Pyemotes tritici (Acari: Pyemotidae): a parasitoid of Agrilus auroguttatus and Agrilus coxalis (Coleoptera: Buprestidae) in the southwestern United States of America and southern Mexico

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Abstract—The straw itch mite, Pyemotes tritici Lagrèze-Fossat and Montané (Acari: Pyemotidae), was discovered parasitising the goldspotted oak borer, Agrilus auroguttatus Schaeffer (Coleoptera: Buprestidae), an invasive exotic species to California, United States of America, and the Mexican goldspotted oak borer, Agrilus coxalis Waterhouse (Coleoptera: Buprestidae), during surveys for natural enemies for a classical biological control programme for A. auroguttatus. Pyemotes tritici caused low levels of mortality to each species of flatheaded borer, but it will likely not be a good candidate for a biological control programme because it is a generalist parasitoid with deleterious human health effects.

The straw itch mite, Pyemotes tritici Lagrèze-Fossat and Montané (Acari: Pyemotidae), a common ectoparasitoid of Coleoptera, Lepidoptera, and Hymenoptera, was found parasitising the goldspotted oak borer, Agrilus auroguttatus Schaeffer (Coleoptera: Buprestidae), in southern California and southeastern Arizona, United States of America and a congener, the Mexican goldspotted oak borer, Agrilus coxalis Waterhouse, in southern Mexico. Agrilus auroguttatus and A. coxalis were described in 1905 and 1889, respectively (Waterhouse 1889; Schaeffer 1905); synonymised by Hespenheide (1979); but then restored to species status by Hespenheide et al. (2011). Analyses of mitochondrial DNA from populations in Arizona, California, and Mexico supported the species status of A. auroguttatus and A. coxalis (Coleman et al. 2012b). Agrilus auroguttatus is a flatheaded phloem and wood borer that has been linked to continuing southern California oak (Quercus Linnaeus (Fagaceae)) mortality (Coleman and Seybold 2008). The beetle was hypothesised to have been introduced to California from southeastern Arizona on infested firewood (Coleman and Seybold 2011; Coleman et al. 2012b). The movement of infested firewood within California has also likely led to satellite infestations elsewhere in San Diego County as well as in Riverside County (Idyllwild) (Coleman et al. 2012a; Jones et al. 2013).

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Agrilus auroguttatus aggressively attacks large diameter red oak trees (> 45.7 cm diameter at breast height, Section Lobatae) and has caused elevated levels of oak mortality in southern California for more than a decade (Coleman et al. 2012a). Since 2002, ~25 000 dead coast live oaks, Quercus agrifolia Née (Fagaceae), and California black oaks, Quercus kelloggii Newberry (Fagaceae), were attributed to A. auroguttatus-caused injury during aerial surveys in eastern San Diego County (United States Department of Agriculture Forest Health Monitoring 2013). Classical biological control was proposed as a potential long-term management option for this new invasive species in California (Coleman et al. 2012b). To determine candidates for a biological control programme, surveys for natural enemies of A. auroguttatus and A. coxalis were conducted in southeastern Arizona and southern Mexico, as well as in the habitat invaded by A. auroguttatus in southern California.

On 19 April 2011, we discovered P. tritici parasitising A. coxalis pre-pupae (mature larvae in a hair-pin configuration, Flint et al. 2013) while we destructively sampled the bark of Quercus peduncularis Née (Fagaceae) in Chiapas, Mexico (Table 1). The distended opisthosoma of the females (Fig. 1A) were observed on A. coxalis pre-pupae, pupae, and uneclosed adults. All samples of P. tritici were collected on A. coxalis infesting the phloem of eight Q. peduncularis stumps (Fig. 1B). Mites were collected from 23 (10 pre-pupae, eight pupae, and five adults) of 208 A. coxalis samples, representing an infestation rate of 11% (Coleman and Hoddle 2011). Similarly, a 15% parasitism rate for Calosota elongata Gibson (Hymenoptera: Eupelmidae) was observed on A. auroguttatus in southeastern Arizona (Coleman and Seybold 2011; Coleman et al. 2012b). Calosota elongata is a larval ectoparasitoid that has been associated with A. auroguttatus in southeastern Arizona (Gibson 2010; Coleman and Seybold 2011) and southern California (Haavik et al. 2012), but not with A. coxalis. Besides P. tritici, no additional ectoparasitoids or predators were found associated with A. coxalis in Chiapas and Oaxaca, Mexico. Subsequently, P. tritici has been widely collected parasitising A. auroguttatus in Arizona and California (Table 1).

Although, P. tritici has been found throughout much of the A. auroguttatus-infested area (including satellite infestations) in California, it was likely already present at these sites before the arrival of A. auroguttatus because is not phoretic and has a cosmopolitan distribution (Moser 1975). The discovery of infestations of P. tritici was facilitated in the field by the highly obvious gravid females (Fig. 1A). Estimates of parasitism rates were not determined for the Arizona and California A. auroguttatus collections because of inadequate sample sizes (< 20) from individual trees and the low number of infested trees found at some sites. A limited number of P. tritici males were collected with each sample and used to identify the species (identified by J.C.M.).

