Review of North American Verrucoentomon Species (Protura: Acerentomidae, Nipponentominae), with a Key to Species of the Related Genus Imadateiella Rusek

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Review of North American *Verrucoentomon* species (Protura: Acerentomidae, Nipponentominae), with a key to species of the related genus *Imadateiella* Rusek

*Julia Shrubovych*¹*, Josef Rusek*², Jerzy Smykla³ and Ernest C. Bernard⁴*

**Abstract**

Type material of 3 North American *Verrucoentomon* (Protura: Acerentomidae, Nipponentominae) species was studied: *Verrucoentomon imadatei* Nosek, 1977 from Alaska, *Verrucoentomon mixtum* Nosek, 1981 from Alaska and *Verrucoentomon canadensis* (Tuxen, 1955) from northern Canada. Additional morphological characters for *V. imadatei* and *V. canadensis* are provided. *Verrucoentomon mixtum* is redescribed and transferred to the genus *Imadateiella* Rusek, 1974 due to the presence of 4 pairs of A-setae on the metanotum rather than 3 and the absence of teeth on the hind margins of segments IX–XI. *Imadateiella mixta* (Nosek, 1981) is characterized by the presence of P1a setae on tergites I–VII, 4 A-setae on tergite VIII and only 4 setae on sternite VIII. The species is unique within the Nipponentominae in having only one long terminal spine on the labial palp. *Imadateiella* is redefined and a key to its species is provided.

*Palabras Clave:* redescription; chaetotaxy; porotaxy; Alaska; northern Canada

**Materials and Methods**

The type material of *V. canadensis*, *V. imadatei* and *V. mixtum* was borrowed from the Zoological Museum, University of Copenhagen, Denmark (ZMUC) and the National Museum of Natural History (NMNH), Washington, D.C. The identification key to *Imadateiella* spp. is based on original descriptions and redescriptions of type material (Imadaté 1961, 1964; Shrubovych 2014; Yin 1980, 1999).

**Taxonomy**

The genus *Verrucoentomon* is characterized by 3 pairs of A-setae on mesonotum and metanotum, foretarsal sensillum *t1* is filiform, sensillum *t3* is leaf-like, the position of sensillum *d* is close to base of *e*, and seta *β1* is setiform. The position of sensillum *d*’ is level with or distal to the base of *t2*. The genus is similar to all thirteen genera from subfamily Nipponentominae Yin, 1983 by possession of wide calyx of the maxillary gland with a racemose surface, abdominal legs with 2 nearly

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equal setae, 5 pairs of A-setae on tergites II–VI (with except the members of Alaskanentomon Nosek, 1977) and by posterior position of seta P3 on abdominal tergites II–VI (with except Alaskanentomon fjellbergi Nosek, 1977) (Bu et al. 2013; Shrubovych & Smykla 2012; Shrubovych et al. 2012; Shrubovych 2014; Shrubovych et al. 2014a,b,c).

Verrucoentomon canadense (Tuxen 1955) (Figs. 1-3, Table 1)

Material Examined

HOLOTYPE 1 female, CANADA: Yukon, Richardson Mountains, in dry localities with Dryas sp., elev. 600 m, N 68°24' E 135°37', 25-VI-1948, M. Hammer. PARATYPES 1 male, 1 female data same as HOLOTYPE. Other material: 2 maturus juniors, 1 larva II, same data as holotype. All specimens deposited in NMNH.

DIAGNOSIS

Verrucoentomon canadense is characterized by 3 pairs of A-setae on the mesonotum, metanotum and tergite VIII, presence of P1a setae on tergites I–V, absence of M2 on prosternum, 3 A-setae on sternites I–VII, absence of P1a setae on sternites I and VIII, presence of Pc seta on sternite VII, and presence of additional d6 setae on head. Mesonotal accessory seta P1a is twice the length of P2a. Foretarsal sensillum b is longer than c and clearly surpasses the base of seta y3. The male squama genitalis bears 7+7 setae and female squama genitalis has blunt, bifurcated acrostyle.

