A taxonomic review of the Japanese *Trichogramma* (Hymenoptera: Trichogrammatidae) with descriptions of three new species

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Abstract

Numerous errors and confusion in the literature concerning the genus *Trichogramma* in Japan have necessitated a formal review of this genus. This review corrects and updates *Trichogramma* host and distribution records from Hokkaido to the Ryukyu Islands, redescribes and designates a lectotype for *T. jezoense* Ishii, records two *Trichogramma* species new to Japan (*T. ostriniae* Pang and Chen and *T. lingulatum* Pang and Chen) and describes three new species (*T. yabui* Honda and Taylor, *T. okinawae* Honda, and *T. aomoriense* Honda). Additionally a key to the species is provided for the 14 known Japanese species as are ITS-2 DNA sequences and SEM micrographs of male genital capsules for the majority of the species to aid biocontrol workers in *Trichogramma* identification.

Key words: Taxonomy; species description; Japanese *Trichogramma*; DNA sequence; male genital capsule

INTRODUCTION

Egg parasitoids of the genus *Trichogramma* Westwood (Hymenoptera: Trichogrammatidae) parasitize insect pests in over 32 million hectares of agricultural land and forests yearly (Li, 1994), and have been utilized as biological control agents for more than 100 years (Smith, 1996). Of the approximately 180 species described worldwide, about 70 species have been employed in biological control programs concentrating on various crops (corn, rice, wheat, sorghum, sugarcane, sugar beet, cotton, and soybean); fruits (apple, plum, citrus, avocado, and vineyards); and forest trees (pines and spruce) (Li, 1994; Pinto, 1999).

In Japan, *Trichogramma* were first used against the rice stem borer, *Chilo suppressalis* (Walker), in paddy fields during 1930–1940 with little success. In separate field trials, it was concluded that *Trichogramma chilonis* Ishii parasitism rates were too low for controlling *C. suppressalis* (Shibuya and Yamashita, 1936), while high superparasitism rates of *Trichogramma japonicum* Ashmead precluded it from being an effective biological control agent (Iyatomi, 1943; Shibuya and Iyatomi, 1950). More recent releases of *Trichogramma* species against the diamond back moth, *Plutella xylostella* (Linnaeus) (Iga, 1987; Miura et al., 2001; Miura, 2003) and the tobacco budworm, *Helicoverpa armigera* Hübner (Kakimoto et al., 1998) have been performed, but their use is still being evaluated. Three other species have been apparently imported into Japan. Iwasaki et al. (1998) released *Trichogramma evanescens* Westwood imported from France for the control of *Mamestra brassicae* (Linnaeus) in sugar beet fields in Hokkaido in 1997, but it is unknown if these releases became established.

*Trichogramma ostriniae* Pang and Chen was imported from Taiwan in Japan in 1987 (Hirashima et al., 1990), but it was not released in the field (Miura, pers. communication). However, Hirai (2004) recorded *T. ostriniae* as an indigenous natural enemy of *Ostrinia furnacalis* (Gueneé) and some tortricids from Japan, but this record was...
never verified. Test releases using Hirai’s cultured material was later used for *O. furnacalis* control in corn fields in 1992–93 (Yoshizawa, 1995). *Trichogramma brassicae* Bezdenko, another imported species of *Trichogramma*, was used in test releases for the control of *M. brassicae* in sugar beet fields in 1997 (Iwasaki et al., 1998) and for the control of *P. xylostella* in greenhouses in 1999 (Miura et al., 2001). Again their establishment has not been confirmed.

Despite the considerable international attention that *Trichogramma* has received as an important biological control agent, its taxonomy remains inadequately understood for a number of reasons. For example, the collection and curation of these minute (approximately 0.5 mm) parasitic wasps has proven difficult and greatly slowed the accumulation of study material (Platner et al., 1999). Moreover, the early disregard of type specimens has caused much confusion in the literature. Because a number of type specimens are lost, unusable, or described inadequately, many species names have been applied incorrectly and inconsistently in the literature (Pinto et al., 1978; Pinto and Stouthamer, 1994; Pinto, 1999). Finally, *Trichogramma* taxonomy also suffered from an absence of consistent distinguishing morphological characters (Pinto, 1999). This dilemma was partially resolved by Nagarkatti and Nagaraja (1971) who discovered the importance of the male genitalia as a diagnostic taxonomic character. DNA sequences have also been proposed as an aid to identification and used in a number of studies to characterize *Trichogramma* species (Pinto et al., 1997; Silva et al., 1999; Stouthamer et al., 1999).

The history of *Trichogramma* taxonomy in Japan exemplifies many of the taxonomic difficulties prevalent in the genus. For example, Nakagawa (1900) was the first to record *Trichogramma* from Japan by describing in morphological detail, the adult of a *Trichogramma* species parasitic on eggs of the rice stem borer. Although it has been suspected that this first description may be of *T. japonicum*, it can not be confirmed as none of the original material exists. Much later, Ishii (1941) was the first to produce a key to six Japanese *Trichogramma* species based on male genitalia; however, it proved little value as it lacked quantitative measures to aid in species discrimination. Moreover, morphologically important characters presently used to define species such as the dorsal lamina were not adequately described. Minamikawa (1964) later listed the following *Trichogramma* species from Japan: *Trichogramma australicum* Girault, *T. chilonis* Ishii, *T. dendrolimi* Matsumura, *T. evanescens* Westwood, *T. japonicum* and *T. jezoensis* Ishii. A seventh *Trichogramma* species, *T. papilionis* Nagarkatti, was added to the Japanese fauna (Nagarkatti, 1974). Since this time the status of Japanese *Trichogramma* taxonomy has changed greatly. Nagarkatti and Nagaraja (1979) concluded that Asian populations originally identified as *T. australicum* were actually *T. chilonis* and were subsequently synonymized. Pinto et al. (1982) later designated a lectotype for *T. australicum* and stated it remains known only from Girault’s original material collected in Queensland, Australia. Thus, *T. australicum* should no longer be considered a species found in Japan. Questions regarding the exact identity of *T. evanescens* were brought to light by Sugonyaev (1986) and Pinto (1999). It may be impossible to accurately assign this name to a specimen since the holotype of this species is a damaged female. Although both Ishii (1941) and Nagarkatti and Nagaraja (1971) recorded *T. evanescens* from Japan, their identifications may be erroneous as is discussed later in this paper. The status of *T. jezoensis* has also been questioned. Thought to be lost, we have found Ishii’s original material and designate a lectotype herein. Finally, four new species recently have been described from Japan: *T. yawarae* Hirai and Fursov (1998), *T. kurosuae* Taylor, Yashiro, Hirose, and Honda (Taylor et al., 2005), *T. cultellus* Jose, and *T. umerus* Jose (Jose et al., 2005).

