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Brevipalpus californicus, B. obovatus, B. phoenicis, and *B. lewisi* (Acari: Tenuipalpidae): a review of their biology, feeding injury and economic importance

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Abstract. The genus *Brevipalpus* includes most of the economically important species of Tenuipalpidae. Many *Brevipalpus* species reproduce by theletokous parthenogenesis while other species reproduce by male fertilization of female eggs. Previous researchers have determined that *Brevipalpus californicus* (Banks), *B. obovatus* Donnadieu, and *B. phoenicis* (Geijskes) females were haploid with two chromosomes. The life cycle and developmental times for these three species are reviewed. Longevity of each *Brevipalpus* species is two to three times greater than corresponding longevities of various tetranychid mites. *Brevipalpus* mites inject toxic saliva into fruits, leaves, stems, twigs, and bud tissues of numerous plants including citrus. Feeding injury symptoms on selected plants include: chlorosis, blistering, bronzing, or necrotic areas on leaves by one or more *Brevipalpus* mites. Premature leaf drop occurred on 'Robinson' tangerine leaves in Florida (USA). Leaf drop was observed in several sweet orange and grapefruit orchards in Texas (USA) that were heavily infested with *Brevipalpus* mites feeding on the twigs, leaves, and fruit. Initial circular chlorotic areas appear on both sweet orange and grapefruit varieties in association with developing populations of *Brevipalpus* mites in Texas. These feeding sites become progressively necrotic, darker in color, and eventually develop into irregular scab-like lesions on affected fruit. Russeting and cracking of the fruits of other plant hosts are reported. Stunting of leaves and the development of *Brevipalpus* galls on terminal buds were recorded on sour orange, *Citrus aurantium* L., seedlings heavily infested with *B. californicus* in an insectary. The most significant threat posed by these mites is as vectors of a potentially invasive viral disease called citrus leprosis.

Key words: false spider mites, flat mites, *Citrus*, tea, pistachio

Introduction

The Tenuipalpidae are referred to as false spider mites or flat mites and occur mostly in tropical and subtropical climates (Jeppson *et al.*, 1975; Baker and

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Tuttle, 1987). The genus *Brevipalpus* is recognized as the most important group of species within the Tenuipalpidae. Species in this genus range in size from 200 to 410 μm in length (Haramoto, 1969; Jeppson *et al.*, 1975; Smith Meyer, 1979; Baker and Tuttle, 1987). False spider mites are somewhat elongate, dorsoventrally flattened, and usually reddish in color. However, color can vary among species from yellow, red, green, to reddish-green or reddish-black. The mites tend to be slow moving and not readily detected because of their coloration, small size, and sluggish behavior. E.W. Baker (1949) first described the genus *Brevipalpus* and stated that the species within this group were not as important as spider mites. It is becoming increasingly evident that they are potentially serious plant pests, especially with their involvement as vectors of plant viruses (Chagas *et al.*, 2003; Kitajima *et al.*, 2003a, b; Kondo *et al.*, 2003; Rodrigues *et al.*, 2003).

The three *Brevipalpus* species of greatest economic importance are: *B. californicus* (Banks), *B. obovatus* Donnadieu, and *B. phoenicis* (Geijskes). All three species have been reported from many of the same host plants in the same geographical areas worldwide (Childers *et al.*, 2003a). A fourth species, *B. lewisi* McGregor, is found in more arid climatic areas with little overlap with the other three species. This paper reviews the general biology, developmental times, and known feeding injuries to selected plants by selected species of *Brevipalpus* mites and their involvement as vectors of several viruses.

Mite Biology

Many *Brevipalpus* mites are parthenogenetic (thelytokous) with females producing females, and males are rarely found in some species. *Raoiella indica* Hirst and *B. russulus* (Boisduval), are two of a series of tenuipalpid species that are bisexual with females being diploid and having $2n = 4$ chromosomes while the males are haploid with $n = 2$ chromosomes (Pijnacker *et al.*, 1980). *R. indica* is a pest of coconut in Mauritius and other host plants including various palm species (Moutia, 1958; Jeppson *et al.*, 1975). *B. russulus* is found on cactus and succulents in various countries and is capable of causing damage to these plants (Jeppson *et al.*, 1975).

Pijnacker *et al.* (1980) first reported haploid female parthenogenesis of *B. obovatus*. The females of three thelytokous species (*B. obovatus*, *B. phoenicis*, and *B. californicus*) each had two chromosomes (Helle and Bolland, 1972). Weeks *et al.* (2001) demonstrated that haploid *B. phoenicis* females were sustained as a result of an unidentified endosymbiotic bacterial infection. They compared the similarities of this condition with the bacterium *Wolbachia* and its induction of feminization within the isopod *Armadillidium* *vulgare* Latreille (Rousset *et al.*, 1992). It is not clear if this microorganism improves the fitness of the mite host or produces disease within the mite (Perrot, 2002). Weeks *et al.* (2001) were able to treat colonies of *Brevipalpus* mites and increase the frequency of males by floating 1 cm diameter leaf discs of *Phaseolus vulgaris* L. in a solution of tetracycline hydrochloride and distilled water. The mites were allowed to feed for 72 h at 30°C. Not all populations or species of *Brevipalpus* are affected while other species maintain primarily female progeny. Helle and Bolland (1972) increased male frequency in a population of 60 *B. obovatus* females by exposing them to a range of X-rays at 10, 20, and 41 K roentgens. The females were then allowed to oviposit over a period of 14 days and significant increase in numbers of males were obtained compared with the untreated population.

