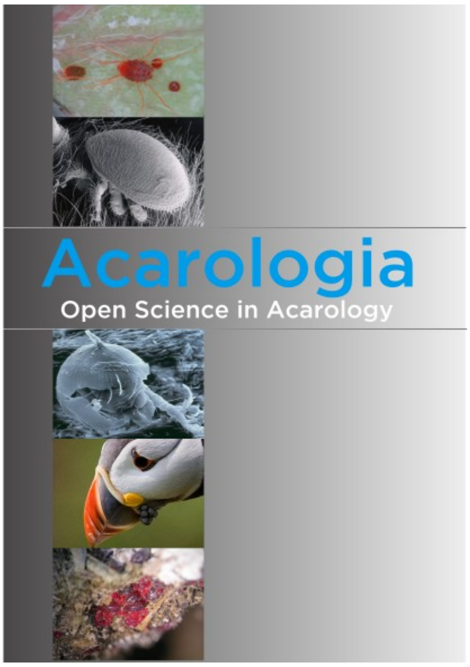

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REVIEW OF THE PHYTOPHAGOUS MITES COLLECTED ON CITRUS IN THE WORLD

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ABSTRACT — A review of the phytophagous mites collected on citrus in the world is presented. The economic importance of citriculture and the economic effects of this important group of Arthropods on citrus are discussed. One hundred and four phytophagous species are treated, belonging to the families Phytoptidae Murray, Eriophyidae Nalepa, Diptilomiopidae Keifer, Tarsonemidae Canestrini and Fanzago, Tenuipalpidae Berlese, Tuckerellidae Baker and Pritchard and Tetranychidae Donnadieu. The information is summarized in tables, where the known species, their pest status and the geographic distribution are listed for each single family. For species with major, medium and minor pest status the fundamental aspects of bio-ecology, damage, natural enemies (mainly insects, mites, pathogens), and control are briefly presented. Also, are discussed the harmfulness of the more important species, and the aspects (systematic, bio-ecology, pest status, natural enemies, means of control, horticultural practices, prevention, and Integrated Pest Control) requiring solutions and appropriate lines of research.

KEYWORDS — Acari; Prostigmata; Trombidiformes; phytophagous; citrus

INTRODUCTION

The citrus pest mites have often been studied on regional and global scales (Quayle, 1938; Bodenheimer, 1951; Ebeling, 1959; Chapot and Delucchi, 1964; Talhouk, 1975; Jeppson, 1978, 1989; Smith and Peña, 2002). Lists of mites species associated with citrus in southern California were published by McGregor (1956), in Florida by Muma (1975), for the Mediterranean area by Vacante *et al*. (1989) and for India by Dhooria *et al*. (2005). Jeppson *et al*. (1975) published a more extensive work that treated all mites injurious to economic plants, including those affecting citrus. Gerson (2003) presented a list of species known for citrus throughout the world and more recently Vacante (2010) reported on 104 species ascribed to the families Phytoptidae Murray, Eriophyidae Nalepa, Diptilomiopidae Keifer, Tarsonemidae Canestrini and Fanzago, Tenuipalpidae Berlese, Tuckerellidae Baker and Pritchard and Tetranychidae Donnadieu.

This review, drawn from the contribution of Vacante (2010), aims to present an updated picture of the problem and is addressed to specialists, technicians and students who deal with the problems of citrus mites. Moreover, the unitary nature of the contribution should help the work of those working in the field of pest mites prevention and control.

The topic is introduced with a brief treatment about the economic importance of citrus in the world and of the phytophagous mites affecting citrus. The species recorded from citrus in the different regions of the world are listed in tables, ac-

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cording to the families. Pest status and geographic distribution are also noted. Brief notes on the bio-ecology, damage, natural enemies and control are provided for major pests. Bio-ecological and technical aspects requiring solutions and lines of research for control are also examined.

THE ECONOMIC IMPORTANCE OF CITRICULTURE

About 140 countries grow citrus in the world and in 2007 it was estimated a total harvested surface of 8,322,605 ha, with a total worldwide production amounted to 115,650,545 tons (FAOSTAT, 2008). The production is intended for fresh consumption on the local and national markets or to be processed into juice. Citrus fruits are present in all world markets and are available in economically developed countries. A strong global demand feeds exports from major producing countries.

In 2002 citrus fruit per capita consumption was calculated to be approximately 22 kg per capita per year (UNCTAD from FAO data). In 2005 the export of citrus fruits in the world was equal to 12,088,535 tons (10% of total), for a value of US$ 6,935,692,000 (FAOSTAT, 2008). Citrus fruit processing accounts for approximately one third of total citrus fruit production. More than 80% of it is orange processing, mostly for juice production. In 2005 exports equalled 5,200,753 tons of citrus juice for an export value of US$ 3,930,898,000 (FAOSTAT, 2008).

Harvested areas, productions and estimated yields of each country of the world are not always related between them and the global picture of the situation presents significant contradictions. For example, China has the greatest harvested area (2,008,700 ha), the second world production (19,617,100 tons) but the eighth estimated yield (97.660 hectogram/ha), while Brazil has the second harvested area (915,056 ha), the greatest world production (20,682,309 tons) and the fourth estimated yield (226.022 hg/ha). The USA have the sixth harvested area (376,050 ha), the third production (10,017,000 tons) and the third estimated yield (266.374 hg/ha), while Nigeria has the third harvested area (732,000 ha), the eighth production (3,325,000 tons) and the tenth estimated yield (45.423 hg/ha) (FAOSTAT, 2008). The different productions and values of yields among the different regions are due to environmental and socio-economic causes, including the uneven availability of technical means and appropriate knowledge and/or specializations in the various fields of agricultural production. This in turn directly affects the quantitative and qualitative standards and the export opportunities and/or consumption of fresh products. From this point of view, knowledge of any biotic factors that adversely affect the citrus crop and its fruits would help to optimize quality and improve yield.

THE ECONOMIC IMPORTANCE OF THE MITES INJURIOUS TO CITRUS

In addition to pathological problems due to viruses (CTV, CiLV, etc.), fungi (*Phoma tracheiphila* (Petri) Kantachveli and Gikachvili, *Phtophtora* spp., etc.) and other injurious organisms, a variety of vertebrate and invertebrate animals infest citrus in the different regions of the world, reducing its quantities and qualities. Insects and mites are very important among these organisms. The citrus mites have been treated in different regions of the world, but there has not been a study that offers organic and up-to-date information. In marginal productive areas or in less developed areas this could cause significant interference with pest control practices and fail to prevent the accidental introduction of pests from other countries, adding more disadvantages (economic, ecological and toxicological).

