Raoiella indica

Scientific Name
Raoiella indica Hirst, 1924

Synonyms:
Rarosiella cocosae Rimando

Suspected Synonyms:
Raoiella camus Chaudhri & Akbar
Raoiella empedos Chaudhri & Akbar
Raoiella neotericus Chaudhri & Akbar
Raoiella obelias Hasan & Akbar
Raoiella pandanae Mohanasundaram
Raoiella phoenica Meyer
Raoiella rahii Akbar & Chaudhri

Common Name
Red palm mite, coconut red mite, scarlet mite

Type of Pest
Mite

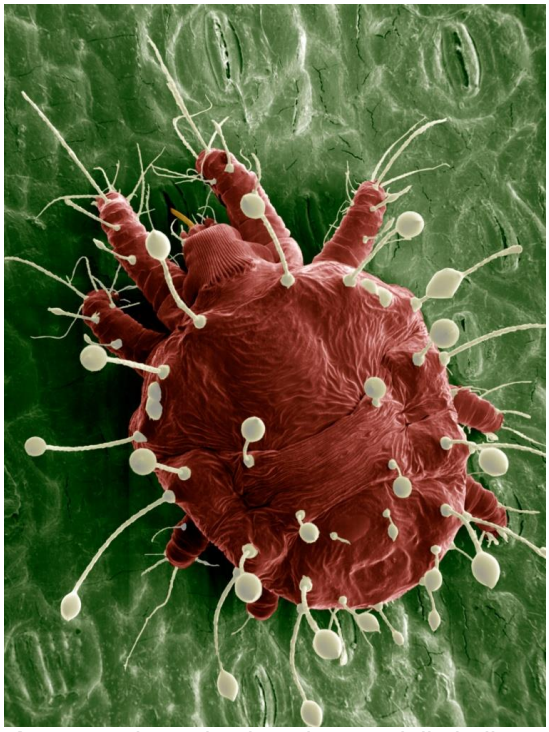

Figure 1. The red palm mite, *Raoiella indica*. (Magnified about 300x) (Image courtesy of Eric Erbe with digital colorization by Chris Pooley).

Taxonomic Position
Class: Arachnida, **Order:** Acari, **Family:** Tenuipalpidae

Reason for Inclusion
Suggestion from CAPS community

Pest Description
Both the immature and adult stages are red in color. All life stages (including non-active stages) have large droplets of clear fluid at the tip of most or all dorsal setae. The role of the fluid is unknown but it is thought to be for defensive purposes (Kane et al., 2012). This species has five life stages: the egg, larva, protonymph, deutonymph, and adult. The immature stage is made up of three parts: the larva, protonymph, and deutonymph. The larvae are smaller than the nymphs, while the nymphs are slightly smaller than the adults.

Eggs:
"Eggs are smooth and 0.12 mm long by 0.09 mm wide [$<^{1}/_{16}$ in]. Each egg is attached to the lower leaf surface by a long slender stipe, that is about twice as long as the egg" (Welbourn, 2009). Eggs are initially reddish pink, soft, smooth, and sticky when laid; a day before hatching, the egg turns opaque white (Nagesha Chandra and ChannaBasavanna, 1984).

Immatures:
"Larvae are smaller (0.18-0.20 mm long [<$^1/_{16}$ in]) than nymphs (0.18-0.25 mm long [<$^1/_{16}$ in]) and have only three pairs of legs. Nymphal stages are slightly smaller than adults, have a smooth integument and dorsal setae are not set on tubercles. The dorsal and lateral setae of the nymphs are distinctly shorter than the adults" (Welbourn, 2009).

