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Brevipalpus mites on citrus and their status as vectors of citrus leprosis

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ABSTRACT. Sixteen species of mites in the family Tenuipalpidae have been reported from citrus worldwide including ten in the genus *Brevipalpus*. In North, Central and South America, *B. californicus* (Banks), *B. obovatus* Donnadieu and *B. phoenicis* (Geijskes) have been reported from citrus and a wide range of other plant hosts. Citrus leprosis is a serious disease of citrus in Argentina, Brazil, Paraguay, Venezuela, and recently in Panama. Citrus leprosis causes yield reduction and eventual death of the trees without acaricidal control. In the late 1800s citrus leprosis was reported in Florida, but has not been reported since the 1960s. *B. californicus, B. obovatus* and *B. phoenicis* have been reported as vectors of citrus leprosis, but only *B. phoenicis* has been proven to be an effective vector. The virus in *B. phoenicis* is transmitted transstadially but not transovarially. Recent work indicates there are two kinds of virus particles, one cytoplasmic and the other nuclear. While citrus leprosis has been mechanically transmitted from citrus to citrus and a few herbaceous plants, attempts to purify and characterize the virus have been unsuccessful.

Key Words: *Brevipalpus* spp. Citrus leprosis, Citrus, Virus, Mites.

Introduction

Mites in the family Tenuipalpidae are mostly found in tropical to subtropical climates (Jeppson *et al.* 1975, Baker and Tuttle 1987). They are referred to as false spider mites or flat mites and several species are of economic importance on various crops including: citrus (Kitajima *et al.* 1972), coffee (Chagas *et al.* 2000), tea (Oomen 1982), pistachio (Rice and Weinberger 1981), passion fruit (Kitajima *et al.* 1997) and numerous ornamental plants (Smith Meyer 1979). False spider mites are somewhat elongate, dorsoventrally flattened, reddish in color and slow moving They frequently are not readily detected because of their small size (200-300 µm in length) and sluggish behavior (Haramoto 1969, Jeppson *et al.* 1975). The genus *Brevipalpus* is recognized as the most important group within the family. Baker (1949) first described this genus and stated that they were not as important as spider mites. As we become more familiar with certain *Brevipalpus* species, it is evident that they can be serious plant pests. Considerable research is needed to address many questions regarding Tenuipalpidae, especially species within the genus *Brevipalpus*.

Citrus leprosis is a serious virus disease that can ultimately kill citrus trees (Rodrigues 2000). The disease has been restricted to South America since its disappearance from Florida prior to 1962. This paper reviews the known species of *Brevipalpus* mites that occur on citrus, their taxonomy, biology, distribution, host plants, involvement as vectors of citrus leprosis, citrus leprosis and similar viruses on other crops.

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Taxonomy

The family Tenuipalpidae is in the superfamily Tetranychoidea and is characterized by having a palpal tibia without an enlarged spine-like seta (i.e., palpal claw) and an apical palp tarsus; pretarsal claws and empodium with tenet hairs and no duplex setae associated with the solenidia on the tarsus of legs I and II (Jeppson *et al*. 1975, Smith Meyer 1979). The reticulate pattern on the idiosoma, type of setae and their arrangement on the body are all distinctive systematic characters for the Tenuipalpidae.

Ten species of *Brevipalpus* have been identified on citrus worldwide and include: *B. amicus* Chaudhri, *B. californicus* (Banks), *B. chilensis* Baker, *B. karachiensis* Chaudhri, Akbar and Rasool, *B. lewisi* (McGregor), *B. mcgregori* Baker, *B. obovatus* Donnadieu, *B. phoenicis* (Geijskes), *B. rugulosus* Chaudhri, Akbar and Rasool and *B. tinsukiaensis* Sadena and Gupta. *B. deleoni* (Pritchard and Baker (1949) is reported on citrus but it is a junior synonym of *B. phoenicis* (Baker and Suigong 1988). Species within other genera found on citrus include: *Tenuipalpus citri* Smith Meyer in Africa (Smith Meyer 1979), *Tenuipalpus* sp. from Chiriqui Province in Panama (Childers, unpublished data), *T. mustus* Chaudhri in India and Pakistan, *T. orilloi* Rimando in Indonesia and the Philippines, and *Pentamerismus tauricus* Livshitz and Mitrofanov (Ghai and Shenhmar 1984). *Tenuipalpus caudatus* (Duges) was found on citrus in India and also occurs in France, Greece, Italy and Portugal and *Ultratenuipalpus gonianensis* Sadana and Sidhu from citrus in India (Sadana 1997).

