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Taxonomic studies on Spilomelinae fauna associated with economically important flower crops of zone 1, 2 and 3 of Karnataka, India

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Abstract
Among the Sub-families of Pyraloidea, Spilomelinae is the largest followed by Crambinae, Pyraustinae, *etc.* which comprises about 4,085 described species under 327 genera. It is one of the most economically important group which comprises of fruit borers, shoot borers, leaf webbers, leaf rollers, *etc*. In the present study, the specimens which were already collected and reared to an adult stage on their respective hosts at the Department of Agricultural Entomology, College of Agriculture, Bheemarayanagudi were utilized to characterize the genera and species of adults Spilomelinae associated with economically important flower crops based on morphological and genital characters. The results revealed that a total of five species *viz. Glyphodes vertumnalis* Guenee, *Nausinoe geometralis* (Guenee), *Nausinoe perspectata* (Fabricius), *Nausinoe peuritia* (Cramer) and *Palpita vitrealis* (Rossi) on jasmine were identified. All these species differ in both morphological and genital characters. Further, genitalia, wing venation and adult habitus photographs were provided.

Keywords: Taxonomy, spilomelinae, flower crops, Karnataka, India

Introduction
Karnataka is divided into 10 agro-climatic zones based on rainfall pattern, topography, soil characteristics, climate and major crops grown *etc*. The zone-1 (North-Eastern transition zone) comprises of Bidar and Kalaburagi, zone-2 (North-Eastern dry zone) comprises of Raichur and Yadagir and zone 3 (Northern dry zone) comprises of Bellary, Koppal and parts of Gadag, Bagalkot, Belagavi, Vijayapur and Dharwad. The major flower crops growing in these zones include jasmine, marigold, rose *etc.* In recent years, cropping pattern in this region has changed immensely and in view of the changed cropping pattern as well as ecological conditions, the productivity is low owing to many factors like both biotic and abiotic stresses. Among various biotic stresses, damage and yield loss caused by insect pests are main causative factors. Among insect pests, the Pyraloidea have great economic importance. The extent of yield loss ranges from 10 to 100 per cent (Jotwani *et al*., 1971) [1]. The Pyraloidea are currently divided into two families (Pyralidae and Crambidae) primarily based on tympanal organ of the adult and a few larval characters (Solis, 2007) [2]. Among families of Pyraloidea, Crambidae is the largest which comprises of 21 sub-families of which, Spilomelinae is the largest which comprises of 4,085 described species under 327 genera (www.pyraloidea.org) [3]. It is the most economically important group of Pyraloidea which includes shoot borers, stem borers, fruit borers, leaf Webber's, leaf folders, leaf rollers *etc*. (Munroe and Solis, 1999; Mitter *et. al.*, 2017) [4, 5]. Most of the taxonomists have undertaken taxonomic studies predominantly by depending on light trap collections and they did not make any efforts to associate Spilomelinae with their host plants (economically important flower crops) except Nagaraj (2014) [6] who made a first effort to survey and document the Pyraloidea fauna associated with major cereals in Hyderabad-Karnataka region. In zone 1, 2 and 3 of Karnataka, the information pertaining to the taxonomy of Spilomelinae associated with economically important flower crops with respect to description and characterization is very meager. Further, no attempt was made to associate Spilomelinae fauna with its host. Hence, the description of a species reared from actual hosts is the need of the hour for accurate identification and authentication of its host.

Materials and methods

To study the adult morphological and genital characters, the specimens already collected (Karnataka) and reared from their actual hosts at Department of Agricultural Entomology, College of Agriculture, Bheemarayanagudi, University of Agricultural Sciences, Raichur 584-104, Karnataka, India were utilized. The morphological as well as genital characters of the adult Spilomelinae were studied following Hampson (1896) [7], Clark (1941) [8], Robinson (1976) [9] and Thomas (2007) [10] with the necessary modifications. Before dissection of genitalia, adult specimens were photographed. Adult structures such as forewing and hindwing, palpi and genitalia were photographed using Trinocular microscope with auto-montage (Leica M 205C).

