

**University of São Paulo  
“Luiz de Queiroz” College of Agriculture**

**Exploration of potential agents for the biological control of the red palm mite, *Raoiella indica* Hirst (Acari: Tenuipalpidae), on coconut palms in Brazil**

**Daniel Chiaradia Oliveira**

Thesis presented to obtain the degree of Doctor in  
Science. Area: Entomology

**Piracicaba  
2015**

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Prof. Dr. **GILBERTO JOSÉ DE MORAES**

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*To GOD, source of perseverance and life.*

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## RESUMO

### **Exploração de agentes potenciais para o controle biológico do ácaro-vermelho-das-palmeiras, *Raoiella indica* Hirst (Acari: Tenuipalpidae), em coqueiros no Brasil**

O ácaro-vermelho-das-palmeiras, *Raoiella indica* Hirst (Acari: Tenuipalpidae), tem sido considerado uma importante praga em coqueiro (*Cocos nucifera* L.) no Novo Mundo. Vários estudos têm sido conduzidos para entender a ecologia deste ácaro, visando ao seu controle. A busca de inimigos naturais eficazes para controlar *R. indica* tem sido considerada uma prioridade para reduzir a sua importância em áreas em que tem sido recentemente encontrado, com atenção especial aos ácaros predadores da família Phytoseiidae. Pouco tem sido publicado sobre a fauna de fitoseídeos da Tailândia, onde *R. indica* tem sido encontrado em baixos níveis populacionais, talvez devido à ação de inimigos naturais. O objetivo geral desta tese foi selecionar ácaros predadores promissores na Tailândia (Bangkok e Kamphaeng Saen) para o controle de *R. indica* em coqueiros no Brasil, introduzi-los e realizar uma avaliação inicial de sua eficiência. Inicialmente, uma lista dos fitoseídeos até então relatados da Tailândia e uma chave taxonômica para ajudar na sua separação foram elaboradas. Trinta e duas espécies de fitoseídeos eram conhecidas da Tailândia antes deste estudo; sete novos registros foram apresentados. Os ácaros predadores associados a *R. indica* na região central da Tailândia e sua dinâmica populacional foram avaliadas. Phytoseiidae foi a família de predadores mais frequentemente encontrada em coqueiro e palmeira ráfia [*Rhapis excelsa* (Thunb.) A. Henry], embora os seus níveis sejam baixos (máximo de 0.003 espécimes/ cm<sup>2</sup> em coqueiro e 0.008 espécimes/ cm<sup>2</sup> em palmeira ráfia). *Amblyseius largoensis* (Muma) foi o predador mais abundante em ambos os locais e em ambos hospedeiros, exceto no coqueiro em Bangkok, em que o mais abundante foi *Euseius nicholsi* (Ehara & Lee). Os níveis de *R. indica* foram muito baixos (máximo de 0.03 espécimes/ cm<sup>2</sup> em coqueiro e 0.48 espécimes/ cm<sup>2</sup> em palmeira ráfia), em comparação com o que tem sido relatado para outras partes do mundo. O efeito direto da chuva sobre a população de *R. indica* foi avaliado em mudas de coqueiro na Tailândia. Os resultados sugeriram que a chuva reduz consideravelmente a população de *R. indica*, principalmente quando a precipitação acumulada em 15 dias foi superior a 100 mm. Um novo gênero e espécie de ácaro da família Blattisociidae coletada em flores de coqueiro na Tailândia foram descritos. Os desempenhos de duas populações de ácaros predadores introduzidos da Tailândia, uma população previamente introduzida de La Reunion e uma população nativa de Roraima, Brasil, foram comparados em relação a seus efeitos sobre a população de *R. indica*. Não foi demonstrada a eficiência dos predadores em mudas de coqueiro, contrastando com o que era esperado a partir dos comportamentos observados no laboratório. Este resultado poderia ser devido à exposição excessiva dos predadores à luz do sol na superfície das folhas, por causa da arquitetura das mudas, provavelmente estimulando-os a se locomover para microambientes mais protegidos. Em coqueiros adultos, em que a superfície abaxial da folha é menos exposta, os predadores avaliados poderiam ter melhor desempenho. Esforços adicionais deveriam ser dedicados para avaliar esta hipótese.

Palavras-chave: Ácaro-vermelho-das-palmeiras; Taxonomia; Ácaros predadores; Controle biológico; Diversidade



## ABSTRACT

### **Exploration of potential agents for the biological control of the red palm mite, *Raoiella indica* Hirst (Acari: Tenuipalpidae), on coconut palms in Brazil**

The red palm mite, *Raoiella indica* Hirst (Acari: Tenuipalpidae), has been considered an important pest on coconut palm (*Cocos nucifera* L.) in the New World. Several studies have been conducted to understand the ecology of this mite, aiming at its control. The search for effective natural enemies to control *R. indica* has been considered a priority to reduce its importance in areas where it has been newly reported, with special attention to predatory mites of the family Phytoseiidae. Little has been published about the phytoseiid fauna of Thailand, where *R. indica* has been found at low population levels, perhaps due to the action of natural enemies. The general objective of this thesis was to select promising predatory mites in Thailand (Bangkok and Kamphaeng Saen) to control *R. indica* on coconut palms in Brazil, to introduce them and to conduct an initial evaluation of their efficiency. Initially, a list of the phytoseiid mites until then reported from Thailand and a taxonomic key to help in their separation were prepared. Thirty two phytoseiid species were known from Thailand before this study; seven new records were presented. The predatory mite fauna associated with *R. indica* in the central region of Thailand and their population dynamics were assessed. Phytoseiidae was the predatory family most frequently found on coconut and lady palm, *Rhapis excelsa* (Thunb.) A. Henry, although at low levels (maximum of 0.003 specimens/ cm<sup>2</sup> on coconut and 0.008 specimens/ cm<sup>2</sup> on lady palm). *Amblyseius largoensis* (Muma) was the most abundant predator in both sites and on both hosts, except on coconut in Bangkok, which the most abundant was *Euseius nicholsi* (Ehara & Lee). The levels of *R. indica* were very low (maximum of 0.03 specimens/ cm<sup>2</sup> on coconut and 0.48 specimens/ cm<sup>2</sup> on lady palm), compared to what have been reported in other parts of the world. The direct effect of rainfall on the population of *R. indica* on coconut seedlings in Thailand was evaluated. The results suggested that rainfall reduces considerably the population of *R. indica*, mainly when the accumulated precipitation in 15 days was over 100 mm. A new mite genus and species of Blattisociidae collected on coconut flowers in Thailand were described. The performances of two predatory mite populations introduced from Thailand, a population previously introduced from La Reunion and a population native from Roraima, Brazil, were compared in relation to their effect on the population of *R. indica*. The efficiency of the predators could not be demonstrated on coconut seedlings, contrasting with what would be expected from their observed behavior in the laboratory. This result could be due to the overexposure of the predators to sunlight on the leaf surface because of the architecture of the seedlings, probably stimulating them to move to more protected microhabitats. On adult coconut plants, in which the abaxial leaf surface is less exposed, the evaluated predators could have a better performance. Further efforts should be dedicated to evaluate this hypothesis.

Keywords: Red palm mite; Taxonomy; Predatory mites; Biological control; Diversity



## 1 INTRODUCTION

The red palm mite, *Raoiella indica* Hirst (Acari: Tenuipalpidae), is an important pest of palms, bananas and ornamentals in the New World. Since its original description from southern India attacking coconut palms, *Cocos nucifera* L., by Hirst (1924), it was reported from few hosts in Asia; however, the number of reported host species increased greatly after it reached the New World (CARRILLO et al., 2012b; KANE et al., 2012). It was first reported in the New World by Flechtmann and Etienne (2004), on the Caribbean island of Martinique, from where it spread quickly to other islands of the same region and to the American continent, now spreading from southern USA to the northern part of South America, as summarized by Carrillo et al. (2011). In Brazil, *R. indica* was first found in 2009, on coconut palms of the urban area of Boa Vista, Capital of Roraima State (NAVIA et al., 2011). Soon after, it was also found Amazonas state (RODRIGUES; ANTONY, 2011).

Although the damage caused by *R. indica* has not been quantified, heavy losses have been reported in the Caribbean area, especially on coconut (personal communication of Mr. Philippe Agostine, President of Trinidad and Tobago Growers Association, reported by RODA et al., 2012). In addition, it could cause some impact on tourism, by turning palm trees less attractive. These plants are some of the most important ornamentals in tropical touristic places.

Given the difficulty in controlling this mite by the use do chemicals, mostly because of the height achieved by the coconut plants, the virtual inexperience of many coconut growers with the use of those products and cost, the search for effective biological control agents of this pest has been considered a priority to reduce its importance in newly invaded areas (CARRILLO et al., 2012a).

Mites of the family Phytoseiidae have been considered the most promising group of predators of pest mites on different crops (GERSON et al., 2003). The taxonomy of these mites has been extensively studied, as summarized by Moraes et al. (2004). Several studies have been conducted in the tropics to search for effective control agents of *R. indica* (TAYLOR et al., 2012; MORAES et al., 2012; SILVA et al., 2014). In these surveys, taxa unknown to science are frequently discovered and subsequently described. Carrillo et al. (2012a) revised the natural enemies commonly reported in association with *R. indica*. Twenty eight species of predatory arthropods, including mites and insects, were mentioned, in addition to some pathogenic fungi. According the authors, the phytoseiid *Amblyseius*

*largoensis* (Muma), is the most abundant predatory mite associated with *R. indica* in all the geographical areas where studies have been conducted.

Applied biological control can be done through three different strategies, namely conservation, augmentation and classical biological control. Within a classical biological control strategy, a first step involves the search for effective control agents, which is usually conducted in areas where major damage does not occur, within the suspected region of origin of the pest (HOY, 2012; MORAES et al., 2012, CARRILLO et al., 2014).

The place of origin of *R. indica* is not categorically known, but one of the theories is that it originated in the Southeast Asian peninsula (DOWLING et al., 2012). Thailand is located in this region, and *R. indica* has been reported from this country at low population levels (M. Kongshuensin, Department of Agriculture of Thailand - DOA, personal communication). There is a possibility that the usually low population levels of *R. indica* in Thailand be due to the action of natural enemies, although other factors cannot be disregarded. Central Thailand is a tropical region, as is also the case of the regions where *R. indica* is now found in the New World. Only two works have been dedicated to the taxonomic study of phytoseiids of Thailand (EHARA; BHANDHUFALCK, 1977; MORAES et al., 1989). All together, thirty two species were reported from that country, nine of which described as new to science.

Abiotic factors have also often been cited as important in reducing *R. indica* population levels in various parts of the world (TAYLOR et al., 2012; GONDIM Jr. et al., 2012.). Knowledge about the role of abiotic factors in periodically reducing the population of *R. indica* could be helpful in the estimation of the impact of natural enemies on this pest, whose role may be confused with that of abiotic factors.

The general objective of this thesis was to select promising species of predatory mites in Thailand to control *R. indica* on coconut palms in Brazil, to introduce them and to conduct an initial evaluation of their efficiency. Specific objectives were:

- Presents a list of the phytoseiid mites reported from Thailand, and provide a key to help in their morphological separation;
- Determine the composition of the predatory mite fauna associated with *R. indica* in the central region of Thailand, while evaluating their population dynamics, for an initial assessment of effective control agents of the pest;
- Evaluate the direct effect of the rainfall on the population of *R. indica* on coconut seedlings in Thailand;

- Describe a new genus and species of a blattosiciid mite collected on coconut flowers in Thailand;
- Evaluate the efficiency of three population of *A. largoensis*, including one introduced from Thailand, one that had been previously introduced from La Reunion island, and one found naturally in Roraima, Brazil; also evaluated was a population of *Amblyseius cinctus* Corpuz-Raros & Rimando, from Thailand.

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## **2 PHYTOSEIIDAE OF THAILAND (ACARI: MESOSTIGMATA), WITH A TAXONOMIC KEY FOR THEIR IDENTIFICATION**

### **Abstract**

Little has been published about the phytoseiid mite fauna of Thailand. The objective of this paper is to present information about the morphology and distribution of phytoseiid mites collected in sporadic samplings in Thailand between 1991 and 2011 on different plant species, a list of the species presently known from that country and a key to help in their morphological separation. Twenty six species belonging to 11 genera were collected and identified in this study, six of which are reported for the first time from Thailand. In total, 38 species of phytoseiid species of 13 genera are reported, 29 of Amblyseiinae, seven of Phytoseiinae and two of Typhlodrominae.

Keywords: Taxonomy; Predatory mites; Biological control; Diversity

### **2.1 Introduction**

Phytoseiid mites have been generally considered the most promising group of predators of pest mites on different crops (GERSON; SMILEY; OCHOA, 2003). The taxonomy of these mites has been extensively studied, as summarized by Moraes et al. (2004b). However, only two works have been dedicated to the taxonomic study of phytoseiids of Thailand (EHARA; BHANDHUFALCK, 1977; MORAES et al., 1989). All together, thirty two species were reported from that country, nine of which described as new to science.

Efforts have been dedicated towards the practical use of these mites in pest control in that country (KONGCHUENSIN et al., 2001; KONGCHUENSIN; CHARANASRI; TAKAFUJI, 2005; KONGCHUENSIN; CHARANASRI; TAKAFUJI, 2006). It is envisioned that these could be intensified if the composition of the Thai phytoseiid fauna were better understood.

The aim of this paper is to present information about the phytoseiid mites collected in sporadic samplings in Thailand between 1991 and 2011 on different plant species, a list of the species presently known from that country and a key to help in their morphological separation.

## 2.2 Material and Methods

Specimens evaluated in this work were collected from various plants in different provinces from Thailand, at irregular intervals. Unless otherwise specified in the text, the specimens were collected by Mrs. Vatana Charanasri (Plant Protection Research and Development Office, Thailand Department of Agriculture).

They were mounted in Hoyer's medium for examination under a phase contrast microscope. Measurements were done with a graded eyepiece. Measurements of structures are given in micrometers. When more than two specimens were measured, measurement of each structure is indicated by the mean followed (in parentheses) by the respective range. The classification system used in this paper is that of Chant and McMurtry (2007). The setal terminology was that of Rowell, Chant and Hansell (1978) and Chant and Yoshida-Shaul (1991) for dorsal and ventral idiosomal setae, respectively.

The taxonomic key was prepared based on the examination of the species available for this study as well as on literature information about other species reported from Thailand by Ehara and Bhandhufalck (1977) and Moraes et al. (1989). Information about previous records were based on Moraes et al. (2004b), except when otherwise indicated in the text.

## 2.3 Results

A total of 26 species belonging to eleven genera of the three subfamilies were collected and identified. Twenty two species belonged to Amblyseiinae, three to Phytoseiinae and one to Typhlodrominae. The genera *Amblyseius* and *Neoseiulus* were the most diverse, with five species each; followed by *Scapulaseius* (four species); *Phytoseius* (three species); *Euseius* and *Proprioseiopsis* (two species each) and *Amblyseiulella*, *Gynaeseius*, *Paraphytoseius*, *Typhlodromips* and *Typhlodromus* (one species each). Specific information of each species is subsequently provided.

### 2.3.1 AMBLYSEIINAE Muma

#### 2.3.1.1 *Amblyseiulella amanoi* Ehara

*Amblyseiulella amanoi* Ehara, in Ehara, Okada and Kato, 1994: 137; Moraes et al., 2004b: 10; Chant and McMurtry, 2003a: 215; 2007: 49.

*Amblyseius (Asperoseius) heveae* (Oudemans).— Ehara and Bhandhufalck, 1977: 76; Liang and Ke, 1982: 351 (misidentifications, according to Yoshida-Shaul and Chant, 1995: 15).

**Specimens examined.** One female, on *Gossypium* sp., at Nan Province, November 1999.

#### FEMALE.

Dorsal shield 340 long and 195 wide; *j1* 40, *j3* 78, *j4* 7, *j5* 6, *j6* 13, *J5* 5, *z2* 22, *z4* 37, *z5* 7, *Z1* 10, *Z4* 80, *Z5* 88, *s4* 103, *S2* 43, *r3* 59, *R1* 32; distances between *St1-St3* 70, *St2-St2* 68, *St5-St5* 80; ventrianal shield 130 long, 72 wide at level of *ZV2*; calyx of spermatheca 3 long and 10 in diameter; fixed cheliceral digit 30 long with 10–12 teeth, movable cheliceral digit 34 long with 3 teeth; *Sge I* 22, *Sge II* 24, *Sge IV* 55, *Sti IV* 53, *St* (basitarsus) *IV* 72, *St* (telotarsus) *IV* 47. Chaetotaxy: genu II 2, 2/0-2/0, 1; genu III 1, 2/1-2/0, 1.

**Previous records.** China (LIANG; KE, 1982), Japan, South Korea and Thailand [Province of Chiang Rai (EHARA; BHANDHUFALCK, 1977)].

**Remarks.** Measurements of the specimen examined are similar to those reported by Ehara and Bhandhufalck (1977) for specimens from Thailand and Liang and Ke (1982) for specimens from southern China, previously identified as *Amblyseiulella heveae* (Oudemans). Examining the holotype, Yoshida-Shaul and Chant (1995) concluded those reports to correspond to a different species. It is considered in this paper that the specimen examined and those previous records correspond to *A. amanoi*. However, the specimen examined differs from the original description by having ten teeth on the fixed and three on the movable cheliceral digits, instead of 6–7 and two teeth, respectively. This species is very similar to several others that can be distinguished from *A. amanoi* as follows: *Amblyseiulella prunii* (LIANG; KE, 1982) – macrosetae of tibia, basitarsus and telotarsus of leg IV about 30% shorter and movable cheliceral digit with two teeth; *Amblyseiulella nucifera* (Gupta, 1979) – macrosetae of tibia, basitarsus and telotarsus of leg IV about 30% shorter; *Amblyseiulella*

*omei* (WU; LI, 1984) – *R1* smooth (serrate in *A. amanoi*) and *z4* about 2.6 as long as *z2*; *Amblyseiulella xizangensis* (WU in WU et al., 1997a) fixed cheliceral digit with three teeth.

### 2.3.1.2 *Amblyseius cinctus* Corpuz-Raros and Rimando

*Amblyseius cinctus* Corpuz-Raros and Rimando, 1966: 119; Moraes, McMurtry and Denmark, 1986: 10; 2004b: 20; Denmark and Muma, 1989: 103; Schicha and Corpuz-Raros, 1992: 35; Wu et al., 1997b: 58; Wu and Ou, 2001: 105; Chant and McMurtry, 2004a: 203; 2007: 78.

*Amblyseius (Amblyseius) cinctus*.— Ehara and Bhandhufalck, 1977: 70; Ehara, 2002: 35.

*Amblyseius (Multiseius) cinctus*.— Denmark and Muma, 1989: 103.

**Specimens examined.** Four females, on *Hibiscus* sp., at Chiang Rai Province, December, 1970, collected by S. Ehara.

#### FEMALE.

Dorsal shield 326 (312–341) long and 223 (218–227) wide; *j1* 25 (24–25), *j3* 45 (44–46), *j4* 5 (5–6), *j5* 4, *j6* 6 (5–7), *J2* 6 (6–7), *J5* 6, *z2* 10, *z4* 7, *z5* 4, *Z1* 7 (7–8), *Z4* 95 (88–106), *Z5* 172 (168–182), *s4* 70 (68–77), *S2* 8 (7–8), *S4* 7 (6–7), *S5* 6 (5–7), *r3* 13 (13–14), *R1* 7 (7–8); distances between *St1-St3* 56 (55–58), *St2-St2* 66 (65–67), *St5-St5* 68 (66–70); ventrianal shield 114 (110–118) long, 80 (78–84) wide at level of *ZV2*; calyx of spermatheca 11 (10–11) long; *Sge I* 34 (32–35), *Sge II* 33 (32–34), *Sge III* 44 (42–46), *Sti III* 31 (28–32), *Sge IV* 84 (80–86), *Sti IV* 49 (46–54), *St IV* 66 (64–67).

**Previous records.** China, Malaysia, Philippines, Singapore and Thailand [Provinces of Bangkok, Chiang Mai, Chiang Rai, Kanchanaburi, Nakhon Pathom and Nakhon Ratchasima (EHARA; BHANDHUFALCK, 1977)].

**Remarks.** No additional specimens of this species were collected in this study. Measurements of only a few structures were given in the original description of *A. cinctus*. Additional measurements of the same and other structures were provided by Schicha and Corpuz-Raros (1992), based on specimens collected in the Phillipines, country where the type specimens had been collected. In both cases, a single measurement was provided for each structure, and thus little is known about the morphological variability for this species in that country. Measurements were provided by Ehara and Bhandhufalck (1977) for a specimen

from Thailand and by Wu et al. (1997b) for specimens from China. The measurements mentioned in the original description and by Schicha and Corpuz-Raros (1992) are very similar to those of Ehara and Bhandhufalck (1977), Wu et al. (1997b) and to our measurements of four specimens collected by S. Ehara in Pan [Phan?], Province of Chiang Rai, northern Thailand, suggesting that they all refer to the same species. The illustration of the spermatheca of this species is not well detailed in the original description of the species. Ehara and Bhandhufalck (1977), Wu and Ou (2001), Wu et al. (1997b) and Ehara (2002) illustrated the calyx and the base of the major duct as “H shaped”. This is also the case for the specimens collected in Chiang Rai by S. Ehara that examined. However, the shape of the calyx illustrated by Schicha and Corpuz-Raros (1992) is slightly different, with the major duct distinctly narrower than the calyx.

### 2.3.1.3 *Amblyseius eharai* Amitai and Swirski

*Amblyseius eharai* Amitai and Swirski, 1981: 60; Moraes, McMurtry and Denmark, 1986: 12; 2004b: 22; Chant and McMurtry, 2004a: 208; 2007: 78.

**Specimens examined.** One female on *Passiflora edulis* Sims, at Sa kaeo Province, November 1998; and one female on *Dimocarpus longan* Lour., at Phichit Province, January 2003.

#### FEMALE.

Dorsal shield 338–340 long and 180–197 wide; *j1* 38–39, *j3* 48–50, *j4* 8–11, *j5* 6–8, *j6* 8–12, *J2* 10–12, *J5* 9–11, *z2* 12–16, *z4* 10–14, *z5* 6–9, *Z1* 10–12, *Z4* 106–115, *Z5* 300–305, *s4* 107–110, *S2* 13–16, *S4* 10–16, *S5* 14, *r3* 11–12, *RI* 11–15; distances between *St1-St3* 65, *St2-St2* 67–69, *St5-St5* 68–79; ventrianal shield 113–116 long, 58–65 wide at level of *ZV2*, 68–74 wide at anus level; calyx of spermatheca 15–18 long; fixed cheliceral digit 25 long, movable cheliceral digit 30–31 long; *Sge I* 46–47, *Sge II* 36–38, *Sge III* 50–52, *Sti III* 43–46, *St III* 33–35, *Sge IV* 152–160, *Sti IV* 113–121, *St IV* 66–70. Chaetotaxy: genu II 1, 2/1-2/0, 1; genu III 2, 2/1-2/0, 1.

**Previous records.** China, Hong Kong, Japan, Malaysia and South Korea.

**Remarks.** Measurements of the specimens examined are similar to those of the original description.

### 2.3.1.4 *Amblyseius herbicolus* (Chant)

*Typhlodromus* (*Amblyseius*) *herbicolus* Chant, 1959: 84.

*Amblyseius* (*Amblyseius*) *herbicolus*.— Muma, 1961: 287; Denmark and Muma, 1989: 59; Denmark and Evans, 2011: 68.

*Amblyseius herbicolus*.— Daneshvar and Denmark, 1982: 5; McMurtry and Moraes, 1984: 34; Moraes, McMurtry and Denmark, 1986: 14; 2004b: 27; Denmark and Muma, 1989: 59; Chant and McMurtry, 2004a: 208; 2007: 78.

*Amblyseius amitae* Bhattacharyya, 1968: 667 (synonymy according to Denmark and Muma, 1989: 59).

*Amblyseius deleoni* Muma and Denmark in Muma, Denmark and De Leon (1970): 68; Schicha, 1981b: 107 (synonymy according to Daneshvar and Denmark, 1982: 5).

*Amblyseius* (*Amblyseius*) *deleoni*.— Ehara and Bhandhufalck, 1977: 67.

*Amblyseius giganticus* Gupta, 1981: 33 (synonymy according to Gupta, 1986: 45).

*Amblyseius impactus* Chaudhri, 1968: 553 (synonymy according to Daneshvar and Denmark, 1982: 5).

*Amblyseius thermophilus* Karg, 1991: 12 (objective synonym according to Moraes et al., 2004b: 27).

**Specimens examined.** One female on *Brugmansia* sp., at Chiang Mai Province, August 2003, collected by M. Kongchuensin.

#### **FEMALE.**

Dorsal shield 360 long and 194 wide; *j1* 37, *j3* 38, *j4* 6, *j5* 5, *j6* 8, *J2* 9, *J5* 7, *z2* 13, *z4* 10, *z5* 7, *Z1* 13, *Z4* 94, *Z5* 270, *s4* 95, *S2* 10, *S4* 11, *S5* 9, *r3* 13, *R1* 9; distances between *St1-St3* 67, *St2-St2* 73, *St5-St5* 68; ventrianal shield 117 long, 56 wide at level of *ZV2*, 70 at anus level; calyx of spermatheca 25 long; fixed cheliceral digit 34 long, movable cheliceral digit 35 long; *Sge I* 50, *Sge II* 39, *Sti II* 30, *Sge III* 48, *Sti III* 40, *St III* 30, *Sge IV* 110, *Sti IV* 85, *St* 72. Chaetotaxy: genu II 2, 2/0-2/0, 1; genu III 1, 2/1-2/0, 1.

**Previous records.** Cosmopolitan, including Thailand [Provinces of Bangkok, Chiang Mai, Chiang Rai and Rayong (EHARA; BHANDHUFALCK, 1977)].

**Remarks.** Measurements of the specimen examined are similar to those reported by Schicha (1981b) for the holotype and for specimens from New South Wales, Australia.

### 2.3.1.5 *Amblyseius hidakai* Ehara and Bhandhufalck

*Amblyseius (Amblyseius) hidakai* Ehara and Bhandhufalck, 1977: 66.

*Typhlodromips hidakai*.— Moraes, McMurtry and Denmark, 1986: 141; 2004b: 214.

*Amblyseius hidakai*.— Wu et al., 1997b: 68; Chant and McMurtry, 2004a: 201; 2007: 78.

**Previous records.** China and Thailand [Province of Chiang Mai (EHARA; BHANDHUFALCK, 1977)].

**Remarks.** No additional specimens of this species were collected in this study.

### 2.3.1.6 *Amblyseius largoensis* (Muma)

*Amblyseiopsis largoensis* Muma, 1955: 266.

*Amblyseius largoensis*.— Muma, Denmark and De Leon (1970): 69; Schicha, 1981b: 105; McMurtry and Moraes, 1984: 29; Denmark and Muma, 1989: 55; Moraes, McMurtry and Denmark, 1986: 17; 2000: 239; 2004a: 143; 2004b: 33; Chant and McMurtry, 2004a: 208; 2007: 78; Zannou et al., 2007: 16.

*Amblyseius (Amblyseius) largoensis*.— Ehara and Bhandhufalck, 1977: 67; Denmark and Evans, 2011: 69.

*Amblyseius amtalaensis* Gupta, 1977: 53 (synonymy according to Gupta, 1986: 51).

*Amblyseius magnoliae* Muma, 1961: 289 (synonymy according to Denmark and Evans, 2011: 69).

*Amblyseius sakalava* Blommers, 1976: 96 (synonymy according to Ueckermann and Loots, 1988: 70).

**Specimens examined.** One female, on *Durio zibethinus*, at Chanthaburi Province, March 1993; and one female on *Plumeria* sp., at Rayong Province, August 1997.

#### **FEMALE.**

Dorsal shield 330–365 long and 180–225 wide; *j1* 33–34, *j3* 40–48, *j4* 5–7, *j5* 4–5, *j6* 7, *J2* 8, *J5* 7–9, *z2* 11, *z4* 9–10, *z5* 5, *Z1* 10–11, *Z4* 89–93, *Z5* 266–272, *s4* 89–95, *S2* 11–14, *S4* 11, *S5* 8–10, *r3* 11–12, *R1* 10–17; distances between *St1-St3* 60, *St2-St2* 71, *St5-St5* 68; ventrianal shield 105–113 long, 46–48 wide at level of *ZV2*, 68–69 at anus level; calyx of

spermatheca 23 long; fixed cheliceral digit 26–27 long, movable cheliceral digit 33 long; *Sge I* 41–42, *Sge II* 35–37, *Sge III* 42–47, *Sti III* 39–41, *Sge IV* 120–121, *Sti IV* 78–86, *St IV* 59–65. Chaetotaxy: genu II 2, 2/0-2/0, 1; genu III 1, 2/1-2/0, 1.

**Previous records.** Cosmopolitan, including Thailand [Provinces of Bangkok, Chiang Mai, Nakhon Pathom, Nakhon Ratchasima (EHARA; BHANDHUFALCK, 1977)].

**Remarks.** Measurements of the specimens examined are similar to those reported by Denmark and Muma (1989) for a specimen of unspecified origin. However, our specimens differ by having longer *Z5* (266–272 instead of 206) and cervix of spermatheca (23 instead of 18). Moraes, Kreiter and Lofego (2000) had also observed such differences for specimens from the Caribbean. Our measurements agree with those reported by Moraes, Kreiter and Lofego (2000) and Schicha (1981b) for specimens from the South Pacific, Moraes, Lopes and Fernando (2004a) for specimens from Sri Lanka and Zannou et al. (2007) for specimens from sub-Saharan Africa.

### 2.3.1.7 *Amblyseius paraaerialis* Muma

*Amblyseius paraaerialis* Muma, 1967: 270; Denmark and Muma, 1989: 128; Moraes, McMurtry and Denmark, 1986: 27; 2004b: 45; Chant and McMurtry, 2004a: 201; 2007: 80.

*Amblyseius (Amblyseius) paraaerialis*.— Ehara and Bhandhufalck, 1977: 68.

**Specimens examined.** Three females, on *Jatropha gossypifolia* L., at Chanthaburi Province, April 2001, collected by T. Thimthong; and one female on *Ipomoea pes-tigridis* L., at Phetchaburi Province, June 2002, collected by S. Yimchan.

