Eur. J. Entomol. **107**: 393–400, 2010
http://www.eje.cz/scripts/viewabstract.php?abstract=1550
ISSN 1210-5759 (print), 1802-8829 (online)

Phylogeny and nomenclature of the box tree moth, *Cydalima perspectalis* (Walker, 1859) comb. n., which was recently introduced into Europe (Lepidoptera: Pyraloidea: Crambidae: Spilomelinae)

RICHARD MALLY and MATTHIAS NUSS

Museum of Zoology, Koenigsbruecker Landstrasse 159, 01109 Dresden, Germany;
e-mails: richard.mally@senckenberg.de; matthias.nuss@senckenberg.de

Key words. Crambidae, Spilomelinae, box tree moth, generic placement, *Diaphania*, *Glyphodes*, *Neoglyphodes*, *Palpita*, *Cydalima perspectalis*, new combination, taxonomy, phylogeny, morphology, nomenclature

Abstract. The box tree moth, *Cydalima perspectalis* (Walker, 1859) comb. n., is native to India, China, Korea, Japan and the Russian Far East. Its larvae are a serious pest of different species of *Buxus*. Recently, *C. perspectalis* was introduced into Europe and first recorded from Germany in 2006. This species has been placed in various spilomeline genera including *Palpita* Hübner, 1808, *Diaphania* Hübner, 1818, *Glyphodes* Guenée, 1854 and the monotypic *Neoglyphodes* Streltzov, 2008. In order to solve this nomenclatural confusion and to find a reasonable and verifiable generic placement for the box tree moth, the morphology of the above mentioned and some additional spilomeline taxa was investigated and their phylogeny analysed. The results show that *C. perspectalis* belongs to a monophylum that includes three of the genera in which it was previously placed: *Glyphodes*, *Diaphania* and *Palpita*. Within this monophylum, it is closely related to the Asian *Cydalima* Lederer, 1863. As a result of this analysis, *Sisyrophora* Lederer, 1863 syn. rev. and *Neoglyphodes* Streltzov, 2008 syn. n. are synonymised with *Cydalima* Lederer, 1863, and five species are transferred to this genus: *Cydalima capriniodes* (Hampson, 1912) (*Glyphodes*) comb. n., *Cydalima decipiens* (Hampson, 1912) (*Glyphodes*) comb. n., *Cydalima joiceyi* (Janse, 1924) (*Margaronia*) comb. n., *Cydalima perspectalis* (Walker, 1859) (*Phakellura*) comb. n. and *Cydalima pfeifferae* (Lederer, 1863) (*Sisyrophora*) comb. rev.

INTRODUCTION

The natural range of the box tree moth (Fig. 3A, B) is the humid subtropical regions of East Asia, in India (Hampson, 1896), China (Walker, 1859), Japan (Inoue, 1982), Korea (Park, 2008) and Russian Far East (Kirpichnikova, 2005). Its larvae feed on the leaves of *Buxus microphylla* Siebold & Zucc., but also accept other *Buxus* species (Maruyama, 1993), seriously damaging these ornamental plants in Asian gardens. Therefore, the ecology of the box tree moth has been well studied in Japan (Maruyama, 1992, 1993; Maruyama & Shinkaji, 1987, 1991, 1993; Tominaga 1998), China (Tang et al., 1990; Zhou et al., 2005) and Korea (Park, 2008). Due to its economic importance in East Asia, there is information on its chemical control (Zhou et al., 2005), biological control using nematodes (Choo et al., 1991; Lee et al., 1996) and its pheromones (Kawazu et al., 2007).

In 2006, the box tree moth was introduced into southwestern Germany (Krüger, 2008). In 2007, it was also found in Switzerland (Käppeli, 2008; Sigg, 2009) and in the Netherlands (Muus et al., 2009). In 2008, it was first reported in Britain (Mitchell, 2009), France (Feldtrauer et al., 2009) and Austria (Rodeland, 2009). Rodeland (2009) provides an overview of its colonization of central Europe. It is assumed that the box tree moth was imported by man into Europe and since then transported within Europe on *Buxus*-plants distributed by tree nurseries (Krüger, 2008; Käppeli, 2008; Muus et al., 2009; Sigg, 2009). In addition, it is also capable of hibernating and spreading naturally in Europe (Krüger, 2008; Feldtrauer et al., 2009; Muus et al., 2009; Sigg, 2009). In Central Europe, larvae of the box tree moth are usually found in high numbers, which defoliate and subsequently kill this evergreen shrub (Krüger, 2008; Käppeli, 2008; Sigg, 2009). Thus, the box tree moth is becoming a serious threat for the West-Palaearctic *Buxus sempervirens* L.

The box tree moth, originally described as *Phakellura perspectalis* Walker, 1859 has been variously placed in the spilomeline genera *Palpita* Hübner, 1808 (= *Phakellura* Guilding, 1830) (Muus et al., 2009), *Diaphania* Hübner, 1818 (Zhou et al., 2005; Feldtrauer et al., 2009; Mitchell, 2009) and *Glyphodes* Guenée, 1854 (Maruyama, 1992, 1993; Maruyama & Shinkaji, 1987, 1991, 1993; Tominaga, 1998; Kawazu et al., 2007; Krüger, 2008; Park, 2008). Unfortunately, there are no good reasons cited in the literature for placing *perspectalis* in any of these genera. In 2008, Streltzov, comparing *perspectalis* with *Diaphania* and *Glyphodes*, pointed to morphological differences between these three taxa and established a new, monotypic genus *Neoglyphodes* for *perspectalis*. This systematic action is uninformative as the new genus was not put into context within the Spilomelinae, with the exception that Streltzov refers to a second, still undescribed species of *Neoglyphodes*. Moreover, the establishment of this new genus makes the systematics of the Spilomelinae even more confusing, as this subfamily currently comprises 277 genera (plus 246 synonyms) with more than 3,700 species (Nuss et al., 2010) and needs to be more extensively taxonomically

and phylogenetically revised. The only phylogenetic studies available are those by Sutrisno (2002a, b, 2005, 2006) and Sutrisno et al. (2006) on *Glyphodes* and allied genera.

Against this background, the morphology of the above mentioned genera and some additional spilomeline taxa were investigated and their phylogeny analysed in order to obtain a reasonable and verifiable generic placement for the box tree moth.

MATERIAL AND METHODS

For the cladistic analysis, taxa of all genera in which *perspectalis* has been placed so far (*Diaphania*, *Glyphodes*, *Palpita*), taxa similar to *perspectalis* identified by screening the collections (*Sisyrophora* and *Cydalima*) and six additional taxa from different spilomeline genus-groups sensu Munroe (1995), were investigated. Altogether, 16 species belonging to 14 different genera were included as in-groups and *Evergestis forficalis* (Crambidae: Evergestinae) as the out-group. Details of the specimens studied are given below:

Evergestis forficalis (Linnaeus, 1758): 1♂, 1♀ Germany, Saxony, Moritzburg, 5.vi.1967; 18.viii.1965, Bembenek & Krause leg., SMTD.

