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Distribution, damage levels and natural enemy fauna of red palm mite, *Raoiella Indica* Hirst: An invasive pest in Trinidad and Tobago, West Indies

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ABSTRACT: The red palm mite (RPM), *Raoiella indica* Hirst (Acari: Tenuipalpidae) is an imperative pest of coconut, date palm, other palm species (infesting over 32 species of palms) and bananas, heliconias, gingers, beans, and durian in diverse parts of the world. It is considered that the pest has serious consequences for the coconut, ornamental palms and banana industries of the Caribbean islands. Damage to coconuts results in 70 per cent yield reduction and possibly job losses leading to a major socio-economic problem for some of the islands. Hence, survey was conducted in Trinidad and Tobago, West Indies to determine the status of red palm mite, the extent of damage, the population levels of RPM and its natural enemy's fauna. Comments on the various aspects are presented.

Keywords: *Raoiella*, Red palm mite, Trinidad and Tobago, invasive pest

INTRODUCTION

Invasive species implies the alarming blow to biodiversity worldwide (Pimentel 2011; Funk 2015), with collision on non-native habitats potentially having pessimistic ecosystem effects (Gurevitch and Padilla, 2004) and sturdy economic burden (Pimentel *et al.* 2005). Coconut is an important tropical perennial crop which is an economically important predominant crop in Asia, Pacific, African countries and a crop of small holders in many countries has become an integral and inseparable part of many a culture, tradition and religion. In Trinidad and Tobago, coconut was one of the major export tree crops which occupied approximately 4,000 ha in small and large holdings and contributed its share in the country's economy. The coconut crop being an integral part of beaches in Caribbean region, found a potential source of income in the tourism industry. After the entry of Red Palm Mite (RPM), *Raoiella indica* into the Caribbean region in 2004 and Trinidad in 2006, it is considered one of the factors hampering coconut production. Further, impact of this invasive alien pest has been reflecting in agriculture, cultural heritage, ecotourism, biodiversity and the industrial sectors of Trinidad and Tobago. Damage to coconuts results in 70 per cent yield reduction and possibly job losses leading to a major socio-economic problem for some of the islands (Roda *et al.* 2012). This backdrop lead to the Memorandum of Understanding (MOU) between Indian Government and the Government of Trinidad and Tobago, West Indies and deputation of a scientist from India as an Indian Technical Economic Cooperation (ITEC) expert for one year to assist in the control of Red Palm Mite in Trinidad and Tobago.

The red palm mite, *Raoiella indica* Hirst (Acari: Tenuipalpidae) also known as the coconut mite, coconut red mite, red date palm mite, leaflet false spider mite, frond crimson mite, scarlet mite was described and figured by Hirst (1924) from coconut leaves in Coimbatore, India. Additional descriptions and figures can be found in Sayed (1942), Chaudhri *et al.* (1974) and Pritchard & Baker (1958). Moreover, same was reported on economically important fruit-producing trees such as coconut, *Cocos nucifera* L. and banana, *Musa* spp. (Nagesha-Chandra and Channabasavanna, 1984 and Welbourn, 2006). Besides that, momentous infestations have been reported on the date palm, *Phoenix dactylifera,* plantains, *Musa* spp., and ornamental palms, including the Christmas palm, *Adonidia merrillii* and the Mexican fan palm, *Washingtonia robusta* (Zaher *et al.* 1969; Etienne and Fletchmann, 2006). The RPM was found in the Caribbean for the first time in Martinique and Saint Lucia in 2004 (Fletchmann and Etienne, 2004), and has now spread throughout the Caribbean islands and invaded Florida and Venezuela (Kane *et al.* 2005; Etienne and Fletchmann, 2006; Gutierrez *et al.* 2007 and Rodrigues *et al.* 2007). *R. indica* was spotted in southeastern Florida in the year 2007 and later established in three counties (Florida Department of Agriculture and Consumer Services 2008). Plants reported by USDA-APHIS to be hosts of *R. indica* in Florida include ornamental palms such as the Fiji fan palm, *Pritchardia pacifica,* the Miraguama palm, *Coccothrinax miraguama*, and the endangered native Florida thatch palm, *Thrinax radiata* (Coile and Garland, 2003).