This paper represents the first revision of Japanese *Trichogramma*. Herein we describe three new species and confirm two *Trichogramma* species (*T. ostriniae* Pang and Chen and *T. lingulatum* Pang and Chen) new to Japan. We provide a species key for all the known species of Japan, in addition to photomicrographs, and diagnostic descriptions of male genital capsules for most of the previously described *Trichogramma* species except for *T. kurosuae*, *T. cultellus*, and *T. umerus* that were recently covered in detail. Additionally, ITS2-DNA sequences that may aid workers in properly identifying *Trichogramma* have been identified, and we document reliable host records that we have verified through examination of preserved *Tri-
**Trichogramma evanescens** material including some material from Ishii’s original collections. Although the literature has recorded many hosts of *Trichogramma* species from Japan, most of the host records including those of Ishii (1941) and Minamikawa (1964) may be unreliable as their *Trichogramma* identifications may have been inaccurate.

We feel such a treatment is necessary at this time not only because many new species are being described in Japan, but also because of the apparent introduction of species into Japan. Accurate species identification is the most critical aspect of any biological control program and several biological control failures can be traced to incorrect natural enemy identifications (Gordh, 1976). Knowing which species occur in Japan may allow biocontrol workers to do two things: study any potential risks of future adventive *Trichogramma* species as advocated by Hirose (2002), and choose the best possible *Trichogramma* species for a given biological control program. It is hoped that this work will provide information for biocontrol workers to identify field collected material.

**MATERIALS AND METHODS**

Species descriptions and specimens prepared for scanning electron microscopy (SEM) and DNA analysis were based on methods previously described (Taylor et al., 2005). Specimens used for SEM were obtained from type localities for *T. yabui*, and *T. okinawae*. Species descriptions and measurements follow anatomical terminology, morphological measurements (± SEM), and ratios used in Pinto (1999). Illustrations for *T. yabui*, *T. okinawae*, *T. jezoense*, and *T. aomoriense* were derived from holotypes. Types are deposited at the Entomological Laboratory, Faculty of Agriculture, Kyushu University (ELKU) (Fukuoka, Japan), with the exception of *T. jezoense* which is deposited at the Laboratory of Insects Systematics, National Institute of Agro-Environmental Sciences (NIAES) (Tsukuba, Japan). Most of the other material examined is located at ELKU.

**TAXONOMY**

*Trichogramma yabui* Honda and Taylor sp. nov.

(Figs. 1–3)


**Diagnosis.** This species appears to be common in disturbed agricultural settings and is most likely to be confused with *T. evanescens* and *T. brassicae*. However, as Pinto (1999) points out, there is much confusion as to what constitutes either species as some researchers consider them conspecific. To further confuse matters, both Ishii (1941) and Nagarkatti and Nagaraja (1971) reported that *T. evanescens* occurs in Japan. We examined material from Ishii’s collection and determined what he described as *T. evanescens* was actually *T. dendrolimi* (see below), while Nagarkatti’s Japanese material is most likely *T. yabui*. Based on European material previously examined (Honda, unpublished data), we feel that both *T. evanescens* and *T. brassicae* are different species and also distinct from *T. yabui*. Discrimination between *T. evanescens* and *T. yabui* can be based primarily on the posterior expansion of the dorsal lamina as it is primarily delta shaped and very pointed at its apex in *T. evanescens*, but more rounded in *T. yabui*. The only noticeable difference between *T. brassicae* and *T. yabui* is that the volsellae in *T. yabui* are longer and almost reach the apex of the parameres while they are significantly shorter in *T. brassicae*, and occupy approximately half the distance of the parameres (see Pinto, 1999). Probably the most reliable way to discriminate between these three species is to compare their DNA sequences (see DNA Sequence section). *Trichogramma yabui* also resembles *T. okinawae* n. sp. and is distinguished from it in the following Diagnosis section.

**Description.** Based on 4 slide-mounted males, 2 slide-mounted females, reported as a mean. Color appearing dark in mounted material. Forewing 0.13 mm±0.13 wide; FWW/FWL=0.43±0.09; 8–9 setae between 4th and 5th tracks; longest fringe setae 0.15±0.08 FWW. Hind wing with 2 and 5 setae in anterior and posterior track, respectively, the latter attaining 0.2 distance from the hamuli to wing apex. Scutellum with anterior pair of setae equal in length to posterior pair.

Male: Flagellum of antennae elongate, slightly curved, 2.6 as long as scape, FL/FW=6.3±1.18, FL/HTL=1.13±0.06; moderately elongate, filiform setae taper gradually to apex, FSL/FWL=3.90±0.7; BPS formula 1-2(1)-1-1(0)-1-1; PLS only very slightly curved, terminal PLS with apical 0.15 extending beyond flagellum. Genital capsule
moderately broad, 0.36±0.24 as wide as long; slightly constricted at base of IVP; PM slightly sinuate and acuminate, convergent at apex; AD/GL = 0.21±0.03; AW/GW = 0.59±0.06; DAL/GL = 0.57–0.58; DLA originating from just below center of genital capsule, distinctly notched with rounded shoulders that do not approach sides of GC, forming a moderately broad linguiform posterior extension, acuminate at apex, whose width at IVP level is 1.5±0.23 more than that of aedeagus, DLA 2.13±0.5 as long as wide, its length from apex of DA = 1.5±0.21 AD and 0.49±0.06 GC; spine of VS ovoid, VS slightly bowed, occupying 0.65±0.06 of AD; IVP spinose occupying 0.57±0.14 AD; VR extremely broad at posterior half, narrowing anteriorly, occupying ca. 0.40 of BD. VP not obviously protuberant, positioned at base of IVP. Aedeagus subequal (0.99±0.06) of GL. AL/HTL = 1.07±0.09; apodemes 0.45±0.04 AL.

