

Cecidomyiidae (Diptera): richness and distribution in the Amazonian forest

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Abstract. The present study aimed to survey the richness and distribution of gall midge species (Cecidomyiidae) in the Amazon forest. Additionally, we compiled data on the characterization of insect galls and host plant species identification, and developed a taxonomic key of gall midge genera registered in the Amazon forest. For this, data were obtained from the literature, but also from papers containing the original description of each gall midge species. A total of 31 gall midge species have been recorded in the Amazonian forest, with the majority reported in the Brazilian Amazon (29) and two species found in the Peruvian Amazon. The genera *Lopesia* was the best represented among gall midges. Calophyllaceae were the plant family with the greatest number of gall midge species. Leaves were the most attacked plant organ (74%). Most morphotypes are globose (75%), green (42%), glabrous (58%), and one-chambered (55%). The state of Amazonas (Brazil) and the department of Loreto (Peru) recorded the highest number of gall-inducing species. Furthermore, 17 gall midges species were described from the Brazilian Amazon, while only two species were described from the Peruvian Amazon. The remaining species (12) were described from other biomes and latter recorded in the Amazon forest. In the 20th and 21st centuries, 13 and six gall midges species were described, respectively, being Rübsaamen and Maia the authors who described the highest number of species. After 1921, there was an 85 years interval without new taxonomic contributions until 2006, when two new species were described from the Amazon forest. The taxonomic key for gall midge genera stands out as one of the few available for distinguishing genera in the Neotropical region, facilitating the work of taxonomists. It is also the first taxonomic key specifically designed for this phytogeographic domain. In order to fill these gaps in the taxonomic information on gall-inducing insect species in the Amazon forest, more efforts are needed in the identification and description of gall-inducing species, particularly within the family Cecidomyiidae.

Keywords. Calophyllaceae; Gall midge species; Host plant; Insect-plant interactions; Rainforest.

INTRODUCTION

It is estimated that there are approximately 5.5 million insect species in the world, with 80% yet to be discovered, and that greater emphasis should be placed on less-studied taxa, such as Diptera (Stork, 2018). The Amazonian forest harbors a rich diversity of Diptera, with 856 species identified across 56 families, with the Cecidomyiidae family being one of the most abundant in this biome (Amorim *et al.*, 2022). Cecidomyiidae is one of the largest families within the Diptera order, encompassing over 6,500 described species worldwide (Gagné & Jaschhof, 2021). However, in the Amazonian forest, only 31 species of Cecidomyiidae have been identified to date (Gagné & Jaschhof, 2021). This limited number can be attributed to the scarcity of taxonomic knowledge regarding gall-inducing insects

in the Amazon. This is primarily due to taxonomic uncertainties, difficulties in identification, and the fact that many species remain undescribed (Grandez-Rios *et al.*, 2015).

The pioneering taxonomic studies on Cecidomyiidae species in the Amazonian forest were conducted between 1905 and 1921 by renowned taxonomists such as Rübsaamen (1905, 1915a, 1915b), Felt (1915, 1921), and Kieffer (1913). These researchers are credited with approximately 55% of the recorded gall-inducing species (Maia, 2021). Additional records were contributed by Möhn (1960), Gagné (1994), Maia & Vasquez (2006), Maia & Fernandes (2006), Fernandes *et al.* (2010), Maia & Vasquez (2010), Proença & Maia (2020), and Gagné & Jaschhof (2021).

Most taxonomic studies on Cecidomyiidae in the Amazon forest have been conducted in the Brazilian Amazon (Maia, 2021), resulting in

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a strong geographic bias in current knowledge. In contrast, other Amazonian countries remain poorly studied, with scarce taxonomic and faunistic information available (Grandez-Rios *et al.*, 2024). This uneven research effort limits our understanding of the true diversity and distribution of gall-inducing species across the Amazon. Furthermore, taxonomic identification keys for Cecidomyiidae are scarce, with the only comprehensive key available for the Neotropical region being that developed by Gagné (1994). The lack of region-specific and updated identification tools may hinder accurate species delimitation, particularly in highly diverse and understudied areas such as the Amazon (Grandez-Rios *et al.*, 2015). In this context, taxonomic keys are essential, as they enable standardized and reliable species identification, improve the quality of biological inventories, and strengthen biodiversity and conservation studies (Espírito-Santo & Fernandes, 2007).

The main objective of this work is to survey the richness and distribution of gall midge species in the Amazon forest. Additionally, we compiled data on the characterization of insect galls, identify the main host plant species, and develop a taxonomic key of gall midge genera registered in the Amazonian forest.

MATERIAL AND METHODS

The study was conducted through a literature survey of data on gall-inducing insects and their host plants in the Amazon forest. Initially, a systematic research was performed in the online databases SciVerse Scopus, Portal Capes, and Google Scholar between June and July 2023, using the following keyword combinations: (galls* OR insect galls*) AND (Cecidomyiidae*) AND (Amazon*) AND (rainforest*), to list gall midge species described in the Amazon forest. Subsequently, papers containing the original descriptions of each species, along with other taxonomic studies, were examined to validate species records and gather detailed information on their occurrence localities and host plants.

Data on gall-inducing insect species, host plants, morphological characteristics of the galls, and geographical distribution (country, state, or department where the gall-inducing insect species occur) were compiled. Botanical names and synonyms of the host plants were verified on the GBIF platform (<https://www.gbif.org>). Plant species determined only at the genus level (*i.e.*, species identified as “sp.”) and family were also included in the list of host plants. To standardize the morphology of the galls, the terminology of Isaias *et al.* (2013) was adopted. Furthermore, a taxonomic key was developed for gall midge genera registered in the Amazonian forests. Morphological data were obtained from the literature. The key includes mainly male and female characters, and some characters of the 3rd instar larva. Most of them are illustrated. Photographs were taken from specimens deposited in the entomology collection of the Museu Nacional do Rio de Janeiro. For genera not represented in the collection, illustrations were obtained from the literature.

