

**NEW STATE RECORDS OF *ACULOPS AILANTHI* (LIN, JIN,
AND KUANG) (ACARIFORMES; TROMBIDIFORMES:
PROSTIGMATA: ERIOPHYIDAE), IN USA; A PEST OR
BIOLOGICAL CONTROL AGENT OF *AILANTHUS
ALTISSIMA* (MILL.) SWINGLE?**

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Abstract.—We report the first detections of *Aculops ailanthi* Lin, Jin, and Kuang (1997) (Acariformes: Trombidiformes: Prostigmata: Eriophyidae) from Montgomery County, Virginia, and Wayne County, Michigan, USA; the fourth and fifth states to report this non-gall forming rust mite on *Ailanthus altissima* (Mill.) Swingle. We initially became aware of the pest in Virginia due to severe symptomology on greenhouse-cultivated *Ai. altissima*. In Michigan, similar observations from a field survey led to the mites' discovery. We tentatively identified the pest as an eriophyid mite of unknown species. Samples from both states were sent to USDA-ARS for identification and, using scanning electron microscopy, confirmed the species as *A. ailanthi* based on the morphological features. Moreover, we describe the impacts that high populations of *A. ailanthi* can have on *Ai. altissima* in greenhouse settings and potential use as a biological control agent. Field observations from Michigan are encouraging that *A. ailanthi* can affect *Ai. altissima* outside of greenhouse settings.

Key Words: *Tree-of-heaven; New state records; Eriophyid mites*

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Tree-of-heaven (hereafter ToH), *Ailanthus altissima* (Mill.) Swingle, is a fast-growing deciduous tree native to China infamous for establishing itself in disturbed environments. Excluding Antarctica, ToH

can be found on every continent (Kowarik and Säumel 2007). In North America, ToH was first introduced for ornamental purposes in 1784; since its introduction, it has become widespread across the

USA and is listed as a noxious weed in many states because it can easily outcompete native species (USDA NRCS 2014). Additionally, existing ToH stands provided ample host material for devastating invasive insects such as *Halyomorpha halys* (Stål), brown marmorated stink bug, and *Lycorma delicatula* (White), spotted lanternfly, in the USA (Hoebeke and Carter 2003; Barringer et al. 2015). Despite being a prolific plant species in the landscape, especially in disturbed forest areas (Nature Conservancy 2020), cultivating ToH in a greenhouse for research on biocontrol agents has been challenging due to unforeseen mite pest problems.

In China, Ding et al. (2006) documented 46 species of herbivorous invertebrates, 16 fungi, and one potyvirus that utilize ToH; seven of those phytophagous arthropods have been introduced and detected in the USA to some degree (Ding et al. 2006; Skvarla et al. 2021). Additionally, in the USA, *Atteva aurea* (Fitch, 1857) (*Ailanthus* webworm moth) is an indigenous species that feeds upon many plants within the Simaroubaceae family and has adapted to ToH (Becker 2009). Two weevil species, *Eucryptorrhynchus brandti* (Harold) and *E. chinensis* (Olivier), show considerable promise as biological control agents, but releases have still not been approved in the USA (Ding et al. 2006; Herrick et al. 2012; Marini et al. 2022). Two species of *Verticillium*, *V. nonalfalfae*, and *V. dahliae*, have been observed to infect ToH in the USA and Europe. They caused withering, yellowing, premature leaf drops, and dieback; the use of either *Verticillium* species as a biological control agent is still in development (Shall and Davis 2006; Brooks et al. 2020; Pisuttu et al. 2020). Furthermore, Snyder et al. (2012) determined that *E. brandti* can transfer *V. nonalfalfae* to ToH.

