Discovery of a New *Plagiotrochus* Species (Hymenoptera: Cynipidae) Inducing Galls on the Evergreen Oak in Japan

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**ABSTRACT** *Plagiotrochus masudai* Ide, Wachi & Abe sp. nov. (Hymenoptera: Cynipidae), a gall inducer on *Quercus* (*Cyclobalanopsis*) *glauca* Thunberg in Japan, is described. This is the first description of an oak gall wasp species (tribe Cynipini) inducing galls on *Cyclobalanopsis*. The unique life cycle of *P. masudai* takes 3 yr to complete. The adult wasps of the sexual generation emerge from bud galls on *Q. glauca* in spring of the first year, and those of the asexual generation emerge from twig galls in spring of the third year.

**KEY WORDS** oak-gall wasp, new species, eastern Palearctic, ring-cupped oak, alternation of generations

Of approximately 1,300 cynipid gall wasps described to date, ≈1,000 species are oak-gall wasps belonging to the tribe Cynipini (Stone et al. 2002, Csóka et al. 2005, Abe et al. 2007). The host plants of these species belong to the family Fagaceae, primarily the genus *Quercus*, but also *Castanea*, *Chrysolepis*, and *Lithocarpus* (Stone et al. 2002, 2009). The genus *Quercus* is divided into two subgenera, *Quercus* and *Cyclobalanopsis*, with the latter subgenus being restricted to the eastern Palearctic region (Nixon 1993, Manos et al. 1999). Despite the extensive distribution of ring-cupped oaks or *Cyclobalanopsis* in Asia, investigations of the oak-gall wasp species richness and host association of this subgenus have revealed that very few gall wasps are known to induce galls on *Cyclobalanopsis* (Abe et al. 2007, Liljeblad et al. 2008). Shinji (1940, 1941) described two species of *Andricus* (tribe Cynipini) from *Quercus* (*Cyclobalanopsis*) *mysrisfolia* Blume under the name *Cyclonopsis* [sic] *mysrisfolia* [sic]. However, based on the characteristics of their galls, it has been suggested that these species of *Andricus* are in fact inquilines (Yukawa and Masuda 1996), which means that cynipid wasps capable of inducing galls on *Cyclobalanopsis* have in fact not yet been actually described.

Fourteen species of *Plagiotrochus* Mayr, 1881 have been described as being gall inducers in section *Cerris* (subgenus *Quercus*) of oak trees (13 species in the Circum-Mediterranean and one species in the Himalayan region) (Bellido et al. 2000, Pujade-Villar et al. 2000). An additional three species have recently been described, one from Jordan and two from Nepal, but their host affiliations have not yet been resolved (Melika et al. 2009).

Here, we describe a new species of *Plagiotrochus* that induces galls on *Quercus* (*Cyclobalanopsis*) *glauca* Thunberg from Japan. This is the first definitive description of a cynipid gall wasp inducing galls on the subgenus *Cyclobalanopsis*. The life cycle of this species was reported previously by Yukawa and Masuda (1996) on the basis of the rearing experiments conducted by H. Masuda. The description reported in this study used specimens from his rearing experiments.

**Materials and Methods**

The following morphological abbreviations are used: OOL, the ocular-ocellar line (the distance from the outer edge of a lateral ocellus to the compound eye); POL, the postocellar line (the distance between the inner edges of the two lateral ocelli); and LOL, lateral-ocellar line (the distance between lateral and frontal ocelli). Morphological terminology mainly follows Richards (1977) and Ronquist and Nordlander (1989), and description of surface sculpture mainly follows Harris (1979).

The external structure of dry-mounted wasp and gall specimens was studied with binocular stereomicroscopes (model SZ60, Olympus, Tokyo, Japan; model MZ12, Leica, Solms, Germany, fitted with model DS-L1, Nikon, Tokyo, Japan), and the lengths of the forewing and hind tibia were measured using an ocular micrometer. Three specimens (one asexual female, one sexual female, and one sexual male) were gold-coated with a sputter coater and examined with a scanning electron microscope (model JSM-5600LV, JEOL, Tokyo, Japan).

