15

Biological Studies and Pest Management of Phytophagous Mites in South America

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1. Introduction

Mites are the most diverse representatives of an ancient lineage in phylum Arthropoda-subphylum Chelicerata- subclass Acari. Their body plan is strikingly different to that of other arthropods in not having a separate head, instead, an anterior region, the cephalothorax, combines the functions of sensing, feeding, and locomotion (Walter & Proctor 1999). Antennae, mandibles and maxillae are also absent; rather, a pair of often pincer-like mouthparts are present, the so-called chelicerae. Those members of the subclass Acari, which feed on plants, are known as phytophagous mites. Mites constitute one of the most heterogeneous cheliceran groups, since they are extremely diverse in their morphology, biology and ethnology, enabling them to colonize different environments. Their remarkable diversity in acarine morphology is reflected in the variety of ecological and behavioral patterns that mites have adopted (Krantz 2009). Thus, species can inhabit soil, litter (i.e. Cryptostigmata, Mesostigmata and Prostigmata), water (Hydrachnidia) or plants (Prostigmata or Mesostigmata). Phytophagy is widespread enough among the Trombidiform Acariformes so as to suggest that there was an early evolution commitment to plant feeding by several primitive predaceous and saprophagous trombidiform lineages (Krantz 2009). Some Prostigmatan mites, chiefly spider mites, false spider mites and eriophoid mites, use their specialized mouthparts to feed on the vascular tissues of higher plants and with their activity they can cause losses to field and protected crops (Evans 1992), becoming economically important pests.

This review summarizes more important phytophagous mites in tropical crops in South America, biological aspects, damage, and also main control strategies in tropical conditions.

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2. Economically important mite species

Species of agricultural importance can exhibit either phytophagous or predatory habits. Most important taxa including exclusively phytophagous mites are Eriophyoidea, Tetranychoidea (Tetranychidae, Tenuipalpidae). Tarsonemidae is also a family of mites which includes several pest species. All these taxa cover the most important crop pest species distributed worldwide, and several more geographically restricted species. The Eriophyoidea is a large superfamily of worldwide distribution. Over 3,000 species belonging to about 250 genera are known in the world. These worm-like or fusiform mites cause many forms of plant abnormalities such as galls, leaf blisters and rusts. Most eriophyid mite species are monophagous or are limited to plant species within a single genus. Some rust mites and gall mites are important pests on economic plants.

The Tetranychidae, also known as spider mites, is a large family including of some 1,200 species belonging to over 70 genera of worldwide distribution. Spider mites cause mechanical damage by sucking cell content from leaves. At first, it shows up as a stippling of light dots on the leaves; and sometimes leaves became bronze in color. As feeding continues, the leaves turn yellow and drop off. Often leaves, twigs, and fruit are covered with a large amount of webbing. In Tenuipalpidae, also known as false spider mites or flat mites, about 800 species have been described in over 25 genera. Only *Brevipalpus*, *Tenuipalpus* and *Raoiella* and few other genera become pests of economic plants, mainly on tropical fruit crops and ornamental plants. Virus transmission has only been documented in some Eriophyidae or Tenuipalpidae species.

Due to the economic losses caused by mite pests, management tactics need to be established to keep population levels under the economic threshold of infestation. This practice should be based on integrated pest management (IPM) including spraying chemical products, using biological control agents and/or resistant varieties. Currently, chemical control has to deal with serious control failures in mite populations, since the evolution of pesticide resistance in phytophagous mites is very common. Consequently, different chemical molecules are being currently developed to face this phenomenon, mainly in spider mites. However, the low level of immigration of susceptible individuals and the rapid reproductive rate associated to these mite groups have made it difficult to manage population in crops.

Biological control is an environmentally safe, cost-effective and energy efficient pest control, either on its own or as a component of integrated pest management. Although several mite species belonging to Bdellidae, Cheyletidae, Cunaxidae, Stigmaeidae and Tydeidae have shown predatory habits, Phytoseiidae mites have been more widely included in biological control programs, due to their capacity for surviving and reproducing on other arthropods. Additionally, some phytoseiid mites have shown to be resistant or less susceptible to chemical compounds commonly used to control pest mites in commercial crops, thus making them suitable for their use in integrated pest management programs.

3. Spider mites

This family consists of two subfamilies: Bryobinae and Tetranychinae. Spider mites occur on most of the major food crops and ornamental plants in almost all environments where mainly Tetranychinae species can potentially cause economic damage.

Spider mites are soft-bodied, medium-sized mites. They are often red, green, orange or yellow in color when alive. The gnathosoma has a capsule-like structure known as the stylophore, which is formed by the fusion of chelicerae. The movable digit of the chelicerae is very long, often whip-like and recurved proximally. A pair of stigmata is located near the base of the chelicerae, where the peritremes arise. The palps are five-segmented. The palp-tarsus and tibia often form a thumb-claw process. The tarsus often has an enlarged distal eupathidium (spinneret) in the Tetranychinae and this is used to spin webbing in many species. The size and shape of the spinneret is of taxonomic significance. The idiosoma is often covered with a striate cuticle. The pattern of the striation and the shape/density of lobes distributed on the striae are useful diagnostic characters.

There are three or four pairs of normal setae in two rows (*v*1-2, *sc*1-2) and two pairs of eyes on the dorsal propodosoma. On the opisthosomal dorsum, there are five rows of setae: *c*, *d*, *e*, *f* and *h*. The number, location, length and structure of dorsal setae are of taxonomic significance. Female genital pores are transverse and are bordered anteriorly by a genital flap and laterally by characteristic cuticular folds. The structures of the paired lateral claws and the medial empodium are of taxonomic importance. The empodium may be claw-like or pad-like with tenant hairs. Claws may bear dorsal or ventral hairs. The tarsi of legs I and II bear duplex setae (a long solenidion and a short normal tactile seta with their bases joined together. The number of duplex setae and their positions are of taxonomic significance.

Wedge-shaped males are smaller than ovoid females and have a tapering opisthosoma. Males have a protrudable aedeagus, the shape of which is very important in species identification.

Life history and biology: as other Prostigmata mites, the spider mite life cycle consists of egg, larva, protonymph, deutonymph and adult stages, except for some *Schizotetranychus* and *Eotetranychus* species, which may have one nymphal stage in males (Zhang 2003). Moulting takes place during the quiescent stages between each active stage. Development from egg to adult often takes one to two weeks or more, depending on mite species, temperature, host plants, humidity and other environmental factors. Males develop slightly faster than females and soon they search for and fight for quiescent deutonymph females. Unfertilized eggs produce only haploid males, while fertilized eggs produce diploid females.

3.1 Spider mite species of economic importance in South America

3.1.1 *Tetranychus urticae* Koch

The two-spotted spider mite (TSSM) is considered one of the most harmful tetranychid species in agriculture both in temperate or tropical countries (Cerna *et al.* 2009, González Zamora *et al.* 1993). Although a recent checklist includes some 920 host plant species in 70 genera (Bolland *et al.* 1998), only 150 of these host species have relevant economic value. The TSSM feeds on cell chloroplast on the underside of the leaves and symptoms become clearly visible on the upper side as characteristic whitish or yellowish punctures which, under high population levels, can join and become brownish o even cause leaf drop and plant death (Tomczyk & Krompczyńska 1985, Zhang 2003).

Due to its relevance and economic impact on tropical agriculture in South America, the TSSM has been the most extensively studied spider mite species. A number of papers related to biological aspects of the TSSM are available (Table 1).

Host Plants	Life cycle (days)	N° eggs/female/day	Longevity (days)	Reference
Sweet pepper	8.2 (27°C, 70% RH)	2.6	12.2	Gallardo *et al.* (2005)
Cotton	Non Bt 7.5 Bt 7.3 (25°C, 57.4% RH)		Non Bt: 16.7 Bt: 16.6	Esteves Filho *et al.* (2010)
Gerbera	21.6 (25°C, 70% RH)	3.75	8.83	Silva *et al.* (2009)

Table 1. Some biological parameters of the TSSM in various host plant and environmental conditions in South America.

Population management: For decades population management of tetranychid mites has been based mostly on chemical control in South America. However, biological control is being increasingly used under greenhouse conditions, mainly in Argentina, Brazil, and Colombia. In Colombia reductions of TSSM population on rose trees have been observed after periodical release of *Neoseiulus* sp. (Forero *et al.* 2008). Even though a lower number (19.4%) of phytophagous mites was found in plots chemically treated, a lower percentage (damage index 1 and 3, 8 and 13% less, respectively) of leaf damage was observed when *Amblyseius* sp. was released. On the other hand, the consumption rate (functional response) after a 24 h. period was 6.66 eggs, 18.06 larvae, and 19.15 nymphs under laboratory conditions and 4.56 eggs, 12.65 larvae, and 15.71 nymphs under greenhouse conditions (Forero *et al.* 2008). Greco *et al.* (2005) found that *Neoseiulus californicus* (McGregor) is a promising agent for successful TSSM control through conservation techniques, on strawberry crops in La Plata, Argentina. Accordingly, the authors showed that initial relative densities had an important effect on system dynamics. Thus, when pest/predator ratio was 5/1 (at initial pest densities from 5 to 15 females/leaflet) the final number of active *T. urticae*/leaflet was significantly lower than the economic threshold level (ETL), while at 20 females/leaflet this number did not differ from the ETL. At 7.5/1 ratio, the final number of active *T. urticae*/leaflet, at initial pest densities from 5 to 15 females/leaflet, reached the ETL without surpassing it. At 10/1 and 15/1 ratios, pest densities exceeded the ETL only at 15 initial *T. urticae*/leaflet. Since *N. californicus* showed to be very effective in limiting pest densities, conservation of this predator promoting favorable pest/predator ratios may result in early control of *T. urticae*.

Furthermore, *Phytoseiulus macropilis* (Banks) demonstrated a positive functional response (increases prey consumption). However, all indices evaluated showed that *P. macropilis* was unavailable to control the TSSM efficiently when the population numbers were low, possibly to keep itself in an environment with low populations (Ferla *et al.* 2011). Biological control by this predator is more efficient when five or more prey items are present at a given time.

