A CLADISTIC ANALYSIS OF THE FAMILY GEOMETIDAE (LEPIDOPTERA: HETEROCERA) FROM PAKISTAN

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Abstract

A cladistic analysis of twenty three species of the fourteen genera of the family Geometridae is performed using apomorphic characters scanned from whole body characters and male and female genitalia. A cladograme is also constructed and discussed the above species with their sister group and out group relationship.

Introduction

Cladistic analysis of different families of the Lepidoptera were attempted by various autors viz. Peigler (1993), Kamaluddin *et al.* (1997 1999, 2000 and 2013).
Emerson *et al.* (1997), Willmott (2003), Brower (2000), and De Camargo *et al.* (2009).

Kamaluddin *et al.* (1997) attempted review and cladistic analysis of Lymantridae genera, in 1999 they also studied cladistic analysis, key to the genera and disteibution ranges of the representatives of the family Sphingidae. In 2000 they studied cladistic analysis of the sub-family Trifinae of the family Noctuidae and in 2013 and 2013b Kamaluddin *et al.* attempted the cladistic analysis of the sub-families Plusiinae and Noctuinae representatively of the family Noctuidae using apomorphic characters.

Materials and Methods

The external morphological characters of head components, wings and their veins and genital characters of males and females were studied and selected from included taxa and are compared with those characters which were found in sister group as well as out group with in the family Geometridae. A cladogram is constructed showing relation ship of the included taxa, The code ao, bo, co, do etc indicate pleisiomorphy which are not discussed where as the states 1, 2, 3, 4 and so on in assending order explain derived, more derived states.

Result

Characters:

ao Vertex of head wanting.
a_1 Vertex of head reduced (*Oxymacaria palliata* to *Larentia interrupta*).
a_2 Vertex of head humped (*Boarmia diversicolor*).

b_0 Frons abscent.
b_1 Frons various shapes and not produced upwardly (*Oxymacaria palliate* to *Oxydia cubana*).
b_2 Frons directed anteriad or obliquely directed (*Oxymacaria palliata* to *Phigalia titea*).
b_3 Frons well produced (*Idaea auricruda* and *Idaea circuitaria*).
b_4 Frons rounded (*Oxydia cubana*).
b_5 Frons directed anteriad (*Idaea auricruda*).
b_6 Frons directed downward (*Idaea circuitaria*).
b_7 Frons sub-acutely produced upwardly (*Antilycouges pinguis*).
b_8 Frons broadly directed downward (*Larentia interrupta*).

c_0 Maxillary palp remarkably large.
c_1 Maxillary palpi are moderate or large (*Oxymacaria palliate* to *Eupithecia unicolor*).
c_2 Maxillary palpi shorter or longer than the length of frons (*Idaea auricruda* to *Idaea accuminata*).
c_3 Maxillary palpi very large directed downward (*Xanthorhoe quadrifesciata*).
c_4 Maxillary palpi large well passing frons (*Idaea auricruda*).
c_5 Maxillary palpi moderate directed upward (*Xanthorhoe sindellus*).
c_6 Maxillary palpi about equal to the length of frons (*Idaea tecturata*).
c_7 Maxillary palpi very short not passing frons (*Idaea circuitaria*).

c_8 Maxillary palpi very short reacting ½ the length of eyes (*Phigalia titea*).

d_0 Maxillary palpi with basal segment much shorter than 2nd segment.
d_1 Basal segment of maxillary palpi about equal or shorter than 2nd segment (*Oxymacaria palliate* to *Phigalia titea*).
d_2 Maxillary palpi with basal segment narrowed equal or shorter than 2nd segment (*Camptogramma* to *Crocallis*).
d_3 Maxillary palpi with basal segment broad and longer than 2nd segment (*Crocallis kametaria*).

e_0 Maxillary palpi with 2nd segment much shorter than 3rd.
e_1 Maxillary palpi with 2nd segment always less than the 3X the basal segment (*Oxymacaria palliate* to *Oxydia cubana*).
e_2 Maxillary palpi with 2nd segment much longer than the 3rd (*Epirrhoa galiata*, *Eupithecia rajata* and *E. substincta*).
e_3 Second segment of maxillary palpi about 2X the 3rd segment (*Camptogramma billiata* to *Tephrina perviria*).
e_4 Maxillary palpi with 2nd segment only slightly longer than the 3rd segment (*Eupithecia unicolor*).

f_0 Maxillary palpi straight.
f_1 Maxillary palpi either anteriorly directed or curved (*Oxymacaria palliata* to *Antilycouges pinguis*).
f_2 Maxillary palpi obliquely, anteriorly or downwardly directed (*Oxymacaria palliate* to *Larentia interrupta*).
f_3 Maxillary palpi straight or oblique (*Xanthorhae quardifesciata* to *Trichopteryx sikkima*).
f_4 Maxillary palpi errect obliquely produced (*Pseudoterpna chlora*).
f_5 Maxillary palpi slightly upturned (*Boarmia diversicolor*).

g_o Both wings unicolourus.
g_1 Usually both wings with vertical striation (*Oxymacaria palliate* to *Pseudoterpna chlora*).

h_0 Anterior angle of fore wings rounded.
h_1 Anterior angle of fore wings sub-roundly produced (*Idaea auricruda, idaea circuitaria* and *Idaea accuminata*).
h_2 Anterior angle of fore wings actually produced (*Idea tecturata*).

i_0 Fore wings with brilliantly coloured.
i_1 Fore wings with a spot at antemedial area (*Idaea auricruda* and *Idaea circuitaria*).
i_2 Fore wings smooth unicolours (*Idaea accuminata*).

j_0 Fore wings with no cell.
j_1 Fore wings with cell formed with radius veins, rectangular shaped and broad (*Xanthorhoe* to *Idaea*).
j_2 Fore wings with cell formed with radius veins elongated and narrowed (*Trichopteryx*).

k_0 Fore wings with more than 13-veins.
k_1 Fore wings with 11 to 13-veins (*Camptogrmma billiata* to *Crocallis kametaria*)
k_2 Fore wings with 12- veins (*Epirrhoa giliata, Eupithecia rajata* and *Eupithecia subtacincta*).
k_3 Fore wings with 11-veins (*Eupithecia unicolour*).
k_4 Fore wings with 10-veins (*Oxymacaria palliata*).