Female: Funicle of antennae 1 and 2 BPS on F1 and F2, respectively. OL/HTL = 0.93–1.2.

Variation. 1 male exhibited 17 setae between the
Table 1. Percentage of ITS-2 sequence similarity between selected *Trichogramma* species. NCBI database accession codes are found beneath each *Trichogramma* species in the rows.

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4th and 5th vein tracks.

**Types.** Holotype (male), allotype (female), and paratypes (12 males). JAPAN. Ishikawa Prefecture: Saita-cho, Kanazawa, vi-30-1997, collected by T. Yabu; ex eggs of *Ostrinia furnacalis* (Guénée) (Lepidoptera: Pyralidae) on sweet corn. Yabu; ex eggs of *Saita-cho, Kanazawa, vi-30-1997, collected by T. paratypes (12 males). JAPAN. Ishikawa Prefecture: 4th and 5th vein tracks.

**Etymology.** Named for the collector, Tetsuo Yabu.

**Host/Plant associations in Japan.** LEPIDOPTERA. Pyralidae: *Ostrinia furnacalis* (see types); Saturniidae: ex *Samia cynthia pryeri* (Butler) host trap card placed in vegetable garden (Takamori, Nagano Pref.).

**Distribution.** Known only in Japan (Honshu).

**Material studied.** 4 males, 2 females; 1 record.

**Records in Japan.** Honshu: Ishikawa Prefecture, Saita-cho, Kanazawa (see types); Nagano Prefecture, Takamori, vi-30-1997, 4 males and 2 females, M. Fukumoto.

**DNA sequence.** An ITS-2 DNA sequence has been deposited in the NCBI database (accession AY518696). DNA sequences range between 485–491 bp and 425–438 bp for *T. yabui* and *T. evanescens* (Silva et al., 1999), respectively. When a *T. evanescens* (accession AF043618) sequence was aligned with *T. yabui*, they showed 85% similarity in base pair composition (Table 1). Interestingly, *T. evanescens* sequences are most similar to *T. papilionis* (see under *T. papilionis*). A DNA sequence obtained from *T. brassicae* (accession AY163006) also was different from *T. yabui* as *T. brassicae* usually measures 406–407 bp and are 79% similar to *T. yabui*. Out of our sample comparison, *T. yabui* is most similar to *T. ostrinia* (89%). Collection data: Ishikawa Prefecture: Saita-cho, Kanazawa; vi-30-1997, ex *Ostrinia furnacalis*, T. Yabu.

**Trichogramma okinawae** Honda sp. nov. (Figs. 4–6)

**Description.** Based on 3 slide-mounted males (HTL=0.12±0.01 mm) and 5 females (HTL=0.12±0.01 mm). Color, olive yellow, mesoscutum suffused with brown, metasomal segments suffused with brown; vertex dark yellow with gena suffused with dark brown. Forewing (*n=5*) 0.20±0.01 mm wide; FWW/FWL=0.46±0.02; longest fringe setae 0.20±0.01 FWW.

Male: Flagellum of antennae moderately long and straight, FL/FW=5.40±0.07, FL/HTL=1.19±0.09; elongate, filiform setae tapering towards apex, FSL/FW=3.55±0.07; BPS, formula 1-1-2-0-1-1; PLS short, terminal PLS ending well before apex of flagellum. Genital capsule narrow, 0.33±0.01 as wide as long; slightly constricted at base of IVP, PM straight, not convergent towards apex; AD/GL=0.30±0.03; AW/GW=0.64±0.001; DAL/GL=0.57±0.03; DLA originating from middle of genital capsule, slightly notched with slight shoulders not extending beyond sides of genital capsule, narrowing posteriorly to a narrow linguliform posterior extension whose width at level of IVP is less
than that of aedeus. DLA 1.52±0.06 as long as wide, its length from apex of DA 1.18±0.01 AD and 0.32±0.001 GL, occupying 0.52±0.02 AD approaching PM apex and ending just prior or to VS; IVP fairly long, narrow, and spindle shaped, attaining 0.45±0.007 AD. VR narrow occupying 0.33±0.007 BD; VP small, not noticeably protuberant, and placed at base of IVP; spine of VS ovoid, VS straight, occupying 0.63±0.01 of AD; aedeagus longer than GL, extends dramatically past para-

meres. AL/HTL=1.10±0.02. Apodemes occupying 0.23±0.01 AL.

Female: OL/HTL=0.99±0.01.

Types. Holotype (male), allotype (female), and paratypes (2 males). JAPAN. Okinawa Prefecture: Takachiho, Shimoji; iii-05-2003; Y. Sadoyama collector; ex eggs of Tetramoera schistaceana (Snellen) (Lepidoptera: Tortricidae) on sugar cane.

Etymology. Named for the Japanese island on which it was collected.
Distribution. Known only from Okinawa Prefecture, Japan.

Host/plant association in Japan. LEPIDOPTERA. Tortricidae: Tetramoera schistaceana (see types).

Material studied. 11 males, 5 females; 5 records.

Records in Japan. Ryukyus: Okinawa Prefecture, Takachiho, Shimoji (see types); Yozu, xi-4-1997, 5 males, J. Honda; Kumadake, Hirara, iii-5-2003, 1 male, Y. Sadoyama; Nagama, Gusukube, iii-5-2003, 3 males and 2 females, Y. Sadoyama; Fukukita, Gusukube, iii-5-2003, 2 males and 3 females, Y. Sadoyama.