Agrioglypta eurytusalis (Walker, 1859): 1♂, 1♀ Cambodia, Cardamom Mts, Tumpor area, 12°22′N, 103°02′E, 1,250 m, 27.ii.–5.iii.2000, Nuss leg., SMTD.

Agrotera nemoralis (Scopoli, 1763): 1♂, France, Department Lot, Douelle, 9.viii.1931, Lhomme leg.; 1♀, NE-Turkey, Rize province, Karadeniz, Dağları, Iyidere valley, above Ikizdere, 840 m, 7.vi.2002, Ochse leg.; SMTD.

Bradina diagonalis (Guenée, 1854): 1♂, 1♀ Vietnam, Province Lao Cai, Mt. Fan Si Pan, Nui Se, 22°21.168′N, 103°46.477′E, 1,927 m, 19.–20.x.2001, Löffler leg., SMTD.

Cydalima laticostalis (Guenée, 1854), Syntype: ♀, with labels “Type”, “Laticostalis | Gn. Sil”, “Assam | Silhet | ex coll. Gn.”, “Paravicini Coll. | B.M. 1937-383.”, BMNH. – 1♂, Cambodia, Cardamom Mts, Tumpor area, 12°22′N, 103°02′E, 1,250 m, 27.ii.–5.iii.2000, Nuss leg.; 1♀, Philippines, South Luzon, Los Baños, Mt. Makiling, 14°08′N, 121°14’E, 815 m, 30.iii.2000, Nuss leg.; SMTD.

The following three names are synonyms of *C. laticostalis* and their types were investigated:

Margarodes conchylalis Guenée, 1854, Syntype: ♀ [abdomen and right antenna missing], with labels “Type”, “Conchylalis | Gn Corom”, “Madras | Coromandel | ex coll. Gn.”, “Paravicini Coll. | B. M. 1937-383.”, BMNH.

Margarodes nitidicostalis Guenée, 1854, Syntypes: 1♀, with labels “Co- | type”, “Nitidicostalis | Gn Silhet”, “Assam | Silhet | ex coll. Gn.”, “Paravicini Coll. | B.M. 1937-383”, BMNH. 1♀ [abdomen missing], same labels, except the identification label, BMNH.

Margaronia leodicealis Walker, 1859, Syntype: ♀, with labels “E Ind” [back] “61 | 83.”, BMNH.

Diaphania indica (Saunders, 1851): 1♂, Kenya, Tana River, Primate N.P., 01°52′34″S, 40°08′25″E, 8.–9.vi.2005, Errolat, Muli, Nuss & Okuku leg.; 1♀, Kenya, Tsavo-West N.P., 2°27′06″S, 38°03′54″E, 1.–2.vi.2005, Errolat, Muli, Nuss & Okuku leg.; SMTD.

Glyphodes capriniodes Hampson, 1912, Syntype: ♂, with labels “Type”, “Bombay”, “Moore Coll. | 94-106.”, “Glyphodes. | capriniodes | type ♂ Hmpsn.”, BMNH.

Glyphodes decipiens Hampson, 1912 Holotype (by monotypy): ♂, with labels “Type”, “Ceram [back] 62 | 18”, “Glyphodes | decipiens | type ♂. Hmpsn.”, “Pyralidae | Brit. Mus. | Slide No. | 2138 ♂”, BMNH.

Glyphodes stolalis Guenée, 1854: 1♂, 1♀ Philippines, South Luzon, Los Baños, Mt. Makiling, 14°08′N, 121°14′E, 815 m 16.iii.2000, Nuss leg., SMTD.

Glyphodes onychinalis (Guenée, 1854): 1♂, 1♀ Cambodia, Cardamom Mts, Tumpor area, 12°22′N, 103°02′E, 1,250 m 27.ii.–5.iii.2000, Nuss leg., SMTD.

Glyphodes sp.: 1♂, Cardamom Mts, Tumpor area, 12°22′N, 103°02′E, 1,250 m, 27.ii.–5.iii.2000, Nuss leg.; 1♀, India, Andaman Is., Middle Andaman, Tagapure, 12°50′72″N, 92°49′29″E, 22.–26.xi.2000, J.-P. Rudloff leg.; SMTD.

Margaronia joiceyi Janse, 1924, Paratypes: 2♂, 2♀, Central Ceram, Manusela, x.–xii.1919, C.F. & J. Pratt, BMNH.

Mecyna lutealis (Duponchel, 1833): 1♂, Italy, Malcesine, Lake Garda, 2.vi.1948, Möbius leg.; 1♀, Switzerland, Wallis, Stalden, 20.iv.1918, Möbius leg.; SMTD.

Nomophila noctuella (Denis & Schiffermüller, 1775): 1♂, Germany, Saxony, Oberfrohna, 16.viii.1946, Ernst leg.; 1♀, Italy, Campania, Napoli, Posillipo, 26.viii.2006, Vegliante leg.; SMTD.

Palpita vitrealis (Rossi, 1794): 1♂, Italy, Abruzzo, Riserva Naturale Lago Penne, Giardino farfalle, 260 m, 24.–25.x.1999, Bellini & Dell’Agata leg.; 1♀, Italy, Province of Rome, Monterotondo, vii.1894, “MR” leg.; SMTD.

Phakellura advenalis Lederer, 1863, Lectotype, with labels “Lectotype”, “Felder | colln”, “Shanghai”, “Phacellura [sic] | advenalis m”, “Lectotype | Phacellura [sic] | advenalis Lederer | E.G. Munroe. 1958”, BMNH.

Glyphodes albifuscalis Hampson, 1899, Syntype, with labels “Type”, “Ichang | 91 45.”, “Glyphodes | albifuscalis | type ♂. Hmpsn.”, BMNH.

Phakellura perspectalis Walker, 1859, Holotype (by monotypy): ♀, “Type”, “N. China | 54.8.”; with a handwritten bottom label “perspectalis | Walk”, BMNH. – 1♂, Germany, Weil am Rhein, ex larva, 2007, Walter leg.; 1♂, Tokio, Nippon, no date given, Staudinger & Bang-Haas; 1♂, China, Tianjin, Nankai University, 15.vii.2009, Nuss & Tränkner leg.; 1♂, China, Zhejiang, Shanghai, Mount Mogan, 29.vi.1931, Höne leg.; 1♂, China, Jiangsu Province, Shanghai, 30.v.1937, Höne leg.; 1♀, China, Zi-Ka-Wey, no date given, Staudinger & Bang-Haas; SMTD.

Pleuroptya ruralis (Scopoli, 1763): 1♂, 1♀ Germany, Saxony, Dresden, Heller, Augustusweg, 17.vii.2008, Tränkner leg., SMTD.

Sisyrophora pfeifferae Lederer, 1863, Holotype (by monotypy): with labels “Ida | Pfeiffer. | Singap. | 1858”, “Sisyrophora | Pfeifferae m”, NHMW. – 1♂, Cambodia, Cardamom Mts, near Cham Kar Chhrey, 12°20′N, 103°01′E, 350 m, 6.iii.2000, Nuss leg.; 1♀, Cambodia, Cardamom Mts, Tumpor area, 12°22′N, 103°02′E, 1,250 m, 27.ii.–5.iii.2000, Nuss leg.; SMTD.