RESULTS

In total, 31 species of Cecidomyiidae from seven tribes and 21 genera were reported in the Amazonian forests (Table 1). The best represented tribes were Lopesiini and Asphondyliini, each with 7 species. The other tribes had lower values: Clinodiplosini had 4 species, while Anadiplosini, Alycaulini, Cecidomyiini, and Dasineurini, each with one species. Additionally, nine cecidogenous species not positioned in tribe were reported. Sixteen genera were represented by a single species, four (*Asphondylia* Loew, 1850, *Bruggmannia* Tavares, 1906, *Clinodiplosis* Kieffer, 1894, and *Macroporpa* Rübsaamen, 1915b) by two, and one (*Lopesia* Rübsaamen, 1908) by seven, the latter being the genus with the highest species richness in the biome.

Gall midge species were associated with 17 botanical families distributed across 19 genera and 21 plant species (Table 1). Calophyllaceae is the plant family with the highest species richness of gall-inducing species (five), followed by Asteraceae with three, Burseraceae, Fabaceae, Malvaceae, Nyctaginaceae, and Urticaceae with two each. All other families host a single cecidogenous species. Ten gall-inducing species are associated with host plants identified only at the genus level, such as *Arrabidaea* sp. (Bignoniaceae), *Cecropia* sp. (Urticaceae), *Clusia* sp. (Clusiaceae), *Coussapoa* sp. (Urticaceae), *Mikania* sp. (Asteraceae), *Neea* sp. (Nyctaginaceae), *Serjania* sp. (Sapindaceae), *Solanum* sp. (Solanaceae), and *Sterculia* sp. (Malvaceae). Two gall-inducing insect species were found on host plants identified only by family, one in Malpighiaceae and another in Lauraceae. Additionally, five cecidogenous species (*Alexomyia ciliata* Felt, 1921, *Haplusia braziliensis* Felt, 1915, *Macroporpa peruviana* Rübsaamen, 1915a, *Macroporpa ulei* Rübsaamen, 1915b, and *Ouradiplosis aurata* Felt, 1915) did not have their host plants reported.

Most galls were induced on leaves (23 morphotypes), representing 74% of the total, followed by stems and fruits, both with two gall morphotypes, and roots with one morphotype. Four gall shapes were reported: globose (21 morphotypes), fusiform (3), marginal roll (2), and conical (2). The galls displayed green, yellow, or brown coloration, with green being predominant (42%). Most galls were glabrous (58%), while the rest were hairy. Seventeen morphotypes (about 55%) had a single chamber, often occupied by a single gall-inducing larva, while four galls were multilocular. The gall shape, color, presence of trichomes, host organ, and number of chambers were not reported for three cecidogenous species: *Alexomyia ciliata*, *Haplusia braziliensis*, and *Ouradiplosis aurata* (Table 1).

Regarding the geographical distribution of the 31 Cecidomyiidae species reported in the Amazonian forests, four occurred in both Brazil and Peru (*Dactylodiplosis heisteriae* Rübsaamen, 1915b, *Lopesia elliptica* Maia, 2003, *Lopesia linearis* Maia 2003, and *Lopesia maricaensis* Rodrigues & Maia, 2010), while 25 species were exclusively reported for Brazil and two species exclusively for Peru (Fig. 1). In Brazil, the highest number of gall-in-

Table 1. Characterization of insect galls recorded for each gall-inducing species in the Amazon forest.