l_0 Fore wings with 3-anal veins.
l_1 Fore wings with one anal vein (*Idaea auricruda, I. circuitaria* and *I. accuminata*).
l_2 Fore wings with 2-anal veins (*Idaea tecturata*).

m_0 Veins Sc and R_1 anastomosing at base.
m_1 Veins Sc and R_1 free (*Idaea auricruda* and *I. circuitaria*).
m_2 Veins Sc and R_1 separate and parallel to each other (*Eupethecia rajata*).
m_3 Veins Sc and R_1 largely stalked (*Eupithecia subtacincta*).

n_0 Fore wings with all radius veins originated from cell.
n_1 Fore wings with veins R_1 and R_2 separated (*Oxymacaria palliate* to *Antilycouges pinguis*)
n_2 Fore wings with veins R_2, R_3, R_4 and R_5 either separated or not all anastomosing or originate from upper angle of cell (*Oxymacaria palliate* to *Boarmia diversicolor*).

n_3 Fore wings with veins R_1 and R_2 either not stalked or stalked unite with other radius vein (*Oxymacaria palliate* to *Eupethecia unicolour*).
n_4 Fore wings with veins R_2, R_3, R_4 and R_5 stalked and anastmosing with each other and originate from upper angle of cell (*Oxydia cubana* and *O. neocubana*).
n_5 Fore wings with veins R_1 and R_2 very largely stalked (*Pseudoterpna chlora*).

n_6 Fore wings with veins R_1 and R_2 largely stalked and free from other radius veins at base (*Phigalia titea*).
n_7 Fore wings with veins R_3, R_4 and R_5 originate from cell (*Tephrina pervaria*).
n_8 Fore wings with veins R_4 and R_5 originate from cell (*Camptogramma billiata*).

o_0 Hind wings with 9-veins.
o_1 Hind wings with 7-veins (*Epirrhoa galliata* to *Eupilhecia unicolour*).
o_2 Hind wings with 8-veins (*Oxymacaria palliate* to *Crocallis kametaria*).

p_0 Hind wings with more than three anal veins.
p_1 Hind wings with three anal veins (*Idaea auricruda*).
p_2 Hind wings with two anal veins (*Xanthorhoe quadrifesciata*).
p_3 Hind wings with one anal vein (*Xanthorhoe sindellus*).

q_0 Hind wings with veins $Sc+R_1$ largely stalked with radius vein.
q_1 Hind wings with veins $Sc+R_1$ stalked with radius vein (*Camptogramma billiata*).
q_2 Hind wings with veins $Sc+R_1$ free (*Tephrina pervaria*).

r_0 Hind wings with veins Rs and M_1 remarkably stalked.
r_1 Hind wings with veins Rs and M_1 anastomosing and originate from upper angle of cell (*Oxydia neocubana*).
r_2 Hind wings with veins Rs and M_1 stalked later anastomosing with M_2 originate from upper angle of cell (*Oxydia cubana*).
r_3 Hind wings with veins Rs and M_1 largely stalked and originate from upper angle of cell (*Trichopteryx carpinata*).
r_4 Hind wings with veins Rs and M_1 anastomosing and originate from lower angle of cell (*Epirrhoa galiata*).

s_0 Hind wings with no veins originate from upper angle of cell.
s_1 Hind wings with M_1 originate from upper angle of cell (*Oxymacaria palliate*).
s_2 Hind wings with veins Rs and M_1 originate from upper angle of cell (*Camtogramma to Crocallis*).

t_0 Hind wings with no veins originate from lower angle of cell.
t_1 Hind wings with veins M_2 and M_3 anastomising and originate from lower angle of cell (*Idaea auricruda, I. circuitaria, I. accuminata* and *I. tecturata*).
t_2 Hind wings with vein M_3 only originates from lower angle of cell and M_2 originates above the lower angle of cell (*Xanthorhoe quadrifesciata* and *X. sindellus*).
t_3 Hind wings with veins M_2 originates from lower angle of cell (*Eupethecia rajata* and *E. subtacincta*).

u_0 Abdomen without tympanal organ.
u_1 Abdomen with tympanal organ (*Oxymacaria palliata* to *Pseudoterpna chlora*).

v_0 In males genitalia simple.
v_1 In males genitalia complicated (*Boarmia diversicolor*).

w_0 Uncus shorter than gnathos.
w_1 Uncus about equal to gnathos (*Idaea circuitaria*).
w_2 Uncus much longer than gnathos, later short (*Idaea auricruda*).

x_0 Uncus simple, lunar-shaped.
x_1 In male genitalia moderate dorsal side of uncus smooth (*Oxymacaria palliata* to *Larentia interrupta*).
x_2 Uncus sickle-shaped (*Idaea auricruda* and *I. circuitaria*).
x_3 Uncus straight cup-shaped (*Trichopteryx carpinata*).
x_4 Uncus curved, beak-shaped (*Trichopteryx sikkima*)
x_5 Uncus knife-like, apex upwardly turned (*Idaea accuminata*).
x_6 Uncus bifurcated, force- like (*Oxymacaria palliata*).

y_0 Saccus saucer-shaped.
y_1 Saccus somewhat cup-shaped (*Idaea circuitaria*).
y_2 Saccus somewhat Y-shaped (*Idaea auricruda*).
z_0 Paramere simple plate-like.
z_1 Paramere unilobed (*Idaea auricruda* and *I. circuitaria*).
z_2 Paramere very long about 2X the tegumen, unilobed with striation (*Tephrina perviria*).
z_3 Paramere large about equal to tegumen, bilobed, posterior lobe with spines (*Camptogramma billiata*).
z_4 Paramere bilobed posterior lobe large basal with numerous spines (*Idaea accuminata*).
z_5 Apex of paramere tetra-lobed (*Eupithecia unicolor*)

za_0 Theca without thecal appendage.
za_1 Theca with hand-shaped thecal appendage (*Eupithecia unicolor*).
zb_0 Membranous conjunctiva simple
zb_1 Membranous conjunctiva of different shape with cornuti (*Oxymacaria palliata* to *Antilycouges pinguis*).
zb_2 Membranous conjunctiva of different shape and size (*Oxymacaria palliata* to *Oxydia cubana*).
zb_3 Membranous conjunctival lobe moderate (*Oxymacaria palliata* to *Eupithecia unicolor*).
zb_4 Membranous conjunctiva with blunt-like cornuti (*Idaea auricruda* and *I. circuitaria*).

