thailand has never been treated taxonomically at all. The previous researchers, on acarine in general, reported only generic and/or family level of these mites. Dr. Edwards W. Baker, during his visiting to Thailand in 1974-1975, examined mite specimens in the collection at the Post-Entry Quarantine Building in Bang Khen. He (Baker, 1975) then reported three species of this family: *Neocunaxoides* sp., *Pseudocunaxa* sp., and *Dactyloscirus* sp.

Vaivanijkul *et al.* (1978) found *Neocunaxoides* sp. on *Anthocephalus cadamba* Miq., in Lumpini Park, Bangkok.

Charanasri (1990) found the Cunaxidae commonly together with mite pests of pomelo from Pichit, Chainat, Nakorn Pathom and Samut Songkhram.

Charanasri *et al.*, (2001) found one species of cunaxid mites on passion fruits (*Passiflora edulis* Sims), and was only 1.47 % of total predatory mites. They also reported that one individual of this cunaxid mites fed on 3.6 tritonymphs of *Tetranychus fijiensis*, a spider mite pest of passion fruit, per day.

As far as I am aware, five species of the family Cunaxidae were formally reported from Thailand. Boonkong *et al.* (1986) recorded two species of this family, *Cunaxa capreolus* (Berlese), and *Cunaxa setirostris* (Herman), among other mites and insects found on stored garlic in Thailand. Smiley (1992) reported *Armascirus taurus* (Kramer) and described two new species, *Cunaxa rackae* and *Cunaxa thailandicus* from Thailand. The two latters were intercepted from plant products exported from Thailand.