Tribe	Gall-inducing species	Host family	Host plant	Organ	Shape	Color	Trichome	Chambers	References
Alycaulini	<i>Alycaulus mikaniae</i> Rübsaamen, 1915a	Asteraceae	<i>Mikania</i> sp.	Stem	Fusiform	—	No	—	Rübsaamen, 1915a; Gagné, 1994; Gagné & Jaschhof, 2021.
Anadiplosini	<i>Alexomyia ciliata</i> Felt, 1921	—	—	—	—	—	—	—	Felt, 1921; Gagné, 1994; Gagné & Jaschhof, 2021.
Ansphondyliini	<i>Ansphondylia fructicola</i> Maia, 2009	Solanaceae	<i>Solanum</i> sp.	Fruit	Globose	Green	Yes	Multiple	Maia et al., 2009; Gagné & Jaschhof, 2021.
Asphondyliini	<i>Ansphondylia tournefortiae</i> Rübsaamen, 1915a	Heliotropiaceae	<i>Tournefortia angustiflora</i>	Fruit	Globose	—	No	—	Rübsaamen, 1915a; Gagné, 1994; Gagné & Jaschhof, 2021.
Asphondyliini	<i>Macropora uli</i> Rübsaamen, 1915b	Lauraceae	—	Leaf	Globose	—	Yes	Multiple	Rübsaamen, 1915b; Gagné, 1994; Gagné & Jaschhof, 2021.
Asphondyliini	<i>Macropora peruviana</i> Rübsaamen, 1915a	Malpighiaceae	—	Leaf	Globose	—	Yes	1	Rübsaamen, 1915a; Gagné, 1994; Gagné & Jaschhof, 2021.
Asphondyliini	<i>Bruggmannia depressa</i> (Kieffer, 1913)	Nyctaginaceae	<i>Neea</i> sp.	Leaf	Globose	—	—	—	Kieffer, 1913; Gagné, 1994; Gagné & Jaschhof, 2021.
Asphondyliini	<i>Bruggmannia longiseta</i> (Kieffer, 1913)	Nyctaginaceae	<i>Neea</i> sp.	Leaf	Globose	—	No	—	Kieffer, 1913; Gagné, 1994; Gagné & Jaschhof, 2021.
Asphondyliini	<i>Perasphondylia reticulata</i> Möhn, 1960	Asteraceae	<i>Chomolaena odorata</i>	Leaf	Globose	—	—	—	Möhn, 1960; Gagné, 1994; Gagné & Jaschhof, 2021.
Cecidomyiini	<i>Contarinia gemmae</i> Maia, 2003	Calophyllaceae	<i>Calophyllum brasiliense</i>	Stem	Globose	Green	No	Multiple	Madeira et al., 2003; Arriola et al., 2016; Gagné & Jaschhof, 2021.
Clinodiplosini	<i>Clinodiplosis eupatorii</i> (Felt, 1911)	Asteraceae	<i>Chomolaena odorata</i>	Leaf	Conical	—	No	1	Felt, 1911; Gagné, 1994; Gagné & Jaschhof, 2021.
Clinodiplosini	<i>Latrophobia brasiliensis</i> (Rübsaamen, 1908)	Euphorbiaceae	<i>Manihot esculenta</i>	Leaf	Globose	Green	No	1	Rübsaamen, 1908; Gagné, 1994; Gagné & Jaschhof, 2021.
Clinodiplosini	<i>Clinodiplosis cecropiae</i> Proença & Maia, 2020	Urticaceae	<i>Cecropia</i> sp.	Leaf	Globose	Green	No	1	Proença & Maia, 2020.
Clinodiplosini	<i>Schismatodiplosis lantanae</i> (Rübsaamen, 1908)	Verbenaceae	<i>Lantana camara</i>	Leaf	Globose	Green	Yes	1	Rübsaamen, 1908; Proença & Maia, 2014.
Dasiineutini	<i>Dasiineura theobromae</i> Maia, 2006	Malvaceae	<i>Theobroma bicolor</i>	Leaf	Conical	Yellowish	No	1	Maia & Vásquez, 2006; Gagné & Jaschhof, 2021.
Lopesini	<i>Lopesia maricaensis</i> Rodrigues & Maia, 2010	Burseraceae	<i>Protium brasiliense</i>	Leaf	Marginal roll	Green	No	1	Rodrigues & Maia, 2010; Gagné & Jaschhof, 2021; Maia, 2020.
Lopesini	<i>Lopesia similis</i> Maia, 2004	Burseraceae	<i>Protium heptaphyllum</i>	Leaf	Marginal roll	Green	No	1	Narahara et al., 2004; Gagné & Jaschhof, 2021; Maia, 2020.
Lopesini	<i>Lopesia caulinaris</i> Maia, 2003	Calophyllaceae	<i>Calophyllum brasiliense</i>	Stem	Fusiform	Brown	No	1	Madeira et al., 2003; Arriola et al., 2016; Gagné & Jaschhof, 2021.
Lopesini	<i>Lopesia conspicua</i> Maia, 2003	Calophyllaceae	<i>Calophyllum brasiliense</i>	Leaf	Globose	Green	No	1	Madeira et al., 2003; Arriola et al., 2016; Gagné & Jaschhof, 2021.
Lopesini	<i>Lopesia elliptica</i> Maia, 2003	Calophyllaceae	<i>Calophyllum brasiliense</i>	Leaf	Globose	Green	No	1	Madeira et al., 2003; Arriola et al., 2016; Gagné & Jaschhof, 2021.
Lopesini	<i>Lopesia linearis</i> Maia, 2003	Calophyllaceae	<i>Calophyllum brasiliense</i>	Leaf	Globose	Green	No	1	Madeira et al., 2003; Arriola et al., 2016; Gagné & Jaschhof, 2021.
Lopesini	<i>Lopesia aldiniae</i> Fernandes & Maia, 2010	Fabaceae	<i>Aldina heterophylla</i>	Leaf	Globose	Green	No	1	Fernandes et al., 2010; Gagné & Jaschhof, 2021.
—	<i>Heterodiplosis peruviana</i> Maia, 2010	Bigoniaceae	<i>Arrabidaea</i> sp.	Leaf	Globose	Green	No	1	Maia & Vásquez, 2010.
—	<i>Ulei clusiae</i> Rübsaamen, 1905	Clusiaceae	<i>Clusia</i> sp.	Leaf	Fusiform	—	—	—	Rübsaamen, 1908; Gagné, 1994; Gagné & Jaschhof, 2021.
—	<i>Parkianya paranaensis</i> Maia, 2006	Fabaceae	<i>Parkia pendula</i>	Leaf	Globose	Green	No	1	Maia & Fernandes, 2006; Gagné & Jaschhof, 2021.
—	<i>Megastylus sterculiace</i> Rübsaamen, 1915b	Malvaceae	<i>Sterculia</i> sp.	Leaf	Globose	—	Yes	Multiple	Rübsaamen, 1915b; Gagné, 1994; Gagné & Jaschhof, 2021.
—	<i>Dactylopalpis heisteriae</i> Rübsaamen, 1915b	Oleaceae	<i>Heisteria acuminata</i>	Leaf	Globose	—	Yes	1	Rübsaamen, 1915b; Gagné, 1994; Gagné & Jaschhof, 2021.
—	<i>Haplopalpis serjaneae</i> Rübsaamen, 1915b	Sapindaceae	<i>Serjania</i> sp.	Leaf	Globose	—	Yes	1	Rübsaamen, 1915b; Gagné, 1994; Gagné & Jaschhof, 2021.
—	<i>Frauenfeldiella coussapoe</i> Rübsaamen, 1905	Urticaceae	<i>Coussapoa</i> sp.	Root	Globose	—	No	—	Rübsaamen, 1905; Gagné, 1994; Gagné & Jaschhof, 2021.
—	<i>Haplusia brasiliensis</i> (Felt, 1915)	—	—	—	—	—	—	—	Felt, 1915; Gagné, 1994; Gagné & Jaschhof, 2021.
—	<i>Ouaridiplosis aurata</i> Felt, 1915	—	—	—	—	—	—	—	Felt, 1915; Gagné & Jaschhof, 2021.

