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A key to some *Frankliniella* (Thysanoptera: Thripidae) larvae found in Florida with descriptions of the first instar of select species

Thomas Skarlinsky[1] and Joe Funderburk[2]

Abstract

Few publications exist toward the identification of larval thrips. As a result, researchers and practitioners often are unable to report larval species data or may misinterpret what is a host plant when adults of multiple species are collected. Therefore, we conducted repetitive plant sampling and detailed examination of larvae with adults, which revealed morphological differences of some undescribed *Frankliniella* (Thysanoptera: Thripidae) larvae. The morphological differences were confirmed by non-destructive DNA extraction, PCR, and sequencing of the *COI* mitochondrial gene. A larva II morphological key to 7 *Frankliniella* species found in Florida is presented with new larval descriptions of 4 species.

Key Words: thrips; immature; identification; morphology; host plant; *COI* mitochondrial gene

Resumen

Existen pocas publicaciones sobre la identificación de larvas de los trips. Como resultado, los investigadores y los técnicos a menudo no puedan reportar datos sobre las especies de larvas o pueden mal interpretar lo que es una planta hospedera cuando se recolectan múltiples especies de adultos. Por lo tanto, se realizó un muestreo repetitivo de plantas y se examinó en detalle las larvas con los adultos que revelaron diferencias morfológicas de las larvas no descritas de algunas especies de *Frankliniella* (Thysanoptera: Thripidae). Las diferencias morfológicas fueron confirmadas por la extracción no destructiva de ADN, PCR y secuenciación del gen mitocondrial COI. Se presenta una clave morfológica de las larvas II de 7 especies de *Frankliniella* que se encuentran en la Florida con nuevas descripciones de larvas para 4 especies.

Palabras Clave: trips; inmaduro; identificación; morfología; planta hospedero; gen mitocondrial COI

Frankliniella is the second largest genus in the family Thripidae (Thysanoptera) with 233 extant species (ThripsWiki 2015), of which most are native to the Americas (Nakahara 1997). A significant amount of published research has been dedicated to the description of the adult life stages of *Frankliniella*, whereas few publications describe the immature stages. Speyer & Parr (1941) published a description of the 2nd instar of *Frankliniella intonsa* (Trybom). Miyazaki & Kudo (1986) produced a complete morphological and biometric description of the 2nd instar of *F. intonsa*. Kirk (1987) described the 2nd instar of *F. schultzei* (Trybom) and Milne et al. (1997) described the 2nd instar larvae of *F. occidentalis* (Pergande). These authors separated only a single species of *Frankliniella* from other genera, whereas Nakahara & Vierbergen (1998) produced a larval key for the identification of 7 species of *Frankliniella* from Europe. Mound et al. (2005) described the 2nd instar of *F. lantanae* Mound, Nakahara & Day, and Masumoto & Okajima (2013) described the 2nd instar of *F. hemerocallis* Crawford. All of the above larval descriptions and keys were published from Old World locations. Currently, Borbon (2007) is the only publication from the Americas. The author provided a key to the 2nd instar of 5 *Frankliniella* species, with 3 found only in the Americas (Nakahara 1997).

The paucity of larval morphological identification is a continuing problem in all studies on Thysanoptera (Mound 2013). For example, studies conducted in Florida (Reitz 2002; Northfield et al. 2008; Frantz & Mellinger 2009; Baez et al. 2011) reported only total thrips larvae of all species because no larval identification key was available. Furthermore, the lack of larval species identification can result in the misinterpretation of a host plant as defined by (Mound 2013). "A host plant is a plant on which an insect rears its young", and the presence of immature life stages provides a quantitative measure of a plant's suitability as a reproductive host (Terry 1997). Some species of *Frankliniella* are competent vectors of species of plant viruses in the genus *Tospovirus* (Bunyaviridae), whereas other species are not (Webster et al. 2015). Only the larvae acquire tospoviruses; therefore, the ability to identify the larvae is important in research and management programs involving tospoviruses. Our objective was to provide a larval morphological identification tool of important *Frankliniella* species in Florida for researchers and practitioners.