Eriophyid mites (Acari: Eriophyoidea) typically have a high degree of host

specificity and, despite their near microscopic stature, can severely impact their associated host (Skoracka et al. 2010; de Lillo et al. 2018). Four eriophyid mite species in two genera, *Aculops* and *Aculus*, are documented to have associations with ToH: *Aculops ailanthi* Lin, Jin, and Kuang from China; *Aculops taihangensis* Hong and Xue from China; *Aculus altissimae* Xue and Hong from China; *Aculus mosonien-sis* Ripka and Ersek from Hungary. Two of these four mite species, *A. ailanthi* and *A. mosoniensis*, reported from the USA and Europe respectively, show promise as biological control agents (Gardener 2008; Ripka and Ersek 2014; Skvarla et al. 2021; de Lillo et al. 2022). Both mites cause significant damage to ToH saplings and new green growth in greenhouse environments (Gardener 2008; Skvarla et al. 2021; Marini et al. 2022).

To date, *A. ailanthi* has been documented in Maryland, Pennsylvania, and West Virginia (Gardener 2008; Skvarla et al. 2021). As previously mentioned, the cultivation of ToH for research on associated invasive arthropod species and biocontrol agents has become an area of growing interest.

MATERIALS AND METHODS

Samples of infested leaves from Virginia were stored in 30 ml glass vials and then submerged with 70% ethanol; additionally, mite-infested leaves were sent on ice to preserve live specimens for identification. From Michigan, samples of live material were sealed in plastic bags and shipped with frozen gel packs. All specimens were sent to USDA-ARS Systematic Entomology Laboratory for species confirmation.

Tabletop SEM observations were made using a TM 3030Plus scanning electron microscope (Hitachi High Technologies America, Pleasanton, CA, USA) equipped

with a Deben cooler system (Angstrom Scientific Inc., Ramsey, NJ, USA). Eriophyid specimens *in situ* on plant material were attached to 32 mm aluminum specimen holders with carbon sticky pads. Individual mites were removed from the plant material and mounted ventrally. The samples were cooled to -25 C. An accelerating voltage of 5 kV was used to view the specimens.

RESULTS

In the spring of 2022, potted ToH was grown from seed at Virginia Tech greenhouses, Blacksburg, Virginia, USA, for the rearing of *L. delicatula* within quarantine facilities. Shortly after emergence, we observed young ToH seedlings exhibit leaf deformation (like herbicide damage, see Figs. 1, 2), leaf yellowing, leaf rolling upward, premature leaf drop, drying and necrosis of apical meristem, and seedling death. Infested leaves were observed for surface pests using a stereomicroscope and tentatively identified as an unknown species of non-gall-forming eriophyid mites. We suspected the eriophyid mite in question was *A. ailanthis* due to the host specificity of eriophyid mites (Skoracka et al. 2010), lack of galls, and the recent



Fig. 1. Mite-infested, greenhouse-reared, ToH on the left. Healthy ToH on the right. Each ToH seedling was germinated and planted on the same date. Both seedlings were exposed to the same growing conditions, were six months from germination, and were approximately 0.5 meters in height.



Fig. 2. Mite-infested ToH sapling, approximately two meters in height, and observed in field conditions from Wayne County, Michigan, USA.

detection of *A. ailanthis* in surrounding states (Gardner 2008; Skvarla et al. 2021).

Scan images were captured at a resolution of 1,280 x 960 pixels (Fig. 3). The mites were compared with the original descriptions as well as previously collected material and identified as *A. ailanthis*. We document observations and identification of *A. ailanthis* in southwest Virginia in 2022 and Michigan in 2023.

DISCUSSION

It is possible that *A. ailanthis* is present in North America within the distribution of ToH but has not been detected or surveyed for. Ozman-Sullivan et al. (2023) indicated the presence of *A. taihangensis* in Turkey and perhaps in the Middle East. This recent report and our findings support the need to carefully review the original species from China, where ToH is originally from.

Furthermore, the use of *A. ailanthis* as a potential biological control agent against ToH is still being studied at Virginia Tech and Pennsylvania State University (Skvarla et al. 2021). In greenhouse settings, with a lack of natural predators, high populations of *A. ailanthis* can severely impact the growth of ToH (Skvarla et al. 2021).