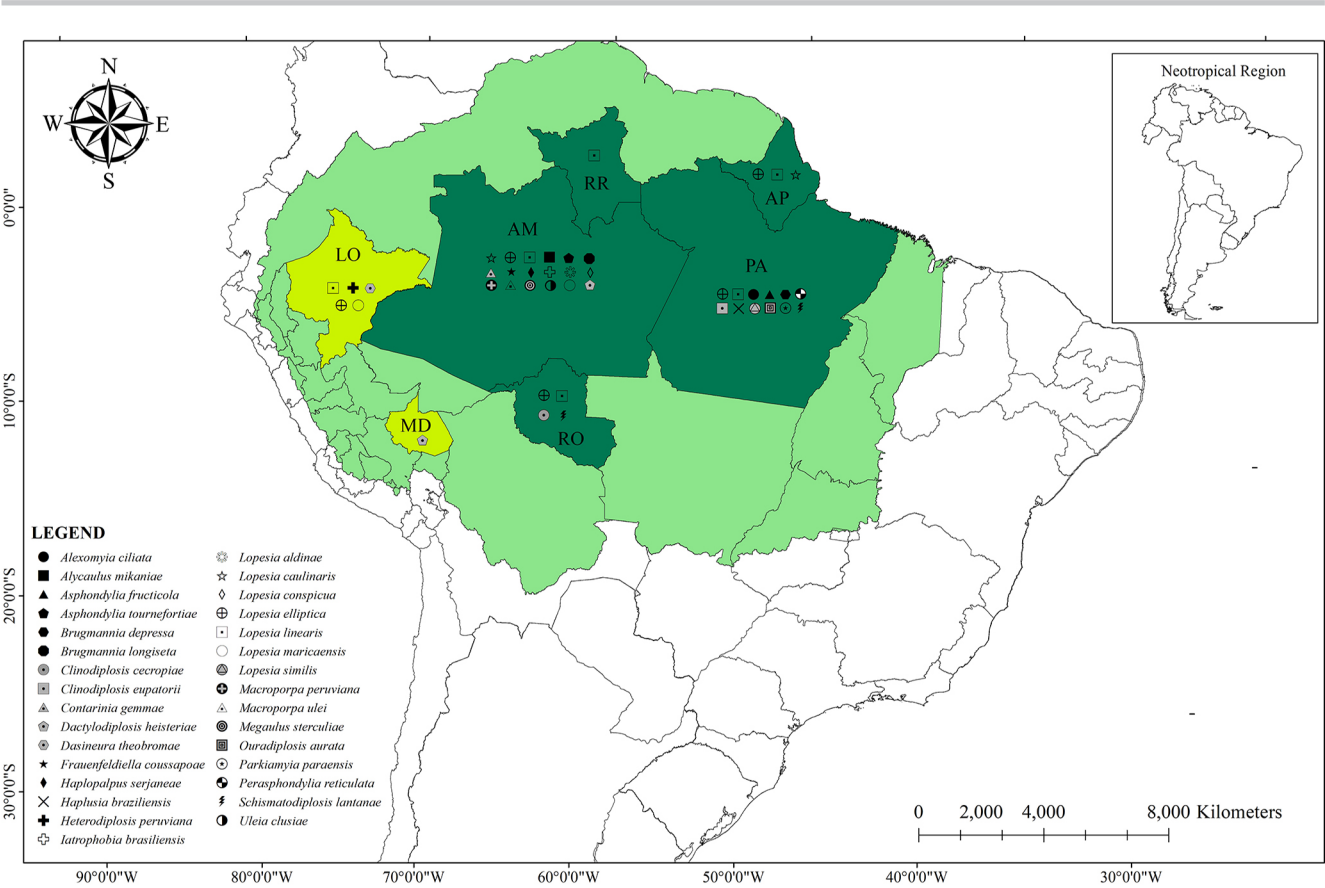


Figure 1. Distribution of the number of Cecidomyiidae species (Diptera) in the Amazon forest, by department in Peru and state in Brazil. Legend: Peru, LO: Loreto and MD: Madre de Dios; and Brasil, AM: Amazonas; AP: Amapá; PA: Pará; RO: Rondônia and RR: Roraima.

ducing species was recorded in the state of Amazonas (18 species), followed by Pará with twelve, Rondônia with four, Amapá with three, and Roraima with one. In Peru, a total of six species were recorded, of which five were reported for the Loreto department and one species for the Madre de Dios department. Additionally, the species *Lopesia linearis*, *L. elliptica*, and *L. maricaensis* were recorded in Brazil across five states (Amapá, Amazonas, Pará, Rondônia, Roraima), four (Amapá, Pará, Rondônia), and one (Amazonas), respectively, and also in one department in Peru (Loreto). Meanwhile, *L. caulinaris* Maia, 2003 (Amapá and Amazonas) and

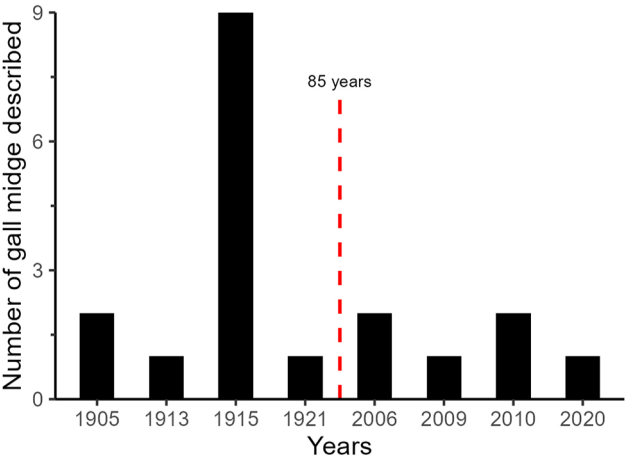


Figure 2. Comparison of the number of gall-inducing insect species described per year in the Amazon forest.

Schimatodiplosis lantanae Rübsaamen, 1908 (Rondônia and Pará) were recorded in two different states in Brazil, while *Dactylodiplosis heisteriae* was reported in one state in Brazil (Amazonas) and one department in Peru (Madre de Dios) (Fig. 1).

Table 2. Insect gall-inducing species of the Cecidomyiidae family (Diptera) described for the Amazonian forest in the 20th and 21st centuries, in chronological order. The hyphen indicates species not placed in a tribe.

