Chapter

Invasive Mite Species in the Americas: Bioecology and Impact

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Abstract

Invasive species represent one of the most relevant threats for biodiversity in many ecosystems, mainly in those so-called agroecosystems due to which they exhibit reduced biodiversity and simplified trophic interactions. These two factors make many niches unoccupied, thus increasing the risk that invasive species especially arthropod pests occupy these niches or compete with native species. In spite of potential impact of invasive species, our understanding of their ecological consequences is developing slowly. In the last years, more attention is being paid on phytophagous mites because several noneconomic species have become severe pests on many crops as a consequence of irrational use of agrochemicals. Also, due to the small size of the mites, they can be transported throughout the world and established in new areas where favorable conditions and the absence of efficient natural enemies favor their development. Thus, phytophagous mites are feasible to become invasive species since they are able to provoke severe damage to plants. Since 2004, *Steneotarsonemus spinki*, *Schizotetranychus hindustanicus,* and *Raoiella indica* have been introduced in the Neotropical region. Information about pest status, seasonal trends, and natural enemies in invaded areas is provided for these species.

Keywords: phytophagous mites, invasive species, Neotropical region, *Steneotarsonemus spinki*, *Schizotetranychus hindustanicus*, *Raoiella indica*

1. Introduction

Natural environments are continuously submitted to severe transformations, including movement of species beyond the limits of their native geographic ranges into areas where they do not naturally occur and where they can inflict substantial changes [1]. Thus, considering changes inflicted by alien species to the properties of an ecosystem, an increasing number of studies that consider the environmental impacts have been published [2]. However, according to Ricciardi [3], a predictive understanding of the ecological impacts of invasive species has developed slowly, owing largely to an apparent lacking of clearly defined hypotheses and of a broad theoretical framework. In this regard, confusion about terminology used for the designation of nonindigenous species, which alternatively have been called "exotic," "introduced," "invasive," and "naturalized," is particularly acute, which leads to confusion about ecological concepts [4].

Another term needing delimitation of definition is referred to concept of impact. On an ecological basis, an impact is defined as a measurable change to the properties of an ecosystem by a nonnative species, which is considered to provoke a positive or negative impact simply by becoming integrated into the system [3].

Various studies have shown that nonnative species can promote extinction of native species, and also they can provoke changes in genetic composition of native populations, behavior patterns, species richness and abundance, phylogenetic and taxonomic diversity, etc.

Finally, when considering invasive species in an agricultural ambit, it is strongly recommended to define invasion threat, which is conceptualized as the likelihood of a particular pest or pathogen arriving in a new location as well as the establishment likelihood considered as the chances of those pests or pathogens to establish in a new location [5].

Plant and animal species have been transported by humans for millennia; even a well-defined period in biological invasions dates as far back as 1500 AD, a period associated with the birth of colonialism and the start of radical changes in patterns of human demography, agriculture, trade, and industry [6]. However, more recently, increasing globalization and world trade have augmented the possibility of arrival of invasive species to geographic regions in which they were previously absent, making necessary to quantify impact of invasive species and develop effective biosecurity policy [4].

Since the end of the twentieth century, more attention is being paid on phytophagous mites because several noneconomic species have become severe pests on many crops as a consequence of irrational use of agrichemicals. Also, due to the small size of the mites, they can be transported throughout the world and set up in new areas, in which favorable conditions and the lack of efficient natural enemies favor their development, resulting in economic losses [7]. There are various examples of introductions of phytophagous mites in new areas such as the cassava green mite [*Mononychellus tanajoa* (Bondar, 1938)], the coconut mite [*Aceria guerreronis* (Keifer, 1965)], and the tomato spider mite [*Tetranychus evansi* Baker and Pritchard, 1960] [7, 8]. Both *M. tanajoa* and *A. guerreronis* were introduced into Africa, while *T. evansi* has been introduced in Africa in the Mediterranean Basin.

Similarly, some phytophagous mite species have been introduced in the Neotropical region, i.e., *Steneotarsonemus spinki* (Smiley, 1967), *Schizotetranychus hindustanicus* (Hirst, 1924), and *Raoiella indica* (Hirst, 1924). In the present review, information about recent phytophagous mite on pest status, seasonal trends, and natural enemies in invaded areas is provided for these species. Because invasive species may evolve during the invasion process, comparison of behavior, and damage and management options between native and invaded areas for these species will be useful for understanding the invader's success and their ability to colonize new regions.