Stemorrhages sericea (Drury, 1773): 1♂, Madagascar, Brickaville, no date given, Staudinger & Bang-Haas; 1♀, Sierra Leone, no date given, Staudinger & Bang-Haas; SMTD.

Udea ferrugalis (Hübner, 1796): 1♂, Italy, S-Tyrol, Bozen, 11.ix.1912, Möbius leg.; 1♀, Italy, Arco, Lake Garda, 27.ix.1930, Möbius leg., SMTD.

For the morphological analysis, dried museum specimens and adults were used. Dissections of abdomens and preparation of genitalia were performed according to Robinson (1976). Photographic documentation of genitalia was done using a Nikon Eclipse E600 Microscope in combination with a Zeiss AxioCam MRc5 camera and AxioVision programme (Version 4.4) on a Windows PC. Morphological characters are coded with respect

TABLE 1. Character matrix.

Character	
	Female genitalia
1	corpus bursae without (0), with one (1) (Fig. 1A) or with two signa (2) (Figs 1B–D) (Sutrisno, 2002b: character 34)
2	signum of corpus bursae shield-shaped and teeth-bearing (0) (Fig. 1C) or thorn-shaped and invaginated into the corpus bursae (1) (Fig. 1D)
3	ductus bursae shorter (0) (Fig. 1A), 1–4 × as long (1) (Fig. 1B) or at least 12 × as long (2) (Fig. 1C) as diameter of corpus bursae (Sutrisno, 2002b: character 35)
4	scobinate field of sclerotisation of ductus bursae anterior to ductus seminalis absent (0) or present (1) (Fig. 1E)
	Male genitalia
5	uncus distally without (0) (Fig. 2A) or with bulbous thickening (1) (Fig. 2B)
6	uncus broadly (0) (Fig. 2B) or very narrowly (1) (Fig. 2C) attached to the tegumen
7	coremata pads absent (0), present and without a distinct, sclerotised margin (1) (Fig. 2A) or present and with a distinct, sclerotised margin (2) (Fig. 2B)
8	sacculus undifferentiated (0) or with an elevated, sclerotised ridge (1) (Fig. 2B)
9	ductus ejaculatorius leaving the phallus apodeme dorsally (0) (Fig. 2D) or anteriorly (1) (Fig. 2E)
10	phallus apodeme shorter (0) (Figs 2D–E) or longer than abdomen length (1) (Fig. 2F) (Sutrisno, 2002a: character 19)
11	ventral, elongated sclerotisation of phallus apodeme absent (0) or present (1) (Fig. 2E) (Sutrisno, 2002b: character 17)
12	sternite 8 without (0) or with U-shaped sclerotisation (1) (Fig. 2G) (Sutrisno, 2002b: character 12)
13	tergite 8 without (0) or with Y-shaped sclerotisation (1) (Fig. 2G) (Sutrisno, 2002b: character 11)
14	tergite 8 posteriorly without (0) or with a paired, laterally situated sclerotised groin (1) (Fig. 2G)
15	sternite 7 at anterior edge without (0) or with a median pointed or triangular extension (1) (Fig. 2G) (Sutrisno, 2002b: character 13)
	Wings
16	costa of forewings without (0) (Figs 3D–F) or with a brown margin (1) (Figs 3A–C, 3G–H)
17	discoidal cell of forewing without (0) (Figs 3C–F) or with (1) (Figs 3A–B, 3G–H) a white spot, partly situated in the brown costal margin
18	termen of fore- and hindwing without (0) (Figs 3F–G) or with (1) brown margin (Figs 3A–E, 3H)
19	violet iridescence of white ground colour present (0) or absent (1)

to homology criteria and congruency. Some of the characters coded were used by Sutrisno (2002a, b) for studying *Glyphodes* and related genera, but the interpretation of these characters is not necessarily identical with that adopted in this study.

The morphological data matrix was transformed into a nexus-file and analysed using Paup 4.0b10 (Swofford, 2000) and the PaupUp graphical interface, version 1.0.3.1 Beta (Calendini & Martin, 2005). All characters used in this analysis were unordered and parsimony-informative. A maximum parsimony analysis was undertaken using the branch and bound algorithm with simple sequence addition. The maximum number of trees to be saved was set to be automatically increased when the limit is reached.

TABLE 2. Morphological data matrix.

	0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9
Evergestis forficalis	2 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1
Agrioglypta eurytusalis	2 0 2 0 1 1 2 1 ? 1 1 1 1 1 1 0 0 1 0
Agrotera nemoralis	1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1
Bradina diagonalis	1 0 1 0 1 0 1 0 0 0 1 1 1 1 0 1 0 1 0
Cydalima laticostalis	0 ? 1 1 1 0 2 1 1 0 1 1 1 1 1 1 1 0 0
Diaphania indica	0 ? 1 0 1 1 2 1 1 0 1 1 ? 1 1 1 0 1 0
Glyphodes stolalis	0 ? 1 0 1 1 2 1 1 0 1 1 1 1 0 0 0 1 0
Glyphodes onychinalis	2 0 0 0 1 1 2 1 1 0 1 1 1 1 0 0 0 1 0
Glyphodes sp.	2 0 2 0 0 1 2 1 ? 1 1 1 1 1 1 0 0 1 0
Mecyna lutealis	1 0 0 0 0 0 0 0 0 0 0 0 1 0 1 0 ? 0 0 1
Nomophila noctuella	1 0 1 0 ? ? ? 0 0 0 1 1 0 1 0 0 0 0 1
Palpita vitrealis	2 1 0 0 1 0 2 1 1 0 1 1 1 1 1 0 0 0 0
perspectalis	2 0 1 1 1 0 2 1 1 0 1 1 1 1 1 1 1 1 0
Pleuroptya ruralis	2 0 0 0 0 0 1 0 0 0 0 0 0 0 1 0 0 0 0 1
Sisyrophora pfeifferae	0 ? 1 1 1 0 2 1 1 0 1 1 1 1 1 1 1 1 0
Stemorrhages sericea	2 1 0 0 1 0 2 1 1 0 1 1 1 1 0 1 0 0 0
Udea ferrugalis	1 0 0 0 1 0 0 0 0 0 0 1 0 0 0 0 0 0 1

To evaluate the robustness of the data set, a bootstrap analysis was performed with 1.000 replicates via branch and bound search with simple addition sequence and re-sampling of all 19 characters in each replicate. TreeGraph 2 (Stöver & Müller, 2010) was used to illustrate the resulting phylogenies.

Abbreviations. BMNH – Natural History Museum London; SMTD – Senckenberg Museum für Tierkunde Dresden; NHMW – Naturhistorisches Museum Vienna.

RESULTS

Nineteen adult characters were coded. Four were of female genitalia, 11 of male genitalia and four of wing patterning. Sixteen of these characters are binary and three are multistate. The characters are listed in Table 1 and the character matrix in Table 2.