Tribe	Gall-inducing species	Author	Year
—	<i>Frauenfeldiella coussapoe</i>	Rübsaamen	1905
—	<i>Uleia clusiae</i>	Rübsaamen	1905
Asphondyliini	<i>Brugmannia longiseta</i>	Kieffer	1913
Alycaulini	<i>Alycaulus mikaniae</i>	Rübsaamen	1915a
Asphondyliini	<i>Asphondylia tournefortiae</i>	Rübsaamen	1915a
—	<i>Dactylodiplosis heisteriae</i>	Rübsaamen	1915b
—	<i>Haplalypus serjaneae</i>	Rübsaamen	1915b
—	<i>Haplusia braziliensis</i>	Felt	1915
Asphondyliini	<i>Macroporpa peruviana</i>	Rübsaamen	1915a
Asphondyliini	<i>Macroporpa ulei</i>	Rübsaamen	1915b
—	<i>Megaulus sterculiae</i>	Rübsaamen	1915b
—	<i>Ouradiplosis aurata</i>	Felt	1915
Anadiplosini	<i>Alexomyia ciliata</i>	Felt	1921
Dasineurini	<i>Dasineura theobromae</i>	Maia	2006
—	<i>Parkiamyia paraensis</i>	Maia	2006
Anadiplosini	<i>Asphondylia fructicola</i>	Maia	2009
—	<i>Heterodiplosis peruviana</i>	Maia	2010
Lopesiini	<i>Lopesia aldinae</i>	Fernandes & Maia	2010
Clinodiplosini	<i>Clinodiplosis cecropiae</i>	Proença & Maia	2020

On the other hand, 17 cecidogenous species were described for the Brazilian Amazon forest between 1905 and 2020, while for the Peruvian Amazon forest, only two species were described, one in 2006 and another in 2010 (Table 2). The remaining species (12) were first reported in other biomes and latter in the Amazon forest. Additionally, in the 20th century, 13 species were described, being Rübsaamen the author with the highest

number of species described during this period (n = 7), while in the 21st century, six species were described, being Maia the author with the greatest contribution (Table 3). The last species described in the 20th century was *Alexomyia ciliata* Felt, 1921, followed by an 85-years interval without new taxonomic contributions until 2006, when two new species were described for the Amazon forest (Table 2, Fig. 2).

Key to genera of Cecidomyiidae recorded in the Amazonian forest

The following key includes 21 genera of Cecidomyiidae recorded in the Amazonian forests. *Lopesia* and *Clinodiplosis* appeared twice and three in the key due their morphological diversity, respectively. The number of species of each genus in the Amazon forest is given in brackets.

1.	Antenna with more than 12 flagellomeres (Fig. 3A).....	2
1'.	Antenna with 12 flagellomeres (Fig. 3B).....	6
2.	R5 shorter than wing (Fig. 3C); ovipositor protrusible (Fig. 3D).....	3
2'.	R5 longer than or as long as wing (Fig. 3E); ovipositor not protrusible (Fig. 3F).....	4
3.	Palpus with three segments (Fig. 3G); male antennal flagellomeres squarish.....	<i>Alycaulus</i> (1 sp.)
3'.	Palpus with four segments (Fig. 3H); male antennal flagellomeres cylindrical.....	<i>Dasineura</i> (1 sp.)
4.	R5 as long as than wing; ovipositor cerci fused (Fig. 3I).....	<i>Uleia</i> (1 sp.)
4'.	R5 longer than wing; ovipositor cerci not fused (Fig. 3J).....	5
5.	Antenna with 14 flagellomeres; palpus with three segments (Fig. 3G).....	<i>Haplusia</i> (1 sp.)
5'.	Antenna with 24 flagellomeres; palpus with one segment (Fig. 3K).....	<i>Haplopalpus</i> (1 sp.)
6.	Palpus with one segment.....	7
6'.	Palpus with three or four segments.....	9
7.	Female cerci fused.....	<i>Alexomyia</i> (1 sp.)
7'.	Female cerci not fused.....	8
8.	Female antenna with sinuous circumfila.....	<i>Frauenfeldiella</i> (1 sp.)
8'.	Female antenna with not sinuous circumfila (Fig. 3L).....	<i>Clinodiplosis</i> in part (2 spp.)
9.	R5 as long as than wing.....	10
9'.	R5 longer than wing.....	13
10.	Ovipositor not protrusible; male with aedeagus wide (Fig. 3M).....	<i>Macroporpa</i> (2 spp.)
10'.	Ovipositor protrusible; male with aedeagus narrow (Fig. 3N).....	<i>Parkiamyia</i> (1 sp.)
11.	First tarsomere with not apical projection (Fig. 4A).....	<i>Bruggmannia</i> (2 spp.)
11'.	First tarsomere with apical projection (Fig. 4B).....	12
12.	Ovipositor with cerci fused.....	<i>Asphondylia</i> (2 spp.)
12'.	Ovipositor with cerci not fused.....	<i>Perasphondylia</i> (1 sp.)
13.	Palpus with three segments.....	14
13'.	Palpus with four segments.....	15
14.	Male with hypoproct almost simple (Fig. 4C).....	<i>Heterodiplosis</i> (1 sp.)
14'.	Male with hypoproct deeply bilobed (Fig. 4D).....	<i>Lopesia</i> in part (7 spp.)
15.	Male with hypoproct simple (Fig. 4E).....	<i>Dactylodiplosis</i> (1 sp.)
15'.	Male with hypoproct bilobed (Fig. 4F).....	16
16.	Male hypoproct with recurved apical lobes (Fig. 4G).....	<i>Iatrophobia</i> (1 sp.)
16'.	Male hypoproct with not recurved apical lobe (Fig. 4H).....	17
17.	Female flagellomeres with circumfilar loops.....	<i>Megaulus</i> (1 sp.)
17'.	Female flagellomeres without circumfilar loops (Fig. 3M).....	18
18.	Female with very elongate cerci.....	<i>Ouradiplosis</i> (1 sp.)
18'.	Female with short cerci (Fig. 4I).....	19
19.	Male cerci with secondarily lobed (Fig. 4J).....	20
19'.	Male cerci not secondarily lobed (Fig. 4K).....	21
20.	Female 10 th tergum setose (Fig. 4L).....	<i>Schismatodiplosis</i> (1 sp.)
20'.	Female 10 th tergum not setose (Fig. 4I).....	<i>Clinodiplosis</i> in part (2 spp.)
21.	Female with cerci closely appressed to one another mesally (Fig. 4M).....	<i>Contarinia</i> (1 sp.)
21'.	Female with cerci not closely appressed to one another mesally (Fig. 5A).....	22
22.	Larva with four pairs of terminal papillae: three pairs corniform (one smaller than others) and one pair setiform (Fig. 5B).....	<i>Clinodiplosis</i> in part (2 spp.)
22'.	Larva with four pairs of terminal papillae, all corniform (Fig. 5C).....	<i>Lopesia</i> in part (7 spp.)