2. Some concepts related to invasive species

The introduction of species beyond their native range as a direct or indirect result of human action causes changes in the ecosystems to which they are introduced [9]. Moreover, these biological invasions are causing tremendous damages to ecosystems and economic activities [10]. Many important terms related to the invasion ecology, such as "invasive," "weed," or "transient," can be susceptible to subjective interpretation, consequently causing a lack of consensus about terms used to define nonindigenous species [4]. Thus, some terms such as "noxious" and "nuisance" are generally used to indicate direct or indirect adverse effects on humans; however, according to Colautti and MacIsaac [4], interactions have three important implications:

a. It is necessary to define if invasive species cause aesthetical displeasing effects and are vectors for serious human diseases.

b. Species might be erroneously considered as an environmental threat (or weedy, invasive, etc.) in areas where they have little or no impact only based on these species had been identified as a disturbance elsewhere, disregarding thus the ecological phenomenon.

c. A particular species can have both beneficial and detrimental effects. *Harmonia axyridis* (Pallas, 1773) (Coleoptera, Coccinellidae) is a well-known predator widely used as a classical biological control agent of aphids around the world; however, this species has provoked the displacement of native aphid species in Brazil and other South American countries [11].

Some definitions of invasive species are the following:

a. An alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health.

b. A species that is nonnative to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm or harm to human health

Invasion consists of a series of steps that an organism must undergo to become a successful invader, and thus, it can inflict an ecological damage [12]. According to Beck et al. [13], successful invasion is preceded by the following stages:

a. *Large-scale geographical barriers*: species from a geographical area is supposed to overcome a geographical barrier (mountain range, ocean, or other physical barriers) to arrive in a new area where it does not previously occur (so-called alien species, nonnative species). This movement is often mediated by human activities, either deliberately or unintentionally.

b. *Survival barriers*: these often refer to environmental barriers such as environmental conditions that let the nonnative organism to survive and develop in its new location. Other survival barriers may include host plants, competitor organisms, predators, and pathogens.

c. *Establishment barriers*: depending on the survival abilities of the alien species, it will be able to form a self-sustaining population and does not need a re-introduction to support a population base.

d. *Dispersal and spread barriers*: once established, alien species must disperse and spread relatively fast from their site of establishment. However, this movement or spread alone does not necessarily make this nonnative species an invasive species.

3. Mite invasions in the Neotropical region

Although bioinvasions have occurred for many years, most documented cases have been reported in recent decades and even invasive or adventive mites have gained attention only in the last few years when they have been the target of research to determine their potential distribution [7]. After colonization, it is fundamental to determine the intrinsic properties of the invasive population, the genetic structure of populations, and the response to environmental factors to developing strategies and policies of management [7].

In the Neotropical region, several mite species have recently invaded the agricultural landscapes in Latin America, for example, the citrus Hindu mite, *S. hindustanicus* (Tetranychidae), the rice mite, *S. spinki* (Tarsonemidae), and the red palm mite, *R. indica* (Tenuipalpidae).

3.1 *Schizotetranychus hindustanicus*

The genus *Schizotetranychus* includes 114 species; however, information about economic importance of most of the species is still scarce [14, 15] (**Table 1**). Most of the species occur in Asia and CIS, and only 20 species (17.5%) are in the Neotropical region, including *S. hindustanicus*.

The citrus Hindu mite, *S. hindustanicus*, was originally described from citrus from southern India (Hirst, 1924), and its occurrence had been reported in this country for almost 80 years; however, in 2005, this species was surprisingly found in the northwestern Venezuela [16] and soon after in Colombia and Brazil [17].

S. hindustanicus had only been reported on four host plant species in India (see **Table 1**); however, posteriorly, it was found on *Acacia* sp., *Melia azedarach* L. and various *citrus* species (**Figure 1**). Symptoms of mite feeding first appear on the upper leaf surface, along the main rib, later extending to the entire leaf; while when feeding on fruits the females webs over concavities or depressions in the rind; attacked fruits become uniformly silvered and hard under severe infestation [18]. Návia and Marsaro [17] reported that although this damage by mite feeding is supposed to affect the commercial value of infested fruits, nothing has been published about the resulting economic impact.

In Venezuela, *S. hindustanicus* has been observed forming colonies in several *citrus* species and/or varieties such as *C. latifolia* (Tanaka ex Yu. Tanaka), *C. aurantifolia* (Chistm) *C. reticulata* Blanco, *C. limon* (L.), and *C. sinensis* (L.) Osbeck [19, 20].

In Colombia, this tetranychid mite species was first reported in the northern coast in Dibulla (Guajira) and Magdalena [21]. After that, ICA (Agropecuary Colombian Institute) carried out samplings in departments of Atlantico, Bolivar, Guajira, Magdalena, and Vichada as shown in **Table 2**. Similarly, presence of circular whitish spots on leaves and fruits of "tahiti" and "galeguinho" lemon trees in urban areas of Roraima (Brazil) is alerted to the Brazilian plant protection authorities as this country is the largest *citrus* producer [17]. According to these authors, dispersion of *S. hindustanicus* could cause high economic impact and/or commercial restrictions due to sanitary.

Since these tetranychid mite species can be the pest on *citrus* spp., some studies have been carried out in Venezuela. Niedstaedt and Marcano [15] observed the effect that the developmental time of *S. hindustanicus* varied from 30.12 to 31.10 days on sweet orange or Persian lime, respectively, at 25°C. Additionally, population studies on Persian lime, lemon, sweet orange, and tangerine showed that number of individuals was relatively low in two peaks: the first peak during June 2005 with 24.17, 21.67, and 12 individuals was observed on tangerine, sweet orange, and Persian lime, respectively, while the second peak with lightly higher number of mites developed during April 2006 was observed with 69.17, 31.2, and 20.2 mites on sweet orange, tangerine, and Persian lime, respectively [22].

