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ARTÍCULO DE INVESTIGACIÓN / RESEARCH ARTICLE

LIFE CYCLE OF *Falconia incaica* (Heteroptera: Miridae) ON *Ricinus communis* (Euphorbiaceae) IN THE BOGOTÁ PLATEAU

Ciclo de vida de *Falconia incaica* (Heteroptera: Miridae) en *Ricinus communis* (Euphorbiaceae) en la sabana de Bogotá

Running head: Life cycle of *Falconia incaica*

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ABSTRACT

Falconia incaica is a plant bug commonly found on *Ricinus communis* (Euphorbiaceae), a plant species widely cultivated in the American tropics to extract its seed oil. Heavily infested leaves exhibit feeding damage from these plant bugs, having the leaves whitish-yellow spots on their dorsal surface. The adults and nymphs are mostly located on the underside of the leaf. This work aimed to document the life cycle of *F. incaica* breeding on *R. communis*, and to recognize and differentiate its nymphal instars based on their morphology. Under laboratory conditions (18°C, relative humidity 70 %) the life cycle duration, from instar I to adult, was 20.16 (SD=1.05) days, with an increasing development time for later instars. Nymphal instars I and II have reddish lateral areas on the head (including scape, pedicel, and first flagellomere), thorax, and first abdominal segment; instars III-V have these areas dark instead of red. Among the nymphal measurements taken, the length of the antennal pedicel allowed for differentiation of each of the five nymphal instars.

Keywords: Colombia, rearing techniques, Neotropical region, insect pests, host plant.

RESUMEN

Falconia incaica es un chinche de las plantas, que se encuentra comúnmente en *Ricinus communis* (Euphorbiaceae), una especie de planta ampliamente cultivada en los trópicos americanos para extraer el aceite de su semilla. Hojas muy infestadas exhiben daños por

alimentación debido a estos insectos, teniendo como consecuencia las hojas manchas de color blanco amarillento en su superficie dorsal. Los adultos y las ninfas se encuentran principalmente en el envés de la hoja. El objetivo de este trabajo fue documentar la duración del ciclo de vida de *F. incaica* al reproducirse sobre *R. communis*, y reconocer y diferenciar sus estadios ninfales en función de su morfología. En condiciones de laboratorio (18°C, humedad relativa 70 %) la duración del ciclo de vida, desde el estadio I hasta el adulto, fue de 20,16 (DE=1,05) días, con un tiempo de desarrollo creciente en los estadios posteriores. Los estadios ninfales I y II tienen áreas laterales rojizas en la cabeza (incluidos el escapo, el pedicelo y el primer flagelómero), el tórax y el primer segmento abdominal; los estadios III-V tienen estas áreas oscuras en lugar de rojas. Entre las mediciones ninfales tomadas, la longitud del pedicelo antenal permitió la diferenciación de cada uno de los cinco estadios ninfales.

Palabras clave: Colombia, insectos plaga, plantas hospedantes, región Neotropical, técnicas de cría.

INTRODUCTION

Plant bugs, or Miridae, represents the most diversified group within Heteroptera (Hemiptera), with more than 11.300 described species (Cassis and Schuh, 2012; Schuh, 2013; Schuh and Weirauch, 2020) distributed in all the major biogeographic regions of the world (Ferreira et al., 2015). Because of the phytophagous habits of a large percentage of the Miridae, numerous species are considered of agricultural importance (Wheeler, 2000, 2001).

Ricinus communis Linnaeus, 1753 (Euphorbiaceae) is a cultivated plant species throughout the world grown for its oil, pharmacological uses, biodiesel fuel, and other industrial uses (Falasca et al., 2012; Ribeiro et al., 2016). Several species of arthropods have been associated with *R. communis*, both natural enemies and pests (López-Guillén et al., 2020). *Falconia incaica* Carvalho, 1987 (Orthotylinae: Orthotylini) is among the insects associated with *R. communis* that are considered as pests in Colombia (Londoño Z, 2011). Adults and nymphs are usually found on the undersides of the leaves. When infestations of this species are high on the plant, the leaves exhibit patches of white and yellow, and overall chlorosis, affecting the foliar photosynthetic area (Londoño Z, 2011; Forero, 2022).

