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ORIGINAL ARTICLE

# A new species of *Anastatus* (Hymenoptera: Eulpelmidae) from China, parasitizing eggs of *Lycorma delicatula* (Homoptera: Fulgoridae)

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**Abstract** A new species of *Anastatus* Motschulsky, 1859 (Hymenoptera: Eupelmidae), *A. orientalis* Yang & Choi，**sp. nov.** is described from China. It is a solitary endo-parasitoid in egg of the spotted lanternfly, *Lycorma delicatula* (White) (Homoptera: Fulgoridae), which causes damages to many ornamental and fruit trees in China. The brief biology of the new parasitoid is also mentioned. The new species has high potential as a biocontrol agent for suppression of the pest because of its parasitism rates of egg masses 30.4% and of eggs 40.2% respectively with sex ratio of female to male 1.9:1.0, as well as the relative easiness for mass rearing. The detailed feature characters and photos of the new species are supplied. Meanwhile, a key to distinguish the present new species from the other close two (*A. japonicus* and *A. bifasciatus*) in the genus is provided. Type specimens are deposited in the Insect Museum, Chinese Academy of Forestry, Beijing, China.

**Key words** Egg parasitoid, new species, *Anastatus*, biocontrol agent, *Lycorma delicatula*, China.

## 1 Introduction

The spotted lanternfly, *Lycorma delicatula* (White) (Homoptera: Fulgoridae), is native to China, Japan, Vietnam and India (Chou *et al.*, 1985). In China, it distributed in most areas in the country, mainly attacking *Ailanthus altissima* and many other ornamental and fruit tree species, such as *Toona sinensis, Ulmus pumila, Catalpa bungei, Vitis vinifera*, *Prunus* spp., *Malus* spp. *Populus* spp., *Salix* spp., *Quercus* spp., *Platanus* spp. and *Acer* spp. *etc*., as well as soybean and some agricultural crops (Chou *et al.*, 1985; Xiao, 1992). The pest was first reported to invade in Korea in 2008 (Han *et al*., 2008). Since then, it has expanded rapidly throughout the country (Park *et al*., 2009). It is thought to have been accidentally introduced from China and has successfully established based on its high population in several locations in Western Korea in 2006 (Han *et al*., 2008). It was found in USA in 2014 and right now in just Berks County of Pennsylvania (Freifelder, 2014; Pennsylvania Department of Agriculture, 2014).

Recent years, the pest has caused a serious damage in grapevine yards, arbores and fruit trees in Korea (Xing *et al*., 2000; Kim *et al*., 2011). For biological control purpose, an international cooperative project on its natural enemy investigation and the development of mass rearing technique of the egg parasitoid was carried out between the Research Institute of Forest

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Ecology, Environment and Protection, Chinese Academy of Forestry (CAF) and the National Academy of Agricultural Science (CAAS) and the Rural Development Administration (RDA) of Korea in 2011. During the survey, an egg parasitoid of *L. delicatula* was found in Northern China, including Beijing, Hebei, Shandong and Shaanxi Provinces. After careful taxonomic research, it is reported as a new species to science, *Anastatus orientalis* Yang & Choi **sp. nov.** (Chalcidoidea: Eupelmidae). Here we described the new species and provide biological observations, as well as a discussion of its biocontrol potential. The type specimens are deposited in Insect Collections of CAF, Beijing.

The genus *Anastatus* is well known for some species developing as parasitoid in eggs of some very harmful defoliators. The known species of *Anastatus* mostly parasitize eggs of Lepidoptera and Homoptera, and few species are parasitic in eggs of Orthoptera, Mantodea and cockroaches (Bouček, 1988). Till now, 153 species have been described worldwide (Noyes, 2015). The female of *Anastatus* is distinguished from other Eupelmidae genera by: 1). gaster widens towards the apex, a pale, mostly white, cross-band on the short second tergite; 2). forewing with an extensive infumation interrupted by a curved whitish cross band which is sometimes reduced to two sports; 3). mid tibia widens and the apex and there, on the anterior side, usually as if partly cleft by a distinct groove outside of a group of several black or brown peg-like spines; 4). pronotum divided medially, transverse suntriangular without distinctly differentiated collar and neck, usually concave. The male of *Anastatus* with feature pteromalid-like, but the flagellum rather stout, particularly with first funicle curved, and clava elongate and undivided (Bouček, 1988; Gibson, 1995).

The genus *Anastatus* has been studied mainly by following entomologists: Nikolskaya (1952) keyed to 6 species of former USSR; Ferrière (1954) revised European species of the genus and gave a key to 10 brachypterous species; Burks (1967) reviewed North American species dealing with 14 species in the area; Kalina (1981) reviewed species of the Palaearctic and recognized 22 species in the region; Bouček (1979) erected a subgenus *Cladanastatus* according to an Indian species, *Anastatus* (*Cladanastatus*) *umae* Bouček, 1979, which is parasitic in cockroaches (thus, the genus has separated into two subgenus: *Anastatus* and *Cladanastatus* right now), he then studied the species in the Australasian areas and found 40 species there (Bouček, 1988); Gibson (1995) revised the genera of Eupelminae (Hymenoptera: Eupelmidae) and well defined the genus *Anastatus*, as well as the two subgenus in the genus, *i.e.* subgenus *Anastatus* and *Cladanastatus*. Meanwhile, he created a new species group, *clavatus*, in the subgenus *Anastatus* (therefore the subgenus *Anastatus* was recognized having two species group: *bifasciatus* and *clavatus*). Narendran (2009) reviewed the species of the Indian subcontinent and recognized 28 species from the region, including 13 new species to science from India.