Field observations on different citrus species have demonstrated that *S. hindustanicus* can colonize which seems to be verifying the entire canopy so far economic impact have not been evaluated in the neotropical areas. There are some studies on this genus, associated mainly with grasses such as rice and bamboo and some fruit trees [23, 24].

Species	Host plants	Distribution
S. agropyron (Tuttle and Baker, 1976)	*Agropyron desertorum* (Fisch. ex Link) Schult.	The USA
S. alni (Beglyarov and Mitrofanov, 1973)	*Alnus* sp.	CIS
S. andropogoni (Hirst, 1926)	*Andropogon annulatus* Forssk., *Chloris incomplete* Roth, *Dichanthium annulatum* (Forssk.) Stapf, *Oryza sativa* L.	CIS, India, Mexico, Pakistan, and Thailand
S. approximatus (Ehara, 1988)	*Bambusa vulgaris* Schrad. ex J.C. Wendl., *Thyrsostachys siamensis Gamble*	Malaysia
S. arcuatus (Meyer, 1974)	*Euclea crispa* (Thunb.) Gürke	South Africa
S. asparagi (Oudemans, 1928)	*Acacia horrida* (L.) Willd., *A. longifolia* (Andrews) Willd., *Ananas* sp., *Aspalathus* sp., *Asparagus* sp., *A. africanus* Lam., *A. officinalis* L., *A. plumosus* Baker, *A. setaceus* (Kunth) Jessop, *A. sprengeri* Regel, *A. suaveolens* Burch., *Protasparagus capensis* (L.) Oberm., *P. compactus* (T.M. Salter) Oberm., *P. laricinus* (Burch.) Oberm., *Pteridophyta*	Australia, Germany, Hawaii, Israel, Morocco, Portugal, Puerto Rico, South Africa, the Netherlands, and the USA
S. australis (Gutierrez, 1968)	*Mundulea pungens* R. Vig., *Tephrosia striata* Ecklon & Zeyher ex Steudel	Madagascar
S. avetjanae (Bagdasarian, 1954)	*Spiraea* sp.	CIS
S. baltazari (Rimando, 1962)	*Citrus grandis* (L.) Osbeck, *C. madurensis* Lour., *C. medica* L., *C. sinensis* (L.) Osbeck	Burma, China, Hong Kong, India, Philippines, Taiwan, and Thailand
S. bambusae (Reck, 1941)	*Arundinaria* sp. *Phyllostachys* sp., *P. nigra* (*Lodd. ex Lindl.*) *Munro*, *P. reticulata* (Rupr.) K. Koch	CIS, China, Hainan Island, Japan, and Korea
S. beckeri (Wainstein, 1958)	*Calamagrostis* sp., *Dactylis* sp., *Helictotrichon* sp.	CIS
S. bhandhufalcki (Ehara and Wongsiri, 1975)	*Cajanus cajan* (L.) Huth, *Cassia* sp., *C. siamea* Lam., *Colocasia esculenta* (L.) Schott, *Pterocarpus macrocarpus* Kurz	Thailand
S. boutelouae (Tuttle and Baker, 1968)	*Bouteloua rothrockii* Vasey¸ *Commelina dianthifolia* L., *Stipa eminens* Cav.	Mexico and the USA
S. brachypodii (Livshits and Mitrofanov, 1968)	*Brachypodium silvaticum* (Huds.) P. Beauv.	CIS
S. brevisetosus (Ehara, 1989)	*Quercus* sp., *Q. glauca* Thunb.	Japan
S. cajani (Gupta, 1976)	*C. cajan*	India

