Observations on the biology of *Winterschmidtia hamadryas* (VITZTHUM) (Acari: Astigmata: Winterschmidtiidae) associated with the almond bark beetle, *Scolytus amygdali* GUERIN-MENEVILLE (Coleoptera: Scolytidae) in Iran

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Abstract

During 2001-2002 survey of mites and insects associated with the almond bark beetle, *Scolytus amygdali* GUERIN-MENEVILLE, 1847, in Iran (Tehran Province), all developmental stages of the mite species, *Winterschmidtia hamadryas* (VITZTHUM, 1923), were collected. The adults, nymphs and larvae of the mite were observed in great numbers in the scolytid galleries, and its deutonymphs were found phoretic on the adult beetles. Of 917 almond bark beetles collected from infested trees, 17.3% had at least one deutonymph of *W. hamadryas*. The attachment sites were the ventral surface of the abdomen, abdominal pleurites, femora, ventral and pleural thorax, between coxae II and III, and rarely on the dorsal body, elytra and on both sides of the head. Most of the deutonymphs (60.3%) were attached to the abdominal pleurites. The greatest number of these mites on a single beetle was 15. This species is one of the most abundant mite species which were found in the beetle galleries. Deutonymphs of this mite probably influence beetle activities or prevent their flight or shorten their dispersal distance.

Keywords: *Winterschmidtia hamadryas*, deutonymph mite, Scolytidae, *Scolytus amygdali*, Karaj, Iran.

Introduction

Bark beetles are one of the most important xylophagous pests of fruit and ornamental trees, which specifically attack the stems and trunks of stressed, weakened, and dead trees. Their damages include: feeding on the phloem and cambium, engraving maternal and larval galleries in the wood surface and under the inner bark, disordered sap flowing, and transferring fungal diseases.

One of the scolytids that attacks rosaceous pome and stone fruit trees is the almond bark beetle, *Scolytus amygdali* GUERIN-MENEVILLE, 1847. This species has been reported in several parts of the World, including Egypt, Morocco, Cyprus, India, Israel, Pakistan, Syria, Russia, Turkey, Austria, Bulgaria, France, Greece, Italy, Spain, former Yugoslavia (WOOD & BRIGHT, 1992; PFEFFER, 1995), Iraq (MANDELSHTAM, personal communication), and Iran (RADJABI, 1991). Its plant hosts include: snowy mespilus (*Amelanchier ovalis* MEDIKUS, 1793), almond (*Amygdalus communis* LINNAEUS, 1753), medlar (*Mespilus germanica* LINNAEUS, 1753), peach (*Prunus persica* BATSCH, 1801), apricot (*Prunus armeniaca* LINNAEUS, 1753) and other species of *Prunus* LINNAEUS, 1753 (WOOD & BRIGHT, 1992; PFEFFER, 1995). RADJABI (1991) indicated that the beetle acts as a secondary pest of stone fruits in Esfahan and East Azarbaijan Provinces of Iran and mentioned that the most important hosts of this species are almond and then apricot. Recently, the scolytid has been observed on other fruit trees such as cherry, sour cherry, apricot and plum in Kamaal-shahr of Karaj and Kereshteh, Joveyn and Vahidiyeh of Shahriyaar, Tehran Province, Iran (AHADIYAT, personal observations).