DNA sequence. An ITS-2 DNA sequence has been deposited in the NCBI database for reference (accession AY518695). The sequence measures 430 bp in length vs. 485–491 bp for T. yabui (82% similar) and 530 bp (74% similar) for T. umerus (accession AY518694). Sequence comparison shows that T. okinawae is most similar (85%) to T. brassicae (Table 1). Collection data: Okinawa Prefecture, Takachiho, Shimoji; iii-05-2003, ex Tetramoera schistaceana, Y. Sadoyama.

Trichogramma aomoriense Honda sp. nov. (Fig. 7)

Diagnosis. Possessing prominent lobed shoulders at the posterior extension of the dorsal lamina, this species possibly can be confused with T. jezoensis, T. dendrolimi, and T. chilonis. However, T. aomoriense can be discriminated between all three based on two main characters: the shape of the dorsal lamina shoulder and the ventral processes. The shoulders in T. aomoriense are very narrow and arise anteriorly of the genital capsule. Additionally, the shoulders extend distinctly beyond the edges of the genital capsule. The ventral processes are very pronounced and heavily sclerotized in T. aomoriense and are highly protuberant. They are less distinct in the other species.

Description. Based on 1 slide-mounted male (HTL=0.13 mm) and female (HTL=0.13 mm). Color appearing dark brown in slide mounted material. Forewing (male only) 0.25 mm wide; FWW/FWL=0.56; longest fringe setae 0.10 FWW.

Male: Flagellum of antennae short, slightly curved and inflated towards apex, FL/FW=4.0, FL/HTL=0.92; elongate, filiform setae taper abruptly at apex, FSL/FW=2.67; BPS formula apparently 1-1-2-0-1-1; PLS straight, terminal PLS with apex extending slightly beyond flagellum. Genital capsule moderately broad, 0.45 as wide as long; slightly constricted at base of IVP, PM slightly arcuate, slightly convergent at apex; AD/GL=0.21; AW/GW=0.60; DAL/GL=0.61; DLA originating from anterior half of genital capsule, highly sclerotized, notched with prominent shoulders extending beyond sides of genital capsule, narrowing posteriorly to a narrow linguiform posterior extension whose width at level of IVP is equal or slightly greater than that of aedeagus. DLA 1.11 as long as wide, its length from apex of DA 2.08 AD and 0.42 GL, occupying 0.87 AD approaching PM apex and ending prior to VS; IVP

Fig. 7. T. aomoriense n. sp. (Holotype). (a) Forewing. (b) Antenna. (c) Dorsal (left) and ventral (right) view of the male genital capsule. (d) Hind wing. Scale bars=0.05 mm.
distinct and triangular, attaining 0.39 AD. VR narrow, occupying 0.55 BD; VP prominent, highly, sclerotized, and protuberant. Somewhat extended into AD, positioned at base or slightly interior to IVP. VS straight, occupying 0.88 of AD. Aedeagus slightly longer than GL. AL/HTL = 0.92. Apodemes occupying 0.52 AL.

Female: OL/HTL = 1.03.

Types. Holotype (male), and allotype (female). JAPAN. Aomori Prefecture: Ipponmatsu, Towada City; xi–4–1975; K. Mori collector; ex eggs of *Neozephyrus taxila japonicus* (Murray) (Lepidoptera: Lycaenidae) on alder.

Etymology. Named after the Japanese prefecture Aomori from which this species was first collected.

Distribution. Known only from type locality in Aomori Prefecture, Japan.

Host/plant association in Japan. LEPIDOPTERA. Lycaenidae: *Neozephyrus taxila japonicus* (see types).

Material studied. 3 males, 2 females; 1 record. Two additional dissected male genital capsules and an additional female collected with the type specimens were found mounted on separate slides and were also examined.

Record in Japan. Honshu: Aomori Prefecture, Ipponmatsu, Towada City, 3 males, 2 females (see types).

**Trichogramma ostrinia**e *Pang and Chen* New Japan Record (Figs. 8–10)


Diagnosis. A thorough diagnosis can be found in Oatman et al. (1982), Pinto (1999), and Chan and Chou (2000). The adenate ventral processes and dark coloration in *T. ostrinia*eae are unique to this species in Japan. A description of *T. ostrinia*eae is given below from Japanese collected specimens.

Description. Based on cultured material. Unless otherwise indicated, quantitative data taken from seven males (HTL = 0.1–0.16) and six females (HTL = 0.14–0.16). Forewings 0.18 ± 0.05 mm wide; FWW/FWL = 0.50 ± 0.04; 6–8 setae between 4th and 5th vein tracks; longest fringe setae 0.15 ± 0.04 FWW, ca. 1.2 times the HTW. Hind wing with 0–3 and 0–6 setae in anterior and posterior track, respectively, the latter attaining 0.2 distance from the hamuli to wing apex. Scutellum with anterior pair of setae subequal to posterior pair.