**FEMALE** (measurements in square brackets refer to the holotype, taken by the last author of this paper).

Dorsal shield 341 (324–366) [330] long and 213 (200–225) [204] wide; *j1* 26 (23–28) [27], *j3* 46 (43–48) [42], *j4* 6 (5–6) [6], *j5* 5 (4–6) [6], *j6* 7 (6–8) [broken], *J2* 7 (6–7) [8], *J5* 7 (6–7) [8], *z2* 11 (10–11) [11], *z4* 8 (6–9) [8], *z5* 6 (5–6) [broken], *Z1* 8 (7–8) [8], *Z4* 76 (72–78) [64], *Z5* 158 (146–170) [122], *s4* 66 (62–70) [56], *S2* 10 (8–10) [11], *S4* 8 (7–8) [8], *S5* 7 (6–9) [8], *r3* 16 (15–16) [16], *R1* 9 (8–9) [9]; distances between *St1-St3* 59 (58–60) [59], *St2-St2* 70 (68–72) [64], *St5-St5* 66 (63–70) [66]; ventrianal shield 114 (110–116) [105] long, 79

(76–83) [83] wide at level of ZV2; calyx of spermatheca 7 (5–8) [6] long; fixed cheliceral digit 28 (28–29) [27] long, movable cheliceral digit 34 (33–35) [32] long; *Sge I* 31 (29–32) [25], *Sge II* 31 (28–33) [25], *Sge III* 41 (40–43) [35], *Sti III* 29 (26–30) [25], *St III* 22 (20–24), *Sge IV* 80 (72–86) [69], *Sti IV* 48 (46–50) [42], *St IV* 56 (53–58) [53]. Chaetotaxy: genu II 2, 2/0-2/0, 1; genu III 1, 2/1-2/0, 1.

**Previous records.** China (CHEN; CHU; ZHOU, 1980), India, Malaysia and Thailand (Provinces of Bangkok, Chiang Mai, Chiang Rai and Kanchanaburi (EHARA; BHANDHUFALCK, 1977)).

**Remarks.** Measurements of the specimens collected in Thailand are similar to those of holotype, but *Z4*, *s4*, *Sge I*, *Sge II*, *Sge III* and *Sge IV* are about 20% longer and *Z5* is about 30% longer, congruent with the fact that the specimens examined are slightly larger than the holotype. The measurements of the Thai specimens are also similar to those reported by Ehara and Bhandhufalck (1977) for specimens from Thailand and Denmark and Muma (1989) for a specimen of unspecified origin (probably from India).

### 2.3.1.8 *Amblyseius tamatavensis* Blommers

*Amblyseius (Amblyseius) tamatavensis* Blommers, 1974: 144.

*Amblyseius tamatavensis*.— Schicha, 1981: 40; Moraes, McMurtry and Denmark, 1986: 31; 2004b: 52; Chant and McMurtry, 2004a: 203; 2007: 81.

*Amblyseius aegyptiacus* Denmark and Matthyse, in Matthyse and Denmark, 1981: 343 (synonymy according to Denmark and Muma, 1989: 13).

*Amblyseius maai* Tseng, 1976: 123 (synonymy according to Denmark and Muma, 1989: 13).

**Specimens examined.** Two females, on *Durio zibethinus* Murray, at Chanthaburi Province, September, 1991; three females, on *Ipomoea pes-tigridis*, at Rayong Province, August 1995; two females, on *Garcinia mangostana* L., at Chanthaburi Province, February, 2002, collected by Pichet; one female and one male, on *Vitis vinifera* L., at Udon Thani Province, October 2003; and one female, on *Morus alba* L., at Bangkok Province, December, 2004, collected by P. Vichitbandha.

**FEMALE.**

Dorsal shield 337 (310–360) long and 213 (190–230) wide; *j1* 32 (28–37), *j3* 52 (49–55), *j4* 5 (4–5), *j5* 4 (3–4), *j6* 5 (4–6), *J2* 5 (5–7), *J5* 6 (4–7), *z2* 7 (6–9), *z4* 7 (5–9), *z5* 4 (3–5), *Z1* 6 (5–7), *Z4* 107 (86–116), *Z5* 231 (212–240), *s4* 86 (80–92), *S2* 7 (6–9), *S4* 6 (5–9), *S5* 6 (5–9), *r3* 14 (9–17), *R1* 7 (6–8); distances between *St1-St3* 60 (58–65), *St2-St2* 70 (67–75), *St5-St5* 74 (69–80); ventrianal shield 117 (110–125) long, 89 (79–100) wide at level of *ZV2*; calyx of spermatheca 12 (9–15) long; fixed cheliceral digit 31 (29–35) long, movable cheliceral digit 38 (35–41) long; *Sge I* 39 (37–44), *Sge II* 36 (34–38), *Sge III* 55 (50–60), *Sti III* 46 (42–48), *St III* 21 (20–25), *Sge IV* 106 (100–120), *Sti IV* 72 (65–77), *St IV* 66 (62–70). Chaetotaxy: genu II 2, 2/0-2/0, 1; genu III 1, 2/1-2/0, 1.

**MALE.**

Dorsal shield 254 long and 170 wide; *j1* 25, *j3* 40, *j4* 5, *j5* 3, *j6* 4, *J2* 5, *J5* 6, *z2* 6, *z4* 6, *z5* 3, *Z1* 5, *Z4* 78, *Z5* 158, *s4* 65, *S2* 6, *S4* 5, *S5* 5, *r3* 11, *R1* 6; ventrianal shield 112 long and 135 wide at level of anterior corners; fixed cheliceral digit 20 long, movable cheliceral digit 23 long; spermatodactyl L-shaped, shaft 16 long, foot 20 long; *Sge I* 30, *Sge II* 30, *Sge III* 37, *Sti III* 34, *Sge IV* 68, *Sti IV* 50, *St IV* 55. Chaetotaxy of genera II and III as in female.

**Previous records.** China, Malaysia, Philippines, Singapore and Thailand [Provinces of Bangkok, Chiang Mai, Chiang Rai, Kanchanaburi, Nakhon Pathom and Nakhon Ratchasima (EHARA; BHANDHUFALCK, 1977)].

**Remarks.** This is one of the most common phytoseiid species in Thailand. Measurements of the specimens collected in this study are similar to those of the original description and to measurements of specimens reported as *A. tamatavensis* from Malaysia (EHARA, 2002), Sri Lanka (MORAES et al., 2004a), Guadeloupe and Marie Galante (MORAES; KREITER; LOFEGO, 2000), and of specimens collected in Pernambuco, Brazil (A.C, Lofego, personal communication). No comparison with *A. cinctus* was done in the original description of *A. tamatavensis*. A comparison of the available measurements of these species show that the former is smaller than the latter and, concurrently, that its longer dorsal setae are shorter than in *A. tamatavensis*. From the studies conducted by Denmark and Muma (1989) and Schicha and Corpuz-Raros (1992), *A. cinctus* could be distinguished from *A. tamatavensis* by being smaller and having most dorsal shield setae as well as calyx of spermatheca shorter, and by having macroseta of tibia IV shorter than macroseta of tarsus IV (although in the illustration of the latter authors *A. cinctus* is shown to have macroseta of the tibia IV about as long as macroseta of tarsus IV). Measurements of the specimens collected in

this study are larger (up to about 20% for the larger setae, almost 40% larger for *r3*, *Sti III* and *Sti IV*) than reported by different authors for *A. cinctus*, but the specimens are also larger (dorsal shield about 10% longer and 20% wider). Denmark and Muma (1989) considered *A. aegyptiacus* and *A. maai* to be junior synonyms of *A. tamatavensis*. Most of the measurements given in the original descriptions of the former two species are closer to those of *A. tamatavensis* than of *A. cinctus*, but some are closer to those of *A. cinctus* (*Z5*, *Sge IV* and *St IV* for *A. aegyptiacus* and *Sge IV* for *A. maai*) while others (*j1* and *Z5* for *A. maai*) are intermediate. Thus, *A. tamatavensis* could conceivably be a junior synonym of *A. cinctus*.

### 2.3.1.9 *Euseius aizawai* (Ehara and Bhandhufalck)

*Amblyseius (Amblyseius) aizawai* Ehara and Bhandhufalck, 1977: 59.

*Euseius aizawai*.— Moraes, McMurtry and Denmark, 1986: 36; 2004b: 60; Chant and McMurtry, 2005a: 215; 2007: 120.

**Specimens examined.** One female, on *Oxyceros künstleri* (King and Gamble), at Chachoengsao Province, January 2001.

#### **FEMALE.**

Dorsal shield 360 long and 230 wide; *j1* 32, *j3* 26, *j4* 9, *j5* 8, *j6* 10, *J2* 12, *J5* 6, *z2* 16, *z4* 16, *z5* 10, *Z1* 11, *Z4* 12, *Z5* 55, *s4* 24, *S2* 15, *S4* 18, *S5* 21, *r3* 16, *RI* 14; distances between *St1-St3* 55, *St2-St2* 66, *St5-St5* 73; ventrianal shield 92 long, 40 wide at level of *ZV2*, 72 at anus level; calyx of spermatheca 9 long; fixed cheliceral digit 25 long, movable cheliceral digit 23 long; *Sge II* 23, *Sge III* 29, *Sti III* 28, *Sge IV* 46, *Sti IV* 40, *St IV* 69. Chaetotaxy: genu II 2, 2/0-2/0, 1; genu III 1, 2/1-2/0, 1.

**Previous records.** China, Malaysia and Thailand [Province of Chiang Mai (EHARA; BHANDHUFALCK, 1977)].

**Remarks.** Measurements of the specimen examined are similar to those of the original description.

### 2.3.1.10 *Euseius neofustis* Moraes and McMurtry

*Euseius neofustis* Moraes and McMurtry, 1988: 16; Moraes et al., 1989: 129; 2004b: 75; Chant and McMurtry, 2005a: 215; 2007: 121.

**Previous records.** Kenya, Tanzania and Thailand [Province of Loei (MORAES et al., 1989)].

**Remarks.** No additional specimens of this species were collected in this study.

### 2.3.1.11 *Euseius nicholsi* (Ehara and Lee)

*Amblyseius (Amblyseius) nicholsi* Ehara and Lee, 1971: 67; Ehara and Bhandhufalck, 1977: 61; Wu, 1984: 224.

*Euseius nicholsi*.— Wu et al., 1997b: 115; Moraes, McMurtry and Denmark, 1986: 49; 2004b: 75; Chant and McMurtry, 2005a: 215; 2007: 121.

**Specimens examined.** Six females and two males, on *Ziziphus mauritiana* Lam., at Ratchaburi Province, April 1995.

#### FEMALE.

Dorsal shield 331 (320–345) long and 254 (235–264) wide; *j1* 29 (26–31), *j3* 25 (24–25), *j4* 11 (10–13), *j5* 11 (10–13), *j6* 14 (12–15), *J2* 16 (14–18), *J5* 7 (5–8), *z2* 19 (17–20), *z4* 21 (19–22), *z5* 12 (10–13), *Z1* 15 (14–16), *Z4* 16 (14–17), *Z5* 58 (48–61), *s4* 34 (28–35), *S2* 21 (18–25), *S4* 25 (22–26), *S5* 27 (23–30), *r3* 15 (12–17), *R1* 14 (13–15); distances between *St1-St3* 57 (52–59), *St2-St2* 67 (65–68), *St5-St5* 77 (70–83); ventrianal shield 101 (95–109) long, 52 (47–56) wide at level of *ZV2*, 76 (72–80) at anus level; calyx of spermatheca 7 (6–8) long; fixed cheliceral digit 24 (23–24) long, movable cheliceral digit 24 (23–25) long; *Sge II* 20 (18–22), *Sge III* 28 (23–32), *Sti III* 23 (21–24), *Sge IV* 45 (41–48), *Sti IV* 33 (31–35), *St IV* 54 (47–56). Chaetotaxy: genu II 2, 2/0-2/0, 1; genu III 1, 2/1-2/0, 1.

#### MALE.

Dorsal shield 230–240 long and 183–185 wide; *j1* 26–28, *j3* 26–29, *j4* 11–12, *j5* 11–12, *j6* 13–14, *J2* 13–15, *J5* 5–6, *z2* 20–22, *z4* 24–25, *z5* 12–14, *Z1* 13–14, *Z4* 16, *Z5* 48–50, *s4* 32–34, *S2* 21–22, *S4* 23–24, *S5* 25–27, *r3* 16–18, *R1* 12–15; ventrianal shield 95–100 long

and 130–150 wide at level of anterior corners; fixed cheliceral digit 19 long, movable cheliceral digit 20 long; spermatodactyl L-shaped, shaft 17–18 long, foot 10–12 long; *Sge II* 19, *Sge III* 24–25, *Sge IV* 38–39, *Sti IV* 29–34, *St IV* 45–48. Chaetotaxy of genua II and III as in female.

**Previous records.** China, Hong Kong and Thailand [Provinces of Nakhon Pathom, Pathum Thani and Phra Nakhon Si Ayutthaya (EHARA; BHANDHUFALCK, 1977)].

**Remarks.** The females examined are slightly smaller than the holotype (dorsal shield about 10% shorter) and the larger setae are congruently shorter than reported for the holotype. The metapodal platelets of some specimens are similar to what was reported in the original description (with a lateral appendix, probably because of the partial fusion of the 2 platelets of each side); however, other specimens have platelets with wavy margin where fusion with smaller platelet could have occurred. Likewise, the males examined are smaller (dorsal shield about 15% shorter) than those reported by Wu (1984) and Wu et al. (1997b), the larger setae being also shorter (seta *ZI* about 40% shorter).

#### 2.3.1.12 *Euseius okumae* (Ehara and Bhandhufalck)

*Amblyseius (Amblyseius) okumae* Ehara and Bhandhufalck, 1977: 61.

*Euseius okumae*.— Moraes, McMurtry and Denmark, 1986: 49; 2004b: 76; Chant and McMurtry, 2005a: 215; 2007: 121.

**Previous records.** Thailand [Province of Chiang Mai (EHARA; BHANDHUFALCK, 1977)].

**Remarks.** No additional specimens of this species were collected in this study.

#### 2.3.1.13 *Gynaeseius* sp.

**Specimens examined.** Three females, on *Rosa* sp., at Sukhothai Province, November 1999.

#### FEMALE.

Dorsal shield 316 (310–320) long and 180 wide; *j1* 25, *j3* 19 (15–25), *j4* 14 (14–15), *j5* 13 (12–13), *j6* 15, *J2* 17 (15–20), *J5* 6 (6–7), *z2* 15 (12–17), *z4* 15 (15–16), *z5* 14 (12–15), *Z1* 15 (13–16), *Z4* 14 (14–15), *Z5* 27 (25–29), *s4* 18 (15–21), *S2* 18 (16–20), *S5* 17 (15–19), *r3*

15, *RI* 14 (13–15); distances between *St1-St3* 63 (63–64), *St2-St2* 61 (59–63), *St5-St5* 73 (72–73); ventrianal shield 100 long, 80 wide at level of *ZV2*; calyx of spermatheca not discernable; fixed cheliceral digit 26 (25–26) long with 11 teeth, movable cheliceral digit 30 (30–31) long with 3 teeth; *Sge II* 14 (12–15), *Sge III* 27 (26–27), *Sti III* 31, *Sge IV* 40 (35–45), *Sti IV* 46 (45–48), *St IV* 43 (40–45). Chaetotaxy: genu II 2, 2/0-2/0, 1; genu III 1, 2/1-2/0, 1.

**Remarks.** According to Chant and McMurtry (2007), 12 species are presently placed in this genus. The species here reported is distinguished from *G. brevisetosus* (Collyer), *G. christinae* (Schicha), *G. duanensis* (Liang and Zeng), *G. eharai* (Gupta), *G. hebridensis* (McMurtry and Moraes), *G. irregularis* (Evans), *G. santosoi* (Ehara) and *G. semirregularis* (Schicha and Corpuz-Raros) by having fixed cheliceral digit multidentate and movable cheliceral digit with 3 teeth. The remaining 4 species, *G. armellae* (Schicha and Gutierrez), *G. ghaiiae* (Denmark and Kolodochka), *G. liturivorus* (Ehara) and *G. ricini* (Ghai and Menon) are very similar to each other and to the species collected in this study. However, it is not possible to tell whether the latter corresponds to any of these species because the spermatheca is not discernible.

#### 2.3.1.14 *Neoseiulus baraki* (Athias-Henriot)

*Amblyseius baraki* Athias-Henriot, 1966: 211; Schicha, 1981a: 207.

*Amblyseius* (*Amblyseius*) *baraki*.— Ehara and Bhandhufalck, 1977: 54.

*Neoseiulus baraki*.— Moraes, McMurtry and Denmark, 1986: 70; 2004a: 149; 2004b: 104; Chant and McMurtry, 2003b: 27; 2007: 25; Zannou et al., 2006: 248.

*Amblyseius dhooriai* Gupta, 1977: 30 (synonymy according to Gupta, 1986: 105).

**Specimens examined.** one female, on *Miscanthus giganteus* J.M.Greef, Deuter ex Hodk., Renvoize, at Chiang Mai Province, October 2002, collected by M. Kongchuensin; and one female, on *Cocos nucifera* L., at Surat Thani Province, February 2011, collected by G.J. de Moraes.

#### FEMALE.

Dorsal shield 345–358 long and 161–170 wide; *j1* 11–15, *j3* 17–19, *j4* 11–12, *j5* 10–12, *j6* 13–15, *J2* 13–15, *J5* 13, *z2* 12–13, *z4* 15, *z5* 10–12, *Z1* 15, *Z4* 20–24, *Z5* 70–76, *s4* 16–18, *S2* 16, *S4* 24–26, *S5* 23, *r3* 16, *RI* 15; distances between *St1-St3* 80–81, *St2-St2* 52–53, *St5-*

*St5* 56–61; ventrianal shield 110–115 long, 90–95 wide at level of *ZV2*; calyx of spermatheca 3–5 long and 11–12 in diameter; fixed cheliceral digit 25–28 long, movable cheliceral digit 30–31; *St IV* 35–40. Chaetotaxy: genu II 2, 2/0-2/0, 1; genu III 1, 2/1-2/0, 1.

**Previous records.** Algeria, Benin (ZANNOU et al., 2006), Brazil (LAWSON-BALAGBO et al., 2008), Burundi (ZANNOU et al., 2006), China, India, Kenya (ZANNOU et al., 2006), Mozambique (ZANNOU et al., 2005), Panama (QUIRÓS-McINTIRE; RODRÍGUEZ, 2010), Sri Lanka (MORAES et al., 2004a), Taiwan and Thailand [Provinces of Bangkok and Chachoengsao (EHARA; BHANDHUFALCK, 1977)].

**Remarks.** Measurements of the specimens examined are similar to those of the original description, except for *S4*, about 25% longer. Our measurements are also similar to those reported by Ehara and Bhandhufalck (1977) for specimens from Thailand, Moraes et al. (2004a) for specimens from Sri Lanka, Zannou et al. (2006) for specimens from sub-Saharan Africa and Sourassou et al. (2012) for specimens from Africa and Brazil; in all of those studies, *S4* is also longer than reported in the original description.

### 2.3.1.15 *Neoseiulus barkeri* Hughes

(Figures 1A–G)

*Neoseiulus barkeri* Hughes, 1948: 141; Moraes, McMurtry and Denmark, 1986: 70; 2004b: 104; Chant and McMurtry, 2003b: 35; 2007: 25; Papadoulis, Emmanouel and Kapaxidi, 2009: 97; Denmark and Evans, 2011: 129.

*Amblyseius (Amblyseius) barkeri*.— Ehara, 1972: 147.

*Amblyseius barkeri*.— Wu et al., 1997b: 81.

*Amblyseius masiaka* Blommers and Chazeau, 1974: 308 (synonymy according to Ueckermann and Loots, 1988: 148).

*Amblyseius mckenziei* Schuster and Pritchard, 1963: 268 (synonymy according to Ragusa and Athias-Henriot, 1983: 668).

*Amblyseius mycophilus* Karg, 1970: 290 (synonymy according to Ragusa and Athias-Henriot, 1983: 668).

*Amblyseius oahuensis* Prasad, 1968: 1518 (synonymy according to Ragusa and Athias-Henriot, 1983: 668).

*Amblyseius picketti* Specht, 1968: 681 (synonymy according to Ragusa and Athias-Henriot, 1983: 668).

*Amblyseius (Amblyseius) usitatus* van der Merwe, 1965: 71 (synonymy according to Ueckermann and Loots, 1988: 148).

*Neoseiulus kermanicus* Daneshvar, 1987: 14 (synonymy according to Faraji et al., 2007: 233).

**Specimens examined.** Three females and two males, on *Allium sativum* L., at Chiang Rai Province, June 2006, collected by Chamlong.

#### **FEMALE.**

Dorsal shield 358 (336–377) long and 193 (185–210) wide (Figure 1A); *j1* 18 (17–19), *j3* 23(23–24), *j4* 17 (16–18), *j5* 17, *j6* 20, *J2* 19 (17–21), *J5* 12 (11–12), *z2* 21 (20–21), *z4* 21, *z5* 18, *Z1* 23 (22–23), *Z4* 33 (32–33), *Z5* 53 (52–55), *s4* 26 (25–26), *S2* 24, *S4* 23 (22–23), *S5* 21 (20–22), *r3* 20, *R1* 20 (19–20); distances between *St1-St3* 69 (67–72), *St2-St2* 68 (65–70), *St5-St5* 61 (60–64); ventrianal shield 131 (122–139) long, 106 (105–108) wide at level of *ZV2* (Figure 1B); calyx of spermatheca 19 (18–20) long (Figure 1C); fixed cheliceral digit 28 (25–30) long, movable cheliceral digit 38 (36–40) (Figure 1D); *St IV* 66 (62–70) (Figure 1E).  
Chaetotaxy: genu II 2, 2/0-2/0, 1; genu III 1, 2/1-2/0, 1.

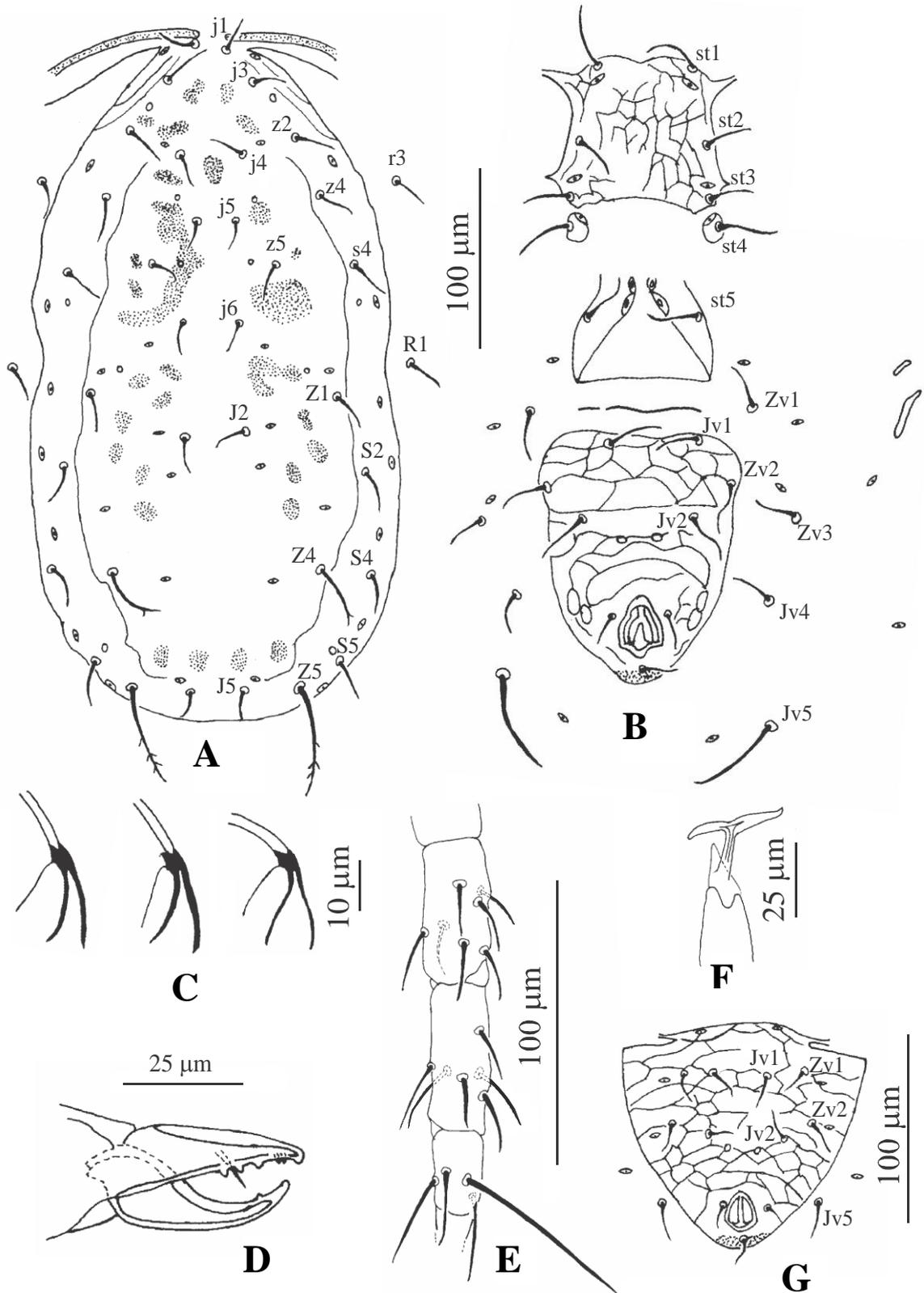


Figure 1 - A-G. *Neoseiulus barkeri* Hughes. A-E. Female, A. dorsal shield, B. ventral idiosoma, C. Spermathecae, D. chelicera, E. leg IV, genu, tibia and tarsus. F-G. Male, F. spermadactyl, G. ventrianal shield.

**MALE.**

Dorsal shield 258–260 long and 165–173 wide; *j1* 11–15, *j3* 18, *j4* 13, *j5* 15, *j6* 13–16, *J2* 12–15, *J5* 8, *z2* 15–19, *z4* 16–17, *z5* 15–16, *Z1* 16–17, *Z4* 22–23, *Z5* 27–29, *s4* 20–21, *S2* 18, *S4* 18–19, *S5* 15–17, *r3* 15–16, *R1* 15; ventrianal shield 110 long and 133 wide at level of anterior corners (Figure 1G); fixed cheliceral digit 22 long, movable cheliceral digit 23–26; spermatodactyl T-shaped (Figure 1F), shaft 13–21 long, transversal section 34–35; *St IV* 43–46. Chaetotaxy of genua II and III as in female.

**Previous records.** Cosmopolitan.

**Remarks.** Measurements of the specimens examined in this study are similar to those reported by Ehara (1972) for specimens from Japan and Wu et al., 1997b for specimens from China. However, the shape of spermatheca of two of the females examined is slightly different from that reported by those authors, being wider near the vesicle and narrowing more abruptly towards the atrium (Figure 1C). The spermathecae of these specimens are more similar to that illustrated in the original description of *Neoseiulus usitatus* (VAN DER MERWE, 1965), junior synonymy of *N. barkeri* according to Ueckermann and Loots (1988). The females of *N. barkeri* here reported have four pairs of pores or solenostomes (gland openings) on the dorsal shield (*gd1*, *gd4*, *gd6* and *gd9*) (Figure 1A), as also observed by Ragusa and Athias-Henriot (1983) for this species. According to those authors, the pores *gd5* and *gd8* are absent in species belonging to genus *Neoseiulus*, while *gd2* may be present or absent. This characteristic has been used to separate closely related species, although a recent work conducted by Tixier et al. (2011) demonstrated that the presence of that structure may vary between individuals of a same population.

**2.3.1.16 *Neoseiulus imbricatus* (Corpuz-Raros and Rimando)**

*Amblyseius imbricatus* Corpuz-Raros and Rimando, 1966: 127.

*Amblyseius (Amblyseius) imbricatus*.— Ehara and Bhandhufalck, 1977: 52.

*Neoseiulus imbricatus*.— Moraes, McMurtry and Denmark, 1986: 84; 2004b: 124; Chant and McMurtry, 2003b: 21; 2007: 29.

*Neoseiulus oryzacolus* Daneshvar, 1987: 18 (synonymy according to Faraji et al., 2007: 233).

**Specimens examined.** Five females, on *Oryza sativa* L., at Phitsanulok Province, April, 2004, collected by Nalinee.

**FEMALE.**

Dorsal shield 375 (350–385) long and 177 (172–183) wide; *j1* 32 (27–34), *j3* 46 (42–50), *j4* 29 (26–31), *j5* 32 (30–35), *j6* 46 (42–50), *J2* 54 (52–57), *J5* 14 (12–15), *z2* 43 (41–49), *z4* 51 (49–55), *z5* 35 (32–37), *Z1* 56 (54–58), *Z4* 66 (62–71), *Z5* 77 (70–82), *s4* 59 (56–61), *S2* 61 (58–66), *S4* 62 (56–70), *S5* 58 (50–66), *r3* 47 (44–50), *R1* 50 (45–55); distances between *St1-St3* 68 (65–70), *St2-St2* 62 (58–64), *St5-St5* 66 (62–69); ventrianal shield 128 (112–139) long, 112 (108–115) wide at level of *ZV2*; calyx of spermatheca 5 (5–6) long and 11 (10–13) in diameter; fixed cheliceral digit 31 (30–32) long, movable cheliceral digit 34 (32–35) long; *Sge IV* 33 (30–36), *Sti IV* 39 (35–43), *St IV* 80 (75–82). Chaetotaxy: genu II 2, 2/0-2/0, 1; genu III 1, 2/1-2/0, 1.

**Previous records.** Azerbaijan, China, India, Iran, Philippines and Thailand [Provinces of Bangkok and Pathum Thani (EHARA; BHANDHUFALCK, 1977)].

**Remarks.** Measurements of the specimens examined are similar to those of the original description and reported by Ehara and Bhandhufalck (1977) for specimens from Thailand.

**2.3.1.17 *Neoseiulus longispinosus* (Evans)**

*Typhlodromus longispinosus* Evans, 1952: 413.

*Amblyseius (Amblyseius) longispinosus*.— Ehara and Bhandhufalck, 1977: 54.

*Amblyseius longispinosus*.— Schicha, 1975: 103.

*Neoseiulus longispinosus*.— Moraes, McMurtry and Denmark, 1986: 85; 1989: 129; 2004a: 150; 2004b: 129; Chant and McMurtry, 2003b: 37; 2007: 29; Denmark and Evans, 2011: 145.

**Specimens examined.** Two females, on *Abelmoschus esculentus* (L.) Moench, at Nakhon Pathom Province, June 1997, collected by W. Hongsaprug; two females, on *Gossypium* sp., at Suphan Buri Province, November, 1998; one female, on *Manihot esculenta* Crantz, at Bangkok Province, April 2005, collected by Yuvann.

