BioOne RESEARCH EVOLVED

A New Species of *Trissolcus* (Hymenoptera: Scelionidae) Parasitizing Eggs of *Halyomorpha Halys* (Heteroptera: Pentatomidae) in China with Comments on its Biology

Author(s): Zhong-Qi Yang, Yan-Xia Yao, Lan-Fen Qiu, and Zhong-Xin Li
Source: Annals of the Entomological Society of America, 102(1):39-47. 2009.
Published By: Entomological Society of America
DOI: http://dx.doi.org/10.1603/008.102.0104
URL: http://www.bioone.org/doi/full/10.1603/008.102.0104

BioOne (www.bioone.org) is a nonprofit, online aggregation of core research in the biological, ecological, and environmental sciences. BioOne provides a sustainable online platform for over 170 journals and books published by nonprofit societies, associations, museums, institutions, and presses.

Your use of this PDF, the BioOne Web site, and all posted and associated content indicates your acceptance of BioOne's Terms of Use, available at www.bioone.org/page/terms_of_use.

Usage of BioOne content is strictly limited to personal, educational, and non-commercial use. Commercial inquiries or rights and permissions requests should be directed to the individual publisher as copyright holder.

BioOne sees sustainable scholarly publishing as an inherently collaborative enterprise connecting authors, nonprofit publishers, academic institutions, research libraries, and research funders in the common goal of maximizing access to critical research.

A New Species of *Trissolcus* (Hymenoptera: Scelionidae) Parasitizing Eggs of *Halyomorpha halys* (Heteroptera: Pentatomidae) in China with Comments on Its Biology

ZHONG-QI YANG,[1,2] YAN-XIA YAO,[1] LAN-FEN QIU,[3] AND ZHONG-XIN LI[4]

Ann. Entomol. Soc. Am. 102(1): 39–47 (2009)

ABSTRACT A new species of *Trissolcus* Ashmead (Hymenoptera: Scelionidae), *Trissolcus halyomorphae* Yang, sp. nov., is described from China. It is a solitary parasitoid in eggs of *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae), an economic pest that causes severe damage to pear, apple and other fruit and that also feeds on the leaves and stems of ornamental and forest trees. The new species is the principal natural enemy of the stink bug, with parasitism rates up to 70% and an average annual rate of 50%. Because of its high parasitism rates and other biological features, it has good potential as a biocontrol agent of the pest. Type specimens are deposited in Insect Museum, Chinese Academy of Forestry, Beijing, China.

KEY WORDS *Halyomorpha halys*, *Trissolcus halyomorphae*, new species, egg parasitoid, biocontrol

Halyomorpha halys (Stål) (Hemiptera: Pentatomidae) is native to Asian countries, including China, Korea, and Japan (Hoffmann 1931, Hsiao 1977, Zhang 1985, Yasunaga et al. 1993, Kang et al. 2003). In China, it was formerly misidentified as *Halyomorpha picus* (F.) with the common name "brown marmorated stink bug" (Hsiao 1977, Zhang 1985, Zhang et al. 1993). In Japan, the bug has recently become a serious pest of fruit such as persimmon and apples (Goto et al. 2002; Funayama 2003, 2004; Toyama et al. 2006). In China, *H. halys* has become a serious polyphagous pest of soybean, vegetables, and tobacco, as well as many forest and ornamental trees, being especially harmful to orchards. It attacks many fruit, including pear, apple (He 1997, Zhang et al. 2007), peach, plum, cherry, pomegranate, common jujube, citrus, persimmon, mulberry, hawthorn, apricot, grape, kiwifruit, and strawberry. Adults of *H. halys* generally feed on the fruit, whereas nymphs feed on leaves, stems, and fruit. Damage by *H. halys* caused the surface of the fruit to become concave and unshapely, decreasing serious yields as well as quality decline, and resulting in economic loss. Furthermore, *H. halys* is recorded as a vector of Paulownia witches' broom disease, an extremely destructive phytoplasma disease of *Paulownia* trees in China. Because of the economic importance of *Paulownia tomentosa* (Thunberg) Steudel, both the disease and *H. halys* have been considered to be serious problems for forestation and "greening" in China (Jin et al. 1981).

H. halys was accidentally introduced into the United States (Hoebeke 2002; Hoebeke and Carter 2003; Bernon et al. 2003, 2004). It was first collected in September 1998 in Allentown, PA, but probably arrived several years earlier. As of April 2007, it was recorded in 24 counties in the state (Jacobs 2007). Subsequently, it was confirmed from several Mid-Atlantic states, as well as in Oregon, California, western Maryland, and West Virginia (Hamilton and Shearer 2003, Hamilton and Nielsen 2005). The list of states from which the pest is recorded will continue to increase as awareness increases (LaBonte 2005). In Pennsylvania, 73 economic plants are known to be hosts, of which 21 species are common hosts, including row crops (soybean), fruit trees (both stone fruit and pomes), ornamentals (butterfly bush), and vegetables (leaves also attacked) (Bernon 2004). According to Bernon (2004), the final distribution of the pest in North America will be similar to *Acrosternum hilare* (Say), the green stink bug, which ranges from Quebec and New England west through southern Canada and the northern United States to the Pacific Coast and south and southwest to Florida, Texas, Arizona, Utah, and California (Bernon et al. 2003). Increasing attention is now being paid to *H. halys* in North America, and there are many studies being made on tracking its expanding distribution, its natural enemies, biocontrol, and integrated pest management (Bernon 2004, Hamilton and Nielsen 2005, Rider 2008).

