A New Species of Sclerodermus (Hymenoptera: Bethylidae) Parasitizing Agrilus planipennis (Coleoptera: Buprestidae) From China, With a Key to Chinese Species in the Genus

ZHONG-QI YANG,1,2 XIAO-YI WANG,1 YAN-XIA YAO,1 JULI R. GOULD,3 AND LIANG-MING CAO1

Ann. Entomol. Soc. Am. 105(5): 619–627 (2012); DOI: http://dx.doi.org/10.1603/AN12017

ABSTRACT A new parasitoid reared from Agrilus planipennis Fairmaire (Coleoptera: Buprestidae), Sclerodermus pupariae n. sp. (Hymenoptera: Bethylidae), is described from China. S. pupariae was reared from A. planipennis in China attacking velvet ash (Fraxinus velutina Torr.), a tree native to North America. Life-history studies of S. pupariae in the field and laboratory indicated it is a gregarious idiobiont ectoparasitoid of pupa and larva of A. planipennis and has up to five generations per year. Parasitism rate in the field was 13%. Adult wasps reared from single host pupa or mature larva ranged from 24 to 56 individuals. Based on laboratory rearing, the emerging adult female to male ratio was 22:1. The new parasitoid species has a high potential as a biocontrol agent for emerald ash borer. Diagnosis of the new species with comparisons to Sclerodermus harmandi (Buysson) and a key to Sclerodermus known in China are provided.

KEY WORDS Agrilus planipennis, Sclerodermus pupariae, new species, pupal and larval parasitoid, biocontrol

Emerald ash borer, Agrilus planipennis Fairmaire (Coleoptera: Buprestidae), attacks ash trees (Oleaceae; Fraxinus spp.) in its native range of northern China, as well as in Mongolia, the Korean Peninsula, Japan, and the Russian Far East. In northern China, it has been a serious pest of imported North American ash (i.e., Fraxinus americana L., Fraxinus velutina Torr., and Fraxinus pennsylvanica Marsh) used in plantations and as ornamentals. It also has been reported attacking native ash [i.e., Fraxinus mandshurica Rupr. and Fraxinus chinensis var. dosidiscata (Roxb.) Hance] and hybrids (Yu 1992). In recent years, A. planipennis has been found in North America, until 2011, with 15 U.S. states (Michigan, Illinois, Indiana, Iowa, Kentucky, Maryland, Minnesota, Missouri, New York, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia, and Wisconsin) and two provinces in Canada (Ontario and Quebec) (http://www.emeraldashborer.info/faq.cfm). It has been predicted that A. planipennis could spread throughout the range of ash in the United States and Canada, causing substantial economic and environmental damage (Haack et al. 2002, Mastro and Readon 2004).

The delay in detection efforts for the concealed A. planipennis larvae until foliage wilt, dead twigs become noticeable, or adult emergence holes are noted hampers control programs, such as with conventional pesticides. The clear threat to ash in North America and China spurred the formation of a Sino-American program and China National Key Technology R&D Program in China’s 11th Five Year Plan (2016–2010) to study the potential for biocontrol of A. planipennis. During exploration for natural enemies in China, an undescribed species of Sclerodermus Latreille (Hymenoptera: Bethylidae) was discovered parasitizing a pupa of A. planipennis and later larva of the buprestid. Preliminary laboratory and field studies of its biology were then initiated there. The description of this new Sclerodermus species, biological observations, and a discussion of its biocontrol potential are presented.

The known species of Sclerodermus mainly attack wood-boring beetle larvae (Cerambycidae, Scolytidae, Anobiidae, and Bostrochidae), but rarely they are associated with buprestid immature (Evans 1964, Gordh and Moczár 1990). Worldwide in distribution, 80 species of Sclerodermus have been described (Gordh and Moczár 1990, Lanes and Azevedo 2008). Sclerodermus is distinguished from other bethylid genera by 1) clypeus short, with anterior margin raised and with a medial V-shaped notch; 2) macropterous individuals forewings, with marginal bristles short, costal and radial veins absent, subcostal, median, and basal veins present, anal and transverse median veins...
absent or present; and 3) head sides and vertex broadly rounded, wider in dorsal than in ventral and slightly longer than wide (Evans 1964, 1978; Terayama 2003a,b; Lanes and Azevedo 2008).