zb_5 Membranous conjunctiva without cornuti (*Pseudoterpna chlora*).
zb_6 Membranous conjunctiva T-shaped (*Antilycouges pinguis*).
zb_7 Membranous conjunctival lobe large apically with four small spines (*Trichopteryx sikkima*).
zb_8 Membranous lobe large bilobed, dorsal lobe with five large thorn-like spines and plate like cornuti (*Trichopteryx carpinata*).
zb_9 Membranous conjunctiva with a series of spine-like cornuti (*Idaea accuminata*).
zb_{10} Membranous conjunctival lobe besets with two sets of dot-like cornuti and two sets of sex comb (*Phigalia titea*).

zc_0 Papillae anales simple.
zc_1 Papillae anales of various shape (*Capmtogramma billiata* to *Trichopteryx sikkima*).
zc_2 Papillae anales short triangular or rectangular-shaped (*Eupithecia rajata* to *E. obtineus*).
zc_3 Papillae anales proximally smooth (*Oxydia neocubana*).
zc_4 Papillae anales proximally dilated (*Oxydia cubana*).
zc_5 Papillae anales semicircular (*Xanthorhoe quadrifesciata*).
zc_6 Papillae anales triangular-shaped (*Eupithecia obtineus*).
zc_7 Papillae anales rectangular-shaped (*Eupithecia rajata*).
zc_8 Papillae anales kidney-shaped (*Crocallis kametaria*).
zc_9 Papillae anales remarkebly elongated (*Epirrhoa galiata*).

zd_0 Both apophysesses simple equal in length.
zd_1 Apophyses posteriors smooth or slightly dilated (*Oxymacaria palliate* to *Phigali titea*).
zd_2 Both apophysesses moderate terminating into pointed end (*Eupithecia rajata* and *E. obtineus*).
zd_3 Both apophyseesses large terminating into blunt end (*Epirrhoa galiata*).
zd_4 The apophyses posteriors proximally highly dilated (*Larentia interrupta*).
zd_5 Apophyses posteriors very large about 2X the apophyses anteriors (*Oxymacaria palliate*).

ze_0 Ductus bursae broad short.
ze_1 Ductus bursae simple (*Oxymacaria palliata* to *Boarmia diversicolor*).
ze_2 Ductus bursae moderate with large corpus bursae (*Eupithecia rajata* and *E. obtineus*).
ze_3 Ductus bursae broad elbow shaped (*Oxydia cubana* and *O. neocubana*).
ze_4 Ductus bursae very large convoluted with short corpus bursae (*Epirrhoa galiata*).

zf_0 Corpus bursae moderate bag-like.

zf_1 Corpus bursae ballon-like with a circular structure at base (*Oxydia cubana* and *O. neocubana*).
zf_2 Corpus bursae unilobed (*Xanthorhoe quadrifesciata*).
zf_3 Corpus bursae bilobed (*Xanthorhoe sindellus*).
zf_4 Corpus bursae very large ballon-shaped (*Eupithecia rajata*).
zf_5 Corpus bursae moderate bag-like terminating into thread-like structure (*Eupithecia obtineus*)

Character states

Vertex of head (a): Vertex of head reduced in *Oxymocaria palliata, Camptogramma billiata, Tephrina perviria, Xanthorhoe quadrifesciata, X. sindellus, Idaea auricruda, Idaea circuitaria, idaea accuminata, Idaea tecturata, Trichopteryx carpinata, T. sikkima, Crocallis kametaria, Epirrhoe galiata, Eupithecia rajata, E. obtineus, E. unicolor, Phigalia titea and Larentia interrupta* show their synapomorphic characters (a_1). In *Boarmia diversicolar* the vertex of head humped shows it autapomorphic condition (a_2).

Frons (b): Frons are of various shape and not produced upwardly from *Oxymacaria* to *Oxydia* show their synapomorphic condition (b_1). From *Oxymacaria palliata* to *Phigalia titea* the frons directed anteriad or obliquely directed show their derived synapomorphic condition (b_2). Frons well produced in *Idaea auricruda* and *I.circuitaria* show their more derived synapomorphic condition (b_3). In *Oxydia cubana* the frons is rounded shows its autapomorpic condition (b_4). The frons directed anteriod in *Idaea auricruda* shows its derived autapomorphic state (b_5). In *Idaea circuitaria* the frons is directed down wardly shows its more derived autapormorphic condition (b_6). The frons sub-acutely produced upwardly in *Antilycouges pinguis* shows its further more derived autapomorphic condition (b_7). In *Larentia interrupta* the frons broadly directed down ward show its specially derived autapomorphic condition (b_8).

Size of maxillary palpi (c): Maxillary palpi moderate or large from *Oxymacaria palliato* to *Eupithecia unicolor* show their synapormophic condition (c_1) In *Idaea auricruda* to *Idaea accuminata* the maxillary palpi shorter or longer than the length of frons show their derived synapomorphic condition (c_2). Maxillary palpi very large directed down ward in *Xanthorhoe quadrifesciata* shows it autapormorphic condition (c_3). In *Idaea auricruda* the maxillary palpi large well passing frons shows it derived autapororphic state (c_4). The maxillary palpi moderate directed upward in *Xanthorhoe sindellus* shows it more derived autapamorphic condition (c_5). In *Idaea tecturata* the maxillary palpi about equal to the length of frons shows its further more derived autapomorphic condition (c_6). The maxillary palpi very short not possing frons in *Idaea circuitaria* shows its specially derived autapomorphic condition (C_7). In *Phigalia titea* the palpi is very short reaching half the length of eyes shows its specially more derived autapomorphic condition (C_8).

Maxillary palpi with basal / 2nd segment (d): Basal segment of maxillary palpi about equal or shorter than 2nd segment from *Oxymacaria palliata* to *Phigalia titea* show their synapomorphic condition (d_1). From *Camptogramma biliata* to *Crocallis kametaria* the maxillary palpi with basal segment show their derived synapomorphic condition (d_2). Maxillary palpi with basal segment broad and longer than second segment in *Crocallis kametaria* shows it autapomorphic state (d_3).