Materials and Methods

Larval character states and chaetotaxy used in this key are adapted from Vierbergen et al. (2010) and Speyer & Parr (1941). Descriptions of *F. fusca* (Hinds), *F. occidentalis*, and *F. schultzei* are based on Nakahara & Vierbergen (1998) and our further examination of larval specimens (Table 1). Character states of *F. insularis* (Franklin)

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Table 1. Species, number of specimens with the instar in parentheses and collection data for the larval thrips examined in this study.

Species	Number (instar)	Host	Locality FL County	Collection date(s)
F. bispinosa	12(I), 88(II)	*Bidens alba*	Highlands Polk Osceola Lake Sumter Marion Alachua Lafayette	3-I-2013 to 12-VI-2013
	1(I), 2(II)	*Coreopsis* sp.	Alachua	9-IV-2013
	36(I),46(II)	*Trifolium* sp.	Alachua	
	1(I), 8(II)	*Vicia sativa*	Alachua	
	42(I), 5(II)	*Cestrum aurantiacum*		
	137(I), 79(II)	*Raphiolepsis indica*		
	1(II)	*Sphagneticola trilobata*	St. Lucie	16-VI-2015
	3(II)	*Lagerstroemia indica*		
	1(II)	*Handroanthus impetigonosus*	Miami-Dade	29-IV-2015
	1(I), 2(II)	*Delonix regia*		
	1(II)	*Asystasia gangetica*		
	17(II)	*Lagerstroemia speciosa*		6-VIII-2010
F. cephalica	534(I), 763(II)	*Bidens alba*	Monroe Miami-Dade Broward Palm Beach Hendry St. Lucie Glades Highlands Polk Osceola Lake Sumter Marion Alachua Suwannee Lafayette	3-I-2013 to 16-VI-2015
F. fusca	1(I), 1(II)	*Arachis* sp.	St. Lucie	16-VI-2015
F. insularis	96(II)	*Abutilon chitenendii*	Miami-Dade	27-III-2010
F. kelliae	1(1), 1(II)	*Cassia javanica*	Miami-Dade	29-IV-2015
	1(I), 5(II)	*Handroanthus impetigonosus*		
	1(II)	*Cassia fistula*		
	18(I), 69(II)	*Delonix regia*		
	74(II)	*Mangifera indica*		20-I-2010
F. occidentalis	15(II)	*Gerbe*ra sp.	St. Lucie	12-III-2009
	16(II)	*Capsicum annuum*		13-IV-2009
	2(II)	*Nasturtium* sp.		
F. schultzei	18(II)	*Lycopersicon esculentum*	Palm Beach	14-IX-2015
	8(II)			7-IX-2009

are from an unpublished description by S. Nakahara (personal communication), from Vierbergen et al. (2010), and from the examination of larval specimens collected with adults (Table 1). The species *F. cephalica* (D. L. Crawford), *F. bispinosa* (Morgan), and *F. kelliae* Sakimura are based on examination of larvae with adults (Table 1). In addition, non-destructive DNA template extraction, PCR, and sequencing of the *COI* mitochondrial gene of *F. cephalica*, *F. bispinosa*, and *F. kelliae* were conducted (Rugman-Jones et al. 2010), to confirm larval morphological observations. The molecular data will be presented in a separate publication.

Northfield et al. (2008) reported mixed adult populations of *F. tritici* and *F. bispinosa* in north Florida. Larvae II specimens collected with adult *F. tritici* from St. Georges County, Maryland, outside of the reported geographic distribution of *F. bispinosa* (Nakahara 1997) were compared with the species in this key. All specimens examined in this study are housed at the USDA, APHIS, PPQ, Plant Inspection Station, Miami, Florida.

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All specimens were examined with a Leica DM LB2 compound microscope under phase contrast at 100×, 200×, and 400× magnification. Measurements used in the key and descriptions are in microns at 400× magnification. Images were taken with a Helicon Focus 6.1.0 system and adjusted for visual clarity with Adobe® Photoshop® Elements 10. All images are at 400× magnification. The larval specimens were mounted in Hoyer's medium, stored in an oven at 38 °C for a minimum of 2 wk and sealed. The adults were mounted in Canada balsam or Hoyer's medium.