Gordh and Moczár (1990) published a catalog of the world species of Bethylidae, including Sclerodermus. Evans (1964, 1978) studied the North American Bethylidae, including Sclerodermus. The Japanese species of the genus were studied by Terayama (1999, 2006). Lanes and Azevedo (2008) listed 71 world species of Sclerodermus when they studied the phylogeny and taxonomy of Sclerodermini. Xiao and Wu (1983) described a Chinese Sclerodermus species, Sclerodermus guani Xiao et Wu. Xiao (1995) described another two species in the genus, Sclerodermus hainanica Xiao and Sclerodermus sichuanensis Xiao.

Materials and Methods

Surveys for stressed ash trees, primarily F. velutina, were conducted from 2003 through 2006 in Tianjin Municipality. Trunk bark of stressed trees was peeled to search for A. planipennis larvae and pupae and their associated parasitoids. A. planipennis larvae and pupae and any possible parasitoid eggs, larvae, and pupae in cocoons were collected and placed in vials (12 mm in diameter by 75 mm in height). Each sample vial contained a single brood of parasitoids and their A. planipennis host larva. The vials were then tightly plugged with sterilized cotton and maintained at ∼23–26°C in a laboratory. Parasitoid eggs, larvae, and pupae were successfully reared to adults. After the parasitoid adults emerged, they were killed and point mounted. Specimens were examined with an SZH 1500 stereo-microscope (Nikon, Tokyo, Japan). Photographs of the new species and other related species were taken with a CX31 microscope (Olympus, Tokyo, Japan) with the UV-C Optical Totally Focuses System developed by Beijing United Vision Technology Co., Ltd. (Beijing, China).

The type series of the three Sclerodermus species described and deposited by the late Prof. Xiao Gangrou in the Insect Collections of the Chinese Academy of Forestry were studied and photographed. A diagnostic key for the Sclerodermus species known to be present in China is provided. The type series of the new species is deposited in the Insects Collection of the Chinese Academy of Forestry (Beijing, China).

Measurements and terminology follow Evans (1964, 1978) and Terayama (2006). The abbreviations of characters used in the descriptions are as follows: L/H, length of head from apical margin of clypeus to midpoint of vertex; WH, width of head at widest point; WF, width of frons (least interocular distance); LT, length of body; HE, maximum height of eye measured in lateral view; LM, length of mesosoma; LMT, length of metasoma; LPD, length of propodeal disc; WPD, width of propodeal disc; LFW, length of forewing; POL, distance between posterior ocelli; AOL, distance between posterior ocellus and anterior ocellus; DAO, diameter of anterior ocellus; WOT, distance across and including posterior ocelli; OOL, distance between a posterior ocellus and compound eye; and OL, distance between anterior ocellus and a posterior ocellus.

Results and Discussion

Lim et al. (2006), Terayama (2006), and Xu and He (2008) listed S. guani as a synonym of S. harmandi (Buysson 1903), but all they did not studied the types of S. guani and they had the conclusion according to some specimens collected in southern China (they indicated this in their paper). During our current study of Sclerodermus, we compared the holotype and paratypes of S. guani Xiao et Wu deposited by the late Prof. Xiao in the Insects Collection of Chinese Academy of Forestry, with the redescriptions of holotype of S. harmandi by Terayama (1999, 2006). Terayama gave both detailed redescriptions and hand drawings of S. harmandi based on holotype. Several characters were found that differentiate S. guani from S. harmandi: 1) apterous female of S. guani with terga 2–5 near posterior margin with transverse impression having a pair of submedial posteriorly directed angles (Figs. 2 and 14; the latter terga 2–5 with posterior margins straight and without such angles submarginally), mesonotum with width 1.2 times its length (the latter mesonotum with length 1.2 times its width), propodeum with maximum width 1.3 times minimum width and at about anterior one-fourth length slightly constricted (the latter with maximum width 1.56 times minimum width and not constricted there, appearing trapezoid); 2) alate male pronotum campanulate with posterior margin width ∼1.7 times anterior margin (the latter pronotum subtriangle with posterior margin width ∼3.0 times anterior margin). Thus, we consider S. guani to be a likely valid species and we use the name in present key to Chinese species of Sclerodermus.