Three Chinese species of *Anastatus* were reported by Liao (1978): *A. disparis* (Ruschka), *A. acherontiae* Narayanan *et al*. and *Anastatus* sp. Sheng *et al*. (1997) described four new species in China: *A. shichengensis* Sheng & Wang, *A. dexingensis* Sheng & Wang, *A. flavipes* Sheng & Wang and *A. fulloi* Sheng & Wang. Sheng and Yu (1998) described another two new species parasitizing pine caterpillars: *A. meilingensis* Sheng and *A. huangi* Sheng & Yu. Xian *et al*. (2008) reported *A. japonicus* Ashmead parasitizing *Tessaratoma papillosa* (Hemiptera: Pantatomidae) and the species has been used to control the bug pest on litchi tree from the 1960' of last century in Southern China (Pu, 1978).

## 2 Materials and methods

Overwintering egg masses of *L. delicatula* were collected from five regions in China (Yangling, Shaanxi Province; Qinhuangdao, Hebei Province; Yantai, Shandong Province; Guangang, Tianjin; Haidian, Beijing) in April from the host tree trunk (*Ailanthus altissima, Toona sinensis, Populus* spp. and *Salix* spp.). Because the egg mass was laid on the surface of host tree bark of both trunk (mainly) and branch, covered with lutescens powder (Figs 27–28), the individual egg mass attached with bark were cut and collected. Then they were kept in glass tubes (115 mm in length and 30 mm in diameter) at room temperature (20–25°C) for rearing, checking daily to gather parasitoid adults. The emerged parasitoid adults were sexed and counted, then being preserved in 75% alcohol and later underwent critical-point drying (Gordh & Hall, 1979), finally mounting on card triangles for taxonomic study.

The egg parasitoid specimens were examined with a Nikon SMZ1500 Stereo-microscope, and the description of the new species is based both on naturally dried and critical-point dried specimens. Figures of the new species were taken with an Olympus CX31 microscope with the "UV-C Optical Totally Focuses System" developed by Beijing United Vision Technology Co., Ltd. Some figures were taken with the fresh specimens, some with the specimens treated by the critical point drier (Gordh & Hall, 1979), and some with natural tried specimens (it is indicated in legend). Terminology follows Gibson *et al*. (1997) and Bouček (1988).

Abbreviations used as following:
POL, shortest distance between the posterior ocelli;
OOL, shortest distance between a posterior ocellus and compound eye.
Type materials are deposited in the Insect Museum, Chinese Academy of Forestry, Beijing.

## 3 Result and discussion

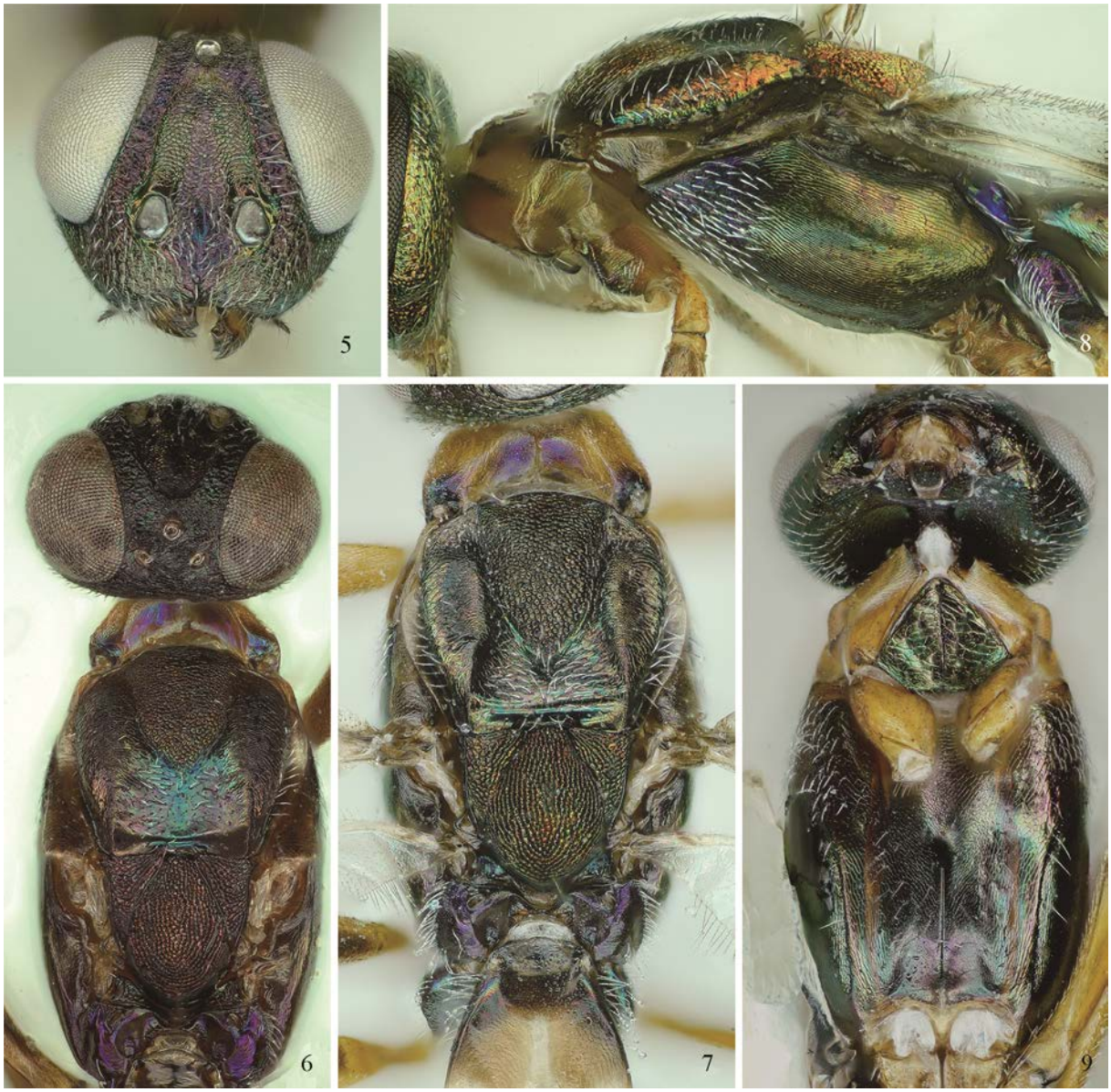
***Anastatus orientalis* Yang & Choi, sp. nov.** (Figs 1–24)