3.1.2 *Tetranychus cinnabarinus* (Boisduval)

This species is commonly known as the carmine spider mite and it is associated with more than 120 host plant species such as cotton, strawberry, tomato, eggplant, and also ornamental species and fruit trees (Biswas *et al.* 2004). In Chile, the carmine spider mite is commonly found on carnation, strawberry, melon and beans from Arica, Parinacota and dessert areas where chemical control is frequently used (Klein & Waterhouse 2000).

Tello *et al.* (2009) found that the life cycle (egg-adult) of *T. cinnabarinus* on carnation var. Celta lasted 12.8 days (29.4 °C, 42.3 RH and 14:10 h (L:D) photo phase) and female longevity and mean daily oviposition rate were 24.28 days and 3.92 eggs/female/day, respectively. Under these conditions life table parameters were as follows: the intrinsic rate of increase (r_m) 0.183; the finite rate of increase (λ) 1.201 individuals/female/day; the mean generation time (T) was 20.24 days; and the net rate of reproduction (R_0) was 40.809.

Control strategies: most efforts to control pest population densities under threshold levels have relied on chemical tactics; however, particular attention has been paid to other management strategies in last decades, including resistant cultivars. So far, kidney bean has shown moderate resistance to other arthropod pests such as thrips (Cardona *et al.* 2002) and it seems to be based on antixenosis and antibiosis mechanisms (Frei *et al.* 2003). In general, these defense mechanisms are considered plant responses to stressing conditions either abiotic (drought, salinity) or biotic (herbivore or pathogens attacks), which induce the development of physical barriers to prevent feeding or secondary metabolites affecting oviposition or survival (Tomczyk & Krompczyńska 1985, Gardner & Agrawal 2002). Vásquez *et al.* (2007) observed that mean oviposition of *T. cinnabarinus* females was significantly lower on 22-day-old-leaf disks, ranging from 0.98 to 1.17 eggs/female/day on ICA-Pijao and Coche beans cultivars, respectively (Table 2), while females reared on 55 day-old leaf disks oviposition increased about 58 or 95%

		Number of eggs/female	
		22 day-old	55 day-old
Cultivar	n		
Tacarigua	25	1.16 a ± 0.7342 (34)	1.66 b ± 0.8119 (72)
Coche	25	1.17 a ± 0.5905 (30)	1.86 b ± 0.7126 (86)
ICA-Pijao	25	0.98 a ± 0.3852 (15)	1.92 b ± 0.8907 (99)

Values in a file followed by same letter did not show significant differences (Tukey's Test; P<0.05) Number in parenthesis represent total egg number during a five day period. From Vásquez *et al.* (2007).

Table 2. Oviposition (mean ± S.D.) of *T. cinnabarinus* on 22 or 55 days-old leaf disks from different kidney bean cultivars.

In general *T. cinnabarinus* females showed a higher rate of survival on 22 day-old disks, ranging from 5.67 to 6.63 living individuals in Tacarigua and Coche leaves; while on 55 day-old leaves survival ranged from 5.42 to 1.80 on Coche and ICA-Pijao, respectively. A significant survival reduction was observed on mites reared on 55 day old leaf disks from ICA-Pijao cultivar (Fig. 1), suggesting that this cultivar could dissuade to mite from feeding, affecting thus mite survival.

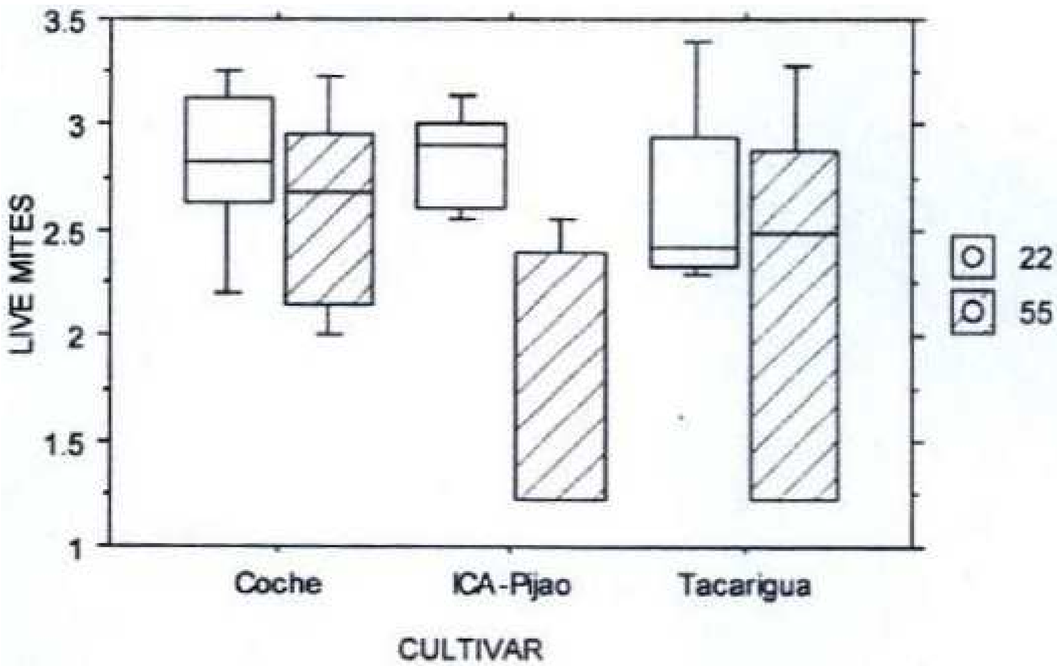


Fig. 1. Number of live mites on kidney bean cultivars on 22- or 55 day-old leaf disks. From Vásquez *et al.* (2007).

3.1.3 Red spider mites (*Tetranychus desertorum* Banks and *Tetranychus ludeni* Zacher)

The red spider mite, *T. desertorum* has been found on about 173 plant species in Argentina, Brazil, China, the United States of America, Mexico, Venezuela and some other countries (Bolland *et al.* 1998). This spider mite species might cause severe damage to bean plants, as *T. urticae* does (Moraes & Flechtmann 2008). In Venezuela, previous studies have demonstrated that bean cultivars are susceptible to *T. desertorum* attacks under irrigation conditions (Doreste 1984). Rivero & Vásquez (2009) showed that total developmental time of *T. desertorum* females on kidney bean 'Tacarigua' was 6.8 days, with partial duration of immature stages corresponding to 3.8, 1.4, 1.0 and 0.7 days for egg, larva, protonymph and deutonymph, respectively. Higher mean fecundity (6.93 eggs/female/day) was observed on day 4 and females lived during 10 days. The recorded life table parameters were as follows: net reproduction rate (Ro) = 41.10 individuals; generation time (T) = 11.15 days; intrinsic natural growth (rm) = 0.144 individuals/female/day, and finite natural increase rate (λ) = 1.155 individuals/female.

Furthermore, *T. ludeni* is a worldwide pest that attacks various plant species, such as *Phaseolus vulgaris* L., representing a severe threat in several countries, including Venezuela (Morros & Aponte 1994). According to these authors, the life cycle (egg-adult) of *T. ludeni* lasted 9.98 and 9.25 days for females and males, respectively (26.34± 3.92ºC and 69.44± 19.44% HR). The life table also showed the following values: reproduction rate (Ro) 77.42; mean generation time (T) 19.63; intrinsic rate of natural increase (r) 0.2526 individuals/female/day; finite rate of natural increase (λ) 1.2874 individual/female/week. Morros & Aponte (1995a, b) evaluated the effect of two levels of mite infestation on vegetative and reproductive stages of the black bean *P. vulgaris* under greenhouse and field conditions. The authors observed greater reduction on number of leaves and internodes, leaf area, and dry weight of vegetative organs when mite infestation occurred in the early vegetative stage (Table 3).

	Greenhouse		Field	
	Development stage			
	Vegetative	Reproductive	Vegetative	Reproductive
Foliar area (cm^2)	263.65	289.84	30.76	36.13
Number of leaves	22.83	25.00	34.54	45.72
Number of internodes	12.77	14.50	13.13	14.63
Dry leaf weight (g)	2.80	3.35	3.28	6.10
Dry plant weight (g)	1.61	1.80	2.41	3.83
Dry pod weight (g)	1.82	1.88	0.36	0.56
Total dry weight (g)	7.26	8.27	6.06	10.50

From Morros & Aponte (1995a, b).

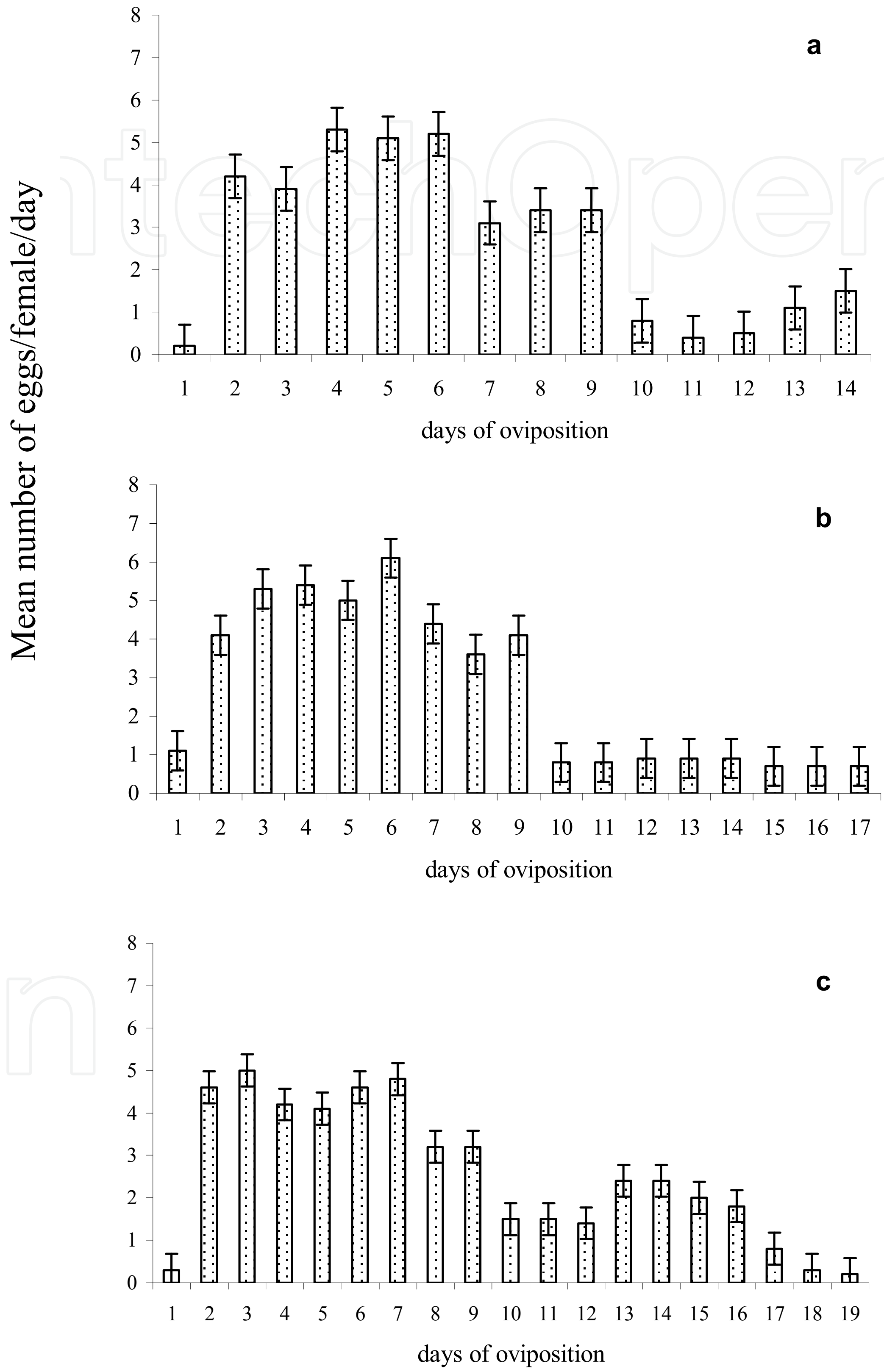
Table 3. Reductions of plant performance as effect of *T. ludeni* feeding on black beans in vegetative or reproductive stages under greenhouse and field conditions.