Many mite species belonging to many groups are associated with bark beetles. One of these groups is the family Winterschmidtiidae OUDEMANS, 1923 which contains saprophagous or fungivorous species. Some species of *Calvolia* OUDEMANS, 1911, *Olafsenia* OUDEMANS, 1927, *Vidia* OUDEMANS, 1905 and *Winterschmidtia* OUDEMANS, 1923 are associated with insects (KRANTZ, 1978). Some species of *Calvolia* and *Winterschmidtia* are phoretic on flies and bark beetles (ZAKHVATKIN, 1941; MOSER & BOGENSCHÜTZ, 1984; KHAUSTOV, 2000), and species of *Ensliniella* VITZTHUM, 1925, *Vespacarus* BAKER and CUNLIFFE, 1960 and *Kurosaia* OKABE & OCONNOR, 2002 are associated with bees and wasps (BAKER & CUNLIFFE, 1960; KLOMPEN & OCONNOR, 1995; OKABE & OCONNOR, 2002), and some other winterschmidtiid mites, i.e. some *Calvolia* species, are associated with plant materials (KRANTZ, 1978). ZAKHVATKIN (1941) recorded several species of this family associated with bark beetles and their galleries, flies, wasps and bees. Table 1 shows the mite species, their hosts and localities according to ZAKHVATKIN (1941).

Winterschmidtiid mites of the subfamily Ensliniellinae are biologically associated with the families Vespidae, Sphecidae, Megachilidae and Colletidae of Hymenoptera, with feeding stages of the mites inhabiting the nest cells of their hosts and deutonymphs dispersing on the bodies of the adult insects (OKABE & OCONNOR, 2002). For instance, OKABE & OCONNOR (2002) described a new genus and species of the subfamily, *Kurosaia jiju*, associated with nests of a Vespidae solitary wasp, *Anterhynchium flavomarginatum micado* (KIRSCH, 1873), in Japan. Mites of the genus

Table 1. List of winterschmidtiid mites associated with insects, their hosts and localities according to ZAKHVATKIN (1941).

Mite species	Insect hosts	Localities
	I) Coleoptera	
Winterschmidtia hamadryas (VITZTHUM, 1923)	in the galleries of *Scolytus rugulosus* (MÜLLER, 1818)	Germany
W. circumspectans (VITZTHUM,1921)	on *Ips stebbingi* (STROHMEYER, 1908)	Tibet
W. nataliae (ZAKHVATKIN, 1941)	on *Hylesinus fraxini* (PANZER, 1799)	Russia
Parawinterschmidtia kneissli (KRAUSSE, 1919)	on *Orthotomicus laricis* FABRICIUS, 1792	Germany
Calvolia bulgarica STÖRKÄN, 1935	on *Aphthona euphorbiae* (SCHRANK, 1781)	Bulgaria, former U.S.S.R.
C. fusiformis ZAKHVATKIN, 1941	on *Tomicus minor* HARTIG, 1834	Russia
C. striata VITZTHUM, 1914	on *Taphrorhynchus* sp. on *Pityogenes lepidus* WISCHMANN, 1914	Italy Africa
C. elliptica ZAKHVATKIN, 1941	on *Ips acuminatus* (GYLLENHAL, 1827)	Russia
	II) Hymenoptera	
Ensliniella parasitica VITZTHUM, 1925	in the nests of and on *Odynerus delphinalis* GIRAUD, 1866	Germany, Armenia and Uzbekistan
E. kostylevi ZAKHVATKIN, 1941	in the nests of *Odynerus* (*Lionotus*) *rosii* LEP.	West and Central Europe, Belarus and Ukraine
Vidia (*Crabrovidia*) *gussakovskii* ZAKHVATKIN, 1941	on: *Crabro fossorius* LINNAEUS *C. impressus* F. SMITH, 1856 *C. solenius* LINNAEUS *Mellinus arvensis* (LINNAEUS, 1758)	Ukraine and Russia
Vidia (*Crabrovidia*) *popovi* ZAKHVATKIN, 1941	on: *Philanthus clypeatus* THUNBERG, 1815 *Crabro alatus* PANZER, 1797 *C. wollmanni* KOHL, 1915 *C. impressus*	Ukraine and Uzbekistan
Calvolia reticulate ZAKHVATKIN, 1941	on *Osmia* (*Anthocopa*) *dalmatina* F. MOR	Switzerland
Vidia lineata OUDEMANS, 1917	in the nests of different species of *Megachile* LATREILLE, 1802	Whole of Europe, East, North and Central Asia, and some parts of former U.S.S.R.
V. undulata OUDEMANS, 1905	on *Hylaeus conformis* Förster, 1871	Italy
Nanacarus spp.	on hymenopterous insects living in wood	?
	III) Diptera	
Calvolia thraca VITZTHUM, 1922	on a small metallic green fly	Bulgaria and former U.S.S.R.
Calvolia calliphorae VITZTHUM, 1922	on *Calliphora vomitoria* LINNAEUS, 1758	Germany