**Specimens Examined.** We examined 60 specimens: 20 asexual females, 10 collected on the Ito Campus of Kyushu University and 10 from the H. Masuda Col-
lection (Kyushu University Museum; KUM); 20 sexual females, ten collected on the Ito Campus and 10 from the H. Masuda Collection; 20 sexual males, 10 collected on the Ito Campus and 10 from the H. Masuda Collection (asexual generation is numbered C-052 and sexual generation C-056 in Yukawa and Masuda, 1996). Thirty specimens collected on the Ito Campus are deposited in the Biosystematics Laboratory, Graduate School of Social and Cultural Studies, Kyushu University, Motooka, Fukuoka, Japan.

Results

Plagiotrochus masudai Ide, Wachi et Abe, sp. nov. (Figs. 1-28)

Type Material. Holotype. Asexual female, with three labels of “Ito Campus, Kyushu-Univ., Motooka, Fukuoka, Japan, 13-V-2009. H. Takahashi leg.”, “Collected by sweeping”, and “Holotype”.

Paratypes. Nine asexual females ovipositing in buds of Quercus glauca on the Ito Campus, Kyushu University, Motooka, Fukuoka, Japan, 9-V-2010, T. Ide; seven and three asexual females reared on Q. glauca in 1970 and 1991, respectively, by H. Masuda.

Other Material Examined (Sexual Generation). Ten females and 10 males reared on Q. glauca in 1989 and 1974, respectively, by H. Masuda; 10 females and 10 males, Ito Campus, Kyushu University, Motooka, Fukuoka, Japan, 12-IV-2009 (em. late April 2009), T. Ide.

Holotype (Asexual Female). Body mainly reddish brown, tip of mandible brown, tarsal claws darker. Head 1.29x as broad as high in anterior view, broader than mesosoma in dorsal view. POL:OOL:LOL = 1.3:2.5:0.6; distance between antennal rims

Figs. 1–8. Asexual female of P. masudai. (1) Head, anterior view (scale bar = 200 μm). (2) Head, dorsal view (scale bar = 100 μm). (3) Mesosoma, dorsal view (scale bar = 200 μm). (4) Mesosoma, posterdorsal view (scale bar = 100 μm). (5) Mesosoma, lateral view (scale bar = 200 μm). (6) Metasoma, lateral view (scale bar = 200 μm). (7) Ventral spine of hypopigium, ventral view (scale bar = 100 μm). (8) Right forewing (scale bar = 500 μm).

Figs. 9–16. Sexual female of P. masudai. (9) Head, anterior view (scale bar = 200 μm). (10) Head, dorsal view (scale bar = 100 μm). (11) Mesosoma, dorsal view (scale bar = 200 μm). (12) Mesosoma, posterdorsal view (scale bar = 100 μm). (13) Mesosoma, lateral view (scale bar = 200 μm). (14) Metasoma, lateral view (scale bar = 200 μm). (15) Ventral spine of hypopigium, ventral view (scale bar = 100 μm). (16) Right forewing (scale bar = 500 μm).
0.33× distance between antennal rim and inner edge of compound eye. Vertex rugulose; upper face rugose; lower face rugose medially and pubescent with striae radiating from lateral clypeus almost to margin of compound eye; clypeus sub-quadrate and slightly incised anteromedially; gena colliculate, broadened behind compound eye, visible in anterior view; malar sulcus absent; base of mandible pubescent. Antenna 14-segmented, relative lengths of flagellomeres 1–12: 2.0, 1.8, 1.6, 1.5, 1.5, 1.4, 1.2, 1.1, 1.1, 1.0, 1.0, 1.9.

Mesosoma longer than height in lateral view, mainly rugose; pronotum pubescent; mesoscutum with sparse short setae along notaulus; notaulus obscure by surface sculpture; anteroadmedian and parapsidal sigilla distinct; median mesoscutal impression absent; mesoscutellum rounded posteriorly with short sparse setae; two scutellar foveae distinct at base of mesoscutellum, separated by carina, weakly wrinkled longitudinally; postalar process conspicuous in dorsal view; metanotal trough smooth with inconspicuous wrinkles; propodeum pubescent laterally; lateral portion of propodeum with confused-rugose carinae; lateral propodeal carina conspicuous, markedly bent outward; radiating carinae present posteriorly between lateral propodeal carinae; median carina bent; mesopleural triangle sparsely pubescent; central area of mesopleuron areolate-rugose, lower area pubescent; dorsal axillary area and axillula pubescent; lateral axillary area inconspicuously wrinkled; subaxillary bar smooth and becoming broader from anterior to posterior part.