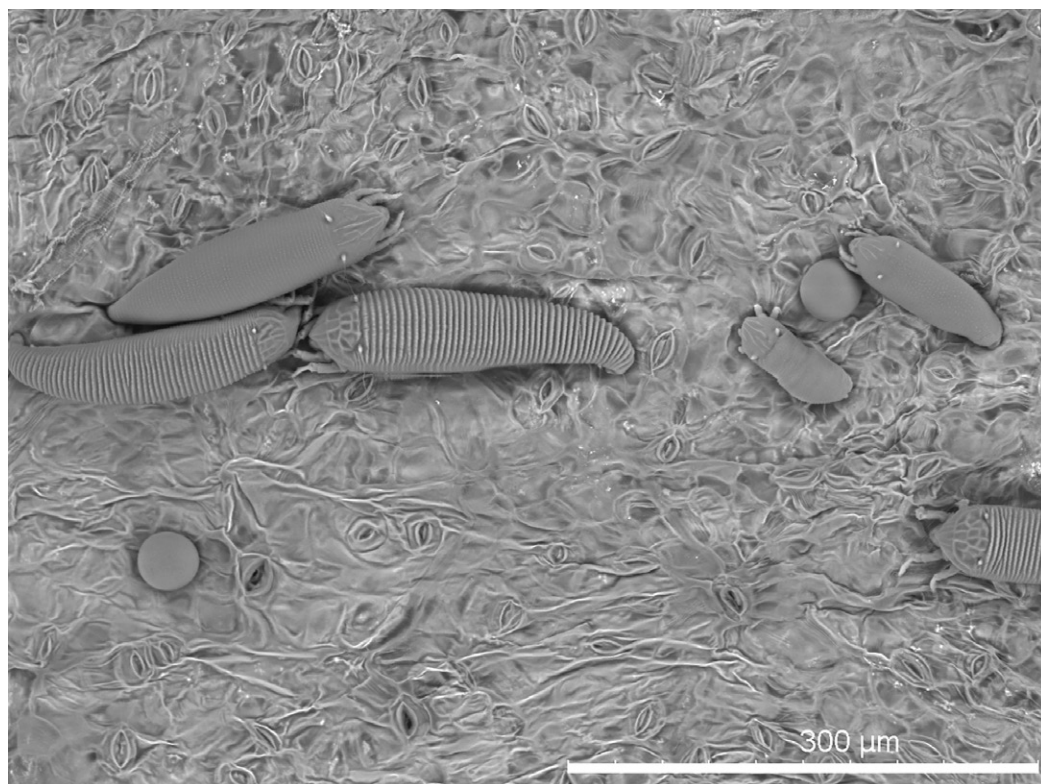


Fig. 3. Scanning electron microscope image of various life stages of *A. ailanthis* *in situ* on the ventral surface of a leaf of ToH (*Ai. Altissima*), including eggs, larvae, nymphs, and adults.

It is unknown if natural populations of *A. ailanthis* outside of a greenhouse setting can equally devastate established stands of ToH. Anecdotal, greenhouse-reared ToH infested with *A. ailanthis* were taken outside and exposed to natural conditions, mite populations subsequently declined. On the other hand, the observations from Michigan of heavily infested new and young growth of naturally established ToH (Fig. 4) offer evidence that there is potential for biological control outside of a greenhouse environment. The material from Michigan had the leaves dorsally and ventrally infested with all the mite stages; most of the eggs were located on the leaf's ventral surface. This may indicate that naturally occurring populations of *A. ailanthis* could build up the population density

required to suppress ToH new growth and saplings. Conversely, *A. ailanthis* was only detected on the ventral surface of plant materials sampled from Virginia. The collapse of the Virginia populations of *A. ailanthis* on plant material taken outside the greenhouse points to the need for a greater understanding of the effects of wind and other natural conditions on *A. ailanthis* behavior. Another reason for further studies of the presence of the eriophyid mites is a possibility of an association with a virus that could help to restrict the spreading of this invasive plant (Ding et al. 2006).