Key to Females of Chinese Species of Sclerodermus Latreille

1. Alate female forewing with two basal cells, the median cell bordered the subcosta, median and basal veins, and the submedian cell bordered by the anal and transverse medial vein (Fig. 28); antenna with flagellum I having width 1.4 times length; mandible with four teeth. . . . . . . Sclerodermus hainanica Xiao 1995
   — Alate female forewing with the median cell only (Fig. 12); antenna with flagellum I having width the same as length (Figs. 6, 9, 23, 25) or length slightly longer than width (Fig. 27); mandible with three teeth (Figs. 7, 8, 23, 26) . . . . . . . . . 2

2. Alete female with combined length of pedicel plus flagellum slightly exceeding head length, flagellum 1 longer than wide with length 1.2 times its apical width (Fig. 27), scape 3.5 times as long as its maximum width; apterous female with combined length of pedicel plus flagellum obviously exceeding head width (1.14 times the latter), and scape 4.0 times as long as its maximum width (Fig. 25) . . . . Sclerodermus guani Xiao & Wu 1983
Alate female with combined length of pedicel and flagellum shorter than head length, and flagellum 1 at most as long as its own width (Fig. 6), scape with length at most 2.7 times as long as its maximum width; apterous female with combined length of pedicel plus flagellum only slightly exceeding head width and never over 1.1 times head width; scape at most 2.7 times as long as its maximum width.  

3. Apterous female with eye bare; width of posterior margin of propodeal disc 1.2–1.4 times basal margin; propodeum at posterior one third with weak lateral carina and it extending downwards as upper lateral margin of declivity, thus posteriodorsal corner more or less angled; sternum 1 medially with three to four lines of setae at anterior two-thirds length before a group setae at posterior margin (Figs. 22 and 24).  

Sclerodermus sichuanensis Xiao 1995  

— Apterous female with eye having very short and sparse hairs; width of posterior margin of propodeal disc about the same with basal margin, or only slightly wider than the latter (never >1.1 times); propodeum at posterior one third without weak lateral carina and posteriodorsal corner slightly convex; sternum 1 medially with two lines of setae at anterior two-thirds length before a group setae at posterior margin (Figs. 3 and 15).  

Sclerodermus pupariae Yang & Yao sp. nov.
Sclerodermus pupariae Yang & Yao, n. sp.

(Figs. 1–21)

HOLOTYPE. Alate female (Figs. 1, 6, 7, 11–13). Full-winged LT, 3.31 mm; LH, 0.63 mm; WH, 0.54 mm; WF, 0.29 mm; LM, 1.13 mm; LPD, 0.49 mm; WPD, 0.43; LFW, 2.13 mm; LMT, 1.55 mm.

Body brownish black with weak black tint; antennae, mandibles, trochanters, tibiae and tarsi fulvous, all coxae and femora concolor with body; tibiae with apical four fifths testaceous; forewing slightly infuscate across wing, hind wing subhyaline, wing veins yellowish brown; each tergum with hind margin fulvous.

