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Exploring the host range of the red palm mite (*Raoiella indica*) in Kerala, India*

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Abstract

Current published records indicate that the red palm mite (RPM), *Raoiella indica* Hirst, has a much broader host range in the New World than in the Old World. Therefore, a series of studies were carried out in Kerala, India in 2009 and 2010 to elucidate the presence or absence of *R. indica* colonies on hosts in addition to coconut *Cocos nucifera* L., and betel-nut palm, *Areca catechu* L., the only previously reported host plants in India. We evaluated the following: RPM numbers on coconut and *Musa* spp. grown in Kerala; the presence of RPM on coconut and bananas grown as a mixed crop; and the possible presence of RPM on palms and other selected plant species mostly grown as ornamentals or reported to be hosts of the RPM in the New World. Results showed that RPM was found in extremely low numbers on *Musa* spp., never clearly colonizing those plants. The pygmy date palm, *Phoenix roebelenii* O´Brien, was found to be an additional breeding host in Kerala, as multi-generational colonies were found on a plant of this species. Possible reasons for observed differences in RPM host ranges between the Old World and the New World are discussed.

Key words: Ecology, host range, Tenuipalpidae.

Introduction

Red palm mite (RPM), *Raoiella indica* Hirst, 1924 (Prostigmata: Tenuipalpidae), was originally described from Coimbatore, India, on coconut (*Cocos nucifera* L.) and later reported in several places in the Old World including India, the Middle East, Mauritius and Reunion (CABI/EPPO, 2007). It was first reported in the New World in 2004, in Martinique (Flechtmann & Etienne, 2004). Since then, RPM has been reported on many islands throughout the Caribbean (CABI/EPPO, 2007) and has subsequently spread to southern Florida (Smith & Dixon, 2008), northern Venezuela (Vásquez *et al*., 2008), and Brazil (Navia *et al*., 2011). The mite causes damage by feeding on the underside of leaves in colonies of up to 330 individuals in the Old World (Mauritius) (Moutia, 1958) but in the New World, colonies of up to 4,000 individuals per leaflet on coconut have been reported (Peña *et al*., 2009). The specific feeding site is thought to be through or around the stomata, as observed by Kane *et al*. (2005), who in addition did not find feeding damage to epidermal cells.

In the Old World, the reported host range of RPM included coconut (Hirst, 1924), the betel-nut palm *Areca catechu* L. (Kapur, 1961), the date palm *Phoenix dactylifera* L. (Sayed, 1942) and the hurricane palm *Dictyosperma album* Wendland & Drude ex Scheffer (Moutia, 1958). Since its introduction into the Caribbean, many different host plants have been reported bringing the total number of host species to 63: Arecaceae (46 species), Heliconiaceae (five), Musaceae (six), Strelitziaceae (two) and Zingiberaceae (four). A review of reported potential host plants can be found in Cocco & Hoy (2009). Understanding the reported host range expansion is vital, as the range now encompasses economically important banana, *Musa* spp., and many ornamental plants, including heliconias, and coconut, the latter suffering the highest losses. Kane *et al*. (2005) first reported the spread of *R.*

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indica onto *Musa* spp., naming *Musa acuminata* (Colla), *M. balbisiana* (Colla), *Musa uranoscopus* Lour and *Musa x paradisiaca* as hosts, and reporting for the first time high population levels of *R. indica* on commercial banana plantations in Dominica. Subsequently, multigenerational colonies were reported by Cocco & Hoy (2009) in the eastern Caribbean on the commercially grown banana varieties Dwarf Cavendish, Giant Cavendish, Robusta and Williams, and on the plantain varieties Apem, Cents Livre, Ordinary, Dwarf French and Horn. Cocco & Hoy (2009) also conducted survival analyses of the introduced pest on various banana varieties using detached leaf disc arenas, finding that RPM females could not establish on Dwarf Cavendish, Dwarf Nino, Gran Nain, Dwarf Zan Moreno, Dwarf Green, Truly Tiny, *Musa sumatrana* x Gran Nain, Dwarf Puerto Rican, Rose, Nang Phaya, Misi Luki, Manzano, Lady Finger, Glui Kai and Ebun Musak. The non establishment of RPM on the detached leaf discs was hypothesised to be associated with leaf age or physical characteristics of the leaf such as the cuticle or quantity of wax on the abaxial surface.