A typical life cycle of a *Brevipalpus* mite consists of four active stages (i.e., larva, protonymph, deutonymph, and adult) (Figure 1a). Between each active stage is a quiescent developmental (chrysalis) stage that is sessile but physiologically active. Eggs and chrysalis stages of the mite remain attached to the plant surfaces of both tea (Oomen, 1982) and citrus (Childers and French, unpublished data). Adults are morphologically different from the immature stages.

Developmental rates are strongly influenced by temperature, relative humidity, and host plant (on *Viola* sp., Morishita, 1954; on *Carica papaya* L., Haramoto, 1969; on *Camellia sinensis* (L.) Kuntze, Chandra and ChannaBasavanna, 1974; on *Oroxylum indicum* (L.) Kurz and *Clerodendron siphonanthus* R. Brown, Lal, 1978; on *Solidago canadensis* L., Goyal *et al.*, 1985). For example, duration of the developmental stages for *B. californicus* (Banks) between 21 and 30°C were: 8.6 days for the larva, 6.2 days for the protonymph, 7.0 days for the deutonymph, and the quiescent stages required 3.6 days each (Manglitz and Cory, 1953). *B. californicus* females begin oviposition about 3.8 days after their last moult and lay one egg per day over 25+ days. In contrast, the developmental rates of *B. obovatus* at 27 and 30°C were: 5.3 and 3.5 days for the larva, 4.0 and 4.1 days for the protonymph, and 4.0 and 2.7 days for the deutonymph, respectively (Jeppson *et al.*, 1975). A total of 54.3 or 32.1 eggs per female were produced over adult life spans of 38.1 and 23.4 days, respectively. Developmental times for *B. phoenicis* reared on tea leaves at 26°C were: 9.53 ± 1.71 days for eggs, 19.13 ± 1.73 days for completion of immature stages, and 41.68 ± 5.92 days for the total life cycle (Kennedy *et al.*, 1996). The gross reproductive rate was 56.7 eggs/female, the generation time was 27.6 days, and the population doubled once in 5.5 days. The duration of the life cycle including individual developmental stages is considerably longer for *B. phoenicis* than that reported for the citrus red mite, *Panonychus citri* (McGregor) (Acari: Tetranychidae) by Beavers and Hampton (1971) and Saito (1979). Oomen

