Trialeurodes abutiloneus (Haldeman) (Hemiptera: Aleyrodidae), a species long present but never officially recorded in Canada

Julia J. Mlynarek,[1] Roselyne M. Labbé

Abstract—*Trialeurodes abutiloneus* (Haldeman) (Hemiptera: Aleyrodidae) is known to have been present in Canada since 1973. Despite this, the species has until now not been officially recorded; a surprising fact considering the close association of the species with economically important crops. The historic distribution expands from Mexico to southern New York and Michigan in the United States of America. In 2016, all life stages of *T. abutiloneus* were collected again on soybean (*Glycine max* (Linnaeus) Merrill; Fabaceae) plants grown in research greenhouses in southwestern Ontario, Canada. Specimens were morphologically and genetically identified to confirm their identity as *T. abutiloneus*. Thereafter, the barcode sequence for this species was also identified from the barcode of life data system, informing on the prior detection of this species from specimens collected at Point Pelee National Park, Ontario, Canada in 2012 during a barcode of life collection. Although this species is not considered a major pest on crops in Canada, it is related to other common pests within the same genus and can potentially transmit similar plant diseases. We provide the barcode COI sequence for the species, give an overview of the documented host range pertinent to Canada, and provide information concerning its natural enemies.

Trialeurodes abutiloneus (Haldeman) (Hemiptera: Aleyrodidae) is a whitefly that has been recorded from South America, Iran, and the United States of America (including Hawaii) (Evans 2008; Russell 1963). Based on available literature, the northernmost limit of the distribution of this whitefly in North America is southern New York and Michigan, United States of America. It is also known to occur at latitudes $>45°$ north in the northwestern United States of America where it is known to overwinter on potato (*Solanum tuberosum* Linnaeus; Solanaceae) (Landis and Getzendaner 1947). In that range, *T. abutiloneus* is a generalist, recorded to feed on plant species from 33 plant families (Russell 1963; Slosser *et al*. 2005; Evans 2008) including important crops such as *Glycine max* (Linnaeus) Merrill (Fabaceae) (soybean), *Ipomoea batatas* (Linnaeus) Lamarck (Convolvulaceae) (sweet potato), *Gossypium* Linnaeus (Malvaceae) (cotton), and *Solanum* Linnaeus (Solanaceae) (tomato) (Jones *et al*. 1975; Liu and Stansly 2000). In soybean crops, *T. abutiloneus* is usually found co-occurring with *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) (Lambert *et al*. 1997). In Canada, *T. abutiloneus* can potentially be found on host plants belonging to 22 families (Table 1).

Trialeurodes abutiloneus has never been officially recorded in the literature as occurring in Canada, although archival specimens have been collected by R.J. McClanahan from Harrow, in southwestern Ontario, Canada dating back to September 1973. These insects were collected from velvet leaf, *Abutilon theophrasti* Medikus (Malvaceae), hosts. Recently, new specimens have been collected from the same region, again at the Harrow Research and Development Centre, in October to November 2016. This note therefore represents the first verifiable (morphological and molecular) published record of this species in Canada. A large population of *T. abutiloneus* was found on greenhouse soybean plants (Fig. 1). Seeing that individuals of this species have

Received 13 December 2017. Accepted 21 February 2018. First published online 25 May 2018.

J.J. Mlynarek,[1] R.M. Labbé, Agriculture and Agri-Food Canada, Harrow Research and Development Centre, 2185 County Road 20, Harrow, Ontario, N0R 1G0, Canada

[1]Corresponding author (e-mail: Julia.mlynarek@canada.ca)
Subject editor: Cécile Le Lann.
doi:10.4039/tce.2018.26

Table 1. Potential host range of *Trialeurodes abutiloneus* in Canada based on host range from Evans (2008) superimposed onto the presence of the plant species in Canada (Vascan database: http://data.canadensys.net/vascan/search?lang=en).