With questions remaining about the observed differences in host range in the Old World and New World, it is important to investigate the host range of RPM within an Old World region where RPM has long been established. Since the first record of RPM in Coimbatore, the mite has been widely reported as a minor seasonal pest of *A. catechu* and coconut throughout the southern states of India, including Karnataka, Tamil Nadu and Kerala (Senapati & Biswas, 1990; Sathiamma, 1996; Loganathan *et al*., 2000; Yadavbabu & Manjunatha, 2007). In that region, RPM populations build up in the hot dry months, between December and April, peaking in April, and return to a low level with the onset of monsoon rains (Taylor *et al*., 2011.). However, there have been no published reports of RPM on *Musa* spp. in that region, or indeed throughout the rest of the Old World in the literature. A collaboration with the Kerala Forest Research Institute, Peechi, enabled seasonal field surveys to be established in areas where infestations of RPM had been reported, to investigate the extent of its host range in Kerala.

Materials and Methods

Four studies were conducted. The first was an evaluation of RPM on coconuts and banana grown in relatively close proximity in each of 17 small properties; the second, to determine the incidence of RPM on different banana cultivars; the third, to investigate whether banana in a mixed plot with coconut (known to have RPM colonies) harboured populations of RPM; and the fourth, a survey of potential additional hosts of RPM.

RPM on coconut and banana

Two surveys were conducted, one in February and one in March, 2009, on the 17 small properties where both coconut and banana were grown in relatively close proximity (less than 10 m apart). The properties were located along a 10 km stretch of road between Thadikkulangara (10˚34'N; 76˚31'E) and Vandazhy (10˚37'N; 76˚30'E) in an area where RPM had been previously recorded. The temperature and humidity of each site was taken during the surveys using a handheld digital thermometer/hygrometer. Average temperature and relative humidity were 36.1°C ± 0.3 and 29.6% ± 1.0 in February and 36.5°C ± 0.2 and 51.6% ± 0.5 in March. Properties were chosen by driving for 15–45 seconds then selecting the nearest appropriate site. Sampling methods differed for palm and banana. For palm, at each site, a lower frond of a randomly chosen coconut palm was divided into lower, middle and upper sections, and one leaflet from each section was chosen at random. These leaflets were detached and stored separately in linen bags which in turn were stored in an air conditioned vehicle and subsequently an air conditioned laboratory. Within one–two days, the number of RPM over the entire lower surface of each leaflet was evaluated under a stereomicroscope. Voucher specimens were sent to B. Mallik, University of Agricultural Sciences, Bangalore,

for species confirmation. The average number of post-embryonic RPM and eggs per leaflet for each site was calculated from the three leaflets sampled from a coconut plant. An overall average for all sites was calculated from each site average. The number of *Musa* spp. present on each plot varied, as did the cultivar (the majority was Palayan kodan, in addition to Poovan and Pondan). As the *Musa* spp. leaves could not be removed, a visual inspection of two–three leaves per plant was done using a hand lens (10–12.5 x), counting the number of RPM individuals in all post-embryonic stages on the whole leaf surface. Leaves were inspected at random on each plant, and on each plot between one–seven plants were inspected. The presence or absence of eggs and cast skins on *Musa* spp. were also noted to indicate whether or not the individuals were part of a reproducing colony. Voucher specimens of RPM were collected and preserved in 80% alcohol and then inspected under the microscope in the laboratory for species confirmation. Leaf areas were not measured for *Musa* spp.; therefore, results presented are a qualitative assessment.