REMARKS

The original description and figures (Nosek 1977) are generally accurate except for the chaetotaxy of tergite I. In the original description the author identified 6 A-setae on tergite I, but the holotype and 2 paratypes have 4 A-setae (A1, A2), with seta A5 absent (Fig. 7). The other 4 paratypes have 6 A-setae (A1, A2, A5). Therefore, the number of A-setae on tergite I is a variable character and cannot be used in the diagnosis of the species. Some corrected and additional characters are given: head with additional d6 seta (length 20 μm), setae β3, δ4 and sd5 setiform, seta δ3 slightly shorter than other 2 (9 and 12 μm, respectively) (Figs. 4, 5). Hind marginal cephalic setae d7 and sd7 lengths nearly equal (20 and 23 μm) (Fig. 4). Pronotal seta 1.1.6 times length of seta 2 (32 and 20 μm) (Fig. 6). Accessory setae P1a and P2a on nota long and setiform, P1a twice the length of P2a (23 and 12 μm) (Fig. 6). Length ratio of mesonotal setae P1: P1a:P2a as 1.2:1.1:1.7 (length of seta P1 27 μm, P2 39 μm). Foretarsal seta B1 setiform and long, seta δ4 short, thickened, blunt. Mesonotum with sl and al pores, metanotum with sl pore only. Prosternum without pores, mesosternum and metasternum with sc pore (Figs. 8, 9). Accessory setae P1a on tergites I–VI longer than seta P2a (22 vs. 19 μm) (Fig. 7). Pores psm present on tergites I–VII between setae P1 and P2, al pores on tergites II–VII, ps1 pores on tergite VII. Accessory setae on sternites I–III shorter (11 μm) than those of sternites IV–VII (13 μm). Sternite VII with pore spm (Fig. 10).

Besides the variation in tergite I-A-setae mentioned above, the following setal variability was noted: tergite VI without seta P1a in holotype, but this seta present symmetrically in 2 paratype specimens and asymmetry in 2 other paratype specimens. Sternite VII with Pc-seta on the holotype, absent on a paratype.

Imadateiella mixta (Nosek 1981) new combination (Figs. 11-27, Table 3)

Material Examined

HOLOTYPE 1 male (No. 75792) and PARATYPE 1 female on slides, ALASKA: Fairbanks, Chena Ridge, litter in forest with Betula sp. and Equisetum sp., 12-VIII-1976, A. Fjellberg, deposited in NMNH.

DIAGNOSIS

The species is characterized by 3 pairs of A-setae on the mesonotum and 4 pairs of A-setae on the prosternum, presence of P1a setae on tergites I–VII, 4 A-setae on tergite VIII and 4 setae on sternite VIII, presence of M2 on prosternum and 5 P-setae on sternite III. Accessory seta P1a is more than 3 times the length of P2a on the mesonotum, metanotum and tergites I–VII. Foretarsal sensillum b is shorter than c...
and does not reach the base of seta γ3. The male squama genitalis has 7+7 setae; female squama genitalis has blunt, trifurcate acrostyli.

**Redescription**

Labium not protruded, additional cephalic setae d6 present, length ratio of posterior cephalic setae d7:sd7:sd5 as 2.8:3.6:1 (Fig. 11). Setae l3, sd4 and sd5 setiform, setae l3 and sd4 slightly shorter than seta sd5, 8 μm and 10 μm long, respectively (Figs. 12, 13). Maxillary gland sensilla slender (Fig. 14). Labial palp with terminal spine, 3 setae and broad sensillum (Fig. 15). Maxillary gland with large, densely granulated calyx and posterior filament with simple dilatation. Foretarsal seta δ1 long and setiform; setae δ4 and δ5 blunt, half the length of δ1 (Figs. 16, 17).

