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Tarsonemid mites (Acari, Heterostigmatina) found in association with bark beetles (Insecta, Curculionidae, Scolytinae) in Iran

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Abstract: The authors report on the presence of species of the family Tarsonemidae in association with three bark beetle species (*Orthotomicus erosus* (Wollaston, 1857), *Scolytus scolytus* (Fabricius, 1775), and *S. multistriatus* (Marsham, 1802)) in two provinces in Central and Northern Iran. The following mite species are new for the fauna of Iran: *Heterotarsonemus hajekae* Smiley and Moser, 1985, *H. magowskii* Khaustov, 2001, and *Tarsonemus crassus* (Schaarschmidt, 1959). The genus *Heterotarsonemus* is newly recorded in Asia. The new record of *H. hajekae* is the second ever known in the world and *H. magowskii* is now established as new phoront of the bark beetle host *O. erosus. Tarsonemus crassus* is recorded outside the Europe for the first time. The taxonomy, identification, relationships with beetle hosts, and biogeography of the newly recorded mite species are briefly discussed.

Key words: Taxonomy, Tarsonemidae, *Orthotomicus*, *Scolytus*, host association, *Ulmus*, *Pinus*

Bark beetles (Coleoptera: Curculionidae: Scolytinae) are one of the most important pests of woody plants, with immense economic impact, attacking unthrifty, broken, over-mature, dying, or, rarely, even healthy hosts (Wood, 1982). Among bark beetle species, the larger European elm beetle, *Scolytus scolytus* (Fabricius, 1775), the smaller European elm beetle, *S. multistriatus* (Marsham, 1802), and the Mediterranean pine engraver beetle, *Orthotomicus erosus* (Wollaston, 1857), are considered harmful pests of several species of forest and ornamental trees. The first of these species is distributed in Asia and Europe, while the other two are found on most continents (Bright, 2014). All of them are considered destructive pests of forest and ornamental trees in Iran (Abai, 2009). Bark beetles share their microhabitats with many species of mites and other microorganisms. Mites of the family Tarsonemidae are considered important biofactors in association with bark beetles and their communities (Lindquist and Bedard, 1961; Moser, 1985; Lombardero et al., 2003, and others). The feeding habits of tarsonemid associates of bark beetles are mostly unknown (*Pseudotarsonemoides*, *Heterostarsonemus*, many *Tarsonemus*) but some *Tarsonemus* species are considered fungivores (Lombardero et. al. 2000) while fewer (*Iponemus* Beer and Nucifora, 1965) feed on eggs of their insect hosts (Lindquist, 1969b). None of the tarsonemids are known to be true parasites of bark beetles, but many use them as phoretic carriers and sometimes can carry and propagate spores of fungi they are feeding on (Moser, 1985; Lombardero et al., 2003).

Tarsonemid fauna associated with scolytines has been well studied in some parts of the world (Lindquist, 1969a, 1969b; Smiley and Moser, 1974; 1985; Moser et al., 1989; Khaustov and Magowski, 2003; Magowski and Khaustov, 2006; Magowski, 2010), but is little known in Iran. To date, only a small number of publications have reported six identified and one unidentified species of Tarsonemidae living in association with bark beetles in Iran (Ostovan and Kamali, 1997; Ahadiyat et al., 2004; Magowski et al., 2007; Magowski, 2010; Arabzadeh et al., 2012). The purpose of the present study was to present new and corrected data on species belonging to the genera *Pseudotarsonemoides* Vitzthum, 1921, *Heterotarsonemus* Smiley, 1969, and *Tarsonemus* Canestrini and Fanzago, 1876 recovered from galleries and individuals of three bark beetle species from Tehran and Guilan provinces in Iran. The taxonomic classification of Tarsonemidae, detailed diagnoses, and descriptions of genera reported herewith can be found in Lindquist (1986). Mite specimens were removed manually from bark samples or insect individuals collected from forests and minor wooded areas during two periods in