Male: Flagellum of antennae slightly curved, 0.17 ± 0.06, about twice as long as scape, FL/HTL = 6.13 ± 0.4, FL/HTL = 1.04–1.25 (n = 6); moderately elongate, filiform setae taper gradually to apex, FSL/FL = 3.3 ± 0.4 (3.0–4.0); unsocketed setae absent; BPS subglobose, PS formula 1-1-(2)-1-1-1; terminal PLS does not extend beyond tip of flagellum. Genital capsule widest at anterior of center of capsule, 0.37 ± 0.05 as wide as long; sides gradually convergent from widest aspect, slightly constricted at base of IVP. PM relatively straight and acuminate, slightly convergent at apex; AD/GL = 0.25 ± 0.01; AW/GW = 0.59 ± 0.03; DAL/GL = 0.6 ± 0.05; DLA originating from anterior third of capsule, with a slight notch that never attains the sides of the capsule and with poorly developed shoulders, gradually tapering to a sublinguiform posterior extension whose width at IVP level is 0.86 ± 0.22 that of aedeagus, and subequal to length of volsellae. DLA 1.7 ± 0.10 as long as wide, its length from apex of DA 1.28 ± 0.16 X AD; VS slightly bowed, narrowing apically, occupying 0.59 ± 0.07 AD, volsellar spines prominent, subconical, asymmetrical, typically spine on right VS directed more dorsilaterally, longer and more arcuate than spine on opposing volsellae. IVP spinose, subequal to VS, occupying 0.46 ± 0.10 of AD; VR elongate, parallel, extends from base of IVP, ca. 0.33 of BD. VP prominent, protuberant, positioned ventrolateral and dorsolateral at base of IVP. Aedeagus subequal ± 0.06 GL. AL/HTL = 0.75 ± 0.25; apodemes ca. 0.47 ± 0.09 AL.

Female: Funicle of antennae typically 1 BPS on F1 and F2. OL/HTL = 1.06 ± 0.14.

Type. Holotype male. CHINA. Beijing; *Ostrinia nubilalis*; viii–3–63; Chen Tai-lu; Beijing Institute of Zoology; not examined.

Distribution. China (Pang and Chen, 1974), Hawaii (Oatman et al., 1982), and introduced into USA in 1990 (Pinto, 1999). Japan new record.

Host/plant association in Japan. LEPIDOPTERA. Pyralidae: *Ostrinia furnacalis* on corn.

Material studied. 7 males, 6 females; 1 record.


DNA sequence. DNA sequences were obtained from specimens collected in Izumo, Shimane Pre-
fecture on *Ostrinia furnacalis* eggs. An ITS-2 DNA sequence has been deposited in the NCBI database for reference (accession AY518695). The sequence measures 445 bp in length and was found to be ≥98% identical to a *T. ostriniae* sample previously submitted from China (accession AY244463). The sequence of *T. ostriniae* appears to be most similar to *T. yabui* (89% [Table 1]). Collection data: Shimane Prefecture, Izumo; 1990, ex *Ostrinia furnacalis*, T. Murai.

*Fig. 8.* Dorsal view of *T. ostriniae* male genital capsule. Scale bar=50 μm.

*Fig. 9.* Ventral view of *T. ostriniae* male genital capsule. Scale bar=50 μm.

*Fig. 10.* *T. ostriniae* male. (a) Forewing. (b) Antenna. (c) Dorsal (left) and ventral (right) view of the male genital capsule. (d) Hind wing. Scale bars=0.05 mm.

**Trichogramma lingulatum** Pang and Chen  New Japan Record  (Figs. 11 and 12)  

**Diagnosis.** This species is closely allied to the Indian species *T. hesperidis* Nagaraja, *T. flandersi* Nagaraja and Nagarkatti, and *T. achaeae* Nagaraja and Nagarkatti in addition to *T. kurosuae* in Japan. All are characterized by a broad, linguiform posterior extension of the dorsal lamina. This extension obscures the parameres and volsellae dorsally in *T.
flandersi and T. hesperidis as well as T. lingulatum, however, the two former species possess distinct notches at the base of the dorsal lamina which is not present in T. lingulatum. The dorsal lamina of T. achaeae while not notched at its base, does not obscure the parameres and volsellae. Trichogramma kurosuae is yellow with a notched base whose dorsal lamina obscures the volsellae, but not the parameres and can be easily distinguished from the darker T. lingulatum.

**Description.** Quantitative data taken from four males (HTL=0.10–0.14 mm). Forewing data taken from one male. Forewing 0.17 mm wide; FWW/FWL=0.47; longest fringe setae 0.21 FWW, ca. 1.9 the HTW.

**Male:** Flagellum of antennae short, fairly straight, 0.10±0.02, about 1.5 times the length of the scape, FL/FW=4.7±0.5, FL/HTL=0.82±0.04, moderately elongate, filiform setae taper gradually to apex, FSL/FW=1.85±0.06; unsocketed setae absent; BPS subglobose, BPS formula apparently 1-1-1-1-1-0; terminal PLS does not extend beyond tip of flagellum. Genital capsule widest at anterior of center of capsule, 0.38±0.01 as wide as long; sides gradually convergent from widest aspect, slightly constricted at base of IVP; PM relatively straight, slightly convergent at apex; AD/GL=0.17±0.01; AW/GW=0.47±0.06; DAL/GL=0.66±0.03; DLA originating near middle of capsule, not notched basally and without shoulders, not narrowing towards posterior and forming a broad linguiform posterior extension whose width at apex of IVP is ca. 0.9 that of aedeagus, elongate obscuring both PM and VS in dorsal view. DLA 1.8±0.20 as long as wide, its length from apex of DA 2.67±0.12 X AD and 0.47±0.02 GL, occupying 1.19±0.12 AD; VS slightly bowed, occupying 0.73±0.06 AD. IVP short, spinose, subequal to VS, occupying 0.19±0.2 of AD; VR elongate, parallel, occupying 0.58±0.06 BD. VP prominent, protuberant and located considerably anterior to base of IVP. Aedeagus equal to GL. AL/HTL 0.99±0.08; apodemes ca. 0.51±0.03 AL.

**Types.** Holotype male. CHINA. Shantung; un-
known Lepidoptera host; v-1-1958; Mao Jing-long; Beijing Institute of Zoology; not examined.

**Distribution.** China (Pang and Chen, 1974). Japan new record.

Host/plant association in Japan. LEPIDOPTERA. Saturniidae: ex. *Samia cynthia pryeri* (Butler) host trap card on mulberry.

**Material studied.** 4 males; 1 record.


**Trichogramma jezoense Ishii** (Fig. 13)

*Trichogramma jezoensis* Ishii (1941): 175.