Length ratio of pronotal setae 1:2 as 2:1. Mesonotum with 3 pairs of A-setae, metanotum with 4 pairs of A-setae. Length ratio of P1a:P1a:P2 on mesonotum as 1.7–1.8:1.20–2.4. Setae M on mesonotum short and slender, on metanotum longer, 15 and 25 μm, respectively. Accessory seta P1a setiform and long (17 μm), seta P2a modified, stumpy and short (5 μm) (Fig. 18). P3a and P4 on mesonotum and metanotum subequal in length and shape, short, setiform; P5 a small sensillum. Mesonotum and metanotum with pores a1 and a2. Prosternum with seta M2, mesosternum and metasternum lacking A1 setae (Fig. 19). Setae A2 and M2 on prosternum and A2 on mesosternum and metasternum setiform (Fig. 20). Prosternum lacking pores; mesosternum and metasternum with pore sc (Fig. 19). Tergite I with 3 pairs of A-setae: A1, A2 and A5 (Fig. 21), and sternite I with 2 pairs of P-setae (P1 and P1a (Fig. 22) rather than one pair. Accessory seta P1a on tergites I–II long and setiform, setae P2a and P4a short, sensilliform, stumpy as on mesonotum (Fig. 18). Accessory setae on sternites setiform, shorter than on tergites, length about 10 μm (Figs. 23, 24). Pores psm present on tergites I–II, psl on tergite VII, al on tergites II–VII. Sternite I with a pair of pores sal (Fig. 21). Sternites II–VII with spm pore. Sternites VI and VII additionally with a pair of pores pspm, situated near bases of P2 setae (Fig. 23). Hind margin of segments VIII–XII smooth, except tergite XI with weak ciliation. Seta 2a on tergites IX and X shorter than remaining setae. Comb with 10 distinct teeth (Fig. 25). Male squama genitalis with 7+7 setae, lateral basiperiphallar setae present (Fig. 26). Female squama genitalis with short, blunt, trifurcated acrostyli (Fig. 27).


**Remarks**

_Imadateiella, Nipponponentom_ Imadate & Yosi, 1959 and _Vesiculotomon_ Rusek, 1974 within Nipponponentinae. _Vesiculotomon_ differs from the other 3 genera in the presence of a large vesicle near the calyx of maxillary gland and in the baculiform sensillum t1 on foretarsus. _Verrucoentomon, Nipponponentom_ and _Imadateiella_ are very similar in morphological characters, as previously discussed by Shrubovych (2014). These genera have a wide, racemose calyx on the maxillary gland without vesicles, 2 nearly equal setae on the legs of Abd. II and III, P3 in posterior position on the abdominal tergites, well-developed striate band with distinct parallel striae, filiform foretarsal sensillum t1 and leaf-like sensillum t3, foretarsal sensillum d close to base of e, and sensillum a’ level with t2 base. _Verrucoentomon_ differs from the other 2 in having only 3 pairs of A-setae on the metanotum. The presence or absence of teeth on segments IX–XI separates _Nipponponentom_ and _Imadateiella_ (Rusek 1974). Therefore, _Verrucoentomon mixtum_ is transferred to _Imadateiella_ Rusek, 1974 (Acerentomidae, Nipponponentinae).
Table 2. Body chaetotaxy of Verrucoentomon imadatei Nosek 1977.

<table>
<thead>
<tr>
<th>Segment</th>
<th>Formula</th>
<th>Setal composition</th>
<th>Formula</th>
<th>Setal composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Th. I</td>
<td>4</td>
<td>1, 2</td>
<td>4+2</td>
<td>A1, 2, M</td>
</tr>
<tr>
<td>Th. II</td>
<td>8</td>
<td>A2, 3, 4, M</td>
<td>5+2</td>
<td>Ac, 2, 3, M</td>
</tr>
<tr>
<td>Th. III</td>
<td>8</td>
<td>P1, 1, a, 2, 2a, 3, 3a, 4, 5</td>
<td>7+2</td>
<td>Ac, 2, 3, 4, M</td>
</tr>
<tr>
<td>Abd. I</td>
<td>4+4(6)</td>
<td>A1, 2, (5)</td>
<td>3</td>
<td>Ac, 2</td>
</tr>
<tr>
<td>Abd. II</td>
<td>10</td>
<td>P1, 1a, 2, 2a, 3, 4</td>
<td>3</td>
<td>P1</td>
</tr>
<tr>
<td>Abd. III</td>
<td>10</td>
<td>A1, 2, 3, 4, 5</td>
<td>5</td>
<td>P1, 1a, 2</td>
</tr>
<tr>
<td>Abd. IV-V</td>
<td>10</td>
<td>P1, 1a, 2, 2a, 3, 4, 4a, 5</td>
<td>3</td>
<td>Ac, 2</td>
</tr>
<tr>
<td>Abd. VI</td>
<td>10</td>
<td>A1, 2, 3, 4, 5</td>
<td>3</td>
<td>Ac, 2</td>
</tr>
<tr>
<td>Abd. VII</td>
<td>8</td>
<td>P1, 1, a, 2, 2a, 3, 4, 4a, 5</td>
<td>9</td>
<td>Pc, 1a, 2, 3</td>
</tr>
<tr>
<td>Abd. VIII</td>
<td>8</td>
<td>A2, 3, 4, 5</td>
<td>3</td>
<td>Pc, 1a, 2</td>
</tr>
<tr>
<td>Abd. IX</td>
<td>12</td>
<td>1, 1a, 2, 2a, 3, 4</td>
<td>4</td>
<td>1, 2</td>
</tr>
<tr>
<td>Abd. X</td>
<td>10</td>
<td>1, 2, 2a, 3, 4</td>
<td>4</td>
<td>1, 2</td>
</tr>
<tr>
<td>Abd. XI</td>
<td>6</td>
<td>1, 3, 4</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Abd. XII</td>
<td>9</td>
<td></td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