The complexity of the topic and the wide distribution of citrus crops, grown throughout the subtropical and tropical regions of the world, do not facilitate pest control problems affecting by regionally different ecological, horticultural and socio-economic aspects. Environmental factors are very important and may directly influence the bio-ecology of the different mite species, therefore requiring strategic choices varying for the same species from one region to another. Examples are the different behavior patterns of citrus rust mite, *Phyllocoptruta oleivora* (Ashmead), Texas citrus mite,

TABLE 1: Mites of the family Eriophyidae Nalepa collected on citrus in the world. Following Gerson (2003) the pest status is indicated as Ma (major), Me (medium), Mi (minor), and U (unknown). For references see Vacante (2010).

Species	Pest status	Geographical distribution
Aceria sheldoni (Ewing)	Ma	worldwide
Circaces citri Boczek	U	Thailand
Cosella fleschneri (Keifer)	U	India, Taiwan
Aculops pelekassi (Keifer)	Ma, Me	Croatia, Greece, Italy, Japan, Paraguay, Taiwan, Thailand, USA (Florida)
Aculops suzhouensis Xin and Dong	U	China
Aculus advens (Keifer)	U	USA (California)
Paratetra murrayae Channabasavanna	U	India (Bangalore)
Tegolophus australis Keifer	Mi	Australia
Tegolophus brunneus Flechtmann	Mi	Brazil
Calacarus citrifolii Keifer	Mi	Angola, Kenya, Mozambique, Nigeria, South Africa, Zambia, Zimbabwe
Phyllocoptruta citri Soliman and Abou-Awad	U	Egypt
Phyllocoptruta oleivora (Ashmead)	Ma	worldwide
Phyllocoptruta paracitri Hong and Kuang	U	China

Eutetranychus banksi (McGregor), and citrus bud mite, *Aceria sheldoni* (Ewing), in the warm and humid areas of Florida in contrast to the warm and arid areas of California (Childers *et al*., 1996). In India, several factors contribute towards declines in the yield of citrus trees, among which the threat from different insects and mites is one of the most important (Bindra, 1970); the losses due to injurious mites are quite substantial, especially during years when climatic conditions favor these pests (Dhooria *et al*., 2005).

Production choices vary among regions and continents and influence mite control. Production for fresh markets generally requires more interventions than for processing juices. The cosmetic appearance of the former represents a priority, whereas in the latter is permitted more tolerance (Allen and Stamper, 1979). In Florida, fruit produced for the fresh market receives 3-4 annual chemical treatments whereas fruit intended for processing is given only 0-2 annual treatments, one with petroleum oil and an acaricidal treatment (McCoy, 1985; Browning, 1992). Mediterranean citrus crops are usually destined also for the fresh market and treated differently.

These facts have a serious economic importance and do not allow for generalizations, as in the case of the control of *Ph. oleivora* in Florida, which has an annual cost of US$ 75 - 100 million (McCoy, 1996), whereas it poses no problem in other important citrus areas where the pest is not present.

The reddish black flat mite, *Brevipalpus phoenicis* (Geijskes), responsible for the transmission in the American Continent of a viral disease commonly known as "Lepra explosive" or "Leprosis" (Childers *et al*., 2001, 2003b) necessitates a prevention program that annually costs about US$ 100 million in Brazil alone (Rodrigues *et al*., 2003), but which is non-existent as the viruses apparently are not vectored by the mite in the Mediterranean region. In Italian and Spain lemon groves, 0-3 acaricidal treatments are applied annually, costing per hectare about €450 per treatment.

THE SPECIES RECORDED ON CITRUS IN THE WORLD

A total of 104 phytophagous mites were reported on citrus worldwide. They belong to the families Phytoptidae Murray, Eriophyidae Nalepa, Diptilomiopidae Keifer, Tarsonemidae Canestrini and Fanzago, Tenuipalpidae Berlese, Tuckerellidae Baker and Pritchard and Tetranychidae Donnadieu.

Most species do not cause any problems in citrus groves (or at most, only sporadically) and their recognition facilitates the separation of these species from those usually harmful (Vacante, 2010).

Phytoptidae

A member of this family, *Phytoptus ficivorus* (Channabasavanna), has been recorded on citrus in India (Prasad, 1974; Dhooria and Gupta, 1998; Dhooria *et al*., 2005; Vacante, 2010). It caused unclear damage and did not require any control.

Eriophyidae

Thirteen species of Eriophyidae have been recorded on citrus in the world (Amrine and Stasny, 1994; Childers and Achor, 1999; Gerson, 2003; Dhooria *et al*., 2005; Vacante, 2010) (Table 1). Of these, only the citrus bud mite, *A. sheldoni*, the pink citrus rust mite, *Aculops pelekassi* (Keifer), and the citrus rust mite, *Ph. oleivora*, are major pests.

The species responsible of minor damage are the brown citrus rust mite, *Tegolophus australis* Keifer, the new brown citrus rust mite, *T. brunneus* Flechtmann, and the citrus grey mite or citrus blotch mite, *Calacarus citrifolii* Keifer. The other seven species have no known pest status. In addition, a few rare vagrant species (*Acaricalus* sp., *Tegolophus* sp., *Abacarus* sp.) were found on citrus in Florida (Childers and Achor, 1999), but their pest status is unknown and they are not been treated in this review.

Phyllocoptruta oleivora is a tropical species, with worldwide distribution. It is a rust mites, injurious to leaves, twigs and citrus fruits. Optimum temperature for development is between 30 and 32°C (Ebrahim, 2000) and it develops well at high RH values and particularly after rain (Pratt, 1957; Dean, 1959).

Aculops pelekassi is a subtropical species recorded in the Palearctic, Oriental and Neotropical regions. It is a rust mite, injurious to leaves, twigs and citrus fruits and its optimum conditions for development are temperatures between 22 and 27°C and 75 to 77% of RH (Ebrahim, 2000).

Aceria sheldoni has worldwide distribution; it is adapted to humid conditions, pertaining in coastal citrus groves. Optimal egg hatching is at 25°C and 98% RH but it is much lower under dry conditions (such as 35-40% RH). Population survival declines rapidly (50% dying within 30 minutes) at extreme low RH values and temperatures of 30 and -15°C (Sternlicht, 1970). The ecological role (and the phytopathological importance) of the citrus bud mite is unclear. The mite is probably a symbiont of the lemon, adjusting the flowering of the host plant that offers protection and nutritional resources (Vacante *et al*., 2007).

Tegolophus australis is a rust mite and its geographical distribution interests only the Australasian region, where apparently it does not cause serious damage to citrus.

Tegolophus brunneus is a rust mite with Neotropical distribution and does not represent any danger to citrus.

Calacarus citrifolii is recorded for the Afrotropical region (Angola, Kenya, Mozambique, Nigeria, South Africa, Zambia and Zimbabwe). The citrus blotch mite transmits a serious citrus disease, known as "concentric ring blotch", caused by its toxic saliva. However, high levels of attack are not always associated with the disease (Rossouw and Smith, 1963) that affects the young tissues and during periods of strong growth damages young leaves, shoots, branches and fruits; mature leaves and shoots appear to be exempt.