Using the branch and bound algorithm with simple addition sequence and with all characters equally weighted, 136 most parsimonious trees (length: 37 steps; CI = 0.5946, RI = 0.8101, RC = 0.4817) were found. Based on this result, a bootstrap 50% majority-rule consensus tree (length = 46 steps, CI = 0.4783, RI = 0.6962, RC = 0.3330) (Fig. 4) was obtained.

Monophyla supported by unambiguous synapomorphies

Agrioglypta + *Glyphodes* sp. Synapormophies: Ductus bursae at least 12 × as long as diameter of corpus bursae (3:2); phallus apodeme longer than abdomen length (10:1).

Cydalima + *Sisyrophora* + *perspectalis*. Synapormophies: Sclerotisation of ductus bursae anterior of ductus seminalis present (4:1); discoidal cell of forewing with a white spot, partly located in the brown costal margin (17:1).

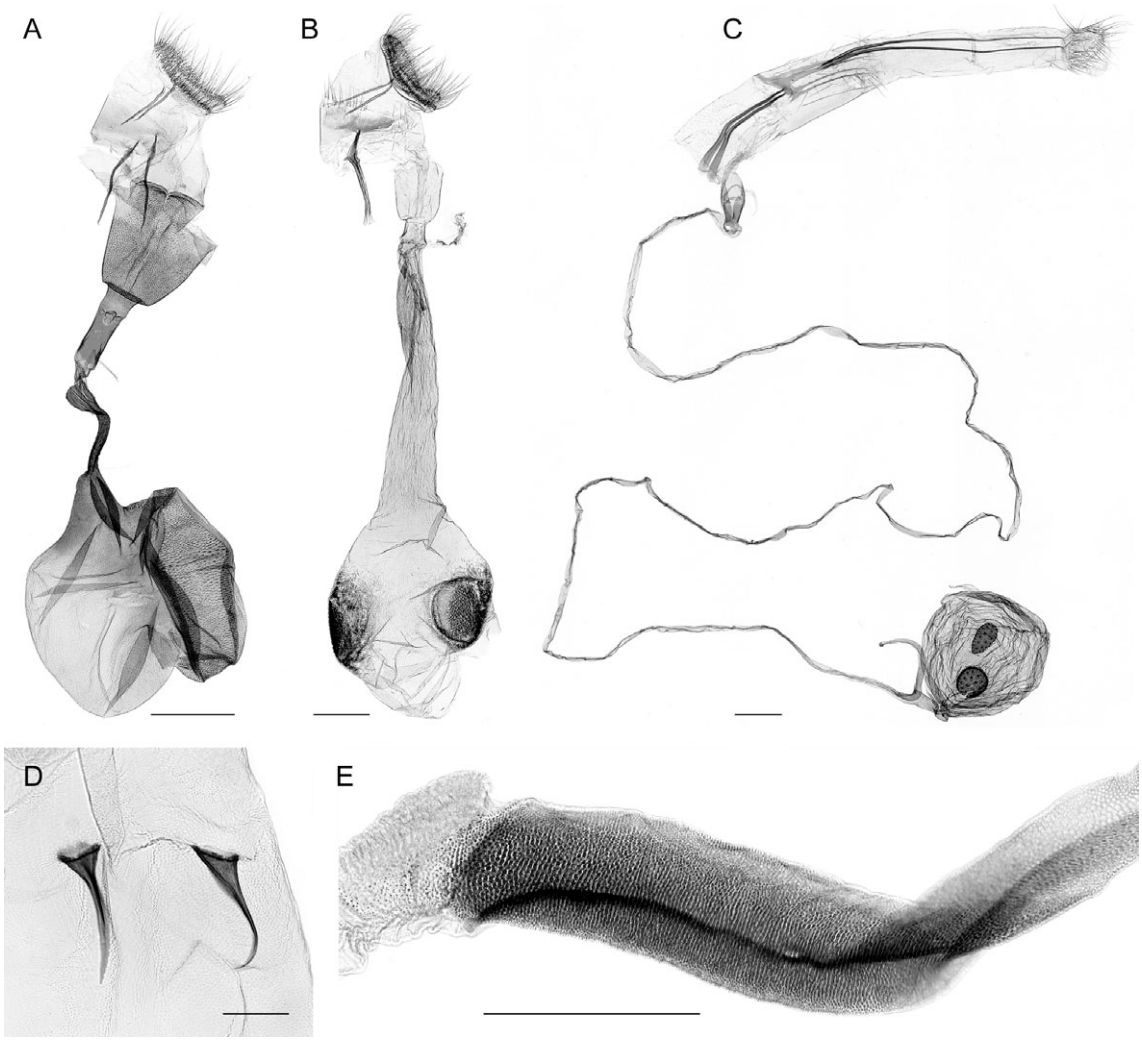

Fig. 1. Female genitalia. A – *Udea ferrugalis*; B – *Evergestis forficalis*; C – *Glyphodes* sp.; D – *Palpita vitrealis*, detail of corpus bursae, showing the signa; E – *Cydalima perspectalis*, detail of ductus bursae, showing sclerotization anterior to ductus seminalis. Scale bars: 500 μm.

Palpita + *Stemorrhages*. Synapormophy: Corpus bursae with a pair of thorn-shaped signa (2:1).

Agrioglypta + *Glyphodes* + *Diaphania* + *Cydalima* + *Sisyrophora* + *perspectalis* + *Palpita* + *Stemorrhages*. Synapormophies: Coremata pads present and with a distinct, sclerotised margin (7:2); sacculus with an elevated, sclerotised ridge (8:1); ductus ejaculatorius leaving the phallus apodeme anteriorly (9:1) [uncertain ("?") in *Agrioglypta* + *Glyphodes* sp.].

Agrioglypta + *Glyphodes* + *Diaphania* + *Cydalima* + *Sisyrophora* + *perspectalis* + *Palpita* + *Stemorrhages* + *Bradina*. Synapomorphies: Uncus distally with bulbous thickening (5:1); tergite 8 with Y-shaped sclerotisation (13:1); violet iridescence of white ground colour present (19:0).

Agrioglypta + *Glyphodes* + *Diaphania* + *Cydalima* + *Sisyrophora* + *perspectalis* + *Palpita* + *Stemorrhages* + *Bradina* + *Nomophila*. Synapormophy: Ventrally sclerotised groin of phallus apodeme present (11:1).

DISCUSSION

The results indicate that *perspectalis* belongs to a monophylum to which also belong the three genera in which it was previously placed: *Glyphodes*, *Diaphania* and *Palpita*. Munroe (1995) treated these genera in a *Diaphania*-group of 18 spilomeline genera centred on the Neotropical region, but did not mention which character(s) supported this group. In the analysis presented here, this monophylum is supported by the three synapomorphies 7:2, 8:1 and 9:1, and in addition contains the Old World taxa *Agrioglypta*, *Cydalima*, *Sisyrophora* and *Stemorrhages*.

First, the possible close relationships of *perspectalis* with the three genera in which it was previously placed are discussed below.