3.1.4 The avocado brown mite, *Oligonychus punicae* Hirst

The avocado brown mite (ABM) is considered an important tetranychid pest in southern California (USA), as high population densities can cause severe defoliation on several avocado cultivars (McMurtry & Johnson 1966; McMurtry 1985). This tetranychid mite predominantly feeds on the upper leaf surface, although feeding could extend to the lower leaf surface at high population levels (Tomczyk & Kropczynska 1985). Damage to host plants is shown by a bronze tone on the leaves, and is associated with the rates of oviposition and female production (McMurtry 1970).

In tropical America, the ABM has been reported in more than 20 plant species, such as *Mangifera indica* L., *Musa sapientum* L., *Punica granatum* L. and *Vitis vinifera* L. (Ochoa *et al.* 1994; Bolland *et al.* 1998). In Venezuela, it was previously recorded on *Musa* spp. from Sur del Lago, Zulia State (Freitez & Alvarado 1978; Quirós 1978). More recently, in Lara State, it has been observed as an occasional pest whose feeding on grape delays fruit ripening (Vásquez *et al.* 2008a). These authors provided information about life cycle, fecundity and longevity of the ABM on six grapevine cultivars (Tucupita, Villanueva, Red Globe, Sirah, Sauvignon and Chenin Blanc), under laboratory conditions at 27 °C, 80% RH, and L12:D12 photoperiod (Tables 4 and 5).

Periods of pre-oviposition, oviposition and post-oviposition in *O. punicae* females varied among grape cultivars. Shorter pre- and post-ovipositional periods were found on Chenin Blanc leaves (1.2 and 0.9 days, respectively), while on others cultivars these parameters ranged from 1.6–2.0 to 1.2–2.5 days, respectively (Table 5). Oviposition periods lasted from 6.7 days (on Villanueva) to 16.1 days (on Sauvignon). Average daily egg production was highest on Tucupita (2.8 eggs/female/day) and lowest on Sirah (0.9 eggs/female/day). Daily oviposition rate ranged from 2.0 to 6.1 eggs/female up to day 7 in females feeding on Tucupita leaves, while on Chenin Blanc, Red Globe, Sauvignon, Sirah and Villanueva leaves it varied from 1.1–6.1, 0.2–5.3, 0.3–5.0, 0.2–2.7 to 0.5–3.5 eggs/female, respectively (Fig. 2). Also, female longevity of *O. punicae* was affected by grape cultivar: females lived longest on Sauvignon (17.5 days), and shortest on Villanueva (8.1 days)


Mean number of eggs/female/day
a
0
1
2
3
4
5
6
7
8
1 2 3 4 5 6 7 8 9 10 11 12 13 14
days of oviposition
b
0
1
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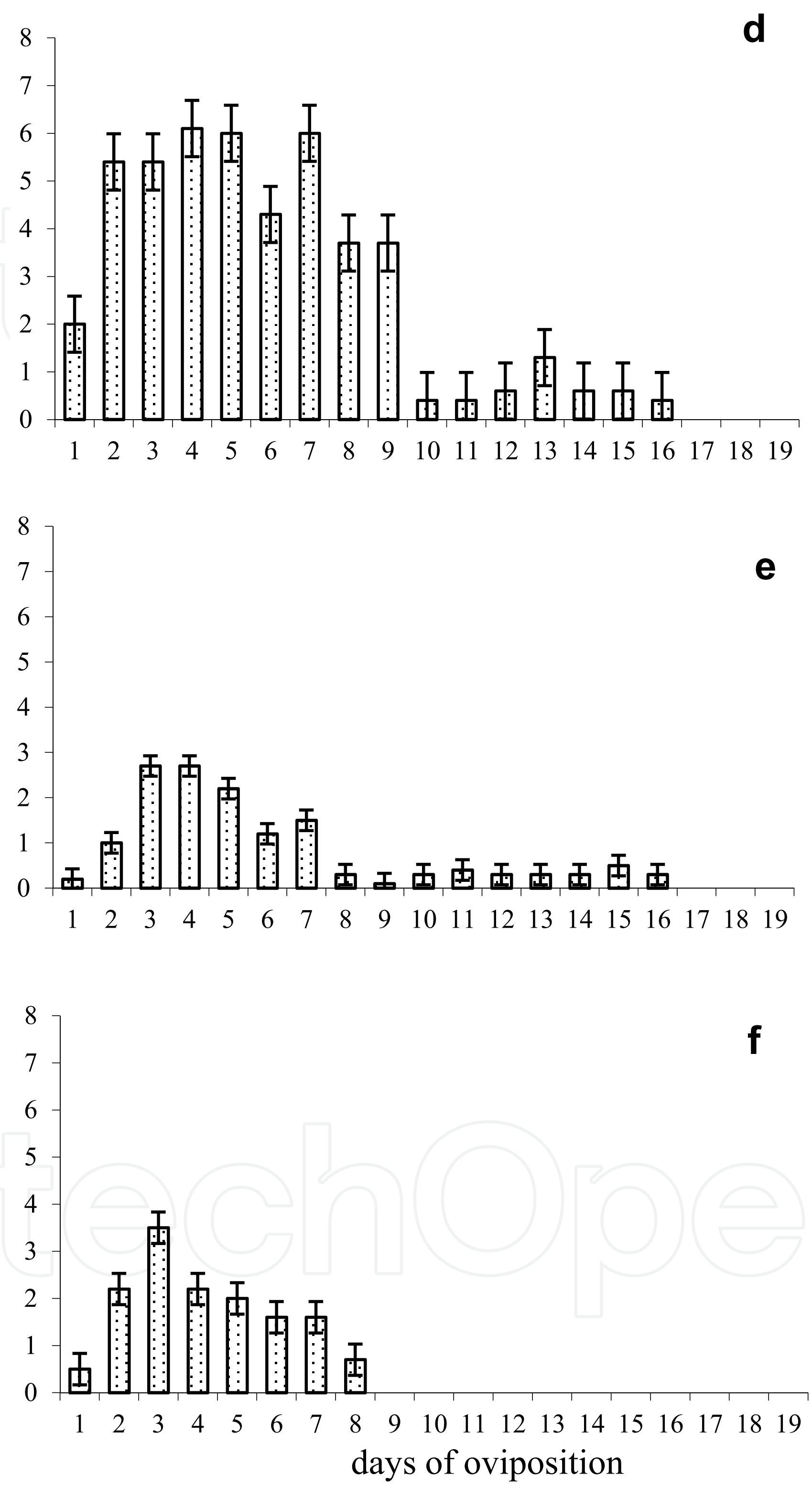


Fig. 2. Daily oviposition rate of *O. punicae* females feeding on grapevine leaves cultivars Red Globe (a), Chenin Blanc (b), Sauvignon (c), Tucupita (d), Sirah (e) and Villanueva (f).

	Mean duration (hours) ± SD					
Stages	Tucupita	Sauvignon	Villanueva	Red Globe	Chenin Blanc	Sirah
Egg	104.80± 5.9330a	106.50± 7.5498a	112.80± 5.215a	105.20± 8.438a	105.60± 6.066a	111.20± 3.347a
Larva	22.40± 1.3416ab	20.25± 4.1130b	22.40± 1.949ab	21.00± 6.042b	29.60± 4.775a	27.60± 4.506ab
Protochrysalis	11.80± 1.4832ab	15.75± 3.403a	10.80± 1.304b	13.80± 3.115ab	13.40± 1.517ab	11.60± 1.517ab
Protonymph	13.00± 2.8284b	14.75± 2.363ab	15.60± 6.229ab	19.00± 2.828ab	21.40± 4.930a	16.60± 5.413ab
Deutocrhysalis	11.80± 1.3038a	11.00± 0.8165a	11.80± 2.950a	12.20± 3.347a	13.50± 4.359a	11.60± 2.074a
Deutonymph	22.60± 2.7928a	17.00± 1.414a	23.60± 3.578a	21.80± 2.775a	20.00± 6.733a	24.40± 5.899a
Teliochrisalis	11.20± 1.9235ab	9.25± 3.403b	10.80± 1.924ab	15.00± 1.414a	11.25± 1.500ab	10.80± 2.683ab
Life cycle[a]	197.6± 4.5056b (8.16)	198.40± 8.5391b (8.27)	208.80± 4.5497ab (8.70)	209.20± 12.6770ab (8.72)	215.00± 13.7840ab (8.96)	217.20± 8.8148a (9.05)

Values in a row followed by the same letter are not significantly different according to the Tukey's multiple comparison differences (P=0.0036, df=5, F=4.78).
[a]Values in brackets, days to complete development. From Vásquez *et al.* (2008a).