Maxillary palpi with 2nd/ 3rd or basal segment (e): Maxillary palpi with second segment always less than 3X length of basal segment from *Oxymacaria palliata* to *Oxydia cubana* show their synapomophic condition (e_1). In *Epirrhoea galiata, Eupithecia rajata* and *E . obtineus* the maxillary palpi with second segment much longer than third segment show their derived synapomorphic condition (e_2). The second segment of maxillary palpi about 2X the length of 3rd segment from *Camptogramma billiata* and *Tephrina perviria* show their more derived synapomorphic condition (e_3). In *Eupithecia unicolor* the maxillary palpi with second segment only slightly longer than 3rd segment shows it autapomorphic condition (e_4). The maxillary palpi with second segment broad large about 3X the length of basal segment in *Antilycouges pinguis* show its derived autapomorphic state (e_5).

Position of maxillary palpi (f): Maxillary palpi either anteriorly directed or curved from *Oxymacaria* to *Antilycouges* show their synapormorphic condition (f_1). From *Oxymacaria* to *Larentia* the maxillary palpi obliquely anteriorly or downwardly directed show their derived synapomorphic condition (f_2).

The maxillary palpi straight or oblique in *Xanthorhoe quadrifasciata* to *Trichopteryx sikkima* show their more derived synapomorphic condition (f_3). In *Pseudoterpna chlora* the maxillary palpi erect obliquely produced shows its autapomorphic state (f_4). The maxillary palpi highly upturned in *Boarmia diversicolor* show it derived autapomorphic condition (f_5).

Striations on wings (g): Usually both wings with vertical striations in all the representatives of the family Geometridae show their synapomorphic condition (g_1).

Anterior angle of fore wings (h): Anterior angle of fore wings sub-roundly produced in *Idaea auricruda, I. circuitaria* and *I. accuminata* show their synapomorphic condition (h_1). In *Idaea tecturata* the anterior angle of fore wings acutely produced shows it autapomorphic condition (h_2).

Colour of fore wings (i): Fore wings with a spot at antemedial area in *Idaea auricruda* and *I. circuitaria* show their synapomaphic condition (i_1). In *Idaea accuminata* the fore wings smooth unicolorous shows it autapomorphic condition (i_2).

Cell of fore wings (j): The fore wings with cell formed by radius veins rectangular–shaped and broad from *Xanthorhoe* to *Idaea* show their synapomorphic condition (j_1). In *Trichopteryx carpinata* and *T. sikkima* the fore wings with cell formed by radius veins elongated and narrowed show their derived synapomorphic condition (j_2).

Number of veins in fore wings (k): The fore wings with 11-13 veins in *Camptogramma billiata* to *Crocallis kametaria* show their synapromorphic condition (k_1). In *Epirrhoa galiata, Eupithecia rajata* and *E. obtineus* the fore wings with 12-veins show their derived synapomorphic condition (k_2). The fore wings with 11-veins shows it autapomorphic condition in *Eupithecia unicolor* (k_3). In *Oxymacaria palliata* fore wings with 10-veins shows it derived autapomorphic state (k_4).

Number of anal veins in fore wings (l): Fore wings with one anal vein in *Idaea auricruda, I. circuitaria and I. accuminata* show their synapomorphic condition (l_1). In *Idaea tecturata* fore wings with two anal veins shows it autapomorphic condition (l_2).

Veins Sc and R_1 (m): Veins Sc and R_1 free to each other in *Idaea auricruda* and *Idaea circuitaria* show their synapomorphic condition (m_1). In *Eupithecia rajata* the veins Sc and R_1 separated and parallel to each other shows it autapomorphic condition (m_2). The veins Sc and R_1 largely stalked in *Eupithecia subtacincta* shows it derived autapomorphic condition (m_3).

Radius veins of fore wings (n): Fore wings with veins R_1 and R_2 separated from *Oxymacaria palliata* to *Antilycouges pinguis* show their synapomorphic condition (n_1). From *Oxymacaria palliata* to *Boarmia diversicolor* the fore wings with veins R_2 , R_3, R_4 and R_5 either separated or not anastomosing or originate from upper angle of cell show their derived synapomorphic condition (n_3). In *Oxydia cubana* and *O. neocubana* the fore wings with veins R_2, R_3, R_4 and R_5 stalked and anastomosing with each other and originate from upper angle of cell show their

further more derived synapomorphic condition (n_4) . Fore wings with veins R1 and R_2 very largely stalked in *Pseudoterpna chlora* shows it autapomorphic condtion (n_5) . In *Phigalia titea* the fore wings with veins R_1 and R_2 largely stalked and free from other radius vein at base shows it derived autapomorphic condition (n_6). Fore wings with veins R_3, R_4 and R_5 originate from cell in *Tephrina perviria* shows it more derived autapomorphic condition (n_7). In *Camptogramma billiata* the fore wings with veins R_4 and R_5 originate from cell shows it further more derived autapomorphic condition (n_8).

Number of veins in hind wings (o): Hind wings with 8-veins in *Oxymacaria pelliata* to *Crocallis kamateria* show their synapomorphic condition (o_1). In *Epirrhoa galiata, Eupithesia rajata, E. obtineus* and *E. unicolor* the number of veins 7 in hind wings show their derived synapomorphic condition (o_2).

Number of anal veins in hind wings (p): Hind wings with three anal veins in *Idaea auricruda* show it autapomorphic conditions (p_1). In *Xanthorhoe quadrifasciata* hind wings with two anal veins shows it derived autapomorphic condition (p_2). The hind wings with only one anal vein in *Xanthorhoe sindellus* shows it more derived autapomorphic condition (p_3)

Hind wings with veins Sc+R_1 (q): Hind wings with veins Sc+R_1 stalked with radius vein in *Camptogramma billiata* shows it autapamorphic condition (q_1). In *Tephrina perviria* the hind wings with veins Sc+R_1 free shows it derived autapormorphic condition (q_2).

Hind wings with veins Rs and M_1 (r): Hind wings with veins Rs and M_1 anastomosing and originate from upper angle of cell in *Oxydia neocubana* shows it autapomorphic condition (r_1). In *Oxydia cubana* the hind wings with veins Rs and M_1 stalked later anastomosing with M_2 and originate from upper angle of cell shows it derived autapomorphic condition (r_2). Hind wings with veins Rs and M_1 largely stalked and originate from upper angle of cell in *Trichopteryx carpinata* shows it more derived autapomorphic condition (r_3). In *Epirrhoa galiata* the hind wings with veins Rs and M_1 anastomosing and originate from upper angle of cell and veins M_2 and M_3 anastomosing and originate from lower angle of cell shows it further more derived autapomorphic condition (r_4).