Family	Genus/species
Aceraceae	*Acer rubrum* Linneaus
Aizoaceae	*Mollugo verticillata* Linneaus
Amaranthaceae	*Amaranthus* Linneaus
Asteraceae	*Ambrosia* Linneaus
	Bidens Linneaus
	Eclipta alba (Linneaus) Hasskarl
	Erigeron Linneaus
	Gerbera jamesonii Adlam
	Heliantheae Cassini
	Helianthus Linneaus
	Heterotheca Cassini
	Lactuca Linneaus
	Mikania scandens (Linneaus) Willdenow
	Pluchea Cassini
	Solidago Linneaus
	Sonchus Linneaus
	Taraxacum Zinn
Brassicaceae	*Lepidium virginicum* Linneaus
Campanulaceae	*Lobelia cardinalis* Linneaus
Convolvulaceae	*Ipomoea* Allioni
Cucurbitaceae	*Cucumis melo* Linneaus
Euphorbiaceae	*Chamaesyce* Rafinesque
	Euphorbia Linneaus
Fabaceae	*Glycine max* (Linneaus) Merrill
	Medicago sativa Linneaus
Fagaceae	*Quercus* Linneaus
Haloragaceae	*Myriophyllum aquaticum* Verdcourt
Labiatae	*Ajuga* Linneaus
	Monarda didyma Linneaus
	Salvia Linneaus
Malvaceae	*Abutilon theophrasti* Medikus
	Hibiscus Linneaus
	Malva Linneaus
	Sida Linneaus
Oxalidaceae	*Oxalis corniculata* Linneaus
Papaveraceae	*Argemone mexicana* Linneaus
Plantaginaceae	*Platanus* Linneaus
Poaceae	*Sorghum bicolor* (Linneaus) Moench
Polygonaceae	*Polygonum* Linneaus
Primulaceae	*Samolus parviflorus* Rafinesque
Solanaceae	*Lycopersicon esculentum* Miller
	Physalis Linneaus
	Solanum Linneaus
Urticaceae	*Urtica* Linneaus

previously been recorded from southern Michigan and New York (Russell 1963), this species can be assumed to be well adapted to climatic conditions in southwestern Ontario, which are on the same latitude as Michigan and New York.

Adults are easily recognised morphologically due to a clear, black, zigzagging pattern on the wing (Fig. 2). Late instars and pupae of *T. abutiloneus* also closely resemble those of congeneric species including their typical top flattened oval shape as well as the production of a waxy peripheral fringe. They can be distinguished from other species by their cream colour and the presence of variably shaped dark dorsal blots along the midline of their body (Fig. 3). As with *Trialeurodes vaporariorum* Westwood that are parasitised by *Encarsia formosa* Gahan (Hymenoptera: Aphelinidae), we have noted the presence of entirely black pupal bodies of *T. abutiloneus* that hosted this parasitoid (Fig. 1: second instar from right side of image).

We sequenced the cytochrome oxidase I barcode region of *T. abutiloneus* specimens in order to confirm its identity. Briefly, DNA was extracted from an adult whitefly using the Chelex extraction method (Walsh *et al.* 1991). We amplified the barcode region using universal insect primers (LCO1490-F: 5'-GGTCAACAAATCATAAAGATATTGG-3'; HCO2198-R: 5'-TAAACTTCAGGGTGACCAAAAAATCA-3') (Folmer *et al.* 1994) and the following thermal cycling condition: denaturation at 94 °C for one minute; followed by five cycles of 94 °C for 40 seconds, 45 °C for 40 seconds, and 72 °C for one minute; followed by 35 cycles of 94 °C for 40 seconds, 51 °C for 40 seconds, 72 °C for one minute, with a final extension at 72 °C for five minutes. Our resulting sequence (MG817067) nearly completely matched sequences available in GenBank (http://www.ncbi.nlm.nih.gov/genbank) and the Barcode of Life Datasystem (BOLD - http://www.boldsystems.org) listed as unidentified Aleyrodidae species. DNA barcoding of our collected specimens also allowed us to determine that this species has been collected from a cactus field in Point Pelee National Park, Ontario, Canada in 2012 (BOLD Sample ID: BIOUG03903-A02) suggesting that this species is mostly likely established in southwestern Ontario.

Trialeurodes abutiloneus is recognised as a pest and can vector for many plant viruses. In the United States of America, *T. abutiloneus* has also been

https://doi.org/10.4039/tce.2018.26 Published online by Cambridge University Press

Fig. 1. Distribution of *Trialeurodes abutiloneus* nymphs and pupae on the underside of a soybean leaf. Circled individual is parasitised.