Pyemotes tritici has been evaluated as a biological control agent for the red imported fire ant, Solenopsis invicta Buren (Hymenoptera: Formicidae), bark beetles (Coleoptera: Scolytidae, sensu Bright 2014), and stored-products insects (Bruce and LeCato 1980; Li et al. 2009). Some advantageous features for biological control include its short developmental cycle (five to seven days); females represent 95% of the population, have a high reproductive potential (~250 adult offspring/gravid female), and ovoviviparity gives rise to adult progeny; no intermediate hosts are required; and populations can be reared easily in the laboratory (Bruce and LeCato 1980; Li et al. 2009). To our knowledge, mites have not figured prominently in the development of the biological control programme for the emerald ash borer, Agrilus planipennis Fairmaire (Coleoptera: Buprestidae). However, P. tritici was found infesting A. lecontei Saunders in Georgia, United States of America (Cross and Moser 1975), whereas Wang et al. (2010) found a Pyemotes Amerling species parasitising A. planipennis in China, but these latter mites were not identified to species.

We hypothesise that P. tritici feeds opportunistically on A. auroguttatus and A. coxalis. Because the mite is a generalist parasitoid; causes low-levels of parasitism; and can cause deleterious health effects to humans (e.g., dermatitis) (Moser 1975; Walker and Landis 1994), it is not likely that P. tritici will be a successful candidate for an augmentative biological control programme for A. auroguttatus in California. However, entire laboratory colonies of A. auroguttatus pre-pupae have been lost to infestations of P. tritici during our research in California and in other quarantine.
Table 1. Collections of the straw itch mite, *Pyemotes tritici*, were discovered parasitising the Mexican goldspotted oak borer, *Agrilus coxalis*, in southern Mexico and the goldspotted oak borer, *Agrilus auroguttatus*, in Arizona and California, United States of America in bark samples of oak, *Quercus* species.

<table>
<thead>
<tr>
<th>Species</th>
<th>Date</th>
<th>State/country</th>
<th>County</th>
<th>Local area</th>
<th>GPS, elevation</th>
<th>Life stage</th>
<th>Oak species</th>
<th>Collectors</th>
<th>Status of host</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>A. auroguttatus</em></td>
<td>VI-20-2011</td>
<td>California, United States of America</td>
<td>San Diego</td>
<td>Pine Creek Trailhead, CNF</td>
<td>32.837095°N, 116.54222°W, 1100 m</td>
<td>Pre-pupa</td>
<td><em>Q. agrifolia</em></td>
<td>M.I.J., L.J.H.</td>
<td>Living trees</td>
</tr>
<tr>
<td><em>A. auroguttatus</em></td>
<td>IV-24-2012</td>
<td>Arizona, United States of America</td>
<td>Cochise</td>
<td>Chiricahua Mountains</td>
<td>32.00882°N, 109.39066°W, 1565 m</td>
<td>Pre-pupa, pupa</td>
<td><em>Q. emory</em></td>
<td>T.W.C., M.I.J.</td>
<td>Standing dead tree</td>
</tr>
<tr>
<td><em>A. auroguttatus</em></td>
<td>IV-24-2012*</td>
<td>Arizona, United States of America</td>
<td>Cochise</td>
<td>Dragoon Mountains</td>
<td>31.93221°N, 109.96090°W, 1478 m</td>
<td>Pre-pupa</td>
<td><em>Q. emory</em></td>
<td>T.W.C.</td>
<td>Standing dead tree</td>
</tr>
<tr>
<td><em>A. auroguttatus</em></td>
<td>XI-26-2011</td>
<td>California, United States of America</td>
<td>Riverside</td>
<td>Idyllwild</td>
<td>33.74419°N, 116.71596°W, 1624 m</td>
<td>Pre-pupa</td>
<td><em>Q. kelloggii</em></td>
<td>T.W.C., M.I.J.</td>
<td>Standing dead tree</td>
</tr>
<tr>
<td><em>A. auroguttatus</em></td>
<td>VI-5-2013</td>
<td>California, United States of America</td>
<td>San Diego</td>
<td>William Heise County Park</td>
<td>33.038411°N, 116.58711°W, 1253 m</td>
<td>Pupa</td>
<td><em>Q. agrifolia</em></td>
<td>T.W.C., M.I.J.</td>
<td>Cut logs</td>
</tr>
</tbody>
</table>

* Voucher specimens were deposited at the Bohart Museum of Entomology, University of California, Davis, California, United States of America.

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facilities in the United States of America because the nascent populations are easily overlooked in the absence of the distended females. The parasitic mite may contribute to mortality of *A. auroguttatus* in southern California along with *C. elongata*, generalist insect predators (e.g., *Ternnochila* Westwood (Coleoptera: Trogossitidae) species, other parasitoids (Coleman and Seybold 2011; Haavik et al. 2012; Lopez and Hoddle 2013)), and the acorn woodpecker, *Melanerpes formicivorus* (Swainson) (Aves: Picidae) (Coleman et al. 2011). However, the levels of mortality from these biotic agents vary greatly among sites and do not appear to be adequately regulating populations of the invasive beetle (Coleman et al. 2012b).

**Fig. 1.** The distended opisthosoma of the female straw itch mite, *Pyemotes tritici*, are easily observed on a pre-pupa (mature larva) of the goldspotted oak borer, *Agrilus auroguttatus*, collected from *Quercus agrifolia* in San Diego County, California, United States of America (A). *Pyemotes tritici* parasitised two Mexican goldspotted oak borer, *Agrilus coxalis*, pre-pupae in the outer phloem of *Quercus peduncularis* from Chiapas, Mexico (B) (T.W.C., photographs).

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