

## ***Tuckerella japonica* (Acari: Tuckerellidae) in China and New Zealand: new data and an alternative hypothesis for its route of invasion**

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The Tuckerellidae is a relatively small family of the Tetranychoida, with just one genus and 28 species (Zhang *et al.* 2011). They are commonly known as peacock mites due to the attractive colour (orange to red) of the body, which is ornamented by rows of white, palmate, oval or circular setae and a row of whip-like caudal setae (Fig. 1). In New Zealand, two species—*Tuckerella flabellifera* Miller, 1964 and *T. litoralis* Collyer, 1969—had been known for over four decades (Collyer, 1969), until Beard *et al.* (2013) added a third species—*T. japonica* Ehara, 1975—based on New Zealand exported mites on blueberry and kiwifruit that were intercepted in Australia. They distinguished *T. japonica* from *T. flabellifera* with excellent descriptions and also noted that *T. japonica* appears strongly associated with tea (*Camellia sinensis*). They hypothesized, after a fascinating historic account of the cultivation and movement of tea, that *T. japonica* has travelled as tea's hidden companion when tea plants were transported around the world. Here, we examine and develop this hypothesis further, especially regarding the origin of *T. japonica* and the possible alternative invasion route to New Zealand. We also report new host association for *T. japonica* in New Zealand.



**FIGURE 1.** *Tuckerella japonica* adult female and also a newly laid egg near its posterior end (note that it is nearly half as long as the female). The female mite was collected from the twig of *Cryptomeria japonica* in Te Puke, New Zealand and reared on a kiwifruit (sepal end around the base of the stalk). Photograph: Rosa Henderson.

### The question of *T. japonica* and its association with tea in China

The distribution record and host association with tea of *T. japonica* in China were based on the synonymy of *T. xinglongensis* Lin & Fu, 1997 with *T. japonica* (Beard *et al.* 2013). According to Beard *et al.* (2013):

“The synonymy is based on the illustrations and description. We were unable to examine the types, despite several attempts to borrow the specimens.”

First, the description and illustrations are relatively short and simple in Lin and Fu (1997); many details needed for diagnosis in the new standard (*sensu* Beard *et al.* 2013) are lacking. The description of *T. xinglongensis* by Lin and Fu (1997) is in broad agreement with that of *T. japonica* by Beard *et al.* (2013), with one notable exception: 8 setae in the genital-anal area in the former versus 9 in the latter. Lin and Fu (1997) used this as one of the two characters to distinguish it from *T. pavoniformis* (Ewing, 1922); so it cannot be assumed that they made a type error here. Lin (1982) observed and illustrated nicely 9 pairs of setae in the genital-anal area for *T. xiamenensis* he described; so it cannot be assumed that his microscope was inadequate for the description.

Second, Lin retired several years ago and is now deceased; this might be one reason why Beard *et al.* (2013) failed to contact him. Even if Lin could be contacted, sending specimens—especially type specimens—overseas is rather complicated as a special permission from a central regulatory body in Beijing is required. As a result, many taxonomists in China are unable to obtain the permissions or do not bother to obtain permits through the long process. Another complicating matter is that Lin and Fu (1997) included a mixture of specimens from two host plant species and each from a different site when they described *T. xinglongensis*. The holotype plus 12 paratypes (all females, No 91-199) of *T. xinglongensis* were collected on 9 October 1991 from *Polyscias fruticosa* var. *plumata* (Araliaceae), in Xinglong, Hainan Province, China and a single paratype female was collected on 14 May 1992 from tea *C. sinensis*, in Wuzhishan, Hainan Province (No. 92-49). By support of his colleague Dr Xiaoyue Hong of Nanjing Agricultural University (Nanjing, China), the lead author of this paper was able to contact Mr Fu, the junior author of *T. xinglongensis*. It was discovered that the specimens of *Tuckerella* at Lin and Fu's institution is in a “poor” condition and the holotype of *T. xinglongensis* could not be found. However, Dr Hong managed to loan some specimens of *Tuckerella* from Fu's collection. Later, Zhang visited Hong's university in 2012 and was able to find the paratype of *T. xinglongensis* (No. 92-49) that originated from tea; the data on the slide match those in Lin and Fu (1997: 312). This specimen, with 6 pairs of whip-like setae (Fig. 2), does not belong to *T. xinglongensis* or *T. japonica*, but it is a close relative of *T. pavoniformis* and *T. xiamenensis*. It is closer to *T. xiamenensis* as setae  $v_1$  on the prodorsum is much longer than wide, but it is well tapered and strongly reticulated and thus is different from those in *T. xiamenensis*. It should be noted that one of the caudal setae— $h_3$ —is broken near the base in the specimen (No. 92-49) from tea and it appears that one side has five whip-like caudal setae if viewed at low magnification when the small base of  $h_3$  is overlooked. This might have misled Lin and Fu (1997) to assign this specimen from tea to *T. xinglongensis* as the profiles of other dorsal setae in this species are broadly similar to those in *T. xinglongensis* or *T. japonica*. Beard *et al.*'s (2013, p. 177) hypothesis “*Tuckerella xinglongensis* Lin and Fu, from tea in China, is considered a junior synonym of *T. japonica*” is here rejected.