The definitions/terminologies have been drawn from a number of sources, including Torre-Bueno (1937) [11], Diakonoff (1954) [12], Bhattacharjee (1962) [13], Munroe *et al*. (1995) [14], Klots (1970) [15], Scoble (1992) [16], Gordh and Headrick (2001) [17], Triplehorn and Johnson (2005) [18] described the parts of the genitalia of Lepidoptera and their arrangement and terminology for external features can be found.

Results and Discussion

The results revealed that a total of five species under three genera were identified from zone 1, 2 and 3 of Karnataka. On flower crops, a total of 5 species were identified *viz.*, *Glyphodes vertumnalis* Guenee, *Nausinoe geometralis* (Guenee), *Nausinoe perspectata* (Fabricius), *Nausinoe peuritia* (Cramer) and *Palpita vitrealis* (Rossi) on Jasmine.

Genus *Glyphodes* Guenee, 1854; type species: *Glyphodes stolalis* Guenee, 1854

Glyphodes vertumnalis Guenee, 1854; type locality: India (Fig. 1)

Description: Body green in colour, neither of the wings fulvous; marginal specks often obsolescent; cilia fulvous; abdomen small and profuse; male having black anal tuft of hairs; female devoid of anal tuft of hairs on hind tibiae; male with black tuft of hairs on hind tibiae at outer margin and extremity; hindwing of male with the inward area compactly clothed below with clumps of yellowish hair.

Wing venation: Fore wing with vein R_5 marginally approaching to R_{3+4}; M_1 arises close towards vein R_5; M_3, M_2 arising from angle of cell; Cu_{1a} from below the angle of cell, Cu_{1b} before angle of cell; hind wing with vein Rs stalked with $Sc+R_1$; M_2 and M_3 closely approximated for short distance; Cu_{1b} before angle of cell.

Male genitalia: Uncus broad and greatly curved, bending forward giving a beak like appearance; gnathos equal to uncus and broad; base of the gnathos and uncus darken laterally; vinculum wide and V-shaped; coremata with long thick as well as fine hair; valvae small, broad, fan-like having chitinous hook-like clasper in the costal base; phallus equally long.

Female Genitalia: Ovipositor slit swollen, wide dorsally and tapered ventrally; anal papillae thick; apophyses short; anterior apophysis twice the length of posterior apophysis; sub-genital plate small, ductus bursae fairly long and thick; corpus bursae spherical with two triangular signa one on each side near the apex.

Materials examined: India: Karnataka: Gulbarga, Raddewadigi, 1♀, 05.ii.2015, reared on jasmine, Nagaharish; Gulbarga, Hattekuni, 1♀, 12.viii.2015, reared on jasmine, Nagaharish; Yadgir, Bgudi, 4♂, 20.iv.2013, at light, S. Murthy; Gulbarga, Raddewadigi, 1♂, 15.x.2015, reared on jasmne, Nagaharish; Yadgir, B gudi, 5♂, 1♀, 03.xii.2012, jasmine, S. Murthy; Yadgir, B gudi, 1♂, 4.ix.2012, at light, S. Murthy; Yadgir, B gudi, 1♂, 16.vii.2012, jasmine, S. Murthy; Yadgir, B gudi, 1♂, 18.vii.2012, jasmine, S. Murthy.

Remarks: *Glyphodes vertumnalis* Guenee intently looks like *G. marginata* Hampson. Both are recognized by wing character. In *G. marginata* Hampson, wings are fulvous; however, in *G. vertumnalis* Guenee wings are not fulvous.

Genus: *Nausinoe* Hubner, 1825; type species: *Phalaena pueritia* Cramer, 1779

Nausinoe geometralis (Guenee, 1854); type locality: Central India (Fig. 2)

Description: Generally, body yellow or slightly fulvous having black striations; Palpi white from below, obliquely upturned, 2nd joint very broadly scaled in front, 3rd porrect; maxillary palpi filiform; antennae longer than forewing and almost simple. Head, thorax, abdomen and wings yellow, striated with black. Forewing with two black-edged ante-medial white spots below the cell; a spot at middle of cell and another at end of it. Hind wing with sub-basal white band; an ante-medial spot between cell and inner margin.

