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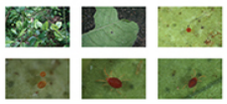

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SHORT COMMUNICATION

The invasive red palm mite, *Raoiella indica* Hirst (Acari: Tenuipalpidae), in Brazil: range extension and arrival into the most threatened area, the Northeast Region

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ABSTRACT

Raoiella indica Hirst (Acari: tenuipalpidae), commonly known as the red palm mite (RPM), is an invasive polyphagous pest, which has emerged as a threat to agriculture in the Americas. In the Americas, the mite has not only spread quickly, but also greatly extended its host range in the new areas where it has been observed. We present here new records of the RPM in Brazilian states, with focus on its arrival into the most threatened area, the Northeast Region. Coconut and banana are important crops in this region of Brazil and represent the main threatened crops by this pest. These new records of RPM reinforce the idea that this species is already widely distributed throughout Brazil eight years after its introduction into the extreme North state of Roraima. Comments on the possible economic, social and environmental impacts are presented.

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Invasive mite pest; Neotropics; South America; coconut; palm trees; banana

Introduction

Invasive species represent one of the most serious threats to biodiversity worldwide (Pimentel 2011; Funk 2015), with impacts on non-native habitats potentially having negative ecosystem effects (Gurevitch and Padilla 2004) and strong economic burden (Pimentel et al. 2005). Phytophagous mites are prone to becoming invasive as they are difficult to detect, have a capacity to survive adverse conditions, some have parthenogenic reproduction and may adapt to new host plants. Some may become pests due to their harm to host plants, vectoring of disease and fast development of pesticide resistance (Navia et al. 2007).

A notable and recent example of a phytophagous mite species that has become an invasive pest is the red palm mite (RPM), *Raoiella indica* Hirst (Acari: Tenuipalpidae). RPM was described from specimens collected from coconut (*Cocos nucifera* L.) in Southern India (Hirst 1924) and found later on other palms (Arecaceae) in several African, Asian and Middle Eastern countries (Mesa et al. 2009). Since its description, the distribution of the RPM remained restricted to the Old World, until it was found damaging coconut palms on the Caribbean island of Martinique in 2004 (Flechtmann and Etienne 2004). Afterwards, RPM was found in other Caribbean Islands (Etienne and Fletchmann 2006; Rodrigues et al. 2007), North America (USA and Mexico; Welbourn 2006; Estrada-Venegas et al. 2010; Kane et al. 2012) and South America (Venezuela, Colombia and Brazil; Vasquez et al. 2008; Carrillo et al. 2011; Navia et al. 2011). In the New World, RPM has not only reached large populations and spread quickly, but it also greatly extended its host range, attacking several palm species (Arecaceae) and a number of Cannaceae, Cycadaceae, Heliconiaceae, Musaceae, Strelitziaceae and Zingiberaceae species, including exotic and native plants, in cultivated or natural areas (Cocco and Hoy 2009; Lima et al. 2011; Gondim et al. 2012; Carrillo et al. 2012a; Navia et al. 2015).

In contrast to other *Raoiella* species, RPM is highly invasive, show rapid dispersal capabilities and feed on monocot hosts (mainly palms), whereas other species are known only from a very restricted host range (feed on dicots; in particular, species in the family Myrtaceae) within a single country (Ochoa et al. 2011; Dowling et al. 2012). Invasion of new areas by RPM is favoured by its high population growth within a broad range of temperatures (Moutia 1958). Owing to an arrhenotokous mode of parthenogenesis (males developing from unfertilized eggs), a small number of individuals or even a single female may initiate a new colony that can build up rapidly as a result of several typical "r-selected" traits including short generation time (Sabelis 1985) and high dispersal ability (Hoy et al. 2006; Welbourn 2006). In addition, because of its small size (eggs are 100 microns long and 80 microns wide while adults are about 245 microns long and 182 microns wide (Hirst 1924; Moutia 1958), RPM can be difficult to detect on plants and may remain undetected in new localities until its presence is revealed by outbreaks and plant symptoms.