Apex of tarsal claws markedly bent, base expanded to a pronounced but blunt lobe, incision rounded.

Marginal cell of forewing open on anterior margin, 3.85× as long as broad; wing surface closely ciliated; cilia of forewing margin inconspicuous.

Metasoma polished; metasomal tergum II with sparse setae laterally and dense minute punctures posteriorly; metasomal terga III–VI with dense minute punctures; metasomal tergum VII with sparse setae and dense minute punctures; each minute puncture on metasomal terga III–VII bearing a very fine seta; metasomal tergum VIII with dense short setae throughout and long setae apically; projecting part of ventral spine of hypopygium 1.67× as long as wide (0.10 mm long; 0.06 mm wide) in ventral view, with long subapical setae forming a tuft.

Length of forewing 2.50 mm, of hind tibia 0.74 mm.

**Variation in Asexual Females Examined.**

Length of forewing (mean ± SD, n = 20) 2.27–2.90 (2.57 ± 0.16) mm; length of hind tibia 0.64–0.85 (0.71 ± 0.05) mm. In the holotype and another specimen, median carina apparently bent, but in other 18 specimens examined, median carina absent. The median carina in the ho-
lototype seems to be one of the carinae radiating from the posterior end of the propodeum.

**Sexual Female.** Differs from the asexual female as follows. Head dark brown to black. Mesosoma black, except for light brown legs and teguła. Metasoma dark brown. POL:OOL:LOL = 1.7:2.4:0.6; distance between antennal rims =0.7 × distance between antennal rim and inner edge of compound eye. Antenna 14-segmented, relative lengths of flagellomeres 1–12: 2.3, 2.1, 2.0, 2.0, 2.0, 1.7, 1.4, 1.3, 1.3, 1.2, 1.2, 2.4; metasomal tergum II obscurely imbricate with few minute punctures posteriorly, metasomal terga III–VII obscurely imbricate with dense minute punctures overall; very fine seta in each minute puncture distinct on posterior terga; ventral spine of hypopygium distinct, = 4.8X as long as wide in ventral view, with sparse setae laterally and long subapical setae forming a tuft. Length of forewing (mean ± SD, n = 20) 2.87–3.39 (3.14 ± 0.13) mm; length of hind tibia 0.78–0.92 (0.86 ± 0.05) mm.

**Sexual Male.** Differs from the sexual female as follows. POL:OOL:LOL = 1.6:2.0:0.6; distance between antennal rims = 0.8 × distance between antennal rim and inner edge of compound eye. Antenna 15-segmented, relative lengths of flagellomeres 1–13: 3.1, 2.8, 2.8, 2.7, 2.5, 2.4, 2.3, 2.2, 2.2, 2.2, 2.1, 2.2; first flagellomere incised on outer margin. Mesosoma less rugose, especially in area between anterodorsal margin, dorsal axillary area and median area of mesoscutellum; parapsidal signum broader; lateral marginal area of mesoscutum transversely wrinkled. Metasoma slenderer, spine shaped. Length of forewing (mean ± SD, n = 20) 2.56–3.52 (3.15 ± 0.21); length of hind tibia 0.64–1.02 (0.83 ± 0.08) mm.

**Asexual Generation.** Somewhat swollen twig; oval larval chambers, 1.0–1.5 mm in diameter and 2.5–3.0 mm in length each, aggregated but separated from one another by yellowish brown or brown wooden wall.

**Sexual Generation.** Somewhat swollen bud, its apical end slightly curved, but almost indistinguishable from the healthy bud on the basis of the outline; one to five larval chambers, 2.0 mm in diameter each, separated from one another by brownish yellow, thin and firm wall at the base of bud and visible by removing bud scales.