Fig. 2. Adult *Trialeurodes abutiloneus*.

recorded to occur on cotton (Clower *et al*. 1971). It has also been recorded to transmit Crinivirus (Closteroviridae) (sweet potato chlorotic stunt virus) to sweet potatoes (Valverde *et al*. 2004) and Abutilon yellows virus (*Crinivirus*; Closteroviridae) to other crops (Liu *et al*. 1997). In the case of Abutilon yellows, *T. abutiloneus* is known to retain the virus for up to three days suggesting that an infected

https://doi.org/10.4039/tce.2018.26 Published online by Cambridge University Press

Fig. 3. Nymphs and pupae of *Trialeurodes abutiloneus*.

individual can have a lasting impact on a crop (Wisler and Duffus 2001). It is also known to vector *Crinivirus* such as blackberry yellow vein associated virus, diodia vein chlorosis virus, and tomato chlorosis virus (Tzanetakis *et al.* 2013). Records also show this species vectoring multiple viruses of the genus *Torradovirus* (Secoviridae) including the tomato marchitez virus, the tomato torrado virus, and the tomato chocolàte virus that are restricted to Mexico (Verbeek *et al*. 2014). Each of these viruses are known to infect *Solanum* plant species and have the potential to cause significant crop losses attributed to leaf necrosis and patches on fruits (Verbeek *et al*. 2014). Together, the viruses transmitted by *T. abutiloneus* can negatively impact multiple crop types and therefore we suggest the development of a monitoring programme for this whitefly species.

Little is known about the biological control of *T. abutiloneus* however some Aphelinidae (Hymenoptera) parasitoid species (*Encarsia* Förster and *Eretmocerus* Haldeman) have been shown to successfully parasitise *T. abutiloneus* (Dysart 1966; Watve and Clower 1976; Polaszek *et al*. 2004; Evans 2008; Greenberg *et al*. 2009; Pickett *et al*. 2013) (Table 2). *Encarsia lutea* (Masi) and *Encarsia pergandiella* Howard are listed among these species (Gerling 1967; Rivnay and Gerling 1987). In the context of our observations, we have also extracted DNA from a parasitised *T. abutiloneus* whitefly and amplified its COI barcode gene using the same protocol as described for the whitefly. This parasitoid shared 99% identity with *E. formosa* as molecularly identified in GenBank and BOLD (MG817066). There is also an entomopathogenic fungus, *Orthomyces aleyrodis* Steinkraus, Humber, and Oliver (Entomophthoraceae) that has been shown to control this species (Steinkraus *et al*. 1998), and it would be likely that entomopathogens such as *Beauveria bassiana* (Balsamo-Crivelli) (Clavicipitaceae) commonly used to control *T. vaporariorum*, would also infect this species. Finally, generalist predators such as Coccinellidae (Coleoptera), Hemiptera, Neuroptera, and Arachnida are also known to prey readily on this species (Watve and Clower 1976; Evans 2008). These include the adults of *Spanagonicus albofasciatus* (Reuter) (Hemiptera: Miridae), which was shown to lower per cent survival of eggs and adults of *T. abutiloneus* to 3–5% after two to three days in cages with the predator (Butler 1961) (Table 2).

Trialeurodes abutiloneus is a species that has not officially been recorded from Canada although it has surely been established for at least 40 years based on collections from McLanahan at the Harrow Research and Development Centre

https://doi.org/10.4039/tce.2018.26 Published online by Cambridge University Press

Table 2. Records of the natural enemies of *Trialeurodes abutiloneus*.