Falconia incaica was initially misidentified in the agricultural literature in Colombia as *Falconia antioquiana* Carvalho, 1987 due toits external similarity (e.g., Londoño Z, 2011; Tapias-Múnera and Gaviria-Rivera, 2018; López-Guillén et al., 2020). Recently, Forero (2022) clarified the identity of the species of Miridae associated with *R. communis* in Colombia. He documented the overall aspect and male genitalic structures of *F. incaica*, pointing out differences among the species present in Colombia. Furthermore, he briefly described the coloration of early and late instars of *F. incaica* (Forero, 2022). Despite the interest in *F. incaica* as a pest of *R. communis*, no biological data has been provided besides general observations on its association with *R. communis* and the characterization of the damage it inflicts on the plant.

In this paper, we present the life cycle of *F. incaica* when bred on *R. communis* in the Bogotá plateau, and additionally, we describe and differentiate each of the nymphal instars

according to its morphological characteristics and provide field observations on their placement on the plant.

MATERIAL AND METHODS

LIFE CYCLE AND FIELD OBSERVATIONS

Specimens of *F. incaica* at different developmental stages (eggs and nymphs) were taken from plants of *R. communis* at the campus of the Universidad Nacional de Colombia, Bogotá, to the laboratory of the entomological museum (UNAB) of the Faculty of Agricultural Sciences for rearing. Experiments were carried out between March and July of 2011 under laboratory conditions, at 18°C and relative humidity of 70 %. Specimens of *F. incaica* were placed in polyethylene boxes with fresh leaves of *R. communis*. The boxes had a tight seal on the lid and two holes, each covered with a fine mesh to prevent an excess concentration of moisture and to allow aeration. Young leaves of *R. communis* were used for breeding. Each leaf was cleaned with cotton and water to remove mites, or other arthropods. To maintain the turgor of the leaves, a 2 ml tube filled with water was placed at the base of each petiole. Each *F. incaica* specimen was taken with a fine brush and placed on the underside of the leaf to avoid direct light. Different numbers of specimens were kept in each box, depending on the instar to avoid crowded conditions. For eggs, about 75 specimens per box were used and for 1^{st} to 5^{th} instar nymphs, about 25 specimens per box. Duration of each instar was measured as the time (in days) it lasted until the next molting. Because eggs were collected from the field, no attempt was made to estimate the duration of the eggs since efforts were put only on the duration of the nymphal instars. Each repetition consisted of a set of specimens of a given set of instars, either hatched from eggs

or collected from the field, that were observed to molt in the lab, thus knowing the number of days it takes to complete a given instar. Field observations were gathered when specimens of *F. incaica* were collected from outdoors stands of *R. communis*.

INSTAR DIFFERENTIATION AND DESCRIPTION

The differentiation between instars was based on the following morphological characters: the length of the second antennal segment, length of wing pads, and the total length of the body. To take measurements, 30 individuals per nymphal instar were mounted on microscope slides. Individuals were cleared in KOH 10 % for 30 minutes and rinsed with 70 % alcohol. Specimens on slides were observed under a light microscope at different magnifications according to the size of the nymphs. Images were taken with a Canon EOS 6D with an MP-E 65 mm macro lens and edited in Adobe Photoshop. Measurements were taken with Image-pro-Express 6.3. Measurements are given in mm. Box-Plot diagrams were used to make the comparative analysis of the data in Microsoft Excel. External morphology used in the description of the nymphs follow Schuh and Weirauch (2020).

RESULTS

LIFE CYCLE

The life cycle of *F. incaica* lasts, on average, 20 days (20.16, SD=1.05) (Table 1). The average duration of each instar is very similar from I to III. Instars I and II last about the same; instar III has slightly longer developmental time than the previous two; and instars IV and V each have longer developmental times with respect to the previous one.

Nonetheless, when considering the SD, only instar V is considerably longer than the previous one (Table 1). Mortality was shown to be highest in instars I and V.

DIFFERENTIATION OF INSTARS

Each one of the five nymphal instars was characterized by the length of the structures measured (Fig. 1). The mesothoracic wing pads are longer in comparison to the metathoracic wing pads (Figs. 1a and 1b). The length of each of the wing pads is very similar between the 2nd and 3rd instar nymphs (Figs. 1a and 1b). On the other hand, the 4th and 5th instar nymphs exhibit an abrupt increase in length with respect to the previous instar. In each instar the length ranges are symmetrical and do not exhibit any outliers. Similarly, the second antennal segment length exhibits a constant increase with each instar (Fig. 1c), and as with the wing pads length, the length data are symmetrical. In both the wing pads and the second antennal segment of each instar is characterized by a particular length, and they barely or do not overlap (Figs. 1a-1c). Finally, the total length of the body increases with each nymphal instar up to the adult stage, although the variation exhibited in each one overlaps with the previous instar (Fig. 1d).