**FEMALE.**

Dorsal shield 330 (315–340) long and 186 (178–195) wide; *j1* 19 (18–21), *j3* 61 (56–68), *j4* 58 (54–62), *j5* 69 (65–72), *j6* 71 (68–73), *J2* 74 (68–81), *J5* 9 (7–12), *z2* 66 (62–70), *z4* 71 (68–75), *z5* 31 (25–36), *Z1* 75 (71–78), *Z4* 71 (65–75), *Z5* 78 (72–81), *s4* 81 (76–85), *S2* 73

(68–80), *S4* 61 (56–68), *S5* 20 (18–25), *r3* 61 (50–67), *RI* 63 (55–70); distances between *St1-St3* 63 (57–85), *St2-St2* 59 (57–60), *St5-St5* 61 (55–64); ventrianal shield 123 (120–125) long, 97 (95–100) wide at level of *ZV2*; calyx of spermatheca 19 (17–22) long; fixed cheliceral digit 23 (22–25) long, movable cheliceral digit 26 (25–27) long; *St IV* 74 (72–77). Chaetotaxy: genu II 2, 2/0-2/0, 1; genu III 1, 2/1-2/0, 1.

**Previous records.** Australia, China, Dominican Republic (FERRAGUT; MORAES; NAVIA, 2011), Egypt, Guadeloupe, Hawaii, Hong Kong, India, Indonesia, Japan, Les Saintes, Malaysia, Marie Galante, Martinique, New Zealand, Pakistan, Papua New Guinea, Philippines, Russia, Saint Barthelemy, South Korea, Sri Lanka (MORAES et al., 2004a), Taiwan, Thailand [Provinces of Ang Thong, Bangkok, Chachoengsao, Chainat, Chanthaburi, Chiang Mai, Chiang Rai, Chonburi, Chumphon, Kanchanaburi, Loei, Nakhon Pathom, Nakhon Ratchasima, Nakhon Sawan, Nonthaburi, Pathum Thani, Phatthalung, Phetchabun, Ratchaburi, Sakhon Nakhon, Samut Prakan, Samut Sakhon, Songkhla, Suphanburi and Tak (EHARA; BHANDHUFALCK, 1977; MORAES et al., 1989; KONGCHUENSIN; CHARANASRI; TAKAFUJI, 2005)] and USA (DENMARK; EVANS, 2011).

**Remarks.** This is one of the most common phytoseiid species in Thailand. The females examined are slightly larger than reported in the original description (dorsal shield about 15% larger); concurrently, setae *z5*, *S2* and *S5* are on average about 15% longer too. Our measurements are similar to those reported by Moraes et al. (2004a) for specimens from Sri Lanka.

### 2.3.1.18 *Neoseiulus taiwanicus* (Ehara)

*Amblyseius (Amblyseius) taiwanicus* Ehara, 1970: 56; Ehara and Bhandhufalck, 1977: 54.

*Neoseiulus taiwanicus*.— Moraes, McMurtry and Denmark, 1986: 97; 2004b: 146 ; Chant and McMurtry, 2003b: 27; 2007: 31.

**Specimens examined.** One female and two males, on *Ananas comosus* (L.) Merr., at Phetchaburi Province, March 2004.

#### FEMALE.

Dorsal shield 320 long and 140 wide; *j1* 10, *j3* 10, *j4* 8, *j5* 8, *j6* 7, *J2* 8, *J5* 7, *z2* 9, *z4* 9, *z5* 8, *Z1* 9, *Z4* 15, *Z5* 43, *s4* 10, *S2* 11, *S4* 11, *S5* 14, *r3* 8, *RI* 8; distances between *St1-St3* 81,

*St2-St2* 50, *St5-St5* 49; ventrianal shield 108 long, 87 wide at level of *ZV2*; calyx of spermatheca 20 long; fixed cheliceral digit 20 long, movable cheliceral digit 27; *St IV* 20. Chaetotaxy: genu II 2, 2/0-2/0, 1; genu III 1, 2/1-2/0, 1.

#### MALE.

Dorsal shield 272–280 long and 122–130 wide; *j1* 9, *j3* 8–10, *j4* 7–9, *j5* 8, *j6* 8–9, *J2* 7–9, *J5* 6–7, *z2* 8, *z4* 8, *z5* 6–8, *Z1* 8, *Z4* 12, *Z5* 35–38, *s4* 8–11, *S2* 8–10, *S4* 11–12, *S5* 11–12, *r3* 8–10, *R1* 8–9; ventrianal shield 100 long and 122–126 wide at level of anterior corners; fixed cheliceral digit 13–14 long, movable cheliceral digit 18–20; spermatodactyl 12 long; *St IV* 14–15. Chaetotaxy of genera II and III as in female.

**Previous records.** China, Philippines, Taiwan and Thailand [Provinces of Bangkok, Chachoengsao and Chiang Mai (EHARA; BHANDHUFALCK, 1977)].

**Remarks.** Measurements of the female examined are similar to those of the original description.

#### 2.3.1.19 *Paraphytoseius cracentis* (Corpuz-Raros and Rimando)

*Ptenoseius cracentis* Corpuz-Raros and Rimando, 1966: 115.

*Amblyseius (Paraphytoseius) multidentatus* Swirski and Shechter.— Ehara and Bhandhufalck, 1977: 79 [misidentified according to Ehara, Gotoh and Amano (2000)].

*Paraphytoseius cracentis*.— Moraes, McMurtry and Denmark, 1986: 104; 2004b: 160; Chant and McMurtry, 2003a: 220; 2007: 53.

**Specimens examined.** Two females, on *Cyanthillium cinereum* (L.) H.Rob., at Rayong Province, November 1996; three females and one male, on *Oxyceros künstleri*, at Chachoengsao Province, January 2001; five females and two males, on *Acacia* sp., at Chanthaburi Province, April 2001, collected by S. Yimchan.

#### FEMALE.

Dorsal shield 292 (265–310) long and 158 (150–168) wide; *j1* 33 (33–39), *j3* 92 (82–98), *j4* 5 (4–6), *j5* 5 (4–6), *j6* 7 (5–9), *J5* 5 (4–6), *z2* 10 (8–13), *z4* 9 (8–12), *z5* 5 (4–5), *Z1* 7 (6–9), *Z4* 80 (75–85), *Z5* 102 (92–105), *s4* 128 (119–134), *S5* 14 (11–17), *r3* 48 (44–50), *R1* 32 (28–38); distances between *St1-St3* 70 (65–75), *St2-St2* 73 (71–76), *St5-St5* 89 (84–92); ventrianal

shield 112 (104–120) long, 66 (53–74) wide at level of ZV2; calyx of spermatheca 8 (7–10) long; fixed cheliceral digit 28 (26–30) long, movable cheliceral digit 34 (32–37) long; *Sge II* 14 (12–16), *Sge IV* 31 (27–33), *Sti IV* 40 (38–42), *St* (basitarsus) *IV* 47 (43–52), *St* (telotarsus) *IV* 47 (45–58). Chaetotaxy: genu II 2, 2/0-2/0, 1; genu III 1, 2/1-2/0, 1.

#### MALE.

Dorsal shield 243 (235–255) long and 143 (140–147) wide; *j1* 26 (24–27), *j3* 59 (58–60), *j4* 5, *j5* 5, *j6* 6 (6–7), *J5* 3, *z2* 10 (10–11), *z4* 10 (9–11), *z5* 5, *Z1* 6 (6–7), *Z4* 52 (50–53), *Z5* 59 (55–62), *s4* 88 (85–89), *S5* 7 (6–7), *r3* 30 (27–33), *R1* 15 (15–16); ventrianal shield 102 (101–102) long and 124 (120–126) wide at level of anterior corners; fixed cheliceral digit 19 (18–20) long, movable cheliceral digit 23 (21–24) long; spermatodactyl 16 (15–17) long; *Sge II* 12, *Sge IV* 21 (20–22), *Sti IV* 30, *St* (basitarsus) *IV* 37 (35–40), *St* (telotarsus) *IV* 38 (37–40). Chaetotaxy of genua II and III as in female.

**Previous records.** China, Hong Kong, Japan, New Caledonia, Papua New Guinea, Philippines, Singapore, Taiwan and Thailand [Provinces of Chiang Mai and Kanchanaburi (EHARA; BHANDHUFALCK, 1977)].

**Remarks.** Measurements of the females examined are similar to those of the original description and those reported by Ehara and Bhandhufalck (1977) for specimens from Thailand. Unlike what was reported by Corpuz and Rimando (1966), females examined have a pair of pores on the ventrianal shield; these are small, difficult to see and located posterior and slightly mediad to JV2. Measures of males are similar to those reported by Ehara and Bhandhufalck (1977) for specimens from Thailand.

#### 2.3.1.20 *Phytoscutus salebrosus* (Chant)

*Typhlodromus* (*Amblyseius*) *salebrosus* Chant, 1960: 58.

*Amblyseius* (*Phytoscutella*) *salebrosus*.— Ehara and Bhandhufalck, 1977: 73.

*Phytoscutella* *salebrosa*.— Moraes, McMurtry and Denmark, 1986: 107.

*Phytoscutus* *salebrosus*.— Moraes et al., 2004b: 166; Chant and McMurtry, 2004b: 307; 2007: 101.

*Phytoscutus* *taoi* Lo, 1970: 49 (synonymy according to Ehara and Bhandhufalck, 1977: 73).

**Previous records.** China, India, Malaysia, Philippines, Taiwan and Thailand [Provinces of Chiang Mai and Chiang Rai (EHARA; BHANDHUFALCK, 1977)].

**Remarks.** No additional specimens of this species were collected in this study.

#### 2.3.1.21 *Phytoscutus wongsirii* (Ehara and Bhandhufalck)

*Amblyseius* (*Phytoscutella*) *wongsirii* Ehara and Bhandhufalck, 1977: 75.

*Phytoscutella wongsirii*.— Moraes, McMurtry and Denmark, 1986: 77.

*Phytoscutus wongsirii*.— Moraes et al., 2004b: 167; Chant and McMurtry, 2004b: 307; 2007: 101.

**Previous records.** Thailand [Province of Bangkok (EHARA; BHANDHUFALCK, 1977)].

**Remarks.** No additional specimens of this species were collected in this study.

#### 2.3.1.22 *Proprioiseiopsis lenis* (Corpuz-Raros and Rimando)

*Amblyseius lenis* Corpuz-Raros and Rimando, 1966: 118; Schicha and Corpuz-Raros, 1992: 32.

*Proprioiseiopsis lenis*.— Moraes, McMurtry and Denmark, 1986: 117; 2004b: 178; Chant and McMurtry, 2005b: 13; 2007: 89.

*Amblyseius sullivanii* Schicha and Elshafie, 1980: 34 (synonymy according to Schicha and Corpuz-Raros, 1992: 32).

**Specimens examined.** One female, on *Ipomoea pes-tigridis*, at Rayong Province, August 1995; five females, on *Ipomoea pes-tigridis*, at Rayong Province, February 1996.

#### FEMALE.

Dorsal shield 334 (325–345) long and 217 (190–240) wide; *j1* 19 (17–20), *j3* 27 (25–28), *j4* 5 (5–6), *j5* 5 (4–6), *j6* 6 (5–6), *J5* 9 (7–10), *z2* 13 (11–15), *z4* 10 (9–11), *z5* 5 (4–5), *Z1* 7 (6–8), *Z4* 73 (70–75), *Z5* 114 (105–120), *s4* 58 (55–61), *S2* 9 (8–10), *S4* 10 (9–10), *S5* 10 (9–12), *r3* 13 (11–15), *R1* 10 (9–12); distances between *St1-St3* 60 (56–61), *St2-St2* 64 (61–65), *St5-St5* 68 (66–70); ventrianal shield 113 (112–113) long, 98 (93–102) wide at level of *ZV2*;

calyx of spermatheca 4 long and 9 (8–10) in diameter; fixed cheliceral digit 29 (27–31) long, movable cheliceral digit 32 (30–34) long; *Sge II* 23 (22–25); *Sge III* 25 (24–25), *Sti III* 20 (19–21), *St III* 22 (21–23), *Sge IV* 48 (45–50), *Sti IV* 29 (27–31), *St IV* 60 (58–63). Chaetotaxy: genu II 2, 2/1-2/0, 1; genu III 1, 2/1-2/0, 1.

**Previous records.** Australia and Philippines.

**Remarks.** Measurements of the specimens examined are similar to those of the original description and those reported by Schicha and Corpuz-Raros (1992) for specimens from the Philippines.

### 2.3.1.23 *Proprioseiopsis ovatus* (Garman)

*Amblyseiopsis ovatus* Garman, 1958: 78.

*Amblyseius ovatus*.— Moraes and McMurtry, 1983: 133.

*Proprioseiopsis ovatus*.— Moraes, McMurtry and Denmark, 1986: 121; 2004b: 184; Chant and McMurtry, 2005b: 15; 2007: 89; Denmark and Evans, 2011: 214.

*Amblyseiulus cannaensis* Muma, 1962: 4 (synonymy according to Denmark and Evans, 2011: 214).

*Amblyseius hudsonianus* Chant and Hansell, 1971: 723 (synonymy according to Denmark and Evans, 2011: 214).

*Amblyseius parapeltatus* Wu and Chou 1981: 274 (synonymy according to Tseng 1983: 42).

*Amblyseius (Amblyseius) peltatus* van der Merwe, 1968: 119 (synonymy according to Tseng, 1983: 42).

*Amblyseius (Proprioseiopsis) peltatus*.— Ehara and Bhandhufalck, 1977: 71.

*Iphiseius punicae* Gupta, 1980: 213 (junior synonym of *P. peltatus* according to Gupta, 1986: 134).

*Proprioseiopsis antonellii* Congdon, 2002: 15 (synonymy according to Denmark and Evans, 2011: 214).

**Specimens examined.** One female, on *Durio zibethinus*, at Rayong Province, August 1994; three females, on *Ipomoea pes-tigridis*, at Rayong Province, February 1994; one female, on *Durio zibethinus*, at Chanthaburi Province, August 1994; two females, on *Ipomoea pes-tigridis*, at Rayong Province, February 1996; and one female, on *Gossypium* sp., at Nan Province, November 1999.

**FEMALE.**

Dorsal shield 329 (320–337) long and 268 (225–315) wide; *j1* 26 (24–29), *j3* 64 (60–68), *j4* 6 (5–8), *j5* 5 (5–6), *j6* 11, *J5* 8 (6–9), *z2* 34 (31–36), *z4* 22 (20–27), *z5* 5 (4–6), *Z1* 21 (18–25), *Z4* 109 (105–115), *Z5* 92 (83–96), *s4* 100 (98–100), *S2* 21 (14–25), *S4* 16 (12–18), *S5* 12 (10–15), *r3* 21 (17–25), *R1* 10 (10–11); distances between *St1-St3* 54 (52–55), *St2-St2* 73 (70–77), *St5-St5* 92 (90–97); ventrianal shield 106 (100–115) long, 112 (109–115) wide at level of *ZV2*; calyx of spermatheca 14 (12–17) long; fixed cheliceral digit 30 (29–31) long, movable cheliceral digit 31 (29–34) long; *Sge III* 27 (24–29), *Sti III* 24 (22–26), *St III* 28 (25–31), *Sge IV* 55 (45–61), *Sti IV* 37 (35–40), *St IV* 88 (83–90). Chaetotaxy: genu II 2, 2/0-2/0, 1; genu III 1, 2/1-2/0, 1.

**Previous records.** Cosmopolitan, including Thailand [Provinces of Chachoengsao, Chiang Mai, Chiang Rai and Phra Nakhon Si Ayutthaya (EHARA; BHANDHUFALCK, 1977)].

**Remarks.** The females examined are slightly smaller than the holotype (dorsal shield about 10% shorter), considering the measures given by Moraes and McMurtry (1983). Setae *j4*, *j5* and *z5* are also about 30% shorter, although setae *Z1* and *S2* are about 20% longer. Our measurements are similar to those reported by Ehara and Bhandhufalck (1977) for specimens from Thailand and Moraes et al. (2004a) for a specimen from Sri Lanka.

**2.3.1.24 *Scapulaseius anuwati* (Ehara and Bhandhufalck)**

*Amblyseius (Amblyseius) anuwati* Ehara and Bhandhufalck, 1977: 63.

*Typhlodromips anuwati*.— Moraes, McMurtry and Denmark, 1986: 136; 2004b: 205.

*Scapulaseius anuwati*.— Chant and McMurtry, 2005c: 335; 2007: 67.

**Specimens examined.** One female, on *Trichosanthes anguina* L., at Nong Khai Province, September 2007, collected by P. Konvipasruang.

**FEMALE.**

Dorsal shield 320 long and 215 wide; *j1* 12, *j3* 10, *j4* 7, *j5* 6, *j6* 8, *J2* 10, *J5* 9, *z2* 10, *z4* 10, *z5* 10, *Z1* 10, *Z4* 15, *Z5* 61, *s4* 13, *S2* 11, *S4* 10, *S5* 8, *r3* 10, *R1* 9; distances between *St1-St3* 48, *St2-St2* 55, *St5-St5* 62; ventrianal shield 103 long, 88 wide at level of *ZV2*; calyx of spermatheca 34 long; fixed cheliceral digit 20 long, movable cheliceral digit 24 long; *Sge II* 8,

*Sge III* 20, *Sti III* 15, *St III* 15, *Sge IV* 28, *Sti IV* 18, *St IV* 29. Chaetotaxy: genu II 2, 2/0-2/0, 1; genu III 1, 2/1-2/0, 1.

**Previous records.** China, Malaysia, Taiwan and Thailand [Province of Bangkok (EHARA; BHANDHUFALCK, 1977)].

**Remarks.** Measurements of the specimen examined are similar to those of the original description.

### 2.3.1.25 *Scapulaseius asiaticus* (Evans)

*Typhlodromus asiaticus* Evans, 1953: 461.

*Amblyseius* (*Amblyseius*) *asiaticus*.— Ehara and Bhandhufalck, 1977: 58.

*Typhlodromips asiaticus*.— Moraes, McMurtry and Denmark, 1986: 137; 2004b: 206.

*Scapulaseius asiaticus*.— Chant and McMurtry, 2005c: 335; 2007: 67.

*Amblyseius linearis* Corpuz-Raros and Rimando, 1966: 125 (synonymy according to Schicha and Corpuz-Raros, 1992: 60).

*Amblyseius* (*Amblyseius*) *siaki* Ehara and Lee, 1971: 64 (synonymy according to Ehara and Bhandhufalck, 1977: 58).

**Specimens examined.** Four females and 1 male, on *Morus alba*, at Sakon Nakhon Province, October 1992; two females, from mass rearing Laboratory of Kasetsart University, at Bangkok Province, October 2007, collected by P. Vichitbandha; and two females, on *Passiflora foetida* L., at Chumphon Province, April 2007, collected by P. Konvipasruang.

### FEMALE.

Dorsal shield 301 (283–318) long and 200 (181–222) wide; *j1* 21 (19–23), *j3* 15 (10–16), *j4* 8 (7–10), *j5* 8 (6–10), *j6* 10 (9–12), *J2* 11 (10–12), *J5* 8 (7–8), *z2* 13 (11–15), *z4* 16 (14–17), *z5* 9 (8–11), *Z1* 11 (10–12), *Z4* 52 (49–58), *Z5* 74 (70–83), *s4* 21 (18–23), *S2* 16 (13–18), *S4* 14 (11–15), *S5* 14 (12–19), *r3* 14 (13–15), *RI* 11 (7–13); distances between *St1-St3* 54 (50–58), *St2-St2* 59 (57–61), *St5-St5* 61 (58–64); ventrianal shield 103 (97–110) long, 84 (80–87) wide at level of ZV2; calyx of spermatheca 35 (29–40) long; fixed cheliceral digit 22 (21–23) long, movable cheliceral digit 25 (23–25) long; *Sge I* 17 (15–20), *Sge II* 11 (8–13), *Sge III* 17 (15–18), *Sge IV* 27 (24–30), *Sti IV* 22 (18–26), *St IV* 49 (44–52). Chaetotaxy: genu II 2, 2/0-2/0, 1; genu III 1, 2/1-2/0, 1.

**MALE.**

Dorsal shield 237 long and 175 wide; *j1* 17, *j3* 16, *j4* 7, *j5* 8, *j6* 8, *J2* 10, *J5* 7, *z2* 13, *z4* 15, *z5* 9, *Z1* 10, *Z4* 35, *Z5* 50, *s4* 20, *S2* 15, *S4* 13, *S5* 13, *r3* 15, *R1* 10; ventrianal shield 104 long and 140 wide at level of anterior corners; fixed cheliceral digit 19 long, movable cheliceral digit 21 long; spermatodactyl 14 long; *Sge I* 15, *Sge II* 8, *Sge III* 12, *Sge IV* 21, *Sti IV* 19, *St IV* 42. Chaetotaxy of genua II and III as in female.

**Previous records.** Angola, China, Cyprus (PAPADOULIS; EMMANOUEL; KAPAXIDI, 2009), Hong Kong, India, Indonesia, Malaysia, Philippines, Singapore, Sri Lanka (MORAES et al., 2004a) and Thailand [Provinces of Bangkok, Chiang Mai, Chiang Rai and Phra Nakhon Si Ayutthaya (EHARA; BHANDHUFALCK, 1977)].

**Remarks.** Measurements of the specimens examined are similar to those of the original description, but the lengths of *Z4* and *Z5* of females are closer to those reported for the allotype male and vice versa. This pattern was also observed by Ehara and Bhandhufalck (1977) for specimens from Thailand and for paratype females from Indonesia and Malaysia. The measurements here reported for females are also similar to those reported by Moraes et al. (2004a) for a specimen from Sri Lanka.

**2.3.1.26 *Scapulaseius cantonensis* (Schicha)**

*Amblyseius cantonensis* Schicha, 1982: 48.

*Amblyseius* (*Amblyseius*) *newsami* (Evans).— Ehara and Bhandhufalck, 1977: 62 (misidentification, according to Ehara and Amano, 2002).

*Typhlodromips cantonensis*.— Moraes et al., 2004b: 209.

*Scapulaseius cantonensis*.— Chant and McMurtry, 2005c: 335; 2007: 67.

**Specimens examined.** One female, on *Vitis vinifera*, at Udon Thani Province, October 2003.

**FEMALE.**

Dorsal shield 376 long and 260 wide; *j1* 25, *j3* 13, *j4* 11, *j5* 11, *j6* 12, *J2* 15, *J5* 8, *z2* 12, *z4* 13, *z5* 12, *Z1* 15, *Z4* 16, *Z5* 58, *s4* 15, *S2* 14, *S4* 15, *S5* 15, *r3* 13, *R1* 13; distances between *St1-St3* 55, *St2-St2* 68, *St5-St5* 78; ventrianal shield 114 long, 62 wide at level of *ZV2*, 80 at anus level; calyx of spermatheca 23 long; fixed cheliceral digit 25 long, movable cheliceral digit 29 long; *Sge I* 24, *St I* 34, *Sge II* 30, *Sge III* 38, *Sti III* 25, *St III* 22, *Sge IV* 58, *Sti IV* 35, *St IV* 46. Chaetotaxy: genu II 2, 2/0-2/0, 1; genu III 1,2/1-2/0, 1.

**Previous records.** China, Hong Kong, Japan, Taiwan and Thailand [Provinces of Bangkok, Chiang Mai, Chiang Rai and Nakhon Pathom (EHARA; BHANDHUFALCK, 1977)].

**Remarks.** Measurements of the specimen examined are similar to those of the original description, but the macrosetae of tibia and tarsus of leg IV are about 15% shorter than the lower limit of the range shown for these setae in the original description.

### 2.3.1.27 *Scapulaseius okinawanus* (Ehara)

*Amblyseius* (*Amblyseius*) *okinawanus* Ehara, 1967: 72; Ehara and Bhandhufalck, 1977: 58.

*Neoseiulus okinawanus*.— Moraes, McMurtry and Denmark, 1986: 91.

*Amblyseius* (*Neoseiulus*) *okinawanus*.— Ehara and Amano, 1998: 37.

*Typhlodromips okinawanus*.— Moraes et al., 2004b: 220.

*Scapulaseius okinawanus*.— Chant and McMurtry, 2005c: 335; 2007: 68.

**Previous records.** China, Hong Kong, Indonesia, Japan, Papua New Guinea, Russia, South Korea, Taiwan and Thailand [Provinces of Chiang Mai and Chiang Rai (EHARA; BHANDHUFALCK, 1977)].

**Remarks.** No additional specimens of this species were collected in this study.

### 2.3.1.28 *Scapulaseius siamensis* (Ehara and Bhandhufalck)

*Amblyseius* (*Amblyseius*) *siamensis* Ehara and Bhandhufalck, 1977: 63.

*Typhlodromalus siamensis*.— Moraes, McMurtry and Denmark, 1986: 134.

*Typhlodromips siamensis*.— Moraes et al., 2004b: 223.

*Scapulaseius siamensis*.— Chant and McMurtry, 2005c: 335; 2007: 68.

**Specimens examined.** Three females, on *Durio zibethinus*, at Chanthaburi Province, November 1991; and two females on *Passiflora edulis*, at Surat Thani Province, April 1999.

#### FEMALE.

Dorsal shield 352 (333–375) long and 249 (206–273) wide; *j1* 11 (10–11), *j3* 9 (9–10), *j4* 6 (6–7), *j5* 7 (6–8), *j6* 7 (7–8), *J2* 9 (7–10), *J5* 8 (7–9), *z2* 16 (15–18), *z4* 10 (10–11), *z5* 7, *Z1* 9 (8–10), *Z4* 9 (8–10), *Z5* 41 (40–42), *s4* 11, *S2* 10 (9–11), *S4* 9 (6–11), *S5* 7 (6–8), *r3* 10 (7–

11), *R1* 9 (9–10); distances between *St1-St3* 48 (47–50), *St2-St2* 62 (60–63), *St5-St5* 77 (75–80); ventrianal shield 99 (95–102) long, 77 (72–83) wide at level of *ZV2*, 76 (73–79) at anus level; calyx of spermatheca 9 (8–10) long; fixed cheliceral digit 22 (21–22) long, movable cheliceral digit 25 (24–27) long; *Sge III* 11 (10–12), *Sti III* 14 (12–16), *Sge IV* 13 (11–14), *Sti IV* 18 (17–20), *St IV* 33 (30–36). Chaetotaxy: genu II 2, 2/0-2/0, 1; genu III 1, 2/1-2/0, 1.

**Previous records.** Thailand [Province of Bangkok (EHARA; BHANDHUFALCK, 1977)].

**Remarks.** Measurements of the specimens examined are similar to those of the original description.

### 2.3.1.29 *Typhlodromips syzygii* (Gupta)

*Amblyseius syzygii* Gupta, 1975: 44.

*Amblyseius (Amblyseius) syzygii*.— Ehara and Bhandhufalck, 1977: 56.

*Typhlodromips syzygii*.— Moraes, McMurtry and Denmark, 1986: 150; 2004b: 226; Chant and McMurtry, 2005c: 327; 2007: 63.

**Specimens examined.** One female and two males, on *Bambusa* sp., at Kanchanaburi Province, December 1992.

#### FEMALE.

Dorsal shield 323 long and 240 wide; *j1* 17, *j3* 20, *j4* 9, *j5* 10, *j6* 12, *J2* 14, *J5* 9, *z2* 13, *z4* 12, *z5* 10, *Z1* 13, *Z4* 33, *Z5* 75, *s4* 20, *S2* 13, *S4* 10, *S5* 9, *r3* 14, *R1* 12; distances between *St1-St3* 55, *St2-St2* 65, *St5-St5* 73; ventrianal shield 128 long, 70 wide at level of *ZV2*, 75 wide at anus level; calyx of spermatheca 4 long and 12 in diameter; fixed cheliceral digit 24 long, movable cheliceral digit 28 long; *Sge I* 26, *Sge II* 26, *Sti II* 19, *St II* 26, *Sge III* 35, *Sti III* 26, *St III* 23, *Sge IV* 52, *Sti IV* 41, *St IV* 55. Chaetotaxy: genu II 2, 2/0-2/0, 1; genu III 1, 2/1-2/0, 1.

#### MALE.

Dorsal shield 252–255 long and 185–188 wide; *j1* 15, *j3* 24–25, *j4* 9, *j5* 8–9, *j6* 9–10, *J2* 12, *J5* 5–7, *z2* 11–12, *z4* 11–12, *z5* 8–9, *Z1* 11–12, *Z4* 29, *Z5* 55–56, *s4* 18–20, *S2* 10–15, *S4* 10, *S5* 7, *r3* 13–14, *R1* 11; ventrianal shield 108–110 long and 157–162 wide at level of anterior corners; fixed cheliceral digit 22 long, movable cheliceral digit 23–25 long;

spermatodactyl 15 long; *Sge I* 22, *Sge II* 21–22, *Sge III* 25–26, *Sti III* 24–25, *St III* 22–24, *Sge IV* 38, *Sti IV* 31, *St IV* 46–47. Chaetotaxy of genu II and III as in female.

**Previous records.** India, Indonesia, Papua New Guinea and Thailand [Provinces of Chiang Mai, Chiang Rai and Samut Sakhon (EHARA; BHANDHUFALCK, 1977)].

**Remarks.** Measurements of the female examined are similar to those of the original description. However, the macrosetae of the genu and tarsus of leg IV are about 15% shorter and that of the tibia is about 30% shorter than the holotype. Measurements of the female and males here reported are similar to those reported by Ehara and Bhandhufalck (1977) for specimens from Thailand.

### 2.3.2 PHYTOSEIINAE Berlese

#### 2.3.2.1 *Phytoseius brevicrinis* Swirski and Shechter

*Phytoseius (Dubininellus) brevicrinis* Swirski and Shechter, 1961: 106.

*Phytoseius (Phytoseius) brevicrinis*.— Ehara and Bhandhufalck, 1977: 46; Moraes, McMurtry and Denmark, 1986: 218.

*Phytoseius brevicrinis*.— Moraes et al., 2004b: 232; Chant and McMurtry, 2007: 129.

**Specimens examined.** One female, on *Bambusa* sp., at Kanchanaburi Province, December 1992.

#### FEMALE.

Dorsal shield 300 long and 162 wide; *j1* 28, *j3* 15, *j4* 10, *j5* 10, *j6* 12, *J5* 7, *z2* 12, *z3* 22, *z4* 21, *z5* 12, *Z4* 57, *Z5* 55, *s4* 45, *s6* 48, *r3* 35; distances between *St1-St3* 55, *St2-St2* 59, *St5-St5* 60; ventrianal shield 103 long, 53 wide at level of *ZV2*, 49 at anus level; calyx of spermatheca 3 long and 6 in diameter; fixed cheliceral digit 19 long, movable cheliceral digit 23 long; *Sge IV* 8, *Sti IV* 43, *St* (basitarsus) *IV* 23, *St* (telotarsus) *IV* 22. Chaetotaxy: genu II 2, 2/0-2/0, 1; genu III 1, 2/0-2/0, 1.