minae), because it has 8 A-setae on metanotum (6 in Verrucoentomon) and does not possess teeth on hind margins of segments IX–XI (present in most Nipponentomon spp.).

Imadateiella spp. are united in having 4 pairs of A-setae on metanotum, 5 pairs of A-setae on tergites II–VI, 4 pairs of A-setae on tergite VII, 5 A-setae on the mesosternum, 7 setae on the metasternum, 2 pairs of P-setae on sternite I (except I. yosiiana), and 3 A-setae on sternites I–VII. Verrucoentomon mixtum is similar to other Imadateiella spp. in these characters, but has only 2 pairs of A-setae on tergite VIII (3 pairs in other members of Imadateiella) and in the shape of the labial palp. The species is similar to I. shideiana shideiana and I. shideiana eos in the presence of P1a setae on tergite VII, 5 P-setae on sternite III, 4 setae on sternite VIII and in the shape of accessory setae on tergites I–VII (long setiform seta P1a and very short sensilliform setae P2a and P4a). Verrucoentomon mixtum is more similar to I. shideiana eos in the absence of P3a setae on tergites II–VII and P1 setae on sternite VII. Besides the presence of only 2 pairs of A-setae on tergite VIII V. mixtum possesses a long foretarsal sensillum a that reaches the base of sensillum t2 (in I. shideiana eos sensillum a shorter, apex not reaching t2 insertion).

Key to Imadateiella Species

1.— Mesonotum and metanotum with P2a’ setae ........................................ I. murka Szeptycki – Russia, Siberia.
1’.— Mesonotum and metanotum without P2a’ setae ........................................ 2
2. (1’).— Sternite VIII with P1a setae ......................................................... 3
2’.— Sternite VIII without P1a setae ......................................................... 6
3. (2).— Tergite VII with P1a setae ......................................................... 4
3’.— Tergite VII without P1a setae ......................................................... 5
4. (3).— Sternite VI with Pc seta .............................................................. I. sharovi (Martynova) – Russian Far East.
4’.— Sternite VI without Pc seta .............................................................. I. shiria (Imadaté) – Japan.
5. (3’).— Foretarsal empodium with globule apically ................................ I. sphaerempodia Yin – China.
5’.— Foretarsal empodium smooth .......................................................... I. saurosi Yin – China.
6. (2’).— Tergites II–VI with P1a setae, sternite I with 4 P-setae, sternite III with 5 P-setae ........................................ 7
6’.— Tergites II–VI without P1a setae, sternite I with 2 P-setae, sternite III with 6 P-setae ........................................ 8
7. (6).— Tergite VIII with 6 setae ..............................................................