Species	Host plants	Distribution
S. camur (Pritchard and Baker, 1955)	*Arundinaria* sp.	USA
S. celarius (Banks, 1917)	*Arundinaria hindsii* Munro, *Bambusa* sp., *Ficus stipulata* Thunb., *Miscanthus sinensis* Andersson, *Oryza* sp., *Phyllostachys* sp., *P. makinoi* Hayata, *P. nigra* (Lodd. ex Lindl.) Munro, *P. reticulata* (Rupr.) K. Koch	Australia, China, France, Hawaii, Hong Kong, Japan, Korea, Okinawa Island, Taiwan, the Netherlands, and the USA
S. celtidis (Tuttle and Baker, 1968)	*Celtis reticulata* Torr., *Leptochloa uninervia* (J. Presl) Hitchc. & Chase, *Sporobolus flexuosus* (Thurb. ex Vasey) Rydb., *Tridens pulchellus* (Kunth) Hitchc.	Mexico and the USA
S. cercidiphylli (Ehara, 1973)	*Cercidiphyllum japonicum* Siebold & Zucc.	Japan
S. chiangmaiensis (Ehara and Wongsiri, 1975)	*Calotropis gigantea* (L.) W.T. Aiton	Thailand
S. colocasiae (Ehara, 1988)	*Colocasia* sp.	Malaysia
S. cornus (Pritchard and Baker, 1955)	*Dysoxylum spectabile* Hook. f., *Elaeocarpus dentatus* (J.R. Forst. and G. Forst.) Vahl	New Zealand
S. cynodontis (McGregor, 1950)	*Agrostis* sp., *Cynodon dactylon* (L.) Pers.	USA
S. dalbergia (Meyer, 1974)	*Dalbergia melanoxylon* Guill. & Perr.	Zimbabwe
S. denmarki (Baker and Tuttle, 1994)	Poaceae	USA
S. echinulatus (Mitrafanov, 1978)	*Spiraea* sp.	CIS
S. elongates (Wang and Cui, 1991)	Bambusaceae	China
S. elymus (McGregor, 1950)	*Agropyron* sp., *Agrostis* sp., *Aristida adscensionis* L., *Bouteloua hirsuta* Lag., *C. dactylon*, *Distichlis stricta* (Torr.) Rydb., *Elymus* sp., *E. trachycaulus* (Link) Gould, *Hordeum* sp., *Malva parviflora* L., *Panicum obtusum* Kunth, *P. scribnerianum* Nash, *Stipa ichu* (Ruiz & Pav.) Kunth, *Tridens pulchellus* (Kunth) Hitchc., *Triticum aestivum* L., *Typha latifolia* L., *Vicia pulchella* Kunth	Mexico and the USA
S. emeiensis (Wang, 1983)	Bambusaceae	China
S. eremophilus (McGregor, 1950)	*Aristida adscensionis* L., *A. glabrata* (Vasey) Hitchc., *Bothriochloa saccharoides* (Sw.) Rydb., *Bouteloua* sp., *B. barbata* Lag., *C. dactylon*, *Distichlis stricta* (Torr.) Rydb., *Lycurus phleoides* Kunth, *Tridens pulchellus* (Kunth) Hitchc.	Mexico and the USA
S. euphorbiae (Livshits and Mitrofanov, 1968)	*Euphorbia amygdaloides* L.	CIS

Species	Host plants	Distribution
S. fauveli (Gutierrez, 1978)	*Ficus edulis* Burm. f., *F. fraseri* Miq., *F. habrophylla* G. Benn. & Seem.	New Caledonia
S. filifolius (Meyer, 1974)	*Aster filifolius* Vent.	South Africa
S. floresi (Rimando, 1972)	*Arundo formosana* Hack., *Bambusa* sp., *B. spinosa* Roxb.	Philippines, Taiwan
S. fluvialis (McGregor, 1928)	*A. adscensionis, C. cajan, Epicampes rigens* Benth., *Muhlenbergia rigens* (Benth.) Hitchc.	India, USA
S. freitezi (Ochoa, Gray and von Lind., 1990)	*O. sativa*	Costa Rica
S. gahniae (Davis, 1969)	*Gahnia aspera* Spreng.	Australia
S. garmani (Pritchard and Baker, 1955)	*Acer* sp., *Populus tremula* L., *Quercus* sp., *Q. robur* L., *Salix* sp., *S. caprea* L., *S. humilis* Marshall, *S. petiolaris* Sm., *S. tristis* Aiton	Iran, Poland, Switzerland, and the USA
S. gausus (Baker and Pritchard, 1960)	Unknown	Zaire
S. glabrisetus (Ugarov and Nikolskii, 1937)	Poaceae	CIS
S. graminicola (Goux, 1949)	*Molinia caerulea* Milk.	France and the Netherlands
S. guatemalae-novae (Stoll, 1886)	*Cassia nictitans* L.	Guatemala
S. halimodendri (Waistein, 1958)	*Halimodendron halodendron* (Pall.) Druce	CIS
S. hilariae (Tuttle and Baker, 1968)	*A. adscensionis, Hilaria rigida* (Thurb.) Benth. ex Scribn.	USA
S. hindustanicus (Hirst, 1924)	*Azadirachta indica* A. Juss., *Citrus* sp., *Cocos nucifera* L., *Sorghum bicolor* (L.) Moench	India
S. ibericus (Reck, 1947)	*Quercus* sp.	CIS
S. imperatae (Wang, 1983)	*Imperata* sp.	China
S. jachontovi (Reck, 1953)	*Quercus* sp.	CIS
S. kaspari (Manson, 1967)	*Calopogonium mucunoides* Desv., *Cordyline kaspar* W.R.B. Oliv.	Hainan Island and New Zealand
S. kochummeni (Ehara, 1988)	Bambusaceae	Malaysia