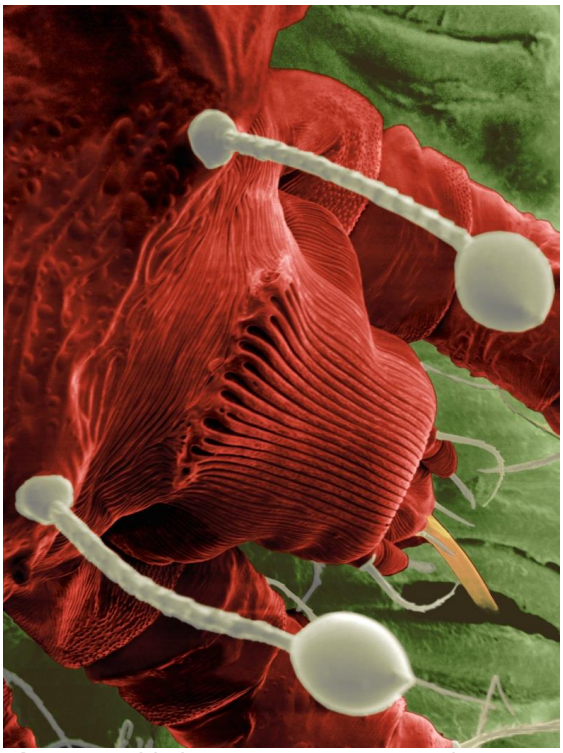

Figure 2. This low-temperature scanning electron micrograph shows that the red palm mite uses its stylet to feed deeper into leaf tissue than most plant-feeding mites do (Magnified about 3,000x.) (Image courtesy of Eric Erbe with digital colorization by Chris Pooley).

Larvae:
"Body dark red; broadly ovate; 125.0 *μ* long and 93.0 *μ* wide. Dorsuin smooth with incomplete suture between propodosoma and hysterosoma; all dorsal setae clavate and plumose. Propodosoma with 3 pairs of setae, the second longer than any dorsal ones. Hysterosoma with 3 pairs of centrals, 4 sublaterals, 1 humeral and 5 laterals; centrals longer than the laterals and both decrease in length posteriorly; first and second sublaterals longer than the third and the fourth and any of the laterals but similar to the first and second centrals" (Zaher et al., 1969).

Nymphs:
Protonymphs: "Body dark red; nearly rounded; 210.0 *μ* long and 159.0 *μ* wide. Dorsal chaetotaxal pattern differs from that of the larva in having the humeral, first arid second laterals longer than the sublaterals and any other hysterosomals" (Zaher et al., 1969).

Deutonymphs: "Body dark red; broadly ovate; 272.0 *μ* long and 179.0 *μ* wide. Dorsal chaetotaxal pattern similar to that of protonymph and adult (Zaher et al., 1969).

Adults:
The adults are bright red with long spatulate setae with a droplet of liquid at the end of most setae in living specimens (Welbourn, 2009). Adult females may sometimes have black patches across their backs (Welbourn, n.d.). "Adult females are about 0.32 mm long and often exhibit dark patches on their body. Males are smaller than females with a distinctly triangular body. Dorsal setae in both sexes arise from tubercles of the dorsal integument" (Welbourn, 2009).

Biology and Ecology
On coconut in Mauritius, *R. indica* has a development period (from egg to adult) of 18 to 26 days during the summer and 30 to 36 days in the winter (André Moutia, 1958).

Raoiella indica populations generally increase during non-monsoon seasons; densities increase when conditions are warmer and drier (Taylor et al., 2011).

This species can reproduce sexually (producing only females) or through arrhenotokous parthenogenesis (where unfertilized eggs develop into haploid males) (Nagesha Chandra and ChannaBasavanna, 1984; Rodrigues and Irish, 2011). Eggs can be found in groups on the underside of leaves (Welbourn, 2009). Females usually lay eggs in depressions or near leaflet veins of host plants (Zaher et al., 1969); they may also be found around the edges if a colony is established. Colonies are generally found along the midrib of host plants (Welbourn, 2009) on the undersides of leaves (EPPO, 2006).

Females lay 28 to 50 eggs each, and eggs hatch within six to nine days (Peña et al., 2006; Welbourn, 2009). Peña et al. (2006) state that females usually lay two eggs per day for an average of 27 days. Males usually emerge from eggs before females (Zaher et al., 1969). Once hatched, males begin looking for mates. If a male finds a female deutonymph (last immature stage), he will wait up to two days for her to molt in order to mate (Hoy et al., 2010). Females must feed before they begin laying eggs (Nagesha Chandra and ChannaBasavanna, 1984).