Diaphania contains 89 described species occurring in the Neotropical region, including *D. indica* Saunders, 1851 (Munroe, 1995). The latter species also occurs abundantly in the tropics of the Old World. Its larvae are pests of different cultivated plants, particularly Cucurbitaceae, but also Malvaceae, Amaranthaceae, Leguminosae

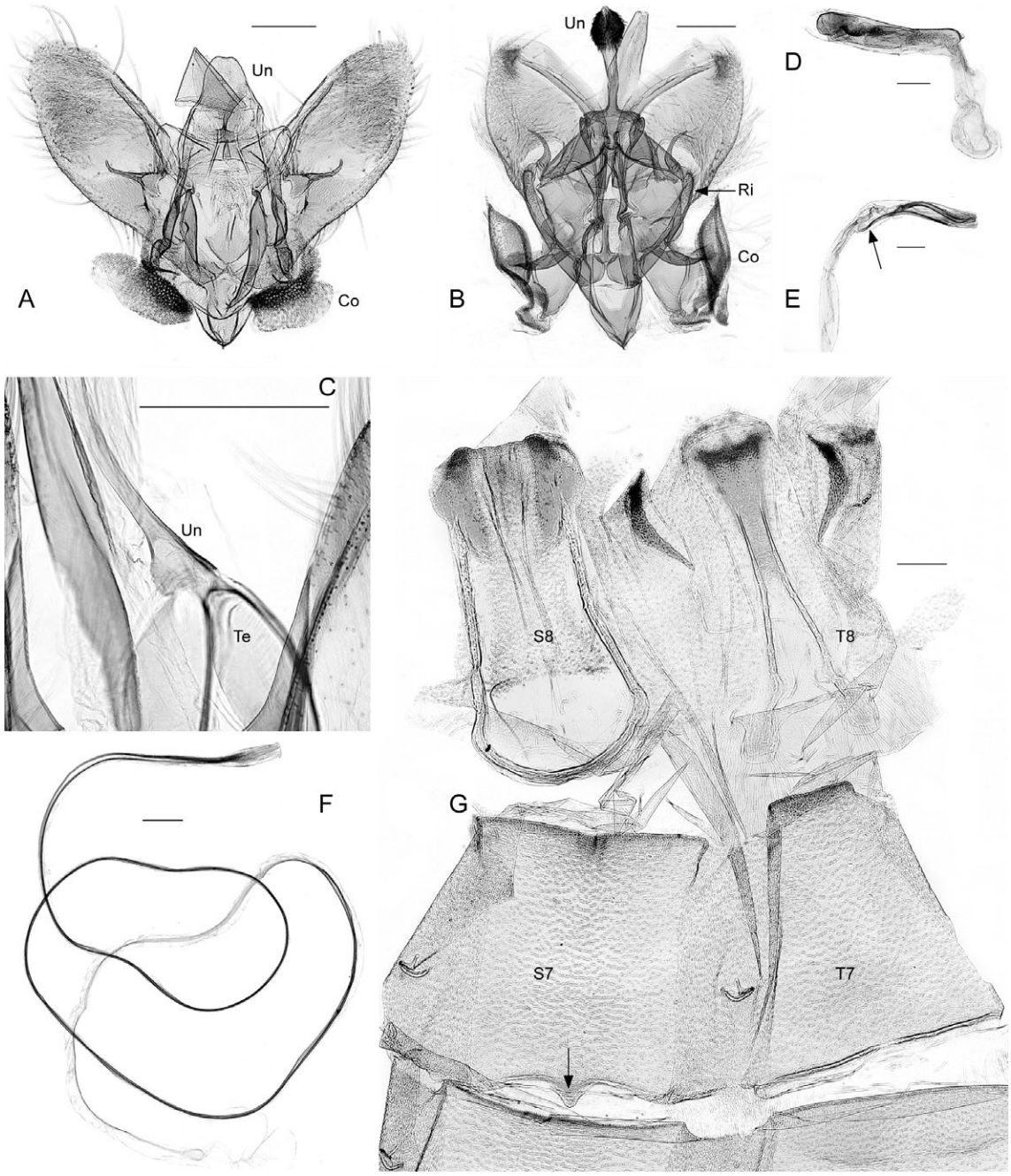

Fig. 2. Male genitalia. A – *Pleuroptya ruralis*, caudal view; B – *Cydalima laticostalis*, caudal view; C – *Glyphodes* sp., uncus base, caudal view; D – *Pleuroptya ruralis*, lateral view, phallus; E – *Cydalima perspectalis*, phallus, lateral view; arrow indicates ventrally sclerotised groin; F – *Glyphodes* sp., phallus, lateral view; G – *Cydalima perspectalis*, 7th to 8th abdominal segments; arrow indicates anterior median extension of sternite 7. Co – Coremata; Ri – Ridge of Sacculus; S – Sternite; Te – Tegumen; T – Tergite; Un – Uncus. Scale bars: 500 µm.

and Solanaceae. Thus, it might be assumed that *D. indica* was introduced by man into the Old World. There is a second species of *Diaphania* in the Old World, *D. holophaealis* (Hampson, 1900) on Christmas Island, which might be a melanic form of *D. indica* (J. Shaffer & Munroe, 2007). Thus, it is highly probable that *Diaphania* is a neotropical taxon. Apart from characteristic wing patterns and features of their genitalia, J. Shaffer & Munroe (2007) recognize species of *Diaphania* by the presence of anal tufts of spatulate scales in both sexes. This character is unique for *Diaphania* in our matrix, and therefore was omitted from the analysis because it is parsimony-uninformative. On the basis of these arguments, there is no evidence for placing *perspectalis* in *Diaphania*.

Glyphodes is pantropical in distribution, comprising more than 120 species and in need of revision (Robinson et al., 1994). Similar to Sutrisno (2002a, b) the morphological analysis presented here does not support the monophyly of *Glyphodes* (=*Dysallacta* Lederer, 1863, as synonymised by Inoue 1982). In this analysis, all