Species	Host plants	Distribution
S. laevidorsatus (Ehara, 1988)	Bambusaceae, *Gigantochloa levis* (Blanco) Merr.	Malaysia
S. lanyuensis (Tseng, 1975)	*Unknown*	Taiwan
S. lechrius (Rimando, 1962)	*Cassia siamea* Lam., *Citrus* sp., *C. esculenta, Glycine max* (L.) Merr., *Pterocarpus indicus* Willd., *P. vidalianus* Rolfe	Indonesia, Philippines, and Taiwan
S. lespedeza (Beglyarov and Mitrofanov, 1973)	*Bauhinia* sp., *Desmodium* sp., *Lespedeza* sp., *L. bicolor*	CIS, China, Japan, Korea, and Taiwan
S. levinensis (Manson, 1967)	Poaceae	New Zealand
S. longirostrus (Feres and Flechtmann, 1995)	*Bambusa* sp.	Brazil
S. longus (Saito, 1990)	*Sasa senanensis* (Franch. & Sav.) Rehder	Japan
S. luculentus (Tseng, 1990)	*Diospyros* sp.	Taiwan
S. lushanensis (Dongsheng, 1994)	*Cinnamomum camphora* Meisn.	China
S. lycurus (Tuttle and Baker, 1964)	*Leersia oryzoides* (L.) Sw., *Lycurus phleoides* Kunth, *Setaria macrostachya* Kunth	Mexico and the USA
S. malayanus (Ehara, 1988)	*Manihot* sp.	Indonesia and Malaysia
S. malkovskii (Waistein, 1956)	*Calamagrostis* sp.	CIS
S. mansoni (Gupta, 1980)	*Oryza* sp.	India
S. minutus (Wang, 1985)	Bambusaceae	China
S. miscanthi (Saito, 1990)	*Miscanthus* sp., *M. sinensis* Andersson	Japan
S. miyatahus (Meyer, 1974)	*Pterocarpus rotundifolius* (Sond.) Druce	South Africa
S. montanae (Tuttle and Baker, 1968)	*Muhlenbergia montana* (Nutt.) Hitchc., *Pappophorum mucronulatum* Nees	Mexico and the USA
S. nanjingensis (Ma and Yuan, 1980)	*Phyllostachys* sp.	China
S. nesbitti (Meyer, 1965)	Poaceae	South Africa
S. nugax (Pritchard and Baker, 1955)	*Hilaria mutica* (Buckley) Benth., Poaceae	Mexico and the USA

Species	Host plants	Distribution
S. oryzae (Rossi de Simons, 1966)	*O. sativa, Panicum maximum* Jacq.	Argentina, Brazil, Colombia, Surinam, and Venezuela
S. oudemansi (Reck, 1948)	*Vaccinium uliginosum* L.	CIS
S. paezi (Alvarado and Freitez, 1976)	*O. sativa, P. maximum*	Colombia and Venezuela
S. papillatus (Flechtmann, 1995)	Bambusaceae	Brazil
S. paraelymus (Feres and Flechtmann, 1995)	*Bambusa* sp.	Brazil
S. parasemus (Pritchard and Baker, 1955)	*C. dactylon, Dactylis glomerata* L., *Distichlis spicata* (L.) Greene, *D. stricta* (Torr.) Rydb., *Paspalum notatum* Flüggé, *Vitis* sp.	Brazil, Colombia, Poland, and the USA
S. pennamontanus (Meyer, 1987)	*Lebeckia linearifolia* E. Mey.	Namibia
S. prosopis (Tuttle, Baker and Abbatiello, 1976)	*Prosopis juliflora* (Sw.) DC.	Mexico
S. protectus (Meyer, 1975)	*Cliffortia linearifolia* Eckl. & Zeyh., *C. repens* Schltr.	South Africa
S. pseudolycurus Ochoa, (Gray and von Lind., 1990)	*O. sativa*	Costa Rica and Panamá
S. recki (Ehara, 1957)	*S. senanensis*	Japan
S. reticulatus (Baker and Pritchard, 19600	*Grewia* sp.	Comoro Island and Zaire
S. rhodanus (Baker and Pritchard, 1960)	Unknown	Zaire
S. rhynosperus (Flechtmann and Baker, 1970)	*Rhynchospora* sp.	Argentina and Brazil
S. russeus (Davis, 1969)	*Lomandra multiflora* Britten	Australia
S. saba-sulchani (Reck, 1956)	*C. dactylon*	CIS
S. saccharum (Flechtmann and Baker, 1975)	*Saccharum officinarum* L.	Brazil