Incidence of RPM on different banana cultivars

Because of the low numbers of RPM on *Musa* spp. observed in the previous study (see Results), an evaluation involving several banana cultivars was done, including a cultivar reported as a host in the Caribbean (Robusta). The Banana Research Station in Kannara was chosen as study site as it contained a wide range of banana cultivars not commonly grown in the region, and is located in an area where RPM has been recorded (*pers. obs.*). The study was conducted in March 2010 (when RPM populations were high), in four separate abandoned or non-chemically treated plots established previously by the Banana Research Station, containing varieties with two different ploidies (AAA and AAB). Two AAB varieties, Nendran (equivalent to the horn cultivar grown in the Caribbean) and Poovan (a local equivalent of the Mysore cultivar in the Caribbean) and two AAA varieties, Red and Robusta, were selected. Nendran plants were approximately four months old and were grown under a bi-weekly watering regime. Plants were planted close to each other (1–2 m spacing), creating a shaded dense canopy. Poovan plants were approximately six months old and watered once a month; they were more widely spaced than the Nendran plants (3–4 m). Red plants were approximately six months old, grown on a bi-weekly watering regime and spaced at approximately 2 m. Robusta plants were approximately 4–5 months old, under no regular irrigation and approximately 3–4 m spacing. No pesticides had been applied to these plants since planting. Two lower leaves from six plants in each plot were examined on one occasion for the presence of RPM, using a hand lens (10x or 12x) along with at least three leaflets from two fronds from adjacent coconut or *A. catechu* plants which often fringed the plots. RPM found were collected in 80% alcohol.

RPM on coconut and banana in a mixed crop

Further to the initial survey, a study was carried out in March 2010 on a mixed plot of coconut and banana located between Mudappallur and Vadakkencherry (10°35'37.50"N; 76°30'13.10"E) and known to be infested by RPM annually (*pers. obs.*). The plot consisted of 22 coconut seedlings and 19 banana plants of cultivar Palayan kodan (AAB). The aim of the survey was to determine whether RPM populations would be found on *Musa* sp. in a plot known to have RPM infested coconut palms. The plot was mapped to assess for neighbour effects. The number of post-embryonic life stages of RPM was counted on five leaflets of each of two fronds of each coconut palm, and on two whole leaves of the banana plants, using a hand lens. Leaflets were not removed as this plot was part of an on-going study area. The average number of RPM per coconut leaflet or banana leaf was calculated and plotted on a spatial graph. RPM counts were log (x+1) transformed and an ANOVA was carried out to compare counts from the coconut palms and banana plants. Voucher specimens of RPM were taken from coconuts and all suspected RPM specimens found on banana were stored in 80% alcohol for identification in the laboratory.

Host range

To assess the presence or absence of RPM on other hosts in the area, surveys were carried out in March 2010 in small properties around the towns of Mudappallur, Vandazhi and Vadakkencherry in Kerala as well as at the Banana Research Station, in Kannara. These places were chosen for the study because previous surveys (Taylor *et al*., in prep.) showed the presence of RPM in that general area. In total, ten plant species were examined (31 plants in total) for the presence of RPM colonies/individuals in 10 collecting sites, in small properties or along the roadside. Nearby coconut or *A. catechu* palms were also inspected, to check for the presence of RPM. Inspections for mites were carried out with either a 10x or 12x hand lens and any RPM individuals found were collected in 80% alcohol and returned to the laboratory for slide mounting and species confirmation.

Results

RPM on coconut and banana

The average number of post-embryonic RPM on per coconut leaflet were much higher than the number per *Musa* spp. leaf in February (29.6 ± 16.8, n= 17 and 0.9 ± 0.3, n= 17, respectively) and in March (19.1 ± 8.3, n =17 and 0.2 ± 0.1, n =17). The average number of RPM eggs observed per coconut leaflet was also much higher than the number per *Musa* spp. leaf in February (39.1 ± 28.1 and 0.1 ± 0.1) and March (7.6 ± 4.6 and 0.0). Eggs of RPM were found on only two *Musa* spp. plants and cast skins were found on only one of the 56 *Musa* spp. plants surveyed from the 17 plots in February. In that same month, only one of the 17 *Musa* spp. plots had a 'colony' which consisted of three postembryonic individuals, four eggs and four cast skins; this plant was directly adjacent to a heavily infested coconut palm. In comparison, RPM colonies were present on coconut palms at 13 out of 17 plots in the same survey; on leaflets of these palms, eggs and cast skins were abundant, evidencing the formation of RPM colonies. The number of post-embryonic stages counted on each coconut leaflet ranged between 0–618 in February and 0–210 in March, whereas the number of eggs ranged between 0–750 in February and 0–170 in March. In comparison, the number of post-embryonic RPM recorded per banana leaf ranged between 0–10 in February and 0–2 in March and the number of eggs ranged between 0–4 in February and no eggs were found in March.