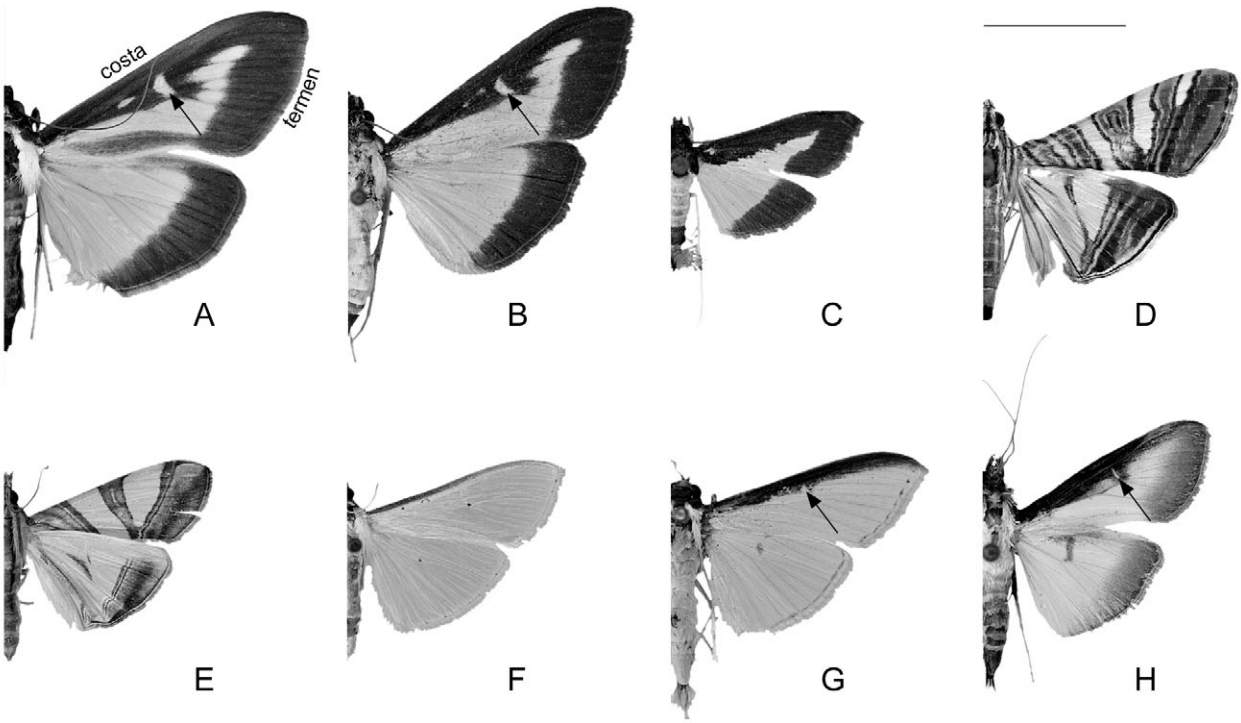

Fig. 3. Wing pattern. A – *Cydalima perspectalis* with brown anal margin on forewing; B – *Cydalima perspectalis* with white anal margin on forewing; C – *Diaphania indica*; D – *Glyphodes stolalis*; E – *Glyphodes* sp.; F – *Palpita vitrealis*; G – *Cydalima laticostalis*; H – *Sisyrophora pfeifferae*. Arrows indicate white spot in discoidal cell. Scale bar: 10 mm.

Glyphodes-species, together with *Agrioglypta* and *Diaphania* are characterized by character 6:1, uncus very narrowly attached to the tegumen. In contrast, the base of uncus in *perspectalis* is broadly attached to the tegumen. Externally, species of *Glyphodes* characteristically have colourful wings, which are easily distinguished from the white, brown edged wings of *perspectalis*. On the basis of these arguments, there is no evidence for placing *perspectalis* in *Glyphodes*.

Palpita comprises 146 described species mainly in the Neotropical, Afrotropical, Oriental and Australian regions (Nuss et al., 2010). The taxonomic revisions of the Asian and Australian species by Inoue (1996, 1997, 1999) indicate that these species and *Stemorrhages sericea* all have a pair of thorn-shaped signa in the corpus bursae (character 2:1), which unambiguously supports the monophyly of this group. On the basis of these arguments, there is no evidence for placing *perspectalis* in *Palpita*.

The above indicates that *perspectalis* is not closely related to *Diaphania*, *Glyphodes* or *Palpita*. A fourth generic name, *Neoglyphodes*, was proposed for *perspectalis* in 2008 by Streltzov. This genus is monotypic and Streltzov does not provide any hypothesis for its relationship. He lists eight diagnostic characters for this genus: (1) "In colouration – forewings with broad black or dark grey band along outer margin, continuing in narrower bands along costal and anal margins". This character complex is also present in other genera, e.g. the costal band in *Diaphania*, *Cydalima*, *Palpita* and *Sisyrophora*; the terminal band in *Diaphania* and *Glyphodes*, while the anal band in *perspectalis* can be present or absent. (2) "Triangular central field white with violet glistening". In the analysis presented here, this character state is 19:0 and supports the monophyly of *Agrioglypta* + *Glyphodes* + *Diaphania* + *Cydalima* + *Sisyrophora* + *perspectalis* + *Palpita* + *Stemorrhages* + *Bradina*. (3) "Hindwings white with the same band at outer margin as in forewings". This character is also present in *Diaphania*. (4) "In wing venation – discal cells are open." This character was investigated here and there are only closed discal cells in *perspectalis*, a character state that is also visible in the photograph of *perspectalis*, but not in the drawing of its wing venation in Streltzov (2008). (5) "In male genitalia – uncus bifurcate". This character is homoplastic in Spilomelinae, as it is also present in *Pycnarmon* Lederer, 1863 and *Nacoleia* Walker, 1859. (6) "Valva apex with three processes" is present only in an undescribed species mentioned by Streltzov (2008), but not in *perspectalis*. (7) "Aedeagus [phallus] long and narrow" is a description, which is valid for most Lepidoptera. (8) "In female genitalia – ductus short and strongly sclerotized." Here, Streltzov (2008) probably refers to the sclerotization of the ductus bursae anterior to the ductus seminalis that is identical to the character state 4:1 in the present study, which is shared by *Cydalima laticostalis* and *Sisyrophora pfeifferae*. It is the only diagnostic character given by Streltzov (2008), which, according to the analysis presented here supports relationships of *perspectalis* with other taxa, but none of these characters are autapomorphic for *Neoglyphodes*.

In contrast, the analysis presented indicates a close relationship of *perspectalis* with *Cydalima laticostalis* and *Sisyrophora pfeifferae*. The taxon formed by these three species is supported as monophyletic by the character