DESCRIPTION OF INSTARS

Egg (Fig. 2a): Elongate, cylindrical; chorion punctate, white and bright; changes color from white to cream before hatching; basal portion of the egg with an inclined prolongation; operculum beside elevated rim, apparently flat. After oviposition, eggs may appear laterally compressed, but then they become turgid, with slight changes in width that occur during development.

First-instar nymph (Fig. 2b): Overall coloration pale yellow; red band laterally on the head extending to the first abdominal segment; antenna with scape and pedicel red, basiflagellomere red, basally pale, distiflagellomere with basal half pale, distal half pale reddish-yellow; slight darkened areas on meso- and metafemora and tibiae; abdomen piriform, antennae with four segments, pedicel a little longer than scape, distiflagellomere with setae on its entire surface; wing pads not developed.

Second-instar nymph (Fig. 2c): Overall coloration yellow, lateral red band, and antennal coloration more intense than 1st instar; dark areas of meso- and meta femora and tibiae darker than in 1st instar, with black spots on prothoracic legs; pedicel approximately 0.05 times long compared to with the 1st instar (Table 2); wing pads slightly developed.

Third-instar nymph (Fig. 2d): Same coloration pattern as in 2nd instar, but red areas darker; dark areas of legs darker than in previous instar; antennal pedicel increased approximately 0.08 times in length in comparison to the 2nd instar; dark base of setae of abdominal terga five to seven wider than in previous instar; setae next to spiracles wider than in previous instar; mesothoracic wing pads slightly covering base of metathoracic wing pads, the latter barely developed.

Fourth-instar nymph (Fig. 2e): Same coloration as 3rd instar but antenna dark red and distiflagellomere pale yellow; length of antennal pedicel about twice as long as in 3rd instar (Fig. 1c); dark areas of lateral setae on mediotergites larger in comparison to 3rd instar; dark

base of setae of abdominal terga five to seven wider than in previous instar; mesothoracic wing pads covering metathorax and reaching second abdominal tergite.

Fifth-instar nymph (Fig. 2f): Same coloration as 4th instar but lateral areas of head and thorax black; wing pads glossy black; metathoracic legs mostly black; length of antennal segment pedicel 1.55 times longer than in 4th instar (Fig. 1c); mesothoracic wing pads reaching seventh abdominal tergite, metathoracic ones reaching sixth abdominal segment.

Adult (Fig. 3a): Males and females of similar coloration. Hemelytron pale yellow except for a dark area apical adjacent to the claval commissure extending to the corial area next to the membrane; cuneus apically darkened; head mostly black except for the vertex; pronotum black with posterior margin broadly pale yellow. Other coloration details as described by Forero (2022).

FIELD OBSERVATIONS

In the field, all instars of *F. incaica* were found on the underside of leaves of *R. communis*. First and second instars tend to group together, with a minor presence of other instars. These early instars feed mostly close to the main leaf vein and at the base of the petiole. When the number of individuals of *F. incaica* reached high numbers per leaf, the dorsal surface of the leaf started to exhibit chlorosis (Fig. 3b).

Feces of nymphs and adults are found as black spots all over the surface of the leaf, particularly on the underside where the feeding occurs. Adults and nymphs of *F. incaica*

are not highly mobile, but if exposed to direct light, or if disturbed, they tend to move to the opposite side of the leaf. Sometimes it is possible to find an adult perched on the upper side of the leaf, and if approached it quickly flies away over a short distance.

Eggs of *F. incaica* are embedded on the underside of the leaf tissue of the plant without preference for a specific place on this abaxial surface. They were neither found on the stems of the plant. Females lays the eggs singly or in groups up to 18 eggs, usually covered with a black cement giving them a dark appearance. Eggs are anchored into the leaf by an egg process which is inserted into a vein or epidermal lamellar tissue (Forero 2022).

DISCUSSION

Very little is known about the basic biology of *Falconia* species. What is known is based mostly on *F. intermedia* (Distant, 1893), a promising biological control agent of *Lantana camara* Linnaeus, 1753 (Verbenaceae) (Baars et al., 2003; Day and McAndrew, 2003). Our study is the first to provide data on the life cycle of a different species of *Falconia*. In *F. intermedia* it takes about 13 (Baars et al., 2003) or 15 days (Day and McAndrew, 2003) from instar I to reach the adult stage, whereas in *F. incaica*, it takes about 20 days (Table 1). Although average developmental time from first-instar nymph to adult is different between *F. intermedia* and *F. incaica*, it is difficult to assess if the difference is due to the biology of each species, given a series of confounding factors. For instance, the two species feed on two different host plants, and thus different developmental times could be attributed to the nutritional effect of their host plants. Nonetheless, the temperature used in rearing *F. intermedia* was higher (27°C, Day and McAndrew, 2003; 28°C, Baars et al., 2003)

compared to the one used for *F. incaica* (18°C). Thus, differences in developmental time among species of *Falconia* might respond to various factors.