Among the host plants infested by the RPM, coconut and bananas seem to be the most threatened (Peña et al. 2010; Navia et al. 2013). In Trinidad and Tobago, some growers have reported 70% losses to coconut production (unpublished information of Philippe Agostine, President of Trinidad and Tobago Growers Association, reported by Roda et al. 2012). There are no data on banana production loss due to RPM attacks; however, in some localities, e.g. Dominican Republic, Trinidad and Tobago and Colombia, this crop has been seriously affected as several basal leaves have died completely and mature leaves have become completely chlorotic (Navia et al. 2013).

In Brazil, RPM was first reported in samples from coconut and banana leaves from the urban area of Boa Vista, the capital of the

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northern state of Roraima in 2009 (Navia et al. 2011). Authorities from the Brazilian Ministry of Agriculture, Livestock and Food Supply (MAPA) established quarantine measures restricting the movement of plant material and products (banana and coconut fruits) from infested areas to other states. However, these measures failed to prevent the spread of RPM to the urban area of Manaus, the capital of neighbouring Amazonas state, two years later (Rodrigues and Antony 2011). Because of its occurrence in Roraima and Amazonas states, the status of RPM was changed in 2013 from a quarantine pest not present to a quarantine pest present with restricted distribution in Brazil, allowing other states to adopt measures to prevent its arrival. For about five years, the distribution of RPM remained restricted to Northern Brazil. Nevertheless, recent reports on RPM in São Paulo (Southeastern) (Oliveira et al. 2016) and Paraná (Southern) (Hata et al. 2017) showed that it has spread to other regions of Brazil.

Here, we present: (i) eleven new records of the RPM in Brazilian states; and (ii) discussion on the dispersal pathways of RPM in Brazil.

Despite governmental efforts and warnings made by researchers, the RPM has reached Northeast Brazil. In 2016, examination of coconut leaflets and banana leaves confirmed for the first time the presence of RPM in the Northeast region (Ceará state). After a few months, this invasive mite pest was also detected in 10 other states [7 in Northeastern Brazil (Alagoas, Bahia, Paraíba, Pernambuco, Piauí, Rio Grande do Norte and Sergipe), 2 in Midwestern Brazil (Distrito Federal and Goiás) and 1 in South-Eastern Brazil (Minas Gerais) (Figure 1 and Table 1)]. All RPM developmental stages and numerous exuviae were observed in the new records for all host plants, except for oil palm plants (*Elaeis guineensis*). For this host, small adult colonies were observed. According to Gómez-Moya et al. (2017), *E. guineensis* in not considered a typical host for the RPM. Hence, it is probable that its occurrence in this plant species is casual. We found typical host plants (Heliconia sp., Phoenix sp., Roystonea sp.) growing near the *E. guineensis* plants. After each detection, a memorandum documenting presence of the RPM was sent to the Plant Health Service of MAPA, at each state, to prompt the adoption of appropriate measures.

Under natural conditions, RPM long-distance dispersal is probably by wind as for other plant-feeding mites (Welbourn 2006). However, the great distance between previously infested areas in Brazil – North and Southeast regions – and from these regions to the Northeast suggests that spread of RPM via natural dispersion alone is unlikely and that the pest reached new regions by transportation of host plants or infected plant material.

Brazil is the third and fourth largest producer of coconut and banana, respectively (FAO 2017). The major coconut-producing area lies in the Northeast region while the banana production areas are scattered across the country (IBGE 2016). The Northeast region comprises about 81% (219,472 ha) of the coconut area in Brazil: the state of Bahia is the main producer, with 28% of the coconut production area; followed by Ceará, with 16.5%; Sergipe, with 14.4%; Rio Grande do Norte, with 8%; Alagoas, with 4.7%; Pernambuco, with 4% and Paraíba, with 3.5% (IBGE 2016). Banana production in Brazil accounts for approximately 10% of the entire world and the main producer in Brazil is in the southeastern state of São Paulo. Other notable areas where bananas are cultivated include Bahia, Ceará and Pernambuco in North-East Brazil; Para in North Brazil; Minas