Table 4. Developmental time of different life stages of *O. punicae* in various grapevine cultivars.

Cultivars	N	Longevity	Preoviposition[(1)]	Oviposition [(1)]	Postoviposition [(1)]	Daily fecundity[(2)]
Tucupita	10	12.60 ± 5.1897abc	1.20 ± 0.4216b	11.40 ± 3.2042bc	1.20 ± 0.4216ab	2.82 ± 2.4186a
Sauvignon	10	17.50 ± 4.8028a	1.80 ± 0.4216ab	16.10 ± 2.8460a	1.40 ± 0.8433ab	2.15 ± 1.4130bc
Red Globe	10	13.20 ± 3.3417abc	1.80 ± 0.4216ab	11.10 ± 2.6013bc	1.30 ± 1.0593ab	2.72 ± 1.9132ab
Chenin Blanc	10	14.40 ± 3.8930ab	1.20 ± 0.4216b	13.50 ± 3.3417ab	0.90 ± 1.1005b	2.16 ± 1.9949ab
Villanueva	10	8.10 ± 1.1972c	1.60 ± 0.6992ab	6.70 ± 1.1595d	1.40 ± 1.2649ab	1.79 ± 0.9433cd
Sirah	10	10.30 ± 3.4383bc	2.00 ± 0.6667a	7.90± 4.9318cd	2.50 ± 1.3540a	0.94 ± 0.9532d

[(1)]Transformed values by $y=\sqrt{x+0.5}$ [(2)] Transformed values by $y=\sqrt{x+1.5}$

Values in a column followed by different letter showed significant differences. P<0.05 (preovip: F=4.21; ovip: F=12.8; and postovip: F=2.36; df=5); P<0.001 (longevity: F= 7.05; df=5). From Vásquez *et al.* (2008a).

Table 5. Adult longevity, preoviposition, oviposition and postoviposition times (days) and fecundity (eggs/female/day) of *O. punicae* on several grapevine cultivars.

An effect of host plant on mite reproduction has been established for several Tetranychid species (e.g., de Ponti 1977; Ribeiro *et al.* 1988; Hilker & Meiners 2002; Praslička & Huszár 2004). Previous studies have demonstrated that grape leaves and fruits synthesize phenolic compounds in response to fungal attacks or abiotic factors (Morrissey & Osbourn 1999). Furthermore, Harborne (1994) hypothesized that low molecular weight phenol compounds could act synergistically with tannins to provide plant resistance. Thus, reproductive parameters of *O. punicae* seemed to be associated with flavonoid content of grape cultivars; the higher the flavonoids content, the lower the mites' fecundity (Fig. 3). These findings could be considered an ecological approach for sustainable pest management programs in grapevine in tropical areas.

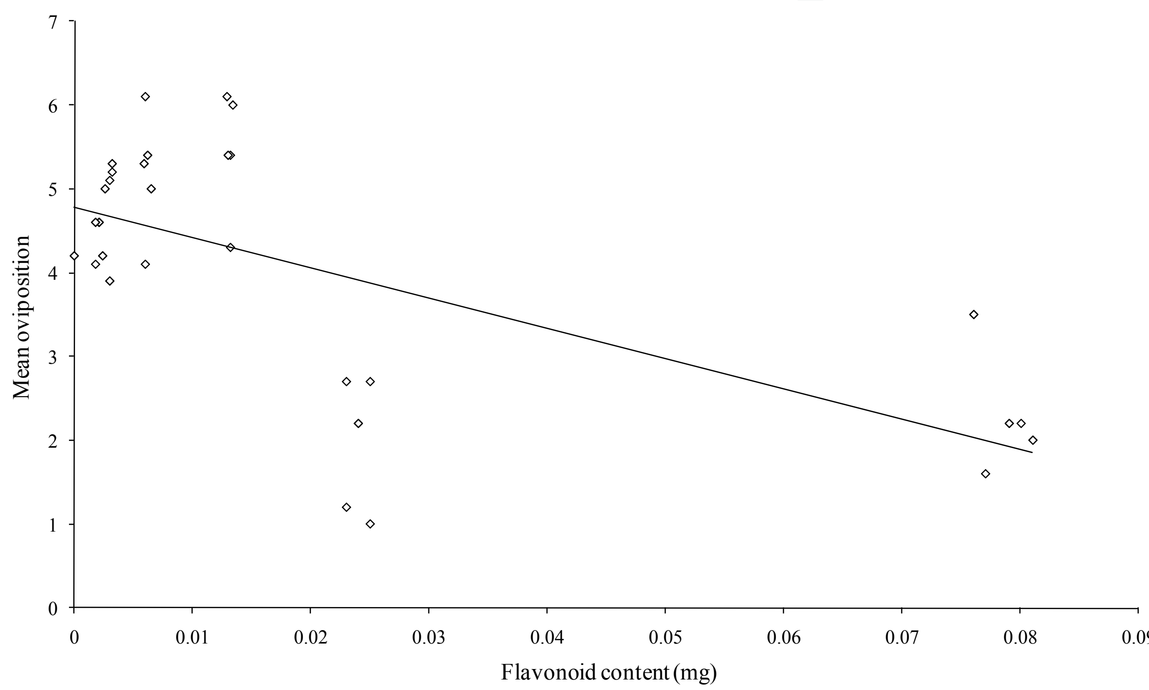


Fig. 3. Lineal regression between flavonoid content and mean oviposition of *O. punicae* on grapevine cultivars (y = 4.78 - 36.42x). From Vásquez *et al.* (2008a).

4. Tenuipalpidae mites

The false spider mites include about 800 described species belonging to over 25 genera, mostly found in tropical and subtropical areas (Jeppson *et al.* 1975, Baker & Tuttle 1987). This family consists of three subfamilies: Tegopalpinae, Brevipalpinae and Tenuipalpinae, the two latter ones including most of the described species: *Brevipalpus* and *Tenuipalpus* are the two largest genera and also the most economically important pest on citrus (Kitajima *et al.* 1972), coffee (Chagas *et al.* 2000), passion-fruit (Kitajima *et al.* 1997) and ornamentals (Smith-Meyer 1979). Since 2004, *Raoiella indica* Hirst is also becoming more important in the Caribbean islands and northern countries in South America (Vásquez *et al.* (2008b).

The false spider mites are also known as flat mites because most species are dorsoventrally flattened. They are slow-moving and are usually found on the lower surface of the leaves near the midrib or veins. Some species feed on the bark while others live in flower heads, under leaf sheaths or in galls. Only a small number of species belonging to a few genera have become pests of economic plants and they are most commonly found on tropical fruit crops and ornamental plants.

Life history and biology: Thelytoky is commonly observed in *Brevipalpus* mites, since female offspring consist in females and rarely males are found (Childers *et al.* 2001), being males and females haploid (Pijnacker *et al.* 1980). Life cycle of *Brevipalpus* is shown in figure 4, consisting in four active stages: larva, protonymph, deutonymph and adult; an inactive stage being observed between each active one. According to Goyal *et al.* (1985), developmental rate depends on temperature, relative humidity and host plant species.

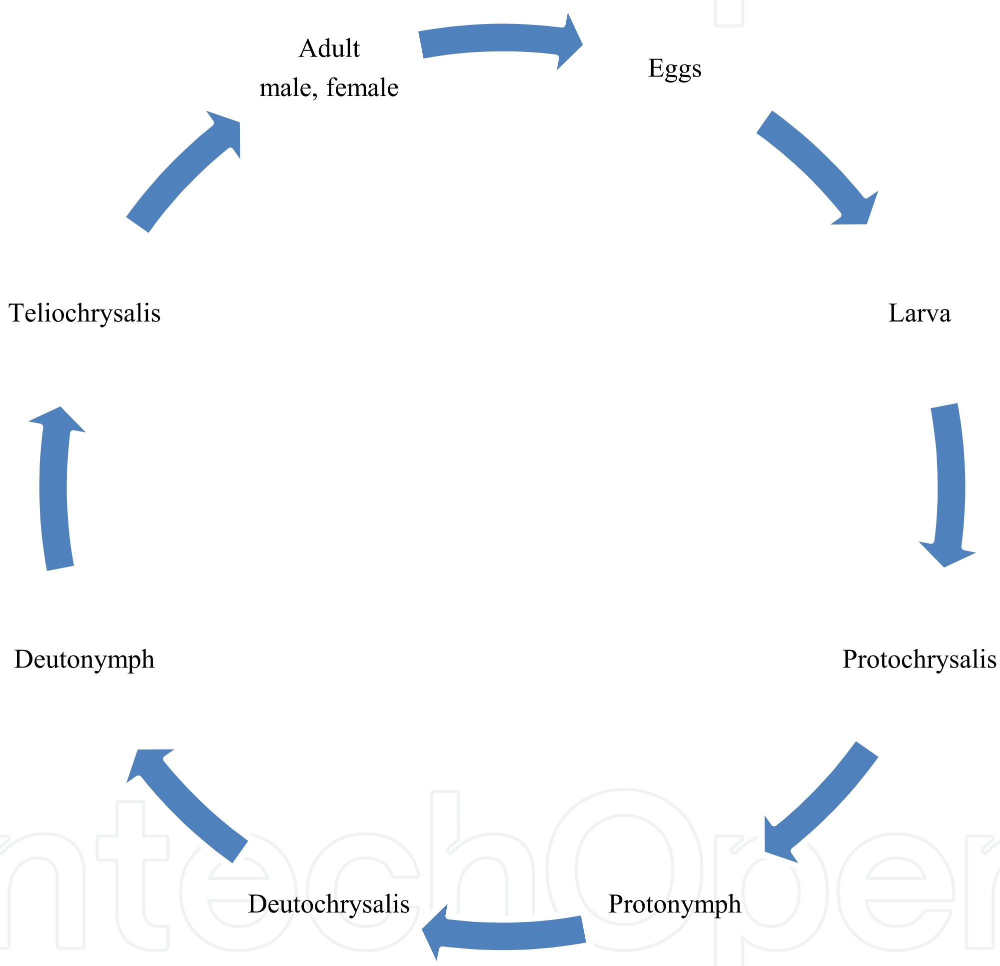


Fig. 4. Life cycle of *Brevipalpus* mites. From Childers *et al.* (2001).