**Previous records.** Hong Kong, Malaysia, Philippines and Thailand [Province of Chiang Mai (EHARA; BHANDHUFALCK, 1977)].

**Remarks.** Measurements of the specimen examined are similar to those of the original description, but setae *j1*, *Z4* and *r3* are about 20% longer. These setae as well as seta *Z5* are

35% longer in the specimens here reported than in the specimens reported by Ehara and Bhandhufalck (1977) from Thailand.

### 2.3.2.2 *Phytoseius fotheringhamiae* Denmark and Schicha

*Phytoseius fotheringhamiae* Denmark and Schicha, 1975: 177; Schicha, 1984: 122; Moraes et al., 2004b: 237; Chant and McMurtry, 2007: 129.

*Phytoseius (Phytoseius) fotheringhamiae*.— Moraes, McMurtry and Denmark, 1986: 221.

**Specimens examined.** Two females, on *Cestrum aurantiacum* Lindl., at Chiang Rai Province, January 1992, collected by M. Kongchuensin.

#### FEMALE.

Dorsal shield 280–295 long and 160 wide; *j1* 32–33, *j3* 45–46, *j4* 5, *j5* 4, *j6* 5, *J5* 6–7, *z2* 12, *z3* 34–35, *z4* 10–12, *z5* 4, *Z4* 85–86, *Z5* 70–72, *s4* 106–115, *s6* 81–82, *r3* 43–45; distances between *St1-St3* 59–75, *St2-St2* 62–64, *St5-St5* 63–64; ventrianal shield 100–105 long, 35–40 wide at level of *ZV2*, 55 at anus level; calyx of spermatheca 2 long and 7 in diameter; fixed cheliceral digit 20 long, movable cheliceral digit 23–24 long; *Sge IV* 20–22, *Sti IV* 50–51, *St* (basitarsus) *IV* 26–28, *St* (telotarsus) *IV* 27. Chaetotaxy: genu II 2, 2/0-2/0, 1; genu III 1, 2/0-2/0, 1.

**Previous records.** Australia and New Zealand.

**Remarks.** Measurements of the specimens examined are similar to those of the original description and those reported by Schicha (1984) for specimens from Australia. However, seta *Z5* is slightly shorter than the lower limit of the range shown for this seta in the original description.

### 2.3.2.3 *Phytoseius coheni* Swirski and Shechter

*Phytoseius (Dubininellus) macropilis coheni* Swirski and Shechter, 1961: 104.

*Phytoseius (Phytoseius) coheni*.— Moraes, McMurtry and Denmark, 1986: 219; Denmark and Evans, 2011: 300.

*Phytoseius coheni*.— Moraes et al., 2004b: 235; Chant and McMurtry, 2007: 129.

*Phytoseius hawaiiensis* Prasad, 1968: 1460 (synonymy according to Denmark and Evans, 2011: 300).

*Phytoseius (Phytoseius) hawaiiensis*.— Ehara and Bhandhufalck, 1977: 48.

**Previous records.** Australia, China, Hawaii, Hong Kong, India, Indonesia, Japan, Malaysia, Mauritius, Papua New Guinea, Philippines, Singapore, Tahiti, Taiwan, Thailand [Provinces of Chiang Mai and Nakhon Ratchasima (EHARA; BHANDHUFALCK, 1977) and USA (DENMARK; EVANS, 2011)].

**Remarks.** No additional specimens of this species were collected in this study.

#### 2.3.2.4 *Phytoseius hongkongensis* Swirski and Shechter

*Phytoseius hongkongensis* Swirski and Shechter, 1961: 99; Moraes et al., 2004b: 240; Chant and McMurtry, 2007: 129.

*Phytoseius (Pennaseius) hongkongensis*.— Ehara and Bhandhufalck, 1977: 46; Ehara and Lee, 1971: 70; Moraes, McMurtry and Denmark, 1986: 211.

**Specimens examined.** Three females, on *Flacourtia indica* (Burm. F.) Merr., at Nakhon Pathom Province, December 1996; two females, on *Ziziphus mauritiana*, at Kanchanaburi Province, June 1996.

#### FEMALE.

Dorsal shield 274 (264–294) long and 145 (135–150) wide; *j1* 28 (25–30), *j3* 72 (70–75), *j4* 5 (4–5), *j5* 4 (4–5), *j6* 6 (5–6), *J2* 9 (7–10), *J5* 6 (6–7), *z2* 17 (16–18), *z3* 44 (39–47), *z4* 10 (8–12), *z5* 4, *Z4* 79 (75–82), *Z5* 80 (75–84), *s4* 103 (102–106), *s6* 84 (80–90), *r3* 45 (43–47), *R1* 16 (15–17); distances between *St1-St3* 61 (60–62), *St2-St2* 69 (66–70), *St5-St5* 64 (63–66); ventrianal shield 97 (95–100) long, 55 (52–58) wide at level of ZV2, 46 (44–49) at anus level; calyx of spermatheca 10 (9–12) long; fixed cheliceral digit 26 (25–27) long, movable cheliceral digit 29 (29–30) long; *Sge IV* 29 (28–31), *Sti IV* 32 (31–32), *St* (basitarsus) *IV* 26 (24–28), *St* (telotarsus) *IV* 27 (25–28). Chaetotaxy: genu II 2, 2/0-2/0, 1; genu III 1, 2/0-2/0, 1.

**Previous records.** Australia, Benin (UECKERMANN et al., 2007), China, Hong Kong, Indonesia, Japan, Kenya, Madagascar, Malawy (UECKERMANN et al., 2007), Malaysia,

Papua New Guinea, South Korea, Taiwan and Thailand [Provinces of Chiang Mai and Nakhon Pathom (EHARA; BHANDHUFALCK, 1977)].

**Remarks.** Measurements of the specimens examined are similar to those of the original description and those reported by Ehara and Lee (1971) for specimens from Hong Kong.

#### 2.3.2.5 *Phytoseius neoferox* Ehara and Bhandhufalck

*Phytoseius (Phytoseius) neoferox* Ehara and Bhandhufalck, 1977: 49; Moraes, McMurtry and Denmark, 1986: 226.

*Phytoseius neoferox*.— Moraes et al., 2004b: 249; Chant and McMurtry, 2007: 129.

**Previous records.** China, India and Thailand [Province of Chiang Mai (EHARA; BHANDHUFALCK, 1977)].

**Remarks.** No additional specimens of this species were collected in this study.

#### 2.3.2.6 *Phytoseius subtilis* Wu and Li

*Phytoseius (Phytoseius) subtilis* Wu and Li, 1984: 99.

*Phytoseius (Pennaseius) subtilis*.— Moraes, McMurtry and Denmark, 1986: 217.

*Phytoseius subtilis*.— Moraes et al. 1989: 132; 2004b: 257; Chant and McMurtry, 2007: 131.

**Previous records.** China and Thailand [Province of Mae Hong Son (MORAES et al. 1989)].

**Remarks.** No additional specimens of this species were collected in this study.

#### 2.3.2.7 *Platyseiella longicervicalis* (Moraes and Denmark)

*Paraphytoseius longicervicalis* Moraes and Denmark, in Moraes et al. 1989: 131.

*Platyseiella longicervicalis*.— Moraes et al., 2004b: 259; Chant and McMurtry, 2007: 131.

**Previous records.** Reunion Island and Thailand [Province of Chumphon (MORAES et al. 1989)].

**Remarks.** No additional specimens of this species were collected in this study.

### 2.3.3 TYPHLODROMINAE Wainstein

#### 2.3.3.1 *Typhlodromus (Anthoseius) serrulatus* Ehara

*Typhlodromus (Anthoseius) serrulatus* Ehara, 1972: 142; Ehara and Bhandhufalck 1977: 45; Ryu, 1993: 117; Moraes et al., 2004b: 350; Chant and McMurtry, 2007: 155.

*Amblydromella serrulata*.— Moraes, McMurtry and Denmark, 1986: 175.

**Specimens examined.** One female and one male, on *Melaleuca leucadendra* (L.) L., at Bangkok Province, August 1992, collected by W. Hongsaprug; one female, on *Bambusa* sp., at Pathum Thani Province, September 1997, collected by T. Thimthong; and one female on *Plumeria* sp., at Rayong Province, August 1997.

#### FEMALE.

Dorsal shield 319 (306–327) long and 184 (180–187) wide; *j1* 16 (15–17), *j3* 20 (18–22), *j4* 13 (11–16), *j5* 15 (13–17), *j6* 18 (17–21), *J2* 22 (20–25), *J5* 11 (10–12), *z2* 16 (15–17), *z4* 19 (17–21), *z5* 17 (15–19), *Z4* 26 (25–29), *Z5* 45 (40–52), *s4* 21 (20–22), *S2* 24 (21–27), *S4* 26 (25–26), *S5* 16 (14–18), *r3* 20 (18–21), *RI* 18 (16–19); distances between *St1-St3* 61 (60–62), *St2-St2* 59 (57–60), *St5-St5* 57 (53–59); ventrianal shield 105 (102–107) long, 75 (73–80) wide at level of *ZV2*; calyx of spermatheca 14 (10–17) long; fixed cheliceral digit 25 long, movable cheliceral digit 27 (26–28) long; *Sge III* 9 (7–11), *Sge IV* 14 (11–16), *Sti IV* 15 (14–16), *St IV* 26 (23–29). Chaetotaxy: genu II 2, 2/0-2/0, 1; genu III 1, 2/1-2/0, 1.

#### MALE.

Dorsal shield 230 long and 155 wide; *j1* 12, *j3* broken, *j4* 11, *j5* 13, *j6* 14, *J2* 16, *J5* 9, *z2* 15, *z3* 16, *z4* 17, *z5* 13, *Z4* 20, *Z5* 29, *s4* 18, *s6* 18, *S2* 18, *S4* 18, *S5* 10, *r3* 16, *RI* 13; ventrianal shield 93 long and 118 wide at level of anterior corners; fixed cheliceral digit 13 long, movable cheliceral digit 18 long; spermatodactyl 26 long; *Sge IV* 9, *Sti IV* 12, *St IV* 17. Chaetotaxy of genua II and III as in female.

**Previous records.** China, Japan, South Korea and Thailand [Provinces of Chiang Mai and Nakhon Ratchasima (EHARA; BHANDHUFALCK 1977)].

**Remarks.** Measurements of females examined are similar to those of the original description, but setae *J2* and *J5* are 25% longer. Measurements of both female and male are very similar to those reported by Ryu (1993) for specimens from Korea.

### 2.3.3.2 *Typhlodromus (Anthoseius) thailandicus* Ehara and Bhandhufalck

*Typhlodromus (Anthoseius) thailandicus* Ehara and Bhandhufalck, 1977: 44; Moraes et al., 2004b: 354; Chant and McMurtry, 2007: 155.

*Amblydromella thailandica*.— Moraes, McMurtry and Denmark, 1986: 177.

**Previous records.** Malaysia (Ehara, 2006) and Thailand [Province of Chiang Mai (EHARA; BHANDHUFALCK, 1977)].

**Remarks.** No additional specimens of this species were collected in this study.

### 2.3.4 Key to the Phytoseiidae known from Thailand based on adult females

- |       |   |                                   |
|-------|---|-----------------------------------|
| 1     | Podonotal region of dorsal shield with 5 or 6 pairs of “lateral” setae ( <i>z3</i> present or absent, <i>s6</i> present) .....  | 2                                 |
| 1’    | Podonotal region of dorsal shield with 4 pairs of “lateral” setae ( <i>z3</i> and <i>s6</i> absent) .....   |                                   |
|       | ..... <b>Amblyseiinae</b> Muma .....  | 10                                |
| 2(1)  | Setae <i>S2</i> , <i>S4</i> and <i>S5</i> present .....   | <b>Typhlodrominae</b> Wainstein   |
|       | ..... <i>Typhlodromus (Anthoseius)</i> .....  | 3                                 |
| 2’    | Setae <i>S2</i> , <i>S4</i> and <i>S5</i> absent .....  | <b>Phytoseiinae</b> Berlese ..... |
|       | ..... 4   |                                   |
| 3(2)  | Dorsal shield reticulate only along lateral margins; seta <i>Z4</i> almost as long as distance between its base and the base of <i>Z5</i> ; <i>StIV</i> about as long as <i>SgeIV</i> ..... |                                   |
|       | ..... <i>Typhlodromus (Anthoseius) thailandicus</i> Ehara and Bhandhufalck  |                                   |
| 3’    | Dorsal shield entirely reticulate; seta <i>Z4</i> about 0.4 as long as distance between its base and the base of <i>Z5</i> ; <i>StIV</i> about twice as long as <i>SgeIV</i> .....          |                                   |
|       | ..... <i>Typhlodromus (Anthoseius) serrulatus</i> Ehara   |                                   |
| 4(2’) | Podonotal region of dorsal shield with 5 pairs of “lateral” setae ( <i>z3</i> absent) .....   |                                   |
|       | ..... <i>Platyseiella longicervicalis</i> (Moraes and Denmark)  |                                   |

- 4' Podonotal region of dorsal shield with 6 pairs of "lateral" setae, including  $z_3$   
 ..... *Phytoseius* Ribaga ..... 5
- 5(4') Seta *R1* present ..... 6
- 5' Seta *R1* absent ..... 7
- 6(5) Seta *J2* absent; seta *Z4* shorter than *Z5*; seta *j3* slightly longer the distance between its  
 base and the base of *j4*; setae *s4* and *s6* subequal in length; leg IV with macrosetae with  
 rounded apices ..... *Phytoseius subtilis* Wu and Li
- 6' Seta *J2* present; seta *Z4* longer than *Z5*; seta *j3* about as long as distance between its  
 base and the base of *j5*; seta *s4* longer than *s6*; leg IV macrosetae notched at apices  
 ..... *Phytoseius hongkongensis* Swirski and Shechter
- 7(5') Macroseta of genu IV much shorter than macrosetae of basitarsus and telotarsus of same  
 segment ..... *Phytoseius brevicrinis* Swirski and Shechter
- 7' Macroseta of genu IV subequal or slightly shorter than macrosetae of basitarsus and  
 telotarsus of same segment ..... 8
- 8(7') Seta *j3* shorter than half the distance between its base and the base of  $z_4$ ; calyx of  
 spermatheca funnel-shaped ..... *Phytoseius coheni* Swirski and Shechter
- 8' Seta *j3* about as long as distance between its base and the base of  $z_4$ ; calyx of  
 spermatheca saccular or cup-shaped ..... 9
- 9(8') Calyx of spermatheca saccular ..... *Phytoseius neoferox* Ehara and Bhandhufalck
- 9' Calyx of spermatheca cup-shaped .....  
 ..... *Phytoseius fotheringhamiae* Denmark and Schicha
- 10(1') Peritremal shield not fused anteriorly with dorsal shield .....  
 ..... **Indoseiulini** Ehara and Amano ..... *Gynaeseius* Wainstein
- 10' Peritremal shield fused anteriorly with dorsal shield ..... 11
- 11(10') Sternal shield with median posterior projection (often lightly sclerotized and difficult  
 to see); with some forward "migration" of preanal setae *JV2* and *ZV2*; cheliceral digits  
 with internal margin concave, with a group of few teeth clustered at distal end of fixed  
 digit ..... **Euseiini** Chant and McMurtry ..... *Euseius* Wainstein ..... 12
- 11' Sternal shield without median posterior projection (except for *Amblyseius eharai* Amitai  
 and Swirskii); without forward "migration" of preanal setae *JV2* and *ZV2*; cheliceral  
 digits with internal margin straight, with teeth evenly distributed along fixed digit  
 ..... 15
- 12(11) Dorsal shield mostly smooth, with striations along the anterolateral margins  
 ..... *Euseius aizawai* (Ehara and Bhandhufalck)

12'	Dorsal shield entirely reticulate .....	13
13(12')	Spermathecal calyx relatively long, slender; macrosetae of leg IV knobbed ..... <i>Euseius neofustis</i> Moraes and McMurtry	
13'	Spermathecal calyx short, slightly inflat near atrium; macrosetae of leg IV with sharp tips .....	14
14(13')	Dorsal shield jagged near <i>R1</i> ; seta <i>j3</i> almost as long as the distance between its base and base of <i>j4</i> .....	<i>Euseius okumae</i> (Ehara and Bhandhufalck)
14'	Dorsal shield smoothly concave near <i>R1</i> ; seta <i>j3</i> about half as long as distance between its base and base of <i>j4</i> .....	<i>Euseius nicholsi</i> (Ehara and Lee)
15(11')	Seta <i>S4</i> absent .....	16
15'	Seta <i>S4</i> present .....	17
16(15)	Setae <i>S2</i> present and <i>S5</i> absent .....	<i>Amblyseiulella amanoi</i> Ehara
16'	Setae <i>S2</i> absent and <i>S5</i> present .....	<i>Paraphytoseius cracentis</i> (Corpuz and Rimando, 1966)
17(15')	Seta <i>s4</i> over 4.0 times as long as <i>Z1</i> ; setae <i>s4</i> , <i>Z4</i> , <i>Z5</i> and eventually <i>j1</i> and <i>j3</i> markedly longer than other dorsal setae; seta <i>J2</i> present/absent .....	<b>Amblyseiini</b> Muma .....
17'	Seta <i>s4</i> less than twice as long as <i>Z1</i> ; setae <i>s4</i> , <i>Z4</i> and <i>Z5</i> not greatly longer than other dorsal shield setae; seta <i>J2</i> present .....	28
18(17)	Seta <i>J2</i> present .....	subtribe <b>Amblyseiina</b> Chant and McMurtry
	..... <i>Amblyseius</i> Berlese .....	19
18'	Seta <i>J2</i> absent .....	25
19(18)	Ventrianal shield vase-shaped, with lateral margins constricted near level of preanal pores .....	20
19'	Ventrianal shield pentagonal, not constricted near level of preanal pores .....	22
20(19)	Posterior margin of the sternal shield with median projection .....	<i>Amblyseius eharai</i> Amitai e Swirski
20'	Posterior margin of the sternal shield straight .....	21
21(20')	Spermathecal calyx tubular, of uniform diameter .....	<i>Amblyseius largoensis</i> (Muma)
21'	Spermathecal calyx flaring towards vesicle .....	<i>Amblyseius herbiocolus</i> (Chant)
22(19')	Macroseta of basitarsus IV longer than macroseta of genu IV; dorsal shield striated anterolaterally .....	<i>Amblyseius hidakai</i> Ehara and Bhandhufalck

22'	Macroseta of basitarsus IV shorter than macroseta of genu IV; dorsal shield entirely smooth .....	23
23(22')	Spermathecal calyx 5-8 $\mu\text{m}$ long; longitudinal axis of spermathecal calyx forming about 90 degree angle with the longitudinal axis of base of major duct ... .....	<i>Amblyseius paraaerialis</i> Muma
23'	Spermathecal calyx 10-16 $\mu\text{m}$ long; longitudinal axis of spermathecal calyx forming wide obtuse angle with the longitudinal axis of base of major duct .....	24
24(23')	Macroseta of tibia IV longer than or as long as macroseta of basitarsus IV..... .....	<i>Amblyseius tamatavensis</i> Blommers
24'	Macroseta of tibia IV shorter than macroseta of basitarsus IV .....	<i>Amblyseius cinctus</i> Corpuz-Raros and Rimando
25(18')	Seta <i>j5</i> present .....	subtribe <b>Proprioseiopsina</b> Chant and McMurtry ..... <i>Proprioseiopsis</i> Muma .....
25'	Seta <i>j5</i> absent .....	subtribe <b>Arrenoseiina</b> Chant and McMurtry ..... <i>Phytoscutus</i> Muma .....
26(25)	Spermathecal calyx longer than its diameter; seta <i>j3</i> about 2.3 times as long as <i>jl</i> .....	<i>Proprioseiopsis ovatus</i> (Garman)
26'	Spermathecal calyx shorter than its diameter; seta <i>j3</i> about 1.4 times as long as <i>jl</i> .....	<i>Proprioseiopsis lenis</i> (Corpuz-Raros and Rimando)
27(25')	Seta <i>z2</i> about half as long as distance between its base and the base of <i>z4</i> ; ventrianal shield with three pairs of preanal setae .....	<i>Phytoscutus salebrosus</i> (Chant)
27'	Seta <i>z2</i> about as long as distance between its base and base of <i>z4</i> ; ventrianal shield with five pairs of preanal setae .....	<i>Phytoscutus wongsirii</i> (Ehara and Bhandhufalck)
28(17')	Genua of legs II and III without macrosetae; fixed cheliceral digit with fewer than six teeth .....	<b>Neoseiulini</b> Chant and McMurtry ..... <i>Neoseiulus</i> Hughes .....
28'	Genua of legs II and III with macrosetae (in <i>S. siamensis</i> absent on genu II); fixed cheliceral digit with more than six teeth .....	<b>Typhlodromipsini</b> Chant and McMurtry .....
29(28)	Dorsal shield smooth .....	30
29'	Dorsal shield reticulated .....	31

- 30(29) Idiosomal dorsal setae barbed (except *j1*, *J5* and *S5*); “dorsocentral” setae *j3-j6* longer than distance between their bases and bases of corresponding subsequent setae of the series ..... *Neoseiulus longispinosus* (Evans)
- 30’ Idiosomal dorsal setae smooth (except *Z4* and *Z5*); “dorsocentral” setae *j3-j6* at most half as long as distance between their bases and bases of the corresponding subsequent setae of the series ..... *Neoseiulus barkeri* Hughes
- 31(29’) Seta *j3* longer than distance between its base and base of *j4*; leg IV with 3 macrosetae, on genu, tibia and basitarsus, respectively .....  
..... *Neoseiulus imbricatus* (Corpuz-Raros and Rimando)
- 31’ Seta *j3* less than half as long as distance between its base and the base of *j4*; leg IV with only one macroseta, on basitarsus ..... 32
- 32(31’) Distance between ventrianal pores approximately subequal to distance between each pore and the nearest *JV2* ..... *Neoseiulus baraki* (Athias-Henriot)
- 32’ Distance between ventrianal pores about 2.5 times as long as distance between each pore and the nearest *JV2* ..... *Neoseiulus taiwanicus* (Ehara)
- 33(28’) Dorsal shield reticulate, with prominent waist at level of *R1* .....  
..... *Typhlodromips syzygii* (Gupta)
- 33’ Dorsal shield mostly smooth, with striae only along anterolateral margins; dorsal shield without prominent waist at level of seta *R1*.....  
..... *Scapulaseius* Karg and Oomen-Kalsbeek ..... 34
- 34(33’) Setae *R1* usually on dorsal shield (eventually one *R1* off dorsal shield, as in *S. asiaticus*) ..... 35
- 34’ Setae *R1* on interscutal membrane ..... 36
- 35(34) Dorsal shield with a lobe on margin next to *R1*; seta *Z5* about 1.5 times as long as *Z4* .....  
..... *Scapulaseius asiaticus* (Evans)
- 35’ Dorsal shield without marginal lobe; seta *Z5* about 4.0 times as long as *Z4* .....  
..... *Scapulaseius siamensis* (Ehara and Bhandhufalck)
- 36(34’) Ventrianal shield vase-shape ..... *Scapulaseius cantonensis* (Schicha)
- 36’ Ventrianal shield pentagonal ..... 37
- 37(36’) Macroseta of genu IV knobbed and about 0.5 times as long as macroseta of tarsus IV; seta *Z5* about twice as long as *Z4* ..... *Scapulaseius okinawanus* (Ehara)
- 37’ Macrosetae of genu IV sharp-tipped and about as long as macroseta of genu IV; seta *Z5* about 5.0 times as long as *Z4* .....  
..... *Scapulaseius anuwati* (Ehara and Bhandhufalck)

## 2.4 Discussion

*Amblyseius eharai*, *Amblyseius tamatavensis*, *Gynaeseius* sp., *Neoseiulus barkeri*, *Proprioiseiopsis lenis* and *Phytoseius fotheringhamiae* are reported for the first time from Thailand.

The numbers of specimens of each species considered in this study do not necessarily represent the relative dominance of the species, given that only a fraction of the specimens collected were mounted for examination.

The higher diversity of Amblyseiinae also has been reported by Ehara and Bhandhufalck (1977) in the survey they conducted in the same country.

The results of this study are those published by Oliveira et al. (2012).

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### 3 POPULATION DYNAMICS OF *Raoiella indica* HIRST AND ITS PREDATORS (ACARI) ON COCONUT AND LADY PALMS (ARECACEAE) IN THAILAND

#### Abstract

The red palm mite, *Raoiella indica* Hirst, is a pest widely distributed in the tropical regions of the world, causing major losses to coconut, (*Cocos nucifera* L.) growers. The search for effective natural enemies to control this pest has been considered a priority to reduce its importance in areas where it was recently found. *Raoiella indica* has been found at low population levels in Thailand, perhaps due to the action of natural enemies. The objective of this study was to determine the composition of the predatory mite fauna associated with *R. indica* in the central region of Thailand on coconut and lady palm, *Rhapis excelsa* (Thunb.) A. Henry, while evaluating their population dynamics, to select most promising species for later evaluations envisioning their possible use as biological control agents. The study was conducted from June 2012 to May 2013, in a site in Bangkok and another site in Kamphaeng Saen. Samples of leaflets, fruits and inflorescences of coconut were collected monthly from ten plants of each site. Samples of leaves of lady palm were also sampled monthly from ten plants of each site. On coconut palm, the most abundant mites belonged to groups composed exclusively by phytophagous species in both sites, followed by mites of groups of variable feeding habits and mites of groups consisting predominantly of predaceous species. *Raoiella indica* was the most abundant species, corresponding to more than 70% of phytophagous mites in both fields. *Euseius nicholsi* (Ehara & Lee) was the most abundant predatory mite in Bangkok, followed by *Amblyseius largoensis* (Muma), both respectively accounting for 15.8 and 15.0% of the predatory mites. *Amblyseius largoensis* was the most abundant predatory mite in Kamphaeng Saen, representing 60.9% of predatory mites. In this last site, *E. nicholsi* was not found. On lady palm, the most abundant mites in both sites were also phytophagous, followed by predatory mites and mites of variable feeding habits. Again *R. indica* was the most abundant species in both sites, corresponding to more than 60% of this group in each site. The most abundant predatory mite was *E. nicholsi* in Bangkok (34.0% of predatory mites) and *A. largoensis* in Kamphaeng Saen (69.4%). *Amblyseius largoensis* was not found on lady palm in Bangkok. The highest densities observed for *R. indica* and phytoseiids on coconut palm (respectively 0.03 and 0.003 mites/cm<sup>2</sup>), were very low compared to what has been mentioned for those groups in other parts of the world. Although on lady palm the highest density of *R. indica* (0.48 mites/cm<sup>2</sup>, in November 2012) is much higher than what was observed on coconut, that population level is lower than what has been mentioned on the same host in the Caribbean region and in Florida. The low densities of *R. indica* in Thailand contrasts with what has been reported for this mite in the New World. Priority should be given to the evaluation of *A. largoensis* and *E. nicholsi* as possible predators of *R. indica* in Brazil.

Keywords: Red palm mite; Tenuipalpidae; Classical biological control; Phytoseiidae

### 3.1 Introduction

The red palm mite (RPM), *Raoiella indica* Hirst (Acari: Tenuipalpidae), is an important pest of palms, bananas and ornamentals in the New World. Since its first report from southern India attacking coconut palms, *Cocos nucifera* L. (HIRST, 1924), this mite has been found in the tropical region of the globe on different plant species (CARRILLO et al., 2012b; KANE et al., 2012). Since its first detection in the New World (FLECHTMANN; ETIENNE, 2004), on the Caribbean Martinique island, it spread quickly to other islands and to the American continent, now spreading from southern USA to the northern part of South America, as summarized by Carrillo et al. (2011) and navia et al. (2011).

Although the damage caused by *R. indica* has not been quantified, heavy losses have been reported in the Caribbean islands, especially on coconut (personal communication of Mr. Philippe Agostine, President of Trinidad and Tobago Growers Association, reported by RODA et al., 2012). Given the difficulty in controlling this mite by the use of chemicals, mostly because of the height achieved by the coconut plants and the virtual inexperience of a wide part of coconut growers, the search for effective biological control agents of this pest has been considered a priority to reduce its importance in newly invaded areas (CARRILLO et al., 2012a). Within the classical biological control strategy, a first step in this effort should be conducted in areas closest to the region of origin of the pest, where major damage does not occur (HOY, 2012; MORAES et al., 2012; CARRILLO et al., 2014).

The lady palm, *Rhapis excelsa* (Thunb.) A. Henry, is an ornamental commonly in urban areas in the tropics. It has been reported as a suitable host of *R. indica*, as all post-embryonic developmental stages of *R. indica* having been shown to be able to feed on it (CARRILLO; PEÑA, 2012; GONDIM Jr. et al., 2012). In a survey conducted in Thailand, Silva et al. (2014) also found *R. indica* feeding on lady palms in Kamphaeng Saen District, Nakhon Pathom Province.

*Raoiella indica* has been found in Thailand at low population levels (M. Kongshuensin, Department of Agriculture of Thailand - DOA, personal communication), perhaps due to action of natural enemies, although other factors cannot be disregarded. Central Thailand is a tropical region, as is also the case of the regions where *R. indica* is now found in the New World.

According to Peña et al. (2009), management programs to control *R. indica* in areas where it has caused damages, as well as preventative measures to reduce the chances of

possible damages in areas where still at low population levels, are urgently needed. The objective of this study was to determine the composition of the predatory mite fauna associated with *R. indica* in the central region of Thailand, while evaluating their population dynamics, for an initial assessment of effective control agents of this pest.

### **3.2 Material and Methods**

The study was conducted on two host plants onto which *R. indica* is found in Thailand, coconut and lady palm, both Arecaceae. On coconut, it was conducted in two non-commercial plantations, one on the Campus of Kasetsart University (13°50'96" N, 100°34'07" E; 21 m altitude) in Bangkok and another in the Kamphaeng Saen District (ca. 100 km northwest of Bangkok; 14°00'22" N, 99°59'78" E; 6 m altitude), Nakhon Pathom Province. In both fields, the plants were of unknown varieties, with about 4 –5 meters high and were used as ornamentals. On lady palm, the study was also conducted in two areas, where plants were used as ornamentals, one in Bangkok, nearby the place where the coconut palms were sampled, and another in Kamphaeng Saen District, at Saen Palm Training Center of Kasetsart University (14°00'46" N, 99°58'28" E; 11 m altitude), about 2 km from the place where the coconut palms were sampled.

Those areas were selected for having plants with symptoms of attack by *R. indica* in a preliminary evaluation and for not being treated with pesticides.

From each field, samples were collected in the second half of each month, between June 2012 and May 2013. For both hosts and at each sampling date, samples were taken randomly from ten plants of each site.