The natural enemies of the Eriophyidae include pathogens (viruses, fungi such as the Clavicipitaceae, Exobasidiomycetidae, Mycosphaerellaceae), molluscs (Orthalicidae), mites (Ascidae, Cheyletidae, Phytoseiidae, Stigmaeidae, Tydeidae), and insects (Cecidomyiidae, Coccinellidae, Coniopterigidae, Psychidae, Thripidae) (Vacante, 2010). *Phyllocoptruta oleivora* is the most studied species, both because of its wide geographical distribution and severe damage. In general, natural enemies do not provide an appreciable measure of control, except in special cases, like the Phytoseiid *Euseius victoriensis* (Womersley) that provides a good control of *T. australis* (Smith and Papacek, 1991).

Citrus rust mites control is usually based on chemical means (Vacante, 2010) and the main innovations consist basically on the definition of thresholds and introduction of new methods of sampling and monitoring of populations (Allen, 1981; Nascimento *et al*., 1982; Oliveira *et al*., 1982; Manzur, 1989; Rogers *et al*., 1994; Childers *et al*., 2007; Hall *et al*., 2007), which are aimed at rationalizing the use of acaricides within integrated pest management (IPM) programs (Rosen, 1986; Vacante, 1986; McCoy, 1996; Childers *et al*., 2007).

Diptilomiopidae

The Diptilomiopidae number on citrus only *Diptilomiopus assamica* Keifer (Vacante, 2010), recorded from India (Keifer, 1959; Chakrabarti and Mondal, 1983; Dhooria *et al*., 2005) and Australasian region (Knihinicki and Boczek, 2002). Keifer (1959) reported that *D. assamica* is a rust mite but produced no serious damage. McCoy (1996) refers that infested leaves showed diffused russeting but control was unnecessary, whereas Gerson (2003) noted that the pest status of the mite on citrus is unknown. In addition, a *Rhynacus* sp. has been found on citrus in Florida (Childers and Achor, 1999).

Tarsonemidae

The Tarsonemidae recorded from citrus are mostly mycophagous and only the broad mite, or citrus silver mite, *Polyphagotarsonemus latus* (Banks), produces severe injury to citrus and other cultivated plants (Jeppson *et al*., 1975; Gerson, 1992; Nucifora and Vacante, 2004; Vacante, 2010).

Polyphagotarsonemus latus probably represents a complex species (Lindquist, 1986) and has a worldwide geographical distribution. Optimum development requires tropical climatic conditions and occurs at 25°C and at near saturation humidities (90-100% RH) (Jones and Brown, 1983). The natural enemies of the citrus silver mite include fungi (Clavicipitaceae, Ascomycota) and mites (Phytoseiidae), and although positive results were reported with fungal pathogens and Phytoseiids, control of the citrus silver mite is commonly based on chemicals (Vacante, 2009). The most important innovations concern studies on the economic injury level (EIL) and on methods of sampling and monitoring of populations (Peña, 1990; Peña *et al*., 2002).

Tenuipalpidae

Twenty four species of Tenuipalpidae have been recorded worldwide from citrus (Jeppson *et al*., 1975; Meyer Smith, 1979, 1993; Gahi and Shenhmar, 1984; Gerson, 2003; Mesa *et al*., 2009; Vacante, 2010) (Table 2). They are usually considered to be secondary pests, but the ability of some species of the genus *Brevipalpus* to vector plant viruses has necessitated an updated review of this relatively little known family (Gerson, 2008). One of these *Brevipalpus* species is very injurious to citrus in Central and Southern America because it transmits the very pernicious forms of Leprosis (Knorr *et al*., 1960, 1968; Kitajima *et al*., 1972; Carter, 1973; Childers *et al*., 2001, 2003a, 2003b, 2003c). In other regions, like the Mediterranean area (Vacante, 2009, 2010) or South Africa (Schwartz, 1977), the economic importance of these species is much less. The reddish black flat mite, *B. phoenicis*, and the ornamental flat mite, *B. obovatus* Donnadieu, are major pests, whereas the citrus flat mite, *B. californicus* (Banks), is of medium or minor pest status. The grape flat mite, *B. chilensis*, and the citrus scab mite, *B. lewisi*, are minor pests. The pest status of the other 19 species is unknown.

Brevipalpus phoenicis is a polyphagous species, with worldwide distribution. The average length of a generation ranges from 27.5 days at 24°C to 18.3 days at 30°C (Prieto Trueba, 1975). On citrus its injury is similar to that of *B. californicus* and *B. obovatus* in Texas (Dean and Maxwell, 1967; France and Rakhi, 1994; Childers *et al*., 2003c) and in South Africa (Schwartz 1970, 1977; Meyer Smith and Schwartz, 1998a). Oranges damaged by reddish black flat mite are usually lighter and their weight is inversely proportional to the degree of infestation, furthermore, affected trees may lose 50% of their yield (Rodrigues *et al*., 2003). In Italy Di Martino (1985) has observed greyish scabby patches and cracks on the medial apical epidermis of mandarin fruit. Many lesions are located on oleiferous glands, which are emptied and dried; affected fruits show rounded reddish orange patches.

The greatest risk from a mite attack consists of the transmission of as "Leprosis" or "explosive Lepra" (Kitajima *et al*., 1972; Carter, 1973; Boaretto and Chiavegato, 1994; Rodrigues *et al*.,

TABLE 2: Mites of the family Tenuipalpidae Berlese collected on citrus in the world. Following Gerson (2003) the pest status is indicated as Ma (major), Me (medium), Mi (minor), and U (unknown). For references see Vacante (2010).

Species	Pest status	Distribution
Brevipalpus amicus Chaudhri	U	India, Pakistan
Brevipalpus californicus (Banks)	Me, Mi	Worldwide
Brevipalpus chilensis Baker	Mi	Chile, India
Brevipalpus cucurbitae Mohanasundaram	U	India
Brevipalpus cuneatus (Canestrini and Fanzago)	U	Italy
Brevipalpus deleoni Pritchard and Baker	U	India , USA (Florida),
Brevipalpus dosis Chaudhri, Akbar and Rasool	U	India, Pakistan
Brevipalpus jambhiri Sadana and Balpreet	U	India (Northern)
Brevipalpus jordani Dosse	U	Egypt, Lebanon, Tanzania
Brevipalpus karachiensis Chaudhri, Akbar and Rasool	U	India, Pakistan
Brevipalpus lewisi McGregor	Mi	Worldwide
Brevipalpus mcgregori Baker	U	USA (California)
Brevipalpus obovatus Donnadieu	Ma, Mi	Worldwide
Brevipalpus phoenicis (Geijskes)	Ma, Mi	Worldwide
Brevipalpus phoenicoides Gonzalez	U	Thailand
Brevipalpus rugulosus Chaudhi, Akbar and Rasool	U	India (Northern), Pakistan
Brevipalpus tinsukiaensis Sadana and Gupta	U	India
Pentasmerinus tauricus Livshitz and Mitrofanov	U	Crimea
Tenuipalpus caudatus (Dugès)	U	France, Greece, Italy, Portugal
Tenuipalpus emeticae Meyer	U	South Africa
Tenuipalpus mustus Chaudhri	U	India, Pakistan
Tenuipalpus orilloi Rimando	U	Indonesia, Philippines
Tenuipalpus sanblasensis De Leon	U	Mexico
Ultratenuipalpus gonianaensis Sadana and Sidhu	U	India