4.1 Tenuipalpidae mite species of economic importance in South America

4.1.1 *Brevipalpus and Tenuipalpus* species

Brevipalpus californicus (Banks), *B. obovatus* (Donnadieu) and *B. phoenicis* (Geijskes) constitute the major economically important species in this genus. These mites usually feed on lower leaf surface and aggregate along the mid-vein or major lateral veins and they inject toxic saliva into fruits, leaves, stems, and bud tissues of their host plant, while *Tenuipalpus pacificus* Baker and

B. phoenicis have been observed feeding on the upper leaf surface of orchids (Childers *et al.* 2003). Ochoa *et al.* (1994) reported 177 host plant species in Central America, including 114 host plants for *B. phoenicis*, 29 for *B. californicus* and 34 for *B. obovatus*.

Probably the major threat related to these three *Brevipalpus* species is that concerning their ability to vectoring a virus borne disease called leprosis (Kitajima *et al.* 1996). Virus particles of citrus leprosis are short, bacilliform, 120–130 nm long (occasionally up to 300 nm), and 50–55 nm wide and occur mostly in parenchyma cells of the lesion area in affected orange leaves, fruits, or stems (Rodrigues *et al.* 2003). Leprosis is a serious disease on citrus from Brazil, Argentina, Paraguay and Venezuela, and probably Colombia and Uruguay (Childers *et al.* 2001). More recently, leprosis has been recorded in Panama (Dominguez *et al.* 2001) and it still represents a long term problem and causes severe damage on trees, yield reduction, and even death of trees if mite population control measurements are not taken into account (Rodrigues 2000).

4.1.2 The red palm mite, *Raoiella indica* Hirst

The red palm mite (RPM) was firstly reported in the Caribbean region in 2004 (Flechtmann & Etienne 2004). It is currently widely distributed in most of the Caribbean islands (Kane *et al.* 2005, Rodrigues *et al.* 2007). Subsequent mainland colonization was verified in Venezuela (Vásquez et al. 2008b) and Florida (Peña *et al.* 2008); and more recently, the pest has been reported to occur in Mexico (NAPPO 2009), Brazil (Návia *et al.* 2011) and Colombia (Carrillo *et al.* 2011). The RPM may cause severe damage to Arecaceae, especially coconut (*Cocos nucifera* L.), but also on Musaceae and other plant families (Flechtmann & Etienne 2004, Flechtmann & Etienne 2005, Etienne & Flechtmann 2006).

In coconut nurseries, mite feeding can provoke death of younger plants; meanwhile damage in adult plants is evidenced by a strong yellowish color in mature leaves (Peña *et al.* 2006, Welbourn 2005). After the red palm mite detection in the Americas, 70–75% fruit production decreasing has been estimated in Trinidad and Tobago and Venezuela (Návia 2008). Although the RPM primarily infests palms and bananas, some wild heliconia, gingers and other ornamental plant species growing under heavily infested coconut trees revealed small and sporadic colonies of the red palm mite (Roda 2008). However, according to Hoy *et al.* (2006), it is not clear whether these are valid host plants or whether the enormous mite populations on coconuts and other palms have temporarily moved on to substory plants under the palms.

Currently, the governments and researchers from those countries where the RPM has been recorded are making efforts to implement an alternative to pest management different from that of chemical control, since application of chemical products is not only hazardous to environment and public health, but also expensive. Thus, research is devoted to test the effectiveness of the predatory mite, *Amblyseius largoensis* Muma, the most frequent phytoseiid mite species found in association to the RPM in the Caribbean islands and Venezuela. Preliminary research has shown that this predator seems to be a promising agent of biological control (Carrillo *et al.* 2010, Rodríguez *et al.* 2010). However, when being considered in a population management program, other ecological strategies should also be included, such as using plant resistance from different genotypes which have been obtained in northern Venezuela by Dr. Antonio Ruiz (Instituto Nacional de Investigaciones Agrícolas [INIA-Irapa]), organic or inorganic fertilization programs in order to reestablish soil fertility and lastly, irrigation to avoid abiotic stress in old and young coconut plantations.

5. Eriophyid mites

The Eriophyoidea is a large superfamily of worldwide distribution. About 3,000 species belonging to over 250 genera are known in the world and a number of new species have been recently described from natural vegetation in South America (Table 6). The superfamily consists of three families: Phytoptidae, Diptilomiopidae and Eriophyidae. About three-quarters of the described species in Eriophyoidea belong to the Eriophyidae.

Species	Host plant	Country	Reference
Abacarus nectandrae *Aceria megalops*	*Nectandra membranacea* (Lauraceae) *Guapira opposita* (Nyctaginaceae)	Brazil	Flechtmann & Moraes (2002b)
Acalitus santibanezi	*Ipomoea murucoides* (Convolvulaceae)	Mexico	García-Valencia & Hoffmann (1997)
Aceria anisodorsum	*Caesalpinia peltophoroides* (Leguminosae)	Brazil	Flechtmann & Santana (2007)
Aceria coussapoae *Shevtchenkella desmodivagus* *Cosella ceratopudenda*	*Coussapoa microcarpa* (Cecropiaceae) *Desmodium barbatum* (Leguminosae) *Piptadenia gonoacantha* (Leguminosae).	Brazil	Flechtmann & Moraes (2002a)
Aceria inusitata	*Caesalpinia echinata* (Leguminosae)	Brazil	Britto *et al.* (2008)
Amrineus cocofolius	*Cocos nucifera* (Arecaceae)	Brazil	Flechtmann (1994)
Dichopelmus ibapitanga	*Eugenia uniflora* (Myrtaceae)	Brazil	Reis *et al.* (2010)
Epitrimerus torus *Epitrimerus angustisternalis*	*Acalypha reptans* (Euphorbiaceae) *Bougainvillea spectabilis* (Nyctaginaceae)	Brazil	Flechtmann (2010)
Juxtacolopodacus phalakros *Procalacarus perporosus* *Scolotosus centrolobii* *Scolotosus hartfordi* *Metaculus tanythrix*	*Mollinedia clavigera* (Monimiaceae) *Randia armata* (Rubiaceae) *Centrolobium robustum* (Leguminosae) *Centrolobium tomentosum* (Leguminosae) *Dicksonia sellowiana* (Dicksoniaceae)	Brazil	Flechtmann & De Queiroz (2010)
Tetra tarabanensis	*Bulnesia arborea* (Zygophyllaceae)	Venezuela	Flechtmann & Vásquez (2007)

Table 6. Some eriophyoid mite species recently described from South America.

Eriophyoid mites are tiny worm-like or fusiform mites and they form galls or live freely on various host-plants (Royalty & Perring 1996; Westphal & Manson 1996). The wounding and injecting of specific salivary secretions into host-cells result in a specific response of the affected leaf, stem, or bud tissues; such as gall differentiation, hypersensitive reaction, or non-distortive feeding effects and in some cases complex symptoms, considered as syndromes (Petanović & Kielkiewicz 2010). Most species are monophagous and many species are limited to plant species within a single genus, with few exceptions (Zhang 2003). Most species cause little harm to their host plants, however, some rust mites and gall mites are important pests on economic plants.

Life cycle: Eriophyid mites passes through the egg, larva, nymph and adult stages. Both females and males complete their life cycle in about a week at an average temperature of around 25°C. The mating process is indirect, since male deposits spermatophores on host plants, and then the genital flap in the female presses the spermatophore into the body and crushes it. Females lay up to three eggs per day for up to a month, with a total of up to 87 eggs per female.

5.1 Eriophyid mite species of economic importance in South America

5.1.1 The coconut mite, *Aceria guerreronis* Keifer

The coconut mite is an invasive mite pest that has been disseminated and established rapidly in main coconut (*C. nucifera*) production areas (Návia *et al.* 2009) causing copra yield reductions, premature dropping of fruit (Moore & Howard 1996). *A. guerreronis* is mostly found in the meristematic region of fruit, under the perianth (Fernando *et al.* 2003). Development of colonies usually starts at earlier stages of fruit formation, resulting in discolored areas that frequently become larger and necrotic, longitudinal cracks and eventually producing an exudate (Haq *et al.* 2002). In addition to fruit damage, this mite attacks the growing tip of plantlets, turning it dark brown and often causing death of attacked plants in Brazil (Aquino *et al.*1968).

Despite the great economic importance of the coconut mite, information on basic aspects is scarce. Acording to Moraes & Zacarias (2002), the use of biological control agents based on the location of the *A. guerreronis* are crucial tools to manage this mite pest.

5.1.2 Tomato russet mite, *Aculops lycopersici* (Masse)

The tomato russet mite (TRM) is cosmopolitan in distribution and widespread in almost all areas where solanaceous crops are grown (Jeppson *et al.* 1975). This eriophyoid is one of the most common key pests of the commercially grown tomato, *Lycopersicon esculentum* Mill on a worldwide scale. In addition, the TRM host range includes tomatillo, potato, eggplant, poha (cape gooseberry), wild blackcurrant, popolo, wild gooseberry, blackberry, tobacco, bell pepper, cherry pepper, tolguacha, eggplant, Jerusalem cherry, hairy nightshade, black nightshade, horse nettle, morning glory, Jimson weed, Chinese thorn apple, petunia, nightshade, small flowered nightshade, amethyst, field bindweed, and Brinjal (Perring 1996). According to Duso *et al.* (2010), it is important to investigate: (a) TRM bioecological data useful to improve control strategies; (b) the different specialized intimate interactions that TRM establishes with different plants and/or different areas of the same plant; (c) the strength of the biochemical and physiological mechanisms/steps determining the intensity of closeness/dependence with the host plant.