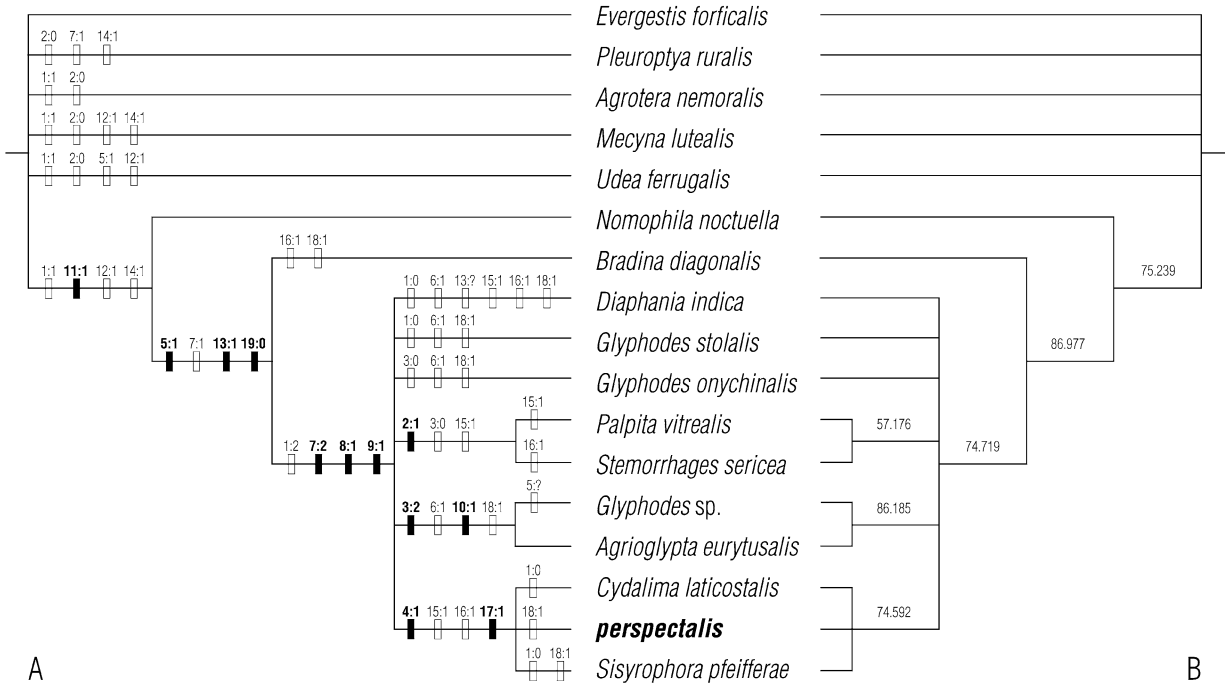

Fig. 4. A – Strict consensus tree of the 136 most parsimonious trees. Black rectangles: synapomorphies; white rectangles: homoplasies. B – 50% majority-rule consensus tree with bootstrap values.

states 4:1, sclerotisation of ductus bursae anterior of ductus seminalis developed and 17:1, a white spot in the discoidal cell of forewing, partly located on the brown costal margin.

Based on this phylogenetic analysis and the above discussion, the following taxonomic changes are proposed:

(1) The box tree moth be transferred to *Cydalima* Lederer, 1863 (type species: *Margarodes conchylalis* Guenée, 1854, a junior subjective synonym of *Cydalima laticostalis* (Guenée, 1854), in the combination *Cydalima perspectalis* (Walker, 1859) comb. n. Since *perspectalis* is the type-species of *Neoglyphodes* Streltzov, 2008 syn. n., this genus name be synonymised with *Cydalima* Lederer, 1863.

(2) Following Hering (1901), *Sisyrophora* Lederer, 1863 syn. rev. be regarded as a synonym of *Cydalima* Lederer, 1863 and its type species *Cydalima pfeifferae* (Lederer, 1863) (*Sisyrophora*) comb. rev. and *Cydalima joiceyi* (Janse, 1924) [*Margaronia* (*Sisyrophora*)] comb. n. be placed in this genus.

(3) Based on the investigation of type specimens, *Cydalima capriniodes* (Hampson, 1912) (*Glyphodes*) comb. n. and *Cydalima decipiens* (Hampson, 1912) (*Glyphodes*) comb. n. be transferred to *Cydalima*.

Based on these nomenclatural changes and the published data, there are currently 9 species (+ 9 synonyms) of *Cydalima*, all occurring in Asia and some also in Australia (Nuss et al., 2010). A taxonomic revision is still required to verify the status of available species group names and new species might be discovered as indicated by Streltzov (2008). Regarding the box tree moth *C. perspectalis* Walker, 1859, the type-specimen from China coincides with the specimens collected in Europe. Species group names currently treated in *Cydalima* and older than *C. perspectalis* Walker, 1859, exclusively belong to *C. laticostalis* (Guenée, 1854) and its synonyms *Margarodes conchylalis* Guenée, 1854, *Margarodes nitidicostalis* Guenée, 1854, and *Margaronia leodicialis* Walker, 1859. The type specimens of these four taxa were also investigated. They are all easily recognized as specifically distinct from *C. perspectalis*. Thus, it is very unlikely that a taxonomic revision of *Cydalima* will affect the species-group name *perspectalis*.

ACKNOWLEDGEMENTS. We thank C. Walter (Weil am Rhein) for providing living larvae from the founder population of *C. perspectalis* in Europe. M. Honey and K. Tuck (London) helped with the study of the collection at the BMNH. We very much appreciated correspondence and discussions with K. Sattler on the box tree moth. R. Bryner (Biel), B. Landry (Genève), I.-K. Park (Seoul), M.G. Ponomarenko (Vladivostok) and A. Streltzov (Blagoveshchensk) kindly provided literature on *C. perspectalis*. S. Gaal-Haszler (Vienna) took the photographs of the holotype of *Sisyrophora pfeifferae*. We thank A. Beyer (Dresden) who participated in this study during his pupil's project. Last but not least, we thank our colleagues M. Fischer for arranging the plates in the figures and C. Schmidt for comments on the manuscript.

REFERENCES

Calendini F. & Martin J.-F. 2005: PaupUP v1.0.3.1 A free graphical frontend for Paup* Dos software. URL: http://www.agro-montpellier.fr/sppe/Recherche/JFM/PaupUp/main.htm

Choo H.Y., Kaya H.K., Lee S.M., Kim T.O. & Kim J.B. 1991: Laboratory evaluation of entomopathogenic nematodes, Steinernema carpocapsae and Heterorhabditis bacteriophora against some forest insect pests. *Kor. J. Appl. Entomol.* **30**: 227–232 [in Korean, English abstr.].

Feldtrauer J.-F., Feldtrauer J.-J. & Brua C. 2009: Premiers signalements en France de la Pyrale du Buis Diaphania per-

spectalis (Walker, 1859), espèce exotique envahissante s'attaquant aux Buis (Lepidoptera, Crambidae). *Bull. Soc. Entomol. Mulhouse* **65**: 55–58.

HAMPSON G.F. 1896: Moths 4. *The Fauna of British India, including Ceylon and Burma*. Taylor & Francis, London, xxviii + 594 pp.

HERING E. 1901: Uebersicht der Sumatra-Pyralidae. *Stett. Entomol. Ztg* **62**: 13–118, 219–348.

INOUE H. 1982: Pyralidae. In Inoue H., Sugi S., Kuroko H., Moriuti S. & Kawabe A. (eds): *Moths of Japan 1, 2*. Kodansha, Tokyo, pp. 307–404 (vol. 1), 223–254; pls 36–48, 228, 296–314 (vol. 2).

INOUE H. 1996: Revision of the genus Palpita Hübner (Crambidae, Pyraustinae) from the eastern Palaearctic, Oriental and Australian regions. Part 1: group A (annulifer group). *Tinea (Tokyo)* **15**(1): 12–46, 148 figs.

INOUE H. 1997: Revision of the genus Palpita Hübner (Crambidae, Pyraustinae) from the eastern Palaearctic, Oriental and Australian regions. Part 2, group B. *Tinea (Tokyo)* **15**(2): 131–181.

INOUE H. 1999: Revision of the genus Palpita Hübner (Crambidae, Pyraustinae) from the eastern Palaearctic, Oriental and Australian regions. Part 3: additions and corrections. *Tinea (Tokyo)* **16**(1): 52–60.

KÄPPELI F. 2008: Der Buchsbaumzünsler – Im Eiltempo durch Basler Gärten. *g'plus – die Gärtner-Fachzeitschrift (Zürich)* **2008**(20): 33.