1997; Childers *et al*., 2003c), a viral disease (CiLV-C, CiLV-N) (Bastianel *et al*., 2006) recorded in Argentina, Brazil, Paraguay, Venezuela and recently also in Panama. In Florida, the disease has been known since the late 1800's but there are no records since 1960 (Morishita, 1954; Childers *et al*., 2001) and following studies suggest the elimination of the virus from Florida and Texas (Childers *et al*., 2003b).

Of the *Brevipalpus* spp. occurring on citrus only *B. phoenicis* transmits the virus throughout its different biological stages, but not transovarially, and in order to become infective, each mite has to acquire the virus separately (Pascon *et al*., 2006), transmitting it mechanically from citrus plant to citrus plant and/or from a few herbaceous plants of the genera *Atriplex*, *Beta* and *Chenopodium* (Chenopodiaceae), *Gomphrena* (Amaranthaceae), and *Tetragon* (Tetragoniaceae) to citrus (Childers *et al*., 2001). Clones of *B. phoenicis* from São Paolo and from Florida differed in their capacity to transmit CiLV (Rodrigues *et al*., 2003), and mite fitness was reduced when it was placed onto new host plants. The phenomenon can be explained by the existence of several host-specialized clones instead of one generalist form, each adapted to different environments and host plants (Groot *et al*., 2005).

In addition, the reddish black flat mite was considered responsible of other disorders, as the "*phoenicis* blotch" in Florida (Jeppson *et al*., 1975), the "*Brevipalpus* galls" (Knorr *et al*., 1960, 1968; Knorr and Denmark, 1970) and "halo scab" (Knorr and Malaguti, 1960; Chiavegato and Kharfan, 1993) in Venezuela; this last disorder is attributed to mite association on fruit of sour orange with scabs of fungus *Elsinoe fawcetti* Bitanic and Jenkins (Elsinoaceae). In Honduras *B. phoenicis* is also associated on sour orange with the same fungus (Evans *et al*., 1993), and a similar interaction between mite and fungi has been reported in Costa Rica (Ochoa *et al*., 1994) and Brazil (Chiavegato and Kharfan, 1993).

The damage caused by Leprosis reduces citrus yields in Brazil and more than 60 million dollars are spent each season on chemical sprays applied to control *B. phoenicis* (Rodrigues, 2006). Acaricide applications for the annual control of infestations of this mite represent 35% of total agrochemical costs and 14% of total production costs in mature orchards. Sequential sampling for Leprosis, based on its binomial distribution, deriving from a study of the spatial patterns of Leprosis and of *B. phoenicis*, indicated that the patterns of the disease and of infested plants deviated from a binomial distribution. Hence, estimates of disease or mite incidence may not be precise (Bassanezi and Laranjeira, 2007). The need to limit the use of chemicals and their attendant disadvantages have been suggested in Brazil.

In order to promote IPM (Gravena, 1998), the technical characteristics of the main acaricides registered for citrus and the detailed procedures of a laboratory bioassay conducted to evaluate the efficacy of acaricides against citrus Leprosis mite were suggested (Graven *et al*., 2005). Other options are to investigate the host plant resistance (Grewal, 1993; Bastianel *et al*., 2005, 2006; Rodrigues, 2006).

The main scientific gained experience includes the study of the biology of the pest populations (Weeks *et al*., 2000; Groot *et al*., 2005) and the need of a taxonomic revision of the group based on modern methods of analyzes. For instance, the problem of synonymy in closely related species (*B. phoenicoides* Gonzalez, *B. phoenicis*, *B. jordani* Dosse, etc.) within the taxonomic revision of the group (Groot and Breeuwer, 2006).

Brevipalpus obovatus is a polyphagous species with worldwide distribution. At 23 ± 1°C and 60 ± 5% RH, the life cycle from egg to adult takes 27.8 days and at 27°C 21.5 days (Trindade and Chiavegato, 1994). In Texas the symptoms of its attack on citrus are similar to those of *B. phoenicis* and *B. californicus* (Dean and Maxwell, 1967; France and Rakhi, 1994; Childers, 1994; Childers *et al*., 2003c). In the USA (Jeppson *et al*., 1975), South Africa (Meyer Smith and Schwartz, 1998b) and Mediterranean region the ornamental flat mite does not cause serious damage to citrus. Although in Argentina the injury of *B. obovatus* feeding on citrus leaves, fruits and twigs has been defined as "Lepra explosive" or "Leprosis" (Vergani, 1945) it is improperly considered responsible for the transmission of citrus Leprosis, as its ability to transmit the virus was not proven (Childers *et al*., 2001). In Venezuela the ornamental flat mite is associated with "halo scab", but when *B. obovatus* and *B. phoenicis* are present on the same plant, the damage to the leaves and stems is more severe and primarily due to the latter species (Knorr *et al*., 1960).

Brevipalpus californicus has a worldwide distribution and similarly to other treated Tenuipalpids is a polyphagous species. At 23 ± 1°C and 60 ± 5% RH, the life cycle from egg to adult develops in 26.5 days and at 27°C in 21 days (Trindade and Chiavegato, 1994). In Australia (Jeppson *et al*., 1975), South Africa (Schwartz, 1977) and in the Mediterranean region (Di Martino, 1985) it causes brown to bronze colored and corky scab-like spots on rind of sweet orange. Feeding by mite produces a silvering of the fruit, particularly of lemon. In Texas the citrus flat mite has been associated with rind spotting of oranges and grapefruit, first yellowish and discoloured in depression on the fruit surface and tending to become darker in color.

In the American Continent the mite is feared for risk of transmitting the Leprosis virus to citrus leaves and fruit, which has strongly limited the development of citrus groves in certain areas of the world (Knorr *et al*., 1968). In Texas and Florida on grapefruit and orange varieties it produces smaller necrotic lesions form on the surface of infested leaves and fruits, called "Leprosis-like spotting" or "nail head rust" (Dean and Maxwell, 1967; Jeppson, 1989; France and Rakhi, 1994). In Florida, the symptoms on twigs and branches are

TABLE 3: Mites of the family Tuckerellidae Baker and Pritchard collected on citrus in the world. Following Gerson (2003) the pest status is indicated as Ma (major), Mi (minor), and U (unknown). For references see Vacante (2010).