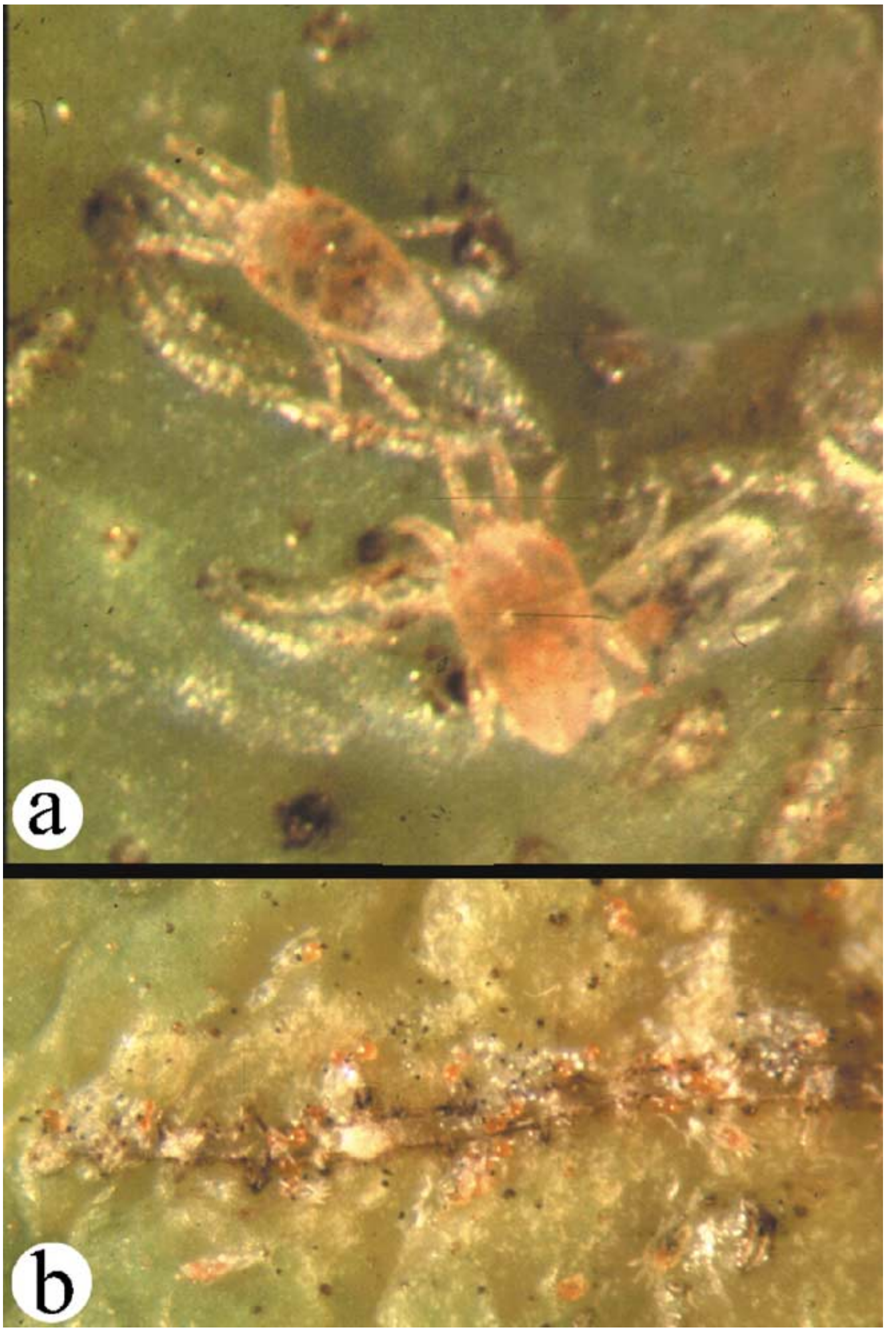

Figure 1. (a) *Brevipalpus* sp. adults on a scarred (rind blemish) area of a citrus fruit. (b) *Brevipalpus* mites and eggs in association with a rind blemish area on a citrus fruit.

(1982) showed that maximum egg production occurred between 8 and 20 days after the onset of oviposition.

Trinidade and Chiavegato (1994) compared the developmental rates of *B. californicus*, *B. obovatus*, and *B. phoenicis* reared on Azalea (*Rhododendron* sp.). No significant differences were found in the developmental rates among the three *Brevipalpus* species at 23 and 27°C. However, when the three species were transferred separately to *Citrus* fruits, *B. phoenicis* had a higher reproductive rate compared with the other two species (Trinidade and Chiavegato, 1990).

Juvenile development of *B. lewisi* on vine leaves of *Vitis champini* cv. 'Dog Ridge' varied from 16.8 days at 34°C/35% RH to 27.9 days at 22°C/70% RH (Buchanan *et al.*, 1980). Mean fecundity of this species varied from 5.7 eggs per female per day at 34°C to 18.5 eggs per female per day at 28°C/35% RH, to 18.8 eggs per female per day at 22°C/70% RH. Optimal net reproductive rates (R_o) of 4.82 and 4.85 were obtained at the latter two temperature-RH conditions, respectively. Buchanan *et al.* (1980) found that the larval and protonymph stages developed the fastest, then the deutonymph followed by the egg stage. The population was devoid of males.

The egg of *B. phoenicis* is elliptical, bright red, and averages 84 μm in length and 60 μm in diameter (Rodrigues and Machado, 1999). Eggs are deposited in cracks, crevices, or other protected niches on citrus fruit surfaces and tend to be deposited in clusters by more than one female (Figure 1b) (Jeppson *et al.*, 1975). The eggs adhere tightly to the plant surface due to an adhesive-like substance on them.

Mite Distribution

Ten species of *Brevipalpus*, five species of *Tenuipalpus*, *Pentamerismus tauricus* Livshitz and Mitrofanov, and *Ultratenuipalpus gonianensis* Sadana and Sidhu have been identified on citrus worldwide (Childers *et al.*, 2001). Of these, *B. californicus*, *B. obovatus*, and *B. phoenicis* are considered the most important in different areas of the world (Lewis, 1949; Dean and Maxwell, 1967; Jeppson *et al.*, 1975; Schwartz, 1977; Childers, 1994; French and Rakha, 1994; Ochoa *et al.*, 1994; Rodrigues, 2000).

Brevipalpus phoenicis is a pest on coffee in Brazil (Chagas *et al.*, 2001), on tea in Asia (Oomen, 1982), on passion fruit (Kitajima *et al.*, 1997) and numerous ornamental plants worldwide (Smith Meyer, 1979). *B. californicus* is a pest on orchids (Ochoa *et al.*, 1994). *B. lewisi* is a pest on citrus (Lewis, 1949; Elmer and Jeppson, 1957), grapes (Buchanan *et al.*, 1980; Arias Giralda and Nieto Calderon, 1985), pistachio (Rice and Weinberger, 1981), walnuts (Michelbacher, 1956), and pomegranate (Ebeling and Pence, 1949). While

Figure 2. (a and b) 'Robinson' tangerine leaves with feeding injury by *B. phoenicis* and *B. obovatus*.

this species has been reported as a pest on several crops, it has never been assessed as a possible vector of citrus leprosis or other related viruses. *B. chilensis* Gonzalez is considered a serious pest of grape (Jeppson *et al.*, 1975) and occurs on citrus in Chile (Renato Ripa, 2002, personal communication). Both its distribution in South America and its ability to vector citrus leprosis remain unknown. Also, *B. chilensis* has not been detected to date on grapes in either southern or northeastern Brazil (D. Navia, 2002, personal communication).