Incidence of RPM on different banana cultivars

No RPM individuals were found on the different *Musa* spp. cultivars at the Banana Research Station. The presence of RPM was confirmed on nearby *A. catechu* palms, at high population levels; however no RPM were observed on the coconut palms examined adjacent to the *Musa* spp. plots.

RPM on coconut and banana in a mixed crop

Significant differences in population densities were found in the study conducted in the plot consisting of coconut palms and banana plants ($F= 15.7$, $p< 0.01$, n= 41). The average number of RPM per leaflet was 13.3 ± 5.6 on coconut and 0.2 ± 0.1 on *Musa* sp.. Fig. 1 shows the average densities of RPM on coconut leaflets and on *Musa* sp. leaves on a spatial scale. RPM was found in very low numbers on *Musa* sp. even though the plants were in close association with infested coconuts. RPM was found on two banana plants out of 19, but these plants were underneath a coconut palm at the edge of the plot; there was no evidence of colony formation on those banana plants.

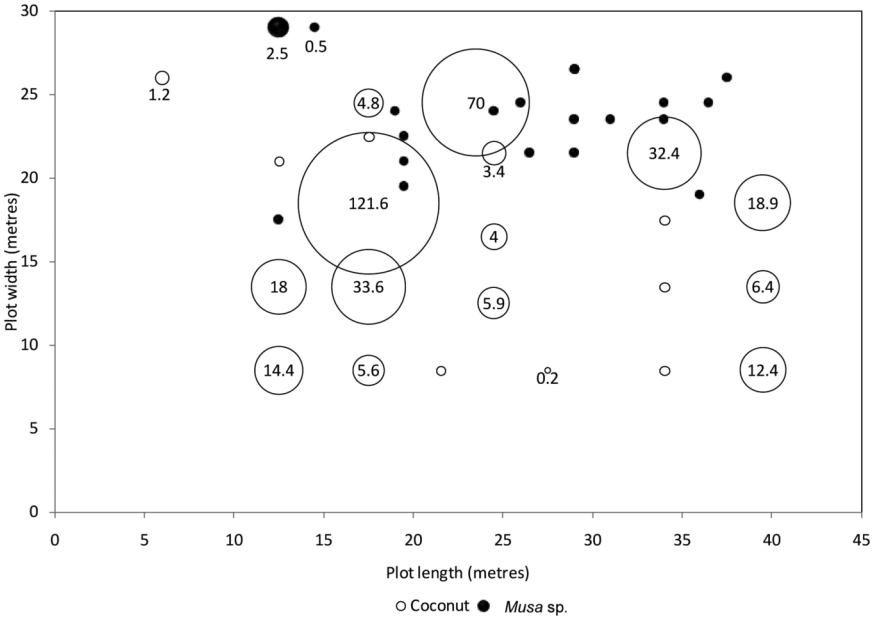

FIGURE 1. Spatial distribution and densities of Red Palm Mite (RPM) in a mixed coconut and *Musa* sp. plot. X and Y axis represent the length and width of the plot in metres. Numbers in/beneath circles indicate average numbers of RPM per leaf on the plant, which are proportional to the size of the circle. Circles with no numbers indicate a plant with no RPM.