Head (Figs. 1 and 11) prognathous, 1.2 times as long as wide; frons, vertex and gena evenly convex with very delicate engraved reticulation and sparse short setae; frons 1.4 times as wide as height of eye; eyes with very short and sparse hairs (magnification ≥100×); distance between median ocellus and eye 0.7 times the eye height; face steeply sunken at the position close to lower margin of eyes as declivity; antennal bases located at the declivity lower margin; malar space 1.6 times torulus width and 0.7 times of mandible basal width; distance between toruli approximately one half of their own width. Each mandible with three teeth and the third tooth smallest (Fig. 7); clypeus triangular, modified as inverted “V” shape lamina located between toruli. Antenna 13-segmented (Fig. 6) with short but dense suberected setae; scape as long as eye height, clavated with its apical width 0.36 times its...
length; length and width of scape, pedicel, and flagellum segments 1–11 with the following proportions: 80(30); 30(21); 16(16); 13(16); 11(17); 16(20); 16(21); 16(21); 17(21); 19(21); 19(21); 18(21); 44(21). Ocelli forming equilateral triangle; OOL, 2.47 times WOT; POL:AOL, 0.8:1; DAO, 0.44 mm.

Mesosoma with delicate engraved reticulation appearing subpolished, covered with brown sparse short setae, the setae denser and longer at lateral sides of pronotal collar, and on scutellum the setae much shorter and denser than those on pronotum and mesoscutum (observed at dorsolateral view). Pronotum campanulate in form, evenly convex, short, length of disc 0.7 times as long as its maximum width; posterior margin slightly curved anteriorly; collar with length =0.15 times pronotal disc; pronotum (including collar) 0.85 times as long as remainder of mesosoma. Mesoscutum strongly convex, 0.5 times as long as maximum width, without notauli; scutellum 0.54 times as long as mesoscutum, and =0.7 times as long as wide, dorsum slightly convex; scutellar pits connected as a transverse furrow. Propodeum slightly convex, propodeal disc at nearly the same level with scutellum and =1.1 times as long as maximum wide and as long as mesonotum, and only a little shorter than pronotum with collar., propodeal disc at anterior one-third length moderately constricted; width of anterior margin about the same with posterior margin; disc at anterior one sixth with raised oblique striations and other part with delicate engraved reticulations; declivity smoothly descending at ≈110° with disc and not forming sharp angle. Mesopleuron considerably convex and with delicate reticulations. Forewing (Figs. 1 and 12) 3.3 times as long as wide; outer margin with long fringe; subcosta, median and basal veins well developed and composing basal cell; stub vein (Rs+M) conspicuous and reaching out-downward anal vein position (anal vein absent); prostigma well developed and pterostigma absent. Hind wing (Fig. 13) simple.

Metasoma (Figs. 1–3, 14, 15) nearly sessile, laceolate in form, ≈2.7 times as long as wide; its width 1.1 times mesoscutum and 1.06 times head, its length 1.3 times mesosoma; terga with delicate reticulation which are more superficial and denser than that on mesosoma; each tergum with sparse and prominent setae, besides the setae terga 4-7 with long bristles with number 6, 8, 12, and 4, respectively, the bristles are more than 2 times longer than the tergae on each own tergum, and the bristles on terga 6 and 7 the longest; tergum 1 with hind margin broadly rounded, terga 2–5 near posterior margin with transverse impression having a pair of submedial posteriorly directed angles, tergum 6 with hind margin curved posteriorly. Sterna 1–4 near posterior margin with transverse impression having a pair of submedial posteriorly directed angles as in terga; sternum 1 anterior half with two submedial longitudinal rows of setae; sternum 1–5 near posterior margin with broad area having short setae and long bristles, the number of the bristles are as eight, eight, eight, six, and four on sterna 1–5, respectively.

Paratype. Alate male (Figs. 16–21): all males full winged; body length 2.6 mm. Body mostly brown black, mesosoma and tergum 1 slightly lighter; antennae with pedicel and flagellum testaceous; apex of mandible and tarsus of legs yellow brown, and other segments of legs concolor with mesosoma; forewing very slightly infuscate, hind wing hyaline. Hind (Figs. 16 and 17) in front view subrounded, ≈1.06 times as long as wide; mandible with four teeth and all teeth well developed. Antenna (Fig. 18) 13-segmented and all segments longer than wide, with flagellum 1.25 times as long as wide, flagellum 11 ≈3.2 times as long as wide; each segment with denser and longer setae than in female; combined length of pedicel plus flagellum 1.5 times head width. Eye with sparse short hairs. Metasoma (Figs. 16, 19, 20) petiolar short (∼=0.12 times as long as propodeum), metasoma length 2.2 times its width and as long as mesosoma; sternum 1 (Fig. 20) anterior two thirds with two rows of setae submedially. For male genitalia see Fig. 21.