Species	Pest status	Distribution
Tuckerella knorri Baker and Tuttle	Ma, Mi	China, Costa Rica, Iran, Philippines, Thailand
Tuckerella nilotica Zaher and Rasmy	U	Egypt
Tuckerella ornata (Tucker)	U	Worldwide
Tuckerella pavoniformis (Ewing)	Mi	Worldwide

called "Florida scaly bark" and in Argentina both symptoms are known as "Lepra explosive" or "Leprosis".

However, the pest does not transmit viral diseases and at present the only known vector of the disease is *B. phoenicis* (Rodrigues *et al.*, 2003).

Brevipalpus chilensis has been recorded in the Oriental and Neotropical regions, where it is responsible for the silvering of citrus fruits. It is a polyphagous species and depending on the climatic conditions completes its life cycle in a range of 18-59 days (Gonzalez, 1968). The mite does not transmit diseases.

Brevipalpus lewisi is a polyphagous species, with worldwide distribution. Its optimal net reproductive rate (R_0) is 4.82 and occurs at 22°C and 70% RH (Buchanan *et al.*, 1980). High densities of the citrus scab mite cause large alterations on the surface of the citrus fruit, reducing seriously the quality of fruit. The pest does not cause damage to leaves or wood and the scablike scars observed on most varieties of citrus rarely occur on grapefruit (Elmer and Jeppson, 1957). On tangerines the citrus scab mite causes grade-reducing scarring on 17-28% of the fruit (16-21% of navel oranges, 18-35% of grapefruits) (Elmer, 1968); on Lisbon lemon fruits, scarring may affect over 25% of the fruit (Lewis, 1949). The pest does not transmit diseases.

The natural enemies of the Tenuipalpids include fungi (Ascomycota, Clavicipitaceae), insects (Coccinellidae) and mites (Cheyletidae, Phytoseiidae, Stigmaeidae, Tydeidae) (Vacante, 2010). In Egypt the Phytoseiid *Euseius scutalis* (Athias Henriot) controlled *B. californicus* after 50 predator individuals were released per citrus tree (El-Halawany *et al.*, 1993). However, most growers lack practical experience in biological control and the control of Tenuipalpid populations is done normally by chemical means; this is also considered safer in order to reduce the risk of disease transmission.

Tuckerellidae

Four species of Tuckerellidae are recorded on citrus worldwide (Vacante, 2010) (Table 3), but their level of damage is unclear. Although Gerson (2003) stated that they neither cause much economic injury nor require control measures, Ochoa *et al.*, (1994) reported that the peacock spider mite, *Tuckerella pavoniformis* (Ewing), and the ornamented mite, *Tuckerella knorri* Baker and Tuttle, damaged citrus fruit in Central America. The pest status of the remaining two species remains unknown.

Tuckerella pavoniformis has a worldwide geographical distribution and has never been associated with serious damage to citrus. The peacock spider mite was recorded in Central America as a pest of citrus plants and fruits. The need for control is not widespread and at present interests only the Central America (Ochoa *et al.*, 1994).

Tuckerella knorri has a wide geographical distribution (Oriental, Neotropical, and Palearctic regions) and in Costa Rica is a serious citrus pest. The ornamented mite occurs in association with the fungus *Sphaceloma fawcetti* Jenkins (Ochoa, 1989) and is considered a causative agent of the cracking of citrus fruits (Aguilar and Gonzalez, 1990). Insufficient information is available, except in Costa Rica where there is the need for control.

Tetranychidae

Sixty species of Tetranychidae have been recorded on citrus in different regions of the world (Pritchard

TABLE 4: Mites of the family Tetranychidae Donnadieu collected on citrus in the world. According to Gerson (2003) the pest status is indicated as Ma (major), Mi (minor), and U (unknown). For references see Vacante (2010).

Species	Pest status	Distribution
Bryobia graminum (Schrank)	U	Worldwide
Bryobia praetiosa Koch	U	Worldwide
Bryobia rubrioculus (Scheuten)	U	Worldwide
Aplonobia citri Meyer	U	Australia, South Africa
Aplonobia honiballi Meyer	U	South Africa
Aplonobia histricina (Berlese)	U	Australia, Israel, Italy, South Africa
Petrobia harti (Ewing)	U	Worldwide
Petrobia latens (Müller)	U	Worldwide
Petrobia tunisiae Manson	U	Iran, Israel, Italy, Spain, Tunisia
Tenuipalponychus citri Channabasavanna and Lakkundi	U	India
Aponychus chiavegatoi Feres and Flechtmann	U	Brazil
Aponychus spinosus (Banks)	U	Brazil, Canada, Paraguay, Philippines, USA
Eutetranychus africanus (Tucker)	Mi	Australia, Comoros, Egypt, India, Japon, Madagascar, Mauritius, Mozambique, Myanmar Burma, Papua New Guinea, Philippines, Reunion Island, South Africa, Thailand
Eutetranychus banksi (McGregor)	Ma	Egypt, Hawaii, India, North, Central and South America, Portugal, Spain
Eutetranychus citri Attiah	Mi	Egypt, India
Eutetranychus cratis Baker and Pritchard	U	Congo, Congo (RDC ex Zaïre), Nigeria
Eutetranychus eliei Gutierrez and Helle	U	Madagascar
Eutetranychus orientalis (Klein)	Ma	Worldwide
Eutetranychus pantopus (Berlese)	U	Australia, Egypt, Sudan
Eutetranychus pyri Attiah	Mi	Egypt

and Baker, 1955; Meyer Smith, 1987; Bolland *et al*., 1998; Migeon and Dorkeld, 2009; Vacante, 2010) (Table 4). Some of these species were accidentally collected and do not appear to produce any damage to the crop (*Bryobia praetiosa* Koch, *Aplonobia citri* Meyer, *A. histricina* (Berlese), *A. honiballi* Meyer, *Petrobia tunisiae* Manson, *P. harti* (Ewing), etc.).

The major pests are the Texas citrus mite, *Eutetranychus banksi* (McGregor), the oriental red mite, *Eutetranychus orientalis* (Klein), the citrus red mite, *Panonychus citri* (McGregor), the six-spotted spider mite, *Eotetranychus sexmaculatus* (Riley), and the two spotted spider mite, *Tetranychus urticae* Koch; 22 species are minor pests and 33 have an unknown pest status. The most important species with minor pest status are the citrus yellow mite, *Eotetranychus kankitus* Ehara, the Lewis spider mite, *Eotetranychus lewisi* (McGregor), and the Yuma spider mite, *Eotetranychus yumensis* (McGregor).