The larvae II of *Frankliniella* are distinguished from other Thripinae larvae by having the campaniform sensillae of abdominal tergite IX separated by more than 1.7 times the distance between the D1 setae of the tergite. Also, variably sized sclerotized teeth are usually present on the posterior margin of tergite IX. Nakahara & Vierbergen (1998) give a complete diagnosis of the *Frankliniella* larvae II.

Results

Key to Larvae II of Select *Frankliniella* Species of Florida Adapted from Nakahara & Vierbergen (1998).

No morphological differences were detected between the larvae II vouchers of *F. bispinosa* and the larva II collected with *F. tritici* adults. Therefore, larvae II that key to *F. bispinosa* from areas of Florida where populations of *F. tritici* are encountered should be reported as *F. bispinosa/tritici*.

1.— Pronotum with 6 pairs of setae (Fig. 1A); mesonotum with 5 pairs of setae (Fig. 1A . . . . . (instar I)

1'.— Pronotum with 7 pairs of setae (Fig. 2B); mesonotum with 8 pairs of setae (Fig. 2C . . . . . 2 (instar II)

2.— Dark band of abdominal tergite IX extends to and sometimes anterior to the campaniform sensilla (Fig. 3G . . . . . .*F. fusca* Hind

2'.— Dark band extends anterior to the D1 setae by about the distance of the diameter of the D1 setal socket (Fig. 3A–E 3

3.— Posteromarginal teeth, abdominal tergite IX, between the D1 setae, longer than the basal width of the D1 setae (Fig. 3A, B, D, E 4

3'.— Posteromarginal teeth, abdominal tergite IX, between the D1 setae, equal to or less than the basal width of the D1 setae (Fig. 3C, F, G 7

4.— Dorsal setae of abdominal tergites VIII broadly pointed or acute (Fig 3B, C, E, G 5

4'.— Dorsal setae of abdominal tergites VIII blunt (Fig 3A, D, F 6

5.— Abdominal tergite VIII discal plaques with poorly developed or rounded microtrichia (Fig. 3B); D1 setae of tergite VIII usually less than 40 µm . . . . . *F. cephalica* (D. L. Crawford)

5'.— Abdominal tergite VIII discal plaques with well-developed or pointed microtrichia (Fig. 3E); D1 setae of tergite VIII usually greater than 40 µm . . . . . *F. occidentalis* (Pergande)

6.— Abdominal tergite VIII discal plaques with broadly pointed to rounded microtrichia (Fig. 3D); D1 setae of tegite VIII 20–30 µm long . . . . . *F. kelliae* Sakimura

6'.— Tergite VIII discal plaques with fine narrowly pointed microtrichia (Fig. 3A); D1 setae of tergite VIII 30–40 µm long . . . . . *F. bispinosa* (Morgan)

7.— Abdominal posteromarginal teeth tergite IX minute, less than the basal width of the D1 setae (Fig. 3F); abdominal tergal setae blunt; antennal segment VII 20–25 µm long; anterior margin of dark band tergite IX often emarginate between the D1 setae . . . . . *F. schultzei* (Trybom)

7'.— Abdominal posteromarginal teeth tergite IX small, most equal to the basal width of the D1 setae, occasionally some teeth laterad of the D1 setae are longer (Fig. 3C); abdominal tergal setae broadly pointed; antennal segment VII 27–33 µm long; anterior margin of dark band tergite IX variously shaped . . . . . *F. insularis* (Franklin)

Frankliniella bispinosa (Morgan) (Figs. 2A–C, 3A)