Paratype. Apterous female (Figs. 2–5, 8–10, 14, 15): Body castaneous with pronotum and mesonotum having posterior margin yellow brown band; declivity of propodeum and each tergum of metasoma with posterior half more or less testaceous, last tergum luteous; antennae testaceous with apex blackish; coxae, femora and tibiae concolor with mesoscutum; trochanters, tarsi and knees concolor with antenna; clpeus and mandible testaceous, mandible teeth castaneous. Head and mesosoma with similar reticulations and setae; metasoma with more delicate reticulation and notable setae. LT, 3.18 mm; LH, 0.68 mm; WH, 0.54 mm; WF, 0.30 mm; LM, 1.0 mm; LPD, 0.45 mm; WPD, 0.32 mm.

Head (Figs. 5) in front view slightly longer than wide with length 1.26 times width, and sides convergent downward with upper side slightly wider than the lower (former 1.16 times the latter); eyes with very short and sparse hairs (magnification >100×); ocellus absent; anterior margin of clpeus strong raised as inverted “V” ridge as in the alate female; mandibles with three teeth, the basal tooth smallest and the second smaller than first (Fig. 5). Antenna (Fig. 9) with radicle prominent and round, ∼=0.21 times as long as scape; scape ∼=3.1 times as long as maximum width; length and width of pedicel and flagellum segments 1–11 with the following proportions: 36(20); 16(16); 16(17); 14(15); 16(20); 18(21); 20(23); 21(24); 21(25); 20(26); 20(27); 48(26). Flagellum 1 constructed in proximal half with apex width 1.4 times basal width; apical segment 1.8 times as long as wide. HE, 0.18 mm; WF, 1.6 times HE; WH, 3.0 times HE.

Pronotal disc (Figs. 2 and 10) 1.2 times as long as wide, posterior margin nearly straight. Mesonotum about as long as wide. In dorsal view propodeal disc with basal width about the same as posterior width and disc slightly constricted medially, with maximum width 1.08 times minimum width; posterior corner convex and bluntly angled without any ridge or carina.

Metasoma (Figs. 2–4, 14–15) in dorsal view lanceolate in shape, dorsum with anterior margin convex and
rounded, not forming angle; its maximum width greater than mesonotum (1.3 times) and head (1.1 times); terga with reticulations and setae as in female, but bristles on each tergum comparatively longer than on alate female, number of bristles on terga 4–7 as 4, 8, 12, and 4, respectively; sternums with characters as in female number of bristles on sterna 2–5 as eight, eight, eight, and four, respectively, sternum 1 no bristle.

Variation. Apterous females varies in color: some individuals with body black, but mandibles, antennae, part of tibiae, tarsi, posterior margins of pronotum fulvous, and metasoma with basal part and posterior margins of each tergum having a narrow fulvous band; some with head, mesosoma and tergum 1 yellow brown and other terga black brown, mesoscutum fulvous, antennae and tarsi yellow.

Type Material. HOLOTYPE: Alate female, CHINA: Guangang Forest Farm, Dagang District, Tianjin Municipality, Wang Xiao-Yi & Yang Zhong-Qi, collected in the gallery of A. planipennis on ash tree F. velutina, 2-VIII-2004. Paratypes: An apterous female and an alate male, with same data as holotype; 80 alate females and 20 apterous females, 20 alate males, 15-VIII-2004, with same location as holotype; 100 alate females and 40 apterous females, 20 alate males, 20-IX-2005, with same location as holotype.

Distribution. China: Tianjin Municipality, probably also Beijing Municipality and Hebei Province where its host A. planipennis is present.

Etymology. The specific name refers to the host stage that the new species parasitized when it was found first.