**Diagnosis.** *Trichogramma jezoense* is closest to *T. chilonis* in that they both possess prominent lateral lobes that do not extend to the edge of the genital capsule as in *T. dendrolimi*. *Trichogramma jezoense* differs from *T. chilonis* having a darker color as Ishii (1941) has stated that this is a darker species and *T. chilonis* is a yellow species with a brownish abdomen. The male flagella also have a higher width to length ratio range (0.21–0.24) than *T. chilonis* (0.15–0.19) (Chan and Chou, 2000). The general shape of the genital capsules is also different. The capsule of *T. jezoense* is smaller and more tear-shaped (0.61±0.01 as wide as long) while *T. chilonis* is robust and oval in shape (0.47–0.59 as wide as long) according to the data of Chan and Chou (2000) for *T. chilonis*. The AL/HTL ratio is also higher in *T. jezoense* ranging from 0.81–1.07 vs. 0.66–0.80 (Chan and Chou, 2000) as is the female OL/HTL ratio which averages 1.16 and 1.05 for *T. jezoense* and *T. chilonis*, respectively.

**Description.** Unless otherwise indicated, quantitative data taken from two males (HTL=0.11–0.14 mm). Color unknown but described as dark by Ishii (1941) for both males and females. Forewing slightly fumate behind venation. Forewing 0.24±0.03 mm wide; FWW/FWL=0.55±0.01; longest fringe setae 0.14±0.02; FWW, ca. 1.5 the HTW.

Male: Flagellum of antennae slightly curved, 0.14±0.01 long, about two times as long as scape, FL/FW=4.37±0.3, FL/HTL=1.10–1.21; moderately elongate, filiform setae taper gradually to apex, FSL/FW=2.9±0.1 (2.27–2.29); BPS subglobose, BPS formula apparently 2-1-2-1-0-1 (only holotype examined); terminal PLS does not extend beyond tip of flagellum. Genital capsule markedly tear-shaped; widest at anterior of center of capsule, 0.61±0.01 as wide as long; sides convergent from widest aspect, slightly constricted at base of IVP, PM tapering slightly and convergent at apex; AD/GL=0.28±0.01; AW/GW=0.65±0.06; DAL/GL=0.64±0.03; DLA originating at middle of capsule, with a deep notch that never reaches the sides of the capsule and with well developed, rounded shoulders, gradually tapering to apex forming a subtriangular posterior extension whose width at IVP level is subequal to that of aedeagus width, apex of extension generally pointed, and subequal to length of volsellae. DLA 1.0±0.05 as long as wide, its length from apex of DA 0.92±
0.10 AD and 0.26±0.05 GL, occupying ca. 0.50 AD; VS slightly bowed, occupying 0.71±0.01 AD; IVP subtriangular, subequal to VS, occupying 0.44±0.01 of AD; VR broad, parallel, extends from base of IVP tapering slightly anteriorly, ca. 0.40 of BD (visible in holotype only); VP prominent, protuberant, positioned at base of IVP. Aedeagus subequal to GL. AL/HTL 0.80±0.02; apodemes ca. 0.49±0.02 AL.

Female: OL/HTL 1.16±0.66 (n=3).

Types. Lectotype male, designated herein circled in ink. Japan. Sapporo: ix-8-1937; collected from the eggs of *Leguminivora* (=*Grapholita*) *glycinivorella* (Matsumura) by H. Kono.

Distribution. Known only from Japan (Hokkaido and Honshu).

Host/plant associations in Japan. LEPIDOPTERA. Pyralidae: *Conogethes punctiferalis* (Guenée); Tortricidae: *Leguminivora glycinivorella*, *Grapholita molesta* (Busck).

Material studied. 7 males, 4 females; 3 records.


*Trichogramma yawarae* Hirai and Fursov (Fig. 14)

*Trichogramma yawarae* Hirai and Fursov (1998):

Diagnosis. *Trichogramma yawarae* displays all the critical characters which define the Retorridum Section. This small species group is exemplified by straight volsellae and a comparatively short inter-volsellar process. As in most of these species, hind wings of *T. yawarae* have complete anterior and posterior setal tracks. Like the North American species, *T. retorridum* (Girault), *T. yawarae* is distinguished by an elongate VR, almost 0.75 of BD, with the ventral processes positioned distinctly anterior of the inter-volsellar process and laterally to the ventral ridge. The slender, subsinuate dorsal lamina most closely resembles that of the nominal species but the elliptical DA is not as narrow at its apex as in *T. retorridum*.

Description. Based on two slide-mounted males originating from a culture initiated from a single, unmated female. Color appearing light gray in mounted material; area of forewing behind venation noticeably darkened. Forewing 0.18 mm wide; FWW/FWL=0.46–0.47; 9–13 setae between 4th and 5th tracks; longest fringe setae 0.02–0.03 FWW. Hind wing with 1 and 6 setae in anterior and posterior track, respectively, the latter attaining 0.03 distance from the hamuli to wing apex. Scutellum with anterior pair of setae long, equal in length to posterior pair.

Male: Flagellum of antennae elongate, very slightly curved, 0.17–0.18 mm, slightly longer than scape, FL/FW=5.8–6.3, FL/HTL=1.02–1.08;
moderately elongate, filiform setae taper abruptly at apex, FSL/FW = 2.4–2.5; unsocketed setae present on F1; formula 2-1-1-1(0)-1(0)-1; terminal PLS does not extend beyond apex of flagellum. Genital capsule widest in anterior half just below center of capsule, 0.35–0.36 as wide as long; sides gradually convergent from widest aspect, moderately constricted at base of IVP. PM straight and acuminate, very slight convergent at apex; AD/GL = 0.22–0.24; AW/GW = 0.47–0.50; DAL/GL = 0.59–0.61; DLA originating from anterior half, not notched at base but immediately narrowing posteriorly, forming a slender linguiform posterior extension whose width at IVP level is ca. a half less than that of aedeagus, elongate and subequal to length of volsellae. DLA 1.6–1.9 as long as wide, its length from apex of DA = 1.0–1.25 AD; VS subrectangular in shape and truncate, occupying 0.75–0.86 AD; VS spines oval, some sclerotization on median surface of volsellae, parallel to apex of IVP. IVP short, subtriangular, less than half the length of VS, occupying only 0.35–0.47 of AD; VR elongate, extends from base of IVP to 0.75 BD. VP papilliform, positioned distinctly anterior to base of IVP, lateral to VR. Aedeagus 1.05–1.07 times greater than positioned distinctly anterior to base of IVP, lateral