H. halys severely attacks many fruit in China. In Heze, Shandong Province, normally 10–25% of pears and sometimes up to 35% of pears were damaged (Ming et al. 2001), whereas 40–60% of pears in Hebei

[1] The Key Laboratory of Forest Protection of China State Forestry Administration, Research Institute of Forest Ecology, Environment and Protection, Chinese Academy of Forestry, Beijing 100091.
[2] Corresponding author, e-mail: yzhqi@caf.ac.cn.
[3] Research Institute of Beijing Horticulture, Beijing 100102, China.
[4] Plant Protection College, Shandong Agricultural University, Tai'an 271018, Shandong, China.

0013-8746/09/0039–0047$04.00/0 © 2009 Entomological Society of America

Province and 50–70% of pears and peaches in Beijing were harmed (Zhang et al. 1993, Qin 1990). In north Henan Province, 23% of apricot and peach fruit were commonly injured, with damage rates as high as 87%. In Beijing, 28.8, 23.4, and 30.8%, respectively, of the fruit of Sangsha, Yata'er, and Fushi varieties of apples were damaged (Zhang et al. 2007). Because of the severe damage caused by *H. halys,* attempts have been made to manage it. However, practical measures for controlling this pest have mainly involved repeated chemical spraying (Chu et al. 1997, Li et al. 1998, Ming et al. 2001), and the development of new management strategies that lower the environmental load and produce "green" fruit are desired. In response, a biocontrol program that mainly uses its natural insect enemies was initiated to suppress the pest in Beijing. During exploration for natural enemies of *H. halys,* we discovered six egg parasitoids in the Beijing area, of which there is one new species of *Trissolcus* Ashmead (Hymenoptera: Scelionidae) belonging to the *flavipes*-species group. It is superior to the other five known parasitoid species because parasitism rates of 20–70% are common, and the average rate of parasitism is 50% in the field. Subsequent to its discovery, laboratory and field studies of its biology and mass rearing were conducted. Here, we describe the new *Trissolcus* species and present biological observations and a discussion of its biocontrol potential.

Species of *Trissolcus* are all egg parasitoids of insects in the superfamily Pentatomoidea (Heteroptera). Many of their hosts are economically important pests. Because of this there has been interest in species as biocontrol agents and some have been used for biocontrol (Johnson 1984, Corrêa-Ferreira and Moscardi 1996). The genus is worldwide in distribution, with 161 species being described (Palearctic, 69; Nearctic, 15; Neotropical, 20; Oriental, 22; Australasian, 23; and Afrotropical, 25) (Johnson 1992). *Trissolcus* is a unique group in the Telenominae (Scelionidae) that is distinguished from other genera in the subfamily by 1) female antennal clava compact and composed of six segments, 2) frons sculptured throughout, and with preoccellar pit located below the median ocellus, 3) scutellum with surface sculpture, 4) second metasomatic tergite wider than long, and 5) eyes seeming glabrous under low magnification (Masner 1980; Johnson 1991).

Masner (1976, 1980) provided keys to identify the world and Holarctic genera of Scelionidae, respectively, including *Trissolcus.* Johnson (1992) catalogued the world species and studied the Nearctic (1984, 1985a, 1985b), Neotropical (1987), and Australasian (1991) species of *Trissolcus.* Kozlov and Le (1976, 1977) revised the *Trissolcus flavipes* species-group and the Palearctic species of *Trissolcus,* respectively. Kozlov (1968, 1978) studied the *Trissolcus* species of Caucasus and provided keys to identify the species from the European part of the former USSR, respectively, whereas Kozlov and Kononova (1983) reviewed all *Trissolcus* species in the former USSR. Ryu and Hirashima (1984) studied the species of Japan and Korea. Hirashima and Yamagishi (1981) redescribed Japanese Scelionidae preserved in the U.S. National Museum, including *Trissolcus japonicus* (Ryu & Hirashima). There have been no systematic studies of the Chinese species of *Trissolcus,* but He (2004) reported two species, *Trissolcus mitsukurii* (Ashmead) and *Trissolcus nigrepedius* (Nagagawa), parasitizing pentatomids in rice paddy fields.

Materials and Methods

Surveys of the natural insect enemies of *H. halys* were conducted in 2001–2007 in pear and peach orchards, as well as in ornamental forests, mainly with the tree *P. tomentosa,* in Beijing, Hebei, and Shandong provinces. The egg masses of *H. halys,* which were usually laid on the underside of leaves, were collected monthly from the above fruit and forest trees. They were then each put into a vial (40 mm in length and 13 mm in diameter), and the vials were sealed tightly with absorbent cotton ball. The egg masses were reared in the laboratory at room temperature (≈25°C). They were checked daily and the parasitoids later emerged. According to numbers of the parasitized and unparasitized eggs of *H. halys,* the parasitism rates were calculated. During the investigations, the biology of the new parasitoid species also was observed, e.g., overwintering status for both host and parasitoid, degree-day determination, and so on (mainly carried out by one of us; Qiu 2007). The parasitoid specimens were identified and examined with an SMZ 10 stereomicroscope (Olympus, Tokyo, Japan). Scanning electron photomicrographs were taken with a 550LV scanning electron microscope (JEOL, Tokyo, Japan).