Besides *F. incaica*, only one additional *Falconia* species has been found associated with *R. communis*, *F. poetica* (Aragón-Sánchez et al., 2021; Forero, 2022); and because this plant is an exotic species on the Neotropics, it is still unknown what the native host plant species is for both *F. poetica* and *F. incaica*, but we anticipate that it might be a species of Euphorbiaceae.

Some of the documented behaviors between *F. incaica* and *F. intermedia* are similar, such as the feeding damage in both species causing chlorosis on the upper surface of the leaf, the small fecal droplets, a product of feeding, and the way the embedded eggs are cemented to the surface of the leaf with a dark substance (Baars et al., 2003). Other behaviors are nonetheless different. Although eggs of both species were found on the underside of the leaf, in *F. intermedia* they were placed on the leaf margin and next to the veins on the proximal half of the leaf, whereas in *F. incaica* the eggs were oviposited all over the underside of the leaf surface. The number of eggs per batch was also different. In *Falconia intermedia* the maximum number of eggs per batch was five (Baars et al., 2003), but in *F. incaica* it was up to 18 eggs per batch. Baars et al. (2003) indicated that nymphs and adults are highly mobile on the plant; however, in *F. incaica* we found that both adults and nymphs were mostly static on the leaf surface, moving only when disturbed.

In both *F. incaica* (see Forero 2022) and *F. intermedia*, there is a basal, inclined process on the egg. Baars et al. (2003) speculated that this process probably has the function of absorbing water from the tissue of the leaf. We argue that rather than serving a hydrating function for the egg, this process might be simply used as an anchoring device to the leaf surface. Nonetheless, definitive evidence for the egg hydrating idea is lacking.

We provide a way to identify the different nymphal instars of *F. incaica* using the length of the antennal pedicel and the meso- and metathoracic wing pads (Table 2). Usually, because nymphs of Miridae are very similar in structure and coloration, determining the nymphal instar a for a given species can be challenging. Aragón-Sánchez et al. (2021) approached this issue by measuring the length of the forefemur and foretibia of *F. poetica*. In their case, although the length of these structures allowed for discrimination of the five instars, some overlapping occurred. In the case of the structures used here for *F. incaica*, very little overlapping between instars was documented. Thus, it is probably easier to use the lengths of the second antennal segment and the lengths of the meso and metathoracic wing pads as proxies for a given nymphal instar. Finally, we also documented and show that early instar nymphs (I and II) can be separated from later instars (II-V) not only based on the relative total length of the specimens, but also on their coloration. More reddish nymphs correspond to earlier instars, whereas darker nymphs usually are later intars.

CONCLUSIONS

We have shown that *F. incaica*, a plant bug found on the exotic *R. communis*, can complete its development from nymphal instar I to adult, under laboratory conditions of the Bogota plateau (18°C, 70 % relative humidity), in 20.16 days (SD=1.05), in which the highest mortality was found in the first and last instars. Furthermore, all the nymphal instars can be differentiated by a combination of the body coloration pattern and the lengths of the second antennal segment and wing pads.

AUTHOR'S PARTICIPATION

CF: Conceptualization, Investigation. CF and DF: Formal analysis, Writing.

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CONFLICTS OF INTEREST

The authors manifest not having any type of conflict of interest.

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TABLES AND FIGURES.