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Iran. The first sampling was carried out from 1995 to 1997 in various parks and landscapes of two provinces: Tehran (Nārmak: 35°45′N, 51°31′E; Sa'adat Abad: 35°46′N, 51°22′E) and Guilan (Rasht: 37°16′N, 49°34′E), and the second sampling was conducted several times between 2006 and 2010 in pine forests in the western region of Tehran Province (Chitgar Park and Peykān-shahr, 35°44′ N, 51°12′ E, 1013 m a.s.l.). Mites were mounted on microscopic slides in Hoyer's medium and subsequently examined with an Olympus BX 50 phase contrast microscope. The material originates from 15 samples. Each sample is represented by collection data differing by at least one characteristic (e.g., collection date) from another. The material collected by H Ostovan is stored permanently at the Department of Entomology, College of Agricultural Sciences, Shiraz Branch, Islamic Azad University (Shiraz, Iran), and that by A Ahadiyat and A Valizadeh at the Department of Entomology, College of Agriculture and Natural Resources, Science and Research Branch, Islamic Azad University (Tehran, Iran) and the Department of Animal Taxonomy and Ecology, A. Mickiewicz University (Poznań, Poland). Collected samples represent three identified and one unidentified bark beetle species and/or their galleries. The identified tarsonemid individuals belong to three genera and five species. Three mite specimens could only be identified to genus level: two of the genus *Tarsonemus* and one *Pseudotarsonemoides*. A list of mite species in systematic order (with their sampling data transcribed from the original labels) is given below.

Family: Tarsonemidae Canestrini and Fanzago, 1877

Subfamily: Pseudotarsonemoidinae Lindquist, 1986

Tribe: Pseudotarsonemoidini Lindquist, 1986

Genus: *Pseudotarsonemoides* Vitzthum, 1921

P. innumerabilis Vitzthum, 1923: 2♀♀ in gallery of *S. multistriatus* on *Ulmus* sp., Tehran, Tehran Province, 7 July 1997, leg. H. Ostovan; *P.* sp. indet.: 1♀ in gallery of *S. scolytus* on *Ulmus* sp., Rasht, Guilan Province, 1 June 1997, leg. H. Ostovan.

Subfamily: Tarsoneminae Canestrini and Fanzago, 1877

Tribe: Hemitarsonemini Lindquist, 1986

Genus: *Heterotarsonemus* Smiley, 1969

H. hajekae Smiley and Moser, 1985: 2♀♀ in gallery of *S. multistriatus* on *Ulmus* sp., Tehran (Sa'adat Abad region), Tehran Province, 24 September 1997, leg. H. Ostovan; *H. magowskii* Khaustov, 2001: 4♀♀ in galleries of *O. erosus* on *Pinus eldarica* Medvédev, 1903, Peykān-shahr, near Tehran, Tehran Province, 14 February 2006, leg. A. Ahadiyat; 8♀♀ in galleries of *O. erosus* on *P. eldarica*, Chitgar Park, near Tehran, Tehran Province, 24 January 2010, leg. A. Valizadeh.

Tribe: Tarsonemini Canestrini and Fanzago, 1877

Genus: *Tarsonemus (T.)* Canestrini and Fanzago, 1876

T. (*T.*) *crassus* (Schaarschmidt, 1959): 1♀ on *Ulmus* sp., Rasht, Guilan Province, 31 May 1997, leg. H. Ostovan; 1♀, 4♂♂, 1 lv in gallery of *S. scolytus* on *Ulmus* sp., Rasht, Guilan Province, 31 May 1997, leg. H. Ostovan; 1♂ in gallery of *S. multistriatus* on *Ulmus* sp., Rasht, Guilan Province, 1 June 1997, leg. H. Ostovan; 1♂, 1 lv in gallery of *S. scolytus* on *Ulmus* sp., Rasht, Guilan Province, 1 June 1997, leg. H. Ostovan; 1♀ in gallery of *S. scolytus* on *Ulmus* sp., Rasht, Guilan Province, 3 June 1997, leg. H. Ostovan; 1♀ phoretic on *S. multistriatus* on *Ulmus* sp., Tehran (Nārmak region), Tehran Province, 28 May 1997, leg. H. Ostovan.

T. (*T.*) *fusarii* Cooreman, 1941: 1♂ in gallery of *S. multistriatus* on *Ulmus* sp., Tehran, Tehran Province, 7 July 1997, leg. H. Ostovan; 1♀ insect host not mentioned, most probably *Scolytus* sp. on *Ulmus* sp., location not indicated (probably Tehran), 15 April 1997, leg. H. Ostovan; 1♀ phoretic on *S. multistriatus* on *Ulmus* sp., location not indicated (probably Tehran), 16 April 1997, leg. H. Ostovan; 1♀ in gallery of *S. multistriatus* on *Ulmus* sp., Tehran (Sa'adat Abad region), Tehran Province, 16 April 1997, leg. H. Ostovan; 1♀ in gallery of *S. multistriatus* on *Ulmus* sp., Tehran (Sa'adat Abad region), Tehran Province, 27 May 1997, leg. H. Ostovan.