Immature *R. indica* go through both active and quiescent larval, protonymphal, and deutonymphal stages. The quiescent stage occurs before molting in which the mite stops feeding and stretches its legs out. The exoskeleton is then shed (Zaher et al., 1969). The larval stage lasts about five to six days, while the protonymph and deutonymph stages last about four to six days each (Zaher et al., 1969). Developmental ranges are influenced by temperature, relative humidity, and the host plant (reviewed in Peña et al., 2006).

Adults live for approximately one month (Welbourn, 2009) and do not produce webbing like many other spider mite species. Females are less active than males (Hoy et al., 2010).

There can be millions of mites per tree (Pons and Bliss, 2007). Rodrigues and Irish (2011) found that infestations were higher in *Musa* spp. when more *Cocos nucifera* (coconut, the main host) were present. This is consistent with preliminary field observations in Puerto Rico and Dominica. In India, population buildup on arecanut (*Areca catechu*) was associated with an increase in temperature (Yadav Babu and Manjunatha, 2007). Rainfall and high humidity can have a negative effect on mite populations (Nagesha Chandra and ChannaBasavanna, 1984). This is the only species in the genus *Raoiella* which has become highly invasive and dispersed rapidly (Dowling et al., 2011).

Damage

Raoiella indica does not feed on the epidermal cells like some mite species. This species feeds through the stomata of the host plant (Ochoa et al., 2011). It is believed this feeding habit may interfere with photosynthesis and respiration in host plants (Carrillo et al., 2011a). Characteristic damage caused by *R. indica* includes yellow

spots or completely discolored palm leaves (Pons and Bliss, 2007). The localized leaf yellowing is followed by necrosis (Welbourn, 2009). Heavy infestations typically occur on the lower surface of the leaf, while yellowing occurs on both sides of the leaf. This species can severely affect very young coconuts to very old palms (>50 ft tall) (Hoy et al., 2010).

Figure 3. Chlorosis and necrosis of pinnae (leaflets) appears to be more pronounced on basal fronds of coconut palms on the island of Dominica (J.E. Peña, University of Florida).

In coconut, feeding causes an initial bronzing of the leaves which will eventually turn into necrotic tissue (Carrillo et al., 2011a). Leaf yellowing is then followed by the abortion of flowers or small nuts (Hoy et al., 2010). Damage can be more noticeable on the lower third part of the plant. On banana and plantain, lower leaves turn yellow with small patches of greenish-yellow areas (EPPO, 2006).

Figure 4. Detail of chlorosis and necrosis on coconut fronds, Dominica, 2005 (J.E. Peña, University of Florida).

Mite clusters can be observed as reddish-brown areas on host material (Pons and Bliss, 2007) with the naked eye, usually on the undersides of the leaves. Colonies can range from a few to hundreds (Welbourn, 2009). Mites are often found in huge numbers (100 to 300 individuals). All life stages are predominantly red; adult females often have dark spots on their body (Kane and Ochoa, 2006). The white cast skins can be found alongside the mites and can be more numerous than living mites if populations are very productive (Welbourn, n.d.).

Pest Importance

Raoiella indica causes serious leaf damage which ruins the ornamental value of host material (Pons and Bliss, 2007). This species is considered a significant pest in Egypt, Mauritius, and the Philippines (Pons and Bliss, 2007) specifically on coconut (André Moutia, 1958). Since its discovery in the New World, this species has become a major concern to both the coconut and banana industries (Taylor et al., 2011).

In the Caribbean, yield reduction on coconut has been estimated at over 50% in some locations (Carrillo et al., 2011b). Some coconut farms have seen crop losses of 70 to 90% (Roda et al., 2008; Dowling et al., 2011). In India, this species is considered a pest of arecanut, (*Areca catechu*) an important cash crop to the country (Yadav Babu and Manjunatha, 2007), as well as coconut (Sarkar and Somchoudhury, 1989). In Trinidad, coconut production decreased by 70% one year after the introduction of *R. indica* (Roda et al., 2012).