Species	Host plants	Distribution
S. sacrales (Baker and Pritchard, 1960)	Fabaceae	Zaire
S. sagatus (Davis, 1969)	*Themeda australis* (R. Br.) Stapf	Australia
S. saitoi (Ehara, 1968)	*B. vulgaris*	Malaysia
S. sayedi (Attiah, 1967)	*Ficus carica* L.	Egypt
S. schizopus (Zacher, 1913)	*Populus* sp., *P. tremula, Salix* sp., *S. alba* L., *S. aurita* L., *S. balsamifera* (Hook.) Barratt ex Andersson*, S. bicolor* Willd., *S. caprea* L., *S. daphnoides* Vill., *S. elegantissima* K. Koch, *S. fragilis* L., *S. nigra* Marshall, *S. purpurea* L., *S. subfragilis* Andersson, *S. viminalis* L., *Vaccinium uliginosum* L.	CIS, China, Germany, Hungary, Japan, Poland, Switzerland, the Netherlands, the UK, and the USA
S. setariae (Meyer, 1987)	*Setaria sphacelata* (Schumach.) Stapf & C.E. Hubb. ex M.B. Moss	South Africa
S. smirnovi (Waistein, 1954)	*Juglans regia* L., *Malus domestica* (Suckow) Borkh., *Morus alba* L., *Prunus armeniaca* L.	CIS
S. spicules (Baker and Pritchard, 1960)	*Citrus* sp., *Murraya koenigii* (L.) Spreng.	India and Kenya
S. spiraefolia (Garman, 1940)	*C. cajan, S. officinarum, Spiraea* sp., *S. latifolia* (Aiton) Borkh., *S. pubescens* Turcz., *S. salicifolia* L., *S. trilobata* L.	China, India, Poland, and the USA
S. taquarae (Paschoal, 1971)	*B. vulgaris*	Brazil
S. tbilisiensis (Reck, 1959)	*Agrostemma githago* L., *Bromus* sp., *Elytrigia repens* (L.) Desv. ex Nevski, *Marrubium* sp.	CIS
S. tephrosiae (Gutierrez, 1968)	*Balanites pedicellaris* Mildbr. & Schltr., *Eriobotrya japonica* (Thunb.) Lindl., *Mikania cordata* (Burm. f.) B.L. Rob., *Mundulea pungens* R. Vig., *M. sericea* Hook. & Arn., *Tephrosia striata* Ecklon & Zeyher ex Steudel	India, Madagascar, and South Africa
S. textor (Waisntein, 1954)	*Elaeagnus angustifolia* L., *Lonicera* sp.	CIS
S. triquetrus (Meyer, 1987)	*Pentzia incana* (Thunb.) Kuntze	South Africa
S. tuberculatus (Ugarov and Nikolskii, 1937)	*Morus* sp.	CIS
S. tumidus (Wang, 1981)	*Melia radula* (nonvalid name)[1]	China
S. tuminicus (Ma and Yuan, 1982)	*Bridelia monoica* (Lour.) Merr.	China
S. tuttlei (Zacher, Gomaa and El-Enany, 1982)	*Arundo donax* L., *Cuscuta planiflora* Ten., *Mentha pulegium* L., *O. sativa*	Egypt

Species	Host plants	Distribution
S. ugarovi (Wainstein, 1960)	*Alhagi pseudalhagi* (M. Bieb.) Desv. ex B. Keller & Shap.	CIS
S. umtaliensis (Meyer, 1974)	*Acacia* sp.	Zimbabwe
S. undulates (Beer and Lang, 1958)	*Acacia nilotica* (L.) Willd. ex Delile, *Beaucarnea stricta* Lem., *Jasminum grandiflorum* L.	India and Mexico
S. vermiculatus (Ehara and Wongsiri, 1975)	Poaceae	Thailand
S. yoshimekii (Ehara and Wongsiri, 1975)	*O. sativa*	China and Thailand
S. youngi (Tseng, 1975)	*Citrus medica* L., *C. paradisi* Macfad.	Taiwan
S. zhangi (Wang and Cui, 1992)	*Quercus gilliana* Rehder & E.H. Wilson	China
S. zhongdianensis (Wang and Cui, 1992)	*Salix* sp.	China

[1]*Species names that are nonvalid according to the MOBOT.*

Table 1.
Worldwide Schizotetranychus species (from [14]).

a b

Figure 1.
Schizotetranychus hindustanicus colony on citrus leaves (a) and citrus leaves showing characteristic symptoms for S. hindustanicus feeding (courtesy of Dr.). (b) Mario Cermelli and Pedro Morales.

3.2 *Steneotarsonemus spinki*

The rice mite, *S. spinki*, is the origin of southeastern Asia, where it has been reported causing damage to rice crops varying from 30 to 90% in China and 20–60% in Taiwan [25]. Presently, it is considered as a serious pest of rice in Tropical Asia and Caribbean [26]. Other than rice, *S. spinki* is associated to more than 70 plant species including weeds growing near rice fields, such as wild rice:

Department	Municipality	Presence/absence	Host plant
Atlántico	Luruaco	–	
	Polonuevo	–	
	Baraona	–	
La Guajira	Dibulla	+	
Magdalena	Santa Marta	+	
	Santa Ana	–	
	Ciénaga	–	
	Zona Bananera	–	
	El Banco		
	Guamal	+	*C. sinensis* *C. limon*
	San Sebastián	–	
	San Zenón	–	
Vichada	Puerto Carreño	–	

Table 2.
Surveyed localities in the northern Colombia to detect occurrence of S. hindustanicus (from ICA, 2012).

O. latifolia, *C. dactylon* (Poaceae), *Cyperus articulatus* L., *Cyperus iria* L., and *Oxycaryum* sp. (Cyperaceae) [26, 27].