Hind wings with veins originate from upper angle of cell (s): Hind wings with veins Rs and M_1 originate from upper angle of cell from *Camptogramma billiata* to *Crocallis kametaria* show their synapomorphic condition (S_1). In *Oxymacaria palliata* hind wings with only vein M_1 originates from upper angle of cell shows it autapomorphic condition (s_2).

Origin of median veins in hind wings (t): Hind wings with veins M_2 and M_3 anastomosing and originate from lower angle of cell in all the representatives of the genus *Idaea* show their synapomorphic condition (t_1). In *Xanthorhoe quadrifasciata* and *X. sindellus* the hind wings with veins M_3 only originate from lower angle of cell and M_2 originates above the lower angle of cell show their derived synapomorphic condition (t_2). The hind wings with vein M_2 only originates from lower angle of cell in *Eupithecia rajata* and *E. subtactincta* show their more derived synapomophic condition (t_3).

Tympanal organs (u): Abdomen with tympanal organs in all the representatives of the family Geometridae show their synapomorphic condition (u_1).

Male genitalia (v): In *Boarmia diversicolor* the male genitalia is highly complicated shows it autapomarphic condition (v_1).

Uncus (w): Uncus about equal to gnathos in *Idaea circuitaria* shows it autapomorphic condition (w_1). In *Idaea auricruda* the uncus is much longer than gnathos later short shows it derived autapamorphic condition (w_2).

Shape of uncus (x): Dorsal side of uncus smooth in *Oxymacarina palliata* to *Larentia interrupta* show their synapomorphic condition (x_1) . In *Idaea auricruda and Idaea circuitaria* the uncus sickle-shaped show their derived synapomorphic condition (x_2). The uncus straight cup-shaped in *Trichopteryx carpinata* shows it autapomorphic condition (x_3). In *Trichopteryx sikkima* the uncus curved, beak-shaped shows it derived autapomorphic condition (x_4). The uncus knife-like with apex upwardly turned in *Idaea accuminata* shows it more derived autapomorphic condition (x_5). In *Oxymacaria palliata* the uncus is bifurcated, forcep- like shows it further more derived autapomorphic condition (x_6). Uncus with a rounded spinulose structure on dorsal side in *Boarmia diversicolor*s shows it specially derived autapomorphic state (x_7).

Saccus (y): Saccus somewhat cup-shaped in *Idaea circuitaria* shows its autapomorphic condition (y_1). In *Idaea auricruda* the saccus somewhat Y-shaped shows it derived autapomorphic condition (y_2)

Paramere (z): Paramere unilobed in *Idaea auricruda* and *Idaea circuitaria* show their synapomorphic condition (z_1). In *Tephrina perviria* the paramare very long about 2X the tegumen, unilobed with striations shows it autapomorphic condition (z_2). Paramere large about equal to tegumen, bilobed, posterior lobe with spines in *Camptogramma billiata* shows it derived autapomorphic condition (z_3). In *Idaea accuminata* the parameres are bilobed with posterior lobe large beset with numerous spines shows it more derived autapomorphic condition (z_4). Apex of parameres tetralobed in *Eupithecia unicolor* shows its specially more derived autapomorphic condition (z_5).

Appendage of theca (za): Theca with hand-shaped thecal appendages in *Eupithecia unicolor* shows it autapomorphic condition (Za_1).

Membranous conjuctiva (zb): Membranous conjunctiva of different shape with cornuti from *Oxymacaria palliata* to *Antilycouges pinguis* show their synapomorphic condition (zb_1). From *Oxymacaria palliata* to *Oxydia cubana* the membranous conjunctiva of different shape and size show their derived synapomorphic condition (zb_2). Membranous conjunctival lobe moderate in *Oxymacaria palliata* to *Eupithecia unicolor* show their more derived synapomorphic condition (zb_3). In *Idaea auricruda* and *Idaea circuitaria* the membranous conjunctive with blunt cornuti show their further more derived synapomorphic condition (zb_4). The memberanous conjunctiva without cornuti in *Pseudoterpna chlora* shows it autapomorphic condition (zb_5). In *Antilycouges pinguis* the membranous conjunctiva T-shaped shows it derived autapomorphic condition (zb_6). The membranous conjunctiva large apically with four small spines in *Trichopteryex sikkima* shows it more derived autapomorphic condition (zb_7). In *Trichopteryx carpinata* membranous conjunctiva large, bilobed, dorsal lobe with four large, thorn-like spines and a plate-like cornuti show it further more derived autapomorphic condition (zb_8). The membranous conjunctiva with a series of spine-like cornuti in *Idaea accuminata* shows it specially derived autapomorphic condition (zb_9). In *Phigalia titea* the membrainous conjunctiva beset with sets of dot-like cornuti and two sets of sex combs shows it specially more derived autapomorphic condition (zb_{10}).

Papillae anales (zc): The papillae anales of various shape in *Camptogramma billiata* to *Trichopteryx sikkima* show their synapomorphic condition (zc_1) In *Eupithecia rajata* and *E. subtactincta* the papillae anales are short triangular or rectangular shaped show their derived synapomorphic condition (zc_2). The papillae anales proximally smooth in *Oxydia neocubana* shows it autapomorphic condition (zc_3). In *Oxydia cubana* the papillae anales proximally dilated shows it derived autapomorphic condition (zc_4). The papillae anales semicircular in *Xanthorhoe quadrifasciata* shows it more derived autapomorphic condition (zc_5). In *Eupithecia subtactincta* the papillae anales are triangular-shaped shows it further more derived autapomorphic condition (zc_6). The papillae anales are rectangular-shaped in *Eupithecia rajata* shows it specially derived autapomorphic condition (zc_7). In *Crocallis kametaria* the papillae anales are kidney-shaped shows it specially more derived autapomorphic condition (zc_8). The papillae anales are remarkably elongated in *Epirrhoa galiata* shows it specially further more derived autapomorphic state (zc_9).

Apophysesses (zd): The apophyses posteriors smooth or slightly dilated in *Oxymacaria palliate* to *Phigalia titea* show their synapomorphic condition (zd_1). In *Eupithecia rajata* and *E. subtacincta* both apophysesses moderate terminating into pointed end show their derived synapomorphic condition (zd_2). Both apophysesses large terminating into blunt end in *Epirrhoa galiata* shows it autapomophic condition (zd_3). In *Larentia interrupta* the apophyses posteriors proximally highly dilated shows it derived autapamorphic condition (zd_4). Apophyses posteriors very large about 2X the apophyses anterious in *Oxymacaria palliata* shows it more derived autapomorphic condition (zd_5).