**Trichogramma chilonis Ishii** (Figs. 15 and 16)


**Diagnosis.** A thorough diagnosis and description is given by Oatman et al. (1982), and Chan and Chou (2000). The SEM images depict several characters defining T. chilonis: prominent lateral lobes (not extending to the edge of the genital capsule), the dorsal lamina the sublinguiform posterior extension abruptly narrowing above the shoulders which reach the level of the volsellae, an elongate and narrowly subtriangular intervolsellar process and papilliform ventral processes just basal to the intervolsellar process. See remarks above to distinguish from T. jezoense.

**Types.** Lectotype male designation; National Institute of Agro-Environmental Sciences, Tsukuba, Japan; examined.

**Host/plant associations in Japan.** LEPIDOPTERA. Danaiidae: Anosia chrysippus chrysippus (Linnaeus); Hypsidae: Asota ficus on fig; Lycaenidae: Zizeeria maha argia (Menetries) (Hirose, 1976); Lymantriidae: Euproctis similis (Fuessly) on mulberry; Noctuidae: Autographa nigrisigna


**DNA sequence.** An ITS-2 DNA sequence has been deposited in the NCBI Database (accession AY518697). The sequence measures 496 bp and is only 42% and 47% similar to T. japonicum and T. brevicapillum Pinto and Platner, respectively. We chose these comparisons as they all belong to the Retorridum Section; however, T. yawarae neither resembles these two species morphologically nor does it share similarity in ITS-2 sequence. Collection data: Fukuoka Prefecture, Nagai, Ikuhashi, viii-27-1997, ex Marasmia exigua, J. Honda.

**Material studied.** 34 males, 1 female; 19 records.


**DNA sequences.** DNA sequences were obtained from many *T. chilonis* populations throughout Japan (Kagoshima, Fukuoka, and Okinawa) and Korea (Cheju Do) and ranged from 410–414 bp. One 413 bp long sequence was deposited in the NCBI Database for reference (accession AY89017). Comparisons were made with a *T. chilonis* sequence obtained from the NCBI database (accession U74674) and were found to be ≥98% identi-

*Trichogramma dendrolimi* Matsumura (Figs. 17 and 18)


**Diagnosis.** A thorough diagnosis and description is given by both Nagarkatti and Nagaraja (1971) and Chan and Chou (2000). The SEM photographs clearly represent the distinguishing characters of *T. dendrolimi*: a dorsal lamina with prominent shoulders extending to the edge of the genital capsule with deep notching, and a prominent subtriangular intervolvellar process (equal in length to the volsellae) occupying about 75% of the apical distance.

**Types.** No type specimen exists for *T. dendrolimi*.

**Distribution.** Japan (Hokkaido, Honshu, Shikoku, and Kyushu) (Ishii, 1941), Russia, Belarus, Ukraine, Moldavia, Kazakhstan, Western Europe (Sorokina, 1993), China (Pang and Chen, 1974), and Taiwan (Chan and Chou, 2000).

**Host/plant associations in Japan.** Lepidoptera. Hypsidae: *Asota ficus* on fig; Lasiocampidae: *Dendrolimus spectabilis* (Butler) on pines (Nagarkatti and Nagaraja, 1971), *D. superans* (Butler) on Himalayan cedar; Limacodidae: *Monema flavescens* Walker on willow, *Scopelodes contractus* Walker on willow; Lymantriidae: *Euproctis pseudoconspersa* (Strand) on camellia (Mizuta, 1981); Noctuidae: *Autographa gamma* (Linnaeus) on sugar beet, *Spodoptera litura* on taro (Hamada, 1992); Notodontidae: *Clostera anatominos* (Linnaeus) on poplar; Nymphalidae: *Inachis io geisha* Stichel on *Humulus lupulus* (Hondo et al., 1995); Papilionidae: *Papilio xuthus* on citrus (Hirose et al., 1980); *P. proterno demetrius* on *Zanthoxylum ailanthoides* (Watanabe et al., 1984); Pyralidae: *Notarcha (=Sylepta) derogata* Fabricius (Ishii, 1941), *Ostrinia furnacalis*; Saturniidae: *Caligula japonica japonica* (Moore); Tortricidae: *Grapholita molesta* (Ishii, 1941), *Homona magnanima* Diakonoff.

**Material studied.** 25 males, 1 female; 16 records.


**DNA sequence.** DNA sequences were obtained from cultured material and measured around between 399–403 bp. One 399 bp long sequence was deposited in the NCBI Database for reference (accession AY895013). Comparisons were made with *T. dendrolimi* sequences obtained from the NCBI database (accession AF422845 and AY244464) and were found to be ≥98% identical. Collection data: Shikoku: Ehime Prefecture, Shimomitani, Iyo, viii-12-2003, ex *Asota ficus*, M. Aono.

**Trichogramma papilionis** Nagarkatti (Figs. 19 and 20)


**Diagnosis.** A thorough diagnosis and description can be found in both Nagarkatti (1974) and Oatman et al. (1982). The SEM photos represent a few distinctive features of *T. papilionis*: rectangular and truncate volsellae clearly separate from the parameres, an obviously robust intervolcellar process with adnate and prominent ventral processes and a dorsal lamina with slightly developed shoulders and a sublinguiform posterior extension. These features coupled with a distinctly orange yellowish color distinguish it from *T. ostriniae* (below).