Family	Species	Reference
Parasitoids		
Aphelinidae (Hymenoptera)	*Encarsia californica* Polaszek	Evans (2008)
	Encarsia formosa Gahan	Evans (2008)
	Encarsia hayati Geng and Li	Evans (2008)
	Encarsia hispida De Santis	Evans (2008)
	Encarsia lutea (Masi)	Gerling (1967)
	Encarsia luteola Howard	Evans (2008)
	Encarsia meritoria Gahan	Polaszek *et al.* (2004)
	Encarsia nigricephala Dozier	Evans (2008)
	Encarsia parvella Silvestri species group	Evans (2008)
	Encarsia pergandiella Howard	Rivnay and Gerling (1987)
	Encarsia quaintancei Howard	Dysart (1966)
	Encarsia sophia (Girault and Dodd)	Evans (2008)
	Encarsia strenua group (Silvestri)	Evans (2008)
	Encarsia tabacivora Viggiani	Evans (2008)
	Encarsia Förster	Watve and Clower (1976)
	Eretmocerus californicus Howard	Evans (2008)
	Eretmocerus haldemani Howard	Watve and Clower (1976)
	Eretmocerus mundus Mercet	Greenberg *et al.* (2009)
	Eretmocerus staufferi Rose and Zolnerowich	Evans (2008)
	Eretmocerus Haldeman	Evans (2008)
Platygastridae (Hymenoptera)	*Amitus aleurodinis* Haldeman	Dysart (1966)
	Amitus bennetti Viggiani and Evans	Evans (2008)
	Amitus fuscipennis MacGown and Nebeker	Evans (2008)
	Amitus Haldeman	Evans (2008)
Signiphoridae (Hymenoptera)	*Signiphora aleyrodis* Ashmead	Evans (2008)
Fungus		
Clavicipitaceae	*Aschersonia aleyrodis* Webber	Evans (2008)
Entomophthoraceae	*Orthomyces aleyrodis* Steinkraus, Humber, and Oliver	Steinkraus *et al.* (1998)
Predator		
Coccinellidae (Coleoptera)	*Coccinella novemnotata* Herbst	Watve and Clower (1976)
	Coleomegilla maculata lengi Timberlake	Watve and Clower (1976)
	Delphastus pusillus (LeConte)	Watve and Clower (1976)
	Hippodamia convergens Guérin-Méneville	Watve and Clower (1976)
	Olla v-nigru (Mulsant)	Evans (2008)
Lygaeidae (Hemiptera)	*Geocoris punctipes* (Say)	Watve and Clower (1976)
Anthocoridae (Hemiptera)	*Orius insidiosus* (Say)	Watve and Clower (1976)
	Orius tristicolor (White)	Evans (2008)
Nabidae (Hemiptera)	*Nabis ferus* (Linneaus)	Evans (2008)
	Nabis Latreille	Watve and Clower (1976)
Chrysopidae (Neuroptera)		Watve and Clower (1976)
Hemerobiidae (Neuroptera)		Watve and Clower (1976)
Miridae (Hemiptera)	*Spanogonicus albofasciatus* (Reuter)	Butler (1961)
Chrysopidae (Neuroptera)	*Chrysopa oculata* Say	Evans (2008)
	Chrysoperla plorabunda (Fitch)	Evans (2008)
Thripidae (Thysanoptera)	*Sericothrips trifasciatus* (Ashmead)	Evans (2008)

(Agriculture and Agri-Food Canada), the Barcode of Life collection in Pointe Pelee National Park, and our own in 2016. It has been a nuisance in the United States of America in cotton and sweet potato crops but we cannot consider it an important pest in Canada. A few potential reasons why

https://doi.org/10.4039/tce.2018.26 Published online by Cambridge University Press

T. abutiloneus has not caused any noticeable damage may be that it is a generalist that does not need to survive on specific crops, that the population size is controlled because of a number of natural enemy species, and that it is outcompeted by closely related species. However, the distribution of this species in Canada still remains unclear and we urge that time be taken for the identification of whiteflies from historical and collection of new ecological and agricultural samples so that we can gain a better understanding of this species in North America.

Acknowledgements

The authors thank George Driedger and Dr. Owen Wally for bringing the specimens to our attention and Dana Gagnier for photographing the adult. The sequencing was performed by R.M.L.

References

Butler, G. 1961. *Spanangonicus albofasciatus* as an insect and mite predator. Journal of the Kansas Entomolgical Society, **38**: 70–75.

Clower, D.F., Watve, C.M., Melville, D.R., and Graves, J.B. 1971. Whiteflies – a new insect problem on cotton. Louisiana Agriculture, **14**: 8–9.

Dysart, R.J. 1966. Natural enemies of the banded-wing whitefly, *Trialeurodes abutilonea* (Hemiptera: Aleyrodidae). Annals of the Entomological Society of America, **59**: 28–33.

Evans, G. 2008. The whiteflies (Hemiptera: Aleyrodidae) of the world and their host plants and natural enemies. United States Department of Agriculture, Animal Plant Health Inspection Service, Washington, District of Columbia, United States of America. Available from http://keys.lucidcentral.org/keys/v3/whitefly/PDF_PwP%20ETC/world-whitefly-catalog-Evans.pdf [accessed 17 April 2018].

Folmer, O., Black, M., Hoeh, W., Lutz, R., and Vrijenhoek, R. 1994. DNA primers for amplification of mitochondrial cytochrome *c* oxidase subunit I from diverse metazoan invertebrates. Molecular Marine Biology and Biotechnology, **3**: 294–299.

Gerling, D. 1967. Bionomics of the whitefly parasite complex associated with cotton in southern California (Homoptera: Aleurodidae; Hymenoptera: Aphelinidae). Annals of the Entomological Society of America, **60**: 1306–1321.

Greenberg, S.M., Jones, W.A., and Liu, T.-X. 2009. Tritrophic interactions among host plants, whiteflies, and parasitoids. Southwestern Entomologist, **34**: 431–445.