Female (Figs 1–2, 5–10, 12–13, 16–20). Length 3.2–3.3 mm. Head brown with metallic purple luster, but occipt and gena with peacock-green luster; setae of head whitish; antenna dark brown except both scape and pedicel brown, as well as clava micropilose area brown basally and whitish apically; pronotum testaceous with lateral corner black and having purple


Figs 1–4. *Anastatus orientalis* Yang & Choi, **sp. nov.**, fresh specimens. 1. ♀, whole body, dorsal view. 2. ♀, whole body, lateral view. 3. ♂, whole body, dorsal view. 4. ♂, whole body, lateral view.

luster; mesoscutum, scutellum and axillae dark brassy with greenish luster except posterior 1/3 of mid lobe of mesoscutum blue-green and shining; forewing dark fumose with veins testaceous and setae black-brown, having two cross hyaline bands with white setae, in which one is behind distal 2/3 of submarginal vein with brown setae at lower 2/5, and the other behind distal 1/2 of marginal vein with a V-like shape, the apex of forewing subhyaline; lateral panel of pronotum and prepectus testaceous; acropleuron with anterior 1/4 having purple luster and posterior 3/4 having green brassy luster; legs with coxae testaceous except hind coxa with the same color as acropleuron, other leg segments dark-testaceous but with femora and tibiae dark brown dorsally; prosternum with dark-green luster and mesosternum concolores as acropleuron; metasoma dark-brown with slight metallic purple luster except tergite 1 which with basal 1/4 brown and gradually becoming whitish towards apex and with posterior 2/5 whitish; syntergum and exposed ovipositor sheath yellowish white.

Head in dorsal view with breadth 2.0 times length; temple 0.34 times eye length; OOL : POL : LOL = 3 : 10 : 7; vertex evenly and slightly convex, coriaceous with dense setae and gradually downward to occipt without occiptal carina; occipt slightly in-curved medially. In front view (Fig. 5), head 1.2 times as wide as high; antennal toruli medially at lower margin




Figs 5–9. *Anastatus orientalis* Yang & Choi, **sp. nov.**, ♀. 5. Head, frontal view, critical-point dried specimens. 6. Head and mesosoma, dorsal view, naturally dried specimen. 7. Mesosoma and basal part of metasoma, dorsal view, critical-point dried specimens. 8. Mesosoma, lateral view, fresh specimen. 9. Head and mesosoma, ventral view, critical-point dried specimens.

line of eyes; scrobal depression deep with margin carinated as an inverted V-like in shape with the distance of its dorsal margin to anterior ocellus about the same as the ocellus diameter; interantennal region convex; frons with the shortest distance between eyes 1.5 times that between toruli; eyes bare and with inner orbits divergent downwards considerably; toruli separated each other by twice of its transverse diameter, and with the distance to inner orbit 1.5 times its transverse diameter; the distance between lower margin of toruli and apex of clypeus 0.56 times that between upper margin of toruli and anterior ocellus; malar sulcus distinct and outcurved a little, 0.49 times eye length; frons and face coriaceous-reticulate with relative dense setae, but the setae on face and interantennal region elongate-lanceolate and porrect (Fig. 5); bottom of scrobal depression with transverse striation; clypeus with anterior margin sub-truncate; mandible bidentate with upper tooth dolabriform. Antenna (Fig. 10) with scape slightly compressed and curved, reached over vertex a little; pedicel plus flagellum 1.6 times head breadth; pedicel short and 1.7 times as long as wide; pedicel and flagellar segments covered with dense brown setae, and flagellar segments clavated and with longitudinal sensillae which are brown and not distinct on each segment; clava with very short setae dorsally and a large micropolose area ventrally, as well as with a row of visible longitudinal sensilla on each segment; the relative length of pedicel, $Fl_{1\text{-}8}$ and clava: 31 : 12 : 49 : 50 : 52 : 42 : 40 : 36 : 30 : 98, their relative breadth:19 : 16 : 19 : 21 : 25 : 28 : 30 : 31 : 33 : 35; clava segments compacted and separated each other by oblique sutures and apical one conical.