Terminology follows Masner (1980) and Johnson (1984), as well as Miko et al. (2007). The type materials of the new species are deposited in the Insect Museum, Chinese Academy of Forestry, Beijing. Authorship of the new species is attributed solely to Y.Z.-Q.

Results and Discussion

Trissolcus halyomorphae Yang, n. sp.
(Figs. 1–15)

Female. Length 1.3–1.8 mm (holotype 1.5 mm).

Head (Figs. 1, 3–4). Transverse from dorsal view (Fig. 3), 3.5 times as broad as its median length, and broader than mesosoma (1.1 times). Vertex slightly arched upwards, with the posterior margin higher than the anterior margin, vertex and frons punctulate-reticulated throughout, covered with few hairs. Hyperoccipital carina present, complete and not sharp. Ocelli arranged in a strongly obtuse-angled triangle. The distance between median ocellus and hyperoccipital carina about equal to its longitudinal diameter, in the front of the median ocellus with a deep fovea and a longitudinal groove arising from the fovea, the groove going toward and reached the upper antennal scrobes. Posterior ocelli distance from hyperoccipital carina ≈0.5 times as long as its longitudinal diameter, and separated from their inner orbits and connected

Figs. 1–2. (1–2) *T. halyomorphae* n. sp.: (1) Female, whole body in dorsal view. (2) Male, whole body in lateral view. (Online figure in color.)

to them by distinct short transverse grooves. The distance from posterior ocellus to the eye much shorter than the ocellar short diameter (only 0.6 times). Occiput broadly concave with the same reticulation as vertex. Eyes glabrous under low magnification with few superficial hairs under high magnification (above 250×) (Fig. 3). In the frontal view, the head (Fig. 4) 1.35 times as broad as high. Frons slightly convex, punctulate-reticulated, scattered colliculose near eyes; eyes 2.1 times as long as broad; orbits of eyes deeply concave and strongly expanded ventrally, their inner margins sharply edged with parascrobes anteriorly and the edges merging into hyperoccipital carina posteriorly. Frons slightly convex; antennal scrobes present, shallowly depressed up to two-thirds distance from antennal toruli to median ocellus, with transverse rugulae inside. Interantennal process raised and nose-like. Antennae (Fig. 3a) 11-segmented, radicle 0.2 length of scape; scape 5.5 times as long as broad; pedicel 2.7 times as long as broad; funicle 1, 1.25 times as long as pedicel and much longer than funicle two (2.0 times), 2.8 times as long as broad; funicle 2 ≈1.4 times and funicle 3 0.8 times as long as broad, respectively. Club six-segmented, proximal segment distinctly broader than long and 0.6 times as long as second club segment medially, second to fourth slightly transverse, the fifth nearly quadrate, apical segment conical, 1.6 times as long as broad.

Mesosoma (Figs. 6–10). Equally long as it is broad, covered with white hairs (Fig. 6). Mesoscutum distinctly convex, reticulate-sculptured and delicately raised but becoming weaker in medial-lateral part, with notauli straight. Mesoscutellum broad, convex and punctulate-reticulate superficially and much finer than that of mesoscutum. The reticulation became more delicate after the median, and the posterior half was shiny, hind margin scattered with a row of puncture. Metascutellum strongly areolated on the surface, ≈0.3 times as long as mesoscutellum medially. Mesopleuron (Fig. 7) had a dorsoventral carina on its surface medially, acetabular field and anteroventral portion of mesepisternum setose. Legs (Figs. 8–10) had hind basitarsus 2.2 times as long as the second tarsus and ≈0.5 times the length of hind tibiae.