Wing venation: Forewing with vein R_5 straight and well separated from R_{3+4}, to which R_2 approximated; Cu_{1a}, M_3 and M_2 from angle of cell and slightly distorted; hindwing cell short; disco-cellular straight; veins Cu_{1a}, M_3 and M_2 from angle of cell; M_1 and Rs shortly stalked, anastomosing with $Sc+R_1$; Cu_{1a} from before angle of cell, curved downwards for a short distance.

Male genitalia: Uncus short, thick with slightly bent spiculated apex; gnathos short; tegumen long; vinculum V-shaped with slightly attenuated apex; valvae short, broad at the apex, narrow at the base fringed with short rigid hairs; cucullus beak like; aedeagus short, stout, having a split at the apex end; cornuti composed of a long pole like sclerotized process.

Female genitalia: Ovipositor cut wide open and short; anal papillae fairly wide; sub-genital plate funnel shaped; anterior apophyses and posterior apophysis short; ductus bursae thin, slim and fairly long; corpus bursae sac like, without signum.

Materials examined: INDIA: Karnataka: Yadgir, B gudi, 3♂, 2.xi.2014, reared on jasmine, S. Murthy; B gudi, 2♀, 10.i.2012, reared on jasmine, S. Murthy; B gudi, 1♀, 21.x.2013, reared on jasmine, S. Murthy; B gudi, 1♂, 15.xi.2012, reared on jasmine, S. Murthy; B gudi, 3♀, 1♂, 29.vii.2014, reared on jasmine, Nagaraj, S. K.; B gudi, 3♀, 29.ii.2014, reared on jasmine, Nagaraj, S. K.; B gudi, 1♀, 27.ii.2014, reared on jasmine, Parvathi; B gudi, 2♂.
9.i.2015, reared on jasmine, Basavaraj, K.; B gudi, 2♂, 2♀, 21.i.2015, reared on jasmine Nagaraj, S. K.; B gudi, 1♂, 15.viii.2015, reared on jasmine S. Murthy; Bidar, Bidar, 1♀, 2♂, 26.viii.2015, reared on jasmine, Nagaharish; Raichur, Raichur, 1♂, 26.viii.2015, reared on jasmine, Nagaharish; Bidar, Bidar, 3♀, 2♂, 27.viii.2015, reared on jasmine, Nagaharish.

Remarks: Morphologically, *Nausinoe geometralis* Guenee appears like *N. perspectata* Fabricius, but they can be easily differentiated based on their genital characters. In *N. geometralis*, absence of Y-shaped band on forewing, and in female, corpus bursa bulbous. While in *N. perspectata*, presence of Y-shaped band on forewing and in female, corpus bursa not bulbous.

Nausinoe perspectata (Fabricius, 1775); type locality: India orientali (Fig. 3)

Description: Palpi white from below, obliquely upturned, 2nd joint very broadly scaled in front, 3rd porrect; maxillary palpi filiform; antennae longer than fore wing and almost simple. Head, thorax, abdomen and wings pale yellowish brown or fuscous brown; abdomen banded with white. Forewing with two black- edged white sub-basal bands, not reaching the costa; a spot in cell; a wedge-shaped mark on inner margin; a disco-cellular white band forming with a patch below the cell a Y-shaped band, with its outer arm shortest; two large black-edged white crescentic postmedial marks. Hindwing with the basal area white, its outer edge angled at vein 5 and with a black edged yellow-brown disco-cellular mark.

Wing venation: Forewing with vein R_5 straight and well separated from R_{3+4}, to which R_2 approximated; Cu_{1a}, M_3 and M_2 from angle of cell and slightly distorted; hindwing cell short; disco-cellular straight; veins Cu_{1a}, M_3 and M_2 from angle of cell; M_1, Rs shortly stalked, anastomosing with $Sc+R_1$; Cu_{1a} from before angle of cell, curved downwards for a short distance.

Male genitalia: not examined.

Female genitalia: Ovipositor slit wide, oblong; anal papillae thick and hairy; apophyses short; subgenital plate cup-shaped; ductus bursae narrow, small in length, ring like at the beginning, fairly thick later; corpus bursae sac-like; signum absent.

Materials examined: INDIA: Karnataka: Yadgir, Bheemarayanagudi, 1♀, 01.ix.2015, reared on jasmine, S. Murthy; Bheemarayanagudi, 1♀, 26.i.2015, reared on jasmine, Nagaharish; Bheemarayanagudi, 1♀, 2.ii.2015, reared on jasmine, Nagaharish.