T. (*T.*) spp. indet.: 1♀ insect host not indicated, on *Ulmus* sp., location not indicated (probably Tehran), 20 April 1997, leg. H. Ostovan; 1♀ in gallery of *S. multistriatus* on *Ulmus* sp., Tehran (Sa'adat Abad region), Tehran Province, 27 May 1997, leg. H. Ostovan.

Identification of the mite material collected in this study has been difficult for multiple reasons. Most importantly, the taxonomy of nearly all tarsonemid species-groups involved is insufficiently understood. The majority of publications originating from the past century contain a number of issues, of which outdated descriptions are the most challenging. A serious effort to sort out the Nearctic fauna of bark beetle tarsonemid associates by Smiley and Moser (1974) was only a partial success. Insufficient insight into some morphological characters resulted in confused diagnoses. Those vague diagnostics and outdated publications (e.g., Vitzthum, 1921; 1923) being the primary source of data make our identification of the *Pseudotarsonemoides* species less reliable. Furthermore, scarce records on the intraspecific variability in the genus *Tarsonemus*, particularly for *T. crassus* and *T. fusarii*, could render the identifications reported herein uncertain. Suski (1970), describing the male of *T. crassus*, contributed to amending its diagnostics, and Magowski and Moser (2003) updated its in-group classification, but still little is known of its natural variability. Specimens identified here as *T. crassus* differ in certain minor morphological characters from the current diagnostic standard. *Tarsonemus fusarii*,

Table. Tarsonemid mites associated with bark beetles in Iran reported in the present and previous studies. Abbreviations: *O.- Orthotomicus*, *Sc.- Scolytus*, *T. - Tarsonemus*, *S.- Schaarschmidtia. P. - Pseudotarsonemoides, H. - Heterotarsonemus.* Mite and beetle records lacking species identification are omitted.

Mite species	Bark beetle species	Tree host	Relationship between mite and beetle	Province	Reference	Current taxonomic status of a record
P. innumerabilis	*Sc. multistriatus*	Elm	in galleries, phoretic on beetles	Alborz, Tehran	Ostovan and Kamali (1997), present report	confirmed
	Sc. scolytus	Elm	in galleries, phoretic on beetles	Guilan, Mazandaran	Ostovan and Kamali (1997)	unconfirmed, probable
H. hajekae	*Sc. multistriatus*	Elm	in galleries	Tehran	present report	confirmed
H. magowskii	*O. erosus*	Pine	in galleries	Tehran	present report	confirmed
T. (T.) sp. nr. *bachmaieri*	*Sc. amygdali*	Fruit trees	-	Alborz, Tehran	Ahadiyat et al. (2004)	confirmed
T. (S.) amygdali	*Sc. amygdali*	Apricot, plum	in galleries	Tehran	Magowski et al. (2007), Magowski (2010)	confirmed
T. (S.) sp. 1 nr. *ips*	*Sc. multistriatus*	Elm	in galleries, phoretic on beetles	Tehran	Ostovan and Kamali (1997)	unconfirmed
T. (S.) sp. 2 nr. *ips*	apple bark beetles	Apple	-	Fars	Arabzadeh et al. (2012)	unconfirmed
T. (T.) pseudolacustris	*Sc. amygdali*	Fruit trees	-	Alborz, Tehran	Ahadiyat et al. (2004)	confirmed
T. (T.) fusarii	*Sc. multistriatus*	Elm	in galleries, phoretic on beetle	Tehran	present report	confirmed
T. (T.) subcorticalis	*Sc. multistriatus*	Elm	in galleries	Tehran	Ostovan and Kamali (1997)	unconfirmed
	Sc. scolytus	Elm	in galleries	Guilan, Mazandaran	Ostovan and Kamali (1997)	unconfirmed
T. (T.) triarcus	*Sc. multistriatus*	Elm	in galleries, phoretic on beetles	Tehran	Ostovan and Kamali (1997)	unconfirmed
	Sc. scolytus	Elm	in galleries	Guilan, Mazandaran	Ostovan and Kamali (1997)	unconfirmed
T. (T.) crassus	*Sc. multistriatus*	Elm	in galleries, phoretic on beetles	Guilan, Tehran	present report	confirmed
	Sc. scolytus	Elm	in galleries	Guilan,	present report	confirmed