Figure 5. Banana leaf showing signs of infestation by the red palm mite, Trinidad, 2006 (J.E. Peña, University of Florida).

In order to prevent the spread of this pest in Brazil, quarantine measures were put into place to prevent host plant movement from infected states. This led to both social and economic impacts on growers that could not ship their products and states that had to deal with increased shipping prices to receive host material from uninfected distant regions (reviewed in Rodrigues and Antony, 2011).

Figure 6. The discolored areas on the underside of this banana leaf are where red palm mites have caused damage to the plant (Image courtesy of Amy Roda, USDA-CPHST).

Raoiella indica poses a significant threat to the United States' banana, coconut, and palm industries (USDA, 2007). NAPPO (2007) states that this mite is considered a direct threat to both the ornamental palm and coconut industries found in Alabama, Arizona, California, Florida, Hawaii, Puerto Rico, and Texas. Although most information available on *R. indica* deals with its relationship with *Cocos nucifera* (coconut), it could also have potentially negative effects on other hosts present in the New World. Its recent find in Florida could affect the Florida palm industry which has $200 million in annual sales and represents 7% of total Florida nursery sales (FDACS, 2009).

Due to its importance as a pest of different palm and banana species, recent research into controls (biological and chemical) and potentially resistant plant varieties has begun (Jalaluddin and Mohanasundaram, 1990; Jayaraj et al., 1991; Peña et al., 2008; Mathurin et al., 2010; Rodrigues and Irish, 2011; Shivanna et al., 2012).

Known Hosts

Since its introduction into the Caribbean and Florida, *R. indica* has increased its already broad host range (Taylor et al., 2011; Beard et al., 2012a) to include more than 25 new reproductive hosts (Carrillo et al., 2011a). However, Cocco and Hoy (2009) state that information from quarantine tests and field observations suggest that the host range may not be as broad as some reports state. Some plants where *R. indica* adults or eggs have been collected may not be true hosts and thus are not suitable for establishment.

Major/Preferred hosts

Cocos nucifera (coconut), *Musa* spp., *Phoenix canariensis*, and *Phoenix dactylifera* (date palm) (banana and plantain) (EPPO, 2012; Faleiro, n.d.).

Relatively high populations have been recorded in field studies. In Florida these include: *Arenga australasica*, *A. engleri*, *A. tremula*, *Caryota urens*, *Gaussia princeps*, *Guihaia grossefibrosa*, *Heterospathe elata*, *H. intermedia*, *Livistona mariae*, *L. muelleri*, *L. rigida*, *Neoveitchia storckii*, and *Phoenix canariensis*; in Trinidad: *Adonidia merrillii*, *Phoenix aucalis*, *Pritchardia pacifica*, *Ptychosperma macarthurii*, *Washingtonia robusta*; in both: *Phoenix roebelenii* and *Rhapis excelsa*. "These species are capable of sustaining large *R. indica* populations and could serve as a source for infestations at other locations" (Carrillo et al., 2011a).

Minor hosts

Adonidia merrillii (Christmas palm), *Areca catechu* (arecanut), *Cassine transvaalensis*, *Dictyosperma album* (hurricane palm), *Eugenia* spp., *Heliconia* spp. (heliconia), and *Musa* x *paradisiaca* (banana) (Kane and Ochoa, 2006; Carrillo et al., 2011b; EPPO, 2012).

Ocimum basilicum (basil) and *Phaseolus* sp. have previously been referred to as hosts. However, Carrillo et al. (2011a) found these to be unsuitable hosts.