Pronotum (Figs 1–2, 6–8) is below mesoscutum with shape subtrianglar and not distinctly differentiated collar and neck, its breadth 3.8 times median length and 0.8 times mesoscutum; hind corner slightly constricted; along with lateral margin convex as ridge-like; disc concave, smooth, bare and with a longitudinal median suture; its sub-corner bulged, dark with about five bristle-like setae on it. Mesoscutum (Figs 1, 6–7) 1.16 times as wide as long and 0.9 times as wide as head and 1.16 times as wide as long; notauli deep, convergent as V-like and meeting at posterior 7/10 medially; sub-lateral margins deep-grooved and thus forming the lateral margin flange film-like; the anterior margin slightly out-curved and the hind margin truncate; closing to hind margin with a notable cross ridge and its anterior area inclined forwardly as a slope to meet V-liked posterior notauli, its lateral borders limited by carinae (Fig. 7). However, in the naturally dried specimens, the area behind the met notauli gradually and evenly raised to the truncate hind margin of mesoscutum with a sub-quadrate form (Fig. 6). Midlobe of mesoscutum sub-triangular and convex; lateral lobes bulged longitudinally and carinated shortly near


Figs 10–15. *Anastatus orientalis* Yang & Choi, **sp. nov.** 10–11. Fresh specimens. 12–15. Critical-point dried specimens. 10. ♀, antenna. 11. ♂, antenna. 12. ♀, forewing. 13. ♀, hind wing. 14. ♂, forewing. 15. ♂, hind wing.

posterior margin; the midlobe with neat, isodiametric and piliferous reticulation; the lateral lobes with transverse coriaceous reticulation and dense long-laceolate white setae. Scutellum and axillae compacted with scutoscutellar suture deep. Scutellum (Figs 6–7) pear-like, convex remarkably, 1.3 times as long as wide with length 0.65 times mesoscutum, with neat piliferously punctured reticulation as on midlobe of mesoscutum, but arranged approximately concentric circle; axillae with about the same sized reticulation as scutellum but running out-downwardly; scutellum with six pairs of brown bristle-like setae along lateral margins and two pairs of them sub-laterally; axillae with three to five setae; hind margin of scutellum abruptly declined in about right-angle. Dorsellum below scutellum directly with crescentic form, slightly convex and sub-smooth, bare and shining with length medially 0.14 times scutellum, and about the same level with lateral panel of metanotum which is in triangular form and rugose. Propodeum with posterior margin arched considerably and contiguously to anterior margin, and bow tie-like (Figs 6–7); collar region raised forming two peaks: one is at inner side of spiracle with the direction posterior-laterally and the other is behind the former with the direction posterior-medially; plical region is at the slopes of the two peaks and the median bottom; the distance between spiracle and anterior propodeal margin is about the spiracle minimal diameter; along lateral margin with long white setae; propodeum dorsally smooth and shining. Forewing (Fig. 12) 2.6 times as long as wide and extending beyond apex of metasoma (Fig. 2); the vein relative length of the submarginal, the parastigmal, the marginal, the postmarginal and the stigmal as: 52 : 18 : 72 : 30 : 10; submarginal vein with about 11 long setae; the upper side of costal cell bare but on under side with a complete line of setae and having more setae at both its proximal and distal parts; basal cell with proximal 1/4 bare and distal 3/4 with dense setae; stigma in shape of foot-like. Hind wing (Fig. 13) 3.2 times as long as wide and about 0.78 times as long as forewing. In lateral view, prepectus bare and with frontal prepectal surface smooth and lateral prepectal surface sub-smooth having very weak engraved reticulation (Fig. 8). The very large acropleuron (Fig. 8) with anterior 1/3 coriacous and covered with white porrect and lanceolate setae, and posterior 2/3 neatly strigose as concentric circle and bare (Figs 2, 8); acropleuron sulcus present at posterior 2/3 along lateroventral side, straight and the anterior part upwards slightly. Fore leg (Fig. 16) with one protibial apical spicule along the dorsoapical margin, and the femur with three lines of brown setae at posterior 1/3 of outer side. Mid leg (Figs 17–18) with tibia widened towards apex with four to six pegs arranging in two lines and with a distinct oblique mesotibial apical groove; the mid tarsus segment 1–4 with two lines conspicuous pegs along each ventrolateral margins (Figs 17–18), the number and status of the pegs on each tarsus segment as Table 1 below.

**Table 1. Peg number and status on ventrolateral margins of mid tarsus 1–4 (female).**

| Tarsus segment | Anterior line of ventrolateral margin | Status | Posterior line of ventrolateral margin | Status |
|---|---|---|---|---|
| Basitarsus | 11–13 | Seratus | 15–17 | Seratus |
| Tarsus 2 | 6–7 | Uniform | 6–7 | Uniform |
| Tarsus 3 | 2–4 | Uniform | 3–4 | Uniform |
| Tarsus 4 | 1 | Uniform | 1 | Uniform |

The very developed mid tibial spur as long as basitarsus; mid femur and tibia compressed remarkably and tibia 1.1 times as long as femur. Hind leg (Fig. 19) with coxa weak coriaceous reticulate and dense long-laceolate setae on whole dorsal surface, tibia only with one apical spur, femur slightly curved and 0.9 times tibia, tarsus as long as tibia. In ventral view, prosternum sub-rhomboid, coriaceous and covered with white setae; mesoventral plate convex evenly, coriaceous reticulate with sparse white setae and a median longitudinal sulcus (Fig. 9).