DESCRIPTION, LARVA II

Head with the D1–D4 setae apically pointed (Fig. 2A); D1 setae 10–13 µm long; D2 21–25 µm long; D3 17–20 µm long, and D4 23–30 µm long. Pronotal setae apically pointed (Fig. 2B). Meso- and metanotal setae with a combination of broadly pointed to apically acute setae (Fig. 2C). The abdominal tergal setae are apically blunt and appear as if the tips were trimmed by scissors. Abdominal plaques tergites II–VI with some developed microtrichia anteromedially of the D1 setae; most plaques anterolateral of the D1 setae with developed microtrichia. Tergite VII plaques anterior of the dorsal setae with well-developed microtrichia and those posterior of the setae rounded. Nearly all plaques on tergite VIII with long finely pointed microtrichia. Tergite IX with a dark band in which the anterior margin extends anteriorly about the diameter of a D1 setal socket. The posteromarginal teeth tergite IX are longer than the basal width of the D1 setae; approximately 12–15 teeth are present between the D2 setae. Ventral posteromarginal teeth tergum IX are minute, about 1/3 the size of the dorsal teeth. Tergite X with a dark band that extends to the campaniform sensilla of the tergite.

DESCRIPTION, LARVA I

Head with the D1–D4 setae apically pointed. Pro-, meso-, and metanotal setae with both apically blunt and broadly pointed setae. Meso- and metanotal plaques, anterior to the posteromarginal row of major setae with rounded microtrichia and those posterior of the setal row without microtrichia. Abdominal segments I–VIII tergal plaques with microtrichia. Approximately 12 thin posteromarginal sclerotized teeth between the D2 setae. Usually, 1–5 small sclerotized teeth lie within the dark band between the D1 setae of the tergite (Fig. 1B). Terga IX and X with dark bands similar to the larva II.

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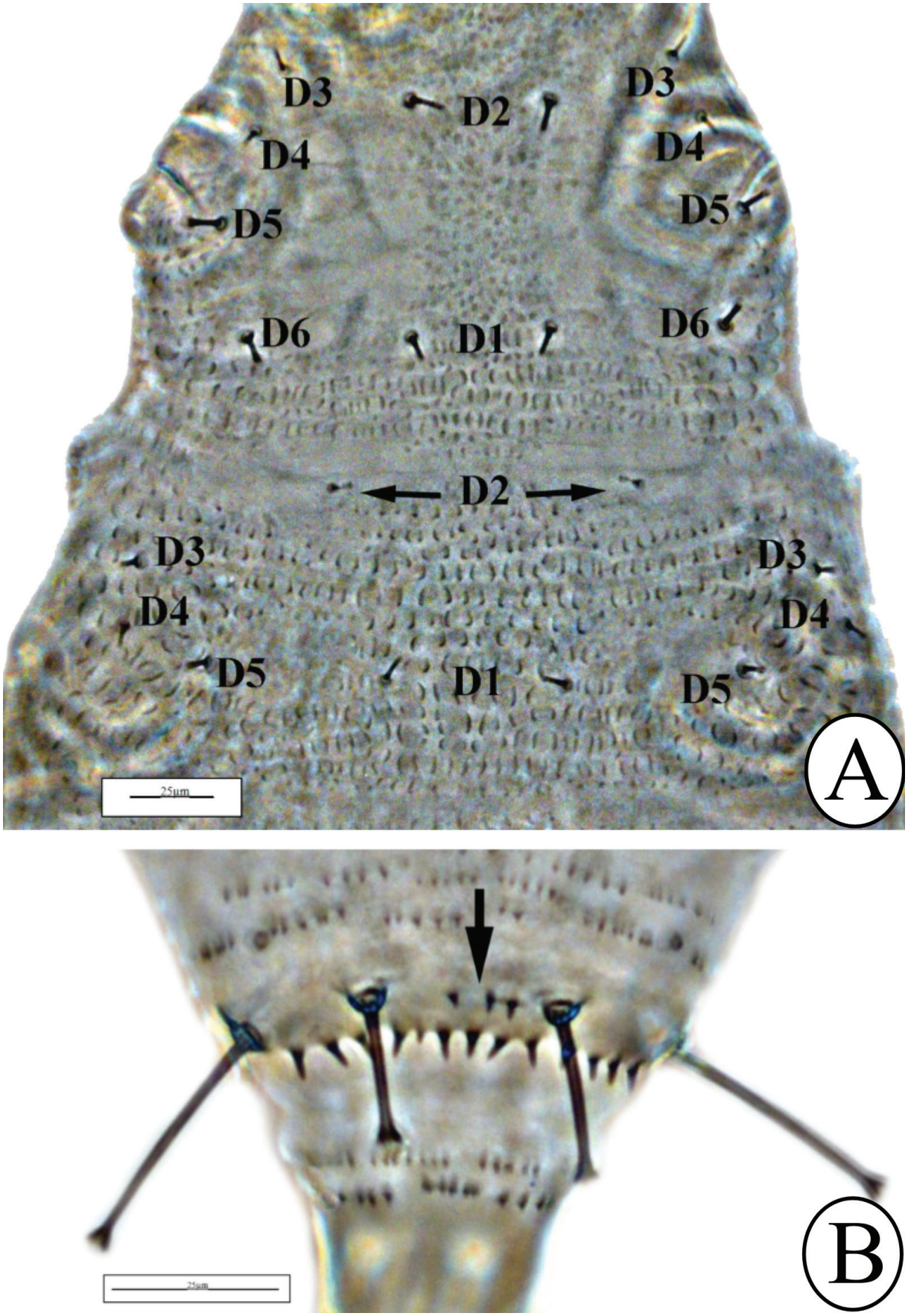