Tenuipalpid mites inject toxic saliva into fruit, leaf, stem, and bud tissues of citrus and other host plants. *B. phoenicis* usually feeds on the lower leaf surface and aggregates along the mid-vein or major lateral veins of citrus causing a yellow blistering of the leaf surface opposite feeding mite aggregations (Figure 2a and b). *B. phoenicis* usually feeds on the stems or green twigs, but then moves to other plant parts as food or space become limited (Haramoto, 1969). The damaged areas become progressively necrotic with subsequent leaf drop, especially when large numbers of *Brevipalpus* mites are present (Childers, 1994). However, this is a rare occurrence in Florida citrus and has been observed by the first author only once in 25 years.

Walnut leaves infested by *Brevipalpus lewisi* had the highest mite populations in the southeast quadrant of the tree canopy, especially around the lower skirt area of the tree in California (Michelbacher, 1956). Feeding injury to the leaves by *B. lewisi* resulted in a coppery appearance with little or no webbing. Defoliation was noticeable and large numbers of exuviae were present on the dropped leaves. The author did not indicate whether feeding injury was confined to the upper or lower leaf surfaces.

Brevipalpus lewisi caused significant russeting and cracking of the rind on pomegranate fruits, with 50–90% damaged in the Porterville area of California (Ebeling and Pence, 1949). Damage to the fruit was first observed near the stem end and occurred during July or August depending upon environmental conditions. Damage extended downward on the fruits with subsequent cracking of the rind and formation of scab tissue between the cracks.

Feeding Injury to Citrus

Brevipalpus californicus was transferred onto sour orange *Citrus aurantium* L. seedlings and held in the insectary between 27 and 32°C in Weslaco, Texas (USA) during 2001. No other plants were held in the insectary and only populations of *B. californicus* were allowed to establish on the multiple seedlings planted within each of the containers. *B. californicus* fed on the twigs, petioles, upper and lower leaf surfaces, and developing buds of the seedlings. Feeding injury by the mites resulted in the formation of rounded leaves that were severely stunted. There was also marginal necrosis and tip burn on affected leaves compared with healthy non-infested seedlings (Figure 3a). Mite feeding also resulted in severe stunting of new shoot growth with the formation of corky swollen buds (Figure 3b). Leaves failed to develop from these affected gall-like terminal buds. This same type of damage was reported on citrus seedlings in Venezuela and Florida and referred to as *Brevipalpus* gall by Knorr and Denmark (1970). The affected plants were unable to produce new leaves following previous feeding injury by *Brevipalpus* mites. This nodal galling and subsequent dying of stricken plants was observed in certain Venezuelan nurseries on container-grown sour orange and 'Pineapple' orange seedlings that were about 37–38 cm tall (Knorr and Denmark, 1970). The researchers stripped leaves from a series of test plants and retained only those leaves at the growing tips. The *Brevipalpus*-infested seedlings had fewer leaves to feed upon compared to healthy seedlings with a full compliment of leaves. Subsequent suppression of normal leaf development and galling occurred on the infested plants with reduced numbers of available leaves. There are no available data indicating that *Brevipalpus* mites prefer leaf tissue compared to developing bud growth. However, the 1970 experiment showed that the *Brevipalpus* mites would definitely feed on bud tissues. Also, Chiavegato (1986) reported that *B. phoenicis* had a faster developmental rate on citrus fruits than on citrus leaves.

Knorr and Malaguti (1960) reported on another situation in a citrus nursery in Venezuela where considerable defoliation and death of sour orange seedlings occurred. Lesions of a fungal pathogen, citrus scab, *Elsinoe fawcetti*, were observed on 40% of the sour orange seedlings, with symptoms ranging from spotting of the leaves to death of the plants. All plants were infected with *E. fawcetti.* However, only those infected plants with yellow halos (2–5 mm diameter) around the fungal lesions were either dead or in various stages of defoliation. The authors reported large numbers of *B. phoenicis* present within the yellow halo areas while plants without the halos and without mites were not affected. Knorr and Malaguti (1960) referred to this as halo scab on sour orange that was caused by *E. fawcetti* and *B. phoenicis*. According to the authors, severe leaf drop occurred only when these scab lesions were infested with *B. phoenicis*. A similar situation between two acarine species and *Sphaceloma fawcetti* was reported by Ochoa *et al.* (1994) on citrus in Costa Rica. Additional studies are needed to identify possible fungal pathogen-mite feeding interactions, especially where two acarine species likely fed at different times during fruit

Figure 3. (a) Feeding injury to sour orange seedlings by *B. californicus* compared with a healthy, non-infested plant. (b) *Brevipalpus* gall formation on two sour orange seedlings.

development. An example would be early feeding on recently developed citrus fruits by broad mite *Polyphagotarsonemus latus* (Banks) (Acari: Tarsonemidae), followed by subsequent feeding and development of *Brevipalpus* populations on the same fruits. This phenomenon is common in the tropics.

