What is the Southern Limit of the Distribution of Red Palm Mite, Raoiella indica (Acari: Tenuipalpidae), in Agricultural Lands in Brazil?

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What is the southern limit of the distribution of red palm mite, *Raoiella indica* (Acari: Tenuipalpidae), in agricultural lands in Brazil?

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**Abstract**

The red palm mite, *Raoiella indica* Hirst (Acari: Tenuipalpidae), has been considered one of the most threatening pests of coconut, banana, and other monocotyledonous plants. It now has been reported from several Brazilian states, but little is known about its current distribution in the southern half of Brazil. The objective of this study was to evaluate the distribution of *R. indica* and the associated predatory mites in mid-southern Brazil, and to determine the possible southern limit to its distribution in the country. It was found in the Federal District and in 49 municipalities of 9 states, of which the southernmost was Iporã, Paraná State (24.00722°S, 53.69833°W). The majority of the surveyed sites south of Iporã had higher altitude than this municipality and surveyed sites immediately north of it. Thus, sites south of Iporã seem ecologically unsuitable to *R. indica*, most probably because of the low temperature in the winter. Eighteen species of predatory mites were found in association with *R. indica*, all of which belong to the order Mesostigmata, and 14 of which belong in the family Phytoseiidae. However, they are not *R. indica*-specific, as most have been reported from coconut (and other plants) in Brazil and elsewhere, regardless of the occurrence of *R. indica*.

**Key Words:** phytoseiid mites; natural enemies; coconut

**Resumo**

*Raoiella indica* tem sido considerada uma das pragas mais importantes de coqueiro, bananeira e plantas de importância florística. Atualmente foi relatado em vários estados brasileiros, mas pouco se sabe sobre sua distribuição atual no sul do Brasil. O objetivo deste estudo foi avaliar a distribuição de *R. indica* e os ácaros predadores associados no centro-sul do Brasil, descartando o possível limite sul de sua distribuição. *Raoiella indica* foi encontrado no Distrito Federal e em 49 municípios de 9 estados, dos quais o mais meridional foi Iporã, estado do Paraná (24.00722°S, 53.69833°W). A maioria dos pontos pesquisados ao sul de Iporã tem altitude maior do que este município e dos pontos pesquisados imediatamente ao norte. Assim, pontos ao sul de Iporã parecem ecologicamente inadequadas para *R. indica*, muito provavelmente por causa da baixa temperatura no inverno. Dezessete espécies de ácaros predadores foram encontradas em associação com *R. indica*, todos dos quais pertencentes à ordem Mesostigmata e 14 pertencem à família Phytoseiidae. No entanto, eles não são inimigos naturais específicos de *R. indica*, pois, a maioria foi relatada em coqueiro (e outras plantas) no Brasil e em outros lugares, independentemente da ocorrência de *R. indica*.

**Palavras-Chave:** Ácaros fitoseídeos; inimigos naturais; coqueiro

The red palm mite, *Raoiella indica* Hirst (Acari: Tenuipalpidae), is considered one of the most threatening pests of coconut, banana, and other monocotyledonous plants on the American continent and in the Caribbean region (Etienne & Flechtmann 2006; Carrillo et al. 2011a; Navia et al. 2015). Infested leaves usually become yellowish, with the attacked area drying as the population grows (Flechtmann & Etienne 2004; Peña et al. 2006). Plants are more seriously affected when infestations are associated with water stress and malnutrition (Navia et al. 2015). *Raoiella indica* was first reported from the Western Hemisphere in the mid 2000s (Flechtmann & Etienne 2004), spreading since then to extensive areas in the tropical and subtropical regions of the American continent and the Caribbean (Welbourn 2006; Rodrigues et al. 2007; Vásquez et al. 2008; Carrillo et al. 2011b; Kane et al. 2012). Since its first report in Brazil in 2009, in the state of Roraima (Navia et al. 2011), new records were published from the states of Amazonas (Rodrigues & Antony 2011), São Paulo (Oliveira et al. 2016), Paraná (Hata et al. 2017), Alagoas, Bahia, Ceará, Distrito Federal, Goiás, Maranhão, Minas...
Gerais, Paraíba, Pernambuco, Piauí, Rio Grande do Norte and Sergipe (Melo et al. 2018). The risk of establishment of this mite in different parts of Brazil has been evaluated by Amaro & Morais (2013), although knowledge about the distribution of this mite in the southern half of the extensive Brazilian territory is still limited (Oliveira et al. 2016; Hata et al. 2017).