Diagnosis. S. pupariae n. sp. is similar to three other Sclerodermus species known in China and can be distinguished from them by the key above. It is also close to S. harmandi, but according to the redescription by Terayama (1999) of the latter species holotype, the new species can be separated from the latter by the following differences of apterous females: 1) mandible with three teeth (the latter with four teeth); 2) mesonotum as long as wide (the latter with mesonotum 1.20 times as long as wide); and 3) posterior margin width of propodeal disc about the same as basal margin, and disc slightly constricted medially, with maximum width only 1.08 times minimum width (the

Figs. 16–21. S. pupariae n. sp., alate male. (16) Habitus in lateral view. (17) Head in front view. (18) Antenna. (19) Metasoma in dorsal view. (20) Metasoma in ventral view. (21) Genitalia in ventral view. (Online figure in color.)
latter with posterior margin broadest and at least 1.3 times basal width, maximum width of propodeal disc 1.56 times minimum width). Another important character of the new species is in biology, i.e., most of the females (>96%) in mass rearing are alate females, compared with other Chinese species in the genus, e.g., *S. guani* and *S. sichuanensis*, nearly all reared females are apterous.

Figs. 22–28. *S. sichuanensis*, apterous female: (22) Habitus in ventral view. (23) Head and antenna in frontoventral view. (24) Sternum 1 in ventral view, showing the setae medially and posteriorly. *S. guani*: (25) Apterous female antenna. (26) Apterous female mandible. (27) Alate female antenna. *S. hainanica*: (28) Alate female forewing. (Online figure in color.)
Biological Observations. *S. pupariae* is a gregarious idiobiont ectoparasitoid that attacks late stage immature emerald ash borers. This species was first discovered attacking emerald ash borer pupae (Fig. 30) in the Guangang Forest Park (38° 56′ N, 117° 29′ E), Dagang District, Tianjin Municipality, China in 2003; however, it was subsequently found to parasitize third- and fourth-instar larvae (Fig. 29) and prepupae. *S. pupariae* overwinters as apterous females in emerald ash borer galleries or in ash bark crevices. Adult females emerge in late June. Once a female locates an emerald ash borer, she chews a hole through the bark of the tree to reach the host. Female *S. pupariae* also can use their front legs to excavate a tunnel through the tightly packed emerald ash borer frass to reach their quarry. Upon access a host, the female first stings the emerald ash borer to paralyze it, and she then feeds on the hemolymph to obtain nutrients for her developing eggs. The preoviposition feeding period lasts for ~1 wk, during which time the female’s abdomen gradually expands and prolongs as the eggs develop. Depending on host size, *S. pupariae* lays 26–58 eggs, spaced evenly over the body of the emerald ash borer host.

Eggs hatch within ~2 d, and the larvae fully develop within a week at ~25°C. The host is entirely consumed, and the mature parasitoid larva spin cocoons and pupate in the host gallery. The pupal stage lasts 15–20 d, and 24–56 adult wasps are produced per brood. The female: male ratio averages 22:1, with a brood typically containing only one or two males.

*S. pupariae* females provide considerable care for their developing progeny. Before laying eggs on the host, the female cleans the host body by taking away frass and dirt to the end of the gallery away from the host. If any eggs or larvae drop off the host during development, the female uses her mouthparts to pick them up and put them back on the host. If any of her progeny become infested by fungi or bacteria, she removes them from the brood and takes them to the far end of the gallery, where she excretes an antibiotic substance to prevent microorganism development. This prevents the spread of the disease to her remaining progeny. Only after her brood has successfully emerged as adults does the female leave the emerald ash borer gallery to search for additional hosts.

Because the new parasitoid has high host-searching and host-attacking abilities, and high proportion of females, as well as alate female proportion (it is advantageous to disperse after releasing in biocontrol), it has high potential as an important natural enemy for the biological control of the buprestid pest.