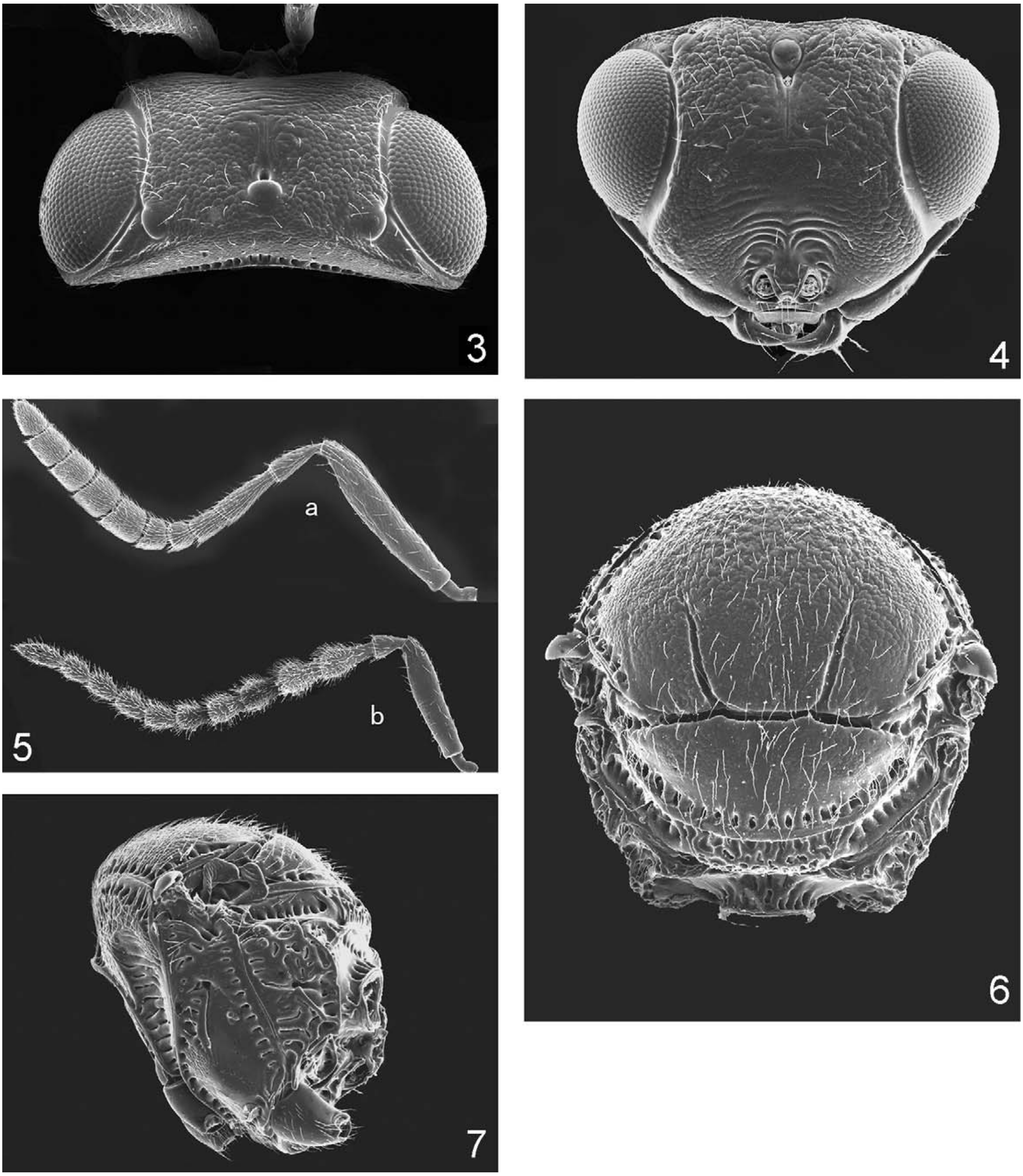
Wings (Figs. 11–12). Forewing (Fig. 11) 2.4 times as long as broad, submarginal vein 1.5 times as long as the poststigmal vein, marginal vein very short, almost venting, stigmal vein 0.6 times as long as poststigmal vein and 3.7 times as long as marginal vein. Hind wing (Fig. 12) 3.5 times as long as broad, and fringes slightly <0.25 times the greatest width of the hind wing.

Metasoma (Figs. 13–14). Metasoma 0.9 times as long as the mesosoma, its breadth greater than length (1.13 times); first tergite transverse with deep longitudinally costae except two sublateral sides with rugae, and side margins each with a row of short but stout hairs; second tergite twice as broad as long, longitudinally striated on nearly proximal three fourths medially, and those striae shortened on sides, the rest smooth and shining, and with spare ciliae. The following tergites strongly transverse, minutely punculate throughout with sparsely ciliae. Fore two sternites (Fig. 14) of metasoma had costae and rugae on the surface, as well as sparse hairs; sternite 2 had narrow lateral setal fields. Ovipositor projected a little beyond the tip of metasoma.

Color. Body black. Antenna fulvous except for the club which was black. Mandibles colored reddish brown. Legs fulvous but coxae black, and femora with anterior and distal parts dark brown. Wing hyaline, veins light brown only proximal darker.

Male (Figs. 2 and 5b). Body length 1.2–1.6 mm.