In the wake of the invasion of *R. indica* into the

Table 1. Survey in Trinidad: Population Counts of RPM, natural enemies and extent of yellowing

Location	Population/115mm² (No)			Population/cm² (No)			Manual Count			Yellowing (%)
	Pest	Natural Enemies		Pest	Natural Enemies		N.E Pop./Leaflet *$_1$ (No)			
	RPM	Ambly	Others	RPM	Ambly	Others	RPM	Ambly	Cun	
Valencia**	16.60	0.08	0.013-cun &0.02-uk	14.43	0.07	0.01-cun & 0.02uk	2628	9	1	6.60
Cumana**	16.83	0.03	-	14.63	0.026	-	977	-	1	24.30
L'Anse Noire**	20.15	0.03	-	17.52	0.026	-	980	19	-	46.80
Guiaco	1.70	0.01	-	1.47	0.008	-	7	-	-	16.10
Manzanilla**	-	-	-	-	-	-	154	-	-	20.90
Guayaguayare	7.75	0.01	-	6.74	0.008	-	8284	11	2[b]	16.70
Mayaro**	17.45	0.01	-	15.17	0.008	-	95	-	-	26.80
Blanchisseuse**	1.88	0.01	-	1.63	0.008	-	-	-	4	27.10
Madamas	3.18	0.01	-	2.77	0.008	-	-	-	1	1.65
19¾mm Blanchisseuse	0.38	-	-	0.33	-	-	-	10	16	0.00
Paria Main Road**	0.03	-	-	0.026	-	-	11452	4	2-uk	-
Las Cuevas**	1.90	0.03	-	1.65	0.026	-	1011	10	1-uk	-
La Fillette	2.75	0.01	-	2.39	0.008	-	11	2	-	-
Maracas Bay	0.42	-	-	0.37	-	-	412	1	-	5.34
Bonasse**	8.20	0.05	-	7.13	0.04	-	1163	18	-	20.00
Columbus Bay Road**	11.83	0.37	-	10.29	0.32	-	2110	10	-	39.32
Icacos	27.90	0.26	0.013-cun	24.26	0.23	0.01	23	1	1	19.20
Wallerfield	0.08	0.18	0.013-cun	0.07	0.16	0.01	13	1	2	1.66
Maloney	5.62	0.01	-	4.89	0.008	-	7	2	-	6.67
Valsayn	23.32	0.24	-	20.32	0.20	-	4258	18	-	10.00
Maraval	-	-	-	-	-		-	-	-	5.83
Diego Martin**	43.28	0.15	-	37.63	0.13	-	438	9	-	35.56
Chaguaramas	0.027	0.01	-	0.02	0.008	-	16	5	-	0.83
Kelly Village	2.93	-	-	2.54	-	-	119	-	1	4.17
Charlieville	-	-	-	-	-	-	-	-	-	2.50
Macaulay	0.25	-	-	0.21	-	-	166	13	-	2.16
Freeport	-	-	-	-	-	-	-	1	-	0.00
Waterloo**	0.08	-	0.013-LW	0.07	-	0.01	397	25	1-uk	1.65
Golconda	0.01	0.01	-	0.008	0.008	-	-	-	-	0.00
Golconda Ring Road	-	-	-	-	-	-	-	-	-	0.03
Siparia	-	-	-	-	-	-	-	-	-	-

New World the need arose to bring together existing information on various aspects. Even though there are wide-ranging compilations published on the world-wide web (FAO, 2005 and CARDI, 2010) and in journals (Sayed, 1942., Elwan, 2000., Gupta, 2001., Mendonca *et al.* 2005., PROSEA, 2006., Rodrigues *et al.* 2007a, b., Vasquez *et al.* 2008 and Carrillo *et al.* 2011), there is a need to spotlight on the distribution, hot spots and natural enemy fauna of *R. indica*. Hence, an attempt has been made to discern the distribution, damage levels, hot spots and natural enemy fauna of invasive red palm mite, *R. indica* in Trinidad and Tobago.

MATERIALS AND METHODS

A roving survey was conducted in Trinidad and Tobago to determine the status of RPM *i.e.,* the extent of damage, the population levels and species of natural enemies present. The palms sampled for the survey were located in different eco-systems which include hills, valleys, slopes, swamps, sea coasts and normal cultivated lands. Locations were selected randomly on the roadside. Two palms were selected randomly from each location. From each palm, six leaflets were sampled from three different levels of palm, @ two leaflets from top, middle and lower whorls, respectively.