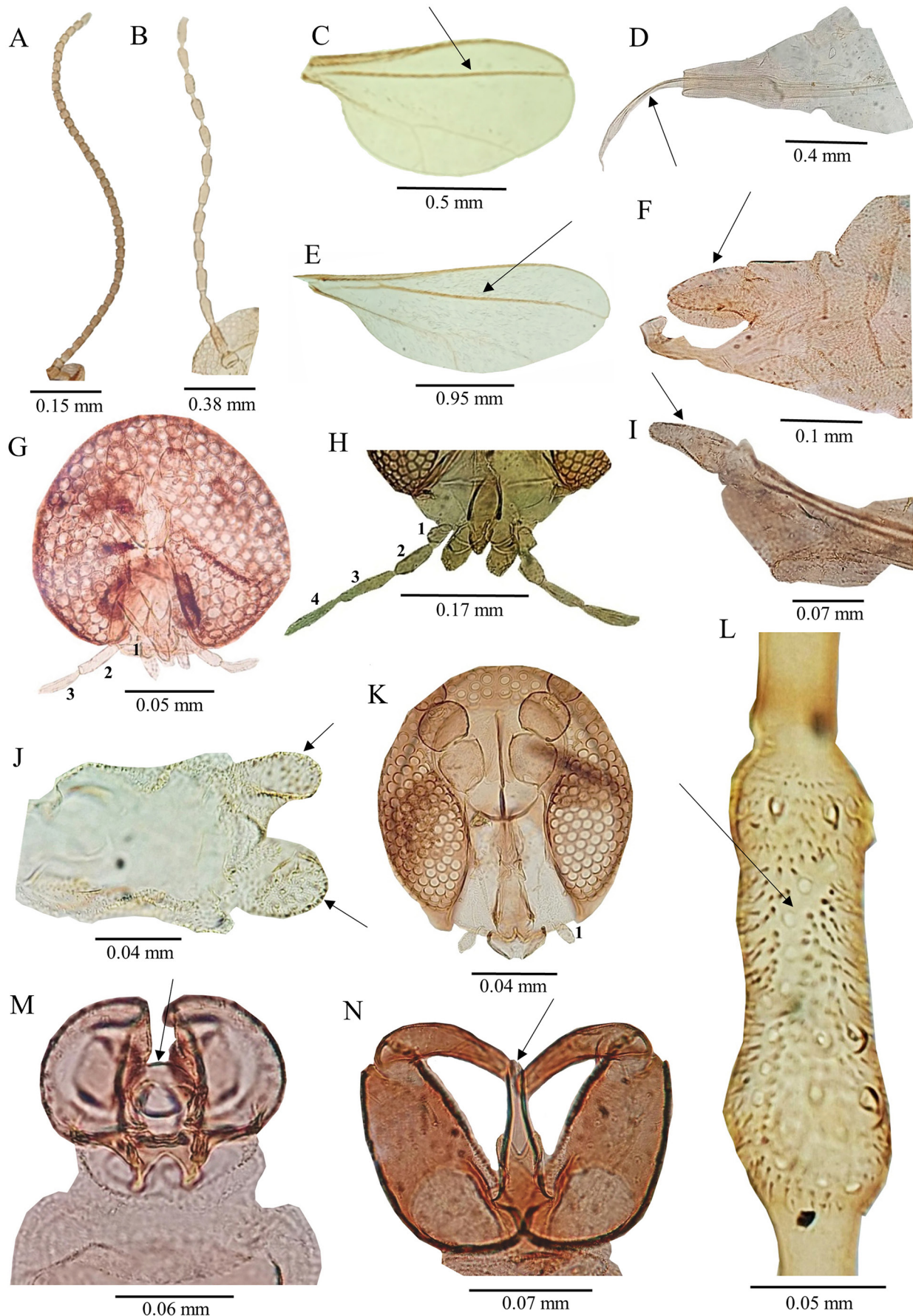


Figure 3. Adults of Cecidomyiidae: (A-B) Female antenna: (A) *Dasineura* sp.; (B) *Lopesia grandis*; (C) *Dasineura* sp., male wing; (D) *Dasineura* sp., ovipositor, lateral view; (E) *Lopesia grandis*, male wing; (F) *Lopesia* sp., ovipositor, lateral view; (G-H) Female head, ventral view: (G) *Lopesia grandis*; (H) *Dasineura* sp.; (I-J) Ovipositor: (I) *Dasineura microstachysae*, lateral view; (J) *Dasineura ovalifoliae*, dorsal view; (K) *Asteromyia* sp., female head, ventral view; (L) *Clinodiplosis agerati*, female 5th flagellomere; (M-N) Male terminalia, dorsal view: (M) *Bruggmannia capixaba*; (N) *Parkiamyia paraensis*.