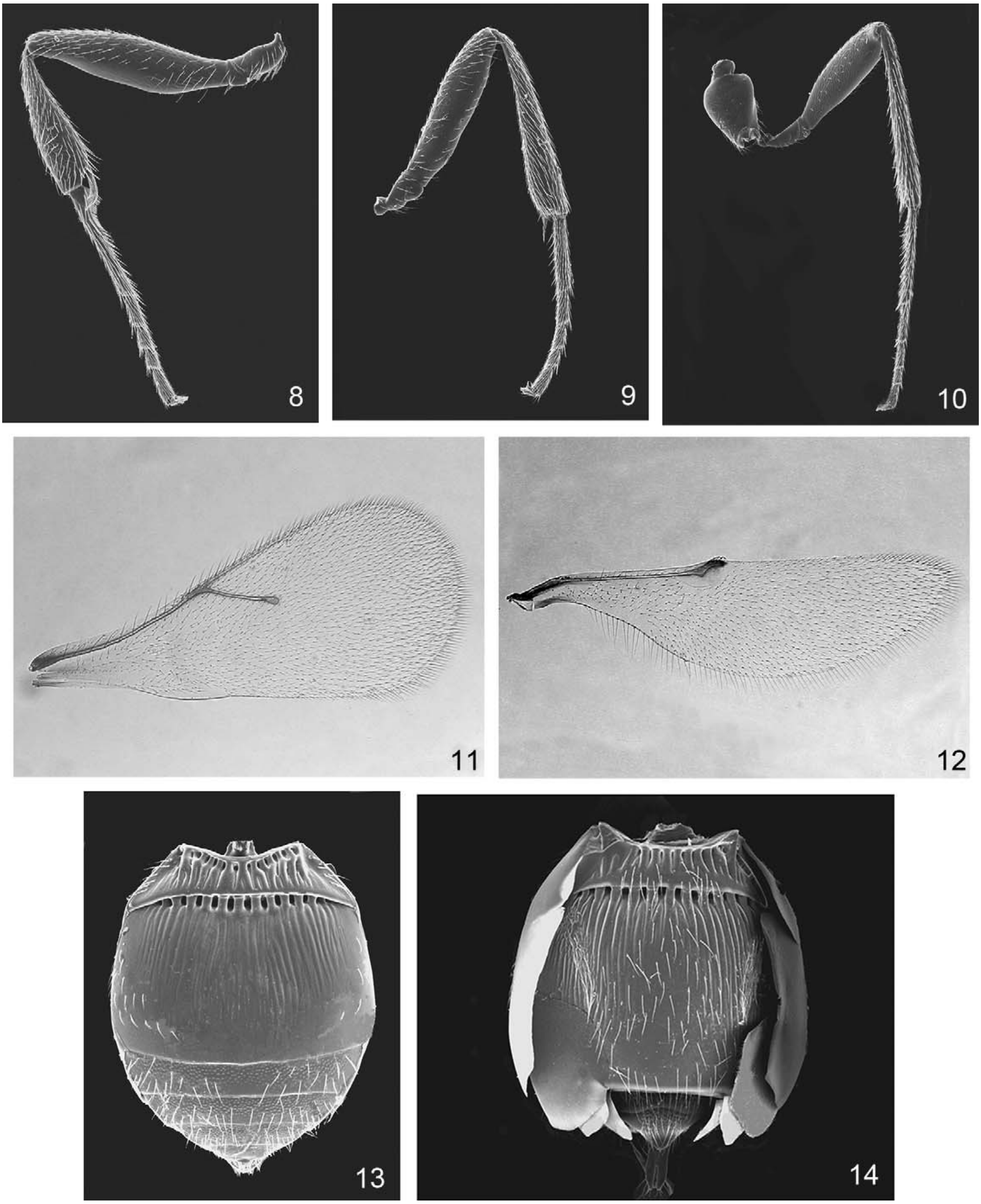
It is similar to female, but characteristics is differ as follows: antennae (Fig. 5b) 12-segmented, fulvous except for the scape tip and five segments of the distad flagellum, which were brown; legs also fulvous but coxae concolorous with body and tip of tarsi dark brown; antenna with radicle short, ≈1/10 of scape length; scape 3.5 times as long as broad, 4 times length of pedicel; pedicel much shorter than the first flagellomere (3.5:6), 1.5 times as long as broad; the first



Figs. 3–7. (3–7) *T. halyomorphae* n. sp.: (3) Female, head in dorsal view. (4) Female, head in frontal view. (5) Antennae (a, female; b, male). (6) Female mesosoma in dorsal view. (7) Female mesosoma in lateral view.

flagellomere slightly longer than the second, twice its breadth; the last four segments with the same breadth, three apical segments were of the same length except the last one, all 1.5 times as long as broad, the apical segment 2.5 times as long as broad, ratio of each flagellomere as 6: 5: 4.1: 3.9: 3.6: 3.1: 3: 3: 3: 5 in length, 3: 3.1: 3: 2.9: 2.6: 2.4: 2: 2: 2: 2 in breadth; each flagellomere was longer than broad; metasoma with second tergite not longitudinally striated in the middle, but formed a smooth triangle area, with only several separated rugae, and lateral striae longer than that in female.

Type Material. HOLOTYPE ♀, Xiangshan, Beijing, Yang Zhong-Qi and Qiu Lan-Fen reared from the eggs of *H. halys*, 7-VIII-2001. PARATYPES: 20 ♀, 5 ♂, same data as holotype; 26 ♀, 5 ♂, Fenghuangling, Beijing, 20-VI-2007; 20 ♀, 4 ♂, Tai'an, Shandong Province, 6-VIII-2001, Li Zhong-Xin col.; 22 ♀, 6 ♂, Baoding, Hebei Province, 15-VII-2006, Yang Zhong-Qi Col.



Figs. 8–14. (8–14) *T. halyomorphae* n. sp.: (8) Female fore leg. (9) Female mid leg. (10) Female hind leg. (11) Female fore wing. (12) Female hind wing. (13) Female metasoma in dorsal view. (14) Female metasoma in ventral view.

Distribution. China: Beijing, Shandong and Hebei provinces. The species may eventually be found throughout China where its host *H. halys* occurs.

Etymology. The species epithet is derived from the generic name of its host, *Halyomorpha.*

Diagnosis. *T. halyomorphae* sp. nov. is similar to *T. japonicus*, but the latter species differs as follows: legs with femora concolorous with other parts, not dark brown; vertex flat and without longitudinal groove in front of median ocellus; the distance from the posterior ocellus to the eye is equal to the minimal ocellar diameter; orbits of eyes very narrow and not expanded ventrally; antennal scrobes have transverse rugulae that extend dorsally to the median ocellus; notauli

Figs. 15–16. (15–16) Parasitized and unparasitized egg mass of *H. halys*: (15) *H. halys* egg mass parasitized by *T. halyomorphae* sp. n. and the new emerged wasps of the parasitoid. (16) Unparasitized egg mass of *H. halys* from which its larvae hatched. (Online figure in color.)

slightly curved outwards anteriorly; forewing slightly infumate; metasoma 1.3 times as long as broad, the second tergite >2.2 times as broad as long and with longer ciliae; hosts: *Plautia stali* Scott, *Plautia splendens* Distant (Pentatomidae), and *Elasmucha putoni* Scott (Acanthosomatidae).