Caribbean host list by family (reviewed in Welbourn, n.d.; Kane et al., 2005b; reviewed in Welbourn, 2009, de la Torre Santana et al., 2010; reviewed in Carillo et al., 2011a):

Arecaceae

Acanthophoenix rubra,[1, 2] *Acoelorrhaphe wrightii* (Everglades palm), *Adonidia merrillii* (=*Veitchia merrillii*) (Manila palm),[1, 2] *Aiphanes* spp. (multiple crown palm), *Aiphanes horrida* (=*A. caryotifolia*) (Coyure palm), [1] *Allagoptera arenaria*,[1, 2] *Archontophoenix alexandrae* (Alexander palm),[1] *Areca* spp., *Areca catechu* (betel nut palm), *Arenga australasica*,[1, 2] *Arenga engleri*,[1, 2] *Arenga microcarpa*,[1, 2] *Arenga pinnata*,[2] *Arenga*

tremula,[1, 2] *Arenga undulatifolia*,[1, 2] *Bactris plumeriana* (coco macaco), *Beccariophoenix madagascariensis* (giant windowpane palm),[1] *Bismarckia nobilis* (Bismarck palm), Brahea armata,[1, 2] *Butia capitata* (pindo palm),[1] *Caryota mitis* (fishtail palm), *Caryota urens*,[1, 2] *Chamaedorea* spp. (chamaedorea palm), *Coccothrinax miraguama* (Miraguama palm),[1] *Cocos nucifera* (coconut palm),[1,2] *Corypha umbraculifera*, *Dictyosperma album* (princess palm), *Dypsis decaryi* (triangle palm), *Dypsis lutescens* (=*Chrysalidocarpus lutescens*) (areca palm), *Elaeis guineensis* (African oil palm), *Gaussia princeps*,[1, 2] *Guihaia grossefibrosa*,[1, 2] *Heterospathe elata* var. *palauensis*,[1, 2] *Heterospathe elmeri*,[1, 2] *Heterospathe intermedia*,[1, 2] *Heterospathe negrosensis*,[1, 2] *Latania* sp.,[2] *Licuala grandis* (Licuala palm), *Licuala spinosa*,[2] *Livistona australis*,[1, 2] *Livistona carinensis*,[1, 2] *Livistona fulva*,[1, 2] *Livistona mariae*,[1, 2] *Livistona muelleri*,[1, 2] *Livistona rigida*,[1, 2] *Livistona chinensis* (Chinese fan palm),[1] *Livistona rotundifolia*,[2] *Phoenix canariensis* (Canary Island date palm),[1, 2] *Neoveitchia storckii*,[1, 2] *Phoenix* spp.,[1, 2] *Phoenix acaulis*,[2] *Phoenix canariensis*, *Phoenix dactylifera* (date palm),[1] *Phoenix reclinata* (Senegal date palm),[1, 2] *Phoenix roebelenii* (pygmy date palm),[1, 2] *Pritchardia pacifica* (Fiji fan palm),[1, 2] *Pritchardia vuylstekeana*, *Pseudophoenix sargentii* (buccaneer palm),[1] *Pseudophoenix vinifera* (cacheo), *Ptychosperma* sp., *Ptychosperma elegans* (solitaire palm),[1] *Ptychosperma macarthurii* (Macarthur palm),[1, 2] *Rhapis excelsa* (lady palm),[1, 2] *Roystonea borinquena* (royal palm), *Roystonea regia* (Florida royal palm), *Schippia concolor* (silver pimento palm),[1] *Syagrus romanzoffiana* (queen palm),[1, 2] *Syagrus schizophylla* (arikury palm), *Thrinax radiata* (Florida thatch palm),[1] *Veitchia* spp. (Manila palm),[1] *Veitchia arecina*, *Washingtonia filifera*, *Washingtonia robusta* (Mexican fan palm),[1] *Wodyetia bifurcata*.

Heliconiaceae
Heliconia spp.,[1, 2] *Heliconia bihai* (Macaw flower), *Heliconia caribaea* (wild plantain), *Heliconia psittacorum* (parrot flower), and *Heliconia rostrata* (lobster claw heliconia).