Ductus bursae (ze): The ductus bursae is simple in *Oxymacaria palliata* to *Boarmia diversicolor* show their synapomorphic condition (ze_1). In *Eupithecia rajata* and *E. subtacincta* the ductus bursae is moderate with large corpus bursae show their derived synapomorphic condition (ze_2). The ductus birsae is broad, albow shaped in *Oxydia cubana* and *O. neocubana* show their more derived synapomorphic condition (ze_3). In *Epirrhoa galiata* the ductus bursae very large convoluted with short corpus bursae shows it autapomorphic condition (ze_4).

Corpus bursae (zf): Corpus bursae balloon-like with a circular structure at base in *Oxydia cubana* and *O. neocubana* show their synapomorphic condition (zf_1). In *Xanthorhoe quadrifasciata* the corpus bursae is unilobed shows it autapomorphic condition (zf_2). The corpus bursae bilobed in *Xanthorhae sindellus* shows it derived autapomorphic condition (zf_3). In *Eupithecia rajata* the corpus bursae is very large balloon- shaped shows it more derived autapomorphic condition (zf_4). The corpus bursae moderate bag-like terminating into thread-like structure in *Eupithecia subtacincta* shows it further more derived autapomorphic condition (zf_5).

Discussion on Cladogram

(Fig. 01)

The present studies of the family Geometridae comprises 14-genera and 23-species from Pakistan and adjoining Northern areas play sister group relationship to each other by their synapomorphies like both wings usually with vertical striations (g_1) and abdomen with tympanal organs (u_1). Among all the representative *Oxymacarmia palliata* to *Antilycouges pinguis* play sister group relationship to each other by their synapomorphies like maxillary palpi either anteriorly directed or curved (f_1), fore wings with veins R_1 and R_2 separted (n_1) and in males the membranous conjuncta are of different shape with cornuti and play outgroup relationship with *Pseudoterpna chlora* by its autapomorphies like maxillary palpi errect obliquely produced (f_4), fore wings with veins R_1 and R_2 very largely stalked (n_5) and membranous conjunctiva without cornuti (zb_1).

The twenty one species from *Oxymacaria palliata* to *Oxydia cubana* play sistergroup relationship to each other by their synapomorphies like frons are of various shape and not produced upwardly (b_1), maxillary palpi with second segment always less than 3X the length of basal segment (e_1) and in males membranous conjunctiva with cornuti (zb_1) play outgroup relationship with *Antilycouges pinguis* by its autapomorphies like frons sub-acutely produced upwardly (b_7), maxillary palpi with second segment broad, large about 3X the length of basal segment (e_5) and membranous conjunctiva T-shaped (zb_6)

Among rest of the 21-species *Oxydia cubana* and *O. neocubana* play sister group relationship with each other by their synapomorphies like fore wings with veins R_2, R_3, R4 and R_5 stalked and anastomosing with each other and originate from upper angle of cell (n_4), In female ductus bursae albow- shaped (ze_3) and corpus bursae balloon-like with a circular structure at base (zf_1) and outgroup relationships with rest of the species from *Oxymacaria palliata* to *Boarmia strigula* by their synapomorphies like fore wings with veins R_2, R_3, R_4 and R_5 either separated or not anastomosing or orginate from upper angle of cell (n_2) and the ductus bursae is simple (ze_1).