Mite Biology

Brevipalpus mites are parthenogenetic (thelytokous) with females producing females and males are rarely found. Both females and males are haploid with 2 chromosomes (Pijnacker *et al*. 1980). A typical life cycle of a *Brevipalpus* mite is shown in Figure 1. There are four active stages: larva, protonymph, deutonymph and adult. Between each active stage is a physiologically active quiescent developmental stage. Adults are morphologically different from the immatures. Development rates are strongly influenced by temperature, relative humidity and host plant (Haramoto 1969, Chandra and Channabasavanna 1974, Lal 1978, Goyal *et al*. 1985). For example, the duration of development stages for *B. californicus* reared between 21 and 30°C was: 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, *B. obovatus* developmental rates 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 were produced per female over adult lifespans 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 *B. phoenicis* egg is elliptical, bright red and averages 84 µm in length and 60 µm in diameter (Rodrigues and Machado 1999). Eggs usually are deposited in clusters of four to eight by different females and adhere tightly to the plant surface. A sticky substance allows eggs to be deposited in cracks, crevices, exuviae or other protected niches on fruit surfaces and remain attached (Jeppson *et al*. 1975). The motile stages are also difficult to remove from fruit surfaces due to their preference for areas with cracks, crevices or rind blemishes.

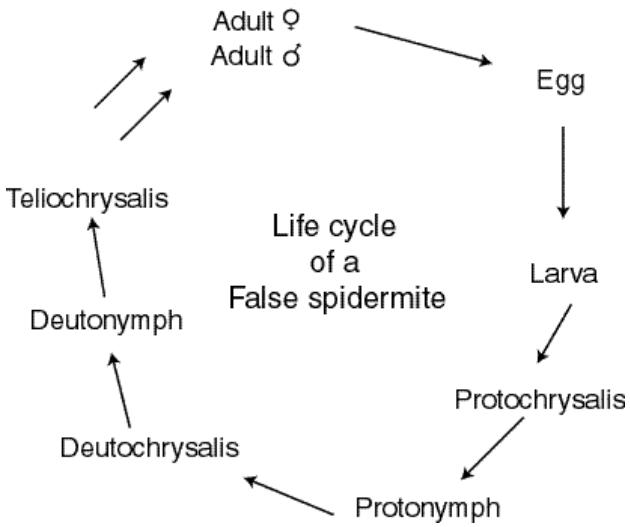

Figure 1. Typical life cycle of a *Brevipalpus* mite.

Host Plants

Haramoto (1969) listed 37 species of plants in 27 families that were hosts for *B. phoenicis* in Hawaii.

Chandra and Channabasavanna (1974) listed 36 species of plants as hosts for *B. phoenicis*. Earlier, Pritchard and Baker (1958) had reported 63 host plants for *B. phoenicis*. *B. californicus*, *B. obovatus* and *B. phoenicis* each had more than 50 plant species recorded as hosts worldwide by Smith Meyer (1979). Ochoa *et al.* (1994) reported 177 hosts for *B. phoenicis*, *B. californicus*, and *B. obovatus* in Central America that included 114 hosts for *B. phoenicis*, 29 hosts for *B. californicus* and 34 hosts for *B. obovatus*.

Citrus leprosis and *Brevipalpus* mite vectors

B. californicus, *B. obovatus*, and *B. phoenicis* have all been identified from citrus in Brazil, Costa Rica, Honduras, South Africa and in the United States (California, Texas and Florida) (Knorr *et al.* 1968, Muma 1975,Smith Meyer 1979,Denmark 1984,Baker and Suigong 1988,Evans *et al.* 1993,Ochoa *et al.* 1994). *B. californicus* was the reported vector of leprosis in Florida according to Knorr (1968). However, voucher specimens are not available from Argentina, Venezuela or Florida to validate identifications.

Leprosis is a very serious disease of citrus in Brazil, Argentina, Paraguay, Venezuela, probably Colombia and Uruguay and more recently documented in Panama for the first time in 1999 (Dominguez *et al*. 2001). The disease remains a significant problem today by creating serious long-term decline in tree quality, yield reduction and eventual death of the trees if acaricidal control is not maintained (Rodrigues 2000).

B. phoenicis is an effective vector of leprosis (Chiavegato and Salibe 1984) with higher transmission efficiency occurring in the larval stage compared with either the nymphal or adult stages (Chagas *et al*. 1984). According to Chiavegato (1995), all feeding stages of *B. phoenicis* were equally effective in leprosis transmission. Once a mite is infected with the virus, it can continue to vector the disease through successive instars (=transstadial transmission) but there is no evidence of transovarial transmission (Rodrigues 2000). Parallel studies with either *B. californicus* or *B. obovatus* are lacking. Virus-like particles similar to those causing citrus leprosis were identified within *B. phoenicis* specimens using electron microscopy (Rodrigues *et al*. 1997).

Brevipalpus mites are long-lived and capable of remaining infective with leprosis virus throughout their lives. The duration of the life cycle including individual developmental stages is considerably longer for *B. phoenicis* when compared with the developmental rate of the citrus red mite, *Panonychus citri* (McGregor) (Tetranychidae) (Beavers and Hampton 1971, Saito 1979) (Table 1). This is a potentially important problem relative to maintenance of the virus in a viruliferous mite population for extended periods of time.