Fig. 1. Larva I of *F. kelliae*: dorsal setae pairs, D1–D6 of pronotum and D1–D5 of mesonotum (A); arrow indicates small sclerotized teeth between D1 setae of abdominal tergite IX (B); scale = 25 µm.

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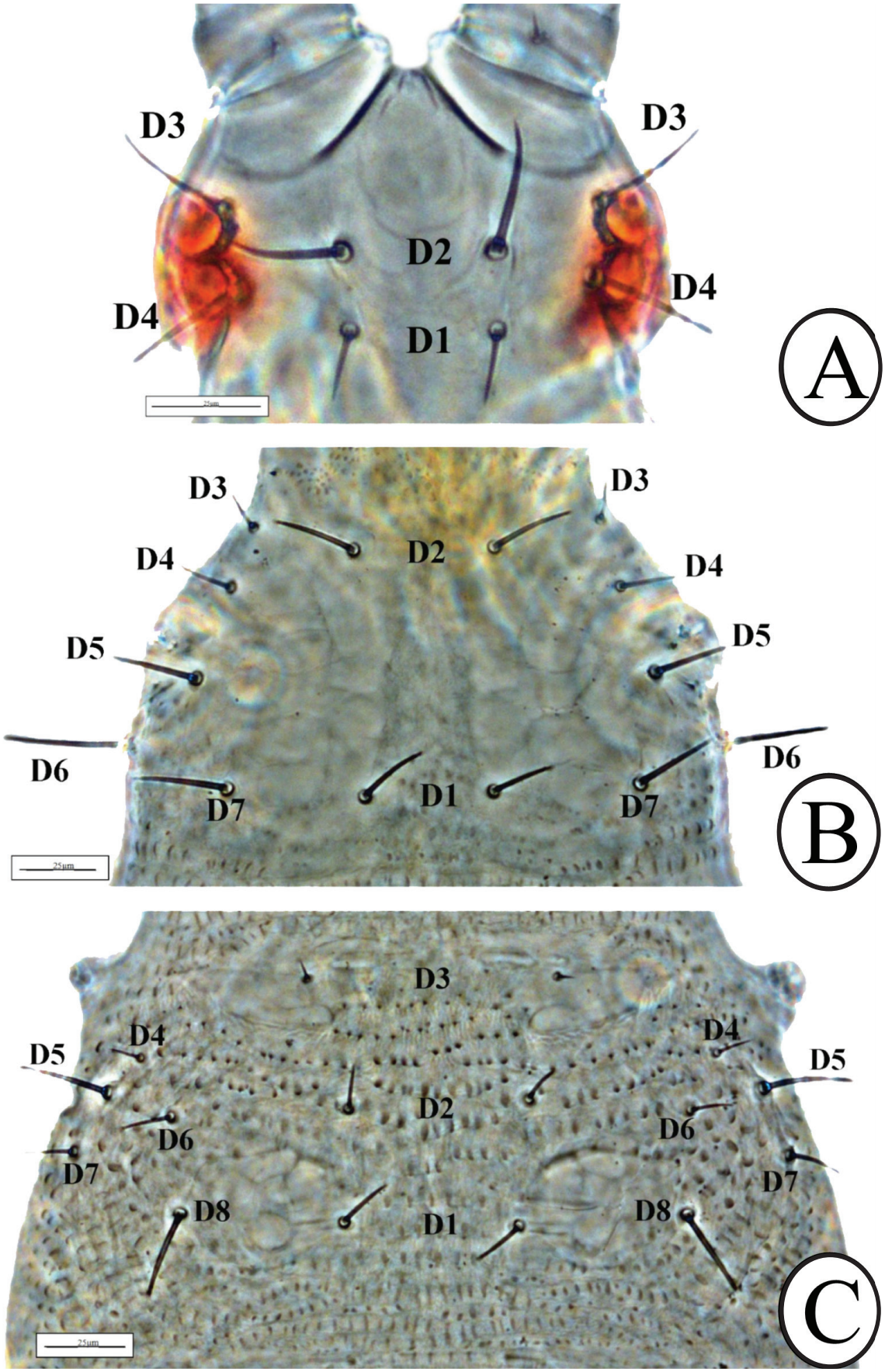