on the other hand, is a well-known and widespread species (see Kaliszewski and Sell, 1990). Samples from the present collectings reveal some atypical morphological variability with regards to its sejugal apodeme. Unlike *T. crassus*, *T. fusarii* is not an obligate associate of bark beetles. As the latter is found in a variety of terrestrial habitats (mostly soils and deteriorating organic substrates) one may speculate that this variability reflects the suboptimal conditions encountered in bark beetles galleries. In his original paper, Khaustov (2001) reported *H. magowskii* phoretic on *Hypophloeus pini* Panzer, 1799 (Tenebrionidae) and in galleries of *Orthotomicus longicollis* (Gyllenhal, 1827). Thus, our record adds a new host, namely *O. erosus*. We observed a relatively high density of *H. magowskii* moving within the sawdust in galleries, whose individuals could occasionally be seen upon uropodine mites (probably of the genus *Trichouropoda*); however, this association may be accidental (see Camerik, 2010a). Our finding of *T. crassus* represents the first extra-European record, associated with same beetle host as in Europe. This association appears more stringent and host-specific in nature and perhaps obligate (Camerik, 2010b). The multitude of situations where *T. fusarii* is found suggests that the notion of "host affiliation" related to this species and bark beetles cannot be safely applied, even though some sparse records (e.g., Khaustov and Magowski, 2003) of co-existence with Scolytinae are known. Of the two species, namely *T. crassus* and *T. fusarii*, reported as phoretic in this study, the phoresy of the latter is questionable as a natural aptitude.

The present knowledge on identities of reported Iranian species of tarsonemids co-occurring with bark beetles is summarized in the Table. It is conceivable that identifications of four recorded species should be re-examined in the light of recent taxonomic literature. Both Iranian records of "*T. ips*" (referred to in the Table as *spp.* nr. *ips* 1 and 2) in Ostovan and Kamali (1997) and Arabzadegh et al. (2012), respectively, were published prior to or unawarely of the revision of the subgenus *Schaarschmidtia* by Magowski (2010), and so the vital diagnostics of this compound group could have not been applied. As originally *T. ips* is known to be associated almost exclusively with pines in North and Central America (Magowski, 2010), it is unlikely that two recorded populations found on elm or apple trees in Iran would represent that, or even one and the same species. Similarly, two other species of the *T. minimax* group (*T. triarcus* and *T. subcorticalis*) were recorded in Iran before the work by Magowski and Moser (2003). While *T. triarcus* seems to be an exclusively North American species, the identity of Eurasian populations of *T. subcorticalis* remains uncertain, as similarly has been realized in the case of two other closely allied Crimean populations of *T.* nr. *endophloeus* Lindquist, 1969 *spp.* 1 and 2 by Khaustov and Magowski (2003). Apart from *T. fusarii*, another two species, namely *T.* nr. *bachmaieri* and *T. pseudolacustris* (Table), are not regular associates of bark beetles. An indiscriminative method of material collecting (by examination of twigs and bark from trees occupied with bark beetles) provided an impression of a more intimate association, which may not be true.

Before the present study, six identified and one unidentified species of the family Tarsonemidae had been reported to be associated with bark beetles in Iran (Ostovan and Kamali, 1997; Ahadiyat et al., 2004; Magowski et al., 2007; Magowski, 2010; Arabzadeh et al., 2012 – see Table), making it the most species-rich mite family in this habitat context (Ahadiyat, personal observations) in this country. Three tarsonemid species were reported in association with *S. amygdali* Guerin-Meneville 1847, four with *S. multistriatus* and three with *S. scolytus* (Table). The results of our study increased the number of identified tarsonemid species to nine. It has also brought the total of the genus *Tarsonemus* species up to six, making it the most diverse genus among Acari associates of bark beetles in Iran. Among all the studied species of bark beetles, *S. multistriatus* appears the most suitable host, apparently presenting a set of optimal microhabitats for six identified species of Tarsonemidae. *Pseudotarsonemoides innumerabilis* is the only species (among those reported herewith) found in four provinces of Iran.

Nearly all tarsonemid species presented herewith (except for *T. fusarii* and *P. innumerabilis*) are new to the Iranian fauna. *Heterotarsonemus magowskii* and *H. hajekae* are both reported worldwide for the second time; moreover, *H. magowskii* is the first extra-European record and *H. hajekae* the first extra-American record. Consequently, both *Heterotarsonemus* species represent first records from Iran and, in a wider context, from Asia.

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