Arakawa et al. (2004) stated that *T. mitrukurii* parasitizes the eggs of *H. halys*, but it differs from *T. halyomorphae* sp. nov. as follows: The head is hardly broader than the mesosoma; the scutellum is sculptured slightly more coarsely than the mesoscutum; female antenna with funicle one as long as pedicel and 1.25 times as long as broad; first segment of club 0.28 times as long as second segment.

T. halyomorphae is also similar to *T. flavipes*, but the latter species is distinguished by: Frons with antennal scrobes having transverse rugulae that extend dorsally to the median ocellus; its head is hardly broader than its mesosoma; the distance between the posterior ocellus and the eye is twice that of the shortest diameter of the ocellus; pedicel is twice as long as it is broad and slightly shorter than funicle 1, which is subconical and twice as long as it is broad; the metasoma with its second tergite is 1.5 times as broad as long.

Remarks. Ming et al. (2001) reported an unnamed scelionid egg parasitoid of *H. halys* in pear orchards in Shandong Province that had parasitism rates of 65–70%. Li et al. (1992) reported that *Trissolcus flavipes* Thomson parasitized 59.16% annually with a maximum rate of 87.05%, and Zhang et al. (1993) recorded the same scelionid species parasitized 42.5% on average with a maximum parasitism rate of 63.3% of *H. halys* eggs in central and south Hebei Province. Chu et al. (1997) reported that "*Telenomus mitsukurii* Ashmead" was the main parasitoid of *H. halys* in pear orchards in Hebei Province, with parasitism rates of 59.2–84.7% [the generic name should be *Trissolcus* based on Johnson (1992)]. The reports of the parasitoid species listed above as attacking the eggs of *H. halys* probably represent misidentifications of *T. halyomorphae* because we reared this species from *H. halys* in the same areas with similar parasitism rates.

Biological Observations. *T. halyomorphae* is a solitary endoparasitoid in the eggs of *H. halys* and overwinters as an adult similar to that of its host. It apparently is the primary biological regulator of populations of the stink bug in northern China. As stated above, it has an annual average parasitism rate of 50%, with a maximum of 70%, though parasitism rates reach 80% in the second generation of its host (Li 2002, Li and Liu 2004). Each of the other five parasitoid species of the stink bug found in the current study had parasitism rates that never exceeded 10%. It is interesting that usually all eggs in an egg mass of *H. halys* were parasitized by *T. halyomorphae.* An average female of *T. halyomorphae* has 42.2 eggs, which indicates one female can parasitize all the eggs in a single egg mass of *H. halys* (in most cases an egg mass of *H. halys* has 28 eggs). Frequently, the males emerged first and waited on the host egg mass until the females emerged, with mating occurring soon thereafter. The female to male ratio of *T. halyomorphae* is 5.45:1. The threshold temperature for development and effective accumulated temperature of *T. halyomorphae* are 12.2°C and 132.5 degree-days respectively by our experiment, i.e., at 25°C the parasitoid needs 10.5 d and at 30°C only 7.3 d for finishing a generation (Qiu 2007). Consequently, *T. halymorphae* can have 10 generations per year compared with two generations of its host. The remnants of the host egg after a parasitoid emerges (Fig. 15) are easily distinguished from those of a nonparasitized egg (Fig. 16). A parasitized egg has a hole on the top with irregular margins whereas a nonparasitized egg has a hole with a regular margin and an attached operculum, as well as an egg-burster that is triangular in shape with a black frame. These characteristics are useful to investigate parasitism rates even after emergence of the parasitoid or *H. halys.*

From the above-mentioned data, it seems that *T. halyomorphae* has the characteristics of an excellent biocontrol agent, including a high female to male ratio, short developmental time, and many more generations than its host, which together could result in large progeny numbers to suppress population levels of *H. halys.* The adults of *T. halyomorphae* and *H. halys* also both overwinter as adults, indicating a close synchrony of biology. We found that *T. halyomorphae* could also successfully parasitize the eggs of a few other species of pentatomid pests in laboratory mass rearings, including *Erthesina fullo* (Thunberg), *Dolycoris baccarum* (L.), and *Plautia crossota* (Dallas) (Qiu 2007). Such alternative hosts may help support high population levels of *T. halyomorphae.* Consequently, *T. halyomorphae* has excellent potential for biological control of *H. halys.*

Acknowledgments

We are indebted to Lubormir Masner (Agriculture and Agri-Food Canada, Research Branch, Ottawa, ON, Canada) who presented specimens of *T. japonicus* and discussed the taxonomy of the new species when Z.-Q.Y. visited him in November 2002. We thank Norman F. Johnson (Department of Entomology, Museum of Biological Diversity, The Ohio State University, Columbus, OH), G.V.P. Reddy (College of Natural and Applied Sciences, University of Guam, Mangilao, Guam), and Gary Gibson (Agriculture and Agri-Food Canada, Research Branch, Ottawa, ON, Canada) for careful reviews and comments on the manuscript. The study is supported by the Beijing Science and Technology Plan No. D0705002040191.

References Cited

Arakawa, R., M. Miura, and M. Fujita. 2004. Effects of host species on the body size, fecundity, and longevity of *Trissolcus mitsukurii* (Hymenoptera: Scelionidae), a solitary egg parasitoid of stink bugs. Appl. Entomol. Zool. 39: 177–181.

Bernon, G. 2004. Biology of *Halyomorpha halys*, the brown marmorated sink bug (BMSB). Final report. U.S. Dep. Agric. APHIS CPHST 2004. (http://www.cphst.org/docs/BernonfinalreportT3P01.pdf).