#### **3.2.1 Sample composition and field procedures**

At each sampling date, samples of coconut palms consisted of leaflets, inflorescences and fruits. Leaflets were taken from a leaf in the median region of canopy of each plant; five leaflets were taken from each of the basal, median and apical thirds of the leaf. Three fruits were taken from the third bunch (counting from the most recently formed fruits) and two spikelets from the median region of a newly opened inflorescence (with intense activity of pollinators), when present. Of each plant, leaflets of each third of the leaf, fruits and spikelets were held in separate plastic bags. For lady palms, one leaf, consisting of approximately 9-14

leaflets, was taken from the median region of each plant at each sampling date. Each of these leaves was held in a separate plastic bag.

The plastic bags with the samples were placed in coolers containing reusable ice bags to maintain the temperature at approximately 20°C for transport to the Entomology Laboratory of Kasetsart University, in Bangkok. In the laboratory, the samples were kept refrigerated (ca. 18 °C) for a maximum of three days, while processed.

### **3.2.2 Screening, slide mounting and mite identification**

In relation to coconut, in total 1800 leaflets of each field, in addition to respectively 148 and 128 fruits, 84 and 60 spikelets of inflorescence from the Kamphaeng Saen and Bangkok fields were examined. A total of 1200 leaflets of lady palm (average of 10 leaflets per leaf) was examined from each field.

The abaxial and adaxial surfaces of each coconut and lady palm leaflet were inspected under a stereomicroscope (40x magnification). The outer surface of fruits and the upper and lower surfaces of its bracts (removed with a knife) were also examined under stereomicroscope. Mites found were collected and immediately mounted on microscope slides, with Hoyer's medium. However, for *R. indica* a maximum of 50 specimens from each plant were mounted to confirm the species, others being only quantified. The spikelets of the inflorescence were bitten over a black surface and the displaced mites were also collected and slide mounted; a maximum of 30 specimens from each couple of spikelet were mounted to confirm the species, others being only quantified.

Mites were identified with the aid of unpublished taxonomic keys used in the Ohio State University Acarology Summer Program, Columbus, Ohio, United States of America, published identification keys (CHANT; MCMURTRY, 1994; MORAES; FLECHTMANN, 2008; KRANTZ; WALTER, 2009), catalogs (MESA et al., 2009; MORAES et al., 2004.) as well as of published species descriptions and redescrptions.

### **3.2.3 Leaf area estimation and calculation of mite densities**

The estimation of coconut and lady palm leaf area was based on leaf area taken from all leaflets collected in one sampling date (November 2012). For both coconut and lady palm, in each field of Bangkok and Kampaheng Saen, leaflets were taken from ten plants. For each

coconut palm, five leaflets from each apical, median and basal thirds of a leaf taken from the median portion of canopy, were taken. For each lady palm, a leaf with approximately 8-14 leaflets was taken from the median portion of the plant.

In the laboratory, each leaflet was cut with a scissors so it fit the length of a bond paper. With the aid of a ballpoint pen, each part of the leaflet was surrounded along its entire perimeter until its shape being reproduced on the bond paper. After doing this for all the leaflets, the drawings were scanned with the help of a scanner table. The areas of the leaflets were obtained through an image processing and analysis software, called i-SOLUTION LITE<sup>®</sup>, by drawing a polygon with coincident edges from those figures drawn by the projections of the leaflets.

Regarding the coconut palm, aiming to get the most precise leaflets average area for each portion of the leaf from each different field sampled (different coconut germplasm may have different leaf area), the leaflets of the same portion of the leaf, but from different fields, were subjected to analysis of variance. Kolmogorov-Smirnov and Bartlett tests were used to verify the normality and homogeneity of variances, respectively, of leaf area from different fields evaluated. For cases in which there was no significant difference in the mean area of the leaflets from the same portion of the leaf, between the different fields sampled, the data were grouped to calculate the average area of leaflets from that portion of the leaf ( $n=100$ ). Where significant difference was observed in the average area of the leaflets from the same portion of the leaf, between the different fields, the average area of leaflets from this portion for each field was calculated based on the leaflets only collected in the field in question ( $n = 50$ ). Statistical analyzes were performed using the statistical software SAS<sup>®</sup> 9.2 (SAS Institute, 2008).

The average area of the leaflets from the apical portion of the coconut leaf was calculated based on the leaflets collected in both fields, once there was no significant difference in the mean area of the leaflets between the sampled fields ( $F=0.02$ ,  $df=99$ ,  $P=0.8833$ ). Furthermore, the average area of the leaflets from the median and basal portions of the leaf was calculated considering the leaflets of each field separately, once was observed significant difference in the average area of leaflets from these portions, between the fields evaluated ( $F=35.10$ ,  $df=99$ ,  $P=0.0001$  and  $F=20.07$ ,  $df=99$ ,  $P=0.0001$ , respectively).

In the case of lady palm, it was also compared the average area of leaves in different fields sampled. Once verified significant difference between the average area of the leaves from Kamphaeng Saen and Bangkok ( $F=4:59$ ,  $df=19$ ,  $P=0.0461$ ), it was calculated considering the leaves of each field separately ( $n = 10$ ).

To calculate the density of mites on coconut leaflets from particular field, the total number of mites found in each sampling month was divided by the total area of the leaflets evaluated, taking into account that the leaflets of each basal, median and apical thirds of the leaves have different leaf areas.

The same procedure was adopted to calculate the density of mites on the leaflets of Lady palm, taking into account that leaves of different fields have different areas and that almost all of mites was found on the lower surface of the leaf.

### 3.2.4 Meteorological data

Temperature and humidity data for Bangkok were obtained from Pathumthani Agromet Station, placed about 25 km to the experiment. For Kamphaeng Saen, those data were obtained from Nakhon Pathom Meteorological Station, located on the campus of Kasetsart University, about 2 km from the experimental site. For graphical representation, values shown at each sampling date refer to average temperature and accumulated rainfall of the respective month.

## 3.3 Results

### 3.3.1 Faunistic composition on coconut palm

In total, 9769 mites were collected and identified at least to the level of suborder (Oribatida), of which 5691 from Bangkok and 4078 from Kamphaeng Saen.

The number of mite species found was about the same in Bangkok (30) and in Kamphaeng Saen (27). Most mites (99.0%) were found on the abaxial leaflet surface. In both fields, phytophagous mites were the most abundant, representing respectively 42.5 and 55.5% of the mites in Bangkok and Kamphaeng Saen. In both fields, these were followed by mites with varied feeding habits and mites with predominantly predatory feeding habit, respectively 40.7 and 16.8% of the mites in Bangkok and 23.8 and 20.7 in Kamphaeng Saen.

In Bangkok, Tenuipalpidae represented 76.5% of the phytophagous mites found, followed by Tetranychidae (23.5%) (Table 1). *Raoiella indica* was again the most abundant species (74.3%), followed by *O. modestus* (21.9%). Other phytophagous species corresponded to at 2.0 % of the mites of this group. Ameroseiidae, exclusively represented by *N. ceylonicus*, corresponded to 91.4% of mites with varied feeding habits found. Each other family of this group was represented by atmost 2.8% of the mites with varied feeding habits.

Phytoseiidae and Cunaxidae were the most abundant among the predators, representing respectively 33.0 and 32.1% of them, followed by Iolinidae (24.2%). Other families corresponded to at most 5.0% of the predators. *Euseius nicholsi* (Ehara & Lee) and *A. largoensis* corresponded to 15.8 and 15.0% of the predators, whereas other species corresponded to at most 4.0% of all predators found. Most mites of all feeding habits were more abundant on leaflets, the main exception being Tarsonemidae and *N. ceylonicus*, most abundant on fruits and inflorescences, respectively.

Table 1 - Mites found on leaflets, fruits and inflorescences of *Cocos nucifera* between June 2012 and May 2013 at Kasetsart University campus in Bangkok, Thailand

Taxa	Leaflets	Fruits	Inflorescences	Total
(continue)				
<b>PHYTOPHAGOUS</b>				
Tarsonemidae	3	63	-	66
Tenuipalpidae				
<i>Brevipalpus californicus</i> (Banks)	-	5	-	5
<i>Brevipalpus phoenicis</i> (Geijskes)	39	10	-	49
<i>Raoiella indica</i> Hirst	1795	-	-	1795
Tetranychidae				
<i>Oligonychus modestus</i> (Banks)	530	-	-	530
<i>Oligonychus velascoi</i> Rimando	33	-	-	33
<i>Tetranychus fijiensis</i> Hirst	5	-	-	5
<b>PREDATORS</b>				
Ascidae				
<i>Asca</i> sp.	1	20	-	21
<i>Gamasellodes</i> sp.	-	6	-	6
Bdellidae				
<i>Spinibdella</i> sp.	13	1	-	14
Cheyletidae				
<i>Caudacheles khayae</i> Gerson	1	3	-	4
<i>Hemicheyletia bakeri</i> (Ehara)	17	21	-	38
<i>Hemicheyletia bregetovae</i> (Volgin)	-	1	-	1
<i>Ker bakeri</i> Zaher & Soliman	4	1	-	5
Cunaxidae	305	2	-	307
Iolinidae	180	52	-	232
Laelapidae	-	3	-	3

Table 1 - Mites found on leaflets, fruits and inflorescences of *Cocos nucifera* between June 2012 and May 2013 at Kasetsart University campus in Bangkok, Thailand

Taxa	Leaflets	Fruits	Inflorescences	Total
(conclusion)				
Melicharidae				
<i>Proctolaelaps</i> sp.	-	10	-	10
Phytoseiidae				
<i>Amblyseius herbicolus</i> (Chant)	1	-	-	1
<i>Amblyseius largoensis</i> (Muma)	143	1	-	144
<i>Amblyseius tamatavensis</i> Blommers	4	-	-	3
<i>Euseius nicholsi</i> (Ehara & Lee)	151	-	-	151
<i>Neoseiulus longispinosus</i> (Evans)	3	1	-	4
<i>Phytoseius coheni</i> Swirski & Shechter	2	-	-	2
<i>Typhlodromus (Anthoseius) serrulatus</i> Ehara	10	-	-	10
VARIED FEEDING HABIT				
Acaridae	5	19	-	24
Ameroseiidae				
<i>Neocypholaelaps ceylonicus</i> Narita & Moraes	3	2	2113	2118
Eupodidae	1	-	-	1
Oribatida	44	2	-	46
Tydeidae	40	22	-	66
General total				5691

In Kamphaeng Saen, most of the phytophagous mites belonged to the family Tenuipalpidae (87.1%), followed by Tetranychidae (12.9%) (Table 2). *Raoiella indica* was the most abundant species, representing 86.1% of the phytophagous mites, followed by *Oligonychus modestus* (Banks) (8.1%). Other phytophagous species corresponded to at most 2.8% of the phytophagous mites. Among the mites of varied feeding habits, the most abundant family was Eupodidae (41.5%), followed by Ameroseiidae (27.8%) and Tydeidae (24.9%). The Phytoseiidae were the most abundant predatory mites (63.9%), followed by Cunaxidae (18.0%). Other families corresponded to at most 7.8% of the predatory mites. The phytoseiid *Amblyseius largoensis* (Muma) was the most abundant predator, representing 60.9% of all predators found. Other species corresponded to at most 6.4% of the predatory mites. *Amblyseius phillipsi* McMurtry & Schicha, found exclusively on leaves of coconut palms in Kamphaeng Saen, was reported by the first time in Thailand. Most mites of all

feeding habits were more abundant on leaflets, the main exception being *N. ceylonicus*, collected almost exclusively on inflorescences.

Table 2 - Mites found on leaflets, fruits and inflorescences of *Cocos nucifera* between June 2012 and May 2013 in the Kamphaeng Saen District, Nakhon Pathom Province, Thailand (continue)

Taxa	Leaflets	Fruits	Inflorescences	Total
<b>PHYTOPHAGOUS</b>				
<b>Tenuipalpidae</b>				
<i>Brevipalpus californicus</i> (Banks)	1	3	-	4
<i>Brevipalpus phoenicis</i> (Geijskes)	14	4	-	18
<i>Raoiella indica</i> Hirst	1949	-	-	1949
<b>Tetranychidae</b>				
<i>Oligonychus biharensis</i> (Hirst)	10	-	-	10
<i>Oligonychus modestus</i> (Banks)	183	-	-	183
<i>Oligonychus velascoi</i> Rimando	36	-	-	36
<i>Tetranychus fijiensis</i> Hirst	63	-	-	63
<b>PREDATORS</b>				
<b>Bdellidae</b>				
<i>Bdella</i> sp.	54	-	-	54
<i>Spinibdella</i> sp.	6	-	-	6
<b>Blattisociidae</b>				
Aff. <i>Adhaerenseius</i> sp.	-	2	12	14
<i>Blattisocius</i> sp.	-	1	-	1
<b>Cheyletidae</b>				
<i>Hemicheyletia bakeri</i> (Ehara)	5	6	-	11
<i>Hemicheyletia bregetovae</i> (Volgin)	-	1	-	1
<b>Cunaxidae</b>	151	1	-	152
<b>Iolinidae</b>	54	12	-	66
<b>Phytoseiidae</b>				
<i>Amblyseius largoensis</i> (Muma)	509	2	3	514
<i>Amblyseius phillipsi</i> McMurtry & Schicha	19	-	-	19
<i>Neoseiulus longispinosus</i> (Evans)	1	-	-	1
<i>Phytoseius coheni</i> Swirski & Shechter	3	-	-	3
<i>Scapulaseius cantonensis</i> (Schicha)	2	-	-	2
<b>VARIED FEEDING HABIT</b>				
<b>Acaridae</b>	12	28	-	40

Table 2 - Mites found on leaflets, fruits and inflorescences of *Cocos nucifera* between June 2012 and May 2013 in the Kamphaeng Saen District, Nakhon Pathom Province, Thailand (conclusion)

Taxa	Leaflets	Fruits	Inflorescences	Total
Ameroseiidae				
<i>Neocypholaelaps ampullula</i> (Berlese)	-	1	46	47
<i>Neocypholaelaps ceylonicus</i> Narita & Moraes	2	2	219	223
Eupodidae	398	5	-	403
Oribatida	12	1	-	13
Tarsonemidae	1	2	-	3
Tydeidae	173	69	-	242
General total				4078

### 3.3.2 Faunistic composition on lady palm

In total, 7626 mites were found and identified at least to the level of suborder (Oribatida), of which only 986 from Bangkok and 6640 from Kamphaeng Saen (Table 3). A slightly higher number of species was found in Bangkok (20) than in Kamphaeng Saen (15). Most mites (98.9%) were found on the abaxial leaflet surface.

Also on lady palm, phytophagous mites were the most abundant group, representing 73.6 and 95.3% of mites found in Bangkok and Kamphaeng Saen, respectively. Differently from coconut palm, predatory mites were more abundant than mites with variable feeding habits, accounting respectively 19.4 and 7.0% of mites found in Bangkok, and 4.5 and 0.2% of mites found in Kamphaeng Saen.

In Bangkok, Tenuipalpidae represented 99.9% of the phytophagous mites found, followed by Tetranychidae (0.1%). *Raoiella indica* was again the most abundant species (64.5%), followed by *B. phoenicis* (34.7%). Each of the other species corresponded to at most 0.4% of the phytophagous mites. Phytoseiidae and Iolinidae were the most abundant among the predators, representing respectively 38.2 and 24.6% of the predators; followed by Cunaxidae (17.8%) and Cheyletidae (12.6%), this later the unique other family present corresponded to 6.8% of the predators found. *Euseius nicholsi* was the most abundant predator, accounting for 34.0% of all found predators; *A. largoensis*, frequently associated to *R. indica*, was not found. Tarsonemidae was the most abundant among the mites with varied

feeding habits (55.1%), followed by Tydeidae (42.0%), others represented by at most 1.4% of the mites with varied feeding habits.

Table 3 - Mites found on leaves of *Rhapis excelsa* between June 2012 and May 2013 in Kamphaeng Saen District, Nakhon Pathom Province, and at Kasetsart University campus in Bangkok, Thailand

Taxa	Bangkok	Kamphaeng Saen	Total
<b>PHYTOPHAGOUS</b>			
<b>Tenuipalpidae</b>			
<i>Brevipalpus phoenicis</i> (Geijskes)	252	98	350
<i>Brevipalpus</i> sp.1	3	-	3
<i>Brevipalpus</i> sp.2	2	-	2
<i>Raoiella indica</i> Hirst	468	6202	6670
<b>Tetranychidae</b>			
<i>Oligonychus</i> sp.	1	-	1
<i>Tetranychus fijiensis</i> Hirst	-	27	27
<b>PREDADORES</b>			
<b>Bdellidae</b>			
<i>Bdella</i> sp.	-	3	3
<i>Spinibdella</i> sp.	13	8	21
<b>Cheyletidae</b>			
<i>Hemicheyletia bakeri</i> (Ehara)	24	8	32
<b>Cunaxidae</b>			
	34	2	36
<b>Iolinidae</b>			
	47	64	111
<b>Phytoseiidae</b>			
<i>Amblyseius largoensis</i> (Muma)	-	209	209
<i>Euseius nicholsi</i> (Ehara & Lee)	65	3	68
<i>Phytoseius coheni</i> Swirski & Shechter	3	2	5
<i>Typhlodromus (Anthoseius) serrulatus</i>	5	-	5
<b>Stigmaeidae</b>			
	-	2	2
<b>HÁBITO ALIMENTAR VARIADO</b>			
<b>Eupodidae</b>			
	1	5	6
<b>Oribatida</b>			
	1	-	1
<b>Tarsonemidae</b>			
	38	1	39
<b>Tydeidae</b>			
	29	6	35
<b>General total</b>	<b>986</b>	<b>6640</b>	<b>7626</b>

In Kamphaeng Saen, the vast majority of the phytophagous mites again belonged to the family Tenuipalpidae (99.6%). *Raoiella indica* was the most abundant species, representing 98.0% of the phytophagous mites, other species representing at most 1.5% of them. Phytoseiidae were the most abundant predatory mites (71.1%), followed by Iolinidae (21.3%), other represented by at most 3.7% of the predatory mites. Although absent in Kamphaeng Saen, *A. largoensis* was the most abundant predator in Bangkok, accounting for 69.4% of all predators found. Tydeidae, Eupodidae and Tarsonemidae were the only families of mites with varied feeding habits found, still at very low levels (1 – 6 mites).

### 3.3.3 Population dynamics on coconut

The average area of leaflets of the apical region of coconut leaves of sampled fields in Bangkok and Kamphaeng Saen was  $113.8 \pm 3.5 \text{ cm}^2$ . For the leaflets of the median and basal portion of leaves, their average areas were  $308.5 \pm 6.3$  and  $141.6 \pm 5.7 \text{ cm}^2$  for coconut palms sampled in Bangkok and  $373.0 \pm 8.9$  and  $179.4 \pm 6.2 \text{ cm}^2$  for coconut palms sampled in Kamphaeng Saen, respectively.

In Bangkok, the population densities of *R. indica* were very low over most of the observation period, increasing only in the last two sampling dates (Figure 2A), reaching a maximum density (0.03 mites/  $\text{cm}^2$ ) in the last month evaluated. Phytoseiids remained at low levels during most of the observation period, remaining at the highest levels only between December 2012 and February 2013. When rainfall was at its highest levels, phytoseiid densities tended to be lower than the density of the second most abundant predators (Cunaxidae).

In Kamphaeng Saen, the lowest densities of *R. indica* occurred in the first six sampling dates (June – November 2012), when temperature was decreasing and rainfall was relatively high, with a peak (458.5 mm) in September 2012 (Figure 2B). At the end of this period, rainfall dropped to zero (Figure 2F), continuing low until April, while temperature (from January 2013) and *R. indica* population densities increased, reaching the highest levels in May 2013, respectively  $30.2 \text{ }^\circ\text{C}$  and 0.02 mites/ $\text{cm}^2$ . The predators, mainly Phytoseiidae, were at the highest population levels (0.003 mites/ $\text{cm}^2$ ) between November 2012 and April 2013, about the period of lowest rainfall. In Kamphaeng Saen, temperature was slightly lower than Bangkok throughout the duration of the study (Figures 2E–F).

### 3.3.4 Population dynamics on lady palm

The average area of lady palm leaves was  $789.9 \pm 51.5 \text{ cm}^2$  for plants from Bangkok, and  $635.6 \pm 50.4 \text{ cm}^2$  for plants from Kamphaeng Saen

Peak density of *R. indica* on lady palm in Kamphaeng Saen (Figure 2D) was much higher than on coconut palms in both sites. Yet, in both sites the pattern of variation of *R. indica* population densities on lady palm was similar to that on coconut, except for an increase in December. Other important differences referred to higher densities of *R. indica* on this host than on coconut in Kamphaeng Saen, as well as the highest densities of phytoseiids in that same place in the last few months of 2012 and the first few months of 2013. As also observed on coconut, when rainfall was at its highest levels, phytoseiid densities tended to be lower in Bangkok (Figure 2C) than the density of the second most abundant predators (in this case, Iolinidae).

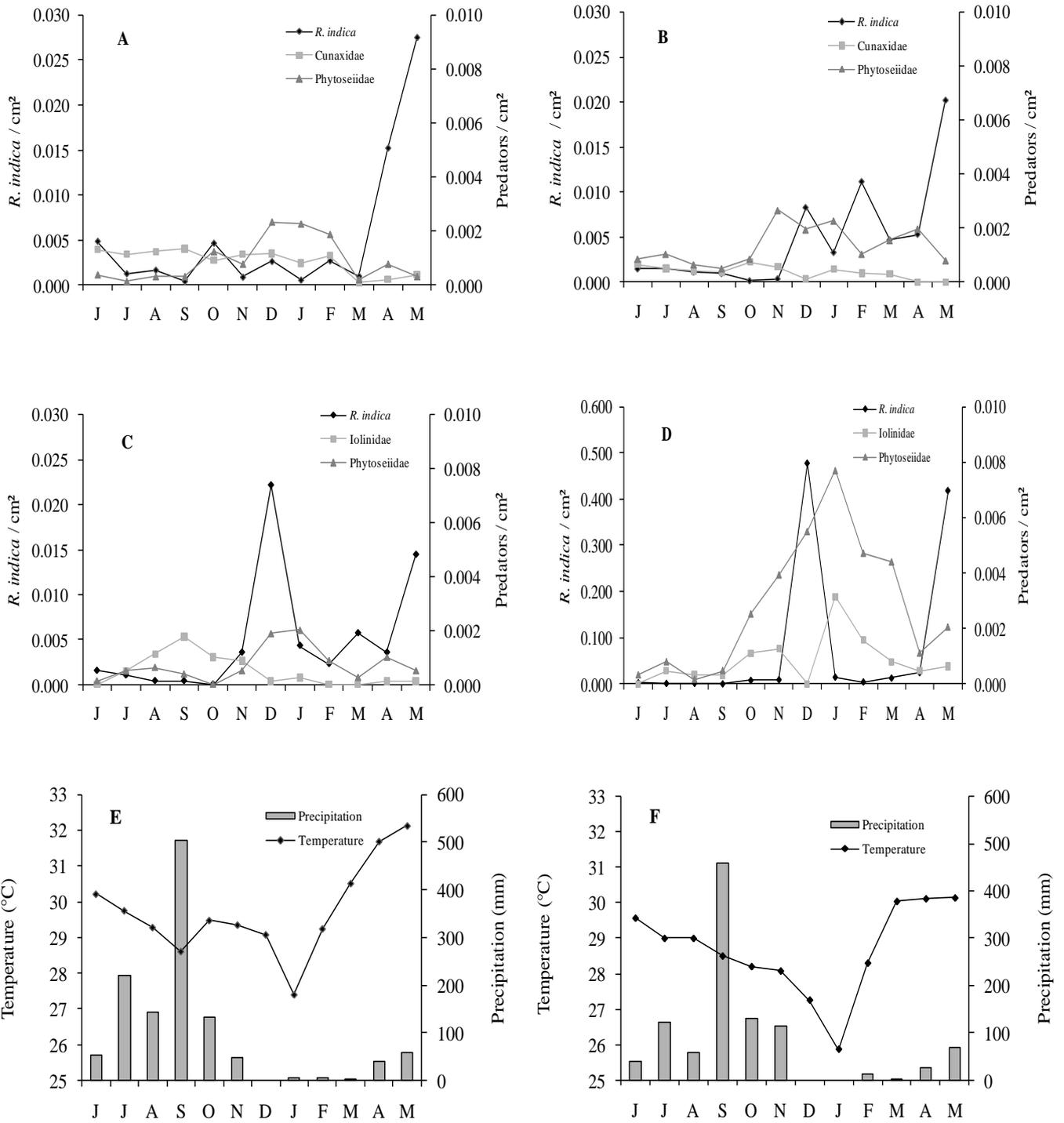


Figure 2 - Density of *R. indica* and predatory mites on leaflets of *Cocos nucifera*, in Bangkok (A) and Kamphaeng Saen (B); on leaflets of *Raphis excelsa*, in Bangkok (C) and Kamphaeng Saen (D) and accumulated precipitation (mm) and average temperature (°C) in Bangkok (E) and Kamphaeng Saen (F), Thailand, between June 2012 and May 2013

### 3.4 Discussion

#### 3.4.1 Coconut palm

The small differences in the results obtained in both fields in relation to faunistic composition and population levels of *R. indica* reflect the considerable similarity between them in terms of the characteristics of the plants as well as in relation to environmental conditions. The fact that on leaflets mites were found almost exclusively on the abaxial surface is compatible with what is known for the groups to which the collected species belong. The vast majority of mites found corresponded to *R. indica*, which feeds by inserting the cheliceral stylets in cells within leaf stomata, on coconut leaflets located exclusively on the abaxial surface (BEARD et al., 2012). Relatively few mites prefer inhabiting the upper leaf surface. The main examples are part of the species of the tetranychid genera *Eutetranychus* Oudemans and *Oligonychus* Berlese (JEPPSON; KEIFER; BAKER, 1975).

The highest proportion of phytophagous mites found in both evaluated fields was due to the predominance of *R. indica*. Despite that, the population levels attained were low, causing very light symptoms of attack. Predominance of *R. indica* among phytophagous mites has also been reported in similar studies conducted in the New World. In a survey conducted in northern Brazil, Gondim Jr. et al. (2012) also found *R. indica* as the predominant species among the phytophagous mites.

The maximum density attained by *R. indica* in this study (0.03 mites/ cm<sup>2</sup> in May 2013, in Bangkok) is extremely lower than reported in other parts of the world. Carrillo et al. (2012b), reported densities on coconut leaflets in Florida to range from 0.59 to 2.49 mites/ cm<sup>2</sup>; the lowest of these densities was still more than 18 times higher than the highest density found in the present study. In a survey conducted in the Caribbean area, Roda et al. (2012) reported densities varying between 0.32 and 1.53 mites/ cm<sup>2</sup> in Trinidad, and between 0.34 and 1.10 mites/ cm<sup>2</sup> in Puerto Rico. Taylor et al. (2012) evaluated the population levels of *R. indica* in southwest India during the dry season, reporting a peak density of 0.94 mites/ cm<sup>2</sup>. In northern Brazil, Gondim Jr. et al. (2012) reported a peak density of 1.5 mites/ cm<sup>2</sup>. The densities of *R. indica* reported in the present study confirm the suspicion of Silva et al. (2014) that *R. indica* does not seem to cause damage to coconut palms in Thailand, based on a quick survey that they conducted in the provinces of Samut Sakhon, Samut Songkhram, Nakhon Pathom, Chumphon and Surat Thani.

In the survey conducted by Gondim Jr. et al. (2012) in northern Brazil, in addition to Tenuipalpidae, Tetranychidae and Eriophyidae were respectively the second and third most abundant phytophagous mites. In the present study, tetranychids were also the second most abundant among phytophagous mites, but eriophyids were not found. In a study examining mainly coconut fruits with symptoms of eriophid attack (superficial tanning) in Thailand, Silva et al. (2014) reported the occurrence of the eriophyid *Colomerus novaehbridensis* Keifer, although at low population levels. Tarsonemidae, the third most abundant group of phytophagous mites in the present study, was also found by Silva et al. (2014) in Thailand; these were identified as *Steneotarsonemus furcatus* De Leon, causing light damage to coconut fruits. Mites of this family were also found by Gondim Jr. et al. (2012) in Brazil.

Overall, the proportion of predatory mites found in both fields in the present study was very low. This fact should not suggest that the system is unbalanced, but rather it may at least in part be a function of the reduced number of available prey, possibly as a function of their predation and other factors. *Amblyseius phillipsi* McMurtry & Schicha is reported for the first time in Thailand, in Kamphaeng Saen. Thus, 39 phytoseiid species are now known from Thailand.

Phytoseiidae was also the most abundant group of predators found by Gondim Jr. et al. (2012) in northern Brazil. So far, basically everywhere surveys have been conducted, *A. largoensis* has been among the predominant phytoseiids found on leaves of coconut palms, as in the Philippines (GALLEGO et al., 2003), Trinidad (RODA et al., 2008), Florida and Puerto Rico (PEÑA et al., 2009), Benin and Tanzania (ZANNOU et al., 2010), Cuba (RAMOS; GONZALES; GONZALES, 2010), Colombia (CARRILLO et al., 2011), India (TAYLOR et al., 2012), La Reunion island (MORAES et al., 2012), Mauritius (ROY, 2012), Venezuela (VÁSQUEZ; MORAES, 2012), Brazil (GONDIM Jr. et al., 2012) and Thailand (SILVA et al., 2014). In fact, this species has been reported as one of the main species on coconut palms and other plants, even in places where *R. indica* has not been reported (GONDIM Jr. et al., 2012).

In parallel with the low number of *R. indica* in this study, the densities of predatory mites were also low in comparison with what has been reported in other studies. Contrasting with the highest density observed on coconut leaflets in this study (0.003 mites/ cm<sup>2</sup> in November 2013, in Kamphaeng Saen), Gondim Jr. et al. (2012) reported densities of 0.009 phytoseiids/ cm<sup>2</sup> in northern Brazil, while Carrillo et al. (2012b) reported an average of 0.03 phytoseiids/ cm<sup>2</sup> in Florida.

Mites with varied feeding habits are often considered important in the maintenance of predatory mites in the environment, allowing the latter to have a greater impact on potentially damaging phytophagous species. An explanation could not be found for the fact that eupodids and tydeids were so numerous in Kamphaeng Saen but barely found in Bangkok, but it could be conceivably be due to the effect of the predatory phytoseiid *Euseius nicholsi* (Ehara & Lee), present in Bangkok but not in Kamphaeng Saen. While in Thailand mites of varied feeding habits were the second predominant group, they were less numerous than the predatory mites in northern Brazil in the study of Gondim Jr. et al. (2012). Eupodidae and Ameroseiidae were the mites of varied feeding habits most abundant in Thailand. In northern Brazil, eupodids were found in very low levels, whereas ameroseiids were not found. The latter have only been reported from coconut inflorescences in Asia and Africa, and they all belong to the genus *Neocypholaelaps* Vitzthum (NARITA; MORAES, 2011). Some ameroseiids were found on leaflets and fruits of coconut palms, probably accidental. *Neocypholaelaps ceylonicus* Narita & Moraes, the ameroseiid most abundant in this work, was also found by Silva et al. (2014) on coconut inflorescences in Thailand.