Table 1. Comparative developmental rates, egg production and adult longevity of *Brevipalpus phoenicis* reared on *Oroxylum indicum* and *Panonychus citri* reared on citrus at 27°C.

Stage	Duration (in days)	
	B. phoenicis	***P. citri***
Egg	6.0	3.4
Larva	4.8	1.9
Protonymph	4.8	1.6
Deutonymph	4.9	2.3
Egg-Adult	20.7	12.0
Adult longevity	20.4	--

(Beavers & Hampton 1971, Lal 1978, Saito 1979).

Leprosis is the major viral disease of citrus in Brazil where it causes significant economic loss (Rodrigues 2000). Sweet orange *Citrus sinensis* (L.) Osbeck varieties are especially susceptible. Severe symptoms occur on leaves, green twigs and fruit. Symptoms may change according to variety, host, region and development of the affected plant part.

Evidence for the viral nature of citrus leprosis

Fawcett and Lee (1926) stated that citrus leprosis was present in Florida since the late 1800s. Association and transmission of leprosis by *Brevipalpus* mites were first reported in Argentina where the disease was known as "lepra explosiva" (Frezzi 1940, Vergani 1945) and later confirmed in Brazil (Musumecci and Rossetti 1963) and in the United States of America (Knorr 1968) suggesting viral etiology. In this direction, Knorr (1968) also showed that the leprosis lesions on the stems expanded to healthy tissue when grafted. Kitajima *et al*. (1972) demonstrated the presence of rodlike particles (40-50 nm x 100-110 nm) in the nucleus and cytoplasm, commonly associated with nuclear and endoplasmic reticulum membranes, as well as an electron lucent intranuclear viroplasm in leaf lesions caused by an isolate of leprosis from the State of Sao Paulo, Brazil. This cytopathic effect, referred here as a nuclear type, is similar to that described in *Orchid fleck virus* (Doi *et al*. 1977) that

was transmitted by *B. californicus* (Maeda *et al*. 1998). However, the cytopathic effects in lesions caused by other isolates of citrus leprosis from Argentina (Kitajima *et al*. 1974) and from Brazil (Colariccio *et al*. 1995) were distinct: short bacilliform, membrane-bounded particles (50-60 nm X 110-120 nm) within cisternae of the endoplasmic reticulum and having an electron dense, vacuolated viroplasm in the cytoplasm. This type of cell alteration is referred to as the cytoplasmic type. In a recent survey in Chiriqui Province in Panama, citrus leprosis lesion samples from Boquete were predominately of the nuclear type, whereas from Potrerillos, the cytoplasmic type was recovered (Dominguez *et al*. 2001). Colariccio *et al*. (1995) added another important piece of evidence for the viral nature of citrus leprosis when they succeeded in mechanically transmitting the causal agent from citrus to citrus and to some other herbaceous hosts (*Chenopodium quinoa* Willd., *C. amaranticolor* Coste & Reyn., *Gomphrena globosa* L.) that produced local lesions. However, to date, attempts to purify and characterize the virus have been unsuccessful.

The cytopathology of citrus leprosis indicates that there may be two different types of viruses (nuclear and cytoplasm types), both transmitted by *Brevipalpus* mites and causing similar symptons. So far, the cytoplasmic type has been the most prevalent. It should be mentioned that these types of cell alterations, either from the nuclear or cytoplasmic types, have been found in many other *Brevipalpus* transmitted diseases (Table 2). These facts have surfaced only recently and the precise relationship among them clearly reflects that the epidemiology of citrus leprosis remains unknown.

Table 2. Diseases transmitted by *Brevipalpus* mites, vector species, geographical distribution and cytopathology (from Kitajima *et al.* 2000).

Disease	Geographical Distribution	Mite vector	Cytopathology*
Citrus leprosis	Americas	*B. phoenicis, B. obovatus, B. californicus*	N, C
Orchid fleck	Worldwide	*B. californicus*	N, C
Ligustrum ringspot	South America	*B. phoenicis, B. obovatus*	C
Coffee ringspot	Brazil	*B. phoenicis*	N
Passion fruit green spot	Brazil	*B. phoenicis*	C
Hibiscus green spot	Brazil, Panama	*B. phoenicis*	C
Hibiscus chlorotic spot	Brazil	Not determined	N
Malvaviscus ringspot	Brazil	*B. phoenicis*	N
Ivy green spot	Brazil	*B. phoenicis*	C
Schefflera ringspot	Brazil	*B. phoenicis*	C
Clerodendron chlorotic spot	Brazil	*B. phoenicis*	N
Clerodendron green spot	Brazil	*Not determined*	C
Solanum violaefolium ringspot	Brazil	*B. phoenicis*	C
Viola chlorotic spot	Australia	not determined	N

* N = nuclear type; C = cytoplasmic type

End Note

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