The taxonomy separating these two genera, *Aculops* and *Aculus*, is currently under investigation (de Lillo et al. 2017; Marini et al. 2021; Skvarla et al. 2021;

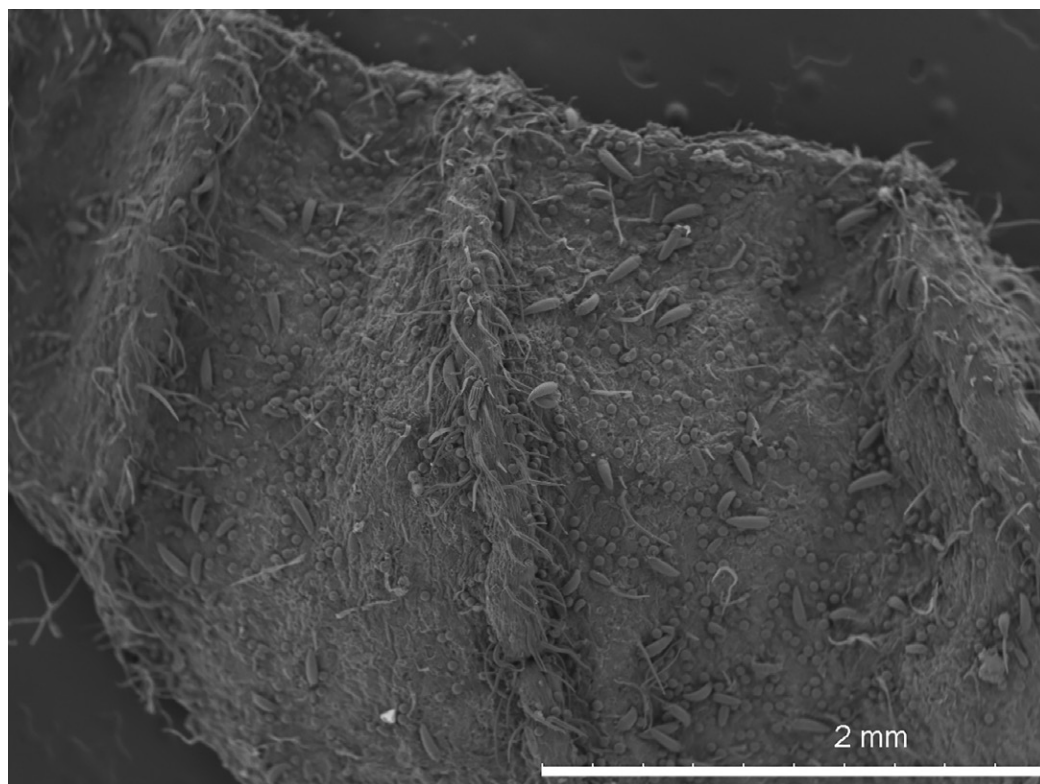


Fig. 4. Scanning electron microscope image of high population density of *A. aylanthi* *in situ* on the ventral surface of a leaf of ToH (*Ai. Altissima*).

de Lillo et al. 2022). Unfortunately, a careful comparison of eriophyid mites associated with ToH was not conducted. Using molecular analysis and morphological observations, de Lillo et al. (2022) indicated *Aculus mosoniensis* belongs to the genus *Aculops* and that *A. mosoniensis* and *A. taihangensis* are taxonomically synonymous. Skvarla et al. (2021) proposed that *A. altissimae*, based on the morphological differences cited in its marginal and unreliable description, is a junior synonym of *A. aylanthi*. These findings suggest a further molecular comparison of *A. aylanthi* with *A. mosoniensis*, as it is likely that the latter is a synonym. In addition to taxonomic confusion, little is documented about *A. aylanthi* phenology;

for example, the overwintering life stage is unknown.

We suggest conducting further surveys to determine the full range of *A. aylanthi* in the USA. The geographic and environmental variance in North America may influence the genotypical expression of *A. aylanthi*, resulting in better-suited phenotypes for the biological control of ToH. The known populations of *A. aylanthi* within the USA should be compared to determine if a superior phenotype for biological control on ToH exists.

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