6. Tarsonemid mites

The Tarsonemidae includes about 545 species of 45 genera widely distributed. This family consists of three subfamilies: Pseudotarsonemoidinae, Acarapinae and Tarsoneminae; the latter including most of the described species in the two large genera: *Tarsonemus* (over 270 species) and *Steneotarsonemus* (over 70 species). Tarsonemid mites exhibit various feeding habits, some species feed on fungus, algae, plants, and some of them can prey on parasite insects (Moraes & Flechtmann 2008). Some plant-feeding tarsonemid mites are pests of agricultural crops, most of them belonging to a few genera in the Tarsoneminae, except for the *Polyphagotarsonemus*. Since Tarsonemid mites feed on surface cells, more significant damage is observed in young tissues of the host plant. Symptoms are characterized by leaf discoloration with a silver aspect. Expanding leaves became shriveled or curled and eventually shed and plants severely attacked stop growing. Occasionally, plant tissue ontogeny is altered due to toxins injected.

Life history and biology: Tarsonemid mites are haplodiploid, being males produced by arrhenotoky and females by sexual reproduction; however, thelytoky has also been observed (Norton *et al.* 1993). Its life cycle consists of egg, larva, "pupa" and adult (male and female) stages, but "pupa" is an inactive stage in which the nymph stage takes place.

Polyphagotarsonemus latus (Banks) is undoubtedly the most important pest of many crops and ornamentals in field or greenhouses worldwide. This species disperses by wind, human transport of infested products and also through insects living on plants. *P. latus* females have been observed as phoront on *Bemisia tabaci* (Gennadius) on beans (*P. vulgaris*) in Colombia and on cucumber (*Cucumis sativus* L.) var. poinsett-76 and sesame (*Sesamun indicum* L.) var. INIA-1 in Venezuela (Bautista *et al.* 2005).

Life-history traits depend on temperature, host plants and even on varieties. On pepper, the developmental period (egg – adult) is, as an average, 4.1 days at 25°C for males and females, respectively. Adult female and male longevity is 11 and 15 days, respectively. The female/male sex ratio is 2.8 in the laboratory, and 2.3 on seedlings in a greenhouse. The intrinsic rate of increase is 0.359, the finite rate of increase is 1.43 individuals/female/day, the mean generation time 10.34 days and the net reproductive rate 41.0.

Tarsonemid mites of the genus *Steneotarsonemus* are phytophagous and specialized on monocotyledon plants (Lindquist 1986; Almaguel *et al.* 2000). In America, *Steneotarsonemus spinki* Smiley is considered the most destructive pest mite in rice ever (Rodríguez *et al.* 2009). In 1997, the rice mite was first reported in Cuba (Ramos & Rodríguez 1998), causing about 30 – 90% yield (Almaguel *et al.* 2000). Soon, *S. spinki* spread to the Caribbean (Haiti, Dominican Republic and Puerto Rico), Central America (Panama, Costa Rica, Nicaragua, Honduras and Guatemala), South America (Colombia and Venezuela) and North America (Mexico and USA) (Rodríguez *et al.* 2009, Sandoval *et al.* 2009). Although the rice mite has been detected in rice fields in Venezuela, important mite infestation focuses have not been observed to affect rice production in this country.

Pest control: Most information about control strategies of this species has been compiled in Cuba. In this country, nine predator species have been found, 4 Phytoseiid, 3 Ascid and 2 Laelapid species (Table 7).

Mite family	Species
Phytoseiidae	*Neoseiulus baraki*
	Neoseiulus paraibensis
	Proprioseiopsis asetus
	Neoseiulus paspalivorus
Ascidae	*Aceodromus asternalis*
	Asca sp.
	Proctolaelaps sp.
Laelapidae	*Aceodromus asternalis*
	Hypoaspis sp.

From Rodríguez *et al.* (2009).

Table 7. Predatory mites associated to *S. spinki* in rice fields in Cuba.

Another important tarsonemid species, *Steneotarsonemus furcatus* De Leon has been found on coconut, damaging fruit in Central America and in Brazil (Ochoa *et al.* 1994, Návia *et al.* 2005) and various gramineous species in Cuba (La Torre *et al.* 2005), and more recently, *Steneotarsonemus concavuscutum* Lofego & Gondim was examined on coconut in northeastern Brazil (Lofego & Gondim 2006).

7. Conclusions

In South America, there is a significant volume of literature dealing with taxonomy, biology and crop damage caused by phytophagous mites on agricultural crops. Research has provided a great deal of valuable information about their impact on several important crops in Brazil, Colombia, Mexico and Venezuela. At present, a multi-institutional and multi-disciplinary project on the biological control of the coconut mite in Tropical America is being developed. As a preliminary step, some explorations have been conducted in target countries to assess the abundance of the coconut mite, the diversity and prevalence of the natural enemies associated with this pest, and to evaluate the potential of these natural enemies as biological control agents for their use in the IPM programs. In addition, much work has been carried out to determine other host plants of the coconut mite and its natural enemies. Furthermore, some Government and Research Institutions from Brazil, Trinidad and Tobago and Venezuela are making efforts to find some ecological strategies to control the Red Palm Mite *Raoiella indica* Hirst (Acari: Tenuipalpidae), and thus minimize its impact on commercial coconut farms and other important crops in tropical areas.

8. References

Almaguel L, Hernández, J, Torre P de la, Santos A, Cabrera RI, García A, Rivero LE, Báez L, Cáceres I, Ginarte A. (2000) Evaluación del comportamiento del ácaro

Steneotarsonemus spinki (Acari: Tarsonemidae) en los estudios de regionalización desarrollados en Cuba. Fitosanidad, 4, 15 – 19.

Aquino MLN, Flechtmann CHW, Arruda GP (1968) Contribuição ao estudo do ácaro causador da necrose do olho do coqueiro em Pernambuco e seu controle. Recife, IPA, 17 pp. (Boletim Técnico, 34).

Baker AE, Tuttle M (1987) The false spider mites of Mexico (Tenuipalpidae: Acari) U.S. Department of Agriculture, Technical Bulletin No, 1706, 237 pp.

Bautista L, E Arnal, O Aponte (2005) Relación forética de *Polyphagotarsonemus latus* (Banks) (Acari: Tarsonemidae) y adultos de *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae). Entomotropica, 20(1): 79 – 80.

Biswas GC, Islam W, Haque MM, Saha RK, Hoque KMF, Islam MS, Haque ME (2004) Some biological aspects of carmine mite, *Tetranychus cinnabarinus* Boisd. (Acari: Tetranychidae) infesting egg-plant from Rajshahi. Journal of Biological Sciences, 4 (5): 588 – 591.

Bolland HR, Gutierrez J, Flechtmann CHW (1998) World catalogue of the spider mite family (Acari: Tetranychidae). Leiden, Koninklijke Brill NV, 408 pp.

Britto EPJ, Gondim Jr. MGC, Návia D (2008) A new deuterogynous eriophyid mite (Acari: Eriophyidae) with dimorphic males from *Caesalpinia echinata* (Caesalpiniaceae) from Brazil: description and biological observations. International Journal of Acarology, 34 (3): 307 – 316.

Cardona C, Frei A, Bueno JM, Díaz J, Gu H, Dorn S (2002) Resistance to *Thrips palmi* (Thysanoptera: Thripidae) in beans. Journal of Economic Entomology, 95: 1066 – 1073.

Carrillo D, Návia D, Ferragut F, Peña JE (2011) First report of *Raoiella indica* (Acari: Tenuipalpidae) in Colombia. Florida Entomologist, 94(2): 370 – 371.

Carrillo D, Peña JE, Hoy MA, Frank JH (2010) Development and reproduction of *Amblyseius largoensis* (Acari: Phytoseiidae) feeding on pollen, *Raoiella indica* (Acari: Tenuipalpidae), and other microarthropods inhabiting coconuts in Florida, USA. Experimental and Applied Acarology, 52(2): 119 – 129.

Cerna E, Landeros J, Ochoa Fuentes YM, Luna Ruiz J, Vázquez Martínez O, Ventura López O (2009) Tolerancia del ácaro *Tetranychus urticae Koch* a cuatro acaricidas de diferente grupo toxicológico. Investigación y Ciencia, 44 (4-10): 4-10.

Chagas CM, Rossetti V, Colariccio A, Lovisolo O, Kitajima EW, Childers CC (2000) *Brevipalpus* mites (Acari: Tenuipalpidae) as vectors of plant viruses. *In:* Int. Congress Acarology (10, 2000, Melbourne). Halliday, RB; Walter, DE; Proctor, HC; Norton, RA; Colloff, MJ. (Eds) Proceedings. CSIRO Pub.

Childers CC, French JV, Rodrigues JCV (2003) *Brevipalpus californicus*, *B. obovatus*, *B. phoenicis*, and *B. lewisi* (Acari: Tenuipalpidae): a review of their biology, feeding injury and economic importance. Experimental and Applied Acarology, 30 (1-3): 5 – 28.

Childers CC, Kitajima EW, Welbourn WC, Rivera C, Ochoa R (2001) *Brevipalpus* como vectores de la leprosis de los cítricos. Manejo Integrado de Plagas, 60: 61 – 65.

de Ponti O (1977) Resistance in *Cucumis sativus* L. to *Tetranychus urticae* Koch. II. Designing a reliable laboratory test for resistance based on aspects of the host–parasite relationship. Euphytica, 26: 641 – 654.

Domínguez FS, Bernal A, Childers CC, Kitajima EW (2001) First report of the citrus leprosis virus in Panama. Plant Disease (Disease Notes), 85(2): 228.

Doreste E (1984) Acarología. San José, Instituto Interamericano de Cooperación para la Agricultura, 391pp.

Duso C, Castagnoli M, Simoni S, Angeli G (2010) The impact of eriophyoids on crops: recent issues on *Aculus schlechtendali*, *Calepitrimerus vitis* and *Aculops lycopersici*. Experimental and Applied Acarology, 51 (1-3): 151 – 168.

Esteves Filho, AB, Oliveira JV de, Torres, JB, Gondim Jr, MGC (2010) Biologia comparada e comportamento de *Tetranychus urticae* Koch (Acari: Tetranychidae) e *Phytoseiulus macropilis* (Banks) (Acari: Phytoseiidae) em algodoeiro bollgardTM e Isolinha não-Transgênica. Neotropical Entomology, 39 (3): 338 – 344.

Etienne J, Flechtmann CHW (2006) First record of *Raoiella indica* (Hirst, 1924) (Acari: Tenuipalpidae) in Guadalupe and Saint Martin, West Indies. International Journal of Acarology, 32: 331-332.

Evans GO (1992) Principles of acarology. CAB International. Wallindford, UK. 563 pp.