Population counts of RPM and its natural enemies on each leaflet were assessed in two ways (1) Manual counting by observing the abaxial surface of entire leaflet through the stereo zoom microscope and recording different life stages of RPM and its natural enemies present (2) Digital counting by focusing the scalar digital camera with 25 times magnification at 12 random spots on the abaxial surface of the leaflet and counting on the monitor by uploading the pictures into the computer. The average number of RPM and its natural enemies/ leaflet was determined by manual counting whereas per unit area *i.e.* cm^2 was obtained in digital pictures by counting on the monitor through the computer. Egg, larval, protonymphal, deutonymphal and adult stages of RPM put together were considered as RPM count and similarly all the stages of natural enemies of individual species were taken as count of natural enemies. The average count of RPM and natural enemies per cm^2 area of leaflet was worked out from the counts of 12 spots of each leaflet, based on the leaf area exposed in digital camera. Later average count for leaflets from top, middle and lower levels of the crown was arrived individually and average count for unit area *i.e.* cm^2 on single leaflet for each sample palm was derived. Finally population counts of RPM and its natural enemies per leaflet as well as per unit area of leaflet were assessed for each location surveyed from two palms data obtained in the respective locations.

The extent of damage caused by RPM on the foliage was expressed as percentage of yellowing or percentage of infestation of leaflet and it was assessed by comparing the damaged area to the healthy area (green colour) of the leaflet. The infestation levels were graded as zero (0%) , low (< 15%), medium (15.1-50%) and high (> 50%). As per the scale of infestation, the particular location was categorized under zero, low, medium or high scale of infestation. A location was considered as hot spot area where percentage of yellowing or infestation of leaflet was >20 per cent or Red Palm Mite population count exceeds 400/leaflet.

RESULTS AND DISCUSSION

Estimation of RPM damage levels and collection of natural enemies in Trinidad:

During the survey, leaf samples were collected for estimation of extent of Red Palm Mite damage, population levels of RPM and natural enemies, and collection of natural enemies from thirty-one locations in seven counties. The RPM infestation in different locations varied from 1.65 to 46.8%, population count ranged from 7.0 to 11,452 per leaf let whereas natural enemy population recorded was 1 to 19 no/leaflet. The occurrence of RPM population/unit area was recorded from 0.008 to 24.26/cm^2 leaf area (Table: 1) in Trinidad.

Information drawn from the survey provided the status of RPM as well as natural enemies of RPM in different locations. It was found that 7 locations *i.e.* Siparia, 19¾ Blanchisseuse, Freeport, Golconda, Paria Main Rd., Las Cuevas and La Fillette are free from RPM infestation, and 13 locations namely Valencia, Madamas , Maracas Bay, Wallerfield, Maloney, Valsayn, Maraval, Chaguaramas, Kelly Village, Charlieville, Macaulay, Waterloo and Golconda Ring Rd. with low infestation and 11 locations (Cumana, L'Anse Noire, Guiaco, Manzanilla, Guayaguayare, Mayaro, Blanchisseuse, Bonasse, Columbus Bay Rd., Icacos and Diego Martin) with medium infestation of RPM out of 31 locations surveyed in Trinidad (Table: 2).

Hotspot areas of RPM in Trinidad

Based on the RPM population and the percentage yellowing of leaf, the following 13 locations from 6 counties (North, South and Central parts of Trinidad) are found to be the hot spot areas of the pest high levels of RPM populations *i.e.* more than 400 per leaflet or high infestation per cent of leaflet (>20%) were recorded in 13 locations; Bamboo, Blanchisseuse, Valencia, Paria Main Road, Las Cuevas, Diego Martin, Cumana, L'Anse Noire, Bonasse, Columbus bay, Manzanilla, Mayaro

Table 2. List of locations indicating status of Red Palm Mite in Trinidad

Scale of infestation			
Nil (0 %)	**Low (0.1% to 15.0%)**	**Medium (>15.0% to 50.0%)**	**High (> 50.0 %)**
1. Siparia	1. Valencia	1. Cumana	
2. 19¾ Blanchisseuse	2. Madamas	2. L'Anse Noire	
3. Freeport	3. Maracas Bay	3. Guiaco	
4. Golconda	4. Wallerfield	4. Manzanilla	
5. Paria Main Rd.	5. Maloney	5. Guayaguayare	
6. Las Cuevas	6. Valsayn	6. Mayaro	Nil
7. La Fillette	7. Maraval	7. Blanchisseuse	
	8. Chaguaramas	8. Bonasse	
	9. Kelly Village	9. Columbus Bay Rd.	
	10. Charlieville	10. Icacos	
	11. Macaulay	11. Diego Martin	
	12. Waterloo		
	13. Golconda Ring Rd		