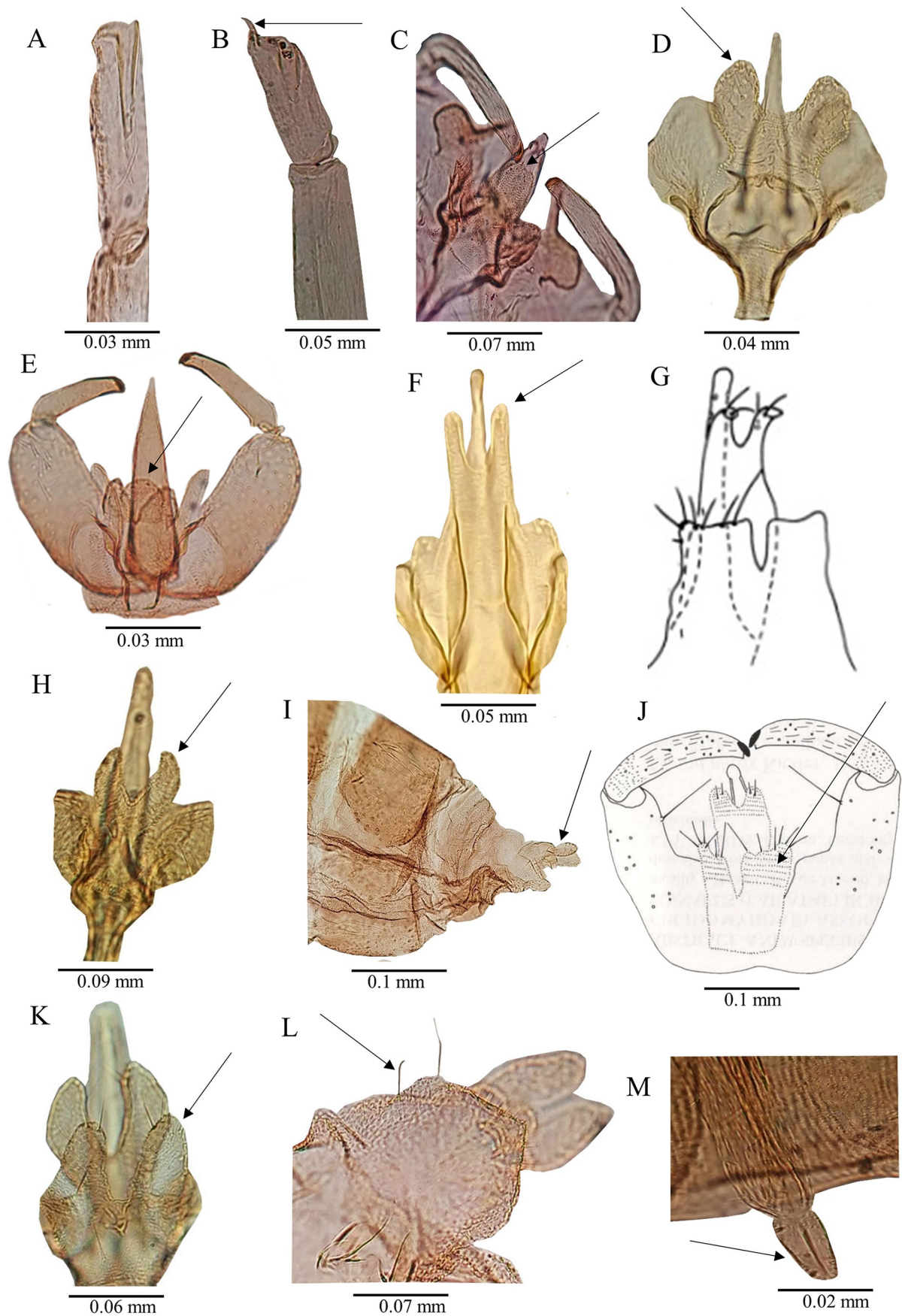


Figure 4. Adults of Cecidomyiidae: (A-B) male anterior and posterior legs, first tarsomere: (A) *Bruggmannia capixaba*; (B) *Asphondylia fluminensis*; (C-F) Male hypoproct and aedeagus, dorsal view: (C) *Heterodiplosis peruviana*; (D) *Lopesia elliptica*; (E) *Dactylodiplosis* sp.; (F) *Iatrophobia brasiliensis*; (G) *Iatrophobia brasiliensis*, male hypoproct with recurved apical lobes and aedeagus, dorsal view (from Gagné, 1994; without scale), (H) *Clinodiplosis agerati*, male hypoproct and aedeagus, dorsal view; (I) *Lopesia conspicua*, last female abdominal segments and cerci, (J-K) Male cerci and hypoproct, dorsal view: (J) *Clinodiplosis melissae* (from Maia, 1993); (K) *Lopesia marginalis*, (L) *Schismatodiplosis lantanae*, female 10th tergum and cerci, dorsal view; (M) *Contarinia* sp., female cerci, dorsal view..