Metasoma (Fig. 20) widened towards the apex with tergite 5 the widest and 2.35 times as wide as the basal of tergite 1, as wide as mesoscutum and 0.8 times as wide as head; tergite 1 scalariform and is the longest with length 0.37 times the whole gaster, its surface sub-smooth and bare dorsally with sparse setae basal-laterally; the other tergites with fine coriaceous reticulation; tergite 2–4 only with setae laterally and tergite 5 and 6 with dense erect setae dorsally and laterally; last tergite conical; cercus with four bristles, in which three of them long with same length and one only about 1/3 as long as the other three. Ovipositor slightly protruded.

Male (Figs 3–4, 11, 14–15, 21–24). Length 2.2–2.4 mm. Body green with metallic luster, but vertex, mesoscutum, scutellum and gaster with dark red-coppery luster; antenna with scape yellow, pedicel, flagellum 1, 2 and sometimes 3 testaceous, flagellum 4 to clava gradually brown to black, flagellum with dense longitudinal sensellae which are dark-brown; legs with coxae concolored with body and other segments yellow; wings hyaline with veins testaceous and setae on disc brown. Head rugulose and vertex with rugose transversely. In dorsal view, head 1.6 times as wide as long; POL : OOL : LOL = 18 : 5 : 8; temple 0.33 times eye length; vertex slightly and evenly convex; occipt in-curved a little medially. In front view,

head 1.3 times as wide as high; eyes sparsely pilose (at 160X magnification); oral part wide and 0.45 times head width; lower margin of toruli at lower ocular line; inner orbits divergent downwards; scrobal depression distinct and campanulate with dorsal apex to lower margin of anterior ocellus 0.7 times the ocellar longitudinal diameter; malar sulcus deep with length 0.63 times eye height; interantennal area convex as a small longitudinal process which extended to face medially; anterior margin of clypeus truncate; upper frons and vertex with normal setae but lower frons and face covered white dense porrect long-lanceolate setae. Antenna (Figs 4, 11) with scape moderately compressed and elliptical, convex dorsally and flat ventrally, about 2.3 times as long as wide, extending to reach vertex; pedicel sub-globose and as long as wide; each flagellum segment with dense brown longitudinal sensillae and dense short setae; the flagellum compressed more or less from funicle 2 with clava even flattened; funicle 1 robust, curved moderately with length 3.5 times its width and nearly as long as scape (35 : 33), 6.0 times pedicel, and with basal width 1.25 times the pedicel; the relative length of scape, pedicel, funicle 1–7 and clava as: 50 : 8 : 48 : 36 : 38 : 32 : 24 : 22 : 17 : 56; clava with a micropilose area at apex 3/5 ventrally.

Mesosoma (Fig. 21) with mesoscutum and scutellum convex considerably and rugulose. Pronotum short directly below mesoscutum, steeply sloped forwards and not differenciated collar and neck. Mesoscutum 1.75 times as wide as long with width 0.78 times head, notauli deep and convergent posteriorly, dorsum covered with dense brown short setae. Scutellum covered with dense brown erected setae, 1.4 times as long as wide and 1.25 times as long as mesoscutum; axillae conspicuously developed; the anterior margin of scutellum only 0.35 times as wide as the width of hind margin of mesoscutum midlobe. Dorsellum small behind scutellum and corialate, and the lateral panel of metanotum sub-smooth. Propodeum 0.26 times medially as long as scutellum, smooth and shining; median carina distinct; hind margin conspicuously arched medially; plical depression present at posterior 3/5; the median panel convex; callus along lateral margin with about 12 setae. Forewing (Figs 3, 14) 2.1 times as long as wide; the relative vein length of the submarginal, the marginal, the post-marginal and the stigmal as: 180 : 95 : 58 : 35; costal cell bare on dorsal side and densely setose on ventral side; basal cell setose; speculum narrow and beyond it densely setose. Hind wing (Figs 3, 15) 0.76 times as long as forewing. In lateral view, prepectus sub-triangular and the surface distinctly reticulate (Fig. 22); acropleuron, anterior 1/3 and posterior 1/6 of mesopleuron smooth, shining and bare; mesopleuron with cross coriaceous strigose, and with a longitudinal ridge ventrolaterally at posterior 1/2, as well as with sparse setae ventrally. Metapleuron sub-triangular, shining, bare and located at upper posterior corner of mesopleuron, thus, their posterior margins about at the same vertical line and hind coxa directly above the mid coxa. Fore and hind coxae coriaceous reticulate, mid coxa smooth. Fore coxa setose, fore tibia with two apical spiculi along dorsoapical margin (Fig. 24). Mid tibia with one apical spur which is as long as basitarsus (Fig. 24); mid coxa bare and small. Hind coxa bare but distal 1/3 of ventral surface setose, the tibia with two apical spurs in which one is twice as long as the other.