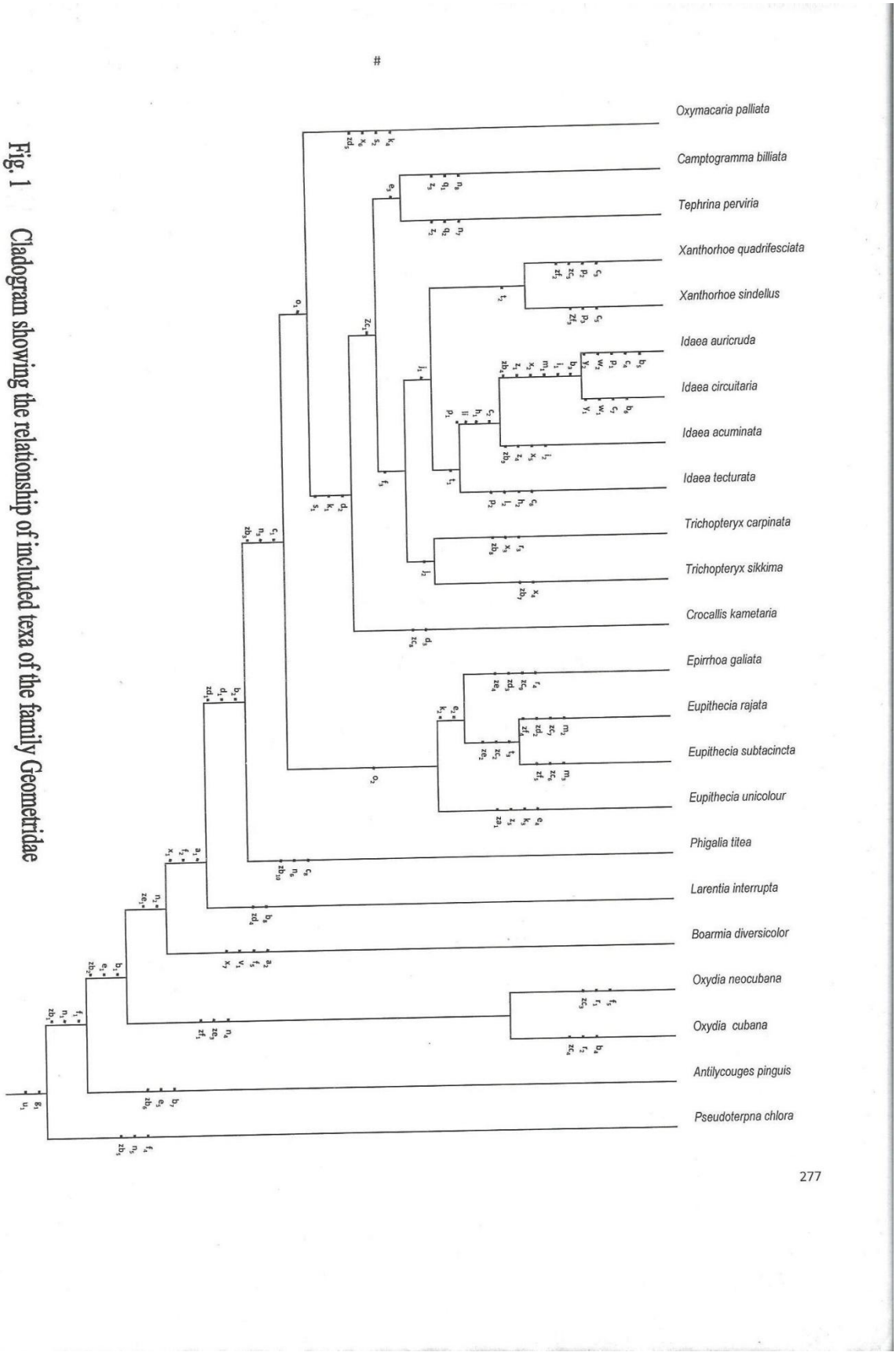

Fig. 1 Cladogram showing the relationship of included texa of the family Geometridae

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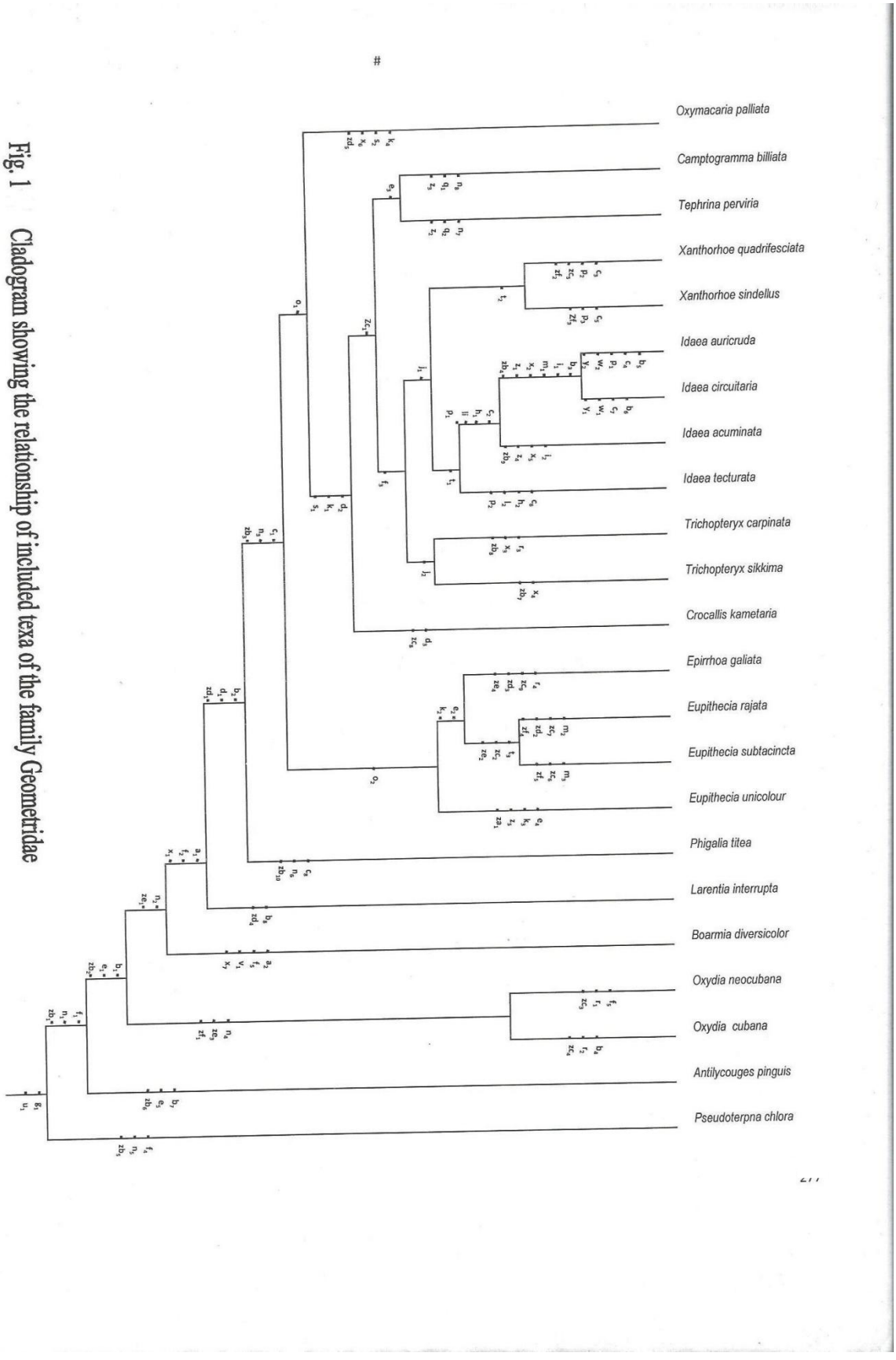

Fig. 1 Cladogram showing the relationship of included texa of the family Geometridae

In the later 19-species, *Oxymacaria palliata* to *Larentia interrrupta*, play sister group relationship to each other by their synapomorphies like, vertex of head reduced (a_1), maxillary palpi obliquely anterior or dowonwardly directed (f_2) and dorsal surface of uncus smooth (x_1) and out-group relation with *Boarmia diversicolor* by its autapomorphies like vertex of head humped (a_2), in males genitalia is highly complicated (v_1) and uncus with a rounded spinulose structure on dorsal side (x_7). Among rest of the 18-species from *Oxymacaria palliata* to *Larentia interrupta*, the 17-species *Oxymacaria palliata* to *Phigalia titea* play sister group relationship to each other by their synapomorphies like frons directed anteriad or obliquely directed (b_2), basal segment of maxillary palpi about equal or shorter than the 2nd segment (d_1) and in female the apophyses posteriors smooth or slightly dilated (zd_1) and out-group relationship with *Larentia interrupta* by its autapomorphies like frons broadly directed downward (b_8) and in female the apophyses posteriors proximally highly dilated (zd_4).