Remarks: *Nausinoe perspectata* Fabricius almost looks like *N. geometralis* Guenee. However, they can be differentiated based on their wing character and tibial hairs. In *N. perspectata* Y- shaped band found on disco-cellular white band, while in *N. geometralis* Y-shaped band absent. Also, *N. perspectata* differs from *N. geometralis* in having hairs on tibia.

Nausinoe pueritia (Cramer, 1780); type locality: Coromandel (Fig. 4)

Description: Pale yellowish brown or fuscous brown; labial palpi white below; abdomen banded with white; forewing with two black-edged white sub-basal bands, not reaching the costa; a spot in cell; a wedge-shaped mark on inner margin; a disco-cellular white band forming with a patch below the cell a Y-shaped band, with its outer arm shortest.

Wing venation: Forewing with vein R_5 straight and well separated from R_{3+4}, to which R_2 approximated; Cu_{1a}, M_3 and M_2 from angle of cell and slightly distorted. Hindwing cell short; disco-cellular straight; veins Cu_{1a}, M_3 and M_2 from angle of cell; M_1 and Rs shortly stalked, anastomosing with $Sc+R_1$; Cu_{1a} from before angle of cell, curved downwards for a short distance.

Male genitalia: not examined.

Female genitalia: Anterior apophysis strongly developed than posterior apophysis; papillae analis oval; ductus bursa long, very thin, thread like; seminal receptaculum from posterior part of ductus bursae; bursa copulatrix small, oval and curved distally; and signum absent.

Materials examined: India: Karnataka: Yadgir, B gudi, 1♂, 2.ii.2015, reared on jasmine, Nagaraj, S.K.; Yadgir, B gudi 1 ♀, 4.vi.2015, reared on jasmine, Nagaraj, S.K.

Remarks: This species morphologically very close to *N. perspectata* Fabricius. But variations found with respect to genitalial characters. In female, ductus bursae long, very thin, thread like and three times long that of bursa copulatrix; corpus bursae without ductus seminalis. While in *N. perspectata* Fabricius, ductus bursae short, narrow and ring like at the beginning, fairly thick later; corpus bursae with seminal receptaculum.

Genus: *Palpita* Hubner, 1808; type species: *Pyralis unionalis* Hubner, 1796

Palpita vitrealis Rossi, 1794; type locality: Indian orientalis (Fig. 5)

Description: Body completely white; antennae filiform; ocelli prominent; maxillary palpi, labial palpi and edges of the thorax fulvous, patagia cone shaped with wide base; wings with the external edge evenly curved, fore wing with costal edge fulvous, rest white; hind wing semi-hyaline; fore tibiae lined with fulvous; forewing generally has traces of two dark colored specks beneath the costa before center, one at each edge of cell, and one underneath inception of vein Cu_{1b}.

Wing venation: Forewing with veins R_5 closely approximated to R_{3+4}, nearly half of its length; R_2 approximated to R_{3+4}; M_3 and M_2 from angle of cell; hindwing with vein Rs stalked with $Sc+R_1$; M_3 and M_2 closely approximated; Rs from upper angle and shortly stalked; Cu_{1b} before angle of cell.

Male genitalia: Uncus rod-like with its tip expanded and dorsally clothed with scale-like setae; tegumen wide and finely sclerotized; valve broad and ellipsoid with narrowly inflated sacculus with a composite armature of dorsally directed projections; aedeagus usually long; vesica with two fixed cornuti and often sclerotized conspicuously.

Female genitalia: Ovipositor opening oblong; anal papillae fairly thick; sub-genital plate tiny; ductus bursae short and stout with asymmetrical sclerotization; bursa copulatrix long and seems sac like with a pair of prominent thorn-like signum.