Table 3. List of Locations indicating status of Red Palm Mite in Tobago

Scale of infestation			
Nil	**Low**	**Medium**	**High**
1. Moriah Road	1. Pig Farm Rd. Goldsborough	1. Castara Recreation Facility	1. Indian Walk, Moriah
2. English Man's Bay	2. Pig Farm Rd. Goldsborough	2. Parlatuvier	2. #143 North Side Rd. Moriah
3. Mt. Irvin Hotel	3. Kendal, Roxborough	3. Speyside Main Rd.	3. Parlatuvier
4. Louis D'or	4. Lambeau Beach, Old Milford Rd.	4. Big Bacolet/ Minister Bay	4. L'anse Fourmi
5. Hermitage	5. Magdalena Resort	5. Cocoa Reef Rest House	5. North Side Road, Parlatuvier
6. Richmond Village	6. Pigeon Pt. Beach Resort		

and Waterloo which are spread over in all types of geographical area in North, South, East and Central parts of Trinidad. It should be highlighted that surveys area snap shot in time and as such further roving as well as fixed plots surveys at periodical intervals throughout the year for longer periods are required to get better understanding of the pest scenario, seasonal abundance/ occurrence and nature of pest (Fig.1) (Table 1).

Cataloguing, identification and status of the indigenous natural enemies in Trinidad:

The natural enemies collected from the field surveys are catalogued in the laboratory. A predatory mite, *Amblyseius largoensis* (Order: Acari, Family: Phytoseiidae) was identified as the most predominant natural enemy among the field collected natural enemies. It's occurrence in the field was found in the ratio of 1:3 to 1: >100 of host population and noticed in 19 locations out of 31locations surveyed. The other predatory mite, the *Bdella* sp. a member from Bdellidae family collected from RPM colonies in 8 locations out of 31 locations surveyed and is present in the ratio of 1:6 to 1: 23. The *A. largoensis* is associated with higher populations of red palm mite whereas the *Bdella sp.* is associated with lower populations of red palm mite. In few locations eggs and immature stages of chrysopid which is an insect predator were found in RPM colonies (Table 4).

Estimation of RPM damage levels and collection of natural enemies in Tobago

A total of 22 locations were surveyed in Tobago covering six counties; St. Andrew, St. David, St. John, St. Mary, St. Patrick and St. Paul.The presence of RPM was recorded in all the 22 locations surveyed. From the data, it was found that the percentage yellowing ranged from 4 to 90 per cent of the palm and 2.5 to 81.0 per cent of leaflet. Population counts of RPM ranged from 2.0 to 87.0/cm^2 and that of natural enemies from 0.03 to 3.0/ cm^2. Whereas, that of RPM number per leaflet ranged from 892 to 8366 and natural enemies from 0.33 to 11.0 (Table: 5).

From the survey in Tobago it was derived, two locations (Moriah Road and English Man's Bay) were free from RPM, 6 locations (Pig Farm Rd. Goldsborough a, Pig Farm Rd. Goldsborough b, Kendal, Roxborough, Lambeau Beach, Old Milford Rd., Magdalena Resort and Pigeon Pt. Beach Resort) were found with low infestation, 5 locations (Castara Recreation Facility, Parlatuvier, Speyside Main Rd., Big Bacolet/ Minister Bay and Cocoa Reef Rest House) medium level of infestation and 5 locations (Indian Walk, Moriah, #143 North Side Rd. Moriah and Parlatuvier) with high infestation. Most of the locations are with few numbers of palms on slopes of hills growing naturally (Table 3).