**Types.** Holotype male, Japan; Hakozaki, Fukuoka Prefecture; *Papilio xuthus*; x-1970; Y. Hirose; U.S. National Museum, Washington, D.C. Registered USNM No. 37107; not examined.

**Distribution.** Japan (Honshu and Kyushu) (Nagarkatti, 1974) and Hawaii (Oatman et al., 1982).

**Host/Plant associations in Japan.** LEPI-

**Fig. 19.** Dorsal view of *T. papilionis* male genital capsule. Scale bar=50 μm.

**Fig. 20.** Ventral view of *T. papilionis* male genital capsule. Scale bar=50 μm.

**Diptera.** Lycaenidae: *Neozeprurus taxila japonicus* on alder; *Zizeeria maha argia*; Noctuidae: *Ctenoplusia albostriata* (Bremer et Grey) on *Solidago altissima*; Nymphalidae: *Dichorragia nesimachus nesiotes* Fruhstorfer; Papilionidae: *Papilio memnon thunbergii* von Siebold (Nagarkatti, 1974), *P. xuthus* on citrus (Hirose et al., 1980); Pieridae: *Pieris rapae crucivora* Boisduval on cabbage; Sphingidae: *Theretra silhetensis* on taro.

**Material studied.** 27 males, 5 females; 9 records. **Records in Japan.** Honshu: Aomori Prefecture,

**Diagnosis.** A thorough diagnosis and description can be found in Nagarkatti and Nagaraja (1971), Oatman et al. (1982), Hirai and Fursov (1998), Pinto (1999), and Chan and Chou (2000). See Pinto (1999) for SEM photographs. The anatomical features distinguishing *T. japonicum* include: a uniformly wide dorsal lamina base, elongate nearly parallel parameres and an exceptionally long apical distance (0.34±0.01 the genital length) (Pinto, 1999).

**Types.** Lectotype male (designated by Oatman et al., 1982). Japan Gifu; “bred... from unknown lepidopterous eggs”; Y. Nawa; USNM (no. 7218); not examined.

**Distribution.** Japan (Ishii, 1941), India, Vietnam, Thailand, Hawaii, Malaysia, Philippines (Sorokina, 1993), Canada, and Australia (Pinto, 1999), China (Pang and Chen, 1974), and Taiwan (Chan and Chou, 2000).

 HOST/plant associations in Japan. LEPIDOPTERA. Hesperiidae: *Parnara guttata guttata* on rice (Nakasuji, 1982); Pyralidae: *Chilo suppressalis* on rice (Ishii, 1941), *Marasmia exigua* on rice.

**Material studied.** 5 males, 4 females; 2 records.


**KEY TO THE TRICHOGRAMMA SPECIES OF JAPAN**

(Proper identification requires slide-mounted specimens and refers to male specimens only; SEM photographs may also aid in identification.)

1. Dorsal lamina broad and rounded with a linguiform posterior extension obscuring at least the volsellae in dorsal view .... 2

1’. Dorsal lamina not as above .......... 3

2(1). Body light yellow, dorsal lamina notched at base with posterior extension obscuring the volsellae in dorsal view

........................................... *T. kuosuae*

2’. Body dark brown, dorsal lamina not notched at base with posterior extension obscuring both volsellae and parameres

........................................... *T. lingulatum*

3(1’). Intervolsellar process short, poorly developed, and occupying 0.20 (or less) the apical distance .. ............... 4

3’. Intervolsellar process prominent, well developed, and occupying greater than 0.33 the apical distance .......... 5

4(2’). Dorsal lamina broad at base, parameres elongate and straight; apical distance 0.34 the genital capsule length

........................................... *T. japonicum*

4’. Dorsal lamina narrow with a sharply tapering posterior extension; parameres slightly convergent at apex; apical distance 0.19 the genital capsule length

........................................... *T. cultellus*

5(3’). Intervolsellar process with adnate ventral processes .................
5’. Intervolsellar process without adnate ventral processes. ............................7

6(5). Volsellae truncate, rectangular, and clearly separate from parameres; intervolsellar process with slightly curved sides, light colored ..............T. papilloniis

6’. Volsellae not as above and appear attached to parameres; intervolsellar process with straight sides. Darkly colored .................................. T. ostriniae

7(5’). Genital capsule relatively broad, 0.4–0.6 as wide as long; lobes of dorsal lamina prounced ..............................................8

7’. Genital capsule not as broad, only 0.35 (or less) as wide as long ............11

8(7). Lobes of dorsal lamina reach or surpass the edge of the genital capsule .......9

8’. Lobes of dorsal lamina do not reach the edge of the genital capsule ..........10

9(8). Lobes of dorsal lamina narrow and extending beyond genital capsule; ventral processes prominent, bulbous, and highly sclerotized ...........T. aomoriense sp. nov.

9’. Lobes of dorsal lamina and ventral processes not as above..............T. dendrolimi

10(8’). Body yellow with brownish abdomen; genital capsule oval ..............T. chilonis

10’. Body dark; genital capsule distinctly tear-shaped .......................T. jezoense

11(7’). Apical width (AW) approximately 0.50 the maximum genital capsule (GC) width .................................................... T. yawarae

11’. Apical width (AW) 0.55 (or more) the maximum genital capsule (GC) width ...........................................................................11

12(11’). Aedeagus length exceeding 1.00 times the hind tibial length ...........13

12’. Aedeagus length only 0.77 times the hind tibial length .....................T. umerus

13(12). Body light in color; aedeagus exceeds genital capsule length; parameres straight and parallel; dorsal lamina length from apex of the dorsal aperture is approximately 1.18 times that of the apical distance and the volsellae occupy 0.52 of the apical distance ..............T. okinawae sp. nov.

13’. Body dark in color; aedeagus subequal to genital capsule length; parameres sinuate and acuminate; dorsal lamina length from apex of the dorsal aperture is approximately 1.50 times that of the apical distance and the volsellae occupy 0.65 of the apical distance ....... T. yabui sp. nov.

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