Ensliniella are associated with eumenine vespid wasps of the genus *Allodynerus* BLÜTHGEN, 1938 (KLOMPEN & OCONNOR, 1995). Six species of this genus are known from the Palaearctic region (VITZTHUM, 1925; ZAKHVATKIN, 1941; BAKER & CUNLIFFE, 1960; KLOMPEN & OCONNOR, 1995). ABE & OKABE (2006) found the hypopi of a new species, *E. asiatica*, in the nests and acarinaria (mite chambers) of the vespid wasp, *Allodynerus mandschuricus* BLÜTHGEN, 1953 from two localities in central Japan. According to BOESI *et al.* (2005), *Vespacarus* mites are associated with two vespid wasps, *Ancistrocerus catskill catskill* (Saussure, 1853) and *A. adiabatus* (Saussure, 1852).

Regarding literature reviews of the relationship between winterschmidtiid mites and bark beetles, KRAUSSE (1919) found deutonymphs of *Parawinterschmidtia kneissli* (KRAUSSE, 1919) on *Orthotomicus laricis* FABRICIUS, 1792. VITZTHUM (1921) collected *Winterschmidtia circumspectans* (VITZTHUM, 1921) from *Ips stebbingi* (STROHMEYER, 1908) in Tibet. According to KINN (1971), WOLFF (1920) found numerous mites of *Calvolia* living parasitically on *O. laricis* and *Tomicus piniperda* (LINNAEUS, 1758). Individual beetles were observed carrying more than twenty-five mites. WILLMANN (1939) found *Winterschmidtia crassisetosa* WILLMANN, 1939 preying on larvae and pupae of *Phloeotribus scarabaeoides* BERNARD, 1792. According to ZAKHVATKIN (1941), VITZTHUM (1923) recorded *Winterschmidtia hamadryas* (VITZTHUM, 1923) from *Scolytus rugulosus* (MÜLLER, 1818) galleries on *Prunus insititia* LINNAEUS, 1759 from Germany. WALTERS & CAMPBELL (1955) found a *Calvolia* species associated with *Dendroctonus pseudotsugae* HOPKINS, 1905. ATKINS (1959) collected adults of *Vidia* sp. under the elytra of *D. pseudotsugae*. KINN (1971) collected deutonymphs of an unidentified mycetophagous *Calvolia* species phoretic on several species of bark beetles, including *Dendroctonus brevicomis* LECONTE, 1876, *Ips* spp., *Pityophthorus* spp., *Scolytus* spp. and *Pseudohylesinus nebulosus* (LECONTE, 1859). MOSER & BOGENSCHÜTZ (1984) collected one species of *Calvolia* phoretic on ventral abdomen of adult *Ips typographus* (LINNAEUS, 1758) in South Germany. KHAUSTOV (2000) recorded six species of *Winterschmidtia*, including three new species, and a new genus, *Parawinterschmidtia*, associated with scolytids from Crimea, Ukraine: *W. nataliae* (ZAKHVATKIN, 1941) on *Leperesinus fraxini* (PANZER, 1799) (= *Hylesinus fraxini* Panzer), *W. brenyi* (COOREMAN, 1963) on *Pteleobius vittatus* (FABRICIUS, 1787), *W. hamadryas* on *Scolytus rugulosus*, *W. chaetoptelii* KHAUSTOV, 2000 phoretic on *Chaetoptelius vestitus* (MULSANT et REY, 1860), *W. villifronsi* KHAUSTOV, 2000 phoretic on *Taphrorychus villifrons* (DUFOUR, 1843), *W. zachvatkini* KHAUSTOV, 2000 phoretic on *Pityogenes calcaratus* (EICHHOFF, 1878) and finally *Parawinterschmidtia kneissli* (KRAUSSE, 1919) on *Tomicus piniperda*. AHADIYAT *et al.* (2004) recorded *W. hamadryas* from *Scolytus amygdali* for the first time for the fauna of Iran, and it was the first record of the mite associated with the almond bark beetle.