Ferla NJ, Marchetti M, Johann L, Haetinger C (2011) Functional response of *Phytoseiulus macropilis* under different *Tetranychus urticae* (Acari: Phytoseiidae, Tetranychidae) population density in laboratory. Zoologia (Curitiba), 28 (1): 17 – 22.

Fernando LCP, Aratchige NS, Peris TSG (2003) Distribution patterns of coconut mite, *Aceria guerreronis*, and its predator *Neoseiulus aff. paspalivorus* in coconut palms. Experimental and Applied Acarology, 31: 71 – 78.

Flechtmann CHW (1994) *Amrineus cocofolius* n.g., n.sp. (Acari: Eriophyidae) from Brazil. International Journal of Acarology, 20(1): 57 – 59.

Flechtmann CHW (2010) Two new *Epitrimerus* Nalepa (Eriophyidae, Prostigmata) species from Brazil and further remarks on the immature stages of a few eriophyoid species. Systematic & Applied Acarology, 15: 71 – 80.

Flechtmann CHW, de Queiroz DL (2010) New taxa in the Eriophyidae (Acari, Prostigmata) from forest trees in southern Brazil. Zootaxa, 2337: 18 – 30.

Flechtmann CHW, Etienne J (2004) The red palm mite, *Raoiella indica* Hirst, a threat to palms in the Americas (Acari: Prostigmata: Tenuipalpidae). Systematic and Applied Acarology, 9:109-110.

Flechtmann CHW, Moraes de, GJ (2002a) New Brazilian eriophyid mites (Acari: Eriophyidae). Zootaxa, 75: 1 – 12.

Flechtmann CHW, Moraes de, GJ (2002b) Three new species of eriophyid mites (Acari: Eriophyidae) from the State of São Paulo, Brazil. Zootaxa, 23: 1 – 8.

Flechtmann CHW, Santana DLQ (2007) A new deuterogynous eriophyid mite (Acari: Eriophyidae) from a semideciduous tree in Southern Brazil. International Journal of Acarology, 33(2): 129 – 132.

Flechtmann CHW, Vásquez C (2007) A new species and new records of plant mites of *Bulnesia arborea* (Zygophyllaceae) from Venezuela. Boletín del Centro de Investigaciones Biológicas, 40 (1): 57 – 67.

Flechtmann, CHW, Etienne J (2005) Un nouvel acarien ravageur des palmiers: En Martinique, premier signalement de *Raoiella indica* pour les Caraïbes. Phytoma, 548: 10-11.

Forero, G, Rodríguez M, Cantor F, Rodríguez D, Cure JR (2008) Criterios para el manejo de *Tetranychus urticae* Koch (Acari: Tetranychidae) con el ácaro depredador *Amblyseius*

(*Neoseiulus*) sp. (Acari: Phytoseiidae) en cultivos de rosas. Agronomía Colombiana, 26 (1): 78 – 86.

Frei A, Gu H, Bueno J, Cardona C, Dorn S (2003) Antixenosis and antibiosis of common beans to *Thrips palmi* Karny (Thysanoptera: Thripidae). Journal of Economic Entomology, 96: 1577 – 1584.

Freitez F, Alvarado G (1978) Contribución al conocimiento de ácaros en Musaceae de Venezuela (Acarina). Revista de la Facultad de Agronomía, 26:197–207.

Gallardo A, Vásquez C, Morales J, Gallardo S (2005) Biología y enemigos naturales de *Tetranychus urticae* en pimentón. Manejo Integrado de Plagas y Agroecología, 74: 34 – 40.

García-Valencia AS, Hoffmann A (1997) Especie nueva de ácaro eriófido en México (Prostigmata: Eriophyidae). Anuales del Instituto de Biología de la Universidad Nacional Autónoma de México, serie Zoológica, 6 (2): 253 – 260.

Gardner SN, Agrawal AA (2002) Induced plant defense and the evolution of counter-defense in herbivores. Evolutionary Ecology Research, 4: 1131 – 1151.

González Zamora JE, García-Marí F, Ribes A, SaquésJ, Masiello L, Orenga S (1993) Métodos de muestreo binomial y secuencial para *Tetranychus urticae* Koch (Acari: Tetranychidae) y *Amblyseius californicus* (McGregor) (Acari: Phytoseiidae) en fresón. Boletín de Sanidad Vegetal y Plagas, 19: 559-586.

Goyal M, Sadana GL, Sharma NK (1985) Influence of temperature on the development of *Brevipalpus obovatus* (Acarina:Tenuipalpidae). Entomon, 10: 125 – 129.

Greco NM, Sanchez NE, Liljesthrom GG (2005) *Neoseiulus californicus* (Acari: Phytoseiidae) as a potential control agent of *Tetranychus urticae* (Acari: Tetranychidae): effect of pest/predator ratio on pest abundance on strawberry. Experimental & Applied Acarology, 37:57 – 66.

Haq MA, Sumangala K, Ramani N (2002) Coconut mite invasion, injury and distribution, pp. 41 – 49. *In*: LCP Fernando, GJ Moraes & IR Wickramananda (Eds.), Proceedings of the International Workshop on Coconut Mite (*Aceria guerreronis*). Sri Lanka, Coconut Research Institute, 117pp.

Harborne J (1994) Do natural plant phenols play a role in ecology? Acta Horticulturae, 381:36 – 43.

Hilker M, Meiners T (2002) Induction of plant responses to oviposition and feeding by herbivorous arthropods: a comparison. Entomologia Experimentalis et Applicata, 104:181 – 192.

Hoy M, Peña J, Nguyen R (2006) Featured Creatures. University of Florida. Florida Department of Agriculture and Consumer Services, Division of Plant Industry. Available in: http://entomology.ifas.ufl.edu/creatures/orn/palms/red_palm_mite.htm#dist. July 19, 2010.

Jeppson H, Keifer H, Baker E (1975) Mites injurious to economic plants. Univ. of California. Press. Riverside. 614 pp.

Kane, E., R. Ochoa, G. Mathurin & E. Erbe. 2005. *Raoiella indica* Hirst (Acari: Tenuipalpidae): An island-hopping mite pest in the Caribbean. The ESA Annual Meeting and exhibition. Ft. Lauderdale, Florida, USA. Available in: http://www.sel.barc.usda.gov/acari/PDF/Raoiella%20indica-Kane%20et%20al.pdf.

Kitajima EW, Muller GW, Costa AS, Yuki VA (1972) Short, rodlike particles associated with citrus leprosis. Virology, 50:254-258.

Kitajima EW, Rezende JAM, Freitas JC (1996) Two types of particles associated with lesions induced by *Brevipalpus* mites in different plant hosts. VII. Encontro Nacional de Virologia. S. Lourenço, MG. 275 (abstract).

Kitajima EW, Rezende JAM, Rodrigues JCV, Chiavegato LG, Piza Jr CT, Morozini W (1997) Green spot of passion fruit, a possible viral disease associated with infestation by the mite *Brevipalpus phoenicis*. Fitopatologia Brasileira, 22: 555 – 559.

Klein C, Waterhouse DF (2000) The distribution and importance of arthropods associated with agriculture and forestry in Chile. ACIAR Monograph 68, Canberra, Australia. 234 p.

Krantz GW (2009) Habits and habitats. pp. 64 – 82. *In*: A manual of acarology. GW Krantz & DE Walter (Eds.) Texas Tech University Press. Lubbock, Texas, USA.

La Torre, P de; Almaguel L, Botta E, Cáceres I (2005) Plantas hospedantes de *Steneotarsonemus furcatus* de leon (Acari: Tarsonemidae) en Cuba. Neotropical Entomology, 34 (3): 517 – 519.

Lindquist EE (1986) The world genera of Tarsonemidae (Acari: Heterostigmata): a morphological, phylogenetic, and systematic revision, with a reclassification of family-group taxa in the Heterostigamata. Memoirs of the Entomological Society of Canada, 136, 1 – 517.

Lofego AC, Gondim Jr MGC (2006) A new species of *Steneotarsonemus* (Acari: Tarsonemidae) from Brazil. Systematic & Applied Acarology, 11: 195 – 203.

McMurtry JA (1970) Some factors of foliage condition limiting populations growth of *Oligonychus punicae* (Acarina: Tetranychidae). Annals of Entomological Society of America, 63:406–412.

McMurtry JA (1985) Avocado. pp. 327 – 338 In: Helle W, Sabelis M (Eds) Spider mites: their biology, natural enemies and control, vol. 1B. Elsevier Science Publishers B. V, Amsterdam, The Netherlands,

McMurtry JA, Johnson HG (1966) An ecological study of the spider mite *Oligonychus punicae* (Hirst) and its natural enemies. Hilgardia 37(11):363–402

Moore, D, Howard FW (1996) Coconuts. pp. 561 – 570. In: Lindquist EE, Sabelis MW & Bruin J (Eds.) Eriophyoid mites: their biology, natural enemies and control. Amsterdam, Elsevier.

Moraes GJ de, Flechtmann CHW (2008) Manual de acarologia: acarologia básica e ácaros de plantas cultivadas no Brasil. Ribeirão Preto, Holos, 288 pp.

Moraes GJ de, Zacarias MS (2002) Use of predatory mites for the control of eriophyid mites. pp. 78–88. *In*: Fernando LCP, Moraes GJ de, Wickramananda IR (Eds.), Proceedings of the International Workshop on Coconut Mite (*Aceria guerreronis*), 6–8 January 2000, Coconut Research Institute, Lunuvila, Sri Lanka.

Morrissey J, Osbourn AE (1999) Fungal resistance to plant antibiotics as a mechanism of pathogenesis. Microbiology and Molecular Biology Reviews, 63:708 – 724.

Morros ME, Aponte O (1994) Biología y tabla de vida de *Tetranychus ludeni* Zacher en caraota *Phaseolus vulgaris* L. Agronomía Tropical, 44(4): 667 – 677.

Morros ME, Aponte O (1995a) Efecto de dos niveles de infestación de *Tetranychus ludeni* Zacher sobre las fases de desarrollo de la caraota I: Nivel de campo. Agronomía Tropical, 54(2): 189 – 194.