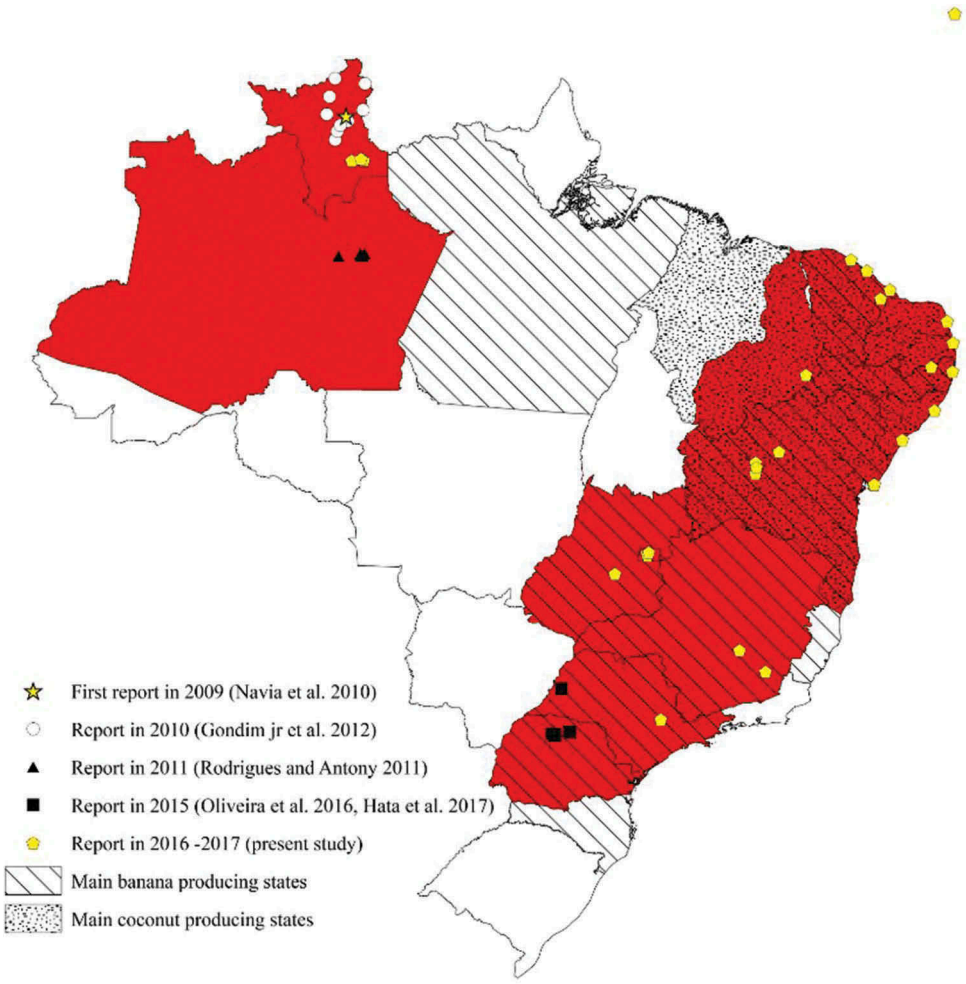

Figure 1. Current red palm mite distribution in Brazil.

Table 1. Locality records for *Raoiella indica* in Brazil.