Among *Oxymacaria palliata* to *Phigalia titea* the 16-species from *Oxymacaria palliata* to *Eupithecia unicolor* play sister group relationship to each other by their synapomorphies like maxillary palpi modertate or large (c_1), fore wings with veins R_1 and R_2 either not stalked or stalked and unite with other radius veins (n_3) and in males membranous conjunctiva moderata (zb_3) and out-group relationship with *Phigalia titea* by its autapomorphies like maxillary palpi very short reaching half the length of eyes (c_8). Fore wings with veins R_1 and R_2 largely stalked and free from other radius veins at base (n_6) and in males membranous conjunctiva beset with sets of dot-like cornuti and two sets of six combs (zb_{10}).

The rest of the species fall into two groups, first group comprises three species of the genus *Eupithecia* and *Epirrhoa galiata* where as the second group comprises 12-species from *Oxymacaria palliata* to *Crocallis kametaria*. Among first group *Epirrhoa galiata, Eupithecia rajata* and *E. substincta* play sister group relationship by their synapomorphies like the maxillary palpi with second segment much longer than third segment (e_2) and fore wings with 12-veins (k_2) and out-group relationship with *Eupithecia unicolour* by its autapomorphies like the maxillary palpi with 2nd segment only slightly longer than third (e_7), fore wings with 11-veins (k_3), apex of paramere tetra lobed (z_5) and theca with hand-shaped thecal appendages (za_1).

In rest of the species of first group the *Eupethecia rajata* and *E. subtacincta* play sister group relationship by their synapomorphies like hind wings with veins M_2 only originates from lower angle of cell (f_3), the papillae anales are short triangular or rectangular-shaped (zc_2) and ductus bursae moderate with large corpus bursae (ze_2) and out-group relationship with *Epirhoa galiata* by its autapomorphies like hind wings with veins R_3 and M_1 anastomosing and originate from upper angle of cell and veins M_2 and M_3 anastomosing and originate from lower angle of cell (r_4), the papillae anales are remarkably elongated (zc_9) , both apophysesses large terminating into blunt end (zd_3) and the ductus bursae vey large convoluted with short corpus bursae (ze_2).

Among second group the 11-species from *Camptogramma billiata* to *Crocallis kametaria* play sister group relationship to each other by their synapomophies like maxillary palpi with basal segment narrowed equal or shorter than second segment (d_2) fore wings with 11-13 veins (k_1) and hind wings with veins R_3 and M_1 originate from upper angle of cell (s_1) and out-group relationship with *Oxymacaria palliata* by its autapomorphies like fore wings with 10-veins (k_4) , hind wings with only vein M_1 originates from upper angle of cell (s_2), uncus bifurcated, forcep like (x_6) and apophyses posteriors very large about 2X the apophyses anteriors (zd_5)

Among the remaining 11-species the *Camptogramma billiata* to *Trichopteryx sikkima* play sister group relationship to each other by their synapomorphy like the paplillae anales of various shapes (zc_1) and out-group relationship with *Crocallis kametaria* by its autapomorphies like maxillary palpi with basal segment broad and longer than second segment (d_3) and the papillae anales are kidney-shaped (zc_8).

In rest of the 10-species the *Xanthorhoe quadrifesciata* to *Trichopteryx sikkima* play sister group relationship with each other by their synapomorphies like maxillary palpi straight or oblique (f_3) and out-group relationship with *Camptogramma billiata* and *Tephrina perviria* by their synapomorphy like the second segment of maxillary palpi about 2X the length of third segment (e_3).

Among rest of the eight species the two species of the genus *Xanthorhoe* and four species of the genus *Idaea* play sister group relationship with each other by their synapomorphy like the fore wings with cells formed by the radius veins are rectangular-shaped and broad (j_1) and out-group relationship with two species of the genus *Trichopteryx* by their synapomorphy like the fore wings with cells formed by radius veins elongated and narrowed (j_2). The four species of the genus *Idaea* plays sister groups relationship to each other by their synapomorphy like the hind wings with veins M_2 and M_3 anastomosing and originate from lower angle of cell (t_1) and out-group relationship with two species of the genus *Xanthorhoe* by their synapomorphy like hind wings with veins only M_3 originates from lower angle of cell and M_2 originates above the lower angle of cell (t_2).

Among four species of the genus *Idaea* the three species viz. *Idaea auriuruda , I. circuitaria* and *I. accumminata* play sister group relationship with each other by their synapomorphies like maxillary palpi shorter or longer than length of frons (c_2), anterior angle of fore wings sub-rounded (h_1), and with one anal vein (l_1) and out-group relationship with *I. tecturata* by its autapomorphies like maxillary palpi about equal to the length of frons (c_6), anterior angle of fore wings acutely produced (h_2) and with two anal veins (l_2) . The species

I. auricruda and *I. circuitaria* play sister group relationship to each other by their synapomorphies like fore wings with a spot at antemedial area (i_1), uncus circle-shaped (x_2) , praramere unilobed (z_1) and membranous conjunctiva with blunt cornuti (zb_2) and out-group relationship with *I. accuminata* by its autapomorphies like fore wings smooth unicolours (i_2), uncus knife-like with apex upwardly turned (x_5), parameres are bilobed with posterior lobe large beset with numerous spines (z_4) and the membranous conjunctiva with a series of spine-like cornuti (zb_9) relationship with two species of the genus *Xanthorhoe* by their synapomorphy like hind wings with veins only M_3 originates from lower angle of cell and M_2 originates above the lower angle of cell (t_2).

Among four species of the genus *Idaea* the three species viz. *Idaea auriuruda* , *I. circuitaria*_ and *I. accumminata* play sister group relationship with each other by their synapomorphies like maxillary palpi shorter or longer than length of frons (c_2), anterior angle of fore wings sub-rounded (h_1), and with one anal vein (l_1) and out-group relationship with *I. tecturata* by its autapomorphies like maxillary palpi about equal to the length of frons (c_6), anterior angle of fore wings acutely produced (h_2) and with two anal veins (l_2) . The species *I. auricruda* and *I. circuitaria* play sister group relationship to each other by their synapomorphies like fore wings with a spot at antemedial area (i_1), uncus circle-shaped (x_2) , praramere unilobed (z_1) and membranous conjunctiva with blunt cornuti (zb_2) and out-group relationship with *I. accuminata* by its autapomorphies like fore wings smooth unicolours (i_2), uncus knife-like with apex upwardly turned (x_5), parameres are bilobed with posterior lobe large beset with numerous spines (z_4) and the membranous conjunctiva with a series of spine-like cornuti (zb_9).

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