The questions regarding the presence of *T. japonica* in China and its association with tea plants in China can be answered by (1) returning to the type locality of *T. xinglongensis* and collecting new specimens from type host for comparison with *T. japonica*, and (2) conducting a survey of *Tuckerella* on tea plants in southern China, respectively.



**FIGURE 2.** *Tuckerella* sp. adult female from tea collected in Wuzhishan, Hainan Province (slide No. 92-49), showing the posterior end of dorsal idiosoma [(mis-identified as *T. xinglongensis* by Lin & Fu (1997) and incorrectly attributed to *T. japonica* by Beard *et al.* (2013)]. One caudal seta  $h_3$  is broken near the base. Photograph: Zhi-Qiang Zhang.

#### **Alternative hypothesis for *T. japonica*'s route of invasion into New Zealand**

Although the presence of *T. japonica* in China and its association with tea plants in China are yet to be confirmed, there is little doubt that *T. japonica* is one of the earliest invasive mites that travelled with tea plants around the world (Beard *et al.*, 2013). In Beard *et al.*'s (2013) review, tea plants were shipped to Japan, Sweden, India, Brazil, Russia, Turkey, South Africa and USA, whereas country records for *T. japonica* are Australia, China, Italy, Japan, New Zealand, The Philippines, Turkey, USA, and Vietnam. Of course, we cannot expect the list to be complete for Tuckerellidae because many countries remained to be studied systematically. While the two lists agree broadly in Asia, Europe, and North America, there are gaps in Africa, Australasia and South America: (1) tea plants present in Africa and South America, but no record of *T. japonica* reported there yet (which may be due to lack of survey of mites there, and (2) *T. japonica* record in Australia and New Zealand, but lack of tea production there (at least per the review by Beard *et al.* 2013). Beard *et al.*'s record of *T. japonica* in Australia was based on a sample of mites from *C. japonica* in Sydney, and that for New Zealand was based on New Zealand exported mites on blueberry and kiwifruit that were intercepted in Australia. *C. japonica* is a close relative of tea (*C. sinensis*), however, it is hard to justify the New

Zealand record of *T. japonica* using Beard *et al.*'s hypothesis regarding movement of *T. japonica* on tea plants around the world. Although not reviewed in Beard *et al.* (3013), Chinese tea (oolong) was imported and cultivated (near Hamilton) in New Zealand in the 1990s and was only traded recently under the Brand Zealong (Huang 2012).

We recently examined *Tuckerella* associated with kiwifruits, included newly collected material as well specimens from AQIS collections in Australia (intercepted material); the New Zealand Arthropod Collection, Landcare Research, Auckland; MPI's Plant Health & Environment Laboratory, Auckland; and collections ofASUREQuality, Auckland.

We collected new samples from kiwifruit orchards in Te Puke during March to July, 2012. Sampling of leaves, twigs and barks revealed almost no *Tuckerella* mites (over 100 twigs examined, but only two mites found, one dead, one moving, presumably accidentally arriving from other plants), whereas fruits (sampled from vines) occasionally had mites (*T. japonica*); fallen kiwifruits collected from the ground of kiwifruit orchards rarely had *Tuckerella* mites on them. Thus, *T. japonica* mites found on kiwifruits did not come from its own stems or barks, which sustain no breeding populations of these mites.

Sampling of leaves and twigs of Japanese cedar (*Cryptomeria japonica*) around the orchards showed that *T. japonica* was frequently found on twigs (not leaves)—a new host record for *T. japonica*—and this species was present on their twigs in large numbers (e.g. 20 mites per twig of 20 cm long) compared to near absence on twigs of kiwifruit trees. All stages of mites of a breeding population were found on Japanese cedar twigs. As kiwifruit twigs/leaves bear few *T. japonica* mites with no breeding populations of these mites, it seems obvious that *T. japonica* mites on kiwifruits on vines came from windbreak trees *C. japonica*. Similar aerial invasion into kiwifruit orchards from adjacent hosts is well known for scale insects in New Zealand (Blank *et al.* 1987, 1990).