Fig. 2. Larva II of *F. bispinosa*: dorsal setae pairs, D1–D4 of head (A); dorsal setae pairs, D1–D7 of pronotum (B); dorsal setae pairs, D1–D8 of mesonotum (C); scale = 25 µm.

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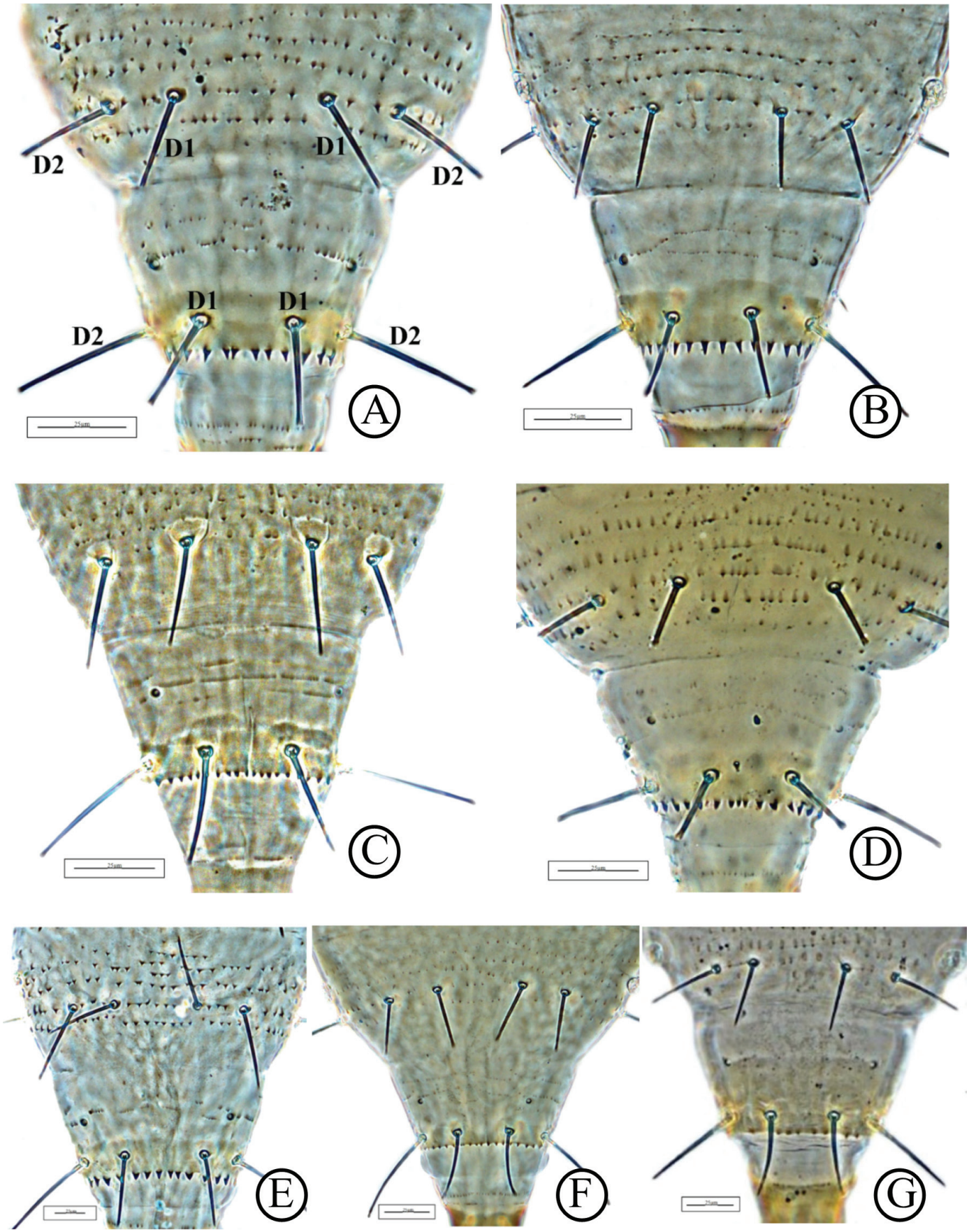