According to KINN & WITCOSKY (1978), phoretic mites can hamper the flight capabilities of their insect hosts. For example, among the Scolytidae, ATKINS (1960) found that mites clustering at the tips of the elytra of *D. pseudotsugae* caused decreased wing beat frequency, and KINN (1966) observed that houseflies with 30 or more phoretic *Macrocheles muscaedomesticae* (SCOPOLI, 1772) are unable to walk, feed or fly. KINN (1971) found flight velocity of *Ips confusus* (LECONTE, 1876) was reduced when it carried phoretic mites. FRONK (1947) observed that southern pine beetle (*Dendroctonus frontalis* ZIMMERMANN, 1868) carrying 40 uropodid mites were unable to fly. However, MOSER (1976) believed that FRANK'S (1947) opinion that *D. frontalis* cannot fly with over 40 uropodids attached seems wrong. He trapped flying *D. frontalis* carrying up to 64 *Trichouropoda australis* HIRSCHMANN, one of the largest and most common phoretic acarines occurring on *D. frontalis*.

The present work is an attempt to study some biological characteristics of *W. hamadryas* associated with the economically important bark beetle, *S. amygdali*.

Material and Methods

The majority of samples were collected from early December 2001 to November 2002 in damaged orchards in Kamaal-shahr region of Karaj, Tehran Province, Iran. This agricultural region includes plant species of rosaceous fruit trees which had sustained substantial damage by scolytid beetles, particularly in unmanaged orchards (Fig. 1). The damaged fruit trees were simply distinguished by the presence of scolytid entrance and exit holes. Afterwards, the beetles were collected by inspecting the inner bark of infested trees. Trunks of infested trees were moved to the laboratory and their bark was

Fig. 1. Substantial damage by *Scolytus amygdali* in an unmanaged plum orchard in Kamaal-shahr of Karaj, Iran.

separated from the wood. This plant material was placed in Berlese-Tullgren funnel. Field collected beetles were examined with a dissecting microscope for phoretic deutonymphs of *W. hamadryas*. The mites were placed in lactophenol for a few days and mounted in Hoyer's medium.

The winterschmidtiid mite species was determined by the authors and confirmed by Alexander KHAUSTOV from Nikita Botanical Gardens, National Scientific Centre, Yalta, Crimea, Ukraine. The beetle specimens were identified by Mikhail YU. MANDELSHTAM from the Department of Molecular Genetics, Institute of Experimental Medicine RAMS, Saint-Petersburg, Russia.

Results

All developmental stages of *Winterschmidtia hamadryas* including larvae, protonymphs, deutonymphs, tritonymphs, adult males and females were collected in late June and early November 2002 from the inner bark of cherry (*Prunus cerasus* LINNAEUS, 1753) and plum (*P. domestica* LINNAEUS, 1753) damaged by bark beetles. Mite specimens were found several times in the scolytid galleries filled with sawdust and beetle excrements, and phoretic deutonymphs were found on adult beetles.