State/City	Coordinates		Host plant	Collected by	Identified by	Date
	Lat y	Long x				
Roraima/Rorainópolis	0.94	−60.43	Christmas Palm (*Adonidia merrillii*)	Morais EGF	Morais EGF	10 June 2015
Ceará/Fortaleza	−3.74	−38.57	Coconut (*Cocos nucifera*) and bananas (*Musa* sp.)	Melo JWS and Mendes JA	MGC Gondim Jr	11 September 2015
Sergipe/Aracaju	−10.91	−37.07	Coconut (*Cocos nucifera*)	Ferreira JMS and Teodoro AV	Biological Institute	15 December 2016
Alagoas/Maceió	−9.66	−35.70	Coconut (*Cocos nucifera*)	Guzzo EC and Souza IV	MGC Gondim Jr	22 December 2015
Rio Grande do Norte/Natal	−5.88	−35.17	Coconut (*Cocos nucifera*)			
Distrito Federal/Brasília	−15.73	−47.90	*Roystonea* sp. (Arecaceae), Oil palm (*Elaeis guineensis*), Areca palm (*Areca* sp.), Date palm (*Phoenix dactilifera*), Pygmy date palm (*Phoenix roebelenii*), Fishtail palm (*Caryota urens*), *Heliconia* sp.	Mendonça RS and Rocha HMC	Mendonça RS	25 May 2016
Roraima/São João da Baliza	0.95	−59.91	Coconut (*Cocos nucifera*)	Morais EGF	Morais EGF	1 August 2016
Roraima/São Luiz	1.01	−60.03	Christmas Palm (*Adonidia merrillii*)	Morais EGF	Morais EGF	1 August 2016
Pernambuco/Recife	8.01	−34.94	Coconut (*Cocos nucifera*) and bananas (*Musa* sp.)	Calvet EC and Paz Neto AA	MGC Gondim Jr.	26 September 2016
São Paulo/Nova Odessa	−22.78	−47.31	Coconut (*Cocos nucifera*)	Morais EGF	Morais EGF	11 December 2016
Minas Gerais/Belo Horizonte/	−19.85	−43.97	Coconut (*Cocos nucifera*)	Morais EGF	Morais EGF	26 December 2016
Ceará/Tabuleiro de Russas	4.55	−37.59	Bananas (*Musa* sp.)	Godoy MS	Melo JWS	11 February 2017
Distrito Federal/Brasília	−15.83	−47.87	Coconut (*Cocos nucifera*)	Navia D	Navia D	10 March 2017
Distrito Federal/Brasília	−15.69	−47.82	Pygmy date palm (*Phoenix roebelenii*)	Navia D	Navia D	10 March 2017
Goias/Goiânia	−16.61	−49.26	Coconut (*Cocos nucifera*)	Navia D and Daud RD	Navia D	12 March 2017
Minas Gerais/Viçosa	−20.76	−42.87	Pygmy date palm (*Phoenix roebelenii*)	Morais EGF	Morais EGF	15 March 2017
Bahia/Ibipeba	−11.42	−42.30	Bananas (*Musa* sp.)	Torres ANL	Navia D	17 May 2017
Pernambuco/Igarassu	7.82	−34.84	Coconut (*Cocos nucifera*)	Calvet EC and Paz Neto AA	MGC Gondim Jr.	27 June 2017
Piauí, Paulistana	−8.16	−41.16	Coconut (*Cocos nucifera*)	Domingos CA	Melo JWS	11 September 2017
Paraíba, Mamanguape	−6.80	−34.92	Coconut (*Cocos nucifera*)	Filgueiras RMC	Melo JWS	29 December 2017

Gerais and Espirito Santo in South-Eastern Brazil; Santa Catarina and Paraná in the southern Brazil and Goias in Midwestern Brazil (IBGE 2016).

Since Northeast of Brazil is characterized by low rainfall and high temperatures, which are favourable conditions for the development of RPM (Nagesha-Chandra and Channabasavanna 1983; Taylor et al. 2012), the arrival of this pest in this region has the potential to cause heavy economic losses as well as social and cultural disturbance. Navia et al. (2016) conducted a study to predict the spatial distribution of RPM in Brazil under current and future climate change scenarios. The prediction maps showed that Brazil presents extensive areas with favourable conditions for the establishment of RPM, especially in northeastern Brazil. An increasing favourability is predicted for future scenarios indicating that the pest impact will worsen with higher RPM populations and a wider distribution within the country.

Economic, social and environmental impacts are expected following a wider distribution of RPM in Brazil. Significant losses to agriculture may occur due to the potential damage of RPM to plants of economic importance, such as coconut, banana, several species of palm-producing oil or wax, and ornamental plants. Quarantine measures may also lead to economic losses, prohibiting the transportation of propagation material or fresh products of RPM host plants from infested to uninfested areas/countries. Social impacts are expected since many smallholders are engaged in the production or extraction of palm products. Environmental impacts are also possible due to RPM colonization of native plants that have an important role in natural ecosystems.

Biological control has been considered the most promising strategy to minimizing impact of this invasive mite pest in Brazil. Although some natural enemies have been introduced for RPM control in Brazil (Moraes et al. 2012; Oliveira 2015), and others have been observed associated with the pest (Carrillo et al. 2012b), an efficient biological control strategy still needs to be defined and research should be intensified for this purpose.

Disclosure statement

No potential conflict of interest was reported by the authors.

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