The rice mite feeds on the adaxial surface of leaf sheaths and developing kernels evidenced by brown lesions and consequently reducing photosynthesis and having a negative effect on fertility [26]. Damage also results in sterile grain syndrome, which is characterized by losing and brown discoloration of the flag leaf sheath, twisted panicle neck, and impaired grain development with empty or incompletely filled grains with brown spots and panicles standing erect. The damage to grains showing sterility and malformed curved appearance is referred to as "parrot-beak" [28]. On the other hand, Shikata et al. [29] found for the first time virus-like particles associated with the tarsonemid mites in the rice plants; the spherical virus-like particles were isolated from the rice plants infected with rice ragged stunt, dwarf, black-streaked dwarf, grassy stunt viruses, as well as from the "healthy" plants, which were not inoculated with those viruses, and in addition, the same particles were also found in the dip preparations of the rice tarsonemid mites and eggs.

S. spinki was first reported in North America in 1960 on *Tagosodes orizicolus* (Muir, 1926) in Louisiana, USA. Several years after, the rice mite was found causing damage in rice crops (*O. sativa*) in Cuba in 1997 [30]. Subsequently, this tarsonemid mite spreads over all the Caribbean and Central America: Dominican Republic [31], Costa Rica [32], Haiti [33], Panama [34], Guatemala, Honduras [35], and Mexico [36]. In South America, it has been reported in Colombia [37] and Venezuela [38].

After being introduced in Cuba, outbreaks were registered from 1997 to 1998 when an increase in vain grains of 15–20% and a loss of 2 t/ha were recorded [25]. At the end of 1998, *S. spinki* was also found in Dominican Republic and Haiti, causing about 30% of yield loss; however, less intense damage was verified as compared to Cuba [34].

3.3 *Raoiella indica*

The red palm mite, *R. indica*, is of Asian origin, and it is widely distributed in India, Pakistan, Russia, Iran, Israel, Oman, Pakistan, Egypt, Sudan, and Mauritius [39]. Since 2004, *R. indica* was reported from several Caribbean islands, including

Martinique [40], Saint Lucia and Dominica [41], Guadeloupe and Saint Martin [42], Puerto Rico and Culebra Island [43], and Jamaica [44] (Welbourn, 2007). More recently, it has also been found in Venezuela [45], Colombia [46], and Brazil [47].

Raoiella indica can cause severe damage not only to Arecaceae, especially coconut (*C. nucifera*), but also to Musaceae and other plant families [40, 42, 48] (**Figure 2**). Infested plants exhibit a characteristic "yellowing" as a result of mites feeding on the nutrient-rich layers of the leaves' mesophyll tissues [40]. *Raoiella* species inflict damage by introducing the infrastratum through the stomatal opening to feed on the underlying mesophyll cells [49]. Therefore, the distribution of the stomata on the leaf surface could have a greater influence on the feeding capacity of *R. indica* on the host plant [50], and the severity of the feeding damage by the red palm mite increases in the young plants [43, 51].

After RPM was reported in the New World, little was known about bioecology of this Red palm mite. Regarding host plant, only coconut and *Adonidia merrillii* (Becc.) Becc. had been recorded as host plants to this mite [41, 48]. After RPM occurrence in South America in the coastal Sucre state of Venezuela, Vásquez et al. [52] registered higher population levels of RPM on coconut, banana (*Musa* spp.), ornamental plants, and weeds in the northern Venezuela (**Figure 3** and **Table 3**). These authors observed all RPM stages only on eight arecaceous, one musaceous,

Figure 2.
Coconut and plantain trees showing symptoms of R. indica feeding (A, B) and a colony of the red palm mite on coconut leaves (C).