**Etymology.** The new species is named in honor of the late H. Masuda, who elucidated its life cycle.

**Diagnosis.** The main diagnostic feature for the genus *Plagiotrochus* Mayr is summarized as follows (Meika and Abrahamson 2002): the gena in the asexual female is broadened behind the eye; the clypeus with radiating striae, does not project as a distinct lamella between mandibles, the malar sulcus is absent; the mesopleuron is shiny, flat in the postero-dorsal margin and ventral area; the metasoma is compressed laterally; the scutellum is as long or only slightly longer than the metascutellum; the propodeum forms an obtuse angle with the scutellum; the lateral propodeal carinae are strongly bent outward, with a more or less impressed median carina; the ventral spine of the hypopygium is thin, with short sparse white setae not forming an apical tuft. *Plagiotrochus masudai* is easily distinguishable from other members of this genus by the following three characteristics: 1) the gena is broadened behind the compound eye in both asexual and sexual generations; 2) the mesopleuron is not shiny but dull; 3) the ventral spine of the hypopygium with dense setae, forming an apical tuft.

**Host Plant.** *Quercus* (*Cyclobalanopsis*) *glauca* (Yukawa and Masuda 1996).

**Geographic Distribution.** Japan: Honshu, Shikoku (Yukawa and Masuda 1996), Kyushu (new record).

**Life Cycle (Fig. 28).** According to Yukawa and Masuda (1996), the life cycle of *P. masudai* can be summarized as follows: the adults of the sexual generation emerge from buds of *Q. glauca* in April. The female wasp lays eggs in elongating shoots of the host plant. These shoots develop to form twigs, but galls are not induced in the first year. In the second year, the affected twigs become slightly swollen and the larvae develop in the latter half of the year. In May or June of the third year, the adults of the asexual generation emerge from the swollen twig and lay eggs in juvenile buds. The larvae then begin their development in summer and hibernate as larvae or pupae. In the spring of the fourth year, the adults of the sexual generation emerge from the bud galls and the cycle is repeated.
Discussion

Of the described oak-gall wasps (tribe Cynipini), *P. masudai* is the first known gall inducer on evergreen oaks of the Asian subgenus *Cyclobalanopsis*. One undescribed species of *Plagiotrochus* galling *Q. (C.) glauca* has been indicated from Taiwan (Melika et al. 2010), but it has not yet been described. Although two species of *Andricus* have previously been described as gall inducers (Cynipini) on *Cyclobalanopsis* in Japan (Shinji 1940, 1941), closer examination of their gall features (Yukawa and Masuda 1996) has suggested that these species are in fact inquiline gall wasps that have been erroneously assigned to the gall inducing wasps of the Cynnini.

Although the host plants of most species of *Plagiotrochus* are restricted to section *Cerris* (subgenus *Quercus*) oaks (Melika et al. 2009, 2010), *P. masudai* and one undescribed Taiwanese species of *Plagiotrochus* induce galls on *Cyclobalanopsis*, which suggests that other *Plagiotrochus* species also may induce galls in this subgenus in the Oriental and eastern Paleartic regions. Although the host plants of *P. folioli* Pujade-Villar & Melika and *P. smetanai* Pujade-Villar & Melika in Nepal are currently unknown (Melika et al. 2009), given the widespread distribution of *Cyclobalanopsis* oak species in the country, it is possible that these cynipid wasps also induce galls on oak trees of this subgenus.

Most Cynipini species exhibit alternation of generations within a year. Generally, the adults of the sexual generation emerge in spring and their offspring emerge as the asexual generation late in the fall of the same year (Yukawa and Masuda 1996, Stone et al. 2002). *P. masudai* also exhibits alternation of generations, but completion of the life cycle requires 3 yr, and the adults of the asexual generation emerge in spring (Fig. 28). A similar 3-yr life cycle has been reported in the oak-gall wasps *Andricus hakonensis* (Ashmead) and *Biorhiza pallida* (Olivier), but 1- and 2-yr cycles also have been reported in *A. hakonensis* (Yukawa and Masuda 1996, Wachi and Abe 2010) and a 2-yr cycle in *B. pallida* (Askew 1984). Although the sexual generation of other *Plagiotrochus* spp. induces galls on catkins and leaves (Melika and Abrahamson 2002), the sexual generation of *P. masudai* induces bud galls. However, as in other members of this genus, the asexual generation of *P. masudai* also induces twig galls. Thus, the life cycle of *P. masudai* spans 3 yr and is characterized by bud gall-induction by the sexual generation and spring emergence of asexual adults.

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