Fig. 3. Abdominal tergites VIII and IX of larvae II: dorsal setae, D1, D2 of tergites VIII and IX *F. bispinosa* (A); *F. cephalica* (B); *F. insularis* (C); *F. kelliae* (D); *F. occidentalis* (E); *F. schultzei* (F); *F. fusca* (G); scale = 25 µm.

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Frankliniella cephalica (D. L. Crawford) (Fig. 3B)

DESCRIPTION, LARVA II

Head with the D1–D4 setae apically pointed: D1 setae 10–15 µm long; D2 12–18 µm long; D3 12–15 µm long, and D4 22–25 µm long. The abdominal setae, tergites II–VII, are broadly pointed. The D1 setae of abdominal tergite IX are blunt and D2 pointed. The dorsal abdominal plaques segments II–VI with few poorly developed or rounded microtrichia anterior of the dorsal setae; most plaques anterior of the dorsal setae segments VII and VIII with rounded microtrichia. Occasionally, a few developed or pointed microtrichia present on tergite VIII. Tergite IX with a darkened band in which the anterior margin extends anteriorly about the diameter of a D1 setal socket. The posteromarginal teeth tergite IX are longer than the basal width of the D1 setae; approximately 12–15 teeth present between the D2 setae. The ventral posteromarginal teeth are minute about 1/3 the size of the dorsal teeth. Tergite X with a transverse dark band that extends to the campaniform sensilla of the tergite.

DESCRIPTION, LARVA I

Head with the D1–D4 setae apically pointed. Dorsal thoracic and abdominal setae I–VIII apically pointed. Tergite IX D1 and D2 setae blunt. Tergite X D1 setae blunt. Meso- and metanotal plaques, anterior to the posteromarginal row of major setae with rounded microtrichia and those posterior of the setal row are crescent shaped and lack microtrichia. Tergal plaques abdominal segments I–VIII with microtrichia. Approximately 10–12 thin posteromarginal sclerotized teeth between the D2 setae of tergite IX. No sclerotized teeth lie within the dark band between the D1 setae of the tergite. Terga IX and X with dark bands similar to the larva II.

Frankliniella fusca Hinds (Fig. 3G)

DESCRIPTION, LARVA II

The primary character that separates this species from the others treated in this key is the longitudinally broad dark band of tergite IX. For a complete description, see Nakahara & Vierbergen (1998).