Hotspot areas of red palm mite in Tobago

Based on the RPM population and the percentage yellowing of leaf, 20 locations from 5 counties are found to be the hot spot areas of the pest (Table: 5). The average population of RPM in counties is 6,690/leaflet with 51.1 per cent leaflet yellowing, 892/ leaflet with 2.5 per cent leaflet yellowing, 5307 /leaflet with 52.5 per cent leaflet yellowing, 5,129/ leaflet with 17.5 per cent leaflet yellowing and 9619/leaflet with 15.5 per cent leaflet yellowing in St. John, St. Paul, St. David, St. Andrew and St. Patrick, respectively (Fig. 2).

It is important to note that few times symptoms of yellowing or infestation was observed without live populations of RPM but more frequently with high numbers of exuvia. On few occasions leaves appeared quite green in colour with RPM live populations. Many times no correlation between pest population and symptoms was observed. These instances are leading to a scope for detailed studies about population dynamics, appearance of symptoms, influence of abiotic factors, seasonal variations, plant reaction *etc.*

Cataloguing, identification and status of the indigenous natural enemies in Tobago

Survey data in Tobago highlighted the presence of natural enemies in all the locations surveyed. The natural enemies recorded are *A. largoensis, Bdella* sp., Chrysopids and coccinellids. Among the natural enemies collected, the predominant natural enemy is *A. largoensis.* Out of 22 locations surveyed, *A. largoensis* was noticed in 17 locations. The ratio of its occurrence to RPM ranged from 1:17 to1: 800 (Table 4).

Comparison of present survey data with earlier reports from Trinidad and Tobago on the damage, population levels of RPM and its natural enemy *A. largoensis* inferred that many folds increase in the damage per cent of leaflet as well as population counts from 8.52 % to 81.0% (2011 to 2012) and 5.42 to 275.3/cm^2 leaf area (2008 to 2012), respectively. Similarly the natural enemy count per leaflet also increased from 3.03 to 25.00 (2009 to 2012) over a period of 3 years. From this information it is evident that even though pest population increasing there is a scope for the build-up of natural enemies.

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).

Table 4. Status of natural enemies of RPM in Trinidad and Tobago

Natural enemy species	Trinidad (31 locations)				Tobago (22 locations)			
	Occurrence (% of Locations)	No./ Leaflet	No/cm²	Ratio	Occurrence (% of Locations)	No/ Leaflet	No/ cm²	Ratio
Amblyseius largoensis (Acari: Phytoseiidae)	61.2	1-25	0.01-0.08	1:3	77.3	0.33-11.0	0.01-3.0	1:17 to 1:800
Bdella sp. (Acari: Bdellidae)	9.7	1-16	0.002-0.08	1:6 to 1:23	9.0	0.16-0.3	-	-
Chrysopid	6.5	-	-	-	9.0	0.3-4.16	0.3	-
Coccinellid	-	2	0.02	-	4.5	0.16	0.04	-

Table 5. Survey in Tobago: population counts of RPM, natural enemies and per cent yellowing

Location	Population /115mm² (No.)			Population /Cm² (No.)			Manual Count		Yellowing (%)		Remarks
							N.E Pop./Leaflet *1 (No.)				
	RPM	Ambly	Others	RPM	Ambly	Others	Ambly	Others	Leaflet	Palm	
Pig Farm Rd, Goldsborough**	0.00	0.00	-	0.00	0.00	-	0.33	0.70-4uk	3.30	-	RPM present Seen
Pig Farm Rd, Goldsborough**	0.00	0.00	-	0.00	0.00	-	0.00	-	3.30	4.00	Chrysopid, RPM present Many
Kendal, Roxborough**	2.30	0.00	-	2.00	0.00	-	0.00	-	2.50	-	Chrysopids & Ambly (10-15 Ambly per leaflet), RPM present
Indian Walk, Moriah**	19.81	0.08	-	87.00	1.00	-	1.00	-	80%	90.00	More Ambly & mites (8 per leaflet)
#143 North Side Rd, Moriah**	22.25	0.17	-	19.00	0.10	-	5.16	-	60%	60.00	RPM present
Moriah Rd Castara Recreation Facility**	0.00	-	-	-	-	-	-	-	-	>50.00	RPM Exuviae present
English Man's Bay, North Side Rd**	9.67	0.01	- 0.30-3cun	8.00	0.01	-	0.30	- 0.30-3cun	16.67	30.00	RPM present
	0.00	-		-	-	-	0.16		-	-	RPM absent