Heavy infestations of *Brevipalpus* mites were observed on green twigs, leaves, and fruit in a mature block of 'Rio Red' grapefruit near Weslaco, Texas (USA) in October 2002. Necrotic areas on the green twigs were evident where the mites had been actively feeding for a period of 2–3 months. Considerable numbers of false spider mite exuviae were also present on the twigs, leaves, and fruit.

Feeding damage by *Brevipalpus* mites to citrus fruit in Texas is most prevalent on inside fruit, especially grapefruit, in the lower tree canopy below two meters. Fruit lesions (=discolored areas) first appear as very slight yellowish circular areas in depressions on the fruit surfaces of grapefruit or oranges (Dean and Maxwell, 1967; French and Rakha, 1994). Examples of these discolored areas are shown in Figure 4a and b. These lesions gradually develop a central brown necrotic area or spot and gradually become darker and corky in texture. The brown spots are irregular in shape and can vary from about 3–12 mm in diameter. They often will coalesce to cover larger areas (50–75 mm) of the fruit surface. The spots become distinctly raised on fruit surfaces. The extent of this damage varies depending upon mite infestation and can cover half or more of the fruit surface, especially on interior clustered red grapefruit varieties in Texas. The irregular, damaged areas on the fruit become progressively necrotic and result in fruit being rejected for the fresh market (Figure 5a and b). Close examination of the areas where lesions first appear often yield infestations of *Brevipalpus* mite stages actively feeding and laying eggs. *B. californicus*, *B. obovatus*, and *B. phoenicis* have all been identified on Texas citrus varieties.

On 'Marrs', 'Ambersweet', and navel oranges in Texas, smaller necrotic lesions form on the fruit surfaces where *Brevipalpus* mites have fed (Figure 6a and b). The injury was referred to as 'leprosis-like spotting' or 'nail-head rust' on both grapefruit and orange varieties in Texas (Dean and Maxwell, 1967; French and Rakha, 1994). Similar types of feeding injury were reported by both teams of authors especially in association with *B. californicus* and *B. phoenicis* infestations across many citrus orchards in south Texas. Feeding injury consisted of irregular-shaped spots that became brownish blemishes and varied in size from 1 to 30 mm or larger. Most damage occurred on the stylar end of the fruit in the inner canopy, consistent with reports of *Brevipalpus* feeding injury on citrus fruits in other parts of the world.