Materials examined: India: Karnataka: Bidar, KVK, 1♀, 03.ix.2015, reared on jasmine, Nagaharish; Gulbarga, Hattekuui, 1♂, 1♀, 22.viii.2015, reared on jasmine, S. Murthy; Bidar, KVK, 1♀, 27.viii.2015, reared on jasmine,

Nagaharish; Bidar, KVK, 1♂, 27.viii.2015, reared on jasmine, Swamy; Yadgir, B gudi, 1♀, 3 ♀, 29.iii.2015, reared on jasmine, Nagaraj, S.K.; Gulbarga, Hattekuni, 1♀, 1♂, 25.ix.2015, reared on jasmine, Nagaraj, S.K.; Yadgir, B gudi, 1♂, 18.xi.2012, at jasmine, S. Murthy; Yadgiri, 1♀, 25.xi.2012, at light, S. Murthy.; Yadgir, B gudi, 1♂, 2♀, 2.ii.2015, reared on jasmine, Nagaraj, S.K.

Remarks: Morphologically, *P. vitrealis* Rossi almost looks like *P. kimballi* Munroe However, both are well differentiated based on their genital characters. In *P. vitrealis*, valvae doesn't have semi-circular-shaped processes, whereas in *P. kimballi* valvae having semicircular-shaped processes.

Similarly, the present study is in line with the previous findings of Landry (2016), [19] who revised the spilomelinae fauna of Galapagos islands, Ecuador where, he observed variations with respect to morphological and genital characters. In another study, Mally *et al*., (2015) [20] studied the morphological and genital characters of the genus *Leucinodes* for investigating the unknown diversity which were existed in solanaceous crops of sub-saharan Africa. Likewise, Bhattacharjee and Menon (1962) [21] studied the various external stages of *Hymenia recurvalis*.

In the previous studies also, Chen *et al.* (2006) [22] observed variations in female genitalia, especially in the bursa copulatrix of *Cirrhocrista* Lederer. Similarly, Dan and Hun (2005) [23] observed differences in male genitalia of *Palpita* Hubner. Likewise, Shaffer and Munroe (2003) [24] and Kumar *et al.*, (2013) [25] observed variations with respect to male and female genitalia of fauna of Aldabra Toll and major lepidopterous pests of north India respectively. In another study, Kim *et al.* (2014) [26] and Park *et al*. (2016b) [27] figured out the variations of male and female genitalia with respect to uncus and bursa copulatrix and also the body colour of *Nacoleia* and *Glyphodes* respectively. Similarly, Sullivan and Solis (2013) [28] pointed out the major morphological and genital variations of various species of *Palpita* Hubner. Further, Rathikannu and Chaitra (2017) [29] also observed the genital variations within the male and female genitalia of various species of *Glyphodes* Guenee.

Conclusion

Most of the taxonomists in India, have conducted taxonomic studies mostly by relying on light trap collections. None of them made any efforts to associate Spilomelinae species with their respective hosts except Nagaraj and Nagaharish. So, in the present investigation an attempt was made to study the Spilomelinae fauna related with the flower crops from zone-1, 2 and 3 of Karnataka. In the current study, 5 species under 3 genera were recognized. The taxonomic descriptions for these species were provided with photographic illustrations of genitalia, wing venation and adult habitus. Further, current taxonomic status of each species was given.