Coconut, *Cocos nucifera* L. (Arecaceae), is the principal host of *R. indica* (Carrillo et al. 2011a; Navia et al. 2015; Otero-Colina et al. 2016; Gómez-Moya et al. 2017; Polanco-Arjona et al. 2017). Although mid-southern Brazil is not very important in the production of coconut, this plant is commonly found in southern Brazil and other parts of the country as backyard plantations, or as ornaments in this and other Brazilian regions (IBGE 2017). Conversely, banana (*Musa* spp.; Musaceae), also a host of *R. indica* (Carrillo et al. 2011a), is an important crop in mid-southern Brazil, especially in the states of Espírito Santo, Minas Gerais, Rio de Janeiro, and São Paulo. In fact, severe damage to banana varieties ‘Prata’ (AAB group) and ‘Cavendish’ (AAA group) was observed in 2016 in Missão Velha, Ceará State, northeastern Brazil (Rita de Cassia Rodrigues, personal communication). High levels of *R. indica* also were report-

| Host plant                        | Family     | State          | Municipality                                                                 |
|-----------------------------------|------------|----------------|------------------------------------------------------------------------------|
| *Adonidia merrillii* (Becc.)      | Arecaceae  | Espírito Santo | Colatina and Marilândia                                                      |
| *Archontophoenix* sp.             | Arecaceae  | Paraná         | Umuarama                                                                     |
| *Cocos nucifera* L.               | Arecaceae  | Goiás          | Colatina, Domingos Martins and Venda Nova do Imigrante                       |
|                                   |            | Mato Grosso    | Pirenópolis                                                                 |
|                                   |            | Mato Grosso do Sul | Bataguassu, Brasilândia, Santa Rita do Pardo and Três Lagos                   |
|                                   |            | Paraná         | Cafetal do Sul, Cianorte, Ibirorã, Iguaraçu, Iporã, Jussara, Londrina, Maringá, Tangará and Umuarama |
|                                   |            | Rio de janeiro | Rio de Janeiro                                                               |
|                                   |            | São Paulo      | Avai, Castilho, Dracena, Itapura, Jaboticabal, Jafa, Lençóis Paulistas, Marabá Paulista, Marilia, Monte Aprazível, Nova Independência, Osvaldo Cruz, Pacaembu, Paulicêia, Piracicaba, Piratinha, Santopólis do Aguapei, Vera Cruz and Ubatuba |
| *Euterpe edulis* Martius           | Arecaceae  | Paraná         | Cruzeiro do Oeste                                                            |
| *Musa* sp.                        | Musaceae   | São Paulo      | Jafa and Piracicaba                                                          |
| *Phoenix roebelenii* O’Brien      | Arecaceae  | Distrito Federal | Brasília                                                                      |
|                                   |            | Espírito Santo | Linhares                                                                      |
|                                   |            | Mato Grosso    | Sinop                                                                        |
|                                   |            | Rio de Janeiro | Petrópolis and Volta Redonda                                                 |
|                                   |            | São Paulo      | Jaguariúna                                                                   |
| *Pritchardia hillebrandii* (Kuntze) Becc. | Arecaceae | São Paulo      | Campinas                                                                      |
| *Rhapis excelsa* (Thunb.) A.Henry  | Arecaceae  | Espírito Santo | Colatina                                                                      |
| *Wodyetia bifurcata* AK Irvine     | Arecaceae  | Espírito Santo | Fundão and Nova Venécia                                                      |

1South of the southernmost site in which *R. indica* was found.
ed on banana cultivation in the Caribbean (Cocco & Hoy 2009; Kane et al. 2012; Rodrigues & Irish 2012).

The objective of this study was to evaluate the distribution of *R. indica* and associated predatory mites in mid-southern Brazil on coconut, banana, and a few other plant species on which this mite has been found, discussing the possible southern limit to its distribution in the country.

**Materials and Methods**

The study was conducted between 2015 and 2018, soon after the first detection of the mite in Brazil south of the Amazonas River (Oliveira et al. 2016). Symptomatic coconut plants (especially), as well as ornamental date and banana plants found along highways, urban parks, and nurseries were examined in the Federal District, and in the states of Espírito Santo (ES), Goiás (GO), Mato Grosso (MT), Mato Grosso do Sul (MS), Minas Gerais (MG), Paraná (PR), Rio de Janeiro (RJ), Rio Grande do Sul (RS), Santa Catarina (SC), and São Paulo (SP). When mites resembling *R. indica* were detected with the use of hand lenses, leaflets or leaf pieces were transferred to vials partially filled with 70% ethanol and transported to the laboratory, where the mites were collected and mounted in Hoyer’s medium. They were subsequently identified to species by comparing their morphology with the information provided in the original descriptions and redescriptions in the literature. Representative specimens of the species collected were deposited in the mite reference collection of Departamento de Entomologia e Acarologia, Escola Superior de Agricultura “Luiz de Queiróz,” Universidade de São Paulo (ESALQ/USP), Piracicaba, São Paulo, Brazil.