This mite was one of the most abundant mite species which was found in the beetle galleries. AHADIYAT *et al.* (in preparation) have found 25 mite species associated with the almond bark beetle, in which some species of the families Acaridae, Pyemotidae and Tarsonemidae were observed in high densities in the beetle galleries as well as Winterschmidtiidae and Trematuridae species. The greatest number of *W. hamadryas* on a single infested beetle was 15 deutonymphs. Of 917 almond bark beetles collected from infested trees, 17.3% had at least one deutonymph of *W. hamadryas*. The

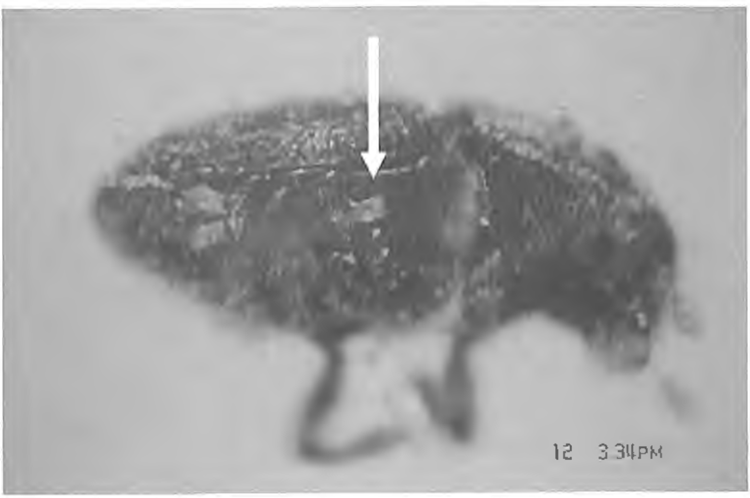

Fig. 2. Deutonymph of *W. hamadryas* on lateral mesothorax (arrow).

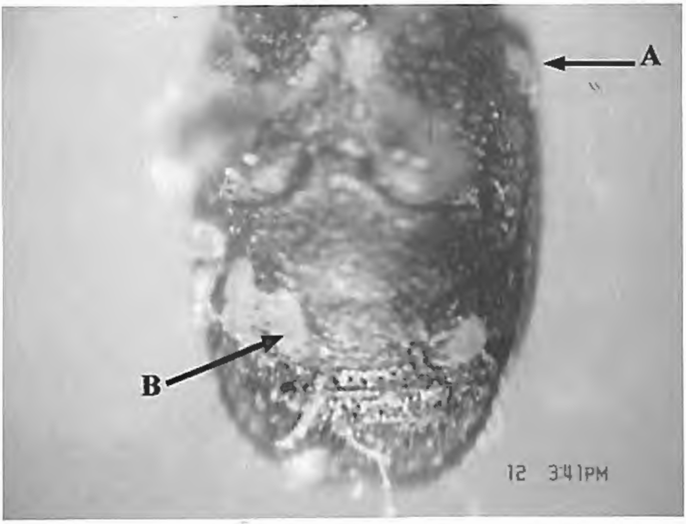

Fig. 3. Deutonumphs of *W. hamadryas* on the lateral metathorax (A) and on the middle of ventral surface of abdomen (B).

Fig. 4. Deutonymph of *W. hamadryas* between femur and tibia III (arrow).

mean number of *W. hamadryas* per infested beetle was 5.7. During the phoresy phenomenon, which allows mites to disperse by means of beetle movement or flight, deutonymphs attached to the pleural prothorax (5.7%), pleural mesothorax (1.9%) (Fig. 2), pleural metathorax (14.7%) (Figs 3A, and 6A), segments of legs I-III (5.2%) (Fig. 4), between coxae I-II and II-III (1.9%), middle of ventral surface of abdomen (5.7%) (Fig. 3B), abdominal

Fig. 5. Deutonymphs of *W. hamadryas* clustering on the lateral abdomen.

Fig. 6. Deutonymphs of *W. hamadryas* (A) on the lateral metathorax and lateral abdomen, and *Trichouropoda bipilis* (B) on the posterior end of the abdomen.

pleurites (60.3%) (Figs 5, and 6A), posterior end of the abdomen (2.5%), on elytra (1.3%) and the other parts of body i.e. ventral thorax, dorsal body and both sides of head (0.8%).