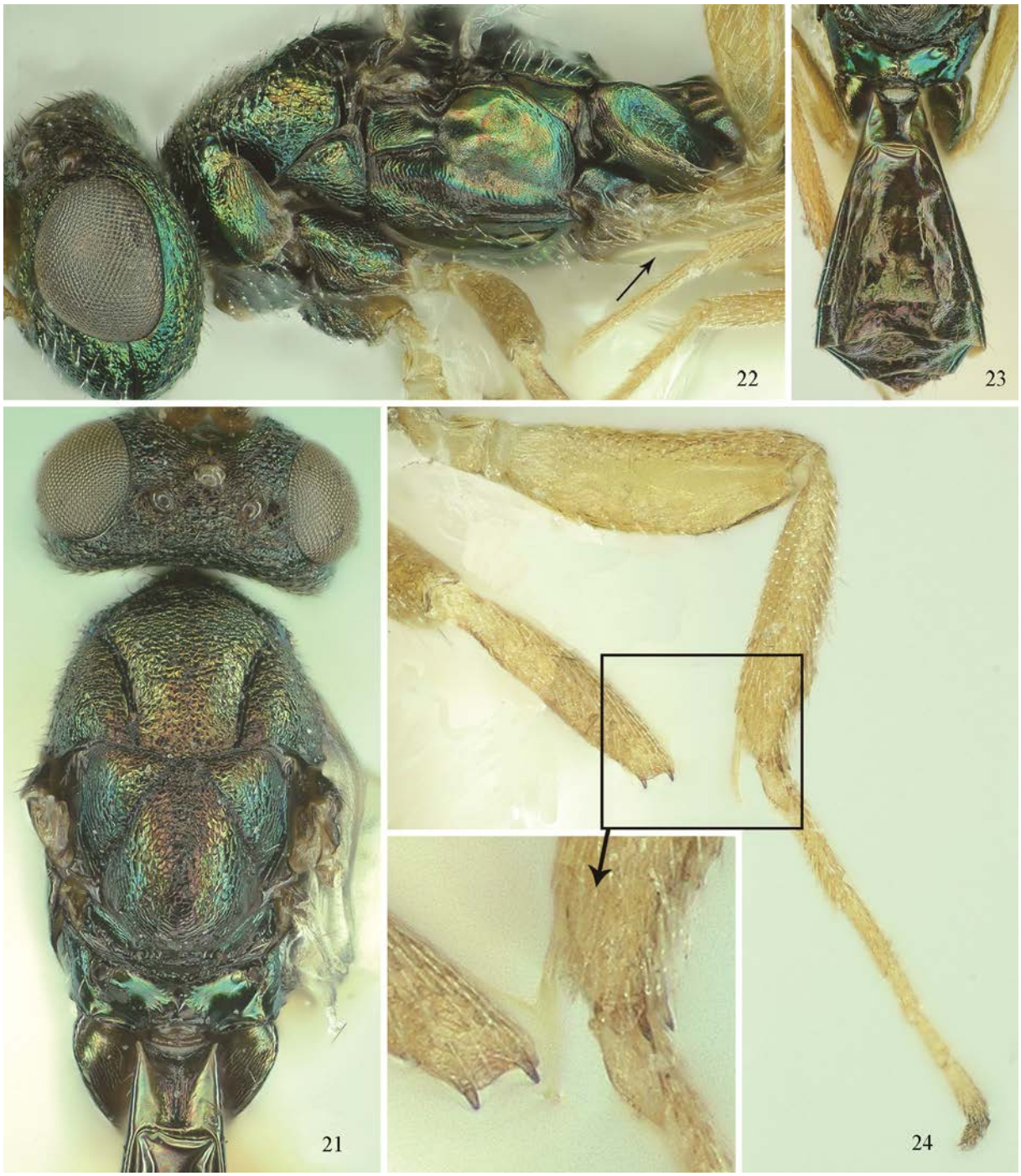
Metasoma (Fig. 23) with petiole narrow and arched conspicuously. Gaster widened towards apex with shape tranpiziform and apex slightly out-curved, 1.75 times as long as wide with the widest (tergite 5) 3.4 times the basal of tergite 1; the length about the same as mesosoma (66 : 68), the width 0.92 times mesosoma and 0.8 times head respectively; dorsum slightly sunken; each tergite with hind margin truncate; tergite 1 and 2 bare and tergite 3–7 with sparse setae; tergite 1 smooth and shining laterally and coriaceous reticulate medially; from tergite 2 to last tergite with very weak engraved coriaceous reticulate. Because the gaster of male weakly sclerotized the metasoma often is tortuous in natural dried specimens, and their shape may change. The description above should be referred.

Diagnosis. The new species belongs to subgenus *Anastatus* (*Anastatus*) and close to both *A. japonicus* Ashmead, 1904 and *A. bifasciatus* (Geoffroy, 1875) which are in the same subgenus with the new species, but can be separated by the key below.