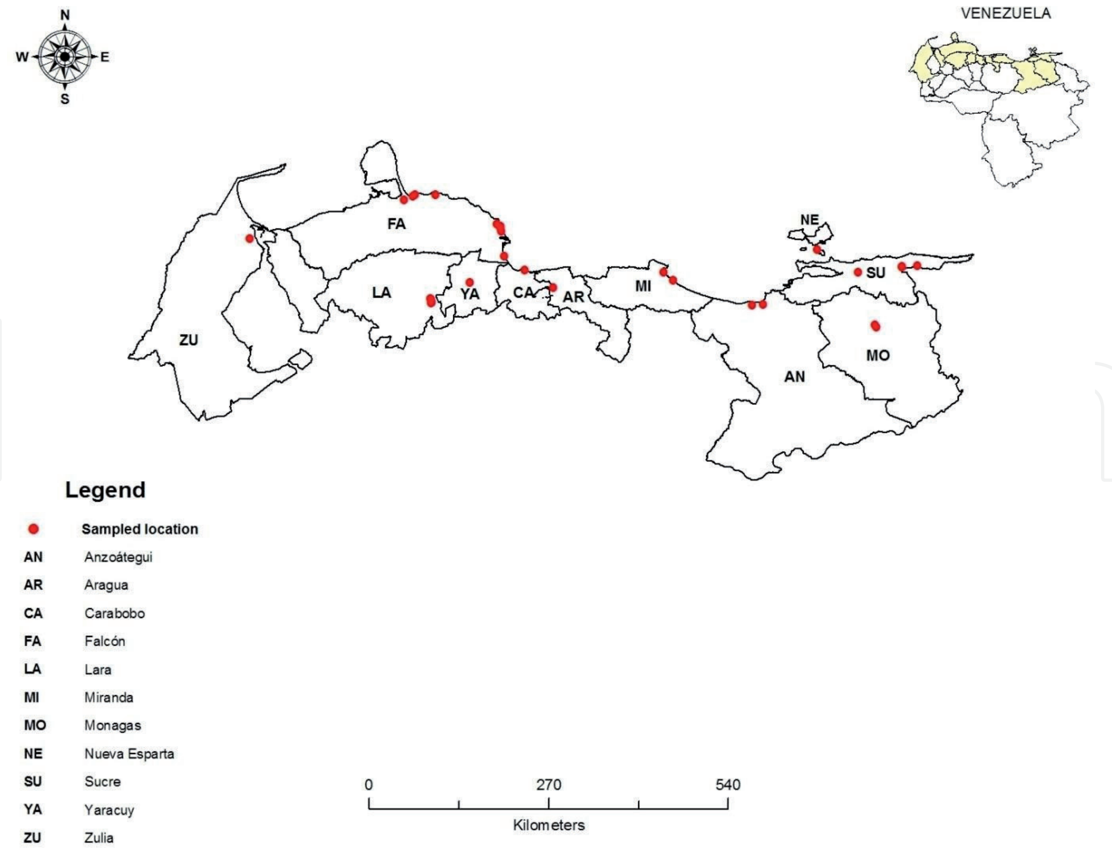

Figure 3.
Distribution of R. indica in Venezuela based on collection records (from 2008 to 2012) [52].

Plant family	Species
Apocynaceae	*Rauvolfia viridis*
Arecaceae	*Adonidia merrillii*
	Cocos nucifera
	Roystonea oleracea
	Pritchardia pacifica
	Ptychosperma macarthurii
	Roystonea regia
	Washingtonia sp.
	Washingtonia robusta
	Phaseolus sp.
Musaceae	*Musa* sp.
Sterculiaceae	*Sterculia* sp.
Strelitziaceae	*Strelitzia* sp.

Table 3.
Plant species onto which Raoiella indica was found in the northern Venezuela (from [52]).

and one streliziaceous species, indicating that the pest developed and reproduced only on these plants, while specimens found on weeds were considered spurious events. Later, the list of host plants increased including 73 species of Arecaceae, six of Musaceae, five of Heliconiaceae, four of Zingiberaceae, and two each of Pandanaceae and Strelitziaceae [53].

Due to the potential impact of *R. indica*, in 2007, the Brazilian Ministry of Agriculture added the RPM to the list of quarantine pests so that an extensive survey was initiated in the state of Roraima, a Brazilian state bordering Venezuela [54].

Only after 2 years, in July 2009, the red palm mite was found in samples of coconut and banana leaves in urban areas of Boa Vista (Roraima) [47]. Despite quarantine efforts, this mite became established in South America inasmuch as in 2011; it was reported in the urban areas of Manaus occurring not only on coconut plants but also on dwarf royal palm (*Veitchia merrillii* (Becc.) H. E. Moore) and fishtail palm tree (*Caryota mitis* Lour) [55]. Recently, in May 2015, the RPM was found in the urban area of Dracena (state of São Paulo), about 2300 km southeast of Manaus, on several arecaceous plants such as *C. nucifera*, *Phoenix roebelenii* O'Brien, and *Rhapis excelsa* (Thunb.) A. Henry [54].

Discovery of *R. indica* in several countries in South America suggests that this region exhibits climate conditions, which, along with the wide diversity of host plant species, stimulate its development, representing an imminent threat to the economy of those countries where coconut palm and banana are grown as crops of economic importance.

4. Conclusions

Biological invasions have increased greatly in the last century due to the intensification in international trade, thus representing one of the most relevant threats for biodiversity in agroecosystems. Over several decades, scientists are more interested in phytophagous mites since some noneconomic species have become severe pests on many crops due to wrong pest management strategies. Thus, phytophagous mites from the Neotropical region such as the cassava green mite, the coconut mite, and the tomato spider mite have been introduced in the Old World. As expected, some mite species have also been introduced in the Neotropical region, i.e., *S. spinki*, *S. hindustanicus*, and *R. indica* with remarkable economic impact on agriculture. These biological invasions in the New World require the participation of several public institutions (Universities, Government Agricultural Institutions) and farmers in order to mitigate the current impact on production of rice, citrus, coconut, and Musaceous crops. Most of the research has been focused on geographical distribution, host plant range, and natural enemies associated, but few studies have dealt with management strategies.

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Conflict of interest

The authors have declared no conflict of interests.

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