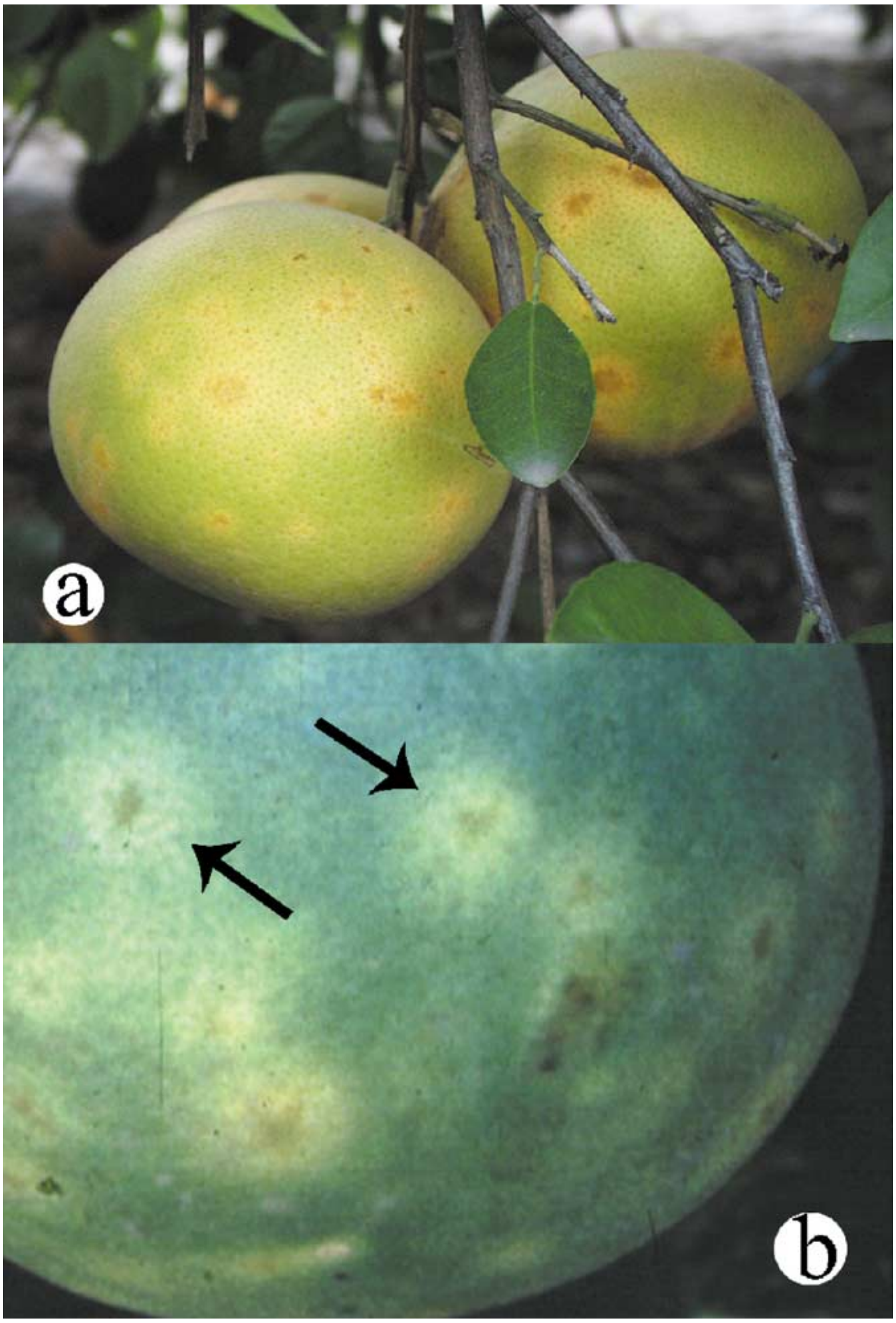

Figure 4. (a) Early injury symptoms on grapefruit in Texas from *Brevipalpus* feeding. (b) Close-up view of the slight yellowish to brownish circular damaged areas on these grapefruit.

Figure 5. (a and b) Progressively older feeding damage symptoms on grapefruit caused by *Brevipalpus* spp. in Texas.

Figure 6. (a and b) Smaller necrotic lesions on ‘Marrs’ oranges in Texas caused by *Brevipalpus* spp. feeding injury.

Several hundred samples of fruit damage collected from Texas citrus orchards were examined by transmission electron microscopy (TEM) in 2001, with no indication of citrus leprosis virus or viral inclusion bodies (Childers *et al.*, 2003b). Therefore, the authors concluded that this was feeding injury from *Brevipalpus* mites and not from citrus leprosis virus.

Brevipalpus mites prefer damaged areas on citrus fruit previously caused by wind scarring, disease or previous insect feeding injuries, or where depressions occur on the fruit surface. Here the mites tend to aggregate, feed, and oviposit. This aggregation phenomenon contributes to localized feeding damage on the fruit. With increasing mite densities and feeding there is increased uniformity in the formation and increased size of localized lesions on citrus fruits (Dean and Maxwell, 1967).

Brevipalpus lewisi and *B. californicus* feed primarily on citrus fruit causing initial silvering of affected tissues (Jeppson *et al.*, 1975). Feeding injury on citrus fruits by *B. lewisi* in California results in scab-like isolated depressions where the mites feed (Elmer and Jeppson, 1957). The rind blemished areas ultimately develop as scars. Lewis (1949) reported over 25% of 'Lisbon' lemon fruits in one orchard were not marketable due to rind scarring by *B. lewisi*. A brown speckling of the rind on sweet orange varieties occurs from both *B. californicus* and *B. phoenicis* feeding injuries in South Africa (Schwartz, 1977). Feeding injury to 'Valencia' orange fruits in South Africa by *B. phoenicis* results in uniform, larger scab-like spots in depressions on the rinds of affected fruits that turn brown to bronze in color and eventually become corky (Schwartz, 1977). In Chile, feeding injury by *B. chilensis* results in a roughened silvering of the rind on lemons (Ripa and Rodriguez, 1999).

Feeding Injury to Other Plants

Brevipalpus lewisi causes similar feeding injury on pistachios in California as reported for citrus fruit in Texas (Rice and Weinberger, 1981). The mite feeds on the nut cluster petioles, stems, and nuts. Dark, irregular, and roughened scab-like blotches form on the surface where the mites aggregate and feed along the edges of damaged tissue. This mite overwinters on current year and 1-year-old wood, especially in nut-cluster petiole scars of pistachio in California (Rice and Weinberger, 1981). *B. lewisi* was most abundant in late July and early August, and increased to damaging densities despite daily temperatures that averaged 40°C with low humidity conditions. *B. lewisi* adults and immatures were also readily found on the fruit in the outer canopy of 'Valencia' orange trees near Bakersfield, California (USA) in August 2002 at air temperatures of 35–40°C and low relative humidity conditions in this desert climate. However, no visible injury to the fruit was observed at that time.

Arias Giralda and Nieto Calderon (1985) reported that *B. lewisi* overwinter on grape vines or in soil litter in Spain. In the spring, the mites were found feeding on all green tissues and separated inflorescences. On grapes, the mite was present solely at the base of grape canes early in the season in Victoria, Australia (Jones, 1967; Buchanan *et al.*, 1980). Later, *B. lewisi* was present on all green tissues and caused superficial scarring of bunched fruits and berry stems. Continued feeding results in the tissues withering and becoming dry.