Acknowledgments

We thank Richard Reardon and Wu Yun (USDA-FS, Forest Health Technology Enterprise Team, Morgantown, WV) for help in the study. We also thank Gui-Jun Liu and En-shan Liu (Administrative Office of Guangang Forest Park, Tianjin) for help during this investigation. This research was supported by U.S. Department of Agriculture, Animal & Plant Health Inspection Service and Forest Service; the National Key Technology R&D Program in the 11th Five Year Plan of China (2006BAD08A12); the Basic R&D Special Fund Program for National Level, Scientific Research Institutes (2004DJB41J166), and Forestry Scientific Research Program of State Forestry Administration of China (2003-033-L33).

References Cited

Evans, H. E. 1964. A synopsis of the American Bethylidae (Hymenoptera: Aculeata). Bull. Mus. Comp. Zool. 132: 1–222.

Evans, H. E. 1978. The Bethylidae of America North of Mexico. Mem. Am. Entomol. Soc. 27. 1–332.

Gordh, G., and L. Móczár. 1990. A catalog of the world Bethylidae (Hymenoptera: Aculeata). Mem. Am. Entomol. Inst. 46. The American Entomological Institute, Gainesville, FL.

Haack, R. A., E. Jendek, H. Liu, K. B. Marchant, T. R. Petrice, T. M. Poland, and H. Ye. 2002. The emerald ash borer: a new exotic pest in North America. News. Mich. Entomol. Soc. 47: 1–5.

Mastro, V., and R. Reardon. 2004. Forward, p. III. In V. Mastro and R. Reardon [eds.], Emerald ash borer research and technology development meeting, September–October 2003, Port Huron, MI. Tech. Trans. Bull. FHTET-2004-2. U.S. Dep. Agric. Forest Service, Forest Health Technology Enterprise Team, Morgantown, WV.

Lanes, G. O., and C. O. Azevedo. 2008. Phylogeny and taxonomy of Sclerodermus (Hymenoptera, Bethylidae, Epyrininae). Insect Syst. Evol. 39: 85–96.

Lim, J., D. Lyu, O.-S. Chol, Y.-J. Jeong, S.-C. Shin, and S. Lee. 2006. A taxonomic note on *Sclerodermus harmandi*, ectoparasite of stem and wood boring insect larvae (Hymenoptera: Chrysidioidea: Bethylidae) in South Korea. J. Asia-Pac. Entomol. 9: 115–119.
Terayama, M. 1999. Descriptions of new species of the family Bethylidae from the Ryukyus, and taxonomic notes on the Japanese species of the genus Sclerodermus. [reprinted from Yamane, Seiki, Shuichi Ikudome and Mamoru Terayama. Identification Guide to the Aculeata of the Nansei Island, pp. 701–725. Hokkaido University Press, Sapporo, Japan].

Terayama, M. 2003a. Phylogenetic systematics of the family Bethylidae (Insecta: Hymenoptera). Part I. Higher classification. Acad. Rep. Fac. Eng. Tokyo Polytechnic Univ. 26: 1–15.

Terayama, M. 2003b. Phylogenetic systematics of the family Bethylidae (Insecta: Hymenoptera). Part II. Keys to subfamilies, tribes and genera in the world. Acad. Rep. Fac. Eng. Tokyo Polytechnic Univ. 26: 16–29.

Terayama, M. 2006. The insects of Japan, volume 1: Bethylidae (Hymenoptera). Entomological Society of Japan, Fukuoka, Japan.

Xiao, G.-R. and J. Wu. 1983. A new species of Sclerodermus from China. Sci. Silv. Sin. 8: 81–84.

Xiao, G.-R. 1995. Two new species of the genus Scleroderma from China (Hymenoptera, Bethylidae), pp. 1–5. Forest Research 8. Memoir of the Academic Symposium of Forest Entomology. The Entomological Society of China.

Xu, Z.-F., and J.-H. He. 2008. Revision on the scientific name of the bethylid regarded as Scleroderma guani which used widely in forest of China. J. Environ. Entomol. 30: 192–194.

Yu, C.-M. 1992. Emerald ash borer, pp. 400–401. In Xiao Gang-rou [ed.], Forest insects in China, 2nd ed. China Forestry Publishing House, Beijing, China.

Received 13 February 2012; accepted 6 June 2012.