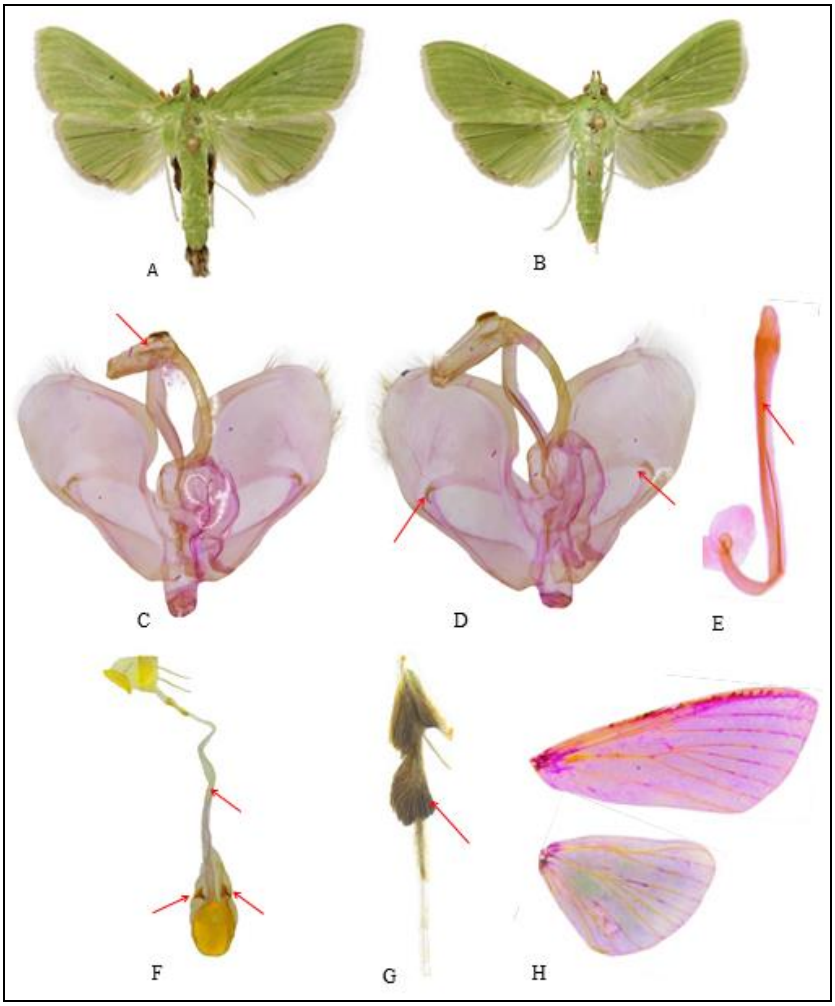

Fig 1: Genital and morphological characters of adult *Glyphodes vertumnalis* Guenee (A. male; B. female; male genitalia, C. ventral view; D. dorsal view; E. aedeagus; F. female genitalia; G. male hind tibia with tuft of hairs on outer extreme region; H. wing venation)

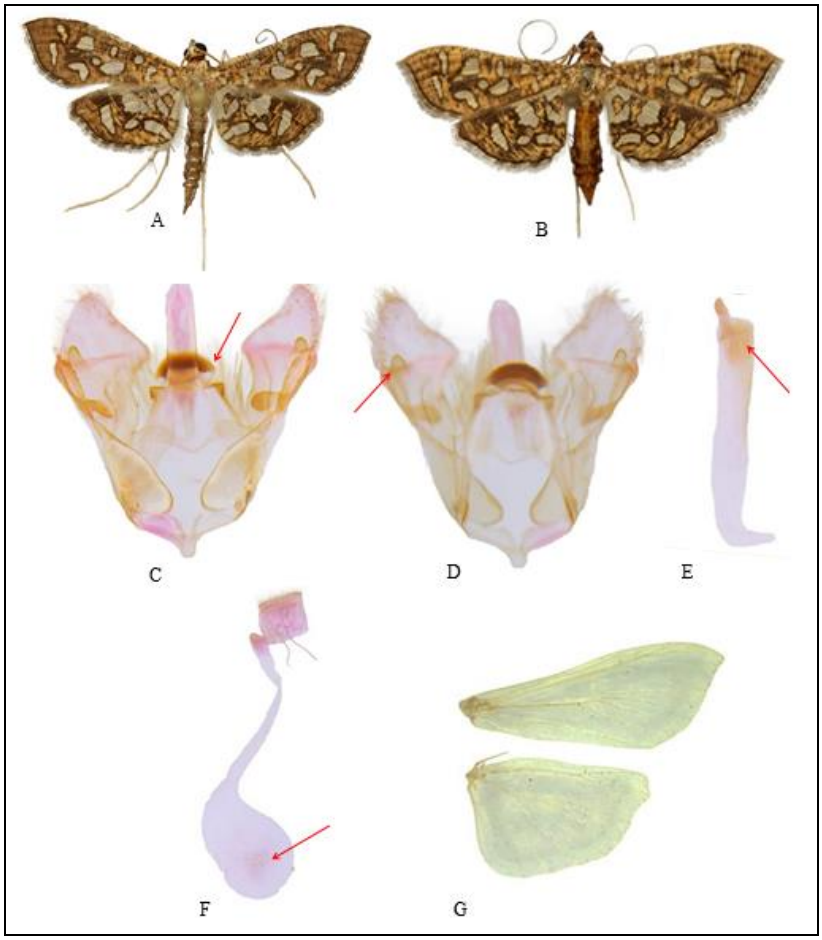

Fig 2: Genital and morphological characters of adult *Nausinoe geometralis* (Guenee) (A. male; B. female; male genitalia, C. ventral view; D. dorsal view; E. aedeagus; F. female genitalia; G. wing venation)