Feeding injury by *B. californicus*, *B. obovatus* and *B. phoenicis* to twigs of citrus, and *B. phoenicis* to twigs of coffee, or passion fruit have not been adequately described. However, presence and intensity of their feeding is accentuated with the evident lesion development on citrus twigs from citrus leprosis or on passion fruit twigs with the virus, green spot of passion fruit (Rodrigues *et al.*, 2003; Kitajima *et al.*, 2003a).

Both *B. phoenicis* and *Tenuipalpus pacificus* Baker feed on the upper leaf surface of orchids. Feeding injury is first noted as stippling (silvering) that eventually becomes rusty and brown (Manglitz and Cory, 1953). Ochoa *et al.* (1994) reported leaf chlorosis on guava with irregular, necrotic areas occurring along the leaf margins due to feeding by *B. phoenicis*. Leaves and fruit of *Annona muricata* L. become severely bronzed due to feeding injury by *B. phoenicis*, while leaves of *Grevillea robusta* Cunningham, become chlorotic, turn brown, and prematurely drop due to feeding by *B. californicus* (Ochoa *et al.*, 1994).

According to Banerjee (1971), *B. phoenicis* was a severe pest on tea in India, especially Chinese hybrid varieties. The lower surface of leaves of all ages were attacked, as were tender twigs and branches, and occasionally the axillary buds. All plant tissues were affected by *Brevipalpus* mite feeding. Occasionally axillary buds are affected too (Banerjee, 1971). Removal of sap from the twigs results in drying and splitting of the bark and premature leaf drop. Longitudinal splitting of tea branches of pencil diameter or smaller have been observed in a commercial tea planting in South Carolina between 1996 and 2002 in association with *Brevipalpus* and another mite species in the family Tuckerellidae. However, no exclusion data are available to confirm these associations.

Brevipalpus californicus, *B. obovatus*, and *B. phoenicis* are all reported as pests on tea (Cranham, 1966). *B. californicus* reportedly was the most common species on tea in Sri Lanka and southern India. Bronzing of the lower leaf surfaces of mature tea leaves is caused by *B. californicus* in South Africa (Smith Meyer, 1981). *Brevipalpus* mites were reported as causing significant feeding injury to leaves, bushes, and wood of tea in Sri Lanka by Green (1900) and later identified by Baker (1949) as

Table 1. List of plant injuries associated with *Brevipalpus* mites

Plant	Injuries	Local	Mite	Reference
Acanthaceae				
Aphelandra sp.	Browning and malformation of the leaves	Florida (USA)	*B. phoenicis*	Denmark (1975)
Anacardiaceae				
Spondias purpurea L.		Costa Rica	*B. salsi*	Ochoa (1986)
Cactaceae				
Schlumbergera sp.	Phylloclade-drop	Sweden	*B. obovatus*	Pettersson (1981)
		Florida (USA)	*B. russulus*	Denmark (1978)
Several cactus genera	Epidermis with reddish grey aspect	Worldwide	*B. russulus*	Jeppson *et al.* (1975)
Caricaceae				
Carica papaya L.	Callous-like, tannish, and scaly	Hawaii	*B. phoenicis*	Haramoto (1969)
Ericaceae				
Rhododendron sp.	Browning or bronzing of foliage	New Jersey (USA)	*B. obovatus*	Hamilton (1953)
Labiatae				
Clerodendron siphonanthus R. Brown	Leaves show zigzag curling and shrinkage	India	*B. phoenicis*	Lal and Mukharji (1979)

Myrtaceae				
Psidium guajava L.	Brownish patches on the fruit surface	Venezuela	*B. phoenicis*	Guerere and Quiros-Gonzalez (2000)
Oleaceae				
Ligustrum spp.	Defoliation and dieback	Florida (USA)	*B. obovatus*	McGregor (1916)
Ligustrum japonicum Thunberg	Gall formation	São Paulo State	*B. phoenicis*	Rodrigues (unpublished data)
Ligustrum lucidum Aiton F.	Defoliation	Brazil	*B. phoenicis*	Rodrigues (unpublished data)
Ligustrum sinense Loureiro	Ringspot-mite toxemia	Argentina	*B. obovatus*	Vergani (1945)
Palmae				
Cocos nucifera L.	Corky ring-like band around the fruit	India	*B. phoenicis*	Jagadish *et al.* (1983)
Passifloraceae				
Passiflora edulis Sims	Defoliation and dieback	Hawaii (USA)	*B. phoenicis*	Haramoto (1969)
Pinaceae				
Pinus radiata D. Don	Chlorosis, stippling, and needle browning	California (USA)	*B. pini*	Landwehr and Koehler (1980)
Portulacaceae				
Portulaca oleracea L.	Stem browning and defoliation	São Paulo State, Brazil	*B. phoenicis*	Rodrigues (1995)

Table 1. (*continued*)