Musaceae
Musa spp. (banana, plantain),[1] *Musa acuminata* (=*M. corniculata*) (edible banana),[1, 2] *Musa balbisiana* (wild banana), *Musa corniculata*, *Musa* x *paradisiaca* (edible banana), *Musa uranoscopus* (ornamental banana).

Pandanaceae
Pandanus spp., *Pandanus utilis* (screw pine).

Strelitziaceae
Ravenala madagascariensis (traveler's tree) and *Strelitzia reginae* (bird of paradise).

Zingiberaceae
Alpinia purpurata (red ginger), *Alpinia zerumbet* (shell ginger),[1] and *Etlingera elatior* (red torch ginger).

[1]These are confirmed hosts in Florida (Welbourn, 2009; Carrillo et al., 2011a).

[2]Identified as reproductive hosts in Carrillo et al. (2011a).

Although *R. indica* has a broad host range on a variety of palms, it is not known to feed on *Sabal* spp. (cabbage palms) (Beard et al., 2012a). Carrillo et al. (2011a) looked at three native palm species in nursery and field studies. Their data suggest that cabbage palms (*Sabal palmetto*) and saw palmetto (*Serenoa repens*) are not reproductive hosts of *R. indica*. However, Florida thatch (*Thrinax radiata*) was found to be a reproductive host from the field study (Carrillo et al., 2011a).

Pathogen or Associated Organisms Vectored

This species is not known to vector any pathogens or other associated organisms.

Known Distribution

This species was found in the Caribbean in 2004 and has since spread throughout the region (USDA, 2007).

Asia: Cambodia,[1] India, Philippines, Sri Lanka, and Thailand; **Africa:** Benin, Egypt, Kenya, Mauritius, Reunion, Tunisia, and Sudan; **Caribbean:** Antigua, Aruba, Barbados, Cayman Islands, Cuba, Dominica, Dominican Republic, Granada, Guadeloupe, Haiti, Jamaica, Martinique, Puerto Rico, Saint Lucia, Saint Martin, Saint Thomas, Saint Vincent, Trinidad and Tobago, Turks and Caicos Islands, and the U.S. Virgin Islands; **Central America:** Panama; **Middle East:** Iran, Iraq, Israel,[2] Oman, Pakistan, Saudi Arabia, and United Arab Emirates; **North America:** Mexico, United States (Florida); **South America:** Brazil, Columbia, Venezuela (Welbourn, n.d.; reviewed in CABI, 2007; Pons and Bliss, 2007; Vásquez et al., 2008; reviewed in Welbourn, 2009; reviewed in Carrillo et al., 2011b; Rodrigues and Antony, 2011; Beard et al., 2012b).

Beard et al. (2012b) states that records of *R. indica* being present in Russia are erroneous.

[1]EPPO (2012) states that *R. indica* is absent from Cambodia and records of this distribution are unreliable.

[2]EPPO (2012) states that *R. indica* is no longer present in Israel.

Raoiella indica was reported from Puerto Rico in 2006. This species was found in Florida and the U.S. Virgin Islands in 2007 (Welbourn, 2009). As of April 2009, it has been found in five counties in Florida: Broward, Miami-Dade, Martin, Monroe, and Palm Beach (FDACS, 2009).

Pathway

The main dispersal method of this pest throughout the Caribbean region is most likely through movement of infested plants and plant material. This species has been intercepted over 470 times at U.S. ports of entry. All except for two of the interceptions originated from Central America and the Caribbean. The top four places of material origin are the U.S. Virgin Islands (262 interceptions), Puerto Rico (94), Dominican Republic (37), and Jamaica (33). All interceptions were on host material, most notably *Cocos nucifera* (310), handicrafts material (57), Arecaceae (53), and *Musa* sp. (20).

Almost all interceptions occurred in baggage (465) (AQAS, 2012; queried March 27, 2012). Individuals returning from the Caribbean to the continental United States are at risk of moving this pest if they bring back souvenirs containing host material, like palm-leaf handicrafts that have not been bleached, dyed, painted, or shellacked (USDA, 2007).