Frankliniella insularis (Franklin) (Fig. 3C)

DESCRIPTION, LARVA II

Head with D1–D4 setae broadly pointed: D1 setae 20–23 µm long; D2 setae 25–30 µm long; D3 setae 20–30 µm long, and D4 setae 27–37 µm long. All the abdominal tergal setae are broadly pointed apically. The abdominal plaques segments II–VII with few poorly developed or rounded microtrichia anterior of the dorsal setae; those on VIII are more abundant. Sometimes a few pointed microtrichia present on tergite VIII. Tergite IX with a darkened band in which the anterior margin extends anteriorly about the diameter of a D1 setal socket. The posteromarginal teeth tergite IX are about the same length as the basal width of the D1 setae; approximately 18–21 teeth present between the D2 setae. The ventral posteromarginal teeth are minute about 1/2 the size of the dorsal teeth. Tergite X with a transverse dark band that extends to the campaniform sensilla of the tergite.

Frankliniella kelliae Sakimura (Figs. 1A–1B, 3D)

DESCRIPTION, LARVA II

Head with the D1, D2, and D4 setae apically broadly pointed, D3 apically pointed; D1 setae 10–13 µm long, D2 setae 15–18 µm long, D3 setae 17–20 µm long, and D4 setae 22–25 µm long. Pronotal setae apically blunt. Meso- and metanotal setae with a combination of apically truncate to broadly pointed setae. The abdominal tergal setae are apically blunt and appear as if the tips were trimmed by scissors. Abdominal tergites I–VII plaques with rounded microtrichia. Tergite VIII plaques with a combination of broadly pointed to rounded microtrichia. Tergite IX with a darkened band in which the anterior margin extends anteriorly about the diameter of a D1 setal socket. The posteromarginal teeth tergite IX are longer than the basal width of the D1 setae; approximately 15–18 teeth are present between the D2 setae. The ventral posteromarginal teeth are minute about a 1/3 the size of the dorsal teeth. Tergite X with a transverse dark band that extends to the campaniform sensilla of the tergite.

DESCRIPTION, LARVA I

Head with the D1, D2, and D4 setae apically blunt; D3 pointed. Pro-, meso-, and metanotal setae apically blunt. Meso- and metanotal plaques with some reduced microtrichia on the anterior rows. The plaques are crescent shaped giving the integument a sculptured or wrinkled appearance (Fig. 1A). Plaques, abdominal tergites I–V, similar in appearance as the thoracic plaques with reduced microtrichia on the anterior and lateral margins of the tergites. Tergal plaques abdominal segments VI–VIII with microtrichia. Approximately 12 thin posteromarginal sclerotized teeth present between the D2 setae of tergite IX. Usually 1–5 small sclerotized teeth lie within the dark band between the D1 setae of the tergite (Fig 1B). Terga IX and X with dark bands similar to the larva II.

Frankliniella occidentalis (Pergande) (Fig. 3E)

DESCRIPTION, LARVA II

Dorsal abdominal setae broadly to finely pointed. Nearly all plaques on abdominal tergite VIII with long finely pointed microtrichia. Usually 12–15 posteromarginal teeth are present between the D2 setae and 4–6 teeth between the D1 setae of tergite IX. The length of the posteromarginal teeth exceeds the basal width of the D1 setae and often exceeds the diameter of the D1 setal sockets.

Frankliniella schultzei (Trybom) (Fig. 3F)

DESCRIPTION, LARVA II

Dorsal abdominal setae apically blunt. Most plaques on abdominal tergite VIII with reduced apically rounded microtrichia.

Discussion

The number of obvious morphological characters available for larval study was less compared with those available for the adults. Furthermore, many of the larval characters and their respective states were not reliable for separating these congener species. Larval character states in this key, i.e., shape of the integument plaques, microtrichia, and seta, which we found useful in separating the species, may be difficult to discern for the occasional user. Therefore, we recommend using this key to confirm larval identities with vouchered adults when possible. Also, phase contrast microscopy should be used. Subtle differences of the integument and microtrichia were not otherwise visible under bright-field microscopy.

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