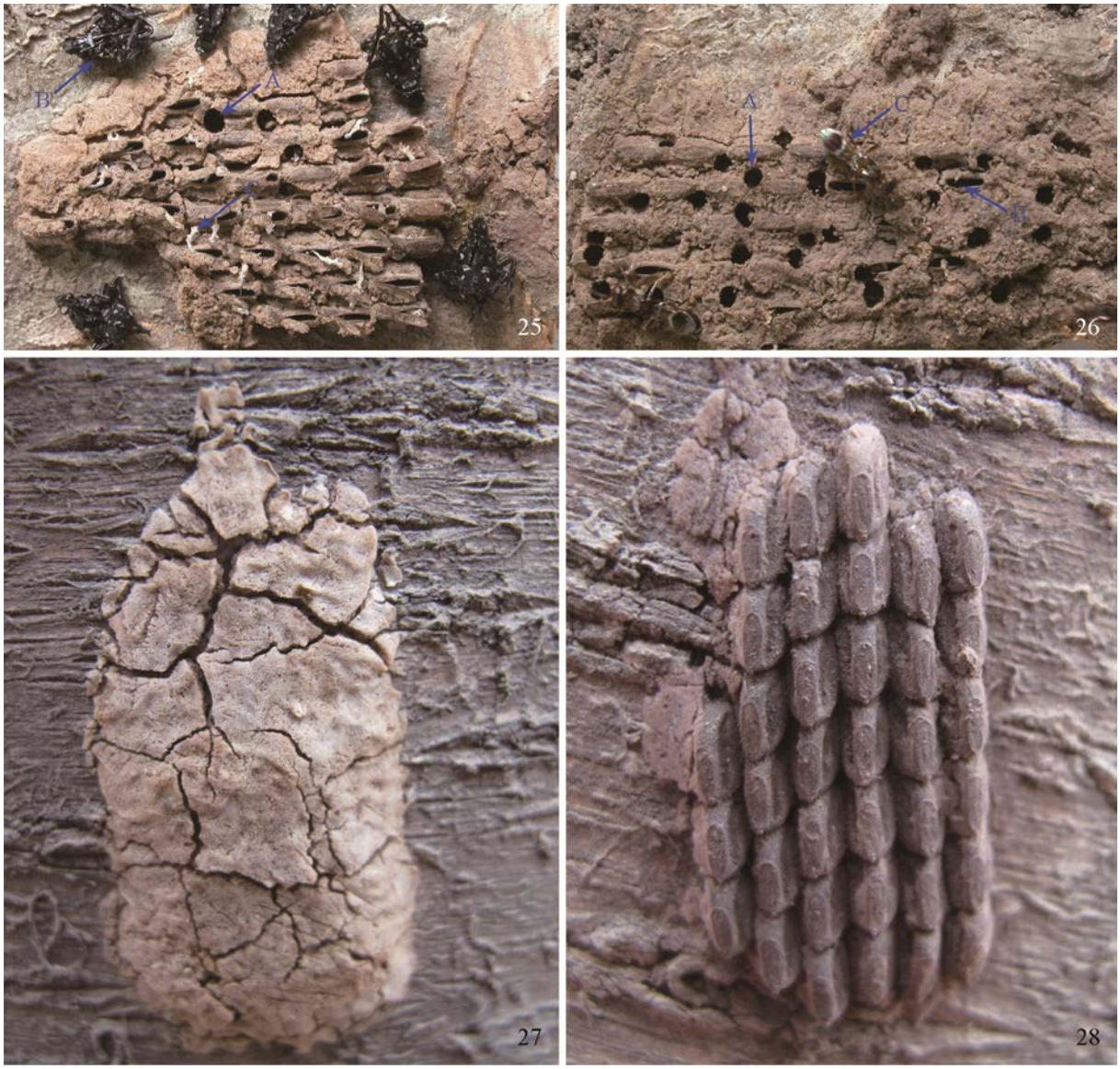
1. The distance between anterior ocellus and apex of scrobes 1.8 times to twice the longitudinal diameter of the ocellus; length of pedicel plus flagellum less than 1.45 times head breadth; length of funicle 2 less than 3.3 times funicle 1; clava over 1.13 times as long as preceding three funicles combined . . . . . 2
   The distance between anterior ocellus and apex of scrobes about 1.0 times the longitudinal diameter of the ocellus; length of pedicel plus flagellum 1.6 times head breadth; funicle 2 with length 4.08 times funicle 1; clava 1.0 times as long as preceding three funicles combined . . . . . ***A. orientalis* Yang & Choi, sp. nov.**
2. The distance between anterior ocellus and apex of scrobes twice the longitudinal diameter of the ocellus; length of pedicel plus flagellum 1.36 times head breadth; funicle 2 with length 2.75 times funicle 1; clava 1.33 times as long as preceding three funicles combined and its apex acuminated. . . . . ***A. bifasciatus* (Geoffroy)**
   The distance between anterior ocellus and apex of scrobes 1.8 times the longitudinal diameter of the ocellus; length of pedicel plus flagellum 1.45 times head breadth; funicle 2 with length 3.3 times funicle 1; clava 1.13 times as long as preceding three funicles combined and its apex blunt. . . . . ***A. japonicus* Ashmead**


Figs 16–20. *Anastatus orientalis* Yang & Choi, **sp. nov.**, ♀, naturally dried specimens. 16. Fore leg, anterior side view. 17. Apex of mid tibia and tarsus, posterior side view (showing the pegs on tarsal segment 1–4). 18. Apex of mid tibia and tarsus, anterior side view (showing the pegs on apex of tibia and on tarsal segment 1–4). 19. Hind leg, anterior side view. 20. Posterior part of mesosoma and metasoma, dorsal view.

Material examined. Holotype ♀, Fragrant Hill, Haidian District, Beijing, Zhong-Qi Yang and Zheng-Rong Hou, collected the egg masses of *Lycorma delicatula* (White) on 6 April 2011 and the parasitoid wasp emerged on 10 May 2011. Paratypes: 50♀, 30♂, same data as holotype; 22♀, 17♂, the campus of Chinese Academy of Forestry, Haidian District, Beijing, collected the egg masses of *L. delicatula* on 10 April 2001, the parasitoid wasp emerged on 1 May 2001; 133♀, 67♂, the campus of the Northwestern Forestry College, Yangling, Shaanxi, Zhong-Qi Yang, collected the egg masses of *L. delicatula* on 21 April 1984, the parasitoid wasp emerged on 7 May 1984; 40♀, 30♂, Yangling , Shaanxi, Cong Wei and




Figs 21–24. *Anastatus orientalis* Yang & Choi, **sp. nov.**, ♂, naturally dried specimens. 21. Head, mesosoma and basal part of metasoma, dorsal view. 22. Head and mesosoma, lateral view. 23. Propodeum and metasoma, dorsal view. 24. Apex of fore tibia (left) and mid leg (right) with enlarged apexes of fore and mid tibiae.