Eutetranychus banksi is a polyphagous species widely distributed (Nearctic, Neotropical, Palearctic, and Oriental regions) and has recently been reported for the first time in the Mediterranean region in Portugal (Gonçalves *et al*., 2002) and Spain (Garcia *et al*., 2003). It develops under dry, low RH conditions and at temperatures close to 27°C (Dean, 1959); the optimum range of development is at 28-31°C (Badii *et al*., 2003). On citrus feeding symptoms of the Texas citrus mite are similar to those of the citrus red mite, *P. citri* (Jeppson *et al*., 1975).

Eutetranychus orientalis is a polyphagous species, with worldwide distribution. Optimum conditions for its development are 21°C and 59-70% RH. It develops at temperatures of 18-30°C and con-

TABLE 4: Continued

Species	Pest status	Distribution
Meyernychus emeticae (Meyer)	Mi	Angola, South Africa
Acanthonychus jiangfengensis Wang	U	China
Eotetranychus cendanai Rimando	Mi	Cambodia, China, Philippines, Taiwan, Thailand
Eotetranychus kankitus Ehara	Mi	China, India, Japan
Eotetranychus lewisi (McGregor)	Mi	Bolivia, Chile, Colombia, Costa Rica, El Salvador, Guatemala, Hawaii, Honduras, Libya, Madeira Island, Mexico, Nicaragua, Panama, Peru, South Africa, Taiwan, USA
Eotetranychus limonae Karuppuchamy and Mohanasundaram	U	India
Eotetranychus limoni Blommers and Gutierrez	Mi	Madagascar
Eotetranychus mandensis Manson	U	India
Eotetranychus pamelae Manson	U	India
Eotetranychus sexmaculatus (Riley)	Ma	Australia, China, Formosa, Hainan Island, Hawai, Korea (Rep. South), India, Iraq, Japan, Korea, New Zealand, Okinawa Island, Taiwan, USA
Eotetranychus yumensis (McGregor)	Mi	Mexico, USA
Mixonychus ganjuis Qian, Yan and Ma	U	China
Mixonychus ziolanensis (Lo and Ho)	U	Taiwan
Oligonychus biharensis (Hirst)	U	Worldwide
Oligonychus coffeae (Nietner)	U	worldwide
Oligonychus gossypii (Zacher)	U	Angola, Benin, Brazil, Cameroun, Central Africa Rep., Colombia, Congo, Congo (RDC ex Zaire), Costa Rica, Ecuador, Ethiopia, Guinea-Bissau, Honduras, Kenya, Madagascar, Nigeria, Sao Tome and Principe, Senegal, Sierra Leone, Tanzania, Togo, Uganda, Venezuela
Oligonychus peruvianus (McGregor)	Mi	Colombia, Costa Rica, Ecuador, Guatemala, Mexico, Peru, Trinidad and Tobago, USA, Venezuela
Panonychus citri (McGregor)	Ma	Worldwide
Panonychus elongatus Manson	Mi	Australia, China, Korea, Myanmar Burma, Papua New Guinea, Taiwan, Thailand
Panonychus ulmi (Koch)	U	Worldwide
Schizotetranychus baltazari Rimando	Mi	China, Hong Kong, India, Indonesia, Myanmar Burma, Philippines, Taiwan, Thailand
Schizotetranychus industanicus (Hirst)	Mi	India
Schizotetranychus lechrius Rimando	U	Indonesia, Philippines, Taiwan
Schizotetranychus spiculus Baker and Pritchard	U	India, Kenya, Zaire
Schizotetranychus youngi Tseng	U	Taiwan

ditions of 35 to 75% RH. Beyond these limits development decreases or stops (Bodenheimer, 1951). Feeding of the oriental red mite on the upper leaf surface and fruit causes stippling, similar to that of the citrus red mite. In heavy levels of attack the trees become silver-grey, leaves may drop and the shoots show dieback. Bare trees are a serious problem in nurseries or young orchards. The combined effect of insufficient water and low infestations produces as much defoliation and twig dieback as a

TABLE 4: Continued

Species	Pest status	Distribution
Tetranychus desertorum Banks	U	Worldwide
Tetranychus fijiensis Hirst	Mi	Australia, Carolina Islands, China, Fiji, Hainan Island, India, Kiribati, Malaysia, Marianas Northern, Marshall Islands, Micronesia Federated States, New Caledonia, Papua New Guinea, Philippines, Seychelles, Sri Lanka, Taiwan, Thailand
Tetranychus gloveri Banks	Mi	American Samoa, Australia, Bermuda, Brazil, Colombia, Costa Rica, Cuba, French Polynesia, French West Indies, Greece, Guadeloupe, Guam Island, Hawaii, Honduras, Les Saintes, Marianas Northern, Mexico, Panama, Paraguay, Peru, Puerto Rico, Samoa (American),
Tetranychus kanzawai Kishida	Mi	Worldwide
Tetranychus lambi Pritchard and Baker	U	Australia, Cook Islands, Fiji, French Polynesia, Iran, New Caledonia, New Zealand, Papua New Guinea, Samoa (American), Samoa (Western), Taiwan, Tasmania, Tonga, Vanuatu, Wallis and Futuna
Tetranychus ludeni Zacher	Mi	worldwide
Tetranychus mexicanus (McGregor)	Mi	Argentina, Brazil, China, Colombia, Costa Rica, Cuba, El Salvador, Guadeloupe, Honduras, Les Saintes, Mexico, Nicaragua, Paraguay, Peru, USA, Uruguay, Venezuela
Tetranychus neocaledonicus André	Mi	worldwide
Tetranychus pacificus McGregor	Mi	Canada, Mexico, USA
Tetranychus paraguayensis Aranda	U	Paraguay
Tetranychus salasi Baker and Pritchard	U	Costa Rica, Nicaragua
Tetranychus taiwanicus Ehara	Mi	China, Hainan Island, Taiwan, Thailand
Tetranychus tumidus Banks	Mi	Colombia, Cuba, Greece, Guam, Panama, Puerto Rico, Thailand, USA
Tetranychus turkestani (Ugarov and Nikolski)	U	worldwide
Tetranychus urticae Koch	Ma, Mi	worldwide

heavy attack (Jeppson *et al.*, 1975; Jeppson, 1989).

Panonychus citri has a worldwide distribution. Temperatures of 40.5°C, or several days of hot dry weather (5% RH and 32°C), along with strong winds commonly cause high mortality. The susceptibility to extreme temperature and RH conditions limits the distribution of the mite and affects its seasonal population trends (Jeppson *et al.*, 1975).

