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 mitochrondrial 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.

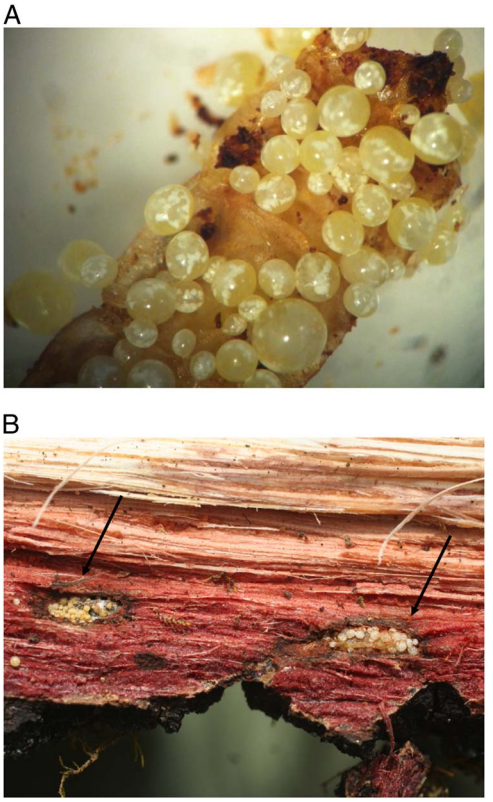
We hypothesise that *P. tritici* feeds opportunistically on *A. auroguttatus* and *A. coxalis*. Because the mite is a generalist parasitoid; causes low-levels of parasitism; and can cause deleterious health effects to humans (*e.g.*, dermatitis) (Moser 1975; Walker and Landis 1994), it is not likely 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.

Species	Date	State/country	County	Local area	GPS, elevation	Life stage	Oak species	Collectors	Status of host
A. coxalis	IV-19-2011	Chiapas, Mexico	Venustiano Carranza	Aguacatenango	16.48426°N, 92.49691°W, 1168 m	Pupa, pre-pupa, uneclosed adult	*Q. peduncularis*	T.W.C., M.S.H.	Cut stumps
A. auroguttatus	IV-28-2011*	California, United States of America	San Diego	Corral Canyon, CNF	32.726848°N, 116.53816°W, 944 m	Pre-pupa	*Q. agrifolia*	M.I.J., L.J.H.	Living trees
A. auroguttatus	VI-20-2011	California, United States of America	San Diego	Pine Creek Trailhead, CNF	32.837095°N, 116.54222°W, 1100 m	Pre-pupa	*Q. agrifolia*	M.I.J., L.J.H.	Living trees
A. auroguttatus	IV-24-2012	Arizona, United States of America	Cochise	Chiricahua Mountains	32.00882°N, 109.39066°W, 1565 m	Pre-pupa, pupa	*Q. emoryi*	T.W.C., M.I.J.	Standing dead tree
A. auroguttatus	IV-24-2012*	Arizona, United States of America	Cochise	Dragoon Mountains	31.93221°N, 109.96090°W, 1478 m	Pre-pupa	*Q. emoryi*	T.W.C.	Standing dead tree
A. auroguttatus	XI-26-2011	California, United States of America	Riverside	Idyllwild	33.74419°N, 116.71596°W, 1624 m	Pre-pupa	*Q. kelloggii*	T.W.C., M.I.J.	Standing dead tree
A. auroguttatus	I-31-2013	California, United States of America	San Diego	Los Coyotes Reservation	33.274349°N, 116.53924°W, 1413 m	Pre-pupa	*Q. agrifolia*	T.W.C., M.I.J.	Standing dead tree
A. auroguttatus	VI-5-2013	California, United States of America	San Diego	William Heise County Park	33.038411° N, 116.58711°W, 1253 m	Pupa	*Q. agrifolia*	T.W.C., M.I.J.	Cut logs

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

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).



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.*, *Temnochila* 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).

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