**Results**

*Raoiella indica* was found in the Federal District and 49 municipalities of the 9 states visited in the study (Table 1), of which the southernmost was Iporã, Paraná State (24.007222°S, 53.698333°W). It was not found in 26 other municipalities south of Iporã (Table 1, Fig. 1), namely: Paraná State: Campo Largo, Candoi, Cascavel, Corbélia, Coronel Vivida, Cruzeiro do Oeste, Curitiba, Guaraniaçu, Guarpava, Imbaú, Irati, Ivaiporã, Laranjeiras do Sul, Mandaguari, Morretes, Palmeira, Palotina, Paranagá, Ponta Grossa, Pontal do Paraná, Terra Roxa, and Toledo; Rio Grande do Sul State: Boa Vista das Missões, Carazinho, and Frederico. Westphalen; Santa Catarina State: Campo Erê.

All 18 species of predatory mites found in association with *R. indica* are found in the order Mesostigmata (Table 2). Fourteen of them were in family Phytoseiidae, 1 in Blattisociidae, and 3 in Melicharidae. By far, the phytoseiid *Euseius citrifolius* Denmark & Muma was the most numerous and widespread (45 specimens found in 5 states), followed by *Iphiseiodes zuluagai* Denmark & Muma, and *Amblyseius largoensis* (Muma), also phytoseiids and both found in similar numbers (17 and 14 specimens in 3 and 1 states, respectively).

**Discussion**

The results of this study expand the known distribution of *R. indica* in Brazil to include areas where its most important host plant, coconut, is not an important crop. Although the absence of *R. indica* in some sampling sites could have been due to the unsuitability of some of the plants examined, this does not seem to have been the case, because in...
most places the plants examined were known hosts of *R. indica*, except for *Syagrus romanzoffiana* (Cham.) Glassman (Arecaceae) (in Coronel Vivida, Curitiba, and Ivaíporã), where coconut was not found.

Although failure to find *R. indica* in some sampling areas could be by chance, its absence in areas of southern Brazil (Rio Grande do Sul, Santa Catarina, and part of Paraná State) could reflect the ecological unsuitability of those places. These results fit well with what was predicted by the model developed by Amaro & Morais (2013), based on 20 environmental variables. The authors concluded that the variables that most influenced their prediction were related to temperature. The altitude of the sites where *R. indica* was not found across the central region of Paraná State is at least about 500 masl, except Morretes, Palotina, Pontal do Paraná, and Terra Roxa (333, 374, 11, and 285 masl, respectively). Conversely, the altitude of the sites where it was found in the northern part of the state is at most 500 masl, except Londrina (543 masl). Hence, being higher and further south make central Paraná State colder than northern Paraná. An examination of the historical records (Continente 2018) showed that average minimum monthly temperatures in places where *R. indica* was found in northern Paraná are at least 9 °C, except Maringá (7.2 °C), whereas in places where it was not found, temperatures are at least 9 °C, except Morretes, Palotina, Pontal do Paraná, and Terra Roxa (12.3, 9.6, 13.7, and 9.8 °C, respectively).

However, according to that the study of Amaro & Morais (2013), it is still possible that the mite could be found further south, along the coast of Rio Grande to Sul and Santa Catarina, areas not surveyed in the present study. According to that study, *R. indica* is expected to be able to extend south of the maximum latitude where it was detected during the current study (Iporã), in neighboring Paraguay and Argentina, along the low lands of the Paraguay River basin.

The highest frequency of *R. indica* on coconut in this study is certainly due to the concentrated effort to search for it on symptomatic coconut, given its known preference for this host plant. The spread of *R. indica* is facilitated by the fact that new coconut plantations are usually established with plantlets acquired commercially, which may harbor the mite at low population levels, allowing its unnoticeable transportation over long distances. Dispersal can be facilitated further by the transportation of other infested plants that are used principally as ornamentals. The permanent availability of the host plant, and the seemingly limited capacity of natural enemies to maintain the pest at low levels, may account also for its ability to disperse (Navia et al. 2013). Hence, occurrence of *R. indica* south of Iporã in Brazil seems possible, in protected or restricted microhabitats, especially on protected ornamentals or in banana-producing areas, usually microhabitats with mild climate.