Feeding symptoms of citrus red mite may be confused with those of the oriental citrus mite. Feeding on the upper leaf surfaces results in the removal of all cytoplasm contents, except for some starch grains (Albrigo *et al.*, 1983). This results in small emptied spaces, consisting of light coloured spots, with a grey or silvery appearance appraised as stipplings on the leaves, mostly on the upper surfaces, the density of the spots being dependent on the severity of the attack. Green immature fruits become pale, and on maturing they are straw-yellow. High levels of attack before fruit maturity may cause fruit drop (Stofberg, 1959; Keetch, 1968; Jeppson *et al.*, 1975). Like other spider mites, *P. citri* may cause worker allergy (Burches *et al.*, 1996).

Eotetranychus sexmaculatus is a polyphagous species and presents a wide geographical distribution (Australasian, Oriental, Nearctic, and Palearctic regions). Its dynamics of population is adversely influenced by dry weather conditions and they reach injurious levels only in the more humid coastal regions. Dry winds hinder the development of the mites populations, which increase gradually during winter and rapidly in spring and summer (Jeppson *et al*., 1975; Jeppson, 1989). The six-spotted spider mite feeds on the undersides of leaves, seldom attacking fruits, except during very wide-spread infestations. Mite feeding on the lower leaf surfaces produces yellow depressions that are covered by webbing, and the areas on the upper surfaces that correspond to the locations of the mite colonies on the lower surfaces become raised and yellow or yellow-white, with a smooth, skinny surface. As the infestation increases the yellowish areas converge and the leaves become entirely yellow, distorted or misshapen, and drop prematurely (McGregor, 1956; Jeppson *et al*., 1975; Jeppson, 1989).

Tetranychus urticae is a very polyphagous species with worldwide distribution. Dry conditions facilitate its development (Pralavorio and Almaguel Rojas, 1980) and optimum development occurs at 30°C and requires 7.3 days (Sabelis, 1981). On citrus the damage of the two spotted spider mite is similar to that of the six-spotted spider mite, and the feeding activity on the undersides of young leaves produces chlorotic areas visible on the upper surface; severe damage may result in leaf drop (Jeppson, 1989). In semitropical areas of the world *T. urticae* infests young leaves and green or mature fruits of all citrus species. The populations usually develop on a limited portion of the leaves. The leaves buckle at the site corresponding to the colonies and the upper surface becomes raised and turn a yellow-ochre colour.

On orange, lemon and other citrus fruits the feeding activity of the mite produces a blackish area around the navel end of fruit that grows when the pest populations infest the whole fruit (Lewis *et al*., 1951; Dosse, 1964; Di Martino, 1985; Vacante, 2009). This species, like other spider mites, may cause worker allergy (Burches *et al*., 1996).

Eotetranychus kankitus has been reported in the Palearctic and Oriental regions and in Japan, where its damage to citrus is similar to that of the six-spotted spider mite (Ehara, 1964). Severe infestations of the citrus yellow mite on citrus trees causing leaves, flowers and fruit to drop prematurely and the withering of branches was reported by Chen (1999).

Eotetranychus lewisi has a wide geographical distribution (Palearctic, Afrotropical, Nearctic, Neotropical, and Oriental regions). The Lewis spider mite is injurious only to citrus fruit, its feeding resulting in a pale stippling of the rind. No damage is usually seen on the leaves but severe infestations cause silvering on lemon and either a silvering or russeting of oranges (McGregor, 1956; Jeppson *et al*., 1975).

Eotetranychus yumensis has been reported in the Nearctic and Neotropical regions. Relatively high temperatures are necessary for its development, which occurs at 21-38°C, but at 43.5°C the eggs do not hatch. This adaptation probably confines the species to hot desert areas. The Yuma spider mite feeds on leaves, fruit and green twigs of citrus and produces a silvering of mature fruit (Elmer, 1969; Jeppson *et al*., 1975).

The natural enemies of the Tetranychidae include viruses (non inclusion viruses), fungi (Ascomycota, Clavicipitaceae, Entomophthoraceae, Exobasidiomycetidae, Neozygitaceae), insects (Aeolothripidae, Anthocoridae, Chrysopidae, Coccinellidae, Coniopterygidae, Endomychidae, Reduviidae, Staphylinidae), araneids (Linyphiidae), and mites (Ascidae, Bdellidae, Cheyletidae, Cunaxidae, Phytoseiidae, Smaridiidae, Stigmaeidae, Tydeidae) (Vacante, 2010).

Despite the numerous beneficials known throughout the world, biological control alone is insufficient and chemical control is usually necessary. However, in some cases the spider mites are controlled by their predators, as for example *P. citri* in the Mediterranean region, where the pest is adequately controlled by the Phytoseiid mite *Euseius stipulatus* (Athias-Henriot) (Vacante, 1986) or where Exobasidiomycetidae fungi *Meira argovae* Boekhout *et al*., *M. geulakonigii* Boekhout *et al*., and *Acaromyces ingoldii* Boekhout *et al*., may control *P. citri*, *E. ori-*

entalis, and *T. urticae*, in the laboratory (Paz *et al.*, 2007).

In general, the control of Tetranychids mites requires the use of acaricides and a correct management of horticultural practices. The choice of pesticides is important, and petroleum oils, despite being an old remedy, are to be preferred (Vacante, 2010), as in the case of *E. orientalis,* where conditions clearly indicated the rational use of insecticides, including the appropriate distribution of petroleum oils and selective acaricides, which together help to limit the mite populations and indirectly promote a preliminary condition for IPM. Various citrus cultivars have sometimes been investigated in order to evaluate their resistance or tolerance to mite attacks (Sadana and Kanta, 1972; Dhooria and Sandhu, 1973; Dhooria, 1982; Singh *et al.*, 1983; Bhumannavar *et al.*, 1988). On the whole, IPM represents the best solution for the control of *P. citri*, *T. urticae* and other species on citrus. This strategy demands the use of selective acaricides and insectides, and particularly of petroleum oils (Rosen, 1986; Vacante, 1986; McCoy, 1996; Childers *et al.*, 2007).

Regrettably, there have been no significant innovations in the control of pests of this family and most efforts of researchers were focused on rationalizing the use of chemical means and on IPM. Of particular importance were the efforts to adopt sampling methods and threshold values, as for *E. kankitus* in China (Wang, 1985), *T. urticae* in Spain (Martinez Ferrer *et al.*, 2006) and *P. citri* in several countries (Jones and Parrella, 1984; Zalom *et al.*, 1986; Rodriguez and Ramos, 1998; Hare and Phillips, 1992; Song *et al.*, 2003). However the monitoring of the populations is difficult, due to variables such as climate, mite distribution and chemical control, all affecting the economic threshold (ET).