In addition to *W. hamadryas*, deutonymphs of the uropodid mite, *Trichouropoda bipilis* (VITZTHUM, 1923) (Mesostigmata: Uropodina: Trematuridae), one of the largest mites associated with *S. amygdali*, were found phoretic on adult beetles (Fig. 6B) by means of their anal pedicels. The mean number of *T. bipilis* per infested beetle was approximately 3.1. Of 917 almond bark beetles collected from infested trees, 6.4% carried both *W. hamadryas* and *T. bipilis* deutonymphs. The mean numbers of *W. hamadryas* and *T. bipilis* both on one infested beetle were 7.3 and 3.7, respectively.

Discussion and conclusion

Deutonymphs of *W. hamadryas* are found phoretic on adult beetles as they emerge from their host tree. The beetles then attack new trees, make subcortical galleries, and lay their eggs individually in maternal galleries. Then deutonymphs disembark from the beetle and continue their complex life history. More probably the mites complete their life cycle under the bark, and adults appear and copulate. After the appearance of deutonymphs, they attach to adult beetles and continue their life cycle.

The attachment sites of mites to many wasp species are often specific and the wasps often house phoretic mites in a specific part of their bodies. For example, the wasp genus *Allodynerus* has a specialized structure called acarinarium, which is an elaborate, deeply invaginated chamber that harbors the deutonymphs of *Ensliniella* (OCONNOR & KLOMPEN, 1999; MAKINO & OKABE, 2003). In most *Parancistrocerus* BEQUAERT, 1925 wasp species, the hypopi of *Vespacarus* are located in an acarinarium between tergites I and II of the abdomen (KROMBEIN, 1967). OKABE & MAKINO (2003) found deutonymphs of *K. jiju* exclusively on the ventral surface of the thoracic segments of *A. flavomarginatum micado* and rarely on the head or the lateral sides of the thorax. Only a few researches are devoted to the attachment sites of mites to the bark beetle bodies, for example, *Trichouropoda australis* deutonymphs are found on the tip of the abdomen of its host, if not too numerous (KINN, 1983). The percentage of attaching *W. hamadrys* deutonymphs on the almond bark beetle body shows that the mite prefers the lateral thorax and abdomen, probably to avoid being hit and falling off the beetle.

We didn't specifically examine the effects of *W. hamadrys* and *T. bipilis* on the beetles' activities, but the presence of their phoretic deutonymphs probably affect the beetles' behaviour.

Apparently, *W. hamadryas* could be one of factors affecting the population dynamics of *S. amygdali*, and its importance should be evaluated. Although beetles may not be immobilized by phoretic mites, the presence of phoretic mites appears to influence their flight. The number of mites required to immobilize *S. amygdali* is unknown. Also, the critical weight that *S. amygdali* can sustain in flight is still unknown, but probably a large number of mites affect the beetles' behaviour, and some beetles will be prevented from reaching a new host tree. Further researches are necessary to specify the relationship between the mite and the beetle, although it seems that the mite, especially, in the deutonymphal stage, can influence the beetles' activities or prevent its flight or shorten its distance. Also the food habits of *W. hamadryas* have not been investigated yet, but according to KHAUSTOV (personal communication), this mite has a complex life history with two different generations: in one generation the females feed on bark beetle eggs, and, in the other generation they feed on dead organic substrates, sawdust, scolytid excrements, fungi, dead bark beetles and their larvae. But the field recognition and study of this mite are difficult because *W. hamadryas* is small (body length of females, males, tritonymphs, deutonymphs, protonymphs, and larvae is 375-445, 316-356, 286-326, 178-190, 227-258 and 138 μm, respectively), almost transparent, and its biology and association with different hosts are not well known.

In any case, it should be noted that *W. hamadryas* may probably feed on the hosts eggs and larvae and, therefore, control its host. The mite biology should be studied further in this respect.

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