North Side Rd, Parlatuvier**	5.13	0.11	-	4.00	0.10	-	5.00	-	44.17		RPM present
North Side Rd, Parlatuvier**	24.16	0.92	-	21.00	1.00	-	5.83	-	80.82		RPM present
L'anse Fourmi**	-	-	-	-	-	-	-	-	-	-	Lots of RPM
Hermitage**	-	-	-	-	-	-	-	-	-	-	& Ambly
Charlotteville**	-	-	-	-	-	-	-	-	-	-	RPM present
		76mm²									
Speyside Main Rd**	15.42	0.00	0.03-[1]chry	20.00	1.00	0.30-[1]chry	1.20	0.03-[1]chry	28.3	25.00	RPM present
Louis D'or**	-	-	-	-	-	-	-	-	-	10.00	RPM present
Richmond Village**	-	-	-	-	-	-	-	-	-	-	RPM present
Big Bacolet/Minister Bay**	12.71	0.00	-	17.00	0.00	-	1.20	-	27.5	30.00	RPM present Seen
Lambeau Beach, Old Milford Rd**	4.78	0.00	-	6.00	0.00	-	3.00	-	7.50	17.50	Chrysopid, RPM present Seen
Magdalena Resort**	38.5	0.00	-	50.00	3.00	-	5.60	-	13.33	30.00	Coccinellids, RPM present Plenty Ambly,
Coco Reef Rest House**	8.80	0.03	0.03-[1]chry	11.00	0.40	0.04-[2]coc	3.70	4.16-[1]chry 0.16-[2]coc	21.7	40.00	Coccinellids, RPM & RPM Exuviae Plenty Ambly
Pigeon Pt Beach Resort**	11.0	0.02	0.16-[3]cun	14.00	0.03	-	11.00	0.16-[3]cun	11.7	25.00	, RPM present, Ambly, Chrysipid , lacewings present &
Mt. Irvine Hotel**	-	-	-	-	-	-	-	-	-	-	RPM present

*- At Location 6,11,12,13,15,16 & 22 nos. leaf samples could not be collected as they are on the hill; *$_1$- Average area of a leaflet : 446cm²

1. Chrysopids, 2. Coccinellids, 3. Cunaxids, 4. Unknown, Ambly: Amblyseius; RPM: Red Palm Mite and POP: Population

**- Hotspot areas of red palm mite pest in Trinidad based on Pop/Leaflet (No) and Yellowing of Leaflet (%)

Afterwards, RPM was found in other Caribbean Islands (Etienne and Fletchmann, 2006 and Rodrigues *et al.* 2007), North America (USA and Mexico; Welbourn 2006, Estrada-Venegas *et al*. 2010 and Kane *et al*. 2012) and South America (Venezuela, Colombia and Brazil; Vasquez *et al.* 2008; Carrillo *et al.* 2011and 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 other plant sp. such as 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 and 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 and 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).

Most RPM population management strategies in the Eastern hemisphere have focused on chemical control (Senapati and Biswas, 1990 and Jayaraj *et al.,* 1991). In the Neotropical region, several systemic insecticides (phosphamidon, monocrotophos, dimethoate, formothion and demeton-methyl) exhibited toxicity to larva, nymphs and adults (Rodrigues and Pena, 2012). Although RPM population management has relied on chemical compounds, there is some knowledge about its natural enemies, mainly in the eastern hemisphere (Pena *et al.,* 2006). Recent information has shown that *Amblyseius largoensis* (Muma) is very common on coconut palms and thus is the primary predator associated with RPM (Carrillo *et al.,* 2012b, Domingos *et al.,* 2013) suggesting that it can play a role in controlling RPM (Carrillo *et al.,* 2010).