Although the diversity of predatory mites associated with *R. indica* in this study could not be considered low, not much can be said about the type of relationship they have to that prey, because basically most of those species found in this work have been reported from coconut in Brazil and elsewhere, regardless of the presence of *R. indica* (Lawson-Balagbo et al. 2008; Oliveira et al. 2012). *Amblyseius largoensis*, the third most numerous phytoseiid predator in association with *R. indica* in the present study, often has been reported in association with *R. indica* in the Neotropics, usually in coastal areas (Etienne & Flechtmann 2006; Rodrigues et al. 2007; Roda et al. 2008; Carrillo et al. 2010; Hastie et al. 2010; Carrillo et al. 2011c; Gondim Jr. et al. 2012; Moraes et al. 2012; Flores-Gallano et al. 2017).

Table 2. Mesostigmatid mites associated with *Raoiella indica* on host plants in mid-southern Brazil in surveys conducted between 2015 and 2018.

| Taxa                               | Number of specimens | State           | Host plant                             |
|------------------------------------|---------------------|-----------------|----------------------------------------|
| Phytoseiidae                       |                     |                 |                                        |
| *Amblyseius acalyphus* Denmark & Muma | 5                   | São Paulo       | *Cocos nucifera* L.                    |
| *Amblyseius aeriaulis* (Muma, 1953) | 1                   | Rio de Janeiro  | *C. nucifera*                          |
| *Amblyseius chiensiensis* De Leon   | 6                   | Espírito Santo and Paraná | *Archontophoenix sp.*             |
| *Amblyseius compositus* Denmark & Muma | 2                   | Paraná          | *C. nucifera*                          |
| *Amblyseius herbiculus* (Chant)     | 2                   | Paraná          | *C. nucifera*                          |
| *Amblyseius largoensis* (Muma)      | 14                  | Espírito Santo  | *Adonidia merrillii* (Becc.)           |
| *Amblyseius tomatavensis* Blommers  | 8                   | Espírito Santo and São Paulo | *C. nucifera*                  |
| *Amblyseius sp.*                    | 1                   | Espírito Santo  | *C. nucifera*                          |
| *Euseius alatus* De Leon           | 2                   | Paraná          | *Archontophoenix sp.*                  |
|                                    | 45                  | Goiás, Mato Grosso do Sul, Paraná, Rio de Janeiro and São Paulo | *C. nucifera*                  |
| *Euseius citrifolius* Denmark & Muma |                     |                 |                                        |
| *Euseius concords* (Chant)          | 5                   | Espírito Santo, Paraná and São Paulo | *A. merrillii, C. nucifera and E. edulis* |
| *Iphiseiodes zuluagai* Denmark & Muma | 17                  | Mato Grosso do Sul, Rio de Janeiro and São Paulo | *C. nucifera*                  |
| *Neoseiulus anonymus* (Chant & Baker) | 1                   | São Paulo       | *C. nucifera*                          |
| *Proproprioseis ovatus* (Garman)    | 2                   | São Paulo       | *C. nucifera*                          |
| *Typhlodromus* (Anthoseius) *transvaalensis* (Nesbitt) | 2                   | São Paulo       | *C. nucifera*                          |
| Immatures                          | 23                  |                 |                                        |
| Males                              | 3                   |                 |                                        |
| Blattisociidae                     |                     |                 |                                        |
| *Blattisocius dentriticus* (Berlese, 1918) | 5                   | São Paulo       | *C. nucifera*                          |
| Melicharidae                       |                     |                 |                                        |
| *Proctolaelaps* bickleyi* (Bram)    | 2                   | Mato Grosso do Sul and São Paulo | *C. nucifera*                  |
| *Proctolaelaps pygmaeus* (J. Müller) | 1                   | São Paulo       | *C. nucifera*                          |
| *Proctolaelaps* bulbosus* Moraes, Reis & Gondim Jr | 4                   | São Paulo       | *C. nucifera*                          |
| Immatures                          | 5                   |                 |                                        |
| Males                              | 5                   |                 |                                        |
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predator has received the most attention as a possible candidate for practical use as biological control agent of the pest (Carrillo et al. 2010; Carrillo et al. 2011c; Carrillo et al. 2012; Domingos et al. 2012; Carrillo et al. 2014; Morais et al. 2016; Mendes et al. 2018).

In conclusion, since its first report in Brazil, *R. indica* now has been found in 18 states in the country, in sites ranging from 2°N to 23°S latitude. Complementary studies, especially in western Brazil, might demonstrate that it is also present there.

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