### 3.4.2 Lady palm

The much higher number of mites in Kamphaeng Saen than in Bangkok reflects the much higher number of *R. indica* in the former. The reason for this striking difference between the population levels in those sites could not be determined. Despite the overall climatic similarities between those sites, these plants were scattered among other ornamentals, widely spread in each site and next to different buildings. Thus, it seems possible that the prevailing microclimate was more favorable for *R. indica* in Kamphaeng Saen. Stronger competition with *B. phoenicis* in Bangkok could be considered another reason, but this does not seem to be the case, given the low absolute numbers of this species on lady palm leaflets (at most 0.007 *B. phoenicis*/ cm<sup>2</sup> in February, 2013). Other possible reasons refer to the different care to these plants in each site in relation to irrigation (watering the leaves), pruning, possible fertilization etc. An additional and important possibility refers to the action of predatory mites, which, although in much lower total number in Bangkok, were at a much higher proportion in relation to the number of *R. indica* in this site (totals of 191: 468 in Bangkok and 301: 6202 in Kamphaeng Saen). A major difference between the composition of the predatory fauna in the two sites refer to the predominance of *A. largoensis* in Kamphaeng

Saen and its total absence on this host in Bangkok throughout the evaluation period, despite its presence of coconuts in the same place. Presence of *A. largoensis* on lady palm in Kamphaeng Saen had already been reported by Silva et al. (2014). In Bangkok, the predominant predatory mite was the phytoseiid *E. nicholsi*. Although species of *Euseius* Wainstein have been classified by McMurtry; Moraes and Sourassou (2013) as generalist predators with preference for feeding on pollen, *E. nicholsi* could have an important predatory impact on *R. indica* on lady palm. In a preliminary investigation in the laboratory during this study, feeding by the former on the latter was observed.

Despite the high density of *R. indica* on lady palm (maximum of 0.48 mites/ cm<sup>2</sup> in December 2012, in Kamphaeng Saen), this density is low compared to what was reported on the same host in Florida (1.06 mites/ cm<sup>2</sup>) by Carrillo et al. (2012b), who found no phytoseiids associated with the pest.

### 3.5 Conclusion

*Raoiella indica* was the dominant phytopagous mite on coconut palm and lady palm in both sites in which this study was conducted. In all fields and both host plants, it was associated with 6 – 7 other phytophagous species. None of those species reached damaging levels. It is not possible to disregard the role played by climatic factors as the main elements affecting the population of *R. indica* and other phytophagous mites in Thailand, especially rainfall. That effect could either be by a direct interference with the pest or through the influence of humidity on its biological control agents.

Gondim Jr. et al. (2012) reported that although their analyzes could not demonstrate a direct relation between levels of rainfall and the population densities of *R. indica*, they could observe that the pest population decreased the during period of high precipitation and relatively lower temperatures. Lima et al. (2011) reported a similar pattern on banana in Cuba. Taylor et al. (2012) also observed that during the period of high precipitation, the population densities of *R. indica* on coconut palm and areca palm, *Areca catechu* L., tend to decrease. The biggest difference between the results of the present study and the results of those authors is that the levels attained by *R. indica* in the dry season in Thailand was not sufficiently high to cause damage to the plants, as observed in this study and as reported by Thai researchers and growers in personal consultations. This suggests a possible positive role of the local predators; incidence of pathogens on *R. indica* was never observed in the present study.

Gondim Jr. et al. (2012) reported the apparent role of humidity on the inadequate performance of a local population of *A. largoensis* as a possible control agent of *R. indica* in northern Brazil. They suggested that effort should be dedicated to finding predators that could tolerate the levels of humidity prevailing in the dry periods of northern Brazil, so as to effectively control the pest. Several species of predatory mites were found in each site in which the present study was conducted, most of which belonging to the Phytoseiidae, which was represented by 4 – 7 species in each site. Whereas *A. largoensis* was the dominant predator on both hosts in Kamphaeng Saen, in Bangkok *E. nicholsi* was about as abundant as this species on coconut palm and was the dominant predator on lady palm. Other phytoseiids were found very infrequently and at very low numbers. Thus, priority should be given to evaluation of the Thai populations of *A. largoensis* and *E. nicholsi* as candidates for practical use as biological control agents of *R. indica*. However, predators of other families, as Bdellidae, Cunaxidae and Iolinidae, should also be taken into account in subsequent studies.

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#### 4 EFFECT OF RAINFALL ON THE POPULATION OF *Raoiella indica* HIRST (ACARI: TENUIPALPIDAE) ON COCONUT SEEDLINGS IN THAILAND

##### Abstract

The red palm mite, *Raoiella indica* Hirst (Acari: Tenuipalpidae), has been considered an important pest on coconut (*Cocos nucifera* L.) in the New World. Several studies have been conducted to understand the ecology of this pest, aiming at its control. The objective of this study was to evaluate the direct effect of rainfall on the population of *R. indica* on coconut seedlings, in Thailand. The study was conducted from July to November 2012, at Kasetsart University campus in Kamphaeng Saen, Nakhon Pathom Province, Thailand. Twenty healthy coconut seedlings, 4 – 5 months old, were infested with *R. indica* and maintained in a greenhouse. After 30 days, they were distributed on a flat lawn spaced at 4 m from each other, in four rows of five seedlings. In alternating distribution, half of seedlings were protected from the rain by using roughly cubic structures whose upper surface was covered by a plastic film. Eight biweekly assessments of the population level of the combined developmental stages of *R. indica* were done, the first being carried out 30 days after infestation. In the first seven evaluations, *R. indica* densities were estimated in ten random areas of 1 cm<sup>2</sup> on the abaxial leaf surface of each seedling, using a hand lens. In the last sampling date, mites of the entire abaxial surface of all leaves of all seedlings were counted under a stereomicroscope. From the fourth sampling date, the densities of *R. indica* were significantly higher on the protected seedlings, with maximum density of 23.1 *R. indica*/ cm<sup>2</sup> (on September 22), in contrast with a maximum of 7.7 *R. indica*/ cm<sup>2</sup> on unprotected seedlings (on September 7). The results suggested that rainfall of up to 100 mm within a period of 15 days allows increase in *R. indica* population, although at a lower rate than in the absence of rain, and that rainfall at some level between 100 and 259 mm in that same period causes major reduction (but not immediate elimination) in *R. indica* population.

Keywords: Red palm mite; *Cocos nucifera*; Rain; Ecology

##### 4.1 Introduction

The red palm mite, *Raoiella indica* (Acari: Tenuipalpidae), has been considered an important pest on coconut palms, *Cocos nucifera* L, especially in the Caribbean area, where losses of up to 70% have been reported (personal communication of Mr. Philippe Agostine, President of Trinidad and Tobago Growers Association, reported by Roda et al., 2012). In addition to the coconut palms, several other species of palms (Arecaceae), as well as species of Musaceae, Heliconiaceae, Cannaceae, Pandanaceae, Strelitziaceae and Zingiberaceae are suitable as hosts for this mite (CARRILLO et al., 2012; GONDIM Jr. et al., 2012).

Since its original description from South India (HIRST, 1924), on coconut leaves, *R. indica* has been reported in many tropical regions of the world, mainly on coconut palms (FLECHTMANN; ETTIENE, 2004; ZANNOU et al., 2010; TAYLOR et al., 2012, SILVA et

al., 2014). In Brazil, *R. indica* was first found in 2009, on coconut palms in the urban area of Boa Vista, capital of Roraima state (NAVIA et al., 2011). Soon after, it was reported from Amazonas state (RODRIGUES; ANTONY, 2011).

Different methods have been evaluated for the control of *R. indica*, especially chemical and the biological control (RODRIGUES; PEÑA, 2012; MORAES et al., 2012). Chemical control has been shown impractical and costly. Biological control has been considered a priority, but efforts are still being dedicated to make it practical for the control of this pest.

Abiotic factors have often been cited as important in reducing the population levels of *R. indica* in various parts of the world (TAYLOR et al., 2012; GONDIM Jr. et al., 2012.), but the real effect of those factors have not been evaluated. Few studies have been conducted to quantify the effect of rainfall on mite population densities (YANINEK; HERREN; GUTIERREZ, 1989). The purpose of this study was to evaluate the direct effect of the rainfall on the population of *R. indica* on coconut seedlings in Thailand.

## 4.2 Material and Methods

This work was carried out from July to November 2012, at the National Biological Control Research Center (NBCRC), Central Regional Center (CRC), campus of Kasetsart University in Kamphaeng Saen, Nakhon Pathom Province, Thailand (14°02'12'' N, 99°58'57'' E).

### 4.2.1 Planting and infestation of the coconut seedlings

Twenty healthy 4 – 5 months old coconut seedlings (*Cocos nucifera* L.), containing about 3 – 4 unfolded leaves and about 0.65 m high were used in the study. The seedlings were planted in pots (30 cm diameter and 40 cm in height), filled with a substrate consisting of mixed soil and sand at the proportion 3:1 in volume, and the leaves were washed with a jet of water and a soft sponge to remove possible contaminant arthropods.

A week later, the seedlings were infested with *R. indica*. For this, highly infested leaves of lady palm, *Rhapis excelsa* (Thunb.), were inspected under a stereomicroscope to ensure the absence of predators. Three to four lady palm leaves (with 8 – 14 leaflets each) free of predators were distributed among the leaves of each coconut seedling, to which they were

fixed with the aid of clips. All seedlings were then maintained in a screen house, protected from the rain.

#### 4.2.2 Distribution of the seedlings in the field and protection from the effect of the rainfall

Thirty days after the infestation, the seedlings were distributed randomly and equidistantly in four lines of five seedlings each (spaced at 4 x 4 m) in a flat lawn (Figure 3).

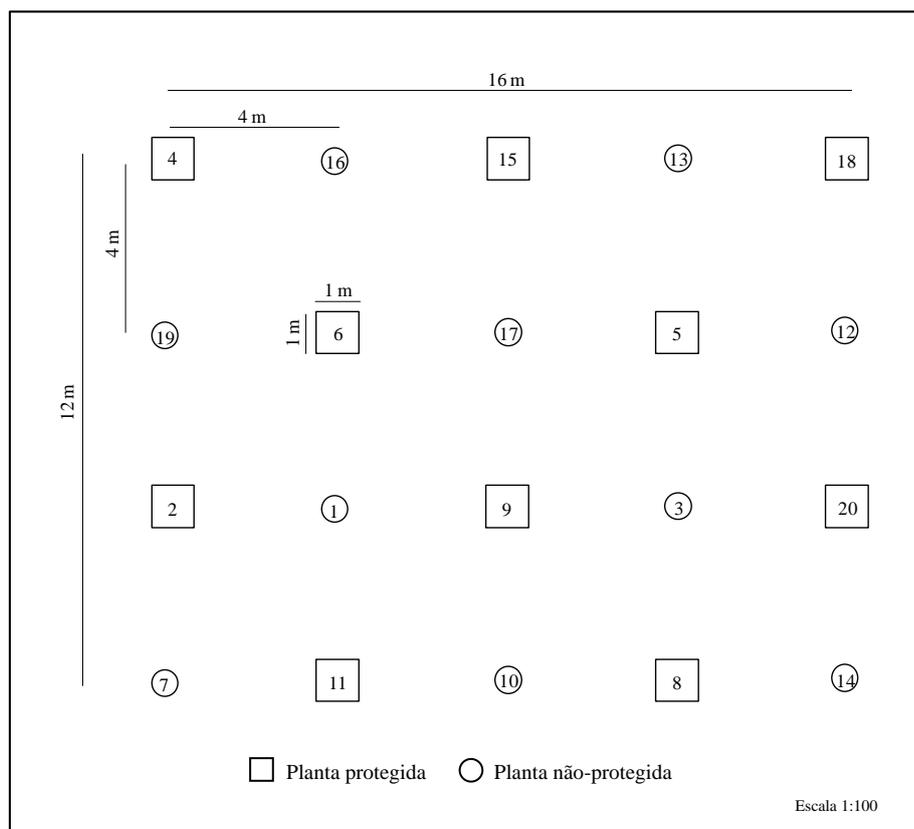


Figure 3 - Layout of the experiment to evaluate the effect of rain on the population of *Raoiella indica* on coconut seedlings in Thailand

Half of the seedlings were then protected from the rain, covering each with a plastic, tubular frame (Figure 4A) whose top was covered with a plastic film (Figure 4B). Bamboo stakes were used to fix the structure to the ground, preventing dislodgment by the wind (Figure 4C). The distribution of the protecting frames in the site was done in such a way as to ensure regular distribution of protected and unprotected seedlings, so that a protected seedling would have as neighbors only protected seedlings and vice-versa.



Figure 4 - Structure used to protect the coconut seedlings against the effect of rainfall in the experiment conducted in Kamphaeng Saen, from July to November 2012. A: general view of the plastic, tubular structure; B: detail of the plastic top; C: detail of the fixation to the ground

#### 4.2.3 Samplings

The total number of all developmental stages of *R. indica* was evaluated every 15 days, starting on August 08, 2012 and ending on November 22 of the same year. The evaluation was done with a hand lens (20 X) in ten areas of 1 cm<sup>2</sup> taken at random from different regions of the different leaves of each seedling.

In the last sampling, all the unfolded leaves of each coconut seedling were collected and held in separate plastic bags. The samples were put in coolers containing reusable ice bags to maintain the temperature at approximately 15°C for the transport to the laboratory for the evaluation. The samples were kept at ca. 18°C for a maximum of three days until processed.

#### 4.2.4 Screening and mite identification

The abaxial and adaxial surfaces of each leaf were inspected under a stereomicroscope (40 X). Except for *R. indica*, mites found were collected and immediately mounted on microscope slides, with Hoyer's medium. For *R. indica*, found in much higher numbers than

other mites, a maximum of 50 specimens from each plant were mounted for species confirmation, the remaining specimens being only counted.

Mites were identified with the aid of unpublished taxonomic keys (used in the Ohio State University Acarology Summer Program, Columbus, Ohio, USA), published identification keys (CHANT; MCMURTRY, 1994; MORAES; FLECHTMANN, 2008; KRANTZ; WALTER, 2009), catalogs (MESA et al., 2009; MORAES et al., 2004.) as well as of published species descriptions and redescriptions.

#### **4.2.5 Determination of mite densities and comparison of means**

Each plant was considered an experimental unit. From the first to the penultimate sampling, the number of *R. indica* per cm<sup>2</sup> corresponding to each plant was calculate as the average of the ten samples of each plant. For the last sampling date, the number of mites per cm<sup>2</sup> was calculated by considering the total number of specimens of this species collected on all leaves of each plant and dividing it by the calculated leaf area. Calculation of the area was done with the use of an image processing and analysis software called i-SOLUTION LITE<sup>®</sup>. The original data were submitted to non-parametric Kruskal-Wallis test, 5% significance level. Statistical analyzes were conducted using the program SAS<sup>®</sup> 9.2 (SAS Institute, 2008).

#### **4.2.6 Meteorological data**

Temperature and humidity data were obtained from Nakhon Pathom Meteorological Station, located on the campus of Kasetsart University, about 3 km from the experimental site. For graphical representation, values shown at each sampling date refer to average temperature and accumulated rainfall of the 15 days preceding the respective sampling dates, i. e., between two consecutive sampling dates.

#### **4.2.7 Microclimate analysis for protected and unprotected seedlings**

A complementary evaluation was conducted after the experiment was concluded, to evaluate the possible alteration of the temperature and relative humidity due to use of the structure used to protect the seedlings from the effect of rainfall.

This evaluation was conducted between December 18, 2014 and January 19, 2015, at Embrapa Roraima, Boa Vista, Roraima, Brazil (2°45'27" N, 60°43'52" W), using two coconut seedlings with similar characteristics as those used in Thailand. These were placed at about three meters from each other on a flat lawn, protecting one of them from the effect of rainfall using the same type of structure as used in Thailand (Figure 5A).

A temperature and relative humidity measuring and recording equipment (INSTRUTHERM<sup>®</sup>, MODEL HT-500), adjusted to store the data every 24 h, was glued to the abaxial surface of a leaf of each seedling (Figure 5B). To maintain the same exposure in both seedlings, the apical end of the leaf of each seedling onto which the equipment was glued was tied to a plastic tube stuck in the pot (Figure 5C).



Figure 5 - Experiment conducted in Boa Vista, Roraima, between December 18, 2014 and January 19, 2015, to evaluate the microclimate in protected and unprotected seedlings. A: general view of the experiment established in the field; B: detail of the temperature and relative humidity recording equipment glued to the abaxial surface of the coconut seedling; C: detail of the apical end of the leaf containing the equipment, tied to a plastic tube stuck in the pot

Temperature and relative humidity measured on both protected and unprotected seedlings were not normally distributed and variances were not homogeneous according to respectively Shapiro-Wilk and Bartlett's tests ( $P < 0.05$ ). Thus, a comparison between them was done using non-parametric Kruskal-Wallis test, at 5% significance level. Statistical analyzes were conducted using the program SAS<sup>®</sup> 9.2 (SAS INSTITUTE, 2008).

#### 4.4 Results

The densities of *R. indica* on protected and unprotected seedlings had similar patterns of fluctuation, increasing respectively until late and early September and decreasing progressively to nearly zero in the last sampling date in late November (Figure 6A). The peak density of *R. indica* was 23.1 mites/ cm<sup>2</sup> on protected and only 7.8 mites/ cm<sup>2</sup> on unprotected seedlings. Despite the high variability of the data, typical of experiments conducted with *R. indica* and other mites of the same family, densities on protected seedlings were significantly higher than on unprotected in all evaluations since the peak level was attained on protected seedlings.

There was a desynchronization between the pattern of variation of the densities of the population of *R. indica* on unprotected seedlings and of rainfall, the former reaching the maximum fifteen days later than the latter. Despite the low variation in average temperature during the experimental period (difference between maximum and minimum averages being only of ca. 1°C) (Figure 6B), relation between the fluctuation of densities on these seedlings and temperature variation was more evident, except for the last two sampling dates, in which increase in temperature was not obviously followed by increase in *R. indica* densities.

The pattern of fluctuation of the densities on protected seedlings was almost the same as that of rainfall. Relation between densities on protected seedlings and temperature was less obvious, although the reduction phase of the population level on these seedlings coincided with a tendency for reducing temperature.

Results of the complementary test showed that average temperature and relative humidity near the abaxial surface of unprotected and protected seedlings were respectively  $31.6 \pm 0.3$  and  $30.9 \pm 0.2$  °C and  $63.2 \pm 0.8$  and  $63.7 \pm 0.7$  %. Difference between those parameters were not statistically significant ( $X^2=0.16$ ,  $df=1$ ,  $P=0.6874$  and  $X^2=0.01$ ,  $df=1$ ,  $P=0.9400$ , respectively).

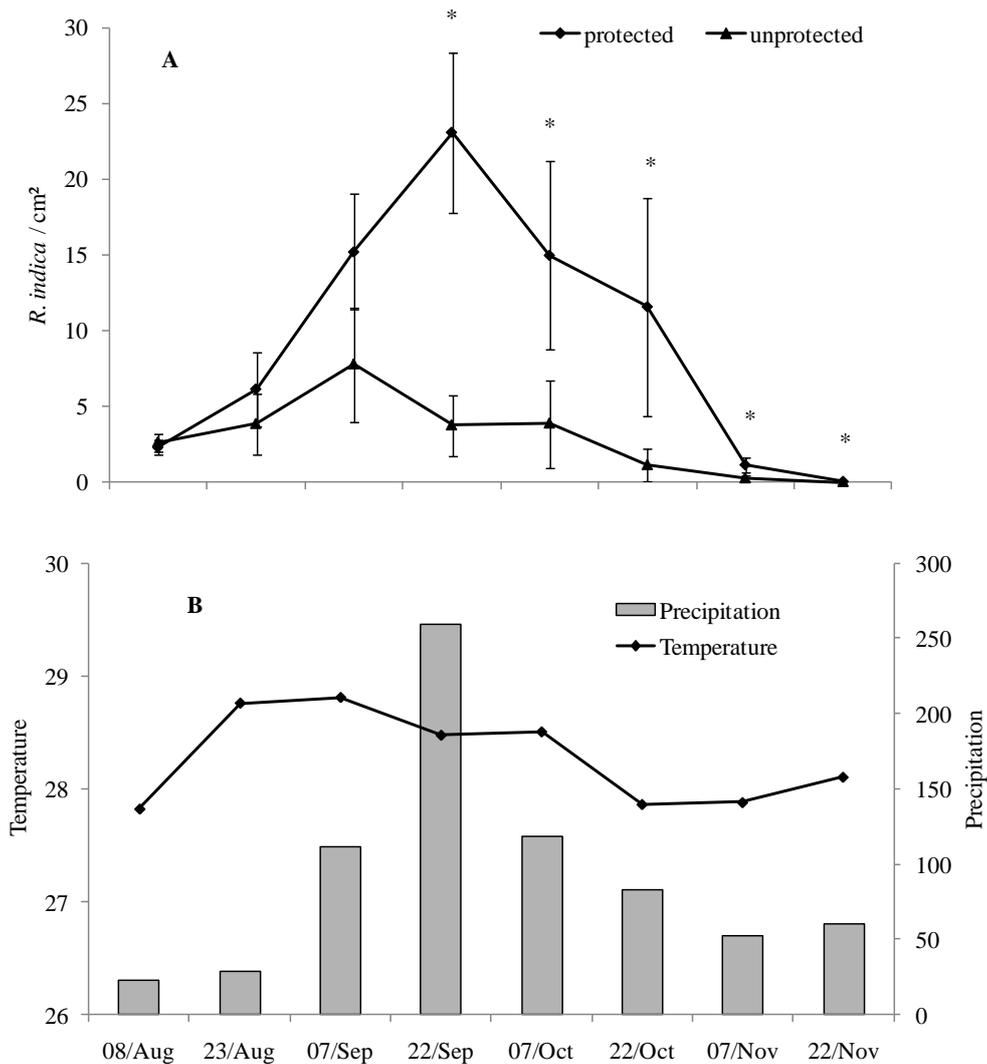


Figure 6 - A. Densities of *Raoiella indica* coconut seedlings protected and unprotected from the rain; B. Temperature (°C) and accumulated precipitation (mm) in the experimental area (Kamphaeng Saen, Nakhon Phatom, Thailand) from August to November 2012. Asterisk indicates significant differences between averages in protected and unprotected seedlings ( $p < 5\%$ , Kruskal-Wallis test)

In the final evaluation, 1301 mites were found, of which 1009 on protected and 292 on unprotected plants (Table 4). Overall, 90.5% were mites belonging to predominantly phytophagous groups, 7.4% predators and 2.1% mites with variable feeding habits. Among the phytophagous mites, *Oligonychus modestus* (Banks) was the most abundant species, accounting for 90.7% of the mites, followed by *R. indica* (8.3%) and *Oligonychus velascoi* Rimando (0.8%). Regarding the predators, *A. largoensis* and *Neoseiulus longispinosus* (Evans) were the most abundant species, representing 43.8 and 42.7% of all predators found, respectively. Most of the mites with variable feeding habits belonged to Oribatida not belonging to Acaridae.

Taking into account all mites together, the total number on protected seedlings was about three times as high as on unprotected seedlings. Almost all *R. indica* and by far most predatory mites were found on protected seedlings. *Oligonychus modestus* was also more abundant on protected seedlings, although a fifth of the total number was also found on unprotected seedlings.

Table 4 - Mites found on leaves of the *Cocos nucifera* seedlings, in the final assessment made in November 2012, at Kamphaeng Saen District, Kakhon Pathom Province, Thailand

Taxa	Protected seedlings	Unprotected seedlings	Total
<b>PHYTOPHAGOUS</b>			
<b>Tenuipalpidae</b>			
<i>Brevipalpus californicus</i> (Banks)	-	1	1
<i>Raoiella indica</i> Hirst	97	1	98
<b>Tetranychidae</b>			
<i>Oligonychus modestus</i> (Banks)	806	262	1068
<i>Oligonychus velascoi</i> Rimando	-	10	10
<b>PREDATORS</b>			
<b>Cunaxidae</b>			
	1	-	1
<b>Iolinidae</b>			
	1	-	1
<b>Phytoseiidae</b>			
<i>Amblyseius cinctus</i> Corpuz-Raros & Rimando	1	-	1
<i>Amblyseius largoensis</i> (Muma)	41	1	42
<i>Amblyseius tamatavensis</i> Blommers	-	1	1
<i>Neoseiulus longispinosus</i> (Evans)	40	1	41
<i>Scapulaseius cantonensis</i> (Schicha)	-	7	7
<i>Typhlodromips syzygii</i> (Gupta)	-	2	2
<b>VARIABLE FEEDING HABITS</b>			
<b>Acaridae</b>			
	1	5	6
<b>Tarsonemidae</b>			
	1	-	1
<b>Other Oribatida</b>			
	20	1	21
<b>Total</b>	<b>1009</b>	<b>292</b>	<b>1301</b>

#### 4.4 Discussion

Although the number of *R. indica* used in the initial infestation of the plants could not be quantified, the non-significant difference between the average densities on protected ( $2.3 \pm 0.5$ ) and unprotected seedlings ( $2.6 \pm 0.6$ ) in the first evaluation indicates that the methodology used for the infestation was adequate. Similarly, the non-significant differences between the temperature and relative humidity levels on the abaxial surface of leaves of protected and unprotected seedlings demonstrated that the structure used, by being covered only on the top, did not interfere with these climatic factors, while allowing evaluation of the effect of rainfall.

The densities reached by *R. indica* was very high in comparison with levels determined in the study about the population dynamics of this mite in Bangkok and Kamphaeng Saen, reported in chapter 2 (varying from about 200 to 1000 times higher for respectively unprotected and protected seedlings). These densities were considered satisfactorily high to allow a comparison between protected and unprotected seedlings.

The coincidence of the patterns of fluctuation of the population densities on protected seedlings and of rainfall could express better development and/ or reproduction of *R. indica* with increasing rainfall. Perhaps the occurrence of rain may facilitate the feeding by *R. indica*, which has been reported to attack cells within the stomata (BEARD et al., 2012). Stomata are known to close during periods of water stress (YORDANOV; VELIKOVA; TSONEV, 2000; BEARD et al., 2012). It remains to be known at which rate stomatal opening of seedlings regularly irrigated and protected from direct rainfall, as in this experiment, are affected by the rain.

Alternatively, the coincidence between the increase in *R. indica* densities on protected seedlings and rainfall could have been just casual. The population density in the beginning was low, and it would obviously tend to increase with time, given the known suitability of coconut to the mite (independently of the rate of rainfall, given that the seedlings were protected); the beginning of the reduction of the densities could be related to increased conditioning of the leaves due to feeding by *R. indica* or other mites, turning them less suitable to *R. indica*, to the increase of the population of predators (whose population fluctuation was not assessed in this work), or other unknown factors. Although these other mites could not be monitored along the experiment, to prevent disturbance of *R. indica* population, the evaluation done at the end of the experiment and gross observations during the experiment showed those other mites to be found in relatively high numbers. In fact, *O.*

*modestus* was almost ten times as numerous as *R. indica* in the last sampling date, while the number of predators in general was almost as high as that of *R. indica*.

Still, despite the protection certainly provided by the structure used in this experiment, rain could have had some effect on protected seedlings, as the structures, to prevent undesirable changes microclimatic factors, was covered only the top. This would seem particularly true in windy days. Yet, even if that occurred, the experimental set up was considered sufficient for this evaluation.

The coincidence between the pattern of variation of the densities of *R. indica* and temperature seems to have been casual, as the former seems to have been determined mostly by rainfall. Levels of rainfall of up to ca. 111.4 mm in a period of 15 days (up to September 7) was not sufficient to deter the increase in the population of *R. indica*, despite reducing the rate of increase in comparison with protected seedlings. However, the occurrence of rainfall of about 259.1 mm between September 7 and 22 seemingly had a major impact in the latter, reducing the *R. indica* population level on unprotected seedlings, compared to a major increase in the same period on protected seedlings. Population reductions thereafter was seemingly due to a sustained relatively high levels precipitation, at least until late October, complemented (apparently) by an increasing competition with *O. modestus* and/ or effect of predatory mites. The occurrence of *N. longispinosus* at about the same level as *A. largoensis* in this study (differently from what was mentioned in chapter 2) is probably related to the higher levels of occurrence of *O. modestus*. *Neoseiulus longispinosus* and other species of the same genus are known to have a preference to prey on tetranychid mites, especially those that produce webbing (McMURTRY; MORAES; SOURASSOU, 2013).

In conclusion, the results of this study suggest that rainfall of up to 100 mm within a period of 15 days allows increase of the population of *R. indica*, although at a lower rate than in the absence of rain, and that rainfall at some level between 100 and 259.0 mm in the same period causes major reduction (but not immediate elimination) of the population of that species.

However, in this study, the effect of rainfall was determined on seedlings, which have the leaves at a higher angle in relation to the ground surface than adult plants. Thus, the effect of rainfall on adult plants is expected to be less intense than determined in this study, onto which the mites are more protected, especially in areas where prevailing wind speed is not high.

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## 5 A NEW GENUS AND SPECIES OF BLATTISOCIIDAE (ACARI: MESOSTIGMATA) ASSOCIATED WITH COCONUT FLOWERS, IN THAILAND

### Abstract

A new genus and species of blattisociid mite is described in this paper based on specimens collected on coconut flowers, *Cocos nucifera* L. (Arecaceae), from Nakhon Pathom Province, Thailand. Females of the new genus are most similar to those of *Adhaerenseius* Loots and Theron, whose sole known species, *Adhaerenseius floralis* Loots and Theron was collected from flowers of *Astroloba rubriflora* (L.Bolus) G.F.Sm. and J.C.Manning (Xanthorrhoeacea) in South Africa. The main differences between the new genus here described and *Adhaerenseius* are discussed. Modifications are proposed in two known taxonomic key, to facilitate the differentiation of subfamilies and genera of Blattisociidae.

Keywords: Phytoseioidea; Blattisociid; Taxonomy; *Cocos nucifera*

### 5.1 Introduction

Surveys has been conducted in coconut plantations to identify promising predatory mites to control the coconut mite, *Aceria guerreronis* Keifer (Acari: Eriophyiidae), and the red palm mite, *Raoiella indica* Hirst (Acari: Tenuipalpidae). In a recent study conducted in Thailand, a specimen of an undescribed mite genus of the family Blattisociidae was found inhabiting coconut flowers.