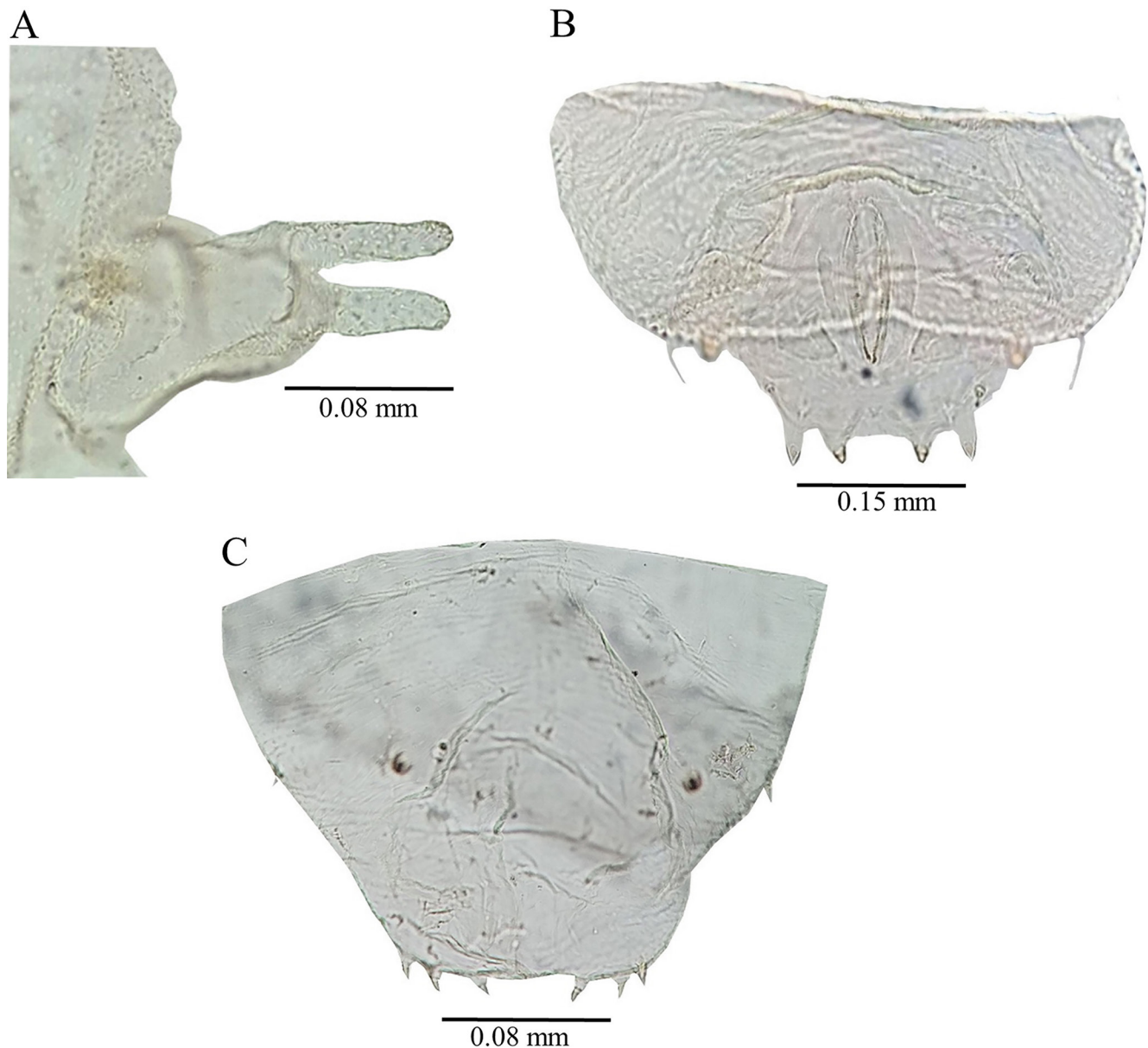


Figure 5. Cecidomyiidae: (A) *Clinodiplosis melissae*, female cerci; (B-C) Larva, terminal segment, dorsal view: (B) *Clinodiplosis* sp.; (C) *Lopesia maricaensis*.

DISCUSSION

The best represented genus of gall midges in the Amazonian forest was *Lopesia*. This genus, belonging to the tribe Lopesiini, is widely distributed with 30 described species, 25 of which are found in the Neotropics (Maia, 2020). Additionally, seven species are known to occur in the Amazonian forest (Maia, 2021), of which *Lopesia elliptica*, *Lopesia linearis*, and *Lopesia maricaensis* have been recorded in both the Brazilian and Peruvian Amazon regions (Arriola et al., 2016; Maia, 2020). Furthermore, *Lopesia* is also well represented in the Cerrado (Maia, 2021) and Atlantic forest (Maia & Silva, 2011).

In this study, Calophyllaceae was identified as the host plant family with the highest number of gall midge species, a finding consistent with the observations of Grandez-Rios et al. (2023) in the Peruvian Amazon. Several studies suggest that a greater diversity of plant species within a family is often associated with a richer fau-

na of galling associates (Gonçalves-Alvim & Fernandes, 2001). Other host plant families that were also found to be important include Burseraceae, Fabaceae, Malvaceae, Nyctaginaceae, and Urticaceae. According to Julião et al. (2014), these families are also recorded in the Amazonian forest as hosts for gall-inducing insect species.

Leaves were the most frequently galled plant organ in our study. Generally, leaves are the most attacked plant organ, likely because they represent a constant and abundant resource for the gallers (Maia, 2011). According to Grandez-Rios et al. (2023) and Proença & Maia (2023), 90% and 81% of galls, respectively, occurred on leaves in the Amazon forest. The globoid shape was also the most common. According to Isaías et al. (2013), this is the most common shape in the Neotropical region. Most galls were green color, with a glabrous surface and a single chamber. These predominant characteristics are consistent with previous studies conducted in the Amazon forest (Grandez-Rios et al., 2023; Proença & Maia, 2023).

The gall-inducing midge species are primarily distributed across various Amazonian states in Brazil, with the state of Amazonas recording the highest number of species. In the Peruvian Amazon, only six gall midge species have been recorded. Furthermore, there are no occurrence records of these species in the countries where this biome extends. This reflects the areas of expertise of specialists, who are predominantly located in Brazil (Maia, 2021), revealing a spatial discontinuity of information and indicating the need for collection efforts in areas where no records have been documented.

There are few published taxonomic keys to genus-level for the Neotropical region. The key by Gagné (1994) is the most comprehensive; however, it is outdated, due to the description of several new genera. Additionally, another genus-level key has been developed in Argentina (Maia, 2014). Apart from these, no other keys are available for this region. This new key will be valuable as it will facilitate the work of taxonomists. It is the first taxonomic key specifically designed for this phytogeographic domain.

In the Amazonian forest, gall-inducing insects are poorly known from a taxonomic perspective, with most species being new to science. Of the 31 gall-inducing species reported, 19 were described for the Amazon forests between the years 1905 and 2020, representing 4% of the total species described for the Neotropical region (500 species, Gagné, 1994). Moreover, the majority of these species were described from the Brazilian Amazon. This is because, in recent years, many species from Brazil have been described (Proença & Maia, 2020). On the other hand, only two species of Cecidomyiidae have been described from the Peruvian Amazon, while the estimated number of gall-inducing insect species for Peru is 3,090 species (Grandez-Rios et al., 2015). Additionally, some Cecidomyiidae species did not have a complete identification of their host plants due to the enormous floristic diversity found in the Amazon forests, which complicates the specific determination of botanical specimens (Grandez-Rios et al., 2015).

CONCLUSION

In this study, 31 gall midge species were recorded in the Amazon forest, with 17 species described from the Brazilian Amazon and only two from the Peruvian Amazon. The remaining species were originally described from other biomes and later recorded in the Amazon forest. *Lopesia* was the most represented genus within Cecidomyiidae. The family Calophyllaceae hosted the highest richness of gall-inducing species. Leaves were the most frequently galled plant organ, and the most common gall morphology was globoid. The state of Amazonas (Brazil) and the department of Loreto (Peru) recorded the highest number of gall-inducing species. There was an 85-year gap before new species were described for the Amazon Forest. This is the first taxonomic key at the genus level for the Amazon forest, which will facilitate identification for taxonomists. Furthermore, more efforts are needed in the identification and descrip-

tion of gall-inducing species, particularly for the family Cecidomyiidae. To achieve this, it is essential to establish collaborations among researchers, institutions, and taxonomy experts to advance in this research area and improve our knowledge of gall-inducing insects.

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