<table>
<thead>
<tr>
<th>Segment</th>
<th>Formula</th>
<th>Setal composition</th>
<th>Formula</th>
<th>Setal composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Th. I</td>
<td>4</td>
<td>1, 2</td>
<td>4±4</td>
<td>1, 2, M1, 2</td>
</tr>
<tr>
<td>Th. II</td>
<td>8</td>
<td>A2, 3, 4, M</td>
<td>5±2</td>
<td>A2, 3, M</td>
</tr>
<tr>
<td>Th. III</td>
<td>16</td>
<td>P1, 1a, 2, 2a, 3a, 4, 5</td>
<td>4</td>
<td>P1, 3</td>
</tr>
<tr>
<td>Abd. I</td>
<td>10</td>
<td>A1, 2, 3, 4, M</td>
<td>7±2</td>
<td>A2, 3, 4, M</td>
</tr>
<tr>
<td>Abd. II-III</td>
<td>16</td>
<td>P1, 1a, 2, 2a, 3a, 4, 5</td>
<td>4</td>
<td>P1, 3</td>
</tr>
<tr>
<td>Abd. IV-VI</td>
<td>10</td>
<td>A1, 2, 3, 4, 5</td>
<td>5</td>
<td>Ac, 2</td>
</tr>
<tr>
<td>Abd. VII</td>
<td>16</td>
<td>P1, 1a, 2, 2a, 3a, 4, 5</td>
<td>3</td>
<td>P1, 1a, 2, 3</td>
</tr>
<tr>
<td>Abd. VIII</td>
<td>8</td>
<td>A2, 3, 4, 5</td>
<td>8</td>
<td>Ac, 2</td>
</tr>
<tr>
<td>Abd. IX</td>
<td>14</td>
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<td>P1, 1a, 2, 3</td>
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<tr>
<td>Abd. X</td>
<td>4</td>
<td>A4, 5</td>
<td>4</td>
<td>1, 2</td>
</tr>
<tr>
<td>Abd. XI</td>
<td>15</td>
<td>Pc, 1, 1a, 2a, 2a, 3a, 5</td>
<td>1</td>
<td>1, 2</td>
</tr>
<tr>
<td>Abd. XII</td>
<td>6</td>
<td>1, 2a, 3a, 4</td>
<td>6</td>
<td>1, 2</td>
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</table>

7´.— Tergite VIII with 4 setae .................................................. I. mixta (Nosek) – Alaska.


8´.— Tergites II–VII without P3a setae, sternite VII without Pc seta ........................................... I. shideiana eos (Imadaté) – Japan.

Discussion

Verrucoentomon canadense and V. imadatei differ from nearly all other Verrucoentomon spp. in the presence of 4 setae on sternite VIII (P1a absent). They are also similar in the absence of seta M2 on the pronotum and P1a on sternite I, presence of Pc on sternites III and VII, and in porotaxic pattern. They differ in the presence of seta P1a on tergite VI (absent in V. imadatei) and in length of foretarsal sensillum b (in V. canadense b and c of equal length, b longer than c in V. imadatei). Only one other species, V. rafaliskii Szeptycki, 1997 from Central Europe, has 4 setae in sternite VIII. It is similar to V. canadense and V. imadatei in the absence of seta M2 on the prothorax and P1a seta on sternite I, and in the presence of 5 P-setae on sternite III. It differs in having fewer setae on tergites VIII, IX and X (4 A-setae, 8, 10 setae vs. 6 A-setae, 10, 12 setae in both American species) and lacking seta Pc on sternite VII.

Verrucoentomon mixtum is similar to both American Verrucoentomon spp. in the presence of 4 setae on sternite VIII. Half of the known Imadateiella taxa (I. murka, I. yosiiana, I. shideiana shideiana and I. shideiana eos) also have just 4 setae on sternite VIII, whereas the other 4 Imadateiella spp. and 17 Nipponotomom spp. have 6 setae on sternite VIII (Nipponotomom bifidum Rusek, 1974 from Canada is the only exception). This difference as well as the absence of teeth on the terminal abdominal segments is additional justification for transferring V. mixtum to Imadateiella rather than to Nipponotomom. Also, the porotaxy of I. murka and I. sharovi is similar to I. mixta in possession of pores sal on sternite I. These pores are absent in Nipponotomom spp. (Bu et al. 2013; Nakamura 2004; Shrubovych 2009).

Reduction of the apical tuft of setae on the labial palp to 2-branched or only one terminal spine is rare among acerentomids, and appears to have arisen independently several times. The apical tuft consists of 2 branches in Acerentulus traeagardi Ionescu, 1937 and Acerentulus collaris Szeptycki, 1991, and in Acerentulus ruseki Nosek, 1967 consists of just a single terminal spine (Szeptycki 1991). Members of Yihunentulus have one terminal spine on the labial palp (Bu et al. 2014; Yin 1980). Species of Fjellbergella Nosek, 1978 have 2- or 3-branched apical tufts on their labial palps (Bu et al. 2014; Nosek 1978; Shrubovych & Bernard 2013). This character is very interesting to study, but at this time we cannot confirm the different steps of reduction as good generic characters. Moreover, Bu et al. (2014) noted 2 populations of Imadateiella sharovi that differed in having 4-branched and 2-branched setal tufts on the labial palps. Therefore, this character is not useful for generic placement of I. mixta.

Acknowledgments

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