In the key provided by Lindquist *et al.* (2009), this new genus fits the characterization of Blattisociidae for the following reasons: third pair of sternal lyrifissures (*iv3*) indistinguishable (an exception within the Blattisociidae shared with other genera), fixed cheliceral digit with setiform *pilus dentilis*; sperm access system of the phytoseiid type.

Females of the new genus are most similar to those of *Adhaerenseius* Loots and Theron, described 23 years ago (LOOTS; THERON, 1992) based on *Adhaerenseius floralis* Loots and Theron, collected from flowers of *Astroloba rubriflora* (L.Bolus) G.F.Sm. and J.C.Manning (Xanthorrhoeacea), cited on the original description as *Poellnitzia rubriflora* (L. Bol.) Uitewaal (Asphodelaceae), from Western Cape Province, South Africa.

The aim of this study was to describe this new genus, based on adult females.

## 5.2 Material and Methods

The specimens collected were mounted on microscope slides using Hoyer's medium. They were observed under a phase contrast microscope (OLYMPUS®, BX41). Measurements were done using a graded eye-piece, and illustrations were done with a drawing tube connected to the microscope.

Decision about the identity of the genus within Blattisociidae was done mainly based on Loots and Theron (1992), Halliday et al. (1998), Lindquist and Moraza (2010) and Moraza and Lindquist (2011). In the illustrations of the new genus, setal nomenclature is that of Lindquist and Evans (1965) and Lindquist (1994). Identification of pores and lyrifissures follows those of Athias-Henriot (1969) and Krantz and Redmond (1987). Leg setal notation was that of Evans (1963).

Measurements of each structure are given in micrometers ( $\mu\text{m}$ ), with the average measurement for the individuals examined followed (in parentheses) by the respective range (for variable measurements).

The type specimens were deposited in the mite collection of Departamento de Entomologia e Acarologia, Escola Superior de Agricultura "Luiz de Queiroz" (ESALQ), University of Sao Paulo (USP), in Piracicaba, Sao Paulo State, Brazil.

## 5.3 Results

### 5.3.1 New genus

**Type species.** The species here described, by original designation.

**Diagnosis.** Females and males with paired claws and with central lobe of pulvilli of all legs rounded; gnathotectum with anterior margin inverse-V-shaped, smooth with vertex rounded; corniculi parallel to each other; para-anal setae inserted about in line with posterior margin of anal opening. Female with lateral incisions on dorsal shield, between *s6* and *S1*; absence of *iv3*; podonotal and opisthonotal regions of dorsal shield with 21 and 15 pairs of setae, respectively; 14 pairs of setae on unsclerotized cuticle surrounding the dorsal shield, two on podonotal region and 12 on opisthonotal region; ventrianal shield with four pairs of setae, in addition to circumanals. Male without lateral incisions on dorsal shield; podonotal and opisthonotal regions of dorsal shield with 23 and 22 pairs of setae, respectively; three pairs of setae on opisthonotal region of the unsclerotized cuticle surrounding the dorsal shield;

ventrianal shield with five pairs of setae, in addition to circumanals; ventral spur-shaped setae on leg II.

*Adult female* (Figure 7). Dorsal shield with lateral incisions between *s6* and *S1*, with 36 pairs of setae, including 11 pairs of the *j-J* series (*j1-j6* and *J1-J5*), 11 of the *z-Z* series (*z1-z6* and *Z1-Z5*), 11 of the *s-S* series (*s1-s6* and *S1-S5*) and three of the marginal *r* series (*r2-r4*). For some specimens examined (c.a. 40%), an atypical seta is inserted on the shield in the region between bases of *r3*, *r4* and *s4*, on one or both sides of dorsal shield. Seta *Z5* longer and stouter than other dorsal setae. Nine pairs of marginal (*r5-r6* and *R1-R7*) and three pairs of submarginal (*UR3-UR5*) setae on unsclerotized lateral cuticle. Idiosomal setae setiform and smooth, except *Z5*, stouter and sparsely barbed.

Sternal and genital shields punctate; with two pairs of lyrifissures; third pair (*iv3*) absent; metasternal and endopodal plates absent; metasternal setae (*St4*) on soft cuticle. Ventrianal shield with four pair of opisthogastric setae (*JV1-JV3* and *ZV2*) in addition to circumanals; para-anal setae inserted about in line with posterior margin of anal opening; five pair of opisthogastric setae on soft cuticle around ventrianal shield (*JV4*, *JV5*, *ZV1*, *ZV3* and *ZV4*). Exopodal plate represented by an inverted comma-shaped platelet near posterior margin of coxa II, a more elongate platelet running from anterior margin of coxa III to region between coxae III-IV, narrowing to a thin line near middle of coxa III, and a curved section around posterior margin of coxa IV up to middle section of same coxa, where it fuses with peritrematic plate; the latter narrow, with a pore and two lyrifissures on each side, connecting to the dorsal shield anteriorly almost to the level of *z1*. Peritreme extending anteriorly almost to the level of *z1*. With one pair of ellipsoid metapodal plates. Gnathotectum with anterior margin inverse-V-shaped, smooth with vertex rounded. Fixed cheliceral digit with a large basal tooth, proximal to the setiform, elongate *pilus dentilis* and a small subapical tooth; *pilus dentilis* inserted near mid-length of fixed digit; movable digit with three small teeth, the median closer to the most proximal. Spermatheca with sclerotized cylindrical calyx. Legs not elongate.

*Adult male* (Figure 8). Dorsal shield without incisions and with 45 pairs of setae. Chaetotaxy of dorsum of idiosoma, relative lengths and shape of dorsal idiosomal setae similar to female, except for the position of marginal setae *r5*, *r6* and *R1-R7*, which are inserted on dorsal shield instead on soft cuticle, and for *Z4* and *S3-S5*, relatively longer and thicker than in females. Three pairs of submarginal setae (*UR3-UR5*) on lateral membrane. Sternogenital shield punctate, bearing the three pairs of sternal lyrifissures (including *iv3*); exopodal plates as in female. Ventrianal shield with five pairs of opisthogastric setae (*JV1*,

*JV2*, *JV4*, *ZV1* and *ZV2*) in addition to circumanals; three pair of opisthogastric setae on soft cuticle around ventrianal shield (*JV5*, *ZV4* and *ZV5*). Gnathotectum as in female. Fixed cheliceral digit with five teeth; movable cheliceral digit with a single large median tooth; spermadactyl L-shaped, with a distal lobe. Legs as in adult female, except for the leg II, which bears spur-shaped setae on its ventral surface, one in each of femur, genu and tarsus, and two on tibia.

**Remarks.** The new genus here described is considered to be a member of Blattisociinae, despite the fact that it does not fit well the characterization of this subfamily. As observed in other members of this subfamily, the new genus here described has the median lobe of pulvillus of legs II-IV broadly rounded; seta h1 and internal palptrochanter seta gradually tapering along entire length, not whip-like and not elongated. However, similarly to the other blattisociid subfamily, Platyseiinae, it has the para-anal setae inserted in level to hind margin of anus (also in the blattisociine *Aceodromus* Muma) and femur I has only 11 (instead of 12) setae; it also differs from platyseiines for having only 10 setae on femur II. Also differently from most other genera of this family, it does not have *iv3* and metasternal plates. Within this family, the absence of *iv3* has only been reported for *Krantzoseius* Seeman and some *Aceodromus* Muma. Females of the new genus here described differ of the related *Adhaerenseius* by having 21 pairs of setae on podonotal region of dorsal shield instead 20; 15 pairs of setae on opisthonotal region of dorsal shield instead 12; 12 pairs of setae on lateral unsclerotized cuticle instead eight; peritreme longer, extending anteriorly to level of *z1* instead only to *s1*; third pair of sternal lyrifissures and metasternal plates absent; posterior margin of genital shield truncated instead rounded; para-anal setae inserted in transverse line with instead of anteriorly of hind margin of anus; movable cheliceral digit with three teeth instead edentate; fixed cheliceral digit unidentate instead tridentate; corniculi parallel to each other instead of distally convergent; genu III with nine instead of ten setae; and genu IV with ten instead of 11 setae. Males of the new genus here described differ from male morphotypes I and II of *Adhaerenseius* by having dorsal shield without lateral incisions, instead of with relatively small incisions; seta *Z5* about 2.5 times as long as in "morphotype I", and about 4.0 times about as long as in "morphotype II"; all marginal setae on dorsal shield, instead of some on unsclerotized cuticle; three submarginal setae on unsclerotized cuticle, instead of none; ventrianal shield with five pairs of setae in addition to circumanals, instead of with seven pairs of setae; three pairs of setae on unsclerotized cuticle surrounding ventrianal shield, instead of two pairs of setae; para-anal setae inserted in transverse line with instead of

anteriad of hind margin of anus; spermadactyl- instead of T-shaped; fixed cheliceral digit with five teeth instead of bidentate; ventral spur-shaped setae on leg II instead of on leg IV.

### 5.3.2 New species

(Figure 7–8)

**Diagnosis.** Females and males are distinguished from other Blattisociidae species by the combination of characters given in the description of the genus.

**Specimens examined.** Holotype female, nine paratype females and one paratype male from flowers of *Cocos nucifera* L., Kamphaeng Saen District, 14° 00' 22" N and 99° 59' 78" E, Nakhon Pathom Province, Thailand, August 2012 and March 2013, D.C. Oliveira and S. Buttachon coll., deposited at ESALQ-USP.

**Description.** *Female.* (n=10). Figure 7.

*Dorsal idiosoma* (Figure 7A). Dorsal shield 461 (440–477) long and 252 (232–265) wide at level of setae *r3*; mostly reticulate and punctate, with lateral incisions between *s6* and *S1*. Podonotal region of dorsal shield with 21 pairs of setae, five pairs of lyrifissures and four pairs of pores. Opisthonotal region of dorsal shield with 15 pairs of setae, 11 pairs of lyrifissures and three pairs of pores. Measurements of dorsal shield setae: *j1* 28 (26–30), *j2* 19 (17–21), *j3* 19 (17–21), *j4* 19 (17–20), *j5* 19 (17–20), *j6* 19 (17–21), *J1* 20 (17–22), *J2* 22 (20–24), *J3* 23 (22–24), *J4* 26 (23–28), *J5* 12 (12–13), *z1* 17 (16–19), *z2* 20 (17–23), *z3* 20 (18–22), *z4* 21 (19–22), *z5* 19 (18–20), *z6* 21 (19–23), *Z1* 23 (22–25), *Z2* 24 (22–26), *Z3* 25 (23–26), *Z4* 30 (27–32), *Z5* 49 (45–52), *s1* 18 (17–18), *s2* 18 (17–19), *s3* 22 (20–23), *s4* 22 (20–23), *s5* 23 (21–25), *s6* 24 (22–26), *S1* 25 (23–26), *S2* 29 (27–30), *S3* 33 (30–34), *S4* 40 (35–43), *S5* 37 (33–40), *r2* 24 (22–25), *r3* 24 (22–26), *r4* 24 (22–26). Lateral unsclerotized cuticle with nine pairs of marginal setae and three pairs of submarginal setae. Measurements of setae on unsclerotized cuticle as follows: *r5* 25 (22–26), *r6* 26 (25–27), *R1* 27 (25–27), *R2* 28 (26–30), *R3* 27 (25–29), *R4* 28 (26–31), *R5* 29 (26–30), *R6* 31 (29–34), *R7* 34 (31–36), *UR3* 24 (23–25), *UR4* 26 (23–28), *UR5* 27 (25–29). All setae of rather similar lengths and shapes, setiform and smooth, except *Z5*, longer, relatively stout and sparsely serrate (Figure 7B).

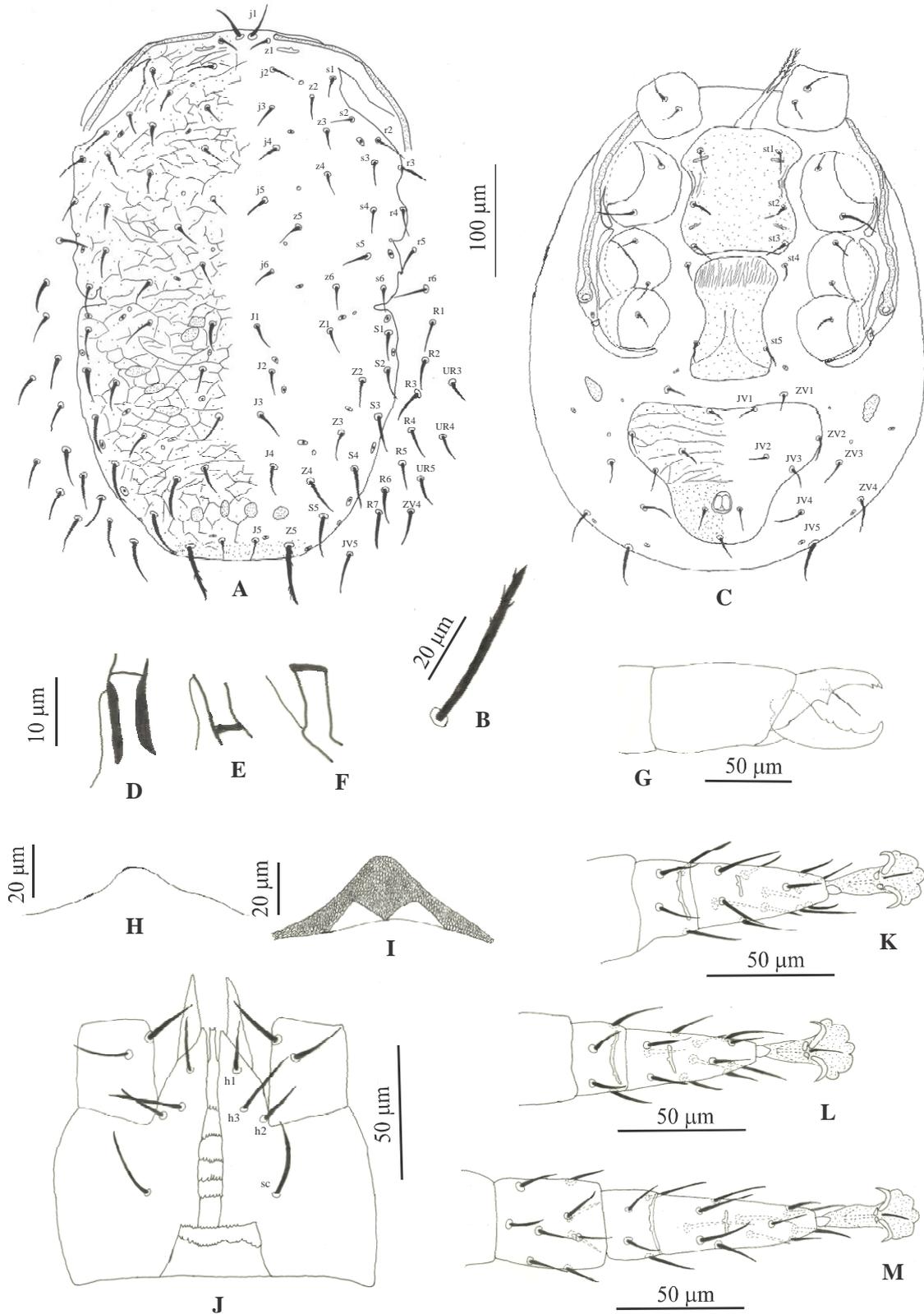


Figure 7 - New species. Female. A. Dorsal shield; B. Enlarged view of seta Z5; C. Ventral idiosoma; D–F. Different views of spermatheca; G. Chelicera; H–I. Different views of gnathotectum; J. Ventral gnathosoma; K. Tarsus of leg II; L. Tarsus of leg III; M. Tibia and tarsus of leg IV

*Ventral idiosoma* (Figure 7C). Sternal shield punctate and with scant lines parallel to lateral margins; with three pairs of setae and two pairs of lyrifissures; setal length: *St1* 30 (28–31), *St2* 24 (18–26) and *St3* 27 (23–30); distances between *St1-St3* 96 (91–102) and *St2-St2* 80 (76–85). Metasternal plates absent; seta *St4* 18 (15–21) on unsclerotized cuticle, third pair of ventral lyrifissures (*iv3*) absent. Epigynal shield punctate, lateral margins moderately concave, truncated posteriorly and bearing genital seta *St5* 19 (15–21); distance between *St5-St5* 61 (56–63); paragenital lyrifissure on unsclerotized cuticle posterolaterad of genital seta. Ventrianal shield 137 (132–145) long, 164 (150–177) wide at level of *ZV2* and 91 (85–95) at anus level; totally punctuate, with points closer together behind *JV3*; reticulate anteriorad of anus; with four pairs of opisthogastric setae: *JV1* 17 (15–19), *JV2* 18 (15–20), *JV3* 20 (19–23) and *ZV2* 20 (18–22), in addition to circumanal setae; postanal seta 26 (23–29); para-anal setae 25 (21–26), inserted in transverse line with the posterior margin of anus. Five pairs of opisthogastric setae on unsclerotized cuticle around ventrianal shield: *JV4* 26 (25–28), *JV5* 39 (36–42), *ZV1* 18 (14–21), *ZV3* 21 (20–21) and *ZV4* 31 (27–33). All setae setiform and smooth. One pair of ellipsoid metapodal plates. Endopodal plates absent. Exopodal plate represented by an inverted comma-shaped platelet near posterior margin of coxa II, a more elongate platelet running from anterior margin of coxa III to region between coxae III-IV, narrowing to a thin line near middle of coxa III, and a curved section around posterior margin of coxa IV up to middle section of same coxa, where it fuses with peritrematic plate; the latter narrow, with a pore and two lyrifissures on each side behind stigma, connecting to the dorsal shield anteriorad of *s1*. Peritreme extending anteriorly at level of *z1*.

*Spermatheca* (Figure 7D–F). Major duct leading to a strongly sclerotized cylindrical calyx, 11 (8–14) long and 5 (4–5) in diameter; minor duct long, rather thin and sometimes difficult to see.

*Gnathosoma*. Cheliceral shaft length, excluding basal article, 121 (115–125); fixed cheliceral digit 47 (44–50) long, with setiform *pilus dentilis* and one tooth and an offset subapical tooth (gabelzahn) in addition to apical hook (Figure 7G); movable cheliceral digit 57 (54–61) long, with three teeth in addition to apical hook. Gnathotectum with anterior margin inverse-V-shaped, smooth with vertex rounded (Figure 1H–I). Deutosternum with seven connected transverse denticulate lines; most distal with three denticles; second to fifth rows each with 6–8 denticles; sixth and seventh rows wider, with ca (15–20) denticles each (Figure 7J). Corniculi parallel to each other. Palpus length 124 (120–125), with normal chaetotaxy for the Gamasina as described by Evans (1964); numbers of setae from trochanter

to tarsus: 2, 5, 6, 14, 15; apotele two-tined. Subcapitular setae aciculate, *h1* 24 (20–26), *h2* 18 (16–19), *h3* 33 (30–35) and *sc* 28 (26–30).

*Legs.* Legs I–IV with paired claws and with central lobe of all pulvilli of all legs rounded, inserted on well developed pretarsi. Leg lengths (from base of coxa to apex of the tarsus): I: 334 (320–350); II: 283 (275–295); III 272 (262–295); IV: 341 (332–360). All setae aciculate and smooth; chaetotaxy of legs I–IV: coxa - 2, 2, 2, 1; trochanter - 6, 5, 5, 5; femur - 11, 11, 6, 6; genu - 13, 11, 9, 10; tibia - 13, 10, 8, 10; tarsus II–IV - 16, 16, 16 (Figure 7K–M).

*Male* (n=1). Figure 8

*Dorsal idiosoma* (Figure 8A). Dorsal shield 350 long and 225 wide at level of setae *r3*; mostly reticulate and punctate. Podonotal region of dorsal shield with 23 pairs of setae, five pairs of lyrifissures and four pairs of pores. Opisthonotal region of dorsal shield with 22 pairs of setae, 11 pairs of lyrifissures and three pairs of pores. Measurements of dorsal shield setae: *j1* 23, *j2* 18, *j3* 18, *j4* 16, *j5* 16, *j6* 17, *J1* 19, *J2* 17, *J3* 24, *J4* 30, *J5* 10, *z1* 17, *z2* 18, *z3* 17, *z4* 19, *z5* 18, *z6* 20, *Z1* 23, *Z2* 23, *Z3* 28, *Z4* 38, *Z5* 60, *s1* 16, *s2* 17, *s3* 21, *s4* 21, *s5* 21, *s6* 24, *S1* 25, *S2* 32, *S3* 42, *S4* 61, *S5* 57, *r2* 23, *r3* 25, *r4* 25, *r5* 27, *r6* 24, *R1* 27, *R2* 28, *R3* 28, *R4* 30, *R5* 28, *R6* 31, *R7* 33. Lateral soft cuticle with three pairs of submarginal setae: *UR3* 24, *UR4* 24 and *UR5* 30; Podonotal setae of rather similar lengths and shapes; opisthonotal setae progressively longer towards posterior end, except *J5*; dorsal idiosomal setae setiform and smooth, except *Z4*, *Z5*, *S3*, *S4* and *S5*, stouter and smooth, except *Z5*, sparsely serrate.

*Ventral idiosoma* (Figure 8B). All setae aciculate. Sternogenital shield punctate, with five pairs of setae and three pairs of lyrifissures; setal length: *St1* 18, *St2* 14, *St3* 13, *St4* 13, *St5* 18; distances between *St1*–*St5* 138, *St2*–*St2* 63 and *St5*–*St5* 35;. Ventrianal shield punctuate and reticulate, 128 long, 180 wide at level of *ZV1* and 100 wide at anus level, covering most of the opisthogaster, not fused to peritrematic and sternogenital shields; with five pairs of opisthogastric setae: *JV1* 20, *JV2* 20, *JV4* 22, *ZV1* 17 and *ZV2* 22, in addition to circumanal setae and three pairs of lyrifissures; postanal seta 31; para-anal setae 23, inserted in transverse line with posterior margin of anus. Three pairs of opisthogastric setae on unsclerotized cuticle around ventrianal shield: *JV5* 48, *ZV4* 36 and *ZV5* 40. Exopodal plate similar to adult female. Anterior end of peritrematic plate fused to dorsal shield at region between *s1* and *s3*; posterior end with a pair of lyrifissures and a pore on each side immediately behind stigma; fused to

posterior remnant of exopodal shield, which curves behind coxa IV; peritreme as in adult female.

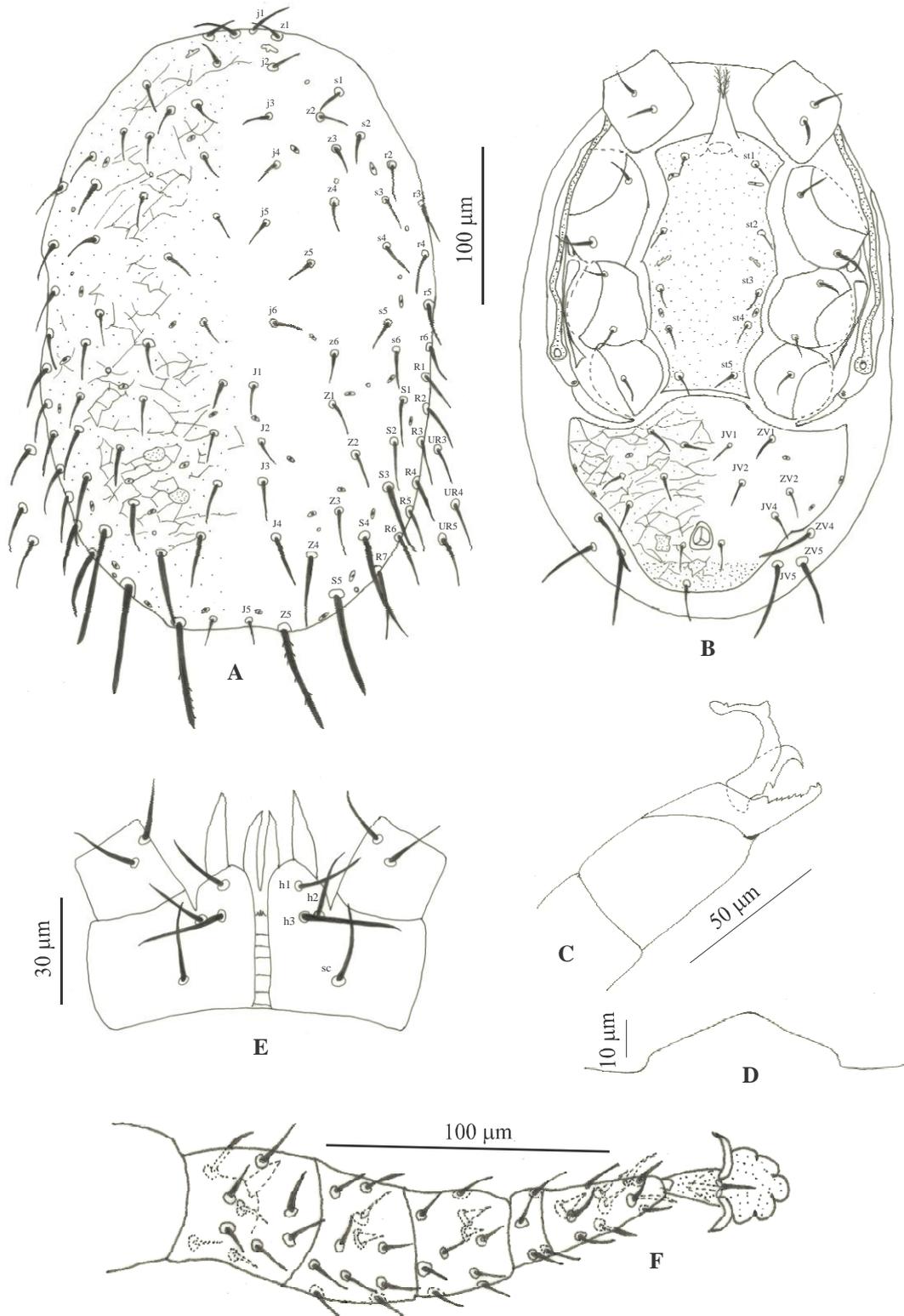


Figure 8 - New species Male. A. Dorsal shield; B. Ventral idiosoma; C. Chelicera and spermadactyl; D. Gnathotectum; E. Ventral gnathosoma; F. Femur, genu, tibia and tarsus of leg II

*Gnathosoma*. Cheliceral shaft length, excluding basal segment, 85 long; fixed cheliceral digit 30 long, with five teeth in addition to apical hook; *pilus dentilis* not visualized; movable cheliceral digit 28 long, with a single proximal tooth in addition to apical hook (Figure 8C). Spermadactyl L-shaped; shaft 21 long; toe 18 long, with an apical lobe. Gnathotectum similar to female (Figure 8D). Deutosternal denticles in seven connected rows; anterior one with 3 denticles; second to seventh rows each with 8–15 very small denticles (Figure 8E). Palpus length 95, with chaetotaxy as in female. Subcapitular setae aciculate: *h1* 22, *h2* 19, *h3* 26 and *sc* 22.

*Legs*. Legs I–IV with paired claws and central lobe of pulvill rounded, inserted on well developed pretarsi. Leg lengths (from base of coxa to tip of tarsus): I: 260; II: 230; III: 225; IV: 287. Chaetotaxy and shape of setae as in adult female, except for femur, genu, tibia and tarsus of leg II, which have respectively 1, 1, 2 and 1 spur-shaped modified setae on its ventral surface (Figure 8F).

## 5.4 Discussion

Lindquist and Moraza (2010) revised the Blattisociidae, which was divided in the subfamilies Blattisociinae Garman, with nine genera, and Platyseinae Evans, with three genera. Moraza and Lindquist (2011) described a new genus in Blattisociinae, updating the key to accommodate the genus, while transferring *Orthadenella* Athias-Henriot from Blattisociinae to Melicharidae; they also considered the blattisociine *Lasioseius* Berlese to be divided into two subgenera.

Thus, with the genus here described, Blattisociidae is now composed of 13 genera, of which 10 are blattisociine. The following modifications are proposed to the recently published keys to accommodate the new genus here described.