Figs 25–28. Egg mass of *Lycorma delicatula.* 25. Egg mass of *L. delicatula* with newly hatched nymphae and the emerged holes of *Anastatus orientalis* Yang & Choi, **sp. nov.** A. The emerged hole of the parasitoid adult. B. The newly hatched nympha of *L. delicatula*. C. The egg-lid and moult of newly hatched nympha of *L. delicatula*. 26. Parasitized eggs with emerged holes of the parasitoid adults and the newly emerged adults of *A. orientalis* Yang & Choi, **sp. nov.** A. The emerged hole of the parasitoid adult. B. The un-parasitized egg with hatched hole of nympha of *L. delicatula*. C. The newly emerged adult of *A. orientalis* Yang & Choi, **sp. nov.** 27. Egg mass of *L. delicatula* covered with lutescens powder. 28. Egg mass of *L. delicatula* which the covered lutescens powder was taken off.

Zhong-Qi Yang, collected the egg masses of *L. delicatula* on 8 April 2011, the parasitoid wasp emerged on 1–18 May 2011; 66♀, 45♂, Qinhuangdao, Hebei, Zhong-Qi Yang and Xiu-Rong Qiao, collected the egg masses of *L. delicatula* on 18 April 2011, the parasitoid wasp emerged on 6 May 2011; 26♀, 20♂, Zhifu, Yantai, Shandong, Chuan-Zhen Wang and Zhong-Qi Yang, collected the egg masses of *L. delicatula* on 15 April 2011, the parasitoid wasp emerged on 21 May 2011; 56♀, 50♂, same data as the previous materials, but the parasitoid wasp emerged on 10 September 2011; 6♀, 5♂, Guangang Forest Park, Tianjin City, Zhong-Qi Yang and Xiao-Yi Wang, collected the egg masses of *L. delicatula* on 20 April 2011, the parasitoid wasp emerged on 2 May 2011.

Distribution. China (Shaaxi, Hebei, Beijing, Tianjin, Shandong), South Korea (Cheongwon-gun, Chungcheongbuk-do (36°38'N, 127°29'E)). The species may eventually be found throughout China where the host *L. delicatula* occurs. Kim *et al.*

(2011) reported an egg parasitoid, *Anastatus* sp., reared from *L. delicatula.* From their description and photos of the species, it should be the present new species.

Etymology. The species epithet is derived from the areas where it was discovered.

Biological observations. *A. orientalis* Yang & Choi, **sp. nov.** is a solitary endo-parasitoid of eggs of *L. delicatula* (Figs 25–26). In early April of 2011, we collected total 450 egg masses of the spotted lantern-fly from the five areas mentioned in materials and methods above and reared in lab, finally 137 egg masses were found to be parasitized by *A. orintalis* with the parasitism rate of egg masses 30.4% and the sex ratio of female to male was 1.9 : 1.0, Then the individual egg parasitism rate was calculated and it was 40.2%. It is easy to recognize the parasitized and non-parasitized host eggs: the former with an emerged hole which is subround (Figs 25-A, 26-A), and the latter with a nymph-hatched hole which is long elliptical with an egg lid attached to egg shell (Figs 25-C, 26-B). Hou (2013) reported that *A. orientalis* had an egg parasitism rate from 20% to 90% with average 44%. Choi *et al*. (2014) reported their investigation results of natural parasitism of *A. orientalis* on eggs of the pest too.

The host of the parasitoid, the spotted lantern fly, has one generation a year and overwinters as egg stage, and its egg-laying period is from the final ten days of August to the final ten days of October in northern China (Xiao, 1992; Hou, 2013). During the investigation in 2011, we found that *A. orientalis* adults had two emergence groups a year within the same egg mass: some individuals in May and others in September. The Spring (mostly in May) emerged group could parasitize the host eggs which were not parasitized in last Autumn, and the group emerged in September could parasitize the host eggs of the new generation. The interesting phenomenon shows that it may be the best strategy for the parasitoid to maintain its population, and the parasitoid has a high host specificity appearing as an uni-host parasitoid. It may not need alternative hosts to succeed its generations and could only develop in the eggs of *L. delicatula.*

We also conducted the experiment for mass-rearing the parasitoid with a selected substitute host eggs. It was found that *A. orientalis* could complete 7–8 generations from April to December in a year under laboratory conditions. It took 18–28 d for one generation development with temperature about 25℃ and humidity about 65±5%. Under the room temperature 23–25℃, the developmental duration of eggs is 1–2 days, 10 days for larvae, 4 days for prepupae and 7 days for pupa stage. The female could survive 100 days with feeding honey dew and one female could produce eggs minimum 64 and maximum 98 (Hou, 2013).

From the investigations and the mass rearing experiment conducted by us it is indicated that the new species has a high potential as a superior biological control agent for suppression of *L. delicatula.*

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