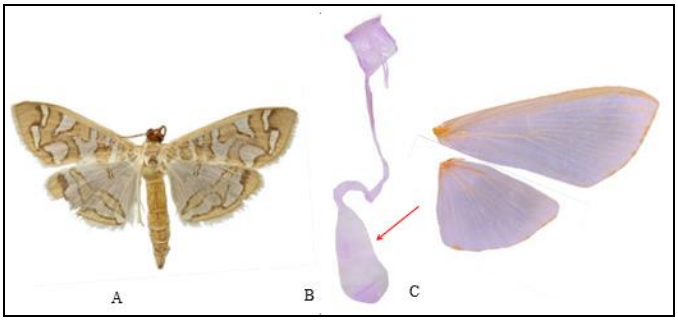

Fig 3: Genital and morphological characters of adult *Nausinoe perspectata* (Fabricius) (A. female; B. female genitalia; C. wing venation)

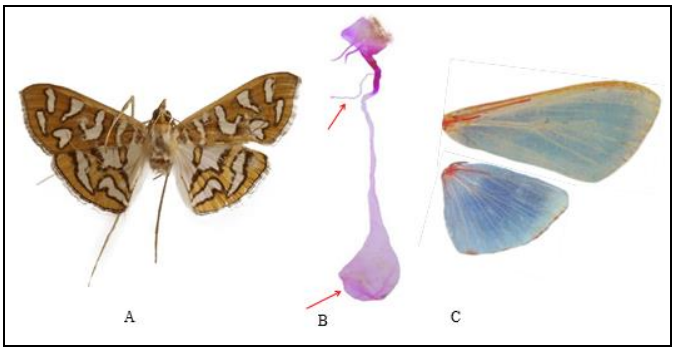

Fig 4: Genital and morphological characters of adult *Nausinoe peuritia* (Cramer) **(**A. female; B. female genitalia; C. wing venation)

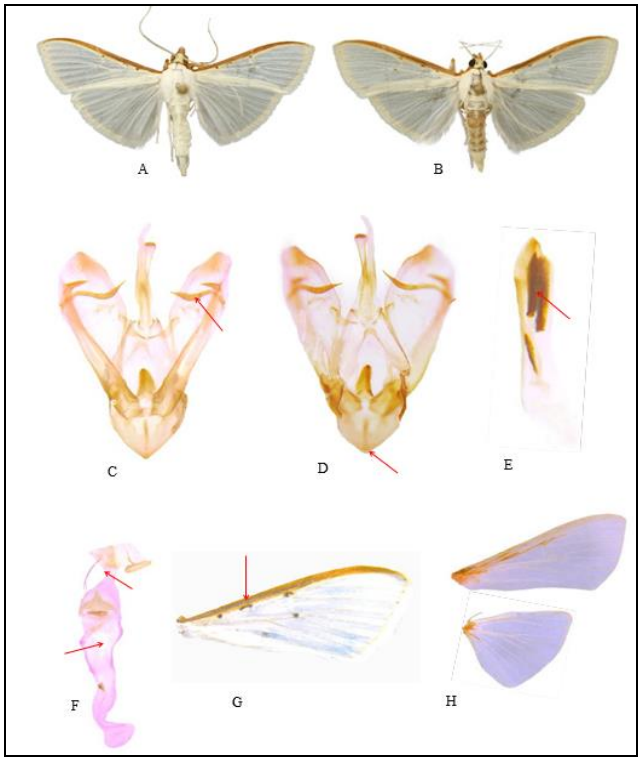

Fig 5: Genital and morphological characters of adult *Palpita vitrealis* (Rossi) (A. male; B. female; male genitalia, C. ventral view; D. dorsal view; E. aedeagus; F. female genitalia; G. forewing usually has traces of two brown specks below the costa before middle one at each angle of cell; H. wing venation)

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