Bernon, G., K. M. Bernhard, E. R. Hoebeke, and M. E. Carter. 2003. *Halyomorpha halys* (Heteroptera: Pentatomidae), new nuisance pest: and future agricultural problem? (http://www.cphst.org/download.cfm?file=ESA2003a.ppt).

Bernon, G., K. M. Bernhard, E. R. Hoebeke, M. E. Carter, and L. A. Beanland. 2004. *Halyomorpha halys* (Heteroptera: Pentatomidae), the brown marmorated stink bug: are trees the primary or reservoir hosts for this new invasive pest? (http://www.cphst.org/docs/Bernon-presentation 04.ppt).

Chu, F.-J., Z.-F. Zhou, R.-P. Li, and X.-C. Liu. 1997. Study on control and observation of the bionomics characteristics of *Halyomorpha picus* Fabricias. J. Agric. Univ. Hebei 20: 12–17.

Corrêa-Ferreira, B. S., and F. Moscardi. 1996. Biological control of soybean stink bugs by inoculative releases of *Trissolcus basalis.* Entomol. Exp. Appl. 79: 1–7.

Funayama, K. 2003. Outbreak and control of stink bugs in apple orchard. Jpn. Agric. Technol. 47: 35–39.

Funayama, K. 2004. Importance of apple fruits as food for the brown-marmorated stink bug, *Halyomorpha halys* (Stål) (Heteroptera: Pentatomidae). Appl. Entomol. Zool. 39: 617–623.

Goto, S., T. Sato, O. Abe, T. Saito, and T. Marukawa. 2002. Damage to persimmons by stink bugs and their seasonal prevalence in Shonai, Yamagata. Annu. Rep. Plant Prot. North Jpn. 53: 276–278.

Hamilton, G. C., and P. W. Shearer. 2003. Brown marmorated stink bug–a new exotic insect in New Jersey. FS002. Rutgers Cooperative Research & Extension, New Brunswick, NJ. (http://www.rce.rutgers.edu/ pubs/pdfs /fs002.pdf).

Hamilton, G., and A. Nielsen. 2005. Monitoring for the brown marmorated stink bug. Rutgers Cooperative Research & Extension, New Brunswick, NJ. (http://www.rce.rutgers.edu/stinkbug/).

He, Z.-C. [ed.] 1997. A colored pictorial handbook of agricultural pests in northern China, pp. 1–491. Liaoning Sci. Tec. Press. Shengyang, China.

He, J.-H. [ed.]. 2004. Hymenopteran insect fauna of Zhejiang. Science Press, Beijing, China.

Hoebeke, E. R. 2002. Brown marmorated stink bug, *Halyomorpha halys* (Stål) (Heteroptera: Pentatomidae). Regulatory Horticulture Entomology Circular, vol. 28, no. 204: 35–37. (http://www.agriculture.state.pa.us/plantindustry/lib/plantindustry/vol28_11.pdf).

Hoebeke, E. R., and M. E. Carter. 2003. *Halyomorpha halys* (Stal) (Heteroptera: Pentatomidae) a polyphagous plant pest from Asia newly detected in North America. Proc. Entomol. Soc. Wash. 105: 225–237.

Hoffmann, W. E. 1931. A pentatomid pest of growing beans in south China. Peking Nat. Hist. Bull. 5: 25–26.

Hirashima, Y., and K. Yamagishi. 1981. Redescriptions of the types of some Japanese Scelionidae preserved in the United States National Museum (Hymenoptera, Proctotrupoidea). J. Fac. Agric. Kyushu Univ. 25: 153–159.

Hsiao, T.-Y. 1977. A handbook for the determination of the Chinese Hemiptera-Heteroptera. vol. 1, Science Press, Beijing, China.

Jacobs, S. 2007. Brown marmorated stink bug, *Halyomorpha halys.* Entomologicalnotes. (http://www.ento.psu.edu/extension/factsheets/brownMarmoratedstinkbug.htm).

Jin, K.-X., C.-J. Liang, and D.-L. Deng. 1981. A study of the insect vectors of witches' broom in Paulownia trees. Linye Keji Tongxum 12: 23–24.

Johnson, N. F. 1984. Revision of the Nearctic species of the flavipes group (Hymenoptera: Scelionidae). Proc. Entomol. Soc. Wash. 86: 797–807.

Johnson, N. F. 1985a. Revision of the New World species the thyantae group (Hymenoptera: Scelionidae). Can. Entomol. 117: 107–112.

Johnson, N. F. 1985b. Systematics of New World *Trissolcus* (Hymenoptera: Scelionidae): species related to *T. basalis.* Can. Entomol. 117: 431–445.

Johnson, N. F. 1987. Systematics of New World *Trissolcus,* a genus of pentatomid egg-parasites (Hymenoptera: Scelionidae): Neotropical species of the *flavipes* group. J. Nat. Hist. 21: 285–304.

Johnson, N. F. 1991. Revision of Australasian *Trissolcus* species (Hymenoptera: Scelionidae). Invertebr. Taxon. 5: 211–239.

Johnson, N. F. 1992. Catalog of world species of Proctotrupoidea, exclude Platygasteridae (Hymenoptera), pp. 1–825. Memories of American Entomological Institute No. 51.

Kang, C. H., H. S. Huh, and C. G. Park. 2003. Review on true bugs infesting tree fruits, upland crops, and weeds in Korea. Korean J. Appl. Entomol. 42: 269–277.