Our study of historical mite material preserved in collections revealed a mixture of an undescribed species of *Tuckerella* (to be described elsewhere) and *T. japonica*, with the latter being the most common mites collected from New Zealand-exported kiwifruits in the last two decades. Specimens collected from kiwifruits in the early decades (1960s to 1980s) are exclusively undescribed *Tuckerella* species, which decreased considerably in the last two decades. This trend seems to correspond to the more common use of exotic trees such as *C. japonica* (which is host to *T. japonica*) as replacements to native trees as windbreak for kiwifruit orchards in the last two decades or so (Moller *et al.* 2007; Mauchline *et al.* 2012). This increase in *T. japonica* might be also related to a shift of kiwifruit pest management practices in the 1980s. According to Blank *et al.* (1990):

“Before 1984 it was considered essential to spray insecticides onto shelter surrounding kiwifruit orchards. However, from 1984/85 seasons onwards, MAF export spray programme has recommended that shelter should not be sprayed unless it was known to be infected with insect pests such as scales.”

The implementation of this certainly conserved predators of spider mites *Tetranychus urticae* (Charles 1989). It also resulted in the build-up of scale insects (Blank *et al.* 1990), and likewise it would also encourage mites such as *T. japonica*. While predators are conserved and may be effective against spider mites *T. urticae*, they are not so effective against *Tuckerella* which have a special defence system using their setae (Ochoa 1989): the flagellate caudal setae are equipped with prominent spines along its entire length and when “predators approach, the caudal setae are moved forward as powerful whips hitting the body of the attacker. This action confuses the predator and gives time for the peacock mite to escape.” Collyer (1969) also observed this behaviour in *Tuckerella* in New Zealand. We likewise observed the same behaviour in *T. japonica* collected from *C. japonica* in Te Puke.

*Cryptomeria japonica* originated from Japan but was “introduced in China centuries ago” (Farjon 1999). It was later introduced by Europeans to Russia, Indonesia (Java) and England around the middle of the nineteenth century. In Europe and the United States, this species is “still largely confined to arboreta and large country parks” according to Farjon (1999). The Agroforestry Database lists this species as native from Japan and China, and exotic in Canada, India, Indonesia, Iran, New Zealand, South Africa, Tanzania, United Kingdom and US (Orwa *et al.* 2009).

*Cryptomeria japonica* is abundant in cultivation throughout New Zealand (Webb *et al.* 1988). But in 1964 only about 70 ha of (*C. japonica*) were planted in pure stands in Auckland Regional Authority's Hunua Ranges and in 1977, it “comprised only 5% of the total exotic forest estate” (Dakin 1982). However, it has become a popular shelterbelt tree species in New Zealand (Sampson 2008). It is now “probably the most commonly planted shelter species in kiwifruit orchards” (Mauchline *et al.* 2012). Our data above show that in New Zealand, *T. japonica* is mainly associated with *C. japonica* and its increasing occurrence on kiwifruits in recent years corresponds to the rise of *C. japonica* as a shelter species in kiwifruit orchards. *T. japonica* does not breed on kiwifruit vines but is found on kiwifruits as a result of aerial cross-contamination from *C. japonica* surrounding the kiwifruit orchards. Beard *et al.* (2013)'s hypothesis on the movement of *T. japonica* with tea plants as the route of invasion is not supported by New Zealand data, which suggest the route of invasion of *T. japonica* into New Zealand via *C. japonica*. The movement of *T. japonica* with tea plants may still be one route into countries such as the USA as suggested by Beard *et al.* (2013). However, the movement of *C. japonica* provides an alternative route for *T. japonica* into countries where *C. japonica* was introduced.

## Acknowledgements

Xiaoyue Hong (Nanjing Agricultural University, China) kindly arranged the loan of specimens of *T. xinglongensis* and other *Tuckerella* from Chinese Academy of Tropical Agricultural Sciences and hosted Zhi-Qiang Zhang's stay when he visited China in 2012. Jurgen Otto kindly arranged the loan of *Tuckerella* from Quarantine and Inspection Service, Australia. Qing-Hai Fan (Ministry of Primary Industries, Auckland) kindly arranged the loan of *Tuckerella* in the collection of MPI's Plant Health & Environment Laboratory, Auckland. John Keall kindly arranged the loan of *Tuckerella* in the collection ofASUREQuality, Auckland. This research was funded by ZESPRI International Limited through its Innovation Portfolio 'Market Access'. We thank past Innovation Leader Jane Adams and current Innovation Leader Mary Black for support. We are also grateful to Project Champion Roger Gilbertson for help and support during the project. Peer review and comments by Qing-Hai Fan, Mary Black and Rich Leschen (Landcare Research, Auckland) are also greatly appreciated. Jenny Beard (Queensland Museum) kindly shared the manuscript in press on *Tuckerella* in 2012 when the research for this paper was carried out.

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Accepted by Q.-H. Fan: 25 Mar. 2013; published 31 Mar. 2013