Table 1. Duration in days of each instar of *F. incaica*. *n* = number of specimens.

	instar I	**instar II**	**instar III**	**instar IV**	**instar V**
n	172	268	280	151	39
Average	3.13	3.07	3.85	4.55	5.57
Standard Deviation	0.99	0.88	1.12	1.22	0.53
Range	2-4	2-5	3-7	2-7	5-6
Mortality %	38.78	19.75	25.83	23.16	36.34

Table 2. Length of wing pads, second antennal segment, and body, for each nymphal instar of *F. incaica*. Values represent average and standard deviation. Measurements in mm. *n* = number of specimens.

	instar I	**instar II**	**instar III**	**instar IV**	**instar V**
Mesothoracic wing pad	Absent	0.135 (±0.011; *n*=31)	0.254 (±0.013; *n*=30)	0.558 (±0.040; *n*=30)	1.159 (±0.048; *n*=30)
Metathoracic wing pad	Absent	0.087 (±0.008; *n*=30)	0.124 (±0.025; *n*=30)	0.336 (±0.036; *n*=30)	0.917 (±0.123; *n*=30)
Antennal segment II	0.15 (±0.005; *n*=30)	0.21 (±0.01; *n*=30)	0.304 (±0.016; *n*=31)	0.497 (±0.019; *n*=30)	0.773 (±0.061; *n*=30)
Total body length	0.83 (±0.081; *n*=27)	1.18 (±0.096; *n*=29)	1.48 (±0.059; *n*=28)	2.1 (±0.105; *n*=30)	2.64 (±0.113; *n*=30)

Figure 1. Length of different nymphal structures of *F. incaica.* N = nymphal instar. a. Mesothoracic wing pads; b. metathoracic wing pads; c. antennal pedicel (second segment); d. total body length (error bars indicate standard deviation).

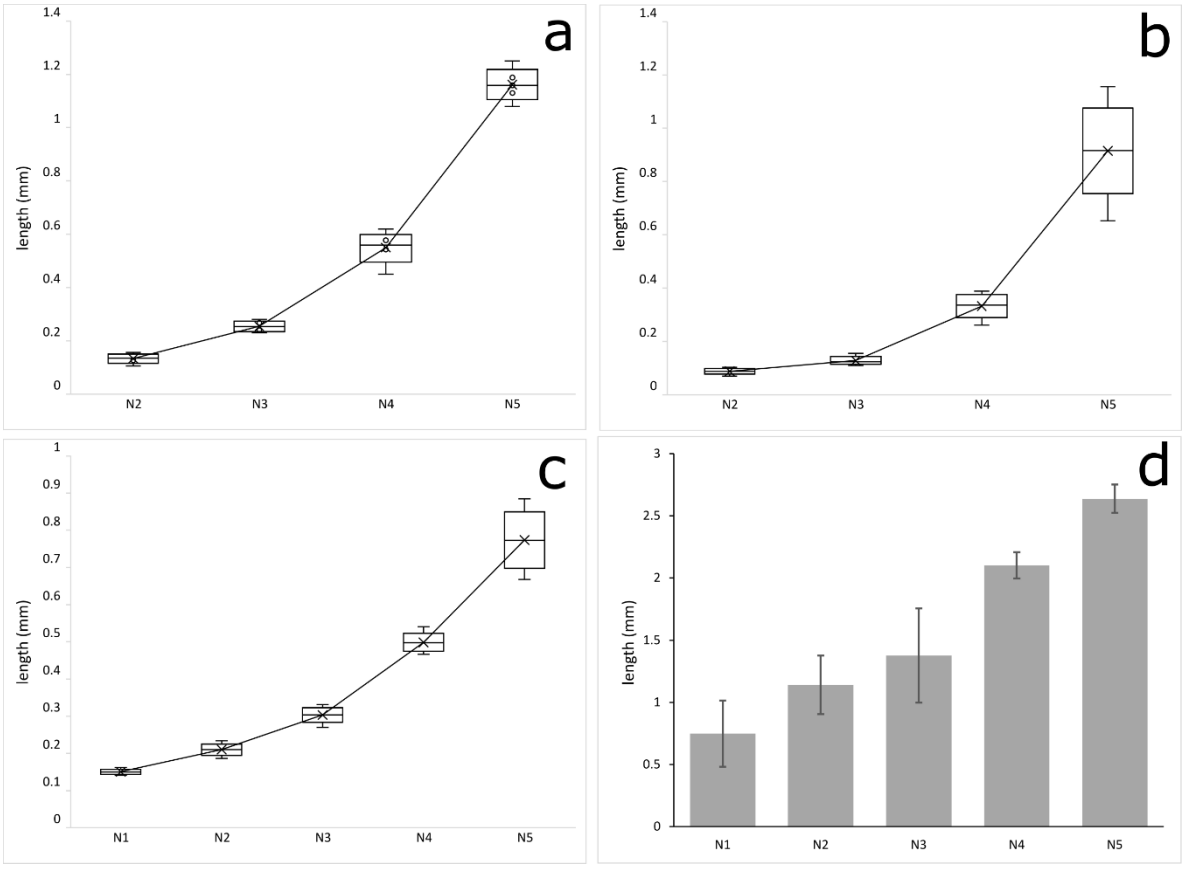

Figure 2. Dorsal view of the different instars of *F. incaica*. a. Egg mass; b. first-instar nymph; c. second-instar nymph; d. third-instar nymph; e. fourth-instar nymph; f. fifth-instar nymph.