Jones, J.E., Clower, D.F., Milam, M.R., Caldwell, W.D., and Melvill, D.R. 1975. Resistance in upland cotton to the bandedwinged whitefly, *Trialeurodes abutilonea* (Haldeman). Proceedings of the Beltwide Cotton Production Research Conference, **1975**: 98–99.

Lambert, A., McPherson, R., and Herzog, G. 1997. Field evaluation of fourteen soybean genotypes for resistance to whitefly (Homoptera: Aleyrodidae) infestations. Journal of Economic Entomology, **90**: 658–662.

Landis, B.J. and Getzendaner, C.W. 1947. *Aleyrodes spiraeoides* infesting potatoes. Journal of Economic Entomology, **40**: 567.

Liu, H., Li, R., Wisler, G., and Duffus, J. 1997. Characterization of Abutilon yellows virus – a new clostero-like virus transmitted by banded-wing whitefly (*Trialeurodes abutilonea*). Phytopathology, **87**: S58–S59.

Liu, T.-X. and Stansly, P.A. 2000. Response of *Trialeurodes abutiloneus* (Homoptera: Aleyrodidae) to sweet potato and two species of *Hibiscus*. Annals of the Entomological Society of America, **93**: 850–855.

Pickett, C., Keaveny, D., and Rose, M. 2013. Spread and non-target effects of *Eretmocerus mundus* imported into California for control of *Bemisia tabaci*: 2002–2011. Biological Control, **65**: 6–13.

Polaszek, A., Manzari, S., and Quicke, D.L.J. 2004. Morphological and molecular taxonomic analysis of the *Encarsia meritoria* species-complex (Hymenoptera, Aphelinidae), parasitoids of whiteflies (Hemiptera, Aleyrodidae) of economic importance. Zoologica Scripta, **33**: 403–421.

Rivnay, T. and Gerling, D. 1987. Aphelinidae parasitoids [Hymenoptera: Chalcidoidea] of whiteflies [Hemiptera: Aleyrodidae] in Israel, with description of three new species. Entomophaga, **32**: 463–475.

Russell, L.M. 1963. Hosts and distribution of five species of *Trialeurodes* (Homoptera: Aleyrodidae). Annals of the Entomological Society of America, **56**: 149–153.

Slosser, J.E., Parajulee, M.N., Idol, G.B., and Hendrix, D.L. 2005. Populations of bandedwinged whiteflies (Homoptera: Aleyrodidae) in the northern Texas rolling plains. Southwestern Entomologist, **30**: 137–147.

Steinkraus, D.C., Oliver, J.B., Humber, R.A., and Gaylor, M.J. 1998. Mycosis of bandedwinged whitefly (*Trialeurodes abutilonea*) (Homoptera: Aleyrodidae) caused by *Orthomyces aleyrodis* gen. & sp. nov. (Entomophthorales: Entomophthoraceae). Journal of Invertebrate Pathology, **72**: 1–8.

Tzanetakis, I.E., Martin, R.R., and Wintermantel, W.M. 2013. Epidemiology of criniviruses: an emerging problem in world agriculture. Frontiers in Microbiology, **4**: 1–15.

Valverde, R.A., Sim, J., and Lotrakul, P. 2004. Whitefly transmission of sweet potato viruses. Virus Research, **100**: 123–128.

https://doi.org/10.4039/tce.2018.26 Published online by Cambridge University Press

Verbeek, M., van Bekkum, P.J., Dullemans, A.M., and van der Vlugt, R.A. 2014. Torradoviruses are transmitted in a semi-persistent and stylet-borne manner by three whitefly vectors. Virus Research, **186**: 55–60.

Walsh, P.S., Metzger, D.A., and Higuchi, R. 1991. Chelex 100 as a medium for simple extraction of DNA for PCR-based typing from forensic material. Biotechniques, **10**: 506–513.

Watve, C.M. and Clower, D.F. 1976. Natural enemies of the bandedwing whitefly in Louisiana. Environmental Entomology, **5**: 1075–1078.

Wisler, G.C. and Duffus, J.E. 2001. Transmission properties of whitefly-borne criniviruses and their impact on virus epidemiology. *In* Virus-insect-plant interactions. *Edited by* K.F. Harris, O.P. Smith, and J.E. Duffus. Elsevier, San Diego, California, United States of America. Pp. 293–308.

https://doi.org/10.4039/tce.2018.26 Published online by Cambridge University Press