Host range

The results from the wider survey of alternative host plants showed *Phoenix roebelenii* O´Brien to be an additional breeding host in the Kerala region. Multi-generational colonies were found on two plants adjacent to and underneath a coconut palm heavily infested with RPM (10°35'32.30"N; 76°31'02.30"E). On this same site, two single RPM females were found on *Cyrtostachys renda* Blume (Red Palm; not reported as a host in Cocco & Hoy, 2009) as well as two solitary females on *Licuala grandis* H. Wndl (reported as a host in Cocco & Hoy, 2009). However, no evidence of colony formation was observed on these plants. On other sites, RPM was never found on *C. renda* (five others inspected). Other Arecaceae species examined were *Borassus flabellifer* Linneaus (not reported as a host in Cocco & Hoy, 2009; six palms, growing wild along the roadside), *Caryota urens* Linneaus (not reported as a host in Cocco & Hoy, 2009; one wild on roadside), *Dypsis lutescens* H. Wndl (reported as a host in Cocco & Hoy, 2009; two ornamental in garden), *Livistona rotundifolia* Lamarck (not reported as a host in Cocco & Hoy, 2009; two potted ornamental palms) and *Roystonea regia* Kunth (not reported as a host in Cocco & Hoy, 2009; three grown in gardens). No RPM were found on these plants, although no infested coconuts were found in their vicinity either, apart from *R. regia* approximately 100 m away from an infested coconut palm. A stand of *Pandanus* sp. (five plants), was examined in the vicinity of infested coconut and *A. catechu* plants (approximately 50–100 m away) as that plant species (although not Arecaceae) has been reported as a host for *Raoiella pandanus* (now synonymised with *R. indica*; Mesa *et al*., 2009). No RPM were found on the plants. In addition to Arecaceae hosts, three separate stands of Heliconiaceae were examined for RPM presence; however no individuals were found, even when heavily infested *A. catechu* palms were within 100 m.

Discussion

In the first study reported here, the population density of RPM reached a maximum of 618 post-embryonic stages and 750 eggs on one coconut leaflet during the study period. Population densities of up to 4,000 RPM per leaflet have been reported in the New World (Peña *et al*., 2009). This difference may be the result of a number of factors, including differences in natural enemy fauna, coconut varieties, climatic differences or differences in agronomic practices.

Musa spp. are widely grown throughout Kerala, often intercropped with coconut; therefore, we expected to find evidence of RPM colonisation on *Musa* spp.. Results from the three studies on *Musa* spp. reported here indicated that RPM colonies occurred very rarely on these plants, despite their proximity to infested coconuts. RPM individuals were found on several of these *Musa* spp. plants, but eggs and cast skins were very rare in these cases. These results are in contrast to reports of multigenerational colonies of RPM found in the New World on various *Musa* spp. cultivars (Kane *et al*., 2005; Cocco & Hoy, 2009). Reasons for these differences could be the same mentioned for coconut.

Tallamy (1999) stated that host range may be constrained not only by behavioural, neuro-physiological and physiological traits of individuals, but the plant species to which an individual has been exposed, competition intensity, predation and parasitism; on relaxation of any of these constraints, changes in host specificity may occur. Peccoud *et al*. (2008) found that habitat and host range expansion of the pea aphid, *Acyrthosiphon pisum* (Harris) (Homoptera: Aphididae), in a newly invaded region was due to multiple introductions of highly specialised clones of the asexually reproducing insect. The possibility of geographic biotypes of RPM, external influences such as host plant varieties and abiotic factors should all be examined as potential causes of differences in host range observed between the Old World and the New World. Cultivar resistance is a likely explanation for these results, and further studies on feeding preferences encompassing a wider range of cultivars such as those grown in other areas of India and the Old World are needed e.g., AAA ploidy banana cultivars commonly grown in other areas of India such as Maharashtra, Tamil Nadu and Andhra Pradesh (Dr. Suma, 2010 Banana research Station Kannara, *pers. comm*.; Rao, 1984).

Except for *P. roebelenii*, no evidence was found of colonization of plants other than coconut or *A. catechu* by RPM. The former was also reported as a host of the RPM in the New World (Welbourn, 2006). It belongs to the same genus as the date palm, *P. dactylifera*, reported as a host in the Old World (Sayed, 1942). Alternative palm species and ornamental plants were in much lower abundance compared to coconut and areca nut in the area where this study was conducted. Because few of the species reported as hosts by Cocco & Hoy (2009) were found in the study area, additional palm species not reported as hosts by these authors from the Arecaceae family were surveyed including *B. flabellifer,* which grows commonly on roadsides in the area of the study. The patchiness of the distribution of ornamentals and heliconias in the area may have reduced the chances of RPM coming into contact with an alternative host. Cultivar resistance is again a possible explanation, but because our study was only small scale, the work needs to be extended to include larger samples and experimental approaches.

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