KAWAZU K., HONDA H., NAKAMURA S. & ADATI T. 2007: Identification of sex pheromone components of the box tree pyralid, Glyphodes perspectalis. *J. Chem. Ecol.* **33**: 1978–1985.

KIRPICHNIKOVA V.A. 2005: Pyralidae. In Ler P.A. (ed.): *Key to the Insects of Russian Far East 5 (2)*. Dal'nauka, Vladivostok, pp. 526–539 [in Russian].

KRÜGER E.O. 2008: Glyphodes perspectalis (Walker, 1859) – neu für die Fauna Europas (Lepidoptera: Crambidae). *Entomol. Z.* **118**: 81–83.

LEE S.M., LEE D.W. & CHOO H.Y. 1996: Biology and pathogenicity entomopathogenic nematodes, Steinernema spp., isolated from forest soil in southern Korea. *FRI J. Forest Sci. (Seoul)* **53**: 117–123.

MARUYAMA T. 1992: Difference in injury levels caused by the box-tree pyralid, Glyphodes perspectalis (Walker) (Lepidoptera: Pyralidae) on various box-trees. *Jap. J. Appl. Entomol. Zool.* **36**: 56–58.

MARUYAMA T. 1993: Life cycle of the box-tree pyralid, Glyphodes perspectalis (Walker) (Lepidoptera: Pyralidae). IV. Effect of various host plants on larval growth and food utilization. *Jap. J. Appl. Entomol. Zool.* **37**: 117–122.

MARUYAMA T. & SHINKAJI N. 1987: Studies on the life cycle of the box-tree pyralid, Glyphodes perspectalis (Walker) (Lepidoptera: Pyralidae). I. Seasonal adult emergence and developmental velocity. *Jap. J. Appl. Entomol. Zool.* **31**: 226–232.

MARUYAMA T. & SHINKAJI N. 1991: The life cycle of the box-tree pyralid, Glyphodes perspectalis (Walker) (Lepidoptera: Pyralidae). II. Developmental characteristics of larvae. *Jap. J. Appl. Entomol. Zool.* **35**: 221–230.

MARUYAMA T. & SHINKAJI N. 1993: The life cycle of the box-tree pyralid, Glyphodes perspectalis (Walker) (Lepidoptera: Pyralidae). III. Photoperiodic induction of larval diapause. *Jap. J. Appl. Entomol. Zool.* **37**: 45–51.

MITCHELL A. 2009: Box tree moth Diaphania perspectalis (Walk.) – a new pyralid moth to Britain and Ireland. *Atropos* **36**: 17–18.

MUNROE E.G. 1995: Pyraustinae: Spilomelini. In Heppner J.B. (ed.): *Atlas of Neotropical Lepidoptera. Checklist: Part 2. Hyblaeoidea – Pyraloidea – Tortricoidea 3*. Association for Tropical Lepidoptera, Gainesville, FL, pp. 58–79.

NUSS M. (ed.) 2010: *Global Information System on Pyraloidea*. URL: www.pyraloidea.org

MUUS T.S.T., VAN HAAFTEN E.-J. & VAN DEVENTER L.J. 2009: De buxusmot Palpita perspectalis (Walker) in Nederland (Lepidoptera: Crambidae). *Entomol. Ber.* **69**: 66–67.

PARK I.-K. 2008: Ecological characteristic of Glyphodes perspectalis. *Kor. J. Appl. Entomol.* **47**: 299–301.

ROBINSON G.S. 1976: The preparation of slides of Lepidoptera genitalia with special reference to the Microlepidoptera. *Entomol. Gaz. (London)* **27**: 127–132.

ROBINSON G.S., TUCK K.R. & SHAFFER M. 1994: *A Field Guide to the Smaller Moths of SE-Asia.* Malaysian Nature Society, Kuala Lumpur, 309 pp.

RODELAND J. (ed.) 2009: *Lepiforum*. URL: www.lepiforum.de

SHAFFER J.C. & MUNROE E.G. 2007: Crambidae of Aldabra Atoll (Lepidoptera: Pyraloidea). *Trop. Lepidopt. (Gainesville)* **14** [2003]: 1–110.

SIGG C.-R. 2009: Auch das noch: Ein neuer Buchs-Schädling schlägt zu. Massive Schäden durch den Buchsbaumzünsler. *Der Gartenbau (Solothurn)* **2009**(4): 2–4.

STÖVER B.C. & MÜLLER K.F. 2010: TreeGraph 2: Combining and visualizing evidence from different phylogenetic analyses. *BMC Bioinformatics* **11**: 7.

STRELTZOV A.N. 2008: A new genus for Glyphodes perspectalis (Walker, 1859) (Pyraloidea, Crambidae, Pyraustinae). *Euroasian Entomol. J.* **7**: 369–372.

SUTRISNO H. 2002a: A preliminary study on relationships among selected Australian members of the tribe Spilomelini (Lepidoptera: Crambidae: Spilomelini). *Zool. Sci. (Tokyo)* **19**: 915–929.

SUTRISNO H. 2002b: Cladistic analysis of the Australian Glyphodes Guenée and allied genera (Lepidoptera: Crambidae; Spilomelinae). *Entomol. Sci. (Tokyo)* **5**: 457–467.

SUTRISNO H. 2005: Molecular phylogeny of Agrioglypta Meyrick and Talanga Moore (Lepidoptera: Crambidae; Spilomelinae) inferred from nuclear EF-1α gene. *Hayati J. Biosci. (Bogor)* **12**: 45–49.

SUTRISNO H. 2006: Evolution of a wingless gene and its utility for inferring the relationships within Glyphodes moths. *Hayati J. Biosci. (Bogor)* **13**: 145–150.

SUTRISNO H., AZUMA N. & HIGASHI S. 2006: Molecular phylogeny of the Indo-Australian Glyphodes and its allied genera (Insecta: Lepidoptera: Crambidae: Spilomelinae) inferred from mitochondrial COI and COII and nuclear EF-1α gene sequences. *Spec. Divers.* **11**: 57–69.

SWOFFORD D.L. 2000: PAUP*. *Phylogenetic Analysis Using Parsimony (*and Other Methods). Version 4*. Sinauer Associates, Sunderland, Massachusetts.
URL: http://paup.csit.fsu.edu/

TANG S.J., QIN H.Z. & SUN W. 1990: Studies on bionomics of Diaphania perspectalis. *J. Shanghai Agric. Coll.* **8**: 307–312.

TOMINAGA S. 1998: Biological notes on Glyphodes perspectalis (Walker) and Herpetogramma basalis (Walker) (Pyralidae) in Okinawa. *Yugato* **154**: 119–120.

WALKER F. 1859: *List of the Specimens of Lepidopterous Insects in the Collection of the British Museum. Part XVIII. Pyralides.* British Museum (Nat. Hist.), London, pp. 509–798.

ZHOU W., XIA C.-Y., SUN X.-Q., ZHU B., LIU X.-P., LIU Z.-C. & WANG Y. 2005: Studies on the biological characteristics and control of Diaphania perspectalis Walker. *J. Shanghai Jiaotong Univ. Agric. Sci.* **23**: 52–56.

Received March 16, 2010; revised and accepted April 26, 2010