Kozlov, M. A. 1968. Telenominae (Hymenoptera, Scelionidae) of the Caucasus-egg parasites of Hemipterous grain-pests. Trudy Vses. Entomol. Obshch. 52: 188–223.

Kozlov, M. A., and X. H. Le. 1976. Paleartic species of the *Tissolcus flavipes* Thomson group (Hymenoptera, Proctotrupoidea, Scelionidae). Entomol. Rev. 55: 108–114.

Kozlov, M. A., and X. H. Le. 1977. Paleartic species of egg parasites of the genus *Trissolcus* Thomson (Hymenoptera, Scelionidae, Telenominae). Insects Mongolia 5: 500–525.

Kozlov, M. A. 1978. Superfamily Proctrupoidea, pp. 538–664. *In* G. S. Medredev [ed.], Keys to the insects of European part of USSR. Hymenoptera, part 2, vol. 3. Nauka Publ., Leningrad, Russia.

Kozlov, M. A., and S. V. Kononova. 1983. Telenominae of the fauna of the USSR, pp 1–336. Zool. Inst. Acad. Sci. USSR No. 136.

LaBonte, J. 2005. Brown marmorated stink bug. Oregon Department of Agriculture Pest Alert. (http://egov.oregon.gov/ODA/PLANT/docs/pdf/ippm halyomorpha.pdf).

Li, Q.-C., A.-Y. Chen, H.-S. Wang, and W.-Y. Zhang. 1998. Control techniques for *Halyomorpha halys* and *Erthesina fullo.* Plant Doctor 11: 27–28.

Li, D.-L., C.-T. Zhang, H.-F. Su, and G.-L. Xu. 1992. A report on preliminary observation of the egg parasitoid of *Halyomorpha halys.* Nat. Enemies Insects 14: 189–190.

Li, Z.-X. 2002. Preliminary studies on *Trissolcus* sp. (Hymenoptera: Scelionidae), an egg parasitoid of *Halyomorpha halys* (Hemiptera: Pantatomidea). M.S. thesis, Shandong Agricultural University, Shandong, China.

Li, Z.-X., and Y.-S. Liu. 2004. Effect of temperature on development of egg parasitoid *Trissolcus halyomorphae* and the eggs of its host, *Halyomorpha halys.* Chin. J. Biol. Control 20: 64–66.

Masner, L. 1976. Revisionary notes and keys to world genera of Scelionidae (Hymenoptera: Proctotrupoidae). Mem. Entomol. Soc. Can. No 97.

Masner, L. 1980. Key to genera of Scelionidae of the Holarctic Region, with descriptions of new genera and species (Hymenoptera: Proctotrupoidae), pp. 1–54. Mem. Entomol. Soc. Can. No. 113.

Miko, I., L., N. F. Vilhelmsen, N. F. Johnson, L. Masner, and Z. Penzes. 2007. Skeletomusculature of Scelionidae (Hymenoptera: Platygastroidea): head and mesosoma. Zootaxa 1571: 1–78.

Ming, G.-Z., X.-B. Zhao, P. Wang, C.-L. Li, and X. Z. Zhao. 2001. The damage of *Halyomorpha halys* to pear and its control techniques. Plant Prot. Technol. Ext. 21: 20–21.

Qin, W.-L. 1990. The damage characteristics and control techniques of *Halyomorpha halys.* Plant Prot. 16: 22-23.

Qiu, L.-F. 2007. Studies on biology of the brown marmarated stink bug *Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae), an important pest for pome trees in China and its biological control. Ph.D dissertation, Chinese Academy of Forestry, Beijing, China.

Rider, D. A. 2008. Hymenoptera parasitoid records, list by pentatomoid species. (http://www.ndsu.edu/ndsu/rider/Pentatomoidea/Natural_Enemies/parasitoid_Hymen_Pent.htm).

Ryu, J., and Y. Hirashima. 1984. Taxonomic studies on the genus *Trissolcus* Ashmead of Japan and Korea (Hymenoptera, Scelionidae). J. Fac. Agric. Kyushu Univ. 29: 35–58.

Toyama, M., F. Ihara, and K. Yaginuma. 2006. Formation of aggregations in adults of the brown marmorated stink bug, *Halyomorpha halys* (Stål) (Heteroptera: Pentatomidae): the role of antennae in short-range locations. Appl. Entomol. Zool. 41: 309–315.

Yasunaga, T., M. Takai, I. Yamashita, M. Kawamura, and T. Kawasawa. 1993. Damage of crops by bugs, pp. 243–300.

In M. Tomokuni [ed.], A field guide to Japanese bugs. Zenkoku Nouson Kyouiku Kyoukai, Tokyo, Japan.

Zhang, C.-T., D.-L. Li, H.-F. Su, and G.-L. Xu. 1993. A study on the biological characteristics of *Halyomorpha picus* and *Erthesina fullo.* For. Res. 6: 271–275.

Zhang, J.-M., H. Wang, L.-X. Zhao, F. Zhang, and G.-Y. Yu. 2007. Damage to an organic apple orchard by the brown marmorated stink bug, *Halyomorpha halys* and its control strategy. Chin. Bull. Entomol. 44: 898–901.

Zhang, S.-M [ed.]. 1985. Economic insect fauna of China, Fasc. 31, Hemiptera (1). Science Press, Beijing, China.

Received 12 March 2008; accepted 22 September 2008.