PEST STATUS, GEOGRAPHICAL DISTRIBUTION AND RISK OF INTRODUCTION

The high number of species reported may emphasize the problem of citrus mites and in particular the possibility of introduction of new pests in the different areas of citrus cultivation. However, there is no risk and the case of the most important species can be evaluated through the use of specialized methodologies, such as diffusion or distribution models (Muirhead *et al.*, 2006; Migeon *et al.*, 2009), ecological niche models (ENM) (Peterson, 2007), etc. In this discussion we do not intend to assess this dimension of problem, considering sufficient a general approach, based on current knowledge on pest status and geographical distribution of each species. These parameters help to first put the risk of harm of the various species and do not preclude a subsequent specialized analysis.

Sixty-four (62%) of the 104 reported species have no pest status, even though they are assigned to the Trombidiformes and possess mouthparts adapted to phytophagy, and 40 (38%) have a well known pest status, including 12 (12%) species with major or medium pest status and 28 (27%) species with minor pest status; 27 (67%) of these latter 40 species are Tetranychids, 6 (15%) are Eriophyids, 5 (12%) are Tenuipalpids and 2 (5%) are Tuckerellids.

The Tenuipalpids number 19 (79%) species with unknown pest status on 24 in total, the Tetranychids 33 (55%) species on 60 in total, the Eriophyids 7 (54%) species on 13 in total and the Tuckerellids 2 (50%) species on 4 in total.

All species with major and medium pest status have a worldwide geographic distribution, whereas less than a quarter of those with minor pest status are worldwide in distribution. The reasons for this are not fully understood although it is conceivable that part of the phenomenon is related to typical bio-ecological adaptations (reproductive potential, climatic limitations, absence or reduced polyphagy, etc.).

The Eriophyids with minor pest status have a narrowly defined geographic distribution coincident with their region of origin, but the limited distribution of the Tenuipalpids and Tuckerellids is more difficult to interpret. Fourteen (52%) of the 27 Tetranychids with minor pest status were reported from the Oriental region, 11 (41%) from the Afrotropical and Palearctic regions, 10 (37%) from the Nearctic and Neotropical regions, and 6 (22%) from the Australasian region. The high number of reported species from the Oriental region emphasizes the relationship between the area of citrus origin and the number of species found thereon.

TOPICS REQUIRING SPECIFIC RESEARCH

In general, the review of bibliographical references highlights the lack of knowledge on the bio-ecology of many species and the necessity to investigate the control of major pests. In this regard we summarize the most important topics requiring a better understanding and/or specific research.

Systematic. Some taxa require a systematic revision, based both on the application of traditional morphological methods and of molecular tools (Navajas and Boursot, 2003; Ben-David *et al.*, 2007, 2009). These last also permit important applications, as in the case of Leprosis and *B. phoenicis* (Weeks *et al.*; 2000, Rodrigues *et al.*, 2003; Groot *et al.*, 2005).

Bio-ecology. The lack of knowledge on bio-ecology of many species suggests encouraging specific research. The intraspecific mechanisms within a species, as the role of endosymbiont bacteria (Breeuwer, 1997; Gotoh *et al.*, 2003), the ecological relationship between host plants and pests and abiotic and biotic factors involved in the population dynamics are interesting. Greater knowledge of the ecology of various species would help to understand their distribution and made to predictive models of risk deriving from their acclimatization and would prepare a database system of the risks deriving from their presence. A better knowledge of bio-ecology of many species will help to avoid irrational choices in the different regions of the world, as for the citrus bud mite, where field evaluations of its damage on lemon in Italy (Vacante and Nucifora, 1984) and California (Hare *et al.*, 1999) have shown that it causes only little real damage and could be a case of symbiosis between mite and lemon (Vacante *et al.*, 2007).

Biological control. Many contributions about the natural enemies of citrus mites concern the Phytoseiidae mites. This aspect is confirmed from many studies on their systematic, bio-ecology and biological control programs, including IPM. The number of described species of Phytoseiidae has increased from about 1,500 in 1986 (Moraes *et al.*, 1986) to about 2,250 to 2004, of which 81 were initially collected on citrus (Moraes *et al.*, 2004). In addition, the records indicated that their number is greatest on citrus, sometimes engendering the increased use of molecular tools in order to identify races, biotypes and cryptic species. Different pathogens such as bacteria and entomopathogenic fungi are also important. Fungi are being extensively investigated and could provide short term control of different species of mites (Paz *et al.*, 2007). The implementation of the methods needs the identification and/or selection of the most suitable strains and requires knowledge of their bio-ecology and industrial production (Zhang *et al.*, 2002). In general, the use of natural substances (Meneley, 2000) does not seem very encouraging.

Chemical control. New technical approaches to chemical control can be derive from new molecules, improving existing products, such as some isomers of known molecules, and looking for new solutions, for instance the plant activator chemistry in the control of plant diseases (Carroll, 2000). It is a valid strategy of control, but does not always provide certain solutions, as regards the impact of new substances on the environment, as for instance the impact of derivatives of tetronic acid on pollinators (http://side-effects.koppert.nl/, 2007) and Phytoseiids (Gravena *et al.*, 2004; Rodrigues and Torres, 2007), and requires a search for alternative means.

Horticultural practices. Biotic and abiotic factors and horticultural practices (Jeppson *et al.*, 1975; McCoy, 1977; Zamora and Nasca, 1985; Smith and Papacek, 1991) hinder the development of pest mite populations, as do fertilizers (Puttaswamy and Channabasavanna, 1982; Jackson and Hunter, 1983) or horticultural practices intended to limit the spread of Leprosis and of *B. phoenicis* (Maia and Oliveira, 2004). The correct application of horticultural practices is very productive but lacks a comprehensive bibliographic information. In general, there is a need for appropriate investigations and/or an intensification of those in progress.

Prevention. Prevention is fundamental in the pest mites control (and other pests), because it is usually easier to prevent damage by pest eradication and thus control of new plant problems (due to pests, diseases, weeds). Regrettably it exist a discrepancy between the risk of introducing any injurious species and protection provided by the legislation in force. It's hard to draw a viable framework for all countries and there is a need to address the topic more broadly.

Integrated Pest Management. The implementation of classical biological control is fundamental for IPM and requires an accurate study of the complex of natural enemies, of their bio-ecology and of impact of chemical means on their populations. Also are useful the application of molecular tools, the knowledge of the effects on non-target species, and global cooperation. The augmentative biological control has been successfully employed on orange and mandarin Shaddock orchards in China, where *Amblyseius cucumeris* (Oudemans) releases produced a control of the citrus red mite, *Panonychus citri* (McGregor), ranged from 93.8 to 98.1% (Zhang *et al*., 2002). Nevertheless the strategy is commonly more expensive than the classical biological control and does not solve all problems of citrus mites. Its application is possible if the mass production of predators or pathogens has an acceptable economic cost and requires information on release rates, timing, and monitoring methods, and on the quality and purity of the natural enemies. This suggests an appropriate economic and technical assessment. Educational challenges plays an important role (Hoy, 2000).

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