Plant	Injuries	Local	Mite	Reference
Rutaceae				
Citrus aurantifolia (Christmann) Swingle	Halo scab – association with fungus	Venezuela	*B. phoenicis*	Knorr and Malaguti (1960)
Citrus sp.	Brownish patches on leaves and leaf-drop	India	*B. californicus*	Gupta *et al.* (1971)
Citrus (Clementine × Orlando)	Resinous leaf patches with opposing leaf		*B. phoenicis*	
	Chlorosis and leaf-drop	Florida (USA)	*B. obovatus*	Childers (1994)
Citrus sinensis (L.) Osbeck	Gall formation	São Paulo	*B. phoenicis*	Rodrigues (1995)
Theaceae				
Camellia sinensis (L.) Kuntze	Necrotic brown spots on leaves	Asia, Africa	*B. phoenicis*	Oomen (1982)
			B. californicus	Cranham (1966)
			B. obovatus	Cranham (1966)
Vitaceae				
Vitis vinifera L.	Superficial scarring of bunch and berry stems	Australia	*B. lewisi*	Buchanan *et al.* (1980)

B. californicus. *B. phoenicis* was more abundant on tea in northern India while *B. obovatus* was rarely found on tea. *B. phoenicis* is an important pest in most tea growing countries and is a major pest of tea in Kenya (Sudoi *et al.*, 2001).

Brevipalpus mites on tea tend to congregate in cracks, crevices, pits, or other protected sites on the leaves, especially at the midrib and other veins (Oomen, 1982). Considerable variation in the susceptibility of different tea clones to phytophagous pest mite species has been reported by Das (1983). On tea, *B. phoenicis* feeds on the underside of the maintenance leaves, on petioles, and non-lignified areas of twigs. Feeding damage results in petiole necrosis followed by defoliation. Mites will move to young leaves or upper leaf surfaces as populations increase. Eventually the maintenance leaf canopies become excessively thinned and growth of mosses and lichens become established. This is an indication that the tea hedges or bushes are in poor condition (Oomen, 1982).

Brevipalpus phoenicis are usually found on the internal leaves, branches, and berries in the lower and mid-regions of coffee plants where they feed (Reis *et al.*, 2000). The mites are prevalent on the lower leaf surface along the midvein, at the crown and peduncle of the berries, and at the nodes on branches. Direct feeding injury by *Brevipalpus* mites has not been reported as being of economic importance on coffee to date. Table 1 summarizes other types of feeding injuries that are caused by different *Brevipalpus* mite species on different plants.

Plant Viruses and *Brevipalpus* Mite Vectors

The most significant threat created by the three *Brevipalpus* mite species in several different agricultural commodities is their direct involvement in vectoring a group of viruses classified as unassigned Rhabdoviriidae (Kitajima *et al.*, 1996). *B. californicus*, *B. obovatus*, and *B. phoenicis* have been identified from citrus in Brazil, Costa Rica, Honduras, South Africa, and Florida and Texas within the United States (Knorr, 1968; Muma, 1975; Smith Meyer, 1979; Denmark, 1984; Evans *et al.*, 1993; Ochoa *et al.*, 1994). *B. phoenicis* is recognized as the vector of: (1) citrus leprosis in Brazil (Rodrigues *et al.*, 1997); (2) coffee ringspot virus (Chagas *et al.*, 2003); (3) passion fruit green spot (Kitajima *et al.*, 2003a); and (4) various viruses of ornamental plants (Kitajima *et al.*, 2003b). In Argentina and Venezuela, citrus leprosis reportedly was vectored by *B. obovatus* (Frezzi, 1940; Vergani, 1945). *B. californicus* was the reported vector of leprosis in Florida according to Knorr (1968) from specimens identified by E.W. Baker. However, voucher specimens are not available from Argentina, Venezuela, or Florida to validate identifications. *B. californicus* is the vector of orchid fleck virus in Japan (Kondo *et al.*, 2003). No studies have been conducted to assess the potential of other *Brevipalpus* species as possible vectors of viruses.

Confusion has existed for decades concerning the differences between feeding injuries caused by *Brevipalpus* mites and leprosis virus infection on citrus. See Rodrigues *et al.* (2003) and Childers *et al.* (2003b) for additional information. To date, the only accurate method for determination of infection by citrus leprosis virus is using transmission electron microscopy (TEM) to verify presence of virus particles or viral inclusion bodies (Rodrigues *et al.*, 2003; Kitajima *et al.*, 2003b). Reports of citrus leprosis occurrence in some areas in Central America remain suspect. Insufficient information has been obtained to date to determine if the reported problems in some areas of Central America are the result of *Brevipalpus* mite feeding injury, citrus leprosis, or other causes. Reluctance on the part of some individuals to clarify this issue merely exacerbates the problem further. Knorr *et al.* (1968) reported on the occurrence of 'false leprosis' in Florida. This problem was observed only in 'Valencia' oranges and citrus leprosis-like lesions were absent on the shoots, twigs, or branches. There were no indications of *Brevipalpus* mites or their exuviae being present on leaves and fruit with leprosis-like symptoms, and the problem disappeared in subsequent years. The ability to correctly identify and separate *Brevipalpus* mite feeding injuries, citrus leprosis virus infections, and unrelated but similar maladies on citrus are essential for citrus producers, shippers, and regulatory personnel involved in international movement of fruits and plants.

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