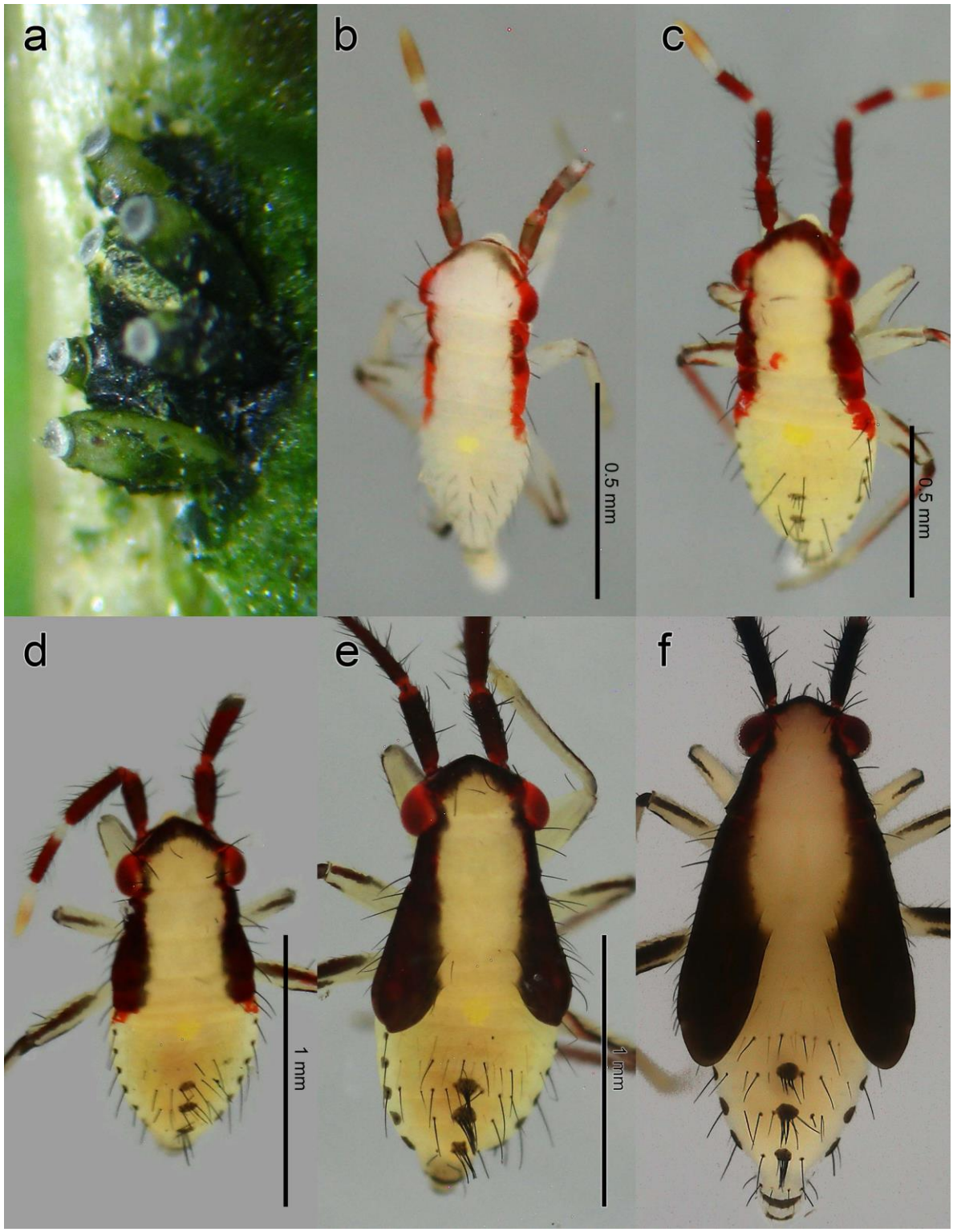
a
b
0.5 mm
c
0.5 mm
d
1 mm
e
1 mm
f

Figure 3. a. Dorsal view of a male and female of *F. incaica*. b. Chlorosis on leaves of *R. communis* caused by *F. incaica* .