Fig. 1. Hotspot areas of red palm mite pest in Trinidad

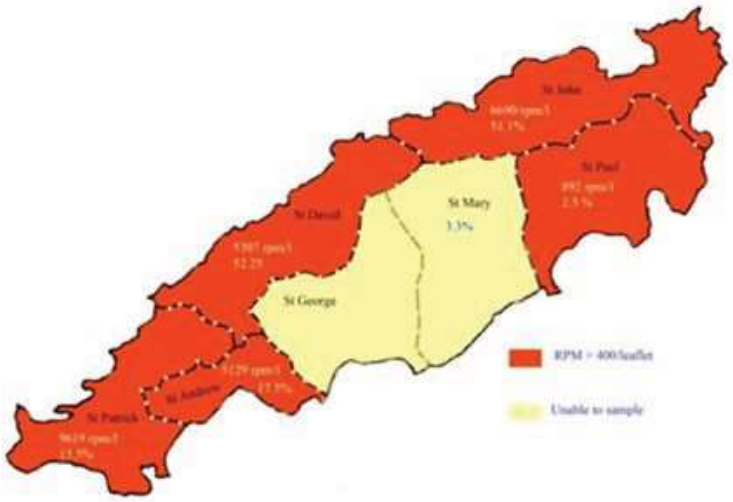

Fig. 2. Hotspot areas of Red Palm Mite in different Counties of Tobago

Review of earlier reports of Trinidad and Tobago about the status of *A. largoensis* revealed increase in a number over a period of time indicating its acclimatization to feed on RPM. It was known that natural predators may offer a good means of controlling RPM populations. The reports from different countries revealed the natural enemies that occur in respective country; in India the phytoselid mite, *Amblyseius channabasavanni* and beetle, *Stethorus keralicus* Kapur (Coleoptera: Coccinellidae) were considered to be the most important predatory species. In Mauritius, the principal predator of *R. indica* in coconut plantations was *Typhlodromus caudatus* Chant (*Amblyseius caudatus* Berlese). In the Western hemisphere, *Neoseiulus longipinosus*, also native to the East has been found to prey on *R. indica* in the Caribbean. Also, there are several conccinellid and phytoseiid potential, endemic predators that are found preying on similar species in the Western Hemisphere. A fungus, possibly, *Hirsutella* spp. has been observed infecting the RPM. According to the available literature, each site has a different natural enemy complex with only one predator species, *A. largoensis*, present in all the geographical areas. *R. indica* was found on 36 palm species and *A. largoensis* was found on half of them. Through various surveys, *A. largoensis* was identified as the most abundant predator and often as the only phytoseiid species associated with *R. indica*.

The characteristics of *A. largoensis* namely, High survival, High reproductive rate, Presence in all areas, Shorter life cycle, The numerical response to pest increase, Abundant presence, Presence throughout the year, can feed, develop and reproduce on a diet consisting only of *R. indica* and the information gathered from the surveys shows *A. largoensis* was found to be the most potential bio-control agent of RPM.

The low abundance of the predatory mite, *Bdella* sp. observed in the field indicates unlikely to be promising predator, further studies are necessary to know its predator status. It would be desirable to intensify search on natural enemies from other classes also that could prey on all stages of RPM and other mortality factors to use in combination for effective suppression of RPM.

Although several studies have demonstrated that a number of Entomophthorales, mainly *Hirsutella thompsonii* and *Neozygites floridana*, are specific to the Acari (Chandler *et al.* 2000), information related to those entomopathogenic fungi associated to RPM is still lacking. So far, it has been reported that a small portion of RPM was infected by a fungus, possibly *Hirsutella spp.* (Pena *et al.* 2006). In the light of limited control by natural enemy populations, limitations of chemical pesticides, biological pesticides could be a potential option for RPM control in the Caribbean islands.

From the above study, it was clearly established that, *A. largoensis* was found to be the most potential bio-control agent of RPM in Trinidad and Tobago which is in line with published facts of various authors. Although *A. largoensis* is a pre-dominant but *Bdella* sp., Chrysopids and coccinellids are also note worthy bio control agents in control of RPM. Various hot spots of RPM were thoroughly identified in large scale, which may be due to the favourable climatic conditions and non adoption of systematic cultivation practices like varietal

selection, weed management, proper nutrient supply, phytosanitary measures, stress relieving measures and other crop management practices. Moreover, ultimate flare up of RPM was noticed in hilly and sloppy areas of Caribbean region. Principally, weather conditions and ecology of the pest might be the reason behind the vulnerability of coconut palm to RPM. Further, wind borne spreading mechanism becomes a huge advantage to the RPM severity and build up. Movement of planting material and palm based souvenir without legislative measures would have helped to pest acceleration. RPM population management strategies is mainly revolving around the chemical control, there is a need to exaggerate the various crop as well as integrated pest management practices in the Trinidad and Tobago by considering the above mentioned issues. However, the main aim of the study was to exhibit the specifics of RPM in Trinidad and Tobago which will be very helpful to devise the location specific integrated pest management programmes.

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