This species can disperse naturally through wind (EPPO, 2007) meaning it has the potential to spread throughout the tropical and subtropical regions of the Americas through hurricanes and other storm systems (Pons and Bliss, 2007). This species can also spread naturally over short distances by walking.

Potential Distribution within the United States

This species has a wide host range. The host range has increased as it has expanded in the Caribbean. This species is likely to establish in areas with sufficient host material and prefers coconuts and banana/plantains (see Known Hosts section). This species also needs a suitable climate. It is considered a tropical pest and is likely to establish in southern areas of the United States where hosts are present. This species was found in Florida in 2007 and can potentially spread to new suitable areas in the United States through natural spread (wind) or through human-mediated movement of infested host material.

Survey

CAPS-Approved Method*:

Visual inspection. There is no known pheromone or effective trap for this species. Visual survey is the only effective survey method at this time. Recent data has shown that fronds from the middle stratum of coconuts had significantly more mites than fronds from the upper and lower stratum (Roda et al., 2012).

To estimate density at the plantation level, one pinna section per tree should be sampled from as many trees as possible (Roda et al., 2012).

*For the most up-to-date methods for survey and identification, see Approved Methods on the CAPS Resource and Collaboration Site, at http://caps.ceris.purdue.edu/.

Literature-Based Methods:

Trapping: Once males emerge, they actively begin searching for females, suggesting that a sex pheromone may be involved (Hoy et al., 2010). However, no pheromone has been found and there is currently no effective trap for this species.

Visual survey: Mites can be collected by examining plant parts under a dissecting microscope or by beating the plants over a sieve screen fitted to a plastic funnel with a vial attached (Hoy et al., 2010).

Survey Site Selection: The main hosts of *R. indica* are coconut and palms. This species is most likely to be found in nurseries with host material, or areas where host material is abundant (both natural and urban landscapes).

Time of year to survey: In India, populations of *R. indica* are negatively affected by rainfall and high relative humidity while they are highest during hot, sunny, and dry conditions. As such, populations are more likely to be found during hot, dry periods (Hoy et al., 2010).

Key Diagnostics/Identification

CAPS-Approved Method*:

Morphological.

Key characters and diagnostic images can be found in Beard et al. (2012a) found here: http://www.usmarc.usda.gov/SP2UserFiles/person/333/External%20mouthpart%20morphology%20in%20the%20Tenuipalpidae%20Raoiella%20a%20case%20study.pdf and Beard et al. (2012b) found here: http://idtools.org/id/mites/flatmites/. Kane and Ochoa (2006) provide descriptions and images of all life stages and can be found here: http://www.sel.barc.usda.gov/Acari/PDF/indicaGuide.pdf.

Work has been done on extracting DNA from *R. indica* (along with other arthropod species) for identification purposes in a way that leaves the specimen intact for use as a voucher specimen (Rowley et al., 2007).

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Easily Confused Pests

The genus *Raoiella* contains several lesser known and poorly described species. *Raoiella indica* is distinguished from other species in this genus by the size of the dorsal setae (Rowley et al., 2007). This species is considered very distinctive and should not easily be confused with other mites when studied under high stereo magnification by an identifier familiar with mites.

This species can be differentiated from spider mites (Tetranychidae) by their red color, long spatulate setae with liquid droplet at the ends, flattened bodies, and absence of webbing (Welbourn, n.d.).

Damage caused by this species may be confused with lethal yellowing found in some palm species or nutritional deficiencies (Welbourn, n.d.; Welbourn, 2009). Symptoms caused by *R. indica* were initially attributed to the Lethal Yellowing phytoplasma in Saint Lucia (Kane et al., 2005a).

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This datasheet was developed by USDA-APHIS-PPQ-CPHST staff. This pest is included as a target in the Palm Survey. Additional information can be found in the **Palm Commodity-based Survey Guidelines**. Cite this document as:

Molet, T. 2013. CPHST Pest Datasheet for *Raoiella indica*. USDA-APHIS-PPQ-CPHST.

Revisions

July 2016: NAPPFAST map removed.