Morros ME, Aponte O (1995b) Efecto de dos niveles de infestación de *Tetranychus ludeni* Zacher sobre las fases de desarrollo de la caraota II: Nivel de invernadero. Agronomía Tropical, 54(2): 195 – 202.

NAPPO (2009) Detecciones del ácaro rojo de la palma (*Raoiella indica*) en Cancún e Isla Mujeres, Quintana Roo, México. Notificación oficial de Plaga. Published on Nov 20, 2009.

Návia D (2008) Riesgo del "ácaro rojo de la palma", *Raoiella indica* Hirst, para Brasil. En: Acta del VI Seminario Científico Internacional de Sanidad Vegetal. La Habana, Cuba. 22–26 sept.

Návia D, Marsaro Jr AL, Silva FR da, Gondim Jr MGC, Moraes GJ de (2011) First report of the red palm mite, *Raoiella indica* Hirst (Acari: Tenuipalpidae), in Brazil. Neotropical Entomology, 40(3): 409 – 411.

Návia D, Moraes GJ de, Lofego AC, Flechtmann CHW (2005) Acarofauna associada a frutos de coqueiro (*Cocos nucifera* L.) de algumas localidades das Américas. Neotropical Entomology, 34(2), 349 – 354.

Návia D, Moraes, GJ, Querino, RB (2009) Geographic pattern of morphological variation of the coconut mite, *Aceria guerreronis* Keifer (Acari: Eriophyidae), using multivariate morphometry. Brazilian Journal of Biology, 69 (3): 773 – 783.

Norton RA, JB Kethley, DE Johnston & BM OConnor (1993) Phylogenetic perspectives on genetic systems and reproductive modes of mites. pp. 8-99. In: DL Wrensch & MA Ebbert (Eds.) Evolution and diversity of sex ratio in insects and mites. Chapman & Hall Publications, New York.

Ochoa R, Aguilar H, Vargas C (1994) Phytophagous mites of Central America: an illustrated guide. CATIE, Turrialba, Costa Rica, 234 pp.

Peña JE, Mannion C, Howard FW, Hoy MA (2008) Red palm mite, *Raoiella indica* Hirst (Acari: Prostigmata: Tenuipapidae). *In*: Encyclopedia of Entomology. Capinera J, Editor. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Peña JE, Mannion CM, Howard FW, Hoy MA (2006) *Raoiella indica* (Prostigmata: Tenuipalpidae): The red palm mite: a potential invasive pest of palms and bananas and other tropical crops of Florida. University of Florida IFAS Extension, ENY-837. 2006 (July 12, 2007). Available in: http://edis.ifas.ufl.edu/BODY_IN681.

Perring TM (1996) Vegetables. pp. 593–606. *In*: Lindquist EE, Sabelis MW, Bruin J (Eds.) Eriophyoid Mites: their biology, natural enemies and control. Elsevier, Amsterdam, The Netherlands.

Petanović R, Kielkiewicz M (2010) Plant–eriophyoid mite interactions: specific and unspecific morphological alterations. Part II. Experimental and Applied Acarology, 51: 81 – 91.

Pijnacker LP, Ferwerda MA, Bolland HR, Helle W (1980) Haploid female parthenogenesis in the false spider mite *Brevipalpus obovatus* (Acari: Tenuipalpidae). Genetica, 51: 211 – 214.

Praslička J, Huszár J (2004) Influence of temperature and host plants on the development and fecundity of the spider mite *Tetranychus urticae* (Acarina: Tetranychidae). Plant Protection Science, 40(4):141–144

Quirós M (1978) Presencia del 'ácaro marrón del aguacate', *Oligonychus punicae* (Hirst) en hojas de plátano del Distrito Baralt, estado Zulia. Revista de la Facultad de Agronomía (LUZ), 5(1):422 – 424.

Ramos M, Rodríguez H (1998) *Steneotarsonemus spinki* Smiley (Acari: Tarsonemidae): Nuevo Informe para Cuba. Revista de Protección Vegetal, 13 (1): 25-30.

Reis AC, Gondim Jr. MGC, Návia D, Flechtmann CHW (2010) Eriophyoid mites (Acari: Prostigmata: Eriophyoidea) from fruit trees in Northeastern Brazil – a new genus, three new species and a redescription. Zootaxa, 2694: 43–56.

Ribeiro LG, Villacorta A, Foerster LA (1988) Life cycle of *Panonychus ulmi* (Koch, 1836) (Acari: Tetranychidae) in apple trees, cultivar Gala and Golden Delicious. Acta Horticulturae, 232:228

Rivero E, Vásquez C (2009) Biologia e tabela de vida de *Tetranychus desertorum* (Acari: Tetranychidae) sobre folhas de feijão (*Phaseolus vulgaris*). Zoologia (Curitiba), 26 (1): 38 – 42.

Roda A, Dowling A, Welbourn C, Peña JE, Rodrigues JCV, Hoy MA, Ochoa R, Duncan RA, De Chi W (2008) Red palm mite situation in the Caribbean and Florida. Proceedings of the Caribbean Food Crops Society, 44(1): 80-87.

Rodrigues JCV (2000) Relações patógeno-vetor-planta no sistema leprose dos citros. Thesis Ph.D. Piracicaba, Brasil,Centro de Energia Nuclear na Agricultura, da Universidade de São Paulo.

Rodrigues JCV, Kitajima EW, Childers CC, Chagas CM (2003) Citrus leprosis virus vectored by *Brevipalpus phoenicis* (Acari: Tenuipalpidae) on citrus in Brazil. Experimental and Applied Acarology, 30: 161–179.

Rodrigues JCV, Ochoa R, Kane EC (2007) First report of *Raoiella indica* Hirst (Acari: Tenuipalpidae) and its damage to coconut palms in Puerto Rico and Culebra Island. International Journal of Acarology, 33(1): 3–5.

Rodríguez H, Miranda I, Louis J, Hernández J (2009) Comportamiento poblacional de *Steneotarsonemus spinki* Smiley (Acari: Tarsonemidae) en el cultivo del arroz (*Oryza sativa* L.). Temas de Ciencia y Tecnología, 13 (39): 55 – 66.

Rodríguez H, Montoya A, Flores-Galano G (2010) Conducta alimentaria de *Amblyseius largoensis* (Muma) sobre *Raoiella indica* Hirst. Revista de Protección Vegetal, 25(1): 26 – 30.

Royalty RN, Perring TM (1996) Nature of damage and its assessment. pp. 493–512. In: Lindquist EE, Sabelis MW, Bruin J (Eds) Eriophyoid mites—their biology, natural enemies and control. Elsevier, Amsterdam.

Sandoval MF, Almaguel L, Fréitez F, Vásquez C (2009) Situación actual del ácaro del arroz, *Steneotarsonemus spinki* Smiley (Acari: Tarsonemidae) en Venezuela. Entomotropica, 24(3): 135 – 139.

Silva EA, Reis, PR, Carvalho, TMB, Altoé, BF (2009) *Tetranychus urticae* (Acari: Tetranychidae) on *Gerbera jamesonii* Bolus and Hook (Asteraceae). Brazilian Journal of Biology, 69(4): 1121 – 1125.

Smith-Meyer MKP. 1979. The Tenuipalpidae (Acari) of Africa with keys to the world fauna. Republic of South Africa. Dept.Agric.Tech.Serv. Entomology Memoir 135 pp.

Tello V, Vargas R, Araya J (2009) Parámetros de vida de *Tetranychus cinnabarinus* (Acari: Tetranychidae) sobre hojas de clavel, *Dianthus caryophyllus*. Revista Colombiana de Entomología, 35(1): 47 – 51.

Tomczyk A; D Krompczyńska (1985) Effects on the host plant. pp. 317 – 329. *In*: Spider mites: their biology, natural enemies and control, vol 1A. W. Helle and M. W. Sabelis. (Eds.) Elsevier, Amsterdam. 405 pp.

Vásquez C, Colmenárez M, Valera N, Díaz L (2007) Antibiosis of kidney bean cultivars to the carmine spider mite, *Tetranychus cinnabarinus* (Boisduval) (Acari: Tetranychidae). Integrated Control of Plant-Feeding Mites. IOBC wprs Bulletin, 30 (5): 133 – 138.

Vásquez C, Morales J, Aponte O, Sanabria ME, García G (2008a) Biological studies of *Oligonychus punicae* (Acari: Tetranychidae) on grapevine cultivars. Experimental and Applied Acarology, 45: 59 – 69.

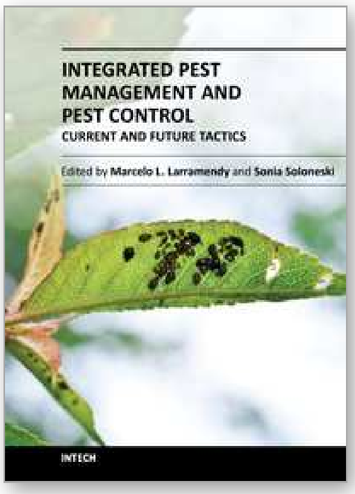
Vásquez C, Quirós de G M, Aponte O, Sandoval MF (2008b) First report of *Raoiella indica* Hirst (Acari: Tenuipalpidae) in South America. Neotropical Entomology, 37 (6): 739 – 740.

Walter D, H Proctor (1999) Mites: ecology, evolution and behaviour. CABI Publishing. University of New South Wales Press, Sydney, New South Wales. 322 pp.

Welbourn C. (2005) Red palm mite *Raoiella indica* Hirst (Acari: Tenuipalpidae). Pest Alert, 2005. (on line). (Accessed on August 17th, 2011) Available in: htpp://www.daocs.state.fl.us/pi/enpp/ento/r.indica.html.

Westphal E, Manson DCM (1996) Feeding effects on host plants: gall formation and other distortion. pp. 231–241. In: Lindquist EE, Sabelis MW, Bruin J (Eds) Eriophyoid mites—their biology, natural enemies and control. Elsevier, Amsterdam.

Zhang ZQ (2003) Mites of greenhouses: identification, biology and control. CABI Publishing. Wallingford UK. 244 pp.



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Integrated Pest Management is an effective and environmentally sensitive approach that relies on a combination of common-sense practices. Its programs use current and comprehensive information on the life cycles of pests and their interactions with the environment. This information, in combination with available pest control methods, is used to manage pest damage by the most economical means and with the least possible hazard to people, property, and the environment.