To the key presented by Lindquist and Moraza (2010):

1. Legs II-IV with median lobe of pulvillus broadly rounded; para-anal setae inserted anterior to hind margin of anus (in line with posterior anal margin in *Aceodromus* and the new genus here described), and subequal or slight shorter than postanal seta; femora I with 11 or 12 setae, and femora II with 11 setae; anterior hypostomatic seta and internal palptrochanter seta

- gradually tapering along entire length, not whip-like, usually not elongate ..... Subfamily  
 Blattisociinae ..... 2
- Legs II-IV with median lobe of pulvillus slender, acute or narrowly rounded; para-anal setae  
 inserted in level with or posterior to hind margin of anus, and usually longer than postanal  
 seta; femora I and II with 11 and 10 setae, respectively (each lacking *v-3*); anterior  
 hypostomatic seta and internal palptrochanter seta long, whip-like, tapering only near tip  
 ..... Subfamily Platyseinae ..... 10

To the key presented by Moraza and Lindquist (2011):

3. Corniculi approximate (well-separated in *Adhaerenseius* and the new genus here described),  
 usually slender; anterior margin of gnathotectum convex and smooth; fixed cheliceral digit  
 with few or no teeth; peritrematic plate slender, barely wider than stigma at level of stigma;  
 female with seta *r3* on dorsal shield or on unsclerotized cuticle beside dorsal shield;  
 protonymph with two setae on palptrochanter ..... 4
- Corniculi well-separated, stout; anterior margin of gnathotectum convex or triramous, smooth  
 or denticulate; fixed cheliceral digit usually with many teeth; peritrematic plate clearly wider  
 than diameter of stigma at level of stigma; female with seta *r3* on dorsal shield; protonymph  
 usually with one seta on palptrochanter ..... 5
4. Dorsal shield without midlateral incisions; seta *r3* on unsclerotized cuticle beside dorsal shield;  
 fixed cheliceral digit well developed or reduced; legs II and IV of male without enlarged,  
 spine-like setae ..... *Blattisocius* Keegan 1944 (including *Paragarmania* Nesbitt,  
 1951, *sensu* Karg, 1991)
- Dorsal shield with midlateral incisions; seta *r3* on dorsal shield; fixed cheliceral digit well  
 developed; legs II or IV of male with enlarged ventral spine-like setae ..... 4a
- 4a. Third pair of sternal lyrifissures (*iv3*) and metasternal plates present; opisthonotal region of  
 dorsal shield with 12 pairs of setae; posterior margin of genital shield rounded; para-anal setae  
 inserted anterior of hind margin of anus; fixed and movable cheliceral digits respective with  
 three and no teeth; corniculi converging distally; genua III and IV respectively with 10 and 11  
 setae; dorsal shield of male with small lateral incisions; male with ventral spur-shaped setae  
 on leg IV ..... *Adhaerenseius* Loots and Theron 1992
- Third pair of sternal lyrifissures (*iv3*) and metasternal plates absent; opisthonotal region of  
 dorsal shield with 15 pairs of setae; posterior margin of genital shield truncate; para-anal setae  
 inserted in transverse line with hind margin of anus; fixed and movable cheliceral digit

respectively with one and three teeth; corniculi parallel to each other; genua III and IV with respectively nine and ten setae; dorsal shield of male without lateral incisions; male with ventral spur-shaped setae on leg II ..... **New Genus**

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## 6 POTENTIAL OF FOUR PHYTOSEIID POPULATIONS TO CONTROL *Raoiella indica* HIRST IN A SCREENHOUSE (ACARI: PHYTOSEIIDAE, TENUIPALPIDAE)

### Abstract

The red palm mite, *Raoiella indica* Hirst (Acari: Tenuipalpidae), is one of the main pests of coconut palms, *Cocos nucifera* L. (Arecaceae). Reported by the first time from southern India in 1923, it has been found in tropical regions of Asia, Africa and America. The aim of this study was to compare the efficiency of three populations of *Amblyseius largoensis* (Muma) from Roraima - Brazil, La Reunion and Thailand, and a population of *Amblyseius cinctus* Corpuz-Raros & Rimando from Thailand in controlling *R. indica*, in a screen-house. Each of 25 coconut seedlings was infested with 30 females of *R. indica*. After 15 days, thirty predatory mites of each population were released on each of five seedlings, keeping five seedlings as control (no predator release); thus, each group of five plants equally treated constituted a treatment. All seedlings of each treatment were isolated with a cage made with voile fabric, to prevent cross-contamination. Castor bean (*Ricinus communis* L.) pollen was offered every other day as an alternative food source for the predators. Thirty days after predator release, all leaves of the seedlings were cut off to quantify the population of *R. indica* and of predators under stereomicroscope (40 x magnification). No significant differences were observed between the densities of *R. indica* on seedlings of the different treatments. *Amblyseius largoensis* from Roraima was the only population showing an apparent tendency to reduce the population of *R. indica*, perhaps for being found in the area where the study was conducted, being more adapted to the prevailing climate conditions. The use of seedlings may have not been adequate to the predator, for having the leaves at a wide angle with the soil surface, exposing the predators to sunlight. Different results could have been obtained had the test been conducted on full grown plants, which have leaves almost parallel to the soil surface.

Keywords: Biological control; Phytoseiid; *Amblyseius largoensis*; Semi field

### 6.1 Introduction

The red palm mite, *Raoiella indica* Hirst (Acari: Tenuipalpidae), is one of the main pests of coconut palms, *Cocos nucifera* L. (Arecaceae), in America. It has also been reported other palm plants (Arecaceae), as well as on some Cannaceae, Heliconiaceae, Musaceae, Pandanaceae, Strelitziaceae and Zingiberaceae (CARRILLO et al., 2012b; GONDIM et al., 2012).

A few year after its first report in America (FLECHTMANN; ETIENNE, 2004), on the Caribbean Martinique island, it was also found to other islands of the same region, as well as in the American continent (KANE et al., 2005; ETIENNE; FLECHTMANN, 2006; RODRIGUES et al., 2007; CARRILLO et al., 2012b; VÁSQUEZ et al., 2008). In Brazil, it was first reported in 2009, in Roraima state (NAVIA et al., 2011). There is no detailed

evaluation of the damage caused by this mite to its hosts. However, it is assumed that in the Caribbean area it causes major economic loss to coconut, with yield reductions estimated to reach 70% [personal communication of Mr. Philippe Agostine, President of Trinidad and Tobago Growers Association, reported by Roda et al., 2012. In Brazil, at the moment this mite seems restricted to Roraima and Amazonas states, in northern Brazil, where coconut is not an important crop; most of the coconut in Brazil is produced in the northeast. Given the high chances of spread of this mite to that region, efforts have been dedicated by Brazilian researchers to find sustainable ways to control it so as to reduce the chances for that to happen.

Biological control has been sought as a possible method to control *R. indica*, given that chemical control is hampered by the height of plants, and possible environmental hazards and human intoxication. Several studies have been conducted in the tropics to search for effective control agents of *R. indica* (ZANNOU et al., 2010; TAYLOR et al., 2012; MORAES et al., 2012). Carrillo et al. (2012a) revised the natural enemies commonly reported associated with *R. indica*. Twenty eight species of predatory arthropods, including mites and insects, were mentioned, in addition to some pathogenic fungi. According to the authors, *Amblyseius largoensis* (Muma) (Phytoseiidae), is the most abundant predatory mite associated with *R. indica* in all the geographical areas where studies have been conducted.

In a recent study conducted in Thailand for the selection of promising predatory mites to control *R. indica* on coconut palms in Brazil, *A. largoensis* was also the most abundant species found on coconut palms (Chapter 2). This species and *Amblyseius cinctus* Corpuz-Raros & Rimando, both of which were found on coconut plants associated with *R. indica* in Thailand, were introduced in Brazil in June 2013 for comparisons with the native population of *A. largoensis* and another population of the same species previously introduced from La Reunion (MORAES et al., 2012). The objective of this study was to compare the efficiency of three populations of *A. largoensis* originated from Roraima - Brazil, Thailand and La Reunion, and one population of *A. cinctus* from Thailand, in controlling *R. indica*, in semi-field conditions.

## 6.2 Material and Methods

The experiment was conducted from August to October 2014, in a screen-house of Embrapa Roraima, Boa Vista – RR (2°45'27" N, 60°43'52" W).

### 6.2.1 Origin of predators and maintenance of the stock colonies

Four populations of two species of predatory mites were evaluated in this study, namely: *A. largoensis* (from La Reunion, Roraima and Thailand) and *A. cinctus* (from Thailand). The population from La Reunion was introduced as reported by Moraes et al. (2012). The populations from Thailand were introduced by D.C. Oliveira (MAPA permit number 208/13). Specimens from these populations were collected from coconut leaves infested by *R. indica* and used to establish laboratory colonies.

The colonies were maintained in climatic chambers at  $27 \pm 2$  ° C,  $70 \pm 10\%$  of relative humidity and photoperiod of 12 h. The rearing unit was composed of a rectangular section (ca. 16 x 9 cm) of a resin plaque (Paviflex®), put onto a foam mat (ca. 20 x 12 cm) in a tray (ca. 25 x 16 cm). The lid contained an opening covered with a fine mesh fabric (voile) allowing gas exchange. The margins of the resin plaque were covered with cotton wool strips (ca. 2.5 cm). The foam mat and the cotton were kept wet by daily addition of distilled water, to serve for the consumption of the predators as well as to prevent them from escaping. A coverslip was placed onto the resin plaque on sections of cotton lint, to serve as shelter and oviposition sites to the predators.

The predators were fed with castor bean pollen, *Ricinus communis* L., offered onto a coverslip; pollen was replenished every third day. Twice a week predators were also fed with all developmental stages of *R. indica* and eggs of *Tetranychus mexicanus* (McGregor) (Tetranychidae); the first collected from coconut leaves and the second on jack bean plants, *Canavalia ensiformis* (L.) DC.

### 6.2.2 Experimental procedure

Twenty-five 4 – 6 months old coconut seedlings were each planted in a pot with 30 cm in diameter and 25 cm in height filled with a substrate consisting of sifted soil, cattle manure and sand (respectively 3: 2: 1 in volume). After the establishment of the plants, part of the leaves was removed, leaving only two undifferentiated leaves per plant. These were washed

with a water jet and a brush with soft bristle to remove contaminating arthropods. After 24 hours, one of the leaves was infested with 30 *R. indica* adult females. In this process, *R. indica* was initially transferred to rectangular sections of filter paper (ca. 2 x 4 cm), which was then fixed with the help of a clip to the leaf.

For each predator species, 15 days later, 30 adult females of the predator were released onto the infested leaf of each of five seedlings. The remaining five seedlings onto which predators were not released served as control. All predators to be released onto a leaf were aspirated from the respective stock colony with the aid of an apparatus constructed with a pipette tip attached to a thin flexible plastic hose. A section of ca. 2 cm<sup>2</sup> of voile fabric was placed at the junction of the pipette tip and the hose, retaining the predators in the former. After aspiration, the tapered end of the tip was sealed. The plastic hose was then sectioned near the connection with the pipette tip. Each pipette tip was fixed with the aid of a clip to the abaxial surface of the infested leaf, after removing the piece of voile fabric and the remaining hose piece.

The seedlings of each treatment were held together on a stand, covered by a cage made of voile fabric on a wooden frame (ca. 1.0 m wide, 3.0 m long and 1.5 m high), to reduce the possibility of cross-contaminations (Figure 9). Four openings were constructed on the sides of each cage, to facilitate manipulation of the plants. These were kept closed with a piece Velcro tape along the edges. The seedlings of each treatment were distributed so as to maintain a minimum distance of about 0.8 m between them. The plants were irrigated four times a day by dripping system, with an irrigation time of 6 minutes and deliver of ca.  $2.25 \times 10^{-6}$  m<sup>3</sup>/s.

To facilitate the establishment and maintenance of the predators, castor bean pollen was added to the adaxial face of each inoculated leaf every third day.

### 6.2.3 Evaluation

Thirty days after releasing the predators, the two leaves of each seedling were cut off to quantify the mites under stereomicroscope (40 X magnification).

Initially, the number of the combined post-embryonic stages of the predator was counted on both sides of the leaves and collected for later species confirmation. Then the eggs and the combined post-embryonic stages of *R. indica* were counted on the abaxial surface of the leaves, given that they have been reported to be restricted to this surface of coconut leaves (BEARD et al., 2012). Because of the high population densities of this species, the total

number on each leaf was estimated by evaluating the numbers in each of six areas of 4 cm<sup>2</sup>, two from each of the basal, median and apical thirds of the leaf, always along each side of the midrib. The area of each leaf was taken with the aid of a leaf area meter (Licor<sup>®</sup>, LI-3100 model). The density of the contaminant *T. mexicanus* was estimated by adopting a scale of rates varying from 0 to 3 (0: no infestation; 1: low; 2: median and 3: high infestation level). The estimated population densities (mites/ cm<sup>2</sup>) at each rate were: low= 0.08 to 0.46 (n= 22 leaves); moderate= 0.63 to 2.00 (n= 6); and high= 2.58 to 5.83 (n= 4).

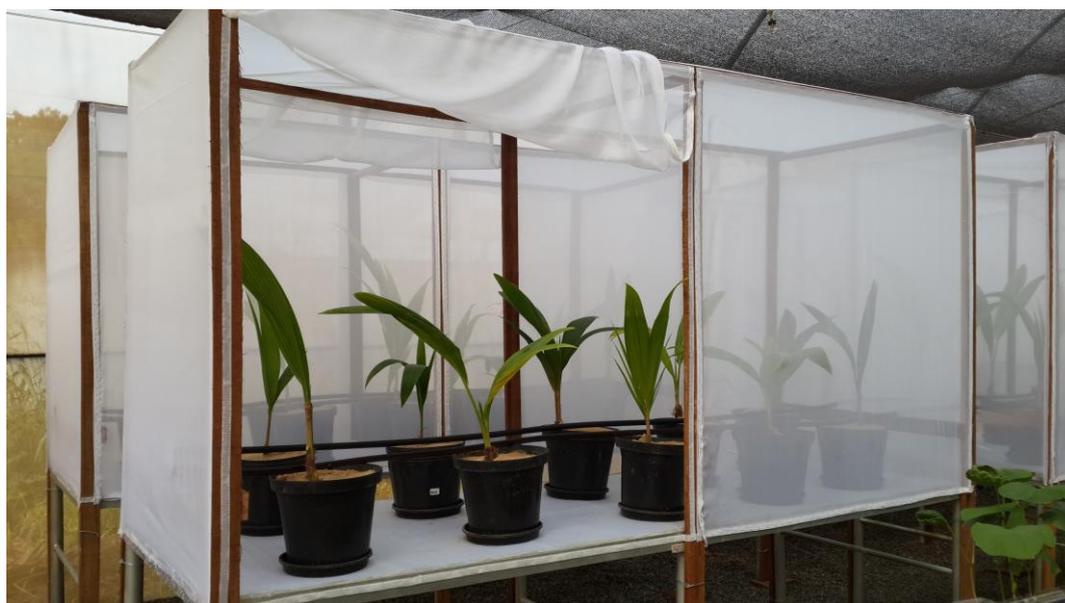


Figure 9 - Detail of a cage used to held the coconut seedlings of each treatment, to reduce the possibility of cross-contaminations

#### 6.2.4 Data analysis

Comparisons of the average densities of *R. indica* were done in three ways: a) considering only the leaves initially infested with *R. indica*; b) considering only the initially uninfested leaves; c) considering the two leaves of each seedling. In all of these comparisons, eggs and the combined post-embryonic stages were considered separately and also combined. A similar procedure was adopted to compare the number of predators found in each treatment, except that in this case eggs were not counted.

The average number of predators and the average densities of *R. indica* were not normally distributed (Shapiro-Wilk test,  $p < 0.05$ ) and their respective variances were not homogeneous (Bartlett test,  $p < 0.05$ ). Thus, comparisons were done with non-parametric

procedures (PROC NPAR1WAY; Kruskal-Wallis test, at 5% significance level). All analyzes were conducted using the statistical program SAS<sup>®</sup> 9.2 (SAS INSTITUTE, 2008).

### 6.3 Results

Considering all developmental stages of *R. indica* and treatments together, densities reached in average  $10.3 \pm 2.9$ ,  $3.0 \pm 1.1$  and  $6.7 \pm 1.6$  specimens/ cm<sup>2</sup> on initially infested, uninfested and on both types of leaves together. Considering all treatments together, no significant differences were observed between the densities (specimens/ cm<sup>2</sup>) of eggs and combined post-embryonic stages on initially infested leaves (respectively  $4.6 \pm 1.7$  and  $5.8 \pm 1.3$ ;  $X^2=2.82$ ,  $df=1$ ,  $P=0.0929$ ), on initially uninfested leaves (respectively  $1.9 \pm 0.7$  and  $1.1 \pm 0.4$ ;  $X^2=0.00$ ,  $df=1$ ,  $P=0.9757$ ) and on both leaves together (respectively  $3.2 \pm 0.9$  and  $3.4 \pm 0.7$ ;  $X^2=0.89$ ,  $df=1$ ,  $P=0.3464$ ).

No statistical differences were observed between densities of *R. indica* eggs or post-embryonic considered separately or together in different treatments, when evaluations were done on any of the leaves or on both leaves together (Figure 10; Table 5).

Table 5 - Statistical parameters for comparisons of the average densities of eggs, post-embryonic and combined stages of *Raoiella indica*, between the five treatments, on initially infested, uninfested and on both types of coconut leaves together (Kruskal-Wallis test;  $P= 0.05$ ;  $df=4$ )

Stages	Initially infested leaves		Initially uninfested leaves		Infested + uninfested	
	$X^2$	$P$	$X^2$	$P$	$X^2$	$P$
Eggs	2.81	0.5904	1.74	0.7841	2.81	0.5896
Post embryonic	4.03	0.4023	0.56	0.9678	3.68	0.4513
Egg – adult	3.38	0.4957	1.02	0.9064	2.70	0.6095

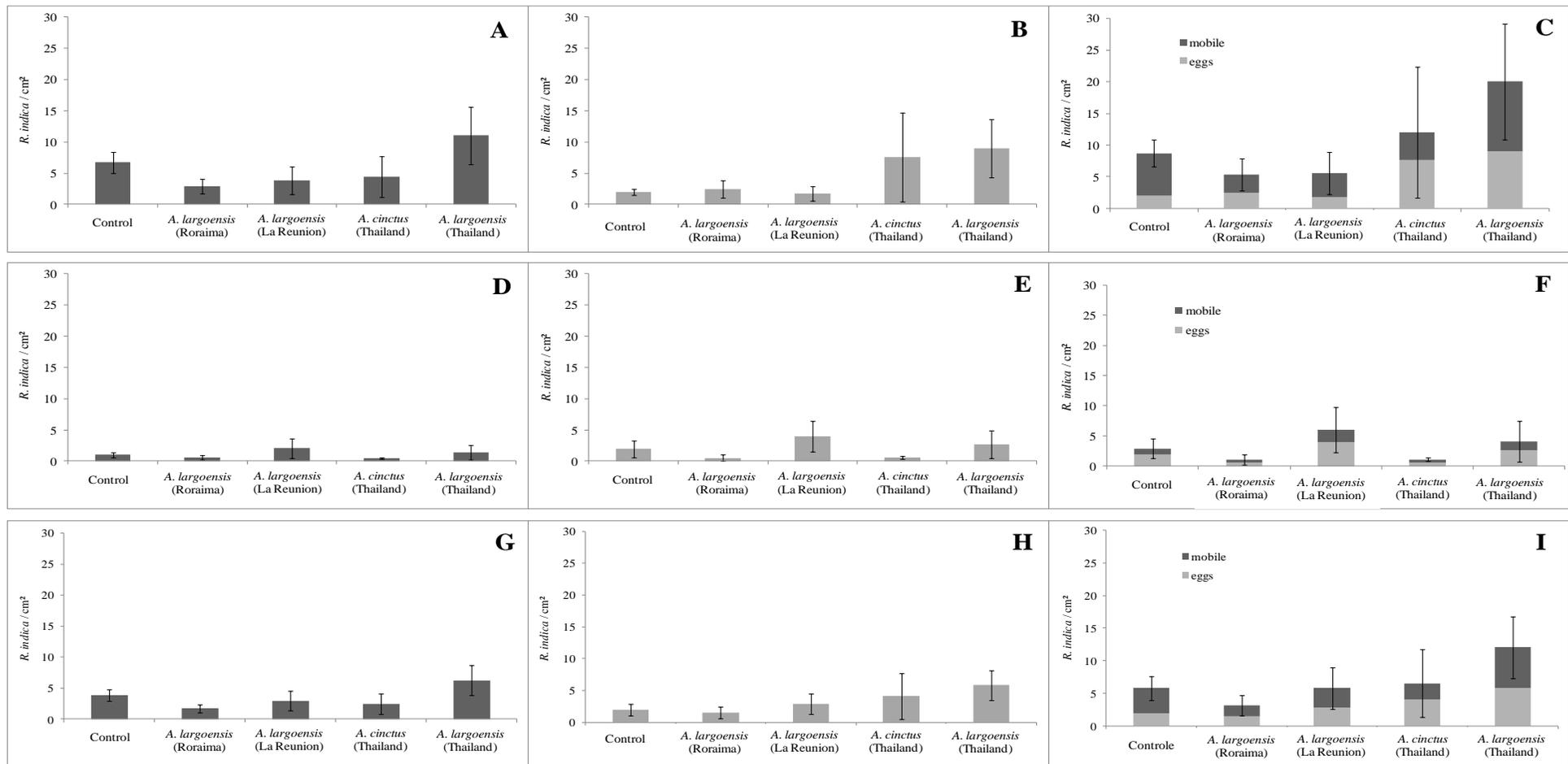


Figure 10 - Average density of eggs, mobile and eggs + mobile stages of *R. indica* on infested and uninfested coconut seedlings, with each predator populations (treatments); A. mobile stages on infested leaves; B. eggs on infested leaves; C. sum of mobile and eggs stages on infested leaves; D. mobile stages on uninfested leaves; E. eggs on uninfested leaves; F. sum of mobile and eggs stages on uninfested leaves; G. mobile stages on infested and uninfested leaves; H. eggs on infested and uninfested leaves; I. sum of mobile and eggs stages on infested and uninfested leaves

At the end of the experiment (30 days of predator release), the numbers of all phytoseiid species were relatively low (no predator found on control plants) on each infested or uninfested leaf (Table 6). The largest determined density (16.2 mites/seedling), for *A. largoensis* from Thailand, was associated with a high standard error (16.0), given that all predators were found on a single seedling. Conversely, the density of *A. largoensis* from La Reunion (11.8 mites/seedling) had more uniform distribution among seedlings (standard error= 5.4). No predators were found on seedlings onto which *A. cinctus* was released or on the control. Because of the high variations, significant differences were not observed between treatments for initially infested leaves ( $X^2=5.90$ ,  $df=4$ ,  $P=0.2066$ ), uninfested leaves ( $X^2=7.61$ ,  $df=4$ ,  $P=0.1070$ ) or per seedling ( $X^2=7.92$ ,  $df=4$ ,  $P=0.0946$ ).

Table 6 - Average numbers of specimens of all post-embryonic stages of phytoseiids on each initially infested and uninfested leaf of coconut seedlings and on each coconut seedling (one infested and one uninfested leaf) (mean  $\pm$  SE) 30 days after predators were released

Predator released	Average number		
	Infested leaves	Uninfested leaves	Coconut seedlings
Control (no release)	0	0	0
<i>Amblyseius largoensis</i> (Roraima)	2.0 $\pm$ 1.3	0.2 $\pm$ 0.2	2.2 $\pm$ 1.5
<i>Amblyseius largoensis</i> (La Reunion)	5.0 $\pm$ 2.3	6.8 $\pm$ 3.8	11.8 $\pm$ 5.4
<i>Amblyseius cinctus</i> (Thailand)	0	0	0
<i>Amblyseius largoensis</i> (Thailand)	3.4 $\pm$ 3.4	12.8 $\pm$ 12.6	16.2 $\pm$ 16.0

Although the leaves were carefully washed to remove contaminants, *T. mexicanus* was found on seedlings of all treatments (Figure 11). This mite was not found on just three of the leaves of the control and one leaf of the seedlings onto which *A. cinctus* was released. In three treatments (*A. largoensis* Roraima and Thailand, and *A. cinctus*), *T. mexicanus* reached high infestation level.

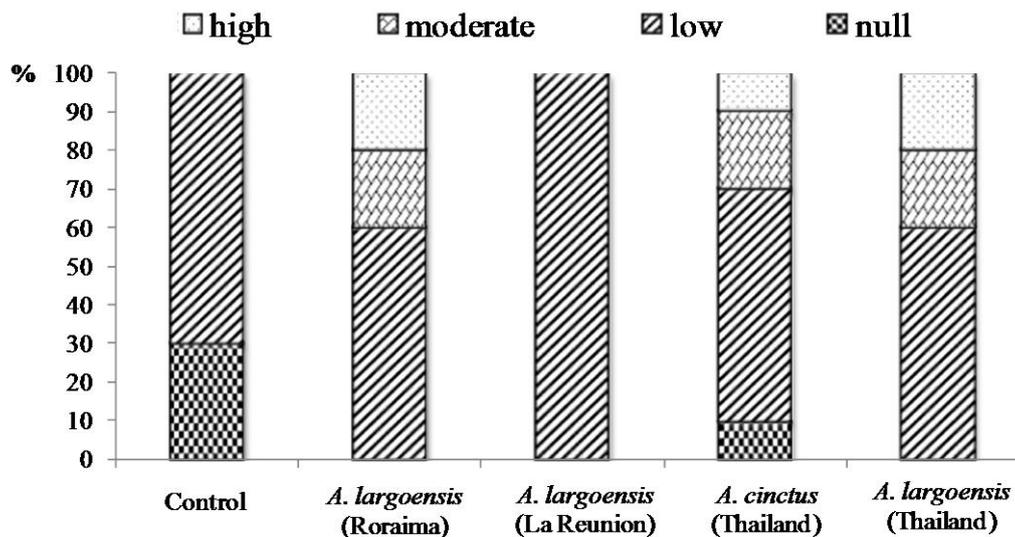


Figure 11 - Percentage of coconut seedling leaves in each treatment (n= 10) infested at different densities of *T. mexicanus*, according to the scores given

#### 6.4 Discussion

Considering the number of *R. indica* initially transferred to coconut seedlings onto which any of the predators was released and the corresponding number after 30 days, it can be concluded that the population increased ca. 11 times during that period. Considering only the control seedlings, the population increased ca. 9 times in the same period. These results do not indicate that predators as a group were able to reduce the rate of increase of *R. indica*.

Those factors, associated with the observed absence of significant differences between the densities of *R. indica* on seedlings with and without predators, indicate that the predators were not sufficiently effective to control the pest. It should be determined why these results were obtained, given that it was expected that some level of control would be detected, given the observed ability of the predators to consume, develop and reproduce when offered *R. indica* as prey in the laboratory (DOMINGOS et al., 2013; CARRILLO; PEÑA, 2012).

One possibility is that the suitability of *R. indica* as prey to those predators only in the laboratory, when the predators are confined within a restrict space with only *R. indica* as possible food source, and where environmental conditions are favorable. As a possible consequence, in the present study, in which predators were not confined to a small space, they moved away, in search of more adequate food or climatic conditions.

Lack of food does not seem to be a triggering factor determining the inability of the predators, as the density of prey may have been even excessive for a proper performance of

the predators. Carrillo, Hoy and Peña (2014) evaluated the effects of different inoculation rates of a population of *A. largoensis* from Florida on the densities of *R. indica* under greenhouse conditions. They reported significant considerable differences in the ability of the predator in reducing the densities of the according to the predator: prey ratios; density reduction varied from ca. 92% to 43% for ratios between 1:10 and 1:30, respectively. The predator: prey ratio was not evaluated in the present study when predators were released. Thus, it is possible that the ratio was too low in the present study, i.e., the number of predator was too low for the number of *R. indica* present on each leaf. Densities reached by *R. indica* on initially infested leaves was high in comparison with densities reported by Gondim Jr. et al. (2012) in Roraima, in a field about 170 km away from the area where the present study was conducted. On uninfested leaves, densities were comparable, or slightly higher than reported by Gondim Jr. et al. (2012). In addition, pollen, determined in the laboratory as adequate food for these predators (YUE; TSAI, 1996) and other related species (McMURTRY; MORAES; SOURASSOU, 2013), was also regularly supplied to the predators onto the leaves of the seedlings.

Climatic conditions do not seem to be a determinant factor for the results obtained in the study, given that the predators were collected from areas which do not seem climatically so different from each other (GONDIM Jr. et al., 2012). However, the inefficiency of the predators could be related to the architecture of the seedlings, which may have not been adequate to the predator, for having the leaves at a wide angle with the soil surface, exposing the predators to sunlight. Different results could have been obtained had the test been conducted on full grown plants, which have leaves almost parallel to the soil surface. Phytoseiid mites are known to avoid direct exposure to light. Studies have shown that solar radiation, particularly ultraviolet radiation, can be lethal to predatory mites (ONZO et al., 2010) while favoring certain phytophagous mites (FUKAYA et al., 2013).

The finding of *T. mexicanus* on the seedlings shows how difficult it is to maintain the conditions of semi-field completely under control. Furthermore, it was shown that the exclusion method used for the removal of undesirable arthropods (washing plant) was not completely efficient.

The presence of *T. mexicanus* could have influenced the dynamics predator / prey in different ways. For example, the webbing produced by that mite could protect *R. indica* from the action of certain predators. McMurtry; Moraes and Sourassou (2013) reported that while some predators are favored by the presence of webbing, others are disfavored. The web could also act as a barrier to *R. indica*, hindering and/ or preventing their mobility, as noted some

times in the evaluation of this experiment, and reducing its population growth. Given the high reproductive capacity of this species (SOUSA; GONDIM Jr.; LOFEGO, 2010), they could more rapidly take over the attacked leaf, forcing *R. indica* to move elsewhere. *Tetranychus mexicanus* could also be considered as an alternative food source for some predators, but, because of the webbing, not for the predators used in this work, as shown for other species of *Amblyseius* (McMURTRY; MORAES; SOURASSOU, 2013). This conclusion is also supported by the fact that few predators were found on the plants after 30 days of predator release.

Carrillo, Hoy and Peña (2014) also found a low population density of *A. largoensis* on coconut seedlings in the experiment they conducted in a greenhouse, for a period of three months. According to those authors, providing an alternative food source could increase the populations of predators, and therefore the control potential on *R. indica*. In our experiment, the provision of a complementary food (castor bean pollen) was not sufficient to retain the predators on the seedlings.

The methodology adopted in this study did not allow the conclusion about the inefficiency of the predators. Future studies should involve a modification of this methodology, especially preventing the exposure of the predators to sunlight and releasing the predators at a higher predator: prey ratios. This should be helpful to reduce the tendency of the predators to move away from the coconut leaf.

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## 7 FINAL CONSIDERATIONS

The phytoseiid fauna of Thailand is relatively poorly known. Until the beginning of the present study, only 32 species had been reported. In chapter 1, new records of six other species were presented, namely *Amblyseius eharai* Amitai & Swirski, *Amblyseius tamatavensis* Blommers, *Gynaeseius* sp., *Neoseiulus barkeri* Hughes, *Proprioseiopsis lenis* (Corpuz-Raros & Rimando) and *Phytoseius fotheringhamiae* Denmark & Schicha.

*Raoiella indica* was the dominant phytopagous mite on coconut palm (*Cocos nucifera* L.) and lady palm [*Rhapis excelsa* (Thunb.) A. Henry] in the sites evaluated in Thailand, although their densities were much lower than reported for other parts of the world, and causing minor damage. Most predatory mites associated with *R. indica* were phytoseiids, being *Amblyseius largoensis* (Muma) the most abundant on coconut and lady palm in both sites where the study was conducted, except on coconut in Bangkok, where it was almost as abundant as *Euseius nicholsi* (Ehara & Lee). Rainfall had an important impact on *R. indica* population, reducing its population growth when intensity was up to 100 mm within a period of 15 days, or reducing its population when density was between 100 and 259.1 mm within that same period. However, the effect of rainfall on adult plants is expected to be less intense than determined in this study, given that on adult plants *R. indica* is less exposed than on coconut seedlings, especially in areas where prevailing wind speed is not high.

The new genus of Blattisociidae described in this study is similar to *Adhaerenseius* Loots & Theron, a genus also known from a single species collected in South Africa from flowers. Nothing is known about the feeding habits of the new species found in this work, but it is believed that it feeds on pollen or nectar.

The results of the evaluation of the performance of the predators introduced from Thailand (*A. largoensis* and *Amblyseius cinctus* Corpuz-Raros & Rimando), as biological control agent of *R. indica* on coconut seedlings, did not allow concluding that they are able to reduce the population of the pest. Again, the architecture of the coconut seedlings may have not been adequate to the predator, exposing them to sunlight. Future studies should involve a modification of the methodology used in the present study, especially preventing the exposure of the predators to sunlight and releasing the predators at higher predator: prey ratios. This